THE LONG ISLAND COMPREHENSIVE WASTE TREATMENT MANAGEMENT PLAN

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THE LONG ISLAND COMPREHENSIVE WASTE TREATMENT MANAGEMENT PLAN

VOLUME I: SUMMARY PLAN

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Project Director

July 1978

NASSAU-SUFFOLK REGIONAL PLANNING BOARD

Hauppauge, New York

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Dedication

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Newsday Photo

Foreword

Water, life's ultimate indispensible mineral, is no match for its greatest enemy, man. But man's victory is hollow.

"Mommy, my toothbrush tastes funny." This scene could be early morning in Levittown, Lynbrook or Port Jefferson, as a typical Long Island family prepares to begin another day. The circumstances along with others similar in consequence could become reality in the absence of the comprehensive water quality management program contained in this multi-faceted work. Even with this document, they might come to pass. The program only shows the way. Unless implemented, toothbrushes may indeed begin to taste funny and surface waters, commercially and recreationally, may become endangered hydrological species. In this brief context—citing hazards but knowing they can be eliminated—I write this introductory segment with utmost pride. This work, in my opinion, represents excellence unusually distinctive in quality, a demonstration of a public agency's ability to create, produce and execute at the highest level of competency.

Long Island possesses rich and unusual natural bounty: white and pebbleless ocean sands, vast expanses of salt meadow, white-cedar swamps, inland pine barrens, flat plains, colorful downs, fiordlike harbors, bays, ponds, lakes and freshwater bogs. It offers something to suit the taste for nature in each of us. It is a remarkably varied, beautiful and fertile insular tract, lying at the threshold of the greatest urban center in the nation. For 250 years after its first settlement Long Island changed little. From 1812 to the turn of the century Suffolk County's total population increase amounted to only 42,582 souls. Even the railroad did little to alter the generally rural atmosphere. All this serenity came to an abrupt end following World War II when people, equal in number to the population of more than a dozen states, emigrated eastward across the city line. Vast public works were carried out, parkways and expressways laced the largest island on the Atlantic seaboard. But it was not until 1974, two years after passage of the Federal Water Pollution Control Act Amendments, that the fruits of environmental management became apparent and resulted in this far-reaching document. Chronologically it represents the Region's fourth most important plan—following the Nassau County Charter in 1938, the Suffolk County Charter in 1959 and the Bi-county Comprehensive Development Plan in 1970—affecting the lives of all its residents.

There is a valid question concerning the Region's success in developing comprehensive studies. Would they be possible without a regional planning agency? Possibly, yes; anything is. But as timely and of such professional calibre; probably not. Therefore, the underlying wisdom in establishing an areawide regional planning agency has been amply justified. The Nassau-Suffolk Regional Planning Board was created in 1965 by adoption of ordinances and resolutions by the Boards of Supervisors of Nassau and Suffolk, in accordance with provisions of the General Municipal Laws of New York State. As the solutions to economic and social problems become increasingly regionwide in nature, having this agency with a proven track record in performance already in place will serve as a source of assurance to Long Island citizens.

It would be extremely shortsighted to view this plan as just another study—its pages like leaves on trees, deciduous and gone, once fallen to the ground. Its direct value is in its use as a working document, important to the life-styles of future generations and business growth. Indirectly, the applicability of its analyses and findings renders it of national importance and in turn assures national recognition of Long Island as a homogeneous entity with identity well beyond its false reputation as simply a bedroom community.

There is a legal expression, "The evidence speaks for itself." So do the following pages. In the main, Long Island's water supply, derived solely from its own groundwater sources (and not even partially from Connecticut—the erroneous impression lingers) is adequate in terms of quantity. Tunnels from upstate or other outside sources are not only unnecessary, they are equally foolish even to consider. But there is the point-blank question of preserving the quality of our water. This stern challenge must be met by the courage of government supported by an informed constituency, sensitive to parochial interests, yet willing to override them for the common good. Effective implementation will provide bread-and-butter benefits in preserving home values, protecting the quality of life and sustaining economic strength.

Elsewhere in this document the reader will find amply justified expressions of appreciation to the numerous private citizens who served on the technical and citizens advisory committees. Policy was always determined by Board members, past and present. Their cooperation along with that of elected officials was crucial to the completion of this work. In this regard our lasting gratitude is enthusiastically extended to the following: to former founding member and Chairman, Leonard W. Hall; former County Executives Ralph G. Caso and H. Lee Dennison; County Executives John V. N. Klein and Francis T. Purcell; former Board members, Thomas Halsey and Robert Flynn; and present Board members: Vice Chairman Seth Hubbard, Vincent Balletta, Robert Bell, Winfield Fromm and John Wickham. Finally, words are often weak and fruitless when attempting to describe the single most important contribution. For that I simply conclude with where it all began, was and will be, by use of proper noun: Dr. Lee E. Koppelman.

Harold V. Gleason
Chairman

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This program has been a collective endeavor in the best sense of that term. Interdisciplinary skills, involving a wide array of scientific talents, and administrative inputs from all levels of government were required. The program could not have been satisfactorily completed without the enthusiastic participation and support of all persons involved in the development of the Nassau-Suffolk Areawide Waste Treatment Management Plan. The dedication and pride of involvement displayed by the members of the various county departments, consulting firms, and members of the public, were indeed a marvel, and credit for the products of this program must be shared with these people. We have tried to acknowledge their contributions by including their names on the Participation Page. We sincerely hope that we have not inadvertently omitted recognition of anyone. In particular, we owe a debt to our colleagues of the United States Environmental Protection Agency, Region II, who displayed as deep a committment to the interests of Long Island as any of the local representatives. Mr. Eckardt Beck, Regional Administrator, and his able colleagues, Mr. Conrad Simon, Mr. Charles Durfor, Mr. Anthony Conetta and others provided invaluable guidance and staff support. They were positive advocates for the program from its inception. Our requests were seriously considered and promptly acted upon—including bringing Federal scientific experts to our agency as specific problems unfolded. We enjoyed similar general support from the New York State Department of Environmental Conservation. Commissioner Peter Berle, Deputy Commissioner Theodore Hullar, Mr. Thomas Eichler, Mr. Michael O'Toole, Jr., Mr. Philip DeGaetano, Mr. Philip Barbato, Mr. Andrew Yerman, Mr. James Redman, and Mr. Wiacheslaw Fedoriw, ably represented the State's interests.

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Prefatory Comments

Introduction

The passage of the Federal Water Pollution Control Act Amendments of 1972 heralded a new era in environmental management. National interest and purpose was stated in the goal to achieve "water quality which provides for the protection and propagation of fish, shellfish and wildlife and provides for recreation in and on the water" by 1983, wherever attainable. It not only set forth a timetable for action but also provided some new approaches to solving the problems of our nation's polluted waters. For the first time there is a clear recognition that improved quality and the prevention of further pollution will also require changes in land use and management of growth in addition to the prevailing practice of building sewage treatment works. Non-point sources of contamination which result from construction and agricultural activities, highway runoff, widespread discarding of the residues of modern society, and the lack of control over animal wastes, etc. must now be considered. The Act is a landmark in three other instances. It provides for a comprehensive planned approach, requires strong citizen participation in the planning process and mandates a commitment from state and local governments to implement the results of the planning effort.

Section 208 of the Act specifically creates a comprehensive water quality management program to deal explicitly with both the treatment and the prevention of water pollution. The plans prepared under this program must include a process for meeting established water quality goals and must show that management institutions exist with sufficient financial and legal authorities to implement the plan; or that new institutional arrangements will be created to achieve this purpose.

The Nassau-Suffolk Regional Planning Board (NSRPB) was designated by Governor Malcolm Wilson in December 1974 as the regional planning entity to carry out Section 208 planning for Nassau and Suffolk Counties. Realizing that a program of this magnitude had to have the support and input from those governmental agencies that either have an interest in, or a mandated role to play in water pollution control, the NSRPB immediately established a Technical Advisory Committee (TAC) to assist it in the preparation of the plan. The initial voting constituency of the TAC included representatives from the Nassau County Departments of Health, Public Works and Planning. The Suffolk County participants were from the Departments of Health and Environmental Control and the Suffolk County Water Authority. The seventh member was the Executive Director of the Nassau-Suffolk Regional Planning Board who served as Chairman of the Technical Advisory Committee and Project Director for the overall program.

In addition to the seven voting members, representatives from the Interstate Sanitation Commission, Region II of the Environmental Protection Agency (EPA), the New York State Department of Environmental Conservation (NYSDEC), the United States Geological Survey (USGS), the Suffolk County Soil and Water Conservation District and the Soil Conservation Service (SCS), the Cooperative Extension Service (CES) and the New York State Department of Health (NYSDH) were invited to participate as resource members.

In accordance with the guidelines for Section 208, and prior practices of the Board in conducting other regional planning studies, the Citizens Advisory Committee (CAC) was created to provide input to the TAC from the general public, and to act as a forum for distributing the findings of the study to the general public.

The Program received a $5.2 million grant from the EPA to carry out the detailed work program necessary to comply with the requirements of the Act.

Between January 1975 and June 1978 the TAC, which was formed prior to the grant award in June 1975, met at least one day a week, first for the design of the Program and selection of consultants, and then for the general conduct of the Program. The CAC met bi-weekly during this period.

The consultants retained to carry out specific technical tasks were selected by national solicitation on the basis of merit. This single factor was one of the key elements in achieving the high level of competence displayed in the Plan.

Report Description

This report is a summary of the numerous working reports and studies prepared by the various consultants and member agencies of the project. It is also a reflection of the original workplan submitted to the EPA, with additional materials developed to meet amendments to the project which resulted from changes in the federal regulations, or work elements generated from requests made by the CAC. In addition to the working reports, six interim reports that summarize the technical documents have been prepared for public distribution. They are: (1) *Population Estimates and Projections 1975-1995,* (2) *Modeling Studies,* (3) *Surface Water Quality,* (4) *Groundwater Conditions,* (5) *Management Options* and (6) *Virus Study.*

This summary report constitutes the last in the general series. The Board also published a Soil Conservation Service study that discusses the impact of animal wastes as a major non-point source of pollutants to the ground and surface waters. The interim reports and the summary report affords the serious reader a reasonably sufficient exposition of the 208 Plan.

In response to the unusually large demand for these reports we have prepared this second printing in a two volume set. Volume 1 contains the Plan Summary. Volume 2 contains all of the previously printed Interim Reports and also contains the nitrogen studies conducted by Dr. Keith Porter of Cornell University and the analyses of the organic sampling study prepared by Energy Resources Company, Inc.

This presentation is in seven sections, plus a bibliographic data summary. *Section One—General Background*—contains a descriptive discussion of regional ground and surface water considerations. This portion has three segments. The first is a discussion of groundwater, including its major uses, existing quality and contamination sources. The second segment discusses the surface waters of the two counties in similar fashion. The third segment describes major options of structural and non-structural nature, and includes a description of the various evaluation and selection factors used in making choices.

Section Two—Assessment of Conditions—is devoted to an assessment of conditions, including population and land use, pollutant sources from point and non-point origin, and a discussion of transport mechanisms. Groundwater quality and quantity, and surface water quality are summarized to include the major findings of the study. The last segment of this chapter describes the marine, fresh water and terrestrial ecological conditions.

Section Three—Alternative Wastewater Management Programs—the major segment of this report, presents various wastewater management alternatives to control point and non-point source pollution. It includes structural and non-structural approaches ranging from sewer installations with varying degrees of treatment, to best management practices (BMP) for runoff control, fresh water conservation, watershed management and land use controls.

The first segment contains a listing and a brief explanation of the objectives that the planning options should achieve in order to insure public health protection, and the protection, enhancement and conservation of the natural resources—freshwater, marine, wetlands and terrestrial of the two counties.

The next segment contains a series of structural and non-structural plan alternatives that, in whole or in part, offer a suitable solution to a defined problem or objective. The alternatives relate both to the hydrogeological nature of the two counties, as expressed by eight distinct zones, and to the marine surface waters. Strong efforts were made to include all reasonable alternatives. In this fashion the public has a general scenario of the many ways in which waste treatment can be addressed, with some explanation of the constraints attendant to each solution, and the consequences thereof.

Section Four—Environmental Assessment—relates the environmental impacts for each of the Plan alternatives discussed in Section Three.

Section Five—Preferred Plan Alternatives—presents the options deemed by the TAC to achieve the objectives of water quality planning for Long Island in the most desirable fashion. Explanations and reasons for the selections are discussed.

Section Six—Citizen Participation—is a two-part discussion of citizen participation. The first portion (6.0—6.5), written by the Project Director, contains a history and critique of the creation, functions, activities and contributions of the CAC. The second portion (6.6—6.11), prepared by the CAC, discusses their critique of the process and planning options developed in the 208 Program.

Section Seven—Implementation—contains the recommendations for management responsibilities—existing, modified or new—to carry out the financing, design, construction, maintenance, monitoring or regulation of the Plan elements. Recommendations for amendments to existing laws or the enactment of new ones at various governmental levels are also mentioned.

Appendix A—Bibliographic Data Summary—identifies the range of data used to reach the plans' conclusions. It also contains a listing of the almost 175 reports and publications prepared by the TAC agencies and consultants in the conduct of the study.

Administrative Observations

The Section 208 effort discussed herein has proven to be challenging and rewarding. Since the Program is entirely new from a national point of view, it can serve as an example for other parts of the nation. An indication of the strengths and weaknesses, successes and failures resulting from this initial effort can assist in the formulation of continuing programs to be carried out in this Region and in other parts of the country.

First among the strengths, we should acknowledge the strong interest and support received from Region II of EPA, which recognized that Nassau and Suffolk Counties are completely dependent on groundwater for potable water supply; have a varied and complex marine environment surrounding the entire Region; and contain areas of human settlement that represent

the full triad of planning concerns, *i.e.,* urban, urban-suburban interface, suburban-rural interface. The recognition by EPA that all three impact the natural environment led to the granting of sufficient funds—well beyond the normal allocation formula—to carry out the program.

Second among them was the full cooperation in the best professional sense, of the various members of the TAC who represented organizations with sometimes strong and differing institutional biases. Third was the very high caliber of talent that exists in public service at all levels of government and which is evidenced in the results of this Study. A fourth source of strength was the impartial selection of consultants by the TAC without any external political or parochial controls to inhibit its national search for the most competent firms; and a fifth was the establishment of a strong CAC, who were self-organized rather than selected by the agency.

The weaknesses of the Program were primarily of an administrative and timing nature. Two major limitations were imposed by the insistence of EPA on plan completion, including approval by the Governor, within a two-year planning period. Although the Act requires Plan development within twenty-four months, provisions existed for project design prior to this phase for up to twelve months. EPA determined to dispense with the pre-planning opportunity. In a sense this fiat is the antithesis of the planning concept itself. The Agency was forced to "learn on the job," thus creating plans by work assignment amendments. The problem was further compounded by the changes in guidelines, regulations and reporting procedures imposed by EPA after the contract and original work program were agreed upon and approved. In essence, EPA was also "learning on the job."

The remedy for these time constraints was either to curtail some of the work efforts or to rigorously manage the productivity of staff and consultants. We chose the latter course, thus placing all of the participants under constant pressure. This in not an optimal administrative choice.

The second shortfall may develop at the end of the planning period. Implementation, in the full sense of the term, often can take as much time as the Plan development process itself. If the intent is to achieve the sincere acceptance and approval of the general public and various elected and appointed officials—and not be the result of default—then the planners and CAC members must have adequate opportunity to present the case. This was attempted in part during the two year period. The Project Director delivered nearly 50 presentations to various governmental, professional, civic, environmental and business groups in the two counties. Other members of the TAC, CAC, and consultants also made many presentations. However, the Plan options themselves could only be finalized at the end of the planning process. Thus, the public information phase has to extend beyond the first two years. This is particularly the case in a Region of almost three million people. One, or even several, "public hearings" are simply not adequate.

The Act also prohibited any work that might have been deemed research, thereby requiring agencies to use only existing techniques. Strict interpretation of this clause served to limit the comprehensiveness of the Study. A detailed example of this last point is discussed in *Section Six—Citizen Participation.*

Lest this litany of pitfalls, pratfalls and problems be deemed a dire prediction, let me stress that I do consider the 208 Program as a challenge and opportunity. Granted, the first generation of plans may show scars and evidence of misfit between expectation and achievement. Nevertheless, optimism should be the hallmark. The Nassau-Suffolk Comprehensive Water Quality Management Plan does address and satisfy the requirements of Section 208 of the Act.

This is the first national effort to cope with major environmental issues on a multi-disciplinary and interdisciplinary basis as part of comprehensive regional planning. Any successes from the first programs should strengthen future efforts and also provide the methodological base for solving other environmental problems.

July 7, 1978

Lee Koppelman
Project Director

Section I General Background

1.0 Introduction

This section sets the stage for the discussion of the options available to the Nassau-Suffolk Region in coping with the management of its waste treatment over the next two decades. The planning boundaries are described, followed by a brief description of the physical characteristics and the problems of growth resulting from three decades of rapid urbanization. One of the key problems readily apparent is the need to protect and properly manage the groundwater—the sole source of potable water for the two counties. In addition, the quality of fresh and marine surface waters must be protected for both commercial and recreational use. The response to these needs constitutes the essence of this report.

A description of the institutional setting, and a capsule summary of the work elements designed to produce a workable plan follow. The last segment discusses the key water quality and quantity issues.

1.1 Planning Boundaries

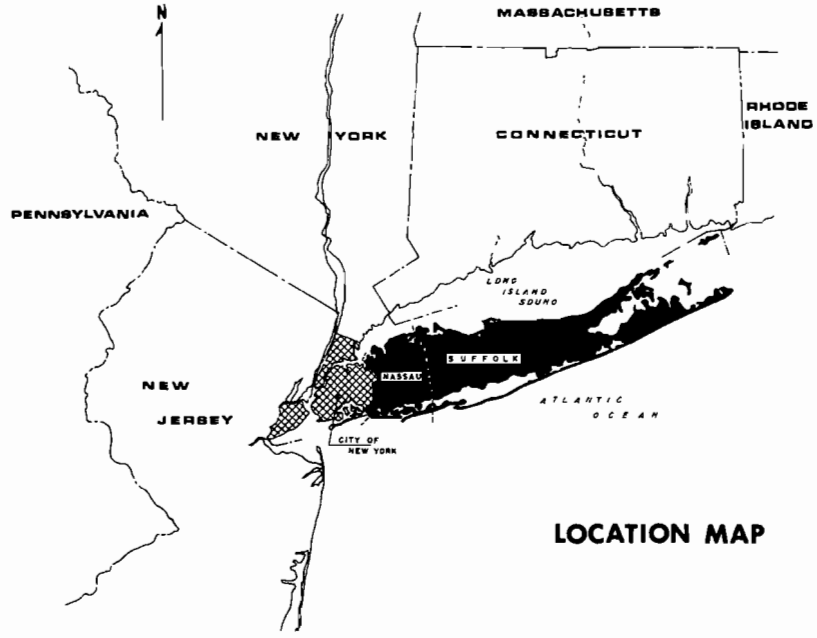
1.1.1 Location. Nassau and Suffolk Counties, occupying one-sixth of the land area of the New York Metropolitan Region, have been two of the fastest growing counties in the United States since the end of World War II. In 1960, the combined Nassau and Suffolk population of two million persons was one-eighth of the total Regional population of sixteen million. It is projected that 25 percent of the additional six million persons that will inhabit the Region by the year 1995 will be living in these two counties. The projected growth of the two counties indicates a potential increase in the impacts on the environment.

The counties, with their streams, lakes, rivers, ōcean, bay and Sound frontages exceeding 1,000 linear miles in total, are familiar natural attributes to millions of persons interested in resort and recreation opportunities. Long Island Sound on the north and the Atlantic Ocean on the south and east afford a decidedly unique advantage for the proper development of marine resources. The south shore is paralleled by barrier beaches, which create bays between the south shore of the Island and the ōcean from Long Beach on the west to the Hamptons in the Town of Southampton; Jones, Fire Island, Moriches and Shinnecock Inlets connect these bays to the ocean. This portion of the Long Island peninsula is over 100 miles long and 20 miles wide at its widest point, which is near the Nassau-Suffolk boundary. The major land area extends eastward from the Queens-Brooklyn and Nassau County border for approximately 60 miles to Riverhead. East of Riverhead two forks or peninsulas continue eastward, separated by the waters of Peconic and Gardiners Bays. The northern fork terminates at Orient Point and is approximately 27 miles in length. The southern fork terminates at Montauk and is about 44 miles long. The land areas of the two counties is approximately 1,200 square miles. Figure 1-1 depicts the municipal boundaries within the Region.

1.2 Geography

1.2.1 Physical Characteristics. A high ridge of glacial origin running approximately east and west from the northwesterly corner of Nassau County and then running in a southeasterly direction through Nassau from the North Shore reaches an elevation of about 300 feet above sea level. North of the ridge the topography is generally abrupt with an overall slope to Long Island Sound. South of the ridge is a long gentle slope terminating in the marsh and meadow land which borders the bays on the south. Four main river watersheds are located in Suffolk County. These are the Nissequogue in the Town of Smithtown, Connetquot in the Town of Islip, Carmans in the Town of Brookhaven and the Peconic in the Towns of Riverhead, Brookhaven and Southampton.

The area is mainly composed of unconsolidated deposits of sand, gravel and clay laid down in more or less parallel beds on a hard bedrock surface. The rock floor is tilted downward in a southeasterly direction, so



KEY TO MUNICIPALITIES IN NASSAU AND SUFFOLK COUNTIES

VILLAGES IN NASSAU COUNTY

Town of Hempstead

1 Atlantic Beach
2. Bellerose
3. Cedarhurst
4. East Rockaway
* 5 Floral Park (North Hempstead)
6 Freeport
7. Garden City
8 Hempstead
9 Hewlett Bay Park
10 Hewlett Harbor
11 Hewlett Neck
12 Island Park
13. Lawrence
14. Lynbrook
15. Malverne
16. Rockville Centre
17. South Floral Park
18. Stewart Manor
19. Valley Stream
20 Woodsburgh

Town of Oyster Bay

21 Bayville
22. Brookville
23. Centre Island
24 Cove Neck
25. Farmingdale
26. Lattingtown
27. Laurel Hollow
28. Massapequa Park
29. Matinecock
30. Mill Neck
31. Muttontown
32. Old Brookville
33. Oyster Bay Cove
34. Sea Cliff
35. Upper Brookville

Town of North Hempstead

36. Baxter Estates
*37 East Hills (Oyster Bay)
38. East Williston
39. Flower Hill
40. Great Neck
41. Great Neck Estates
42 Great Neck Plaza
43. Kensington
44 Kings Point
45 Lake Success
46 Manorhaven
47. Mineola
48. Munsey Park
*49. New Hyde Park (Hempstead)
50 North Hills
*51. Old Westbury (Oyster Bay)
52. Plandome
53. Plandome Heights
54. Plandome Manor
55 Port Washington North
56. Roslyn
57. Roslyn Estates
*58. Roslyn Harbor (Oyster Bay)
59. Russell Gardens
60. Saddle Rock
61 Sands Point
62. Thomaston
63. Westbury
64. Williston Park

CITIES IN NASSAU COUNTY

65 City of Glen Cove
66. City of Long Beach

VILLAGES IN SUFFOLK COUNTY

Town of Huntington

67. Asharoken
68. Huntington Bay
69 Lloyd Harbor
70. Northport

Town of Babylon

71. Amityville
72. Babylon
73. Lindenhurst

Town of Smithtown

74. Head of the Harbor
75. Nissequogue
76 Village of the Branch

Town of Islip

77. Brightwaters
78. Ocean Beach
79. Saltaire

Town of Brookhaven

80. Belle Terre
81. Bellport
82. Lake Grove
83 Old Field
84. Patchogue
85. Poquott
86. Port Jefferson
87. Shoreham

Town of Southampton

88. North Haven
89. Quogue
*90. Sag Harbor (East Hampton)
91. Southampton
92. Westhampton Beach

Town of Southold

93. Greenport

Town of Shelter Island

94. Dering Harbor

Town of East Hampton

95 East Hampton

Incorporated Villages situated within two towns

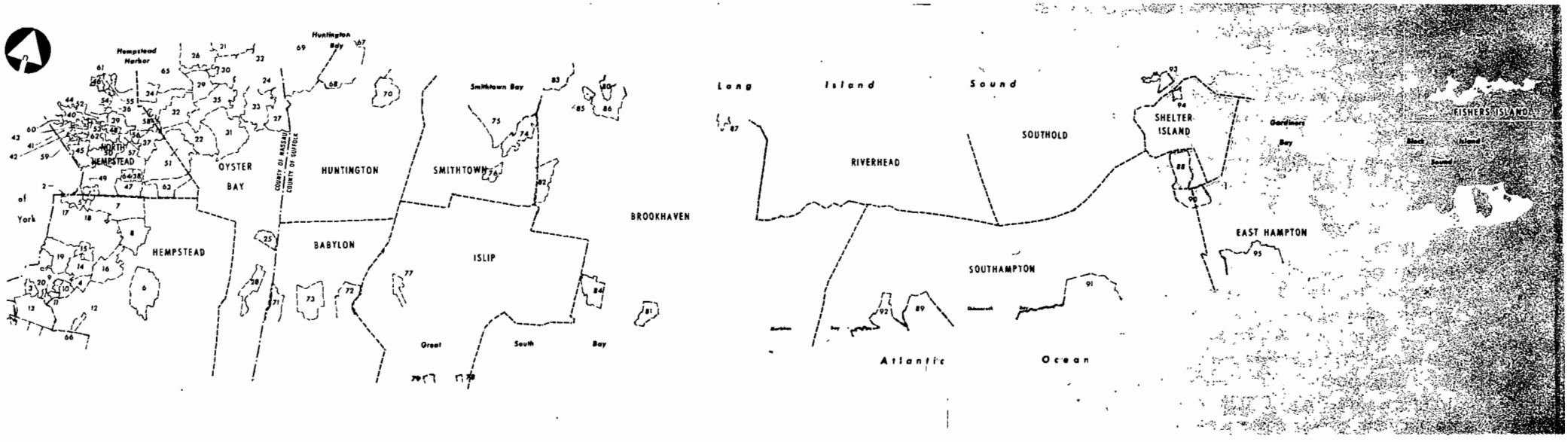


FIGURE 1–1 *Nassau and Suffolk Counties—Municipal Boundaries*

that from a position of surface outcroppings in the northwest end of Long Island (Queens County) it reaches a depth of 2,100 feet below sea level beneath Fire Island. The subsoil is generally sandy and yellow colored except on the ocean side of the south shore dunes, which are of light gray sea sand. The topsoil is particularly suited for agricultural uses in various parts of the Region. Elsewhere the ground is generally covered with scrub growth, mostly oaks and pine. North of the glacial ridge there is an abundance of flora including many of the hardwoods as well as evergreen cover.

Estuarine marshes and the off-shore waters abound in a variety of shell- and finfish. The inland fresh waters, particularly in Suffolk County, have an abundance of trout and other important sport fish.

The water supply for the Nassau-Suffolk Region is obtained entirely from groundwater. Natural replenishment of this supply is derived solely from precipitation (*i.e.,* rain, snow and sleet), which averages 44 inches per year. It has been estimated that approximately 50 percent of the precipitation is lost due to evapotranspiration and other factors, so that only about half of the precipitation reaches water-bearing strata.

1.2.2 Problems of Growth. Obviously, Long Island is an area where the quality of life and large segments of the economy are related to and dependent on the quality of its environment. Tourism, agriculture, seasonal homes and residential communities thrive in areas of healthy and aesthetically attractive natural settings. There are a number of major surface and groundwater pollution problems. Marine water problems include excessive nutrient enrichment and the closing of beaches and shellfishing areas due to bacterial contamination, which is attributed to both point and non-point sources of pollution. Some portions of the fresh water streams have dried up and others are threatened because of lowered groundwater levels due to sewering and excessive well pumpage. Groundwater quality has been degraded by nitrates, chlorides and other contaminants from fertilizers, recharge of domestic and industrial wastewater, landfill leachate, and stormwater recharge. Water quality—both potable and marine—is the key to Long Island's future. Planning for the orderly growth of these communities and the management of their wastes is the linchpin that will determine the quality of the future.

In response to earlier perceived growth problems, *e.g.,* residential sprawl, transportation deficiencies, rapidly changing community characteristics, increased deterioration of older downtowns and housing, and shortages of community facilities, the Boards of Supervisors of Nassau and Suffolk Counties created the Nassau-Suffolk Regional Planning Board in 1965. This agency's prime task was the preparation of a comprehensive plan that would serve as a guide for all units of government in the two counties in coping with future growth and in reversing the negative aspects of past development.

The Comprehensive Land Use Plan was completed in July, 1970. In essence, it recommended controls on the ultimate size of growth, location and form of development, and institutional changes necessary to achieve implementation. Based on environmental data extant at the time, it was apparent that the most obvious limit to growth was the availability of potable water. It was also apparent that some degradation of these waters had already occurred. However, the projected total population of 3.3 million people by 1995, was less than 60 percent of the estimated population that could be sustained, and it was assumed that the Plan was environmentally prudent.

The Nassau-Suffolk Regional Planning Board also recommended that additional funds be sought to conduct water quality studies in order to insure that the two counties' sole source of potable water not be jeopardized. The advent of the 1972 Amendments to the Water Pollution Control Act (PL 92-500), and particularly the Section 208 planning provision, furnished the answer to this quest. In the next section, a brief discussion of the planning program will indicate the nature of the designation process and the organization of the technical staff and will identify the major substantive elements in the Program.

1.3 Institutional Setting

1.3.1 Designation. The 1972 Amendments to the Act provide that the Governor may designate regional planning agencies to engage in 208 planning. Where such agencies are not designated, the State is required to assume the planning responsibility. Several of the operating agencies in Nassau and Suffolk Counties, and the Nassau-Suffolk Regional Planning Board expressed interest in this designation. The two County Executives agreed that the Board should be the applicant.

All agencies that wished to be eligible for 100 percent funding had to receive designation before January 1, 1975 and receive contractual approval from EPA prior to July 1, 1975. In late November 1974, a preliminary work program was quickly assembled and a designation request was made to the Governor. On December 28th, Governor Malcolm Wilson gave the first designation in the State of New York to the Board.

1.3.2 Technical Staffing. The Program represents a joint effort of the Board and various regulatory, operating and planning agencies in Nassau and Suffolk Counties. A Technical Advisory Committee (TAC), with seven voting members, was formed. The Nassau Departments of Health, Public Works, and Planning were matched by representatives from the Suffolk County Water Authority and the Departments of Health Services and Environmental Control. The Executive Director of the Board, who is Project Director for the Program, serves as the Chairman of the TAC.

In addition, the New York State Department of Environmental Conservation, Region II of EPA, and the Interstate Sanitation Commission also provide representatives to serve as non-voting resource persons. The TAC is composed totally of professionals. It was organized in this fashion with the recognition that the agencies with the responsibilities for carrying out portions of the Plan should have the opportunity to participate in its formu-

lation. Also these participants represented the cumulative local expertise and knowledge base at the onset of the Program.

Preparation of a detailed work program was the initial work conducted by the TAC. At first, a list was compiled of each agency's recommended projects. Much culling, additions, deletions and alterations occurred as the items were compared with the requirements and/or limitations of the Act. The document finally submitted to EPA and the State for contract approval was reduced from $17 million to $5.2 million during this iterative design stage, and quite faithfully adhered to the requirements in the Act.

A secondary concern during this pre-planning period was expressed in regard to the work to be conducted by consultants where specialized talents and equipment were needed. The TAC followed the procedure mandated by the Board, and sole source contracts were awarded only to those governmental and/or academic institutions that had a unique talent. In all other cases, the TAC prepared "Requests for Proposals," which were advertised nationally. This procedure was followed in order to secure the best talents in the country. Although this technique was time-consuming and often onerous, it has proven meritorious. The consultants were selected by the voting members of the TAC on the basis of the technical merit of their proposals. Budget information was kept sealed until each selection was made.

1.3.3 Work Elements. The general goals of the Program to achieve water quality criteria established by Federal and State laws require an extensive knowledge of the existing and proposed land uses and demography of the Region; the quantity, quality and hydrology of the ground and surface waters, including inter-relationships between both; the types, sources, amounts and impacts of contaminants entering the waters; the alternative technologies best suited to address any specific problems; the legal, fiscal and institutional arrangements; and the laws, agencies and regulations needed to implement the completed Plan. This aspect will be discussed in the implementation section of this report.

The Comprehensive Land Use Plan released by the Nassau-Suffolk Regional Planning Board in 1970 still serves as the basic guide for the development of the two counties until 1995. The Plan has been updated over the past three years as a result of a United States Department of Housing and Urban Development assisted project that involved the development and testing of a methodology for the integration of coastal zone science with the planning process. Fortuitously, only minor modifications were indicated to enable the Plan to meet specific environmental needs. This affords a strong advantage to the two counties' likelihood of producing a workable waste management plan—the land use plan already exists. Thus it is much easier to develop and test two major management approaches. If we assume that the land use plan will be realized, then it becomes a task of estimating the contamination loadings that will result from the various land uses and recommending treatment facilities, *e.g.,* sewers, treatment plants, etc. Conversely, the land use plan can be modified and population densities altered to avoid the need for structural solutions. Both approaches are examined in this Program.

Comprehensive water supply studies were conducted in each county during the 1960's and early 1970's. These studies evaluated the possible changes in groundwater quantity that might result from the implementation of various wastewater treatment proposals. The United States Geological Survey, which was chosen as one of the public agency consultants by the Board because of their extensive knowledge of Long Island's groundwater, has conducted studies in the bi-county area for many decades. During recent years, the Survey developed an electric analog model, which simulates the physical characteristics of the groundwater system. This model was used in the 208 Study to simulate water level responses to a number of hypothetical water-management options.

Water quality problems are usually of significantly greater complexity than questions of water levels or of water quantity. Investigations and monitoring programs are generally conducted for the purpose of providing information on ambient groundwater conditions, as well as of examining the adverse effects of known or suspected sources of pollution, and to assess water quality improvements attributable to correction measures (*e.g.,* sewers). For example, in the past, studies have been conducted addressing the impacts of individual on-lot sewage disposal systems, landfill leachate, detergents, sewage treatment effluent recharge, stormwater recharge, meteorological conditions, fertilizers and pesticides. The pollutants monitored were limited to those considered relevant to public health and natural resources, for which reliable monitoring procedures were available.

During the past few years, the increasing awareness of the presence of additional hazards to public health and natural resources, as well as the continuing development of sampling and analysis techniques, have resulted in the monitoring of additonal substances, *e.g.,* viruses and organic chemicals. The 208 Program included a study of organic chemicals, heavy metals and viruses in wastewater and groundwater in the bi-county area. Water sample locations were carefully selected to reflect the influence of various types of land use and wastewater activities. Samples were analyzed for heavy metals, organics in trace amounts and viruses.

In order to provide simulation capabilities for water quality evaluations, the Department of Civil Engineering of Princeton University was retained to adapt and apply existing digital models (one, two and three-dimensional) to simulate the impacts of various groundwater levels on saltwater intrusion, and further groundwater pollution. The modeling runs are paralleled with quality evaluations based on empirical data and related literature. The work also included a digitization of the Geological Survey's analog model to facilitate the testing of management alternatives.

Similar emphasis was placed on questions of surface water quality. Various estuarine steady-state and time-variable models were applied to specific bodies of water to estimate the effects of various waste treatment

schemes on receiving water quality.

The reliability of model results bears a direct relationship to the accuracy of pollutant loadings input into them. Point sources of contamination have been routinely identified and tested. In the past this was sufficient because wastewater studies were directed towards engineering solutions to these sources of contamination. Much of the current planning effort is also concerned with non-point sources of pollution—stormwater runoff, sedimentation, uncontrolled deposits of animal wastes, etc. Several responses to these more pervasive and usually unquantified sources were included in the Work Program. The Cooperative Extension Service conducted field studies and literature searches to identify and evaluate the volumes of pesticides, fertilizers and other home and agricultural chemicals used in the two counties. The impact of nitrogenous fertilizers, relative to other sources, was evaluated in part by means or a preliminary regional nitrogen balance. The Suffolk County Soil and Water Conservation District identified other non-point pollution problems associated with various animal populations, runoff and sedimentation. In addition, the two County Health Departments, the Suffolk County Department of Environmental Control (which was already engaged in a study of fertilizers), the Suffolk County Water Authority, and the Town of Islip Department of Environmental Control, all contributed substantially to the sampling and analysis of non-point sources.

The information gathered from the sampling and analysis programs served as inputs for the determination of engineering and non-structural alternatives for the achievement of water quality objectives. This approach afforded the broadest possible array of policy choices as to method, location, timing and cost of solutions.

The alternatives and their consequences have been considered by the TAC for the purpose of selecting the most viable combinations of solutions—structural and non-structural—that in the aggregate form the Comprehensive Areawide Waste Treatment Management Plan for Nassau and Suffolk Counties. The Citizens Advisory Commitee (CAC) has also reviewed and contributed to the final product. In some instances where more than one solution is viable, or where a consensus was not achieved, this report mentions the array of choices.

1.4 Regional Ground and Surface Water Considerations

Within the overall framework of the 208 Program, major technical issues have arisen which have had to be addressed as part of the Study. This segment of Section One includes a discussion of the major considerations. It relies upon the previous segments to describe the regional setting and then discusses ground and surface water uses, and quantity and quality problems. The segment is concluded by generalized descriptions of management options, which may be applicable to the Bi-county Region. It is presented to effect a transition between the planning issues and the scientific/engineering considerations.

1.4.1 Groundwater

1.4.1.1 Major Uses. Groundwater beneath Nassau and Suffolk Counties is the only source of potable water for almost three million people. Pumpage and use characteristics within the Region are complex and fragmented. The user of groundwater can be a single facility operating its own domestic well on a small parcel of land, a large water district with a dozen individual high capacity wells located miles apart in several different communities, a private water company with a single well field serving one subdivision, or an industry partially supplied by its own well system and partially dependent on a local utility. Thus, pumpage for different well owners can range from a few hundred gallons to many millions of gallons per day.

The use of water withdrawn is equally varied. Groundwater pumpage satisfies not only domestic requirements, such as drinking water, but also must meet the needs of industry, commerce, agriculture and recreation.

Water supplies are developed principally from two major water-bearing units: the Upper Glacial and Magothy aquifers. A relatively unexploited third aquifer, the Lloyd, lies beneath the upper two formations, and is separated from them by a thick, confining bed of clay. Total withdrawal from all aquifers now approaches 400 MGD (million gallons per day).

The pattern of pumpage is not uniform. The development of multiple sources of supply, even when not necessitated by fragmented supplies, was deliberate in order to more uniformly withdraw from the system and thus minimize the disruption of equilibrium conditions. Major concentrations of pumpage have been developed near areas of dense population, leaving other portions of the subsurface reservoirs underutilized. This has resulted in a pronounced east-west imbalance in pumpage distribution. Also, degradation of water quality in the Upper Glacial aquifer beneath urbanized areas has led to the abandonment of shallow wells, in favor of withdrawing water from progressively deeper aquifer zones. Thus, the principal water supply aquifer in Nassau County and western Suffolk is the Magothy, whereas the principal water supply aquifer in eastern Suffolk County is the Upper Glacial.

Groundwater discharge supports streamflow for most of each year. The volume of groundwater underflow discharged to surrounding saltwater bodies can affect surface water salinity. Relatively small fluctuations in water table elevations, on the order of a few feet, can cause pronounced changes in stream discharge. On the other hand, underflow to saltwater bodies is not very sensitive to such fluctuations. It has been estimated that substantial changes in consumptive use of groundwater in the Region would be required to significantly affect underflow.

A certain amount of underflow is also needed to maintain the fresh-salt water interface at an equilibrium position. The position of the boundary between fresh and saline groundwater is dependent upon changes in water levels in the various aquifers. However, the fresh-salt water interface is generally some distance offshore in the confined aquifers of Long Island. Therefore, changes in head at the interface, resulting from reductions in

natural recharge or increases in pumpage and consumptive water use, are generally small and localized. Inland movement of saline groundwater is very slow, even in areas where the interface is already onshore and close to centers of pumpage.

1.4.1.2 Existing Quality. The quality of groundwater in the aquifers of Long Island is dependent upon a number of factors. In undeveloped areas, recharge from relatively good quality rainfall, together with whatever natural treatment and pollutant retention is provided by the vegetation, soils and geologic sediments have resulted in the availability of very high quality groundwater in the underlying aquifers. Where the land has been subjected to heavy use or modification by man, groundwater quality has been degraded. The degree of degradation is dependent upon the type of land use; the location of individual sources of contamination, such as cesspools and landfills; the characteristics of the contaminants; and the length of time that the waste disposal practice has been in existence.

Groundwater quality is also extremely dependent upon hydrogeologic factors. Recharge to the Magothy from the water table or Upper Glacial aquifer occurs over a large area along the central east-west corridor of the Island. This region, where groundwater movement is generally vertically downward and unimpeded by intervening clays, is commonly referred to as the Magothy recharge area. Therefore, sources of contamination discharging to the water table can migrate downward to the underlying Magothy.

Deep flow also occurs in portions of the Upper Glacial deposits to the north of the limits of the Magothy recharge area in Nassau and western Suffolk.

Along the South Shore and parts of the North Shore groundwater movement is generally horizontal or upward, and intervening clays inhibit downward movement of groundwater, even where heavy pumping is taking place. This region is referred to as the Magothy discharge area. Groundwater quality is considerably more vulnerable to land use changes and sources of contamination in recharge areas than in discharge areas.

Another factor affecting groundwater quality over the long term is the slow movement of groundwater, especially in the vertical component. Under natural conditions, it takes about 100 years for water from the surface to reach the lower portion of the Magothy in the center of the Island. Heavy pumpage in the Magothy can reduce this time period to about twenty years. Thus, sources of contamination can be eliminated (for example septic tanks and cesspools replaced by sewers) but the effects on deeper aquifers may not be noticeable for many decades. In the Upper Glacial aquifer the effects of pollutants and of remedial measures are realized much faster.

Actual groundwater quality problems in the 208 Region have been characterized by a significant rise in nitrate concentrations in portions of the recharge area of the Magothy aquifer. Also of importance is the discovery of organic chemicals in sections of the two counties in both shallow and deep aquifers. Several independent analyses of nitrate trends in shallow groundwater and in the Upper Glacial aquifer were completed during the period in which the 208 Program was conducted. From this work, it is difficult to make clear-cut generalizations regarding statistically calculated trends, especially with respect to making distinctions between sewered and nonsewered areas. However, there is general agreement that nitrate concentrations are decreasing in many shallow wells in southwestern Nassau County where sewering took place in the 1950's and early 1960's. In unsewered eastern Nassau, one of the analyses also found generally decreasing nitrate trends, while another failed to find a trend. Water in shallow wells in southwestern Suffolk has generally increasing concentrations of nitrate. On the basis of limited data, it appears that the quality of the underlying Magothy has not improved. In Nassau County, the Magothy has apparently sustained an overall decline in water quality.

Individual sources of contamination, such as landfills and industrial waste recharge basins, have developed discrete bodies of contaminated groundwater. These plumes of contaminated water are isolated, but are of extreme importance locally. Analysis of organic chemicals is a new effort, and, thus far, no trends can be developed from the very limited data collected.

1.4.1.3 Contamination Sources and Identification of Control Needs. There are many sources and causes of contamination in the 208 area. Basically, these can be divided into four categories (Table 1–1). The first two categories include discharges of contaminants that are derived from solid and liquid wastes. The third category concerns discharges of contaminants that are not related to wastes, and the fourth category consists of those causes of groundwater contamination that are not discharges at all.

The variety and type of controls available for each category differ. For example, some Category I causes may require a discharge permit, whereas others may be controlled by restrictions on land use. Sources under Category II may require satisfaction of specified construction standards, such as the lining of landfills and the installation of leachate collection systems. Guidelines and manuals (*e.g.,* tons/lane-mile limits on highway deicing salts) may be the only tools available for dealing with Category III. Special types of regulatory controls are available for the causes of groundwater contamination listed under Category IV. An example is the current system of groundwater diversion applications and hearings employed to minimize saltwater encroachment. Another is the continued licensing of drilling contractors in order to upgrade waterwell construction practices.

The protection of groundwater quality involves both the elimination or mitigation of existing problems, and the prevention of new ones. Control needs will vary depending upon the nature and location of the source of pollutants, and upon the prevailing background or baseline conditions.

In the case of an established industrial source, the imposition of effluent controls and monitoring to assure compliance may be the best approach. Where the pollutant generating activity is a necessary one that is not readily controlled by traditional permitting systems, as in the case of landfills,

TABLE 1–1
CLASSIFICATION OF SOURCES AND CAUSES OF GROUNDWATER CONTAMINATION USED IN DETERMINING LEVEL AND TYPE OF CONTROL

Category I	Category II	Category III	Category IV
Systems, facilities or sources designed to discharge waste or wastewaters to the land and groundwaters.	Systems, facilities or sources not specifically designed to discharge wastes or wastewaters to the land and groundwaters.	Systems, facilities or sources that may discharge or cause a discharge of contaminants that are not wastes to the land and groundwaters.	Causes of groundwater contamination that are not discharges.
Domestic on-site waste dispoal systems	Sanitary sewers	Highway deicing and salt storage	Airborne pollution
Sewage treatment plant effluent	Landfills	Fertilizers and pesticides	Water well contruction and abandonment
Industrial waste discharges	Animal wastes	Product storage tanks and pipelines	Saltwater intrusion
Stormwater basin recharge	Cemeteries	Spills and incidental discharges	
Incinerator quench water		Sand and gravel mining	
Diffusion wells (heat)			
Scavenger waste disposal			

relocation to an area where the aquifer is already degraded, and no longer used for water supply, may be appropriate. The prevention of degradation in relatively pristine areas may require a management program that employs a combination of land use and other non-point source controls to prohibit or severely restrict the development of potential pollutant sources.

1.4.2 Surface Water

1.4.2.1 Major Uses. Surface waters on Long Island provide a variety of beneficial uses. Fresh waters, including streams and lakes, are used for aesthetic enjoyment, swimming, fishing and boating. Marine waters, including bays and estuaries, are used for both commercial and recreational purposes. Shellfishing and finfishing are major commercial enterprises in bays and estuaries. Recreational use includes shellfishing, sportfishing, swimming and boating. In addition, the assimilative capacities of surface waters may allow their use as a major receiving system for waste disposal.

In recognition of the variety of, and sometimes competing, beneficial uses, Long Island marine waters have been classified by the New York State Department of Environmental Conservation as to their potential best usage in the public interest.

The New York State Department of Environmental Conservation classification of best usages for marine waters, in decreasing order of water quality requirements, comprises the following four classes:

SA Waters suitable for shellfishing for market purposes and primary[1] and secondary[2] contact recreation.

SB Waters suitable for primary and secondary contact recreation and any other use except shellfishing for market purposes.

SC Waters suitable for fishing and all other uses, except for primary contact recreation and shellfishing for market purposes.

SD Waters not primarily suitable for recreational purposes, shellfish culture, or development of fishlife and which cannot meet the requirements of these uses.

Notes 1. Primary contact recreation means activities where the body may come in direct contact with raw waters to the point of complete submergence (*e.g.,* swimming, diving, water skiing, skin diving and surfing).

2. Secondary contact recreation means activities where contact with the water is minimal and ingestion of water is not probable (*e.g.,* fishing and boating).

These specific uses are dependent upon naturally functioning marine ecosystems which are commonly characterized by a number of water quality parameters. Two major parameters are dissolved oxygen and coliform bacteria concentrations. Adequate dissolved oxygen is essential to the growth and reproduction of finfish and shellfish. Dissolved oxygen is also required in the natural decomposition of organic wastes. Current public health standards call for low coliform bacteria concentrations since the presence of such bacteria is regarded as an indication of potentially pathogenic contamination due to human or animal wastes.

1.4.2.2 Existing Quality. The tidal flushing of Long Island's North Shore bays is substantially greater than in the South Shore bays or the Peconic Estuary. Because of the greater tidal range in Long Island Sound, a parcel of fresh water or waste discharged to a North Shore bay will be flushed out within one to three days, whereas from one to three months may be required in eastern Great South Bay.

The dispersion and flushing of pollutants within any bay is generally maximum for discharges near the inlet and decreases with distance away from the inlet. Localized pollution problems generally exist where streams or municipal waste discharges enter a bay at a point well away from the inlet.

Within each bay, constituent concentrations are modified by biochemical processes. The parameters of primary concern, which reflect the net result of complex processes, are coliform bacteria and dissolved oxygen

concentrations. Levels of these constituents have been established for each bay system by the New York State Department of Environmental Conservation. In addition to these parameters, salinity levels, and the concentrations of inorganic nutrients (such as nitrogen and phosphorus), trace metals, and organic compounds must also be taken into account when assessing the general water quality of surface water systems. Trace metals and certain organic compounds are essential for plant growth but may become toxic at higher concentrations.

Coliform bacteria (both total and fecal) are used as indicators of fecal contamination and possible presence of pathogenic microorganisms. Dissolved oxygen is an important parameter because it is necessary for the health of fin and shellfish as well as other marine and freshwater organisms. Concentrations of dissolved oxygen represent the net result of many processes including photosynthesis, respiration, degradation of organic matter and surface gas exchange. It has been found that photosynthesis and respiration by phytoplankton are the major processes controlling dissolved oxygen concentrations in most of Long Island's marine waters. It has also been shown that nitrogen availability is closely linked with the abundance of phytoplankton. High nitrogen concentrations are indicative of a high potential for phytoplankton growth and resulting fluctuations in dissolved oxygen concentrations.

Because sources of pollution are both temporally and spatially variable, violations of receiving water quality standards are also variable. However, all of Long Island's bays have shown violations of receiving water quality standards for shellfishing. Similarly, all bays have periodically exhibited nutrient concentrations sufficient to allow phytoplankton blooms, with subsequent low dissolved oxygen levels. It should be noted that the coliform standard for shellfishing waters has recently come under criticism and has withstood a court challenge by three local towns and local baymen (August 1977). The standard will be the subject of two separate studies to be performed by New York State Department of Environmental Conservation and Suffolk County Department of Health Services beginning in early 1978.

The existing quality of surface freshwaters is extremely difficult to characterize in broad terms since the water quality of these bodies is highly dependent upon non-point pollution sources and subsurface groundwater inputs. In general, the more highly developed the drainage basin, the poorer the quality of fresh surface waters. Almost all of the freshwater lakes and ponds on Long Island have been periodically closed to swimming because of excessive coliform counts. Some streams in urbanized areas consistently exhibit dissolved oxygen levels below State standards. Conversely, those surrounded by large buffer zones of vacant open space such as the upper Connetquot and Carmans Rivers produce some of the finest fishing and exhibit quality characteristics equal to drinking water standards.

1.4.2.3 Sources of Pollutants. Contamination of surface waters comes from stormwater runoff and groundwater underflow. The relative contribution to surface waters from each source is generally dependent upon the land use and surface area within a specific drainage basin. In general, point source discharges are more common in the highly developed areas of Nassau County, while non-point sources from street runoff and groundwater underflow generally contribute a relatively larger proportion of pollutant loadings in the less developed areas. The surface streams, whether they receive their pollutant loads from point or non-point sources, are a major source of contaminants to the surrounding marine waters. The degree of contamination derived from a particular stream will depend upon the volume of streamflow, the rate and degree of pollutant input, and the degree of mixing of stream and bay waters. Other sources of marine surface water contamination include point source discharges from sewage treatment plants, subsurface inflow from groundwater, discharges from boats, and inputs from adjacent marine waters. In any particular bay, the degree of contamination attributable to those sources depends upon the rate of input of the pollutant and its rate of removal from the system by physical and biological processes.

1.4.3 Management Options

1.4.3.1 Introduction. There are many approaches that can be utilized to manage the ground and surface water quality problems of the Bi-county Region. The more traditional type of program has reacted to existing water quality problems by constructing facilities to ameliorate them. Less traditional approaches are to guide growth and to develop various types of programs which prevent water quantity or quality problems from occurring or to develop solutions which do not include facilities. The former approach can be defined as a structural set of solutions while the latter approach is non-structural in nature. The recommendations of the 208 include implementation of both types of programs.

The 208 has identified and evaluated numerous options and approaches. In some cases, only general evaluations could be performed while at other times, detailed studies were possible. However, the intent throughout has been to identify a viable set of options, both structural and non-structural, which should be studied in detail in more localized studies. This is the key to the relationship between 208 and the more detailed studies (*e.g.,* 201 Facilities Plans) in the Nassau-Suffolk area. The 208 must identify the structural and non-structural alternative approaches which are viable on a regional level. The more detailed local studies must start with the regionally satisfactory options and screen them as to their applicability at the local level.

1.4.3.2 Structural Approaches. The structural approach to wastewater management begins with collection of the waste. Water carriage has been and will continue to be the method of waste transportation in the Nassau-Suffolk Region for all wastes except certain special hazardous wastes. Sewers will be used whether the wastes are conveyed to large regional facilities or to smaller local or sub-regional plants. Modifications such as pressure or vacuum systems may be used in local situations.

The 208 Program has analyzed alternative collection concepts and has determined that vacuum and pressure collection systems should be evaluated

in local studies. The comparison to traditional gravity collection should be made on the basis of construction cost, operation and maintenance costs and on operational reliability. A concern of the 208 is the energy consumption, on a continual basis, of pressure or vacuum systems. As energy costs continue to increase, and as energy resources become increasingly limited, vacuum or pressure collection systems become increasingly less attractive.

Structural treatment options are generally grouped according to the types of wastes that they process. Domestic sewage, for example, is one type of waste; industrial waste, another. A number of processes, both biological and physical/chemical, are available for the treatment of domestic sewage (activated sludge, activated carbon filtration, etc.) and other systems have been proposed or tried on an experimental basis (*e.g.*, spray irrigation, marsh-pond system, etc.). It is worth noting that all biological systems, including conventional biological treatment as well as spray irrigation and marsh-pond, are variations on a single theme, differing in design details such as scale, layout and treatment efficiency.

Industrial liquid wastes can be divided into two categories: toxic and non-toxic. The non-toxic wastes can be handled in the same manner as domestic sewage. The toxic wastes are almost exclusively handled by physical/chemical treatment processes.

Stormwater runoff is difficult to treat by structural approaches because of high and variable flow rates. Sedimentation and disinfection may be feasible options.

The 208 Program has investigated various treatment options and has determined that two of the newer concepts should be tested in a situation where the processes would receive no more than normal operating attention. The marsh-pond treatment process will be tested by Suffolk County at the Village of Greenport sewage treatment plant site (1978 funds approved). Although design procedures and criteria will be obtained during this test, normal operation by plant personnel rather than control by an engineering staff will be used. Similarly, improved septic tank systems, which de-nitrify the waste, should be tested in a small development. Once these systems have operated satisfactorily through all seasonal conditions, and procedures for design and implementation are obtained, their use as potential alternatives to conventional systems can be considered.

The treated effluent and sludge, which includes domestic industrial and hazardous wastes, must be disposed. The normal disposal methods for treated effluent are sea or bay disposal, recharge to the ground, stream augmentation or land surface application. The options available for sludge disposal include barging, various types of incineration and land disposal either on Long Island or outside the area. EPA regulations, however, call for the cessation of ocean dumping of sludge by 1981. The selection of any of these disposal techniques depends upon the toxicity of the waste, cost-effectiveness and the degree of desired protection of ground and surface water quality.

1.4.3.3 Non-Structural Management Options. Non-structural management options identified in this Program relate to the control of potential sources of pollution. They may be categorized as follows:

a. Options to prevent the establishment of sources
b. Options to better manage existing sources
c. Options to eliminate existing sources.

Land use controls can be used to prevent new sources of pollution from arising. An activity may be prohibited, or it may be permitted to develop in a controlled manner consistent with environmental objectives.

Good management practices can minimize pollution discharges. For example, in areas of low soil permeability, septic systems may malfunction as a result of septage not being periodically pumped from the tank. Hence an appropriate management policy may be to require pumping according to a formally required procedure. Likewise, wastes from domestic animals on streets and highways may constitute a major source of contamination in storm drainage water. A non-structural option may be to prohibit littering or to require owners of dogs not to allow their dogs to defecate where water pollution might result. Regular sweeping of streets would also limit the amount of pollutants transported in stormwater.

Another management practice that may be particularly relevant to Long Island is to encourage the use of fertilizers and pesticides at levels not exceeding the requirements of cultivation. Thus householders could be encouraged to adopt "low maintenance" methods of cultivating lawns as opposed to growing species of grasses that demand high levels of water and chemicals for their maintenance.

If use of inorganic fertilizers by householders were to be banned outright, the ban would constitute an example of the total elimination of a potential source of contamination. Such bans are difficult to implement. However, Suffolk County's recent prohibition of the sale of non-biodegradable synthetic detergents is an example of a successful management attempt to eliminate an existing pollution source. Likewise the prohibition of chronically toxic and persistent pesticides such as DDT has begun to reduce the levels of these chemicals in the environment. Similarly, certain organic materials should also be controlled. The substitution of less harmful materials in place of such organic chemicals may provide a partial, non-structural solution.

1.4.3.4 Legal/Institutional. Another set of possible management options deals with the formulation of legal and institutional programs. These types of approaches might include the following:

—strengthening of existing laws or regulations
—enacting new laws or regulations
—restructuring of existing county and town level agencies
—establishment of new agencies
—elimination of existing agencies
—redefinition of responsibilties.

The thrust in these types of management options is to ensure that proper regulatory power exists, that regulation and operation of facilities do not conflict, and an adequate system of monitoring and control is available.

An institutional approach recognizes that improvements can be made in the administration and implementation of water quality management programs. It recognizes the need for improved communication between operating agencies and for a clear definition of responsibilties.

1.5 Summary

Nassau and Suffolk Counties together form a region of about 1,200 square miles, having a total of more than 1,000 miles of ocean and bay shoreline, lakefront and river edge. The area's subsoil is mostly sandy, and groundwater is the sole source of potable water. Precipitation averages 44 inches per year, of which approximately one-half is lost to the atmosphere and to the surface waters by evapo-transpiration and runoff.

Long Island's environment possesses a particular importance, because the area is an important place of resort for vacationers and sportsmen of all kinds. Its waters and marshes abound in shellfish and finfish of many varieties, and its coastline offers esthetic pleasure to many.

The quality of this environment, however, is beginning to suffer from problems due to growth. In areas of more intense development, marine water quality is deteriorating from the discharge of excessive quantities of nutrients. Beaches and shellfishing areas have been closed to the public because of bacterial contamination. In certain locations, heavy pumping of groundwater and the installation of sewers with disposal to marine surface waters have caused a permanent drop in the water table, with the resulting drying up of parts of streams. Groundwater quality, in parts of the Region, has been degraded by pollutants from excessive fertilizer application, the recharge of domestic and industrial wastes, landfill leachate and stormwater recharge.

The dangers of uncontrolled development have been recognized for a long time, and the Nassau-Suffolk Regional Planning Board issued a Comprehensive Land Use Plan in 1970. Since then, Congress has recognized the need for more detailed studies of water pollution problems in many areas, and, in 1972, passed the Federal Water Pollution Control Act Amendments. Under Section 208 of this act, funds have been made available to study the Region's waste disposal and water supply problems, and to devise a plan for their solution.

The plan will include a combination of many management options, which can be categorized under the following three headings:

a. Structural, *e.g.,* the installation of collection and treatment systems, etc.
b. Non-structural, *e.g.,* passing ordinances for the control of animal wastes, instituting special practices for minimizing runoff at construction sites, carrying out public education programs concerning the correct use of certain materials in agriculture and in the home, and so on.
c. Legal/Institutional, designed to improve the administration and implementation of water quality management programs.

Some of these options will have areawide applicability, others will be determined by the specific needs of each locality. In combination, they will protect the Bi-county Region's esthetic and recreational values, and ensure a healthy and adequate water supply for the foreseeable future.

Section 2 Assessment of Conditions

2.0 Introduction

Current land use patterns in the nearly 1,200 square mile Nassau-Suffolk Region have been influenced by the counties' geographic location within the New York Metropolitan Area and by the historic trends that have affected the development of Long Island during the more than three centuries since the first colonial settlements were established in the east end towns of Southampton and Southold.

The earliest settlements clustered around the harbors since Long Islanders were dependent upon the sea for food and for the transport of farm products and wood to the New York City market. The construction of the railroad during the second quarter of the nineteenth century provided impetus for the expansion of farming and for the establishment of new settlements along its route. Decades later, vacationers, increasingly aware of the recreation resources of the Atlantic and Long Island Sound shores, began to come by train or boat to the older villages and to the new resort developments that preempted attractive and accessible shoreline sites in such places as Long Beach, Massapequa, Sea Cliff, Glen Cove, Cold Spring Harbor and Huntington. Soon suburban enclaves appeared in still semi-rural western Nassau County as hardy commuters took up residence in proximity to the railroad stations. Completion of an East River tunnel in the early twentieth century speeded rail travel between Manhattan and Long Island and further spurred development of the communities along the North Shore, main line and South Shore branches of the railroad throughout Nassau and into western Suffolk. Before World War I, and especially during the 1920's, wealthy people purchased large tracts of land and built the mansions, gardens and private clubs that gave rise to the characterization of the North Shore area from Great Neck to Huntington as the "Gold Coast." Others established similarly luxurious weekend or vacation retreats in scattered locations along the South Shore or built summer "cottages" in the seasonal "Gold Coast" colonies in the Hamptons. The less affluent acquired small parcels and built cabins or tiny cottages in the presumably healthful wooded areas around Lake Ronkonkoma and along the moraine or in such shorefront communities as Bayville, San Remo, Babylon, Lindenhurst and Mastic Beach.

As early as the mid 1920's, increased mobility provided by the automobile permitted the expansion of older settlements. However, the Great Depression and, shortly thereafter, World War II brought new construction to a virtual standstill and set the stage for the explosive growth that was to follow the end of hostilities.

Commencing in the late 1940's, new household formations and a backlog of unsatisfied housing needs generated previously unknown levels of construction activity, first in central and eastern Nassau, then in western Suffolk. Increased population brought a need for vastly expanded services and provided a skilled labor force for Long Island's growing defense and high technology industries. Farms and woodlands, older homes and estates gave way to the schools and universities, the offices, stores and shopping centers that accompanied the eastward spread of residential development.

By 1975 growth had just about halted in Nassau and had slowed markedly in western Suffolk. According to the most recent estimates, less than two percent of the land area of Nassau and about 30% of the land area of Suffolk remains vacant. Approximately 95 percent of the vacant land in Suffolk is in Brookhaven and the five eastern towns. The Census Bureau's line indicating the eastern limit of the urbanized area was located in central Brookhaven in 1970, but has now been redrawn to include Long Island's most rapidly developing areas in central and eastern Brookhaven.

2.1 Land Use in the 208 Planning Region

2.1.1 Summary of Existing Land Use Patterns

2.1.1.1 General. The information on existing land use, which has been furnished to the 208 consultants in considerable area-specific detail, was obtained by updating older land use maps through the use of aerial photography, office records and, where necessary, field checks. Computerized tabulations of land use on a 1440 acre grid cell basis are available at the Planning Board. Table 2–1 presents a summary of the land use data, as of 1975.

More than three-fourths of the land area in the 208 Planning Region is built up or otherwise committed, with 44.5 percent in residential and 31.7 percent in non-residential uses. The latter category includes agricultural uses, which occupy about 5.8 percent of the bi-county acreage. Virtually all of the agricultural lands are located in Suffolk County, which has undertaken a multi-million dollar program to preserve at least two-thirds of the existing farmland through the purchase of development rights.

There is little, if any, opportunity to affect water quality or the need for sewer construction through changes in proposed land uses in Nassau

Table 2–1

THE NASSAU-SUFFOLK 208 AREA: PERCENTAGE OF LAND AREA IN VARIOUS USES, BY TOWN AND COUNTY, 1975

	RESIDENTIAL					NON-RESIDENTIAL							
Locality	High Density	5–10/D.U. per acre	2–4/D.U. per acre	0–1/D.U. per acre & Low Density	Total Residential	Industry	Commerce	Utility and Landfill	Agricul-ture	Institutional & Open Space	Total Non-Residential	Vacant	Total Land Area
Nassau													
N. Hempstead	4.6	20.5	19.5	25.5	70.1	2.6	6.3	0.3	–	17.8	27.0	2.9	32,828
Hempstead	4.1	56.1	1.0	1.0	62.2	0.9	6.7	0.4	–	28.4	36.4	1.4	77,413
Oyster Bay	1.4	19.5	14.4	30.4	65.7	2.8	3.9	0.4	–	25.4	32.5	1.8	69,275
County Total	**3.1**	**35.5**	**9.6**	**16.8**	**65.0**	**1.9**	**5.6**	**0.4**	**–**	**25.3**	**33.2**	**1.8**	**179,516**
Suffolk													
Huntington	0.3	7.0	21.8	42.5	71.6	1.2	3.3	0.7	–	17.7	22.9	5.5	59,227
Babylon	3.2	38.4	9.1	–	50.7	5.8	3.6	2.3	–	33.5	45.2	4.1	32,886
Smithtown	0.6	3.6	37.8	22.3	64.3	3.3	3.4	0.3	–	23.3	30.3	5.4	34,160
Islip	1.6	17.9	33.9	6.3	59.7	2.4	2.7	2.9	–	28.6	36.6	3.7	63,909
Brookhaven	0.8	2.7	26.6	11.4	41.5	0.9	1.4	2.1	1.8	18.3	24.5	34.0	163,366
Riverhead	0.3	0.5	4.2	5.6	10.6	0.3	1.0	12.4	45.7	12.8	72.2	17.2	41,462
Southampton	0.2	1.1	6.0	7.7	15.0	0.1	0.9	2.1	12.6	9.0	24.7	60.2	87,100
Southold	0.1	0.8	7.0	6.1	14.0	0.2	0.8	0.1	30.0	9.1	40.1	45.8	30,191
Shelter Island	–	0.9	3.5	5.7	10.1	–	0.8	0.3	0.4	4.3	5.7	84.1	7,603
East Hampton	–	0.3	8.0	4.7	13.0	0.2	0.5	1.8	3.4	17.0	22.9	64.1	46,416
County Total	**0.7**	**6.3**	**18.9**	**12.2**	**38.1**	**1.3**	**1.8**	**2.5**	**7.7**	**18.0**	**31.2**	**30.7**	**566,320**
The Nassau-Suffolk 208 Area	**1.3**	**13.3**	**16.6**	**13.3**	44.5	**1.4**	**2.7**	**2.0**	**5.8**	**19.7**	**31.7**	**23.8**	**745,836**

(Percentages may not total 100.0 due to rounding)

Source: Section C of the Areawide Waste Treatment Management Plan.

County. The townwide figures suggest a similar lack of opportunity in the western Suffolk towns of Huntington, Babylon, Smithtown and Islip. The remaining Suffolk towns, sensitive to real or assumed water supply problems and to other "quality of life" issues, have already moved to impose limits on growth through changes in zoning.

2.1.1.2 Residential Land Use. Gross residential densities generally decrease from west to east, with the highest densities in the Town of Hempstead and particularly in older Nassau communities such as the City of Long Beach and the Village of Hempstead. The next highest densities are found in portions of North Hempstead, southern Oyster Bay and southwestern Suffolk. Lower densities are found in much of northern Oyster Bay, Huntington, Smithtown and most of Brookhaven. The lowest densities are found in the remaining estate areas in northern Oyster Bay, in the extreme eastern part of Brookhaven and in the five east end towns of Riverhead, Southampton, East Hampton, Shelter Island and Southold. Residential densities vary greatly within relatively short distances, tending to be higher in the older harbor-related or rail-related communities, even in eastern Suffolk. According to the 1970 census, densities ranged from a high of 22.8 persons per acre in the City of Long Beach to 0.2 persons per acre in the Town of Shelter Island.

Most of the bi-county population resides in single family detached structures on plots of from 1/10 of an acre to several acres or more. The 1970 census revealed that 84.0 percent of the Region's inhabitants lived in single family dwellings, 15.7 percent in multi-family units and 0.3 percent in mobile homes. The percentage of the population residing in single family units was somewhat higher in Suffolk, while the percentage in multi-family units was somewhat higher in Nassau. Mobile home dwellers were virtually non-existent in Nassau and were of local rather than county-wide significance in Suffolk.

Land use studies distinguish five categories of residential use. The first or most intensive category, high density, includes all development at more than ten housing units per acre. In Nassau, the typical high density development averages about 25 housing units to the acre; in Suffolk, about fifteen. Highest densities were found in high rise apartment areas in Long Beach and Hempstead Village, where they reach 200 and 100 housing units per acre, respectively.

The second category, five to ten housing units per acre, is essentially a single family detached or two family category although it occasionally includes apartments in some of the Nassau communities and a few recreation-related or senior citizen condominiums. Areas in the five to ten housing units per acre category account for well over half of the residential acreage in Nassau, and slightly less than one-sixth of that in Suffolk.

The third category, two to four housing units per acre, like the zero to one and the low density (estate or rural) categories, is a single family dwelling category. It is a predominant category in Suffolk where it accounts for almost half of the residential acreage. Much of the newer housing in this category has been built at two units to the acre. In many areas, sewers have already been provided through connections to existing systems or through the construction of a small collection system and treatment plant to serve a single large development or group of developments. In other areas sewers are needed at present or may eventually be required. There appear to be some locations where individual systems are functioning and may continue to function well enough to meet relevant public health criteria. In areas of low density, individual systems can be constructed so that regional groundwater quality will meet drinking water standards.

The zero to one housing unit per acre category and the low density category account for slightly more than one-fourth of all residential acreage in Nassau and slightly less than one-third of all residential acreage in Suffolk.

2.1.1.3 Non-Residential Land Use. The original tabulations, which were furnished to the consultants, listed eight non-residential land use categories: industrial, commercial, institutional, utility, open space, landfill, agriculture and duck farm. For purposes of the summary table, the acreage reported for landfills has been combined with that reported for utilities. The utilities category includes power plants, waste treatment and water supply facilities, radio and TV transmission sites and transportation facilities. The acreage reported for duck farms has been combined with that for all other agricultural uses; the acreage reported for institutional uses has been combined with that for open space uses. The latter category includes acreage for parks, conservation areas, private clubs or other recreation facilities, and cemeteries.

Industrial uses occupy only 1.4 percent of the land area in the Region; 1.9 percent of the land area in Nassau and 1.3 percent of the land area in Suffolk. Although some manufacturing operations are located in older mixed use areas, increasing numbers of them are concentrated in industrial parks or strip developments, close to the Long Island Expressway, or along several of the major north-south highways.

Commercial uses, among them retail and service establishments, offices, restaurants, marinas and warehouses, occupy nearly twice the area occupied by industrial uses in the Region as a whole; three and one-half times the area occupied by industrial uses in Suffolk. Commercial uses are found in a variety of locations—in older downtowns, in strip and mixed use roadside developments, and in neighborhood, community and regional shopping centers. The Garden City—Hempstead Village—Roosevelt Field area encompasses the greatest single concentration of commercial activity in Nassau County. Smaller concentrations are located along Northern Boulevard from Manhasset to Roslyn; along Sunrise Highway, east to Patchogue; and along Route 110 from the Walt Whitman Shopping Center south to the Long Island Expressway.

Utilities and landfills account for 2.0 percent of the acreage in the 208 area; 0.4 percent of the acreage in Nassau and 2.5 percent of that in Suffolk. Nearly all of the power plants and major sewage treatment facilities are located on shorefront sites in both counties, while water supply, communication and transportation facilities, and landfills are usually located on inland

parcels. Although most uses in this category are unevenly distributed throughout the Bi-county Region, there is at least one landfill in each of the thirteen towns. The larger land users in the utilities category, the communications transmission sites and the airports, are all located in Suffolk, which listed more than twenty times the Nassau acreage in this category.

Agricultural land use represents a shrinking, but nonetheless important, category in Suffolk County and in the Region. It accounts for 5.8 percent of the land area in the Region and 7.7 percent in Suffolk County. The few remaining agricultural enterprises in northeastern Nassau County are generally small scattered operations specializing in nursery crops or produce for local sale and consumption. Estimation techniques preclude separate identification of such uses.

Ninety percent of the farm acreage in Suffolk is located in three towns: Riverhead, Southold and Southampton. The major upland crops are potatoes, cauliflower, sod and nursery stock. Ducks are raised at waterfront locations in Brookhaven, Riverhead and Southampton.

The last non-residential category comprises two major groups of land uses: institutional uses and open space. The institutional uses include churches, schools, hospitals, governmental buildings and other public or quasi-public establishments. The open space uses include parks, parkways, preserves, private recreational facilties, and cemeteries. The combined institutional-open space category accounts for almost one-fifth of the land area in the Region as a whole; a somewhat higher proportion of that in Nassau and a somewhat lower proportion of that in Suffolk. Institutional uses occupy about one-fourth of the acreage in this category. Small institutional uses are dispersed throughout the two county area. Major educational facilities, many of them located on former estates, occupy large sites in northern Oyster Bay and northwest Brookhaven, while a research facility, the Brookhaven National Laboratory, and a nuclear generating plant, now under construction, occupy some areas in northeastern Brookhaven. New York State is gradually phasing out operations at three sizeable Department of Mental Hygiene hospitals in Suffolk: Kings Park, in Smithtown; and Pilgrim and Central Islip, in Islip. Some land has already been sold off or transferred to local government for other uses, and it is expected that eventually New York State will part with most or all of the remaining acreage.

Open space uses occupy about three-fourths of the acreage in the combined institutional-open space category. Although the greater part of the open space acreage is in Suffolk County, the more intensively used recreation areas are in Nassau County. For the most part, the larger Nassau sites are at inland locations; the larger Suffolk sites are on the shore or in stream corridors. In both counties public and private efforts to preserve wetlands and stream valleys have resulted in the commitment of extensive acreage to conservation and other open space use. (See Figure 2–1 in the Map Section.)

2.1.2 Projected Land Use Patterns. The Nassau-Suffolk Comprehensive Plan sets forth priorities for rational social and economic development of Long Island that are compatible with the existing natural environment. The Plan, which was originally completed in 1970, was amended, in part, during 1976 and 1977. The revisions reflect new environmental knowledge and concern. The 1976 and 1977 amendments affected the watershed of the Peconic River, eastern Great South Bay, and Moriches Bay. These are indicated in the 1995 Revised Land Use Plan. It is anticipated that further revisions will be made as increased knowledge and changed conditions dictate. The Plan is a regional one that relates the amount of land that is zoned for categories such as industry, housing and commerce to the amount of land that will be needed for these purposes. The primary goal of the Nassau-Suffolk Comprehensive Plan is to develop a series of corridors, clusters and centers throughout the Bi-county Region. The most valuable recreation land is at the waterfront, and the best location for housing is adjacent to this recreation land. The most logical location for industry and other development is along the central spine of the Island, which would put it in proximity to the major transportation facilities. The use of the corridor concept means that the highest intensity uses would be equidistant from the North and South Shores. The development of high intensity uses in this central corridor would minimize the need for such uses in coastal areas, thus affording some protection to the sensitive shore edge in Nassau and Suffolk Counties. The recommendations for industry include a stipulation that the use of accessible sites along major highways and railroads be reserved to meet the needs of both counties. The corridors along the shorefront would be primarily reserved for water related recreation and low density residential development and, on the eastern forks, for agriculture and fishing. The Plan makes a number of recommendations relating to residential densities. It provides for the lowest density along the shore, with an increase towards the central transportation corridor.

Land for parks and conservation has been accorded a first priority in the Regional Plan. There are many sites that must be preserved in order to provide adequate recreational opportunities for existing and future residents, or to protect the environmental resources from the degradation that could result from improper development.

The Plan recommends the use of clustering techniques, a most effective tool for open space preservation at minimal cost to the community. Clustering allows for the construction of a mix of town houses, apartments and single family detached houses, while maintaining the permitted density for the development as a whole. Through the use of clustering adjoining developments, extensive open space systems can be developed, thus retaining land that is best left in an undeveloped state. This land is valuable for watershed protection and preservation of sites of particular scenic beauty or ecological significance. It also provides sites for certain recreational uses. The clustering technique also allows a reduction in utility costs such as those for water lines and sewers, and a reduction in other public expenditures for road construction and maintenance.

The Plan recommendation for centers is a combination of preservation

and more intelligent use of developable land. There are proposals for new centers to be located only in the portions of the Island that are presently undeveloped and where it is not possible to expand existing small concentrations of non-residential uses. A significant part of the new economic activity should be concentrated in older central business districts that have extensive community facilities but are losing population and importance in their section of the Region. Other locations should be extensions of small business districts that have a nucleus of community services.

The Plan accords a high priority to land for apartments, since changing age patterns and family structure indicate a demand for this type of housing. It is recommended that many of the new apartments be located in older business districts where rebuilding and increased densities would stimulate revitalization, encourage greater use of mass transit and utilize existing services.

The Plan proposes to locate as much new commercial and office space as possible in the existing central business districts. Location of new business activity in the older downtowns would permit the use of existing infrastructure and would reduce some of the pressure on the remaining vacant land.

The 1995 Plan envisions a Region in which more than three-fifths of the acreage is used for residential purposes and less than two-fifths for non-residential purposes, including farming. It is assumed that, by 1995, all of Nassau-Suffolk will have been committed to one or another land use, and that there will be no vacant land. Such an assumption does not preclude further development, which may occur through the sub-division of large estates or non-residential holdings, through in-filling in established residential and commercial areas, and through clearing and redevelopment of older areas. Table 2–2 presents a summary of the proposed 1995 land uses.

Implementation of the Plan as revised will result in an increase in residential land use of slightly more than two percent in Nassau and of more than 59 percent in Suffolk, and an increase in non-residential land use of just over one percent in Nassau and of 26 percent in Suffolk.

In Nassau, almost all of the increase in residential acreage will be in the ten dwelling units or more per acre category, while in Suffolk, approximately two-thirds of the increase will be in the less than one housing unit per acre category and the low density category, and over one-fourth will be in the two to four housing units per acre category.

Of the very small increase in acreage devoted to non-residential uses in Nassau, about three-fifths will be in industrial, one-fifth in institutional and open space, and one-fifth in commercial uses. Of the much larger increase in non-residential acreage in Suffolk, just over four-fifths will be in institutional and open space, about three-twentieths in commercial, and less than one-twentieth in industrial uses. The number of acres in agricultural use will decline, but will still account for more than six percent of the total in Suffolk County and somewhat more than 37 percent and 25 percent of the total in the towns of Riverhead and Southampton, respectively. (See Figure 2–2 in the Map Section.)

2.2 Pollutant Sources

2.2.1 Point Sources. Point sources include all discharges from domestic wastewater treatment plants and from those industries which do not discharge to a municipal system but operate their own treatment facility. The land, the ocean, and the intervening bays all receive waste discharges directly from point sources. Table 2–3 indicates the quantities of industrial and domestic wastes being discharged in Nassau and Suffolk Counties. Although the numbers of industrial and domestic plants are similar, domestic flows exceed industrial by a factor of 40.[1]

The major pattern of discharge differs markedly between Nassau and Suffolk. Nassau, being the more heavily sewered, and having all major treatment plants located near the shore, discharges 98 percent of its treated wastewaters to the surface water. Suffolk, however, discharges approximately the same amount to the land as to the bays. The quantity of wastes being treated also differs significantly, with Nassau treating a total of about 107 MGD compared to Suffolk's 16 MGD. It should be noted that operations of the Southwest District Sewage Treatment Plant are scheduled to commence in 1978. It is anticipated that flow from this plant will add 30 MGD to the Suffolk County surface water discharges by 1986.

Although greatly outweighed by domestic volumes, industrial wastes have caused significant localized degradation, especially of the groundwater resource. Recent well pumping cutbacks in both Nassau and Suffolk have been related to organic industrial discharges (*e.g.,* halogenated hydrocarbons). Leachate from landfills, septic system cleaners and other home products have also been cited as possible sources of contamination. The lack of historical data on organic chemicals makes quantification of this problem extremely difficult.

Pollutants from point sources include oxygen-demanding substances (BOD, COD), micro-organisms, heavy metals, organics, suspended solids and nutrients. For discharges to groundwater, nitrogen compounds and organic chemicals receive the most attention, although localized problems may exist with any of the contaminants listed. Modeling and other studies of the reaction of the ground and surface water to these pollutants have indicated that, for discharges to bays, nitrogen and bacteriological parameters are of primary importance. Analysis of marine water quality has shown that contravention of the dissolved oxygen standard is generally caused by the respiration of excess algae. The most feasible means of reducing dissolved oxygen standards contravention is to limit algal production through limitation of the nutrient element, nitrogen. Nitrogen is a key water quality parameter common to both groundwater and surface water. It has therefore been selected as an important pollution indicator.

The designation of nitrogen as the prime water quality indicator under consideration in this study is based upon the following:

1. The presence of nitrogen in all its forms, but particularly as nitrate, in both ground and marine waters correlates directly with the level of man's activities within the affected areas.

Table 2–2

THE NASSAU-SUFFOLK 208 AREA: PERCENTAGE OF LAND AREA IN VARIOUS USES, BY TOWN AND COUNTY, 1995

	RESIDENTIAL					NON-RESIDENTIAL							
Locality	High Density	5–10/D.U. per acre	2–4/D.U. per acre	0–1/D.U. per acre & Low Density	Total Residential	Industry	Commerce	Utility and Landfill	Agricul-ture	Institutional & Open Space	Total Non-Residential	Vacant	Total Land Area
Nassau													
N. Hempstead	6.0	20.9	19.5	25.5	71.9	2.7	6.9	0.1	–	18.4	28.1	–	32,828
Hempstead	5.5	55.9	1.0	1.1	63.5	1.1	6.8	0.3	–	28.3	36.5	–	77,413
Oyster Bay	2.6	19.7	14.4	30.4	67.1	3.1	4.0	0.3	–	25.5	32.9	–	69,275
County Total	**4.4**	**35.6**	**9.6**	**16.8**	**66.4**	**2.2**	**5.7**	**0.3**	**–**	**25.4**	**33.6**	**–**	**179,516**
Suffolk													
Huntington	1.6	7.1	21.8	43.4	73.9	3.9	3.6	0.5	–	18.1	26.1	–	59,227
Babylon	5.3	38.0	9.0	–	52.3	6.9	3.6	2.1	–	35.1	47.7	–	32,886
Smithtown	1.3	4.3	39.1	22.3	67.0	5.3	3.4	–	–	24.3	33.0	–	34,160
Islip	2.3	18.4	34.2	6.6	61.5	3.5	2.8	3.0	–	29.2	38.5	–	63,909
Brookhaven	1.8	5.1	36.7	23.4	67.0	3.1	1.9	1.5	0.5	26.0	33.0	–	163,367
Riverhead	0.7	1.0	9.3	13.0	24.0	1.5	1.5	12.3	37.3	23.4	76.0	–	41,462
Southampton	0.4	2.0	14.0	44.1	60.5	0.8	1.7	2.5	12.1	22.4	39.5	–	87,100
Southold	0.6	1.0	20.0	27.8	48.4	0.4	1.6	2.0	24.6	22.0	50.6	–	30,191
Shelter Island	–	1.2	8.1	52.0	61.3	–	1.5	0.1	0.4	36.7	38.7	–	7,603
East Hampton	0.1	0.3	15.0	46.3	61.7	0.6	1.4	1.6	3.4	31.3	38.3	–	46,416
County Total	**1.5**	**7.2**	**24.9**	**27.1**	**60.7**	**2.7**	**2.2**	**2.5**	**6.3**	**25.6**	**39.3**	**–**	**566,321**
The Nassau-Suffolk 208 Area	**2.2**	**14.0**	**21.2**	**24.6**	**62.0**	**2.6**	**3.1**	**2.0**	**4.8**	**25.5**	**38.0**	**–**	**745,837**

Source: Section C of the Areawide Waste Treatment Management Plan

2. A numerical standard not to exceed ten milligrams per liter as nitrate nitrogen must be met for all drinking water supplied to the consumer.
3. As noted above, the presence of excess nitrogen in the marine receiving waters is a cause of eutrophication and attendant contraventions of the dissolved oxygen standard.
4. The determination of nitrogen is an accurate and fairly rapid and straightforward analytical procedure.
5. A great deal of historical data exists relative to nitrogen concentrations in both ground and surface waters which can be used to assess trends.

The choice of this parameter, however, does not preclude the consideration of other contaminants, such as organic chemicals and bacteria, in the selection of wastewater management alternatives. This is more clearly exhibited in the following sections.

The distribution of point discharges is illustrated in Table 2–4. The bays of Nassau County currently receive the greatest amount of treated waste discharge, the highest being Hempstead Bay (Reynolds Channel). Suffolk County bays receive relatively little discharge, the highest quantities currently being discharged to Port Jefferson Harbor and Huntington Bay.

Waste treatment plants generate sludge. Currently, Nassau County disposes of approximately 90 million gallons of sludge per year, predominantly

Table 2–3

TOTAL POINT SOURCES–FLOW SUMMARY (JANUARY, 1976)

		Discharge in MGD		
	No. of Plants	To Groundwater	To Surface Water	Total
Nassau	Domestic 23	1.21	104.42	105.63
	Industrial 20	0.79	0.41	1.20
Suffolk	Domestic 101	7.39	6.87	14.26
	Industrial 86	1.20	0.87	2.07

Source: Section C of the Areawide Waste Treatment Management Plan

Table 2–4
DOMESTIC WASTEWATER TREATMENT PLANT DISCHARGES TO BAYS*, 1976

Water Body	County	Flows (MGD)	Total Nitrogen Lbs/day	Total Coliform 10^{10} Organisms/day
Manhasset Bay	Nassau	7.18	1,600	93
Hempstead Harbor	Nassau	6.41	3,000	140
Oyster Bay	Nassau	1.90	390	9.1
Huntington Bay	Suffolk	2.03	360	16
Port Jefferson Harbor	Suffolk	1.44	160	6
Flanders Bay	Suffolk	1.82	840	2.8
East Great South Bay	Suffolk	0.47	130	10
West Great South Bay	Suffolk	0.06	10	<0.001
South Oyster Bay	Nassau	0.0	0	0
East Bay	Nassau	0.18	40	33
Middle Bay	Nassau	4.2	860	130
Hempstead Bay	Nassau	72.45	16,000	4,300
Little Neck Bay	Nassau	1.59	240	3
Total		**99.73**		

*These loadings do not include BOD or suspended solids, since these parameters are not a major concern of the 208 Program. They do not, in general, cause significant water quality problems. Nitrogen and coliforms, on the other hand, impact substantially on water quality in all the bays.

Source: Section C of the Areawide Waste Treatment Mangement Plan.

by barging to the Atlantic Ocean. Suffolk County treatment plants produce approximately twenty million gallons of sludge per year, which is disposed of almost entirely in landfills.

In the context of 208, landfills can be considered as either point sources or non-point sources. In the Bi-county Region, there are a total of 40 major operating and abandoned land disposal sites. The liquid waste generated at landfills is termed "leachate" and is formed by the interaction of rainfall with the buried wastes. Leachate constituents may include organics, heavy metals, nitrogen, chloride, iron and microorganisms. The volume of waste can be significant. Theoretically, given average Long Island rainfall and typical geologic conditions, 100 acres of landfill could generate 40 million gallons of leachate per year.

2.2.2 Non-Point Sources. Non-point sources of pollution are a major water quality management problem in the Nassau-Suffolk area. The sources are wet-weather related, as well as continuous. The pollutant loads are discharged to surface water bodies and to the ground. Non-point discharges have been found to contain a variety of pollutant parameters, ranging from relatively innocuous grit to complex organic compounds in trace (microgram/liter) concentrations. Organics of various types are contributed by the non-point pollution sources listed below.

The pollutant parameters of major concern in non-point sources of pollution are basically the same as those found in point sources: various forms of nitrogen, organic chemicals, coliform bacteria and heavy metals. There is, however, a basic difference in the patterns of occurrence for the two types of sources–pollutant loadings from non-point sources show greater variation over time than those from point sources. This makes accurate quantification difficult and control approaches most costly.

The 208 Program has identified the following non-point sources of pollution as contributing major pollutant loadings to the ground and surface waters of the study area:

1. Stormwater runoff from highways, medium and high density residential areas and commercial/industrial areas. The major contaminants in the runoff from these areas are coliform bacteria, organic chemicals, sediment, heavy metals and nitrogen. The loadings are discharged to surface waters and to the ground.[2]
2. Cesspools and septic systems. Contaminants from properly functioning systems include nitrogen and, to a lesser degree, organic chemicals. The loadings are almost entirely to the groundwater.[3]
3. Fertilizers and pesticides applied to crops, lawns and landscaping. Over-fertilization appears to occur in residential and recreational areas. The major contaminants from agricultural chemicals are nitrogen and organic compounds. The loadings are both to groundwater and to surface water.[4]
4. Groundwater underflow to marine waters. This can be a major source of nitrogen. (See Table 2–7.)

The literature or departmental experiences have also identified a number of other non-point sources of pollution, which may cause local or temporary water quality problems, but are not as pervasive as the sources described in the previous paragraph. These sources include runoff from construction sites, discharges from boats, runoff from oil storage depots, and sand and gravel mining sites, exfiltration from sewers, and leakage from product pipelines. Although these sources are not as regionally important as the four major sources listed in the previous paragraph, they can cause significant local water quality problems.[5]

Sub-surface oil and gasoline storage tanks constitute an additional non-point source that has an impact on groundwater quality. The 208 Program has not been able to quantify the potential contamination from this source but has recognized that it could be substantial. Detailed studies and monitoring/regulatory programs for this non-point source should be continued and expanded.

Table 2–5 summarizes non-point source loadings of key parameters discharged to surface water bodies and Table 2–6 presents corresponding information for discharges to groundwater. The magnitude of the numbers, when compared to the point source loadings of the previous section, testifies to the severity of the non-point source problem. Areas contributing surface runoff directly to streams and salt water bodies are displayed in Figure 2–3.

Because of the magnitude of the loadings and the potential serious impacts on bay water quality, major efforts were made in the 208 Program to define the wet-weather loads to the bays. Studies of pollutant generation were conducted in a limited number of areas selected as representative of land uses or combinations of land uses found on Long Island. Data from

Table 2–5

ESTIMATED STORMWATER RUNOFF LOADINGS TO LONG ISLAND BAYS, 1976

Receiving Water Body	County	Total Nitrogen (Lbs/day)	Total Coliform 10^{12} Organisms/day
Manhasset Bay	Nassau	170	58
Hempstead Harbor	Nassau	220	74
Oyster Bay	Nassau	290	130
Huntington Bay	Suffolk	370	150
Port Jefferson Harbor	Suffolk	200	58
Flanders Bay	Suffolk	30	5
East Great South Bay	Suffolk	670	190
West Great South Bay	Suffolk	440	120
South Oyster Bay	Nassau	270	69
East Bay	Nassau	220	57
Middle Bay	Nassau	330	88
Hempstead Bay	Nassau	90	25

Source: Section L of the Areawide Waste Treatment Management Plan.

Table 2–6

ESTIMATED STORMWATER RUNOFF LOADINGS TO RECHARGE FACILITIES
(Based on 1975 land use data and sampling data)

		Pounds/day		
County	Drainage Basin	Total Nitrogen	Lead	Total Chromium
Nassau	N–1	720	75	14
	N–2	710	71	93
	Subtotal	**1430**	**146**	**107**
Suffolk	S–1	840	79	110
	S–2	790	81	81
	S–3A	610	58	43
	S–3B	30	3	6
	S–11B	170	19	118
	S–12C	10	1	1
	S–13B	20	1	1
	Subtotal	**2470**	**242**	**360**
	Bi-county Total	**3900**	**388**	**467**

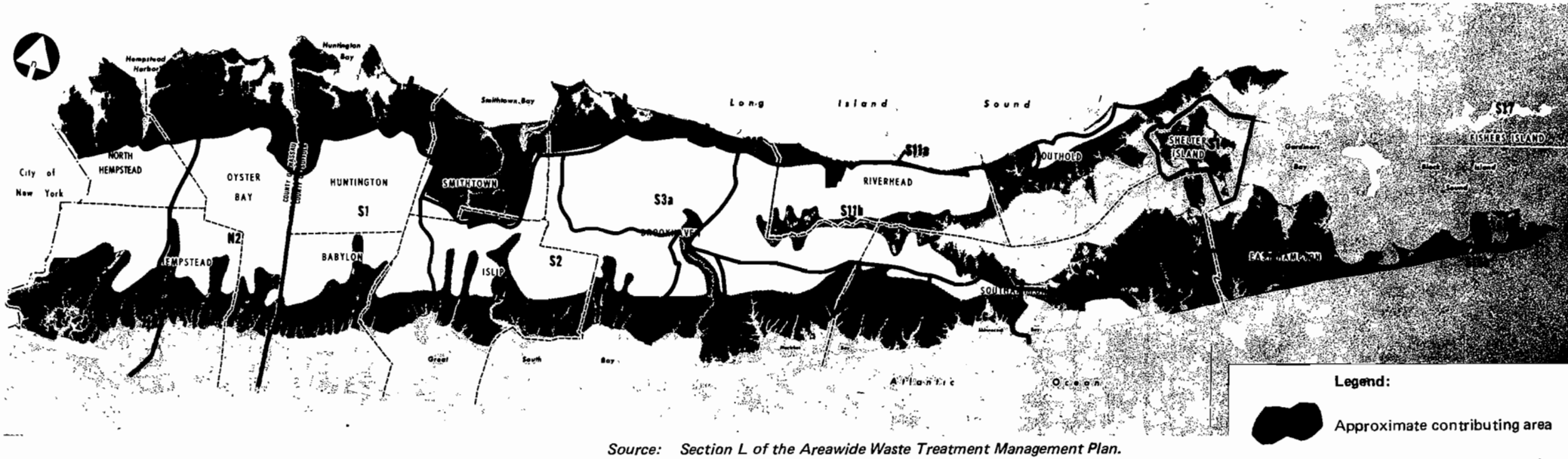
Source: Section L of the Areawide Waste Treatment Management Plan.

these studies was then extrapolated to obtain estimates for the entire SMSA. In Nassau County, which is characterized by extensive urbanization and sewering, point sources contribute the major portion of the pollutant loads of BOD, total nitrogen and total phosphorus. Wet-weather non-point sources contribute the major loadings of suspended solids and fecal and total coliform bacteria, except in Hempstead Bay. In Suffolk County, pollutant loadings are dominated by non-point sources. This is true of all parameters studied for all major surface water bodies except Flanders Bay, which receives an estimated 76 percent of its total nitrogen loading from point sources.

Tables 2–7, 2–8 and 2–9 summarize the total loadings of nitrogen and total and fecal coliforms to the various bays from point and non-point sources.

Along the North Shore of the Bi-county Region, surface runoff patterns conform approximately to the natural contours. Much of the precipitation which falls on developed areas runs off directly to the bays and follows the natural drainage divides. The precipitation which falls on undeveloped land generally infiltrates directly to the groundwater.

Surface runoff patterns along the South Shore are more complex. In general, Sunrise Highway defines the approximate northern limit of direct runoff to the bays. Most of the area north of Sunrise Highway and south of



Legend:

Approximate contributing area

N1, N2, N3... S1, S2, S3..... Drainage Basins

Source: Section L of the Areawide Waste Treatment Management Plan.

FIGURE 2–3 *Areas Contributing Surface Runoff Directly to Streams and Saltwater Bodies*

the moraine along the Long Island Expressway does not contribute surface runoff directly to the bays except for the drainage basins of certain streams. However, the storm related waste load contributed from these areas may be significant. The extent of these drainage basins was estimated in the course of the 208 Program.

The contribution to the groundwater regime occurs through precipitation infiltrating directly or being collected and recharged through recharge basins. Thus, a very large geographic area contributes substantial pollutant loads directly to the groundwater regime.

2.3 Transport Mechanisms of Potential Pollutants

The hydrologic cycle (precipitation, evapotranspiration, recharge to groundwater and runoff) provides a means of transporting contaminants on Long Island by flowing water. As fresh water flows through and over soil, it dissolves soluble materials. Overland flow suspends particulate matter.

Precipitation is the sole source of fresh water on Long Island. Generally, rainfall is distributed uniformly throughout the year and averages about 44 inches per year. Approximately eighteen inches, or about 40 percent of this annual amount, is returned to the atmosphere. Approximately 22 inches, or 50 percent, recharges to the groundwater by percolating down through the soil, and the remaining five to ten percent runs off. In addition, nearly 400 million gallons are pumped daily from the groundwater aquifer, and much of this also becomes a vehicle for contaminant transport.[6]

The major components of the hydrologic cycle may be represented in a highly simplified mass balance equation:

Recharge (fresh water restored to aquifers) = Precipitation – Runoff – Evapotranspiration – Change in Soil Storage

For the purpose of the 208 Program, the elements of this mass balance were computed for the whole Bi-county Region. The unit of time adopted for the calculations was one month, and the spatial units were defined by the 762 grid cells into which the Region was divided. These cells, each having an area of 2.25 square miles, were specified by a system defined by the Nassau-Suffolk Regional Planning Board (NSRPB) for land use planning purposes.

A brief description of the role of these components in transporting potential contaminants is presented in the following sections.

2.3.1 Precipitation. It can be seen in Figure 2–4 that precipitation averages just under four inches per month, and is quite evenly distributed throughout the year. Furthermore, the spatial distribution is also uniform. Precipitation is important, not only because it generates the flows of water that occur on the Island, but also because it is a direct contributor of pollutants. Residual materials that have become airborne over the northeastern

Table 2–7

COMPARISON OF TOTAL NITROGEN LOADINGS TO LONG ISLAND BAYS, BY SOURCE, 1976*

pounds/day
(percentage of total)

	Groundwater	Dry Weather Streams	Rainfall	Storm Runoff	Point Sources	Total
Manhasset Bay	280	140	110	170	1,600	2,300
	(12)	(6)	(5)	(7)	(70)	
Hempstead Harbor	500	340	120	220	3,000	4,180
	(12)	(8)	(3)	(5)	(72)	
Oyster Bay	790	70	170	290	390	1,710
	(46)	(4)	(10)	(17)	(23)	
Huntington Bay	760	130	200	370	360	1,820
	(42)	(7)	(11)	(21)	(20)	
Port Jefferson Harbor	250	70	110	200	160	790
	(32)	(9)	(14)	(25)	(20)	
Flanders Bay	–	120	120	30	840	1,110
		(11)	(11)	(2)	(76)	
Mecox Bay	150	70	30	60	–	310
	(49)	(21)	(9)	(21)		
Shinnecock Bay	180	40	250	60	–	530
	(33)	(7)	(48)	(12)		
Moriches Bay	700	640	290	190	300	2,120
	(33)	(30)	(14)	(9)	(14)	
Eastern Great South Bay	330	830	1,100	670	130	3,060
	(11)	(27)	(36)	(22)	(4)	
Western Great South Bay	720	1,800	640	440	10	3,610
	(20)	(50)	(18)	(12)	–	
South Oyster Bay	430	840	230	270	0	1,770
	(24)	(48)	(13)	(15)	–	
East Bay	270	630	90	220	40	1,250
	(21)	(52)	(7)	(17)	(3)	
Middle Bay	380	680	90	330	860	2,340
	(16)	(29)	(4)	(14)	(37)	
Hempstead Bay	590	80	80	90	16,000	16,840
	(3)	(1)	(1)	(1)	(94)	

**Loadings do not include nitrogen contributed by Long Island Sound or the Atlantic Ocean. See Sections "B" and "D" of the Plan for discussion of estimated loadings.*

Table 2–8

TOTAL COLIFORM LOADINGS TO LONG ISLAND BAYS, 1976*

Organisms (MPN)/day
(percentage of total)

	Dry Weather Streamflow	Storm Runoff	Point Sources	Total
Manhasset Bay	2.4×10^{12}	5.8×10^{13}	9.3×10^{11}	6.1×10^{13}
	(4)	(95)	(1)	
Hempstead Harbor	6.4×10^{12}	7.4×10^{13}	1.4×10^{12}	8.2×10^{13}
	(8)	(90)	(2)	
Oyster Bay	5.6×10^{11}	1.3×10^{14}	9.1×10^{10}	1.3×10^{14}
	–	(99)	–	
Huntington Bay	2.7×10^{12}	1.5×10^{14}	1.6×10^{11}	1.5×10^{14}
	(2)	(98)	–	
Port Jefferson Harbor	1.7×10^{12}	5.8×10^{13}	6.0×10^{10}	6.0×10^{13}
	(93)	(97)	–	
Flanders Bay	1.0×10^{12}	5.1×10^{12}	1.9×10^{12}	8.0×10^{12}
	(13)	(64)	(24)	
Eastern Great South Bay	9.4×10^{12}	1.9×10^{14}	1.0×10^{11}	2.0×10^{14}
	(5)	(95)	–	
Western Great South Bay	2.6×10^{13}	1.2×10^{14}	8.6×10^{6}	1.4×10^{14}
	(18)	(82)	–	
South Oyster Bay	6.0×10^{11}	6.9×10^{13}	0	7.0×10^{13}
	(1)	(99)	–	
East Bay	6.7×10^{11}	5.7×10^{13}	3.3×10^{11}	5.8×10^{13}
	(1)	(98)	(1)	
Middle Bay	9.7×10^{11}	8.8×10^{13}	1.3×10^{12}	9.0×10^{13}
	(1)	(97)	(2)	
Hempstead Bay	1.5×10^{12}	2.5×10^{13}	4.3×10^{13}	6.9×10^{13}
	(2)	(36)	(62)	

**Loadings do not include coliform organisms transported to the bay from Long Island Sound or the Atlantic Ocean. See Sections "B" and "D" of the Plan for discussion of estimated loadings. Total coliform loading estimates have not been made for Moriches, Shinnecock and Mecox Bays.*

portion of the United States are returned to earth in the precipitation. For example, the average concentrations of nitrogen in rainfall vary from about 1.0 milligrams per liter in Nassau County to 0.5 milligrams per liter in eastern Suffolk.[7] Thus precipitation deposits over 3000 tons of nitrogen on the two counties every year. This deposition is a significant source of the nutrient.

Table 2–9

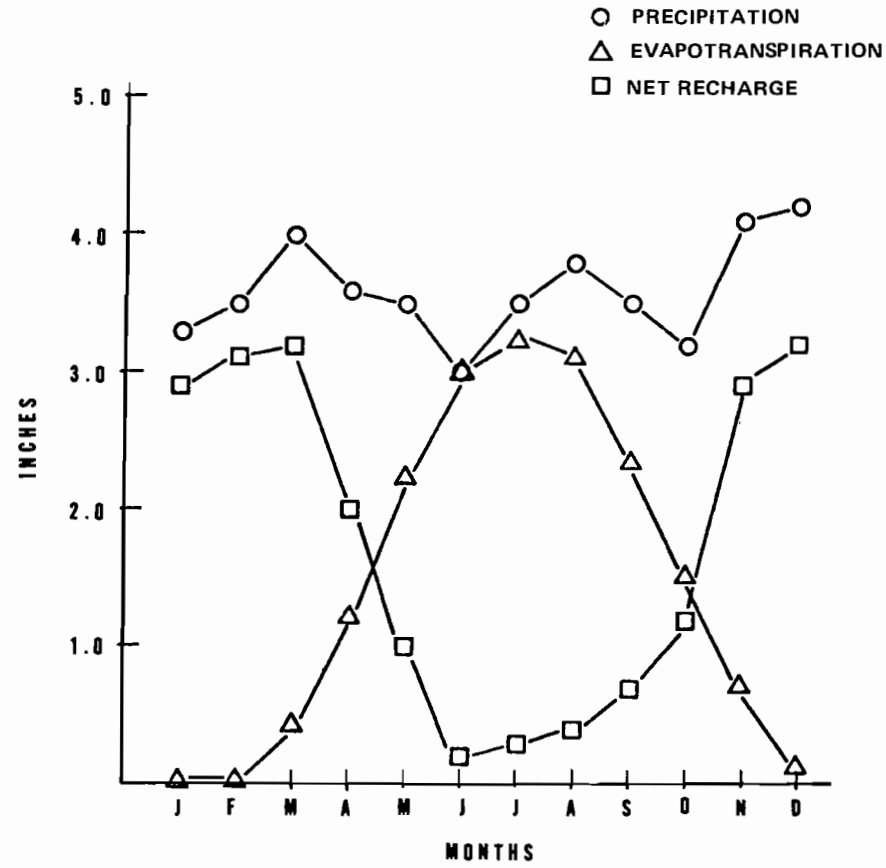
FECAL COLIFORM LOADINGS TO LONG ISLAND BAYS, 1976*

Organisms (MPN)/day
(percentage of total)

	Dry Weather Streamflow	Storm Runoff	Point Sources	Total
Manhasset Bay	1.1×10^{11} (0.5)	2.1×10^{13} (99.5)	2.5×10^{9} (–)	2.1×10^{13}
Hempstead Harbor	3.3×10^{11} (1)	2.6×10^{13} (99)	4.1×10^{9} (–)	2.6×10^{13}
Oyster Bay	9.2×10^{10} (–)	6.6×10^{13} (99)	2.9×10^{8} (–)	6.6×10^{13}
Huntington Bay	2.5×10^{12} (4)	6.2×10^{13} (96)	0.3×10^{9} (–)	6.5×10^{13}
Port Jefferson Harbor	5.7×10^{11} (3)	1.6×10^{13} (97)	2×10^{10} (–)	1.7×10^{13}
Flanders Bay	1.0×10^{12} (14)	4.4×10^{12} (63)	1.6×10^{12} (23)	7.0×10^{12}
Eastern Great South Bay	2.9×10^{12} (5)	5.7×10^{13} (95)	1.6×10^{10} (–)	6.0×10^{13}
Western Great South Bay	8.2×10^{12} (27)	2.2×10^{13} (73)	8.6×10^{6} (–)	3.0×10^{13}
South Oyster Bay	5.7×10^{10} (1)	1.1×10^{13} (99)	0 (–)	1.1×10^{13}
East Bay	2.7×10^{11} (19)	0.9×10^{12} (63)	2.6×10^{11} (18)	1.4×10^{12}
Middle Bay	2.0×10^{11} (1)	1.6×10^{13} (97)	2.5×10^{11} (2)	1.6×10^{13}
Hempstead Bay	8.7×10^{9} (–)	4.5×10^{12} (85)	7.6×10^{11} (14)	5.3×10^{12}

**Loadings do not include coliform organisms transported to the bay from Long Island Sound or the Atlantic Ocean. See Sections "B" and "D" of the Plan for discussion of estimated loadings. Total coliform loading estimates have not been made for Moriches, Shinnecock and Mecox Bays.*

2.3.2 Evapotranspiration. Figure 2–4 shows that evapotranspiration is markedly seasonal, being close to zero during winter months and almost equal to total precipitation during the summer. Evapotranspiration therefore indirectly affects the transport of contaminants, since it can reduce runoff and groundwater recharge to insignificant levels during much of the summer period. It can also affect contaminant transport directly because co-evaporation distillation of contaminants may occur in conjunction with evapotranspiration. For example, a class of pesticides, which includes DDT, is very immobile in soil. Yet quantities of these pesticides have been found in marine environments. It is believed that the primary mode of transport is co-distillation of the pesticides with water from the soil.[8]



Source: Porter, K.S. and L.B. Baskin, 1977, "A Recharge Model for Nassau and Suffolk Counties, Long Island," Prepared under Contract to the 208 Program Study.

FIGURE 2–4 *Average Values for Hydrologic Components on Long Island*

It may also be noted that urbanization, with its associated impervious areas (highways, rooftops and parking areas) effectively decreases evapotranspiration and augments runoff. On Long Island, much of this runoff is collected and allowed to percolate through the soil in excavated basins. Localities containing highly developed areas and recharge basins can thus provide greater quantities of groundwater recharge than rural and agricultural areas. However, the quality of water recharged in urban areas is substantially lower than in rural recharge areas.

2.3.3 Recharge. Recharge water, prior to its passage through the soil, may be contaminated in many ways. Contaminants in the original precipitation and materials on the land surface, such as animal wastes or organic chemicals on highways, may affect the quality of the water before it begins to percolate through the soil. There is, in addition, a major source of contamination within the soil: cesspools and leaching fields are used for human waste disposal by 40 percent of the population of Nassau and 80 percent of the population of Suffolk.

Soil can, to a limited extent, remove organic pollutants, heavy metals and microorganisms, such as bacteria and viruses, from the groundwater by processes such as filtration, adsorption, precipitation and ion exchange. However, highly soluble salts, such as chlorides and nitrates, will generally not be removed. Potential for desorption is an additional complication.

Thus groundwaters underlying Long Island's soils have acquired increasing amounts of inorganic materials as the Region has become urbanized. As shown in Table 2–10A, the estimated annual load of nitrogen carried down to groundwater by regional recharge is over 16,000 tons. This nitrogen is primarily in the nitrate form, and about 30 percent of it originates from human waste being discharged to groundwater. The 16,000 tons which appears in the groundwater is only about 50 percent of the original load. Runoff accounts for very little of the difference and it is believed that denitrification in the soil is a major factor. A very large portion of the nitrogen input to the Long Island system is believed to escape to the atmosphere in the gaseous form.[9]

The figures given in Table 2–10A represent gross averages for the entire Bi-county Region. It must be recognized that a great deal of variability will be encountered under specific conditions. Also, the relative average magnitudes of the various components will change from locality to locality within the Region. For example, Table 2–10B shows gross estimates of nitrogen produced in a residential area with medium density housing. As can be seen, the relative magnitudes of the loads differ from those for the whole Region.

The original total load of nitrogen for the acre would produce a concentration of inorganic nitrogen of about 30 milligrams per liter, if it all leached. It is estimated however, based on work done during the 208 Program, that reductions in nitrogen levels during, or prior to, leaching to groundwater, would produce an actual concentration closer to fifteen milligrams per liter. This compares with ten milligrams per liter that would be

Table 2–10A

GROSS SUMMARY OF ESTIMATED SOURCES AND FATE OF NITROGEN IN THE BI-COUNTY REGION
(Based on 1975 and 1976 data)

Source	Initial Nitrogen Load	Load to Groundwater (tons/yr)	Comment on Sink
Wastewater			
On-site systems	8500	4300	(Denitrification, etc.)
Sewers & sewage treatment			
Sewer leakage	500	200	(Denitrification, etc.)
Effluent discharge to ground	200	100	(Denitrification, etc.)
Effluent discharge to marine bays	4200	–	(Discharge to sea)
Sub-total	13400	4600	
Fertilizers and Animals			
Farm (incl. sod farms)	4000	1000	(Crop removal)
Turf (incl. households, golf courses, etc.)	9300	5600	(Volatilization & Denit.)
Animals (primarily dogs & cats)	1600	800	(Volatilization & Denit.)
Ducks	600	300	(Volatilization & Denit.)
Sub-total	15500	7700	
Precipitation	4000	3700	(By difference from totals)
Totals	32900	16000*	(Totals estimated by water/nitrogen model)

**Assuming an annual recharge of about 500 billion gallons, the resulting concentrations in the leachate equals about 6.8 mg/l.*

Source: Porter et al., 1978, "Nitrogen on Long Island, Sources and Fate," Cornell University/Cooperative Extension Service.

Table 2–10B

ESTIMATED ANNUAL LOADS ORIGINATING ON AN ACRE OF RESIDENTIAL LAND WITH THREE HOUSES

Source	Lbs. of Nitrogen Initial Load	Lbs. of Nitrogen Approx. load to Groundwater	Assumption
10 Persons	100	50	(10 lbs. N/person)
15,000 sq. ft. of turf	45	25	(average household income $16,000)
Pets	10	5	(0.82 lbs/person approx.)
Precipitation	10	6	(1 mg/l)

Source: Porter et al., 1978, "Nitrogen on Long Island, Sources and Fate," Cornell University/Cooperative Extension Service.

predicted by empirical relations based on groundwater data, presented by Porter.[10]

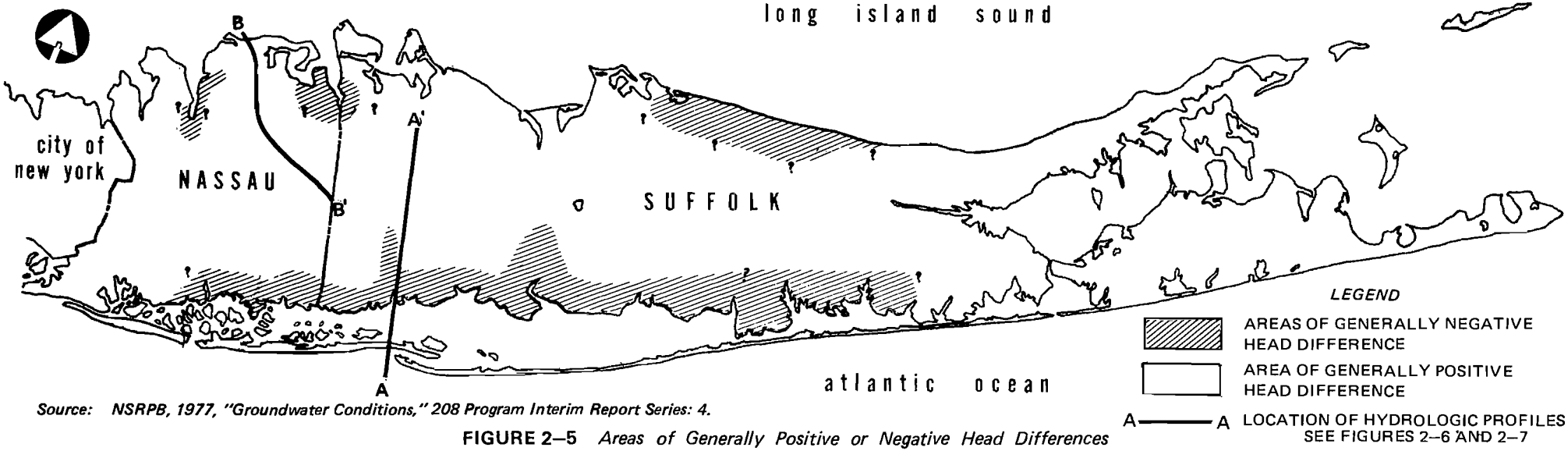
As discussed by Porter, the estimate of ten milligrams per liter is probably an underestimate of the true level of nitrogen in the groundwater due to bias in the data.

2.3.4 Groundwater Flow. Once the recharge water enters the saturated zone, movement is controlled by the natural and artificial flow regimes operating in the system. Although groundwater moves very slowly, it can travel long distances. As a result, sources of contamination of human or natural origin, which are apparently remote, may have prolonged and wide-reaching groundwater impact at some time in the future.

Based on estimated flow rates in the Upper Glacial aquifer, many shallow wells in that aquifer now reflect the quality of water that entered the groundwater system since the late 1940's. The exact age of water at these wells is probably quite variable, depending on depth, location, permeability of the sediments at the particular site, and the influence of pumping.

In the central portion of Long Island, recharge to the Magothy from the water table aquifer occurs over a large area. The definition of this region is critical in trying to assess how chemical contaminants, introduced to the water table from the land surface, will tend to move in the groundwater system. Groundwater in the water-table aquifer near the groundwater divide is subject to hydraulic gradients which tend to carry some of the water vertically downward to the deepest part of the Magothy. To the south and north of this zone, water from the shallow deposit flows with vertical and horizontal components that result in some water moving in the middle portion of the Magothy. Farther toward the coastlines, circulation becomes shallower until, at some point, flow is essentially horizontal in both the water-table and the Magothy aquifers. Beyond this area, water in the Magothy has a vertically upward component, while the water in the shallow deposits flows essentially horizontally until it discharges to streams or saltwater bodies. Under predevelopment conditions, it takes about 100 years for water from the surface to reach the lower portion of the Magothy in the center of the Island. The travel time to the barrier beach is about 800 years and, to the North Shore, about 400 years.[11] However, the travel time may be greatly reduced by pumping. Partial cross sections of Long Island, depicting typical patterns of groundwater flow, are shown in Figures 2–6 and 2–7. The location of these cross-sections is shown in Figure 2–5.

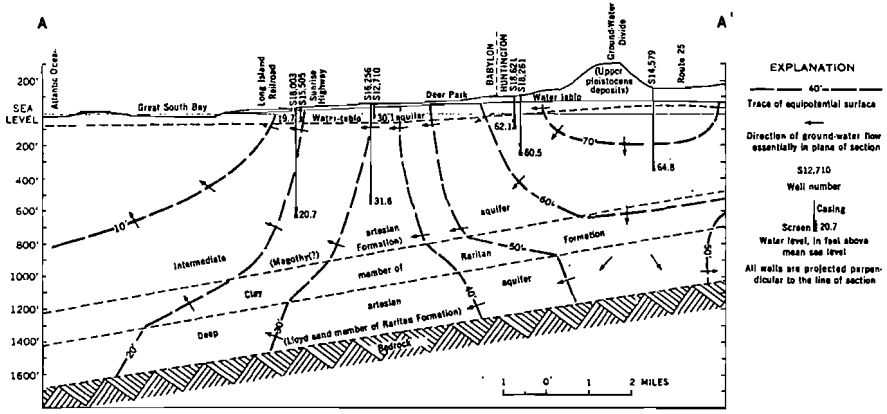
In general, the distribution of known contaminants follows the typical flow patterns shown above. It should be noted, however, that the flow patterns in reality are complicated by layers of different types of materials in the ground, such as clay lenses in otherwise sandy layers. However, groundwater flow into the bays constitutes a significant source of nitrogen to the surface waters. In some cases the nitrogen loads from groundwater inflow are more than one-third of the total input.[12]



Source: NSRPB, 1977, "Groundwater Conditions," 208 Program Interim Report Series: 4.

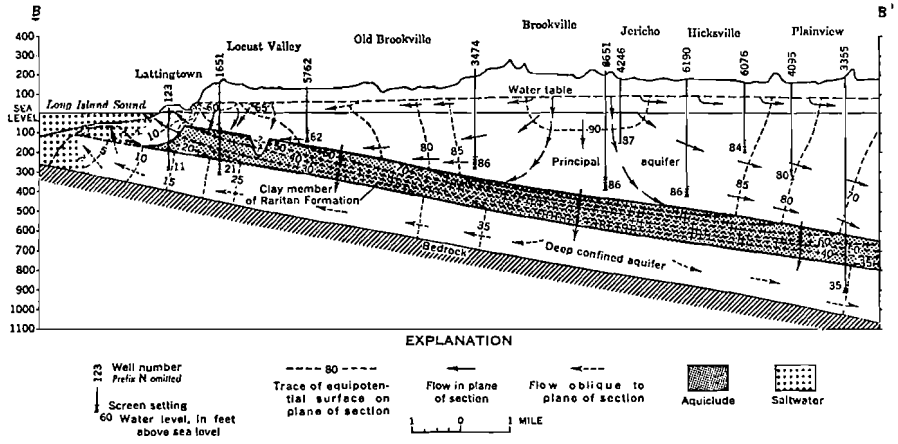
FIGURE 2–5 *Areas of Generally Positive or Negative Head Differences Between Wells Screened in the Water Table and Lower Magothy Aquifers, Based on USGS Maps for 1966, 1972, 1974 and 1975*

NOTE: POSITIVE HEAD DIFFERENCE MEANS THE WATER TABLE ELEVATION IS HIGHER THAN THE ELEVATION OF THE BASAL MAGOTHY POTENTIOMETRIC SURFACE AT A GIVEN POINT.



Source: Pluhowski, E.J. and I.H. Kantrowitz, 1964, "Hydrology of the Babylon–Islip Area, Suffolk County, Long Island, New York," USGS Water Supply Paper 1968.

FIGURE 2–6 *Approximate Hydraulic Profile of the Groundwater Reservoirs Underlying the Babylon–Islip Area, October 1960*



Source: Franke, O.L. and P. Cohen, 1972, "Regional Rates of Ground Water Movement on Long Island, New York," USGS Professional Paper 800–C.

FIGURE 2–7 *Hydraulic Section Through the Groundwater Reservoir from Lattingtown to Plainview, in March, 1961*

2.3.5 Surface Runoff. As already indicated, the volume of surface runoff from undeveloped land represents probably no more than five to ten percent of the original precipitation.

Measurements at twelve sites during the 208 Study produced an estimated average rate of infiltration of over seven inches per hour. This suggests that the soil is capable of infiltrating the precipitation of a 100 year storm, which delivers as much as four inches of precipitation in one hour, or eight inches in 24 hours. It should be noted that extremely heavy precipitation may impact the soil in a way that reduces natural infiltration.

Most runoff occurs as a result of precipitation falling on an impermeable area. It follows that the volume of runoff has been increased by urbanization. The proliferation of residential areas, shopping malls, highways and parking lots has required the provision of drainage systems. Drains and storm sewers all greatly augment the transfer of contaminants. Nitrogen, sediments, coliform bacteria and other pollutants may all be dissolved or suspended and conveyed to surface waters.[13] (See Table 2–11.)

Table 2–11

APPROXIMATE YEARLY LOADS TO SURFACE WATERS FROM WET-WEATHER RUNOFF, 1975

	BOD lbs/yr	Suspended Solids lbs/yr	Total Nitrogen lbs/yr	Total Phosphorus lbs/yr	F. Coli organisms/ yr	T. Coli organisms/ yr
Nassau	1,185,000	8,942,000	597,000	195,000	5.4×10^{16}	1.9×10^{17}
Suffolk	2,307,000	16,911,000	1,137,000	368,000	1.1×10^{17}	3.5×10^{17}
Total	3,492,000	25,853,000	1,734,000	563,000	1.6×10^{17}	5.4×10^{17}

Source: Weston, R. F., 1977, "Wet-Weather, Non-Point Source Pollutant Loads in Nassau and Suffolk Counties," Prepared under contract to the 208 Program Study.

2.4 Groundwater Availability and Quality

A basic understanding of present groundwater conditions and trends is essential in evaluating various 208 plans for waste management. The following sections describe current knowledge of the overall availability of groundwater to meet water supply requirements. In addition, the status of water quality in the various aquifers underlying the 208 Region is discussed.

2.4.1 Groundwater Availability. The limit on the amount of groundwater available for development is termed the "safe" or "permissive" yield of the system. The concept of safe or permissive yield is normally defined as: "the amount of groundwater which can be withdrawn from the system and used consumptively on an annual basis without producing undesired results."[14] Over the years, several values have been proposed for this limiting yield on Long Island. The term "deficiency" refers to exceeding the permissive yield. For the Long Island 208 Region, water used "consumptively"

simply means that it is not returned to the groundwater system.

Domestic and industrial pumpage, that is eventually lost to the system following collection, treatment and bay or ocean discharge, constitutes the principal year-round consumptive use of fresh water on Long Island. Irrigation practices constitute the principal seasonal consumptive use. As consumptive use increases, groundwater is taken from storage, and underflow to streams and the sea is reduced. These stresses on the groundwater system result in water-level declines and saltwater encroachment.

Greeley and Hansen in 1971 estimated a mean permissive yield of 151 MGD for Nassau County. Holzmacher, McLendon and Murrell in 1970 computed a permissive yield of 466 MGD for Suffolk County. The Nassau County Department of Health computed the average consumptive loss in Nassau during the period of 1969 to 1973 to be 133 MGD. Average consumptive loss for Suffolk County was on the order of 40 to 50 MGD for the same period.

Both of the engineering studies estimated that large water-table declines would result from withdrawal at permissive yield rates if most areas were sewered and effluents were discharged by ocean outfall. Greeley and Hansen predicted maximum declines of 30 feet, and Holzmacher, McLendon and Murrell estimated reductions up to 75 percent of present elevations above sea level before equilibrium occurs. The authors of both county investigations felt that, at the permissive yield, the saltwater interface off the South Shore would move landward to a new equilibrium position, perhaps a mile from its present position. The water-level declines predicted for Nassau are significantly greater than those predicted in recent runs of the U.S. Geological Survey (USGS) analog model. A report of the USGS for the 208 Study analyzed groundwater response to proposed sewerage programs and projected population increases in Nassau and Suffolk Counties by 1995.[15] The total modeled increase in withdrawal by 1995 was 9.54 MGD in Nassau County and 46.42 MGD in Suffolk County. The total modeled decrease in recharge by 1995 was 39.9 MGD and 42.67 MGD in Nassau and Suffolk Counties, respectively. It was concluded that by 1995, these stresses would result in a stabilized water table after declines of as much as sixteen feet in east-central Nassau County, and as much as six feet in central Suffolk County. Slightly smaller declines in the potentiometric head may occur in the Magothy aquifer.

Declining water levels will significantly reduce streamflow and will also affect the amount of freshwater underflow to the bays. For instance, a run of the USGS analog model predicted reductions of streamflow of about 55 percent by 1995 in southeast Nassau County, based on present population and sewering projections. Reductions in streamflow may cause changes in the vegetation of certain freshwater wetlands. In addition, significant long-term reductions in groundwater outflow and streamflow to the various saltwater bodies surrounding Long Island may alter salinities. The environmental consequences of these changes are unknown at the present time. A decrease in freshwater discharge to the bays could be offset in part by shifting centers of pumping, stream augmentation or recharge with sewage effluent, importation or transfer of groundwater from surplus areas, or through planned water conservation programs.

A factor that adds some uncertainty to predictions of impacts in Nassau County is the future of the Jamaica Water Company in Queens. This supplier is pumping about 60 MGD, creating significant underflow from western Nassau to Queens. It is understood that, upon completion of New York City's third water tunnel, distribution of surface water to this area will be made possible. However, the lack of additional supply sources upstate, or elsewhere, precludes complete replacement of the present Queens groundwater supply, especially during drought periods. If Jamaica Water Company pumpage is eliminated or reduced in the future, underflow will be reduced and significant recovery of water levels in western Nassau will occur.

The Queens/Nassau common water-level decline illustrates the insignificance of political boundaries when dealing with the management of resources common to the entire Island. The present sub-surface flow from Nassau to Queens is estimated to be between ten and fifteen MGD. While some of this flow is due to natural conditions, a significant portion is undoubtedly due to heavy pumping in Queens. There have been a number of plans proposed for future groundwater development in the 208 area, that call for installing a regional well field in Suffolk County and pumping the water to Nassau County. At the present time, there is little natural exchange of groundwater between these two counties. However, if water levels are allowed to decline substantially in Nassau County, natural underflow of groundwater from Suffolk will occur.

If present patterns of use continue, groundwater outflow within the Magothy will be reduced along both the north and south shores of Nassau and Suffolk Counties. However, on the basis of past and present studies of saline groundwater on Long Island, including those on the North and South Forks, it is expected that the regional impact of saltwater intrusion will be small. The saltwater wedges in the upper and lower Magothy in the southwestern and southern parts of Nassau, an area of historical saltwater contamination, will probably not advance much more than a mile locally, and less than a mile regionally, by the year 2000.[16] This would put the interface of the deep wedge in the vicinity of Sunrise Highway in Valley Stream and Lynbrook. Those few supply wells screened in the lower Magothy would be affected.

From the standpoint of water supply and wastewater management, it is essential that the potential threat of saltwater encroachment be viewed in its proper perspective and be fully understood. The loss of usable groundwater resources as a result of saltwater intrusion has been minor in comparison to the extensive fresh groundwater supplies that still remain in storage and untapped within the 208 Study area. Water-level declines due to increased pumpage, sewering, or temporary deficiencies in rainfall do not bring about

massive encroachment of saltwater bodies within the various aquifers. In only one area of the Bi-county Region (southwestern Nassau), has there been documented evidence that saltwater is actively intruding. Even here, the average rate of movement has been less than twenty feet per year, notwithstanding the fact that water levels in nearby areas have been below sea level for decades.

Many of the past studies infer that a critical shortage of water may be expected within the next few decades. Increased consumptive use and declining water levels have frequently been equated with running out of water. The fact is, that on a bi-county basis, there is sufficient available groundwater to supply Long Island for many years beyond the current 1995 population projection, provided that action is taken to solve problems in specific areas and proper management techniques are adopted.[17] In evaluating wastewater management options, *i.e.,* recharge and stream augmentation, under 208, emphasis must be placed on determining the impact of proposed plans on groundwater quality and the effects on other segments of the environment, such as streamflow and freshwater discharge to the surrounding saltwater bodies.

2.4.2 Groundwater Quality. A further constraint to water supply self-sufficiency is water quality. Past and present waste disposal practices modify the purity of a significant portion of the available groundwater resource. The presence of nitrate, trace organic chemicals and heavy metals in some portions of the aquifer system may be much more important to long-term availability of usable water supply than short-term droughts and saltwater encroachment. In the following discussion, nitrate occurrence and trends are used to illustrate present conditions in the various aquifers. This constituent has been of great concern historically in the 208 Region, and data are available to reach some preliminary conclusions on how changes in land use and the presence of contamination sources have impacted groundwater quality on a regional basis. Other contaminants, such as heavy metals, organics in trace amounts and detergents have been of local importance. Chlorides, related to saltwater intrusion, have been discussed in the previous section on groundwater availability.

2.4.2.1 Water-Table Aquifer. The water-table or uppermost aquifer on Long Island receives most of the contaminants originating at the land surface. This aquifer consists primarily of Upper Glacial deposits and includes some sediments of the Magothy formation, the Manetto gravel and recent deposits. The aquifer has become contaminated to various degrees and is, in some places, unsuitable for use as a source of potable water supply. The groundwater found in these sediments is of special importance because in many areas it supplies water to the deeper Magothy formation. In addition, streams in Nassau and Suffolk Counties are largely dependent on flow from shallow groundwater and closely reflect its quality. Significant input to the bays and most freshwater lakes is also derived from the water-table aquifer by underflow.

The normal background quality of groundwater in the shallow sediments of Nassau and Suffolk Counties is very good. In general, the water can be characterized as soft, mildly corrosive and, in some cases, somewhat high in iron and manganese.

Over the past few decades, widespread effects of urbanization have considerably altered the quality of groundwater in the water-table aquifer. Many studies have detailed the extent and magnitude of these effects, with particular attention paid to nitrate, detergent, chloride and, to a lesser extent, sulfate. These constituents are usually good indicators of contamination. Median concentrations of these parameters in Nassau and Suffolk for the period 1972–76 with the exception of detergents are given in Table 2–12.

Statistical analyses of nitrate concentrations in selected wells throughout Nassau and Suffolk Counties were performed as part of the 208 Program. Trends in nitrate are important not only in themselves, but also because associated contaminants may follow similar trends.

A recent study found that, of 21 wells in Sewage Disposal District No. 2 in Nassau, thirteen show valid decreasing trends in nitrate.[18] Four had increasing trends. The median change in nitrate per year for all of the seventeen wells that showed trends is –0.34 milligrams per liter. Eight of the wells

Table 2–12

CONCENTRATIONS OF SELECTED CONSTITUENTS IN THE UPPER GLACIAL AQUIFER, 1972–1976

	Median		Mean	Range
Southwestern Nassau				
Nitrate	4.9	(159)	4.8	0.04 – 14
Chloride	28	(164)	43	6.6 – 950
Sulfate	44	(128)	47	5.0 – 120
Northern and Eastern Nassau				
Nitrate	3.0	(259)	4.3	0.00 – 36
Chloride*	19	(309)	83	1.3 – 14,000
Sulfate	30	(259)	30	0.00 – 450
Suffolk				
Nitrate	1.4	(1,273)	2.3	0.00 – 23
Chloride*	12	(2,047)	20	0.10 – 2,600
Sulfate	9.2		19	0.00 – 470

Note: The number in parenthesis indicates the number of analyses. Concentrations are in mg/l.

**High concentrations of chloride (i.e., 14,000 and 2,600) are due to contamination by salt water and are not representative of typical concentrations in fresh water.*

Source: Section B of the Areawide Waste Treatment Management Plan.

indicate a pattern of increasing and then decreasing concentrations. The time of inflection, or change from positive to negative slope, occurred during the late 1950's or early 1960's in most of these wells, and does not appear to be a drought-related phenomenon. The change corresponds to large scale sewer construction which started in the early 1950's and was completed in 1964.

In addition to the decreasing trends of nitrate in most of the water-table wells in Sewage Disposal District No. 2, the median nitrate concentration in streams sampled during the period 1972–1975 shows substantially lower levels in southwestern Nassau as compared with those in southeastern Nassau.[19] The median values are shown in Table 2–13. Although it is not possible to identify trends on the basis of the limited data, it appears that sewering may have been responsible for reducing nitrate levels in the stream discharges, which generally represent the most recently recharged water in Sewage Disposal District No. 2.

Despite generally decreasing trends of nitrate in wells in Sewage Disposal District No. 2, the actual concentrations in some wells are still quite high. Possible explanations for this are (1) the sewers are leaking, (2) the use of home fertilizers is such an important input that removal of on-lot sewage disposal systems alone results in only a slow decrease in nitrate levels, or (3) insufficient time has elapsed for even shallow wells to be flushed of high nitrate water.

Applying the criteria used in the study, the number of wells in the unsewered portion of Nassau County (Sewage Disposal District No. 3) is found to be insufficient to permit any conclusions. Three wells show increasing trends in nitrogen concentration, while two show decreasing trends. Wells in northern Nassau County generally show either small increases or small decreases in nitrate concentration.

Twenty-one water-table wells in Suffolk that have nitrate-nitrogen concentrations above background levels show significant nitrate trends. Of eighteen wells in southwestern Suffolk (Babylon and Islip), sixteen show increasing trends, an indication of deteriorating water quality. The period of record for most of these wells started in the 1960's. Southwestern Suffolk is of interest because it is hydrologically similar to Nassau Sewage Disposal District No. 2. Recent land use is also similar, although development took place some years later. The median change per year in nitrate in the eighteen wells in this part of Suffolk is +0.13 milligrams per liter.

An indication of the effects of sewering on groundwater quality is provided by ongoing studies of the U.S. Geological Survey.[20] Preliminary findings or continued evaluation of the information obtained during the preparation of a U.S. Geological Survey report for the 208 Program reveals significantly lower median concentrations of ammonia in shallow groundwater underlying Sewage Disposal District No. 2 compared to shallow groundwater in Sewage Disposal District No. 3 in Nassau County.[21] Again, sewering was undertaken in District No. 2 during the 1950's, whereas the installation of sewers in District No. 3 is still underway. In addition, an evaluation of water quality trends in only the very shallow glacial deposits in District No. 2 and District No. 3 indicates stronger decreasing trends of nitrate in the former. These preliminary findings are indications of the results of a reduction in nitrate loading, apparently due to sewering.

Table 2–13

QUALITY OF NASSAU AND SUFFOLK STREAMS

Stream	Median Nitrate-Nitrogen (mg/l) 1972–75		Median Specific Conductance (μmhos) 1972–75	
North Shore (Nassau and Suffolk)				
Glen Cove Creek	3.39	(11)	228	(14)
Mill Neck Creek	0.77	(26)	164	(35)
Cold Spring Brook	0.50	(12)	76	(13)
Nissequogue River	1.13	(8)	100	(12)
Southwestern Nassau				
Valley Stream	0.88	(6)	150	(9)
Pines Brook	2.03	(9)	340	(11)
Southeastern Nassau				
East Meadow Brook (tributary)	3.61	(28)	449	(38)
Bellmore Creek (tributary)	8.58	(10)	353	(14)
Bellmore Creek	5.87	(12)	340	(14)
Massapequa Creek	7.00	(31)	320	(36)
Southwestern Suffolk				
Santapogue Creek	2.26	(13)	290	(15)
Carlls River	2.93	(14)	215	(16)
Sampawams Creek	3.16	(15)	215	(17)
Penataquit Creek	3.61	(14)	313	(17)
Champlin Creek (Oakdale)	1.85	(14)	151	(16)
Connetquot River	0.93	(12)	80	(15)
Connetquot River (North Great River)	0.88	(12)	84	(14)
Southeastern and Eastern Suffolk				
Patchogue River	1.11	(10)	114	(4)
Swan River	1.20	(10)	90	(12)
Carmans River	0.74	(29)	101	(36)
Peconic River	0.25	(12)	92	(24)

Note: The number in parenthesis indicates the number of analyses.

Source: Section B of the Areawide Waste Treatment Management Plan.

2.4.2.2 Magothy Aquifer. The natural chemical quality of water within the Magothy is generally excellent and characterized by a very low dissolved solids content. Contamination of the Magothy is of great concern, since many public supply wells are screened in this formation. Past water quality investigations have dealt primarily with the distribution and trends of nitrate. From these studies, it has been well established that many wells within the Magothy are pumping chemically altered or contaminated water.

The 1972–76 median concentrations of nitrate, chloride and sulfate in the various portions of the study area illustrate the relative degree of alteration (Table 2–14). Differences in concentrations of these constituents between the two specified areas of Nassau are probably not due to sewering, except possibly at the shallower depths. Other factors, such as location of wells with respect to past land uses, are probably more important. Those water quality trends now occurring in the water-table aquifer, as discussed in the previous section, will undoubtedly be reflected in some way in the Magothy in future years. In general, the levels of contaminants decrease with depth, until near-background concentrations are found in most wells greater than 600 feet deep. The apparent smaller value of nitrate for wells of the sewered area less than 200 feet deep may be due to insufficient sampling.

Table 2–14

MEDIAN CONCENTRATIONS OF SELECTED CONSTITUENTS IN THE MAGOTHY AQUIFER, 1972–1976

Depth (feet)	Southwest Nassau		East and North Nassau		Suffolk	
Nitrate as N						
Less than 200	0.88	(18)	2.8	(104)	2.6	(4)
200 to 399	2.5	(130)	2.8	(443)	0.10	(263)
400 to 599	0.2	(526)	1.1	(515)	0.10	(391)
Greater than 600	0.01	(42)	0.13	(177)	0.01	(322)
Chloride						
Less than 200	18	(18)	13	(108)	14	(13)
200 to 399	12	(136)	10	(45)	5.0	(270)
400 to 599	6.4	(542)	5.8	(532)	4.5	(400)
Greater than 600	4.6	(42)	4.4	(179)	4.0	(355)
Sulfate						
Less than 200	32	(14)	22	(93)	2.6	(11)
200 to 399	13	(122)	7.0	(392)	3.2	(264)
400 to 599	5.0	(500)	2.0	(403)	3.2	(388)
Greater than 600	3.0	(39)	1.0	(159)	3.4	(399)

Note: Numbers in parentheses are the number of analyses. All concentrations in mg/l.
Source: Section B of the Areawide Waste Treatment Management Plan.

A recent U.S. Geological Survey study in southeast Nassau County provides an analysis of vertical and horizontal distributions of nitrate, chloride and dissolved solids.[22] The conclusions reached illustrate the typical history of heavily urbanized areas served by heavy pumpage from local, deep aquifer zones:

1. Downward movement of nitrate in the Magothy between the early 1950's and 1973 ranged from no significant movement in the area south of North Merrick and South Farmingdale to a maximum movement of a few hundred feet in the areas of Westbury, Hicksville and Plainview. There also seems to be a definite horizontal movement of equal nitrate concentration lines through the aquifer.
2. There has been a more rapid downward movement of nitrate in the eastern part of the study area than in the central and western parts. The rapid movement in the eastern part may be partly due to a large increase in pumpage in the Plainview area.
3. There is a zone of high-nitrate water in the Magothy aquifer in the area of Westbury, Hicksville and Plainview. Some of these increases may be attributable to past large-scale farming, and the associated use of fertilizers in the Hicksville and Levittown areas, and to subsurface domestic discharges and pumpage.
4. The downward movement of chloride covers a broader area than does that of nitrate.
5. There has been significant downward movement of higher than normal total solids concentrations between the 1950's and 1973. Overall downward movement ranges from a few feet to approximately 300 feet. A zone of high total solids concentrations of more than 200 milligrams per liter is found in the Hicksville and Plainview areas. The total solids concentration in groundwater in the Plainview area approximately doubled in twenty years.

It is also likely that reduction of pumpage from the Glacial formation and preferential or exclusive development of the Magothy formation has accelerated the downward movement of contaminated waters. A study completed in 1969 reviews the trends of nitrate in 373 public suppy wells in Nassau County.[23] Most of the wells analyzed were deep wells, screened in the Magothy. Eighty wells showed statistically significant increasing trends and nine were decreasing. A general upward trend of nitrate in most Magothy wells is also confirmed by a study presently under way by the U.S. Geological Survey.[24] In this investigation, trends of nitrate in most Magothy wells in Nassau County showed statistically significant increases. Studies in Suffolk County have not been as extensive as in Nassau, but the data indicates no significant change in water quality in the Magothy aquifer.

2.4.2.3 Lloyd Aquifer. The Lloyd aquifer is the least altered by human activities. This is due primarily to the thick confining bed of Raritan clay which overlies the Lloyd in most places and impedes the exchange of water with the Magothy. On the North Shore, however, the Raritan clay is discontinuous in places, and the aquifer is in lateral, and possibly vertical, hydraulic connection with Pleistocene deposits which have replaced the Magothy deposits. Regionally, the Lloyd is recharged through the clay over a broad area covering most of Nassau and Suffolk Counties. Discharge in the western part of the study area is primarily through wells, while in the eastern part discharge is mostly to the bays and to the ocean. (See Table 2–15 for Nassau water quality data.)

Table 2–15

THE MEDIAN CONCENTRATIONS OF SELECTED CONSTITUENTS IN THE LLOYD AQUIFER IN NASSAU COUNTY, 1972–1976

	Southwest Nassau		North and East Nassau	
Nitrate as N	0.07	(13)	0.21	(100)
Chloride	5.1	(12)	5.2	(106)
Sulfate	6.0	(13)	3.0	(94)

Note: Concentrations in mg/l; numbers in parentheses are numbers of analyses.
Source: Section B of the Areawide Waste Treatment Management Plan.

Many of the wells in the north and east area are located in Manhasset, Great Neck and in the northern part of the Town of Oyster Bay. Some of the wells in these areas show elevated levels of nitrate, indicating contamination from the surface. This suggests some degree of hydraulic connection with overlying sediments, probably in areas where the Raritan clay has been eroded and replaced by more permeable deposits.

Uncontaminated water in the Lloyd is characterized by low dissolved solids (less than 50 milligrams per liter). Iron, however, commonly occurs at levels considerably above the recommended limit of 0.3 milligrams per liter.

2.4.2.4 Organic Chemicals. Several years ago, an incident of groundwater contamination was reported near an industrial complex in Nassau County. Subsequent sampling and analysis of water from wells within the complex indicated significant concentrations of vinyl chloride and industrial degreasers such as tri- and tetrachloroethylene. The wells yielding water containing these contaminants were removed from service as sources of potable water. An intensive survey of all public drinking water supply wells in both Nassau and Suffolk Counties has been underway for the past two years. As of October 1977, almost 650 analyses have been performed on samples collected from 475 public water supply wells in both counties. Fifteen wells have been removed from service because of the presence of volatile organic compounds.

The formation of chlorinated hydrocarbons in "finished" waters, as the result of chlorination practices, requires the presence of the precursor compounds. This is very rarely the case in Long Island groundwaters, especially Magothy waters, even though it has been the case in some surface waters.

The 208 Program responded to requests from its TAC and CAC, and initiated a program to analyze samples from groundwaters, stormwater, domestic waste discharges and landfill leachates for the presence of volatile and non-volatile organic compounds. The survey of non-volatile compounds resulted in the detection of substituted benzene compounds, napthalenes and various butyl phthalates. Some of these compounds are common constituents of plasticizers, and some are on the list of those suspected of being carcinogenic to animals. Volatile organic compounds were also detected at parts per billion concentrations, with their sources yet to be determined or evaluated. Studies are continuing.[25] (See Section 4.1.1.2 for a more complete discussion.)

2.5 Surface Water Quality

2.5.1 Introduction. As part of the 208 planning process, an extensive review of historical water quality data was made for selected bays. The bays were chosen for detailed investigation because of current water quality problems or the presence of existing or proposed major discharges. The data, which were collected between 1970 and 1975, were obtained from various sources. These programs were designed for a variety of purposes, not necessarily to characterize the water quality throughout the bay. To supplement this data base and to provide data for mathematical model calibration and verification, an additional data collection program was undertaken during 1976. All of these data, in conjunction with mathematical model results, provide a means to characterize the water quality of each bay. Presentation of data and detailed analyses is contained in a large number of technical reports. This section provides a summary water quality assessment for each bay for eight selected bay systems. A non-modeling water quality assessment was prepared for Moriches, Shinnecock and Mecox Bays, western Long Island Sound and the nearshore Atlantic Ocean.

It is important to note that, on the north shore of Long Island, water quality conditions within the bays are largely influenced by the quality of Long Island Sound water, which provides the boundary values for the bay models. Long Island Sound shows a definite gradient of improving quality from west to east. For example, total coliform bacteria concentrations ranged from approximately 2400 MPN per 100 milliliters near Manhasset Bay to less than twenty MPN per 100 milliliters near Huntington Harbor. Nitrogen shows a similar trend, with concentrations decreasing from approximately 0.8 milligrams nitrogen per liter at Manhasset Bay to approximately 0.3 milligrams nitrogen per liter at Port Jefferson Harbor.[26]

In North Shore bays where boundary conditions are low, relatively high waste loads can be tolerated due to the rapid mixing and high flushing rates. The importance of these boundary values cannot be overemphasized, however, because no waste management program for an individual bay would be able to reduce concentrations significantly below the boundary values.

The Peconic Estuary-Flanders Bay system, as well as the Great South Bay, have relatively long residence times. Dilution and flushing are much less than in the North Shore bays. This characteristic causes water quality in these two systems to be highly sensitive to internal waste loads, and boundary effects to be minimal.

Unlike Long Island Sound's effect on water quality of the North Shore bays, the nearshore Atlantic Ocean water quality does not appear to significantly influence water quality of the South Shore bays. Available water quality data indicate that total nitrogen concentrations are consistently between 0.1 and 0.4 milligrams nitrogen per liter in nearshore Atlantic waters that represent the boundary conditions for the South Shore bays. Furthermore, bacterial water quality local to the Long Island South Shore is determined primarily by contaminant loads emitted by the bays themselves. A review of historical physical and water quality data in the New York Bight Apex indicates that the great majority of wastes emitted from New York Harbor travel south along the New Jersey coast, except during sustained periods of southerly winds. In addition, the sludge dumping practices in the Bight Apex do not, at present, appear to significantly affect water quality along the South Shore of Long Island. For these reasons, waste management plans for reducing waste loads within the South Shore bays should be effective in controlling water quality in these bays.[27]

The following subsections provide a description of observed water quality conditions in all of the bays, and attempt to indicate the amount of pollutants that result from different sources, based on data taken from Sections B and D of the Areawide Waste Treatment Management Plan. The last section provides a summary for all bays. Most of the discussion centers around coliform bacteria and nitrogen concentrations because they have been found to be key indicators of water quality conditions.

2.5.2 Manhasset Bay. Manhasset Bay, the most westerly of the North Shore bays that were studied, is largely influenced by Long Island Sound. Seventy percent of the total nitrogen contributed to the bay from internal loading is from point sources. The remainder (700 pounds per day) comes from non-point sources including groundwater inflow, stream base flow, stormwater runoff and direct rainfall. Storm-related nitrogen inputs are approximately twelve percent of the internal nitrogen loading to Manhasset Bay. Depending on location in the bay, nine to 80 percent of the observed nitrogen comes from internal sources. Concentrations of total nitrogen within the bay range from 0.1 to 3.4 milligrams nitrogen per liter. The high concentrations are found in the vicinity of discharges located in relatively poorly-flushed areas.

The nitrogen concentrations are sufficient to allow large phytoplankton blooms. The field data for 1976 showed chlorophyll a values in excess of 300 micrograms per liter on occasion.

Large masses of phytoplankton generally produce very high dissolved oxygen concentrations during the day through photosynthesis, and very low dissolved oxygen levels during the night due to respiration. While a normal value for dissolved oxygen would be between 7.5 and 9.0 milligrams per liter, the field data for 1976 showed values reaching nearly 20.0 milligrams per per liter during the day. While nighttime measurements of dissolved oxygen were not made, some early morning measurements as low as 3.6 milligrams per liter suggest considerable dissolved oxygen depression at night.

Ninety-five percent of the total coliform bacteria contributed by sources within Manhasset Bay is from stormwater runoff. An additional four percent is contributed by stream base flow, while point sources generally contribute only one percent. These total coliform loadings, in conjunction with high boundary concentrations (2400 MPN per 100 milliliters), have resulted in the classification of Manhasset Bay as unfit for shellfishing and occasionally, after storm events, have resulted in the temporary contravention of the standards for swimming.

2.5.3 Hempstead Harbor. Hempstead Harbor, located just east of Manhasset Bay, is also largely influenced by Long Island Sound water quality. Approximately 72 percent of the internal nitrogen loading is from point sources.

The remainder (approximately 1200 pounds per day) comes from non-point sources, including groundwater inflow, stream base flow, stormwater runoff and direct rainfall. Storm-related nitrogen inputs are approximately five percent of the internal nitrogen loading. Concentrations of total nitrogen within the harbor ranged from 0.3 to 16.8 milligrams nitrogen per liter. Depending on location in the harbor, thirteen to 80 percent of the observed nitrogen comes from internal sources. The high values are found in the vicinity of discharges that are located in relatively poorly flushed areas.

These nitrogen concentrations are sufficiently high to allow large phytoplankton blooms. The field data for 1976 showed chlorophyll a values up to 200 micrograms per liter on occasion. Such large chlorophyll a concentrations generally produce large amounts of oxygen by photosynthesis during the day, and consume larger amounts by respiration at night. Field data showed a range of oxygen concentrations from two to seventeen milligrams per liter.

Ninety percent of the total coliform bacteria contributed by sources within the harbor is from storm runoff. An additional eight percent is contributed by stream base flow and two percent by point sources. These total coliform loadings, along with high boundary concentrations, have resulted in the closing of shellfishing areas in Hempstead Harbor.

2.5.4 Oyster Bay. Oyster Bay receives a total nitrogen loading of approximately 1,700 pounds per day from all pollution sources within the

bay. About 46 percent of the loading is from groundwater underflow and 23 percent from point sources. The nitrogen contribution of Long Island Sound to Oyster Bay is substantially less than to Manhasset Bay and Hempstead Harbor. Concentrations range from a "worst case" boundary condition of 0.45 milligrams nitrogen per liter to an average of about 0.30 observed in August 1976.

Nitrogen concentrations in Oyster Bay observed in August 1976 ranged from 0.1 milligrams nitrogen per liter to 0.53 milligrams nitrogen per liter. The highest concentrations were observed in Mill Neck Creek and the south end of Cold Spring Harbor. In Mill Neck Creek, point sources account for about 34 percent of observed nitrogen concentration. In Cold Spring Harbor, 31 percent of the observed nitrogen concentration is due to point sources. In these areas the additional nitrogen was contributed by Long Island Sound.

Virtually one hundred percent of the total coliform loading to Oyster Bay is from stormwater runoff. Median coliform counts in Long Island Sound at the entrance to Oyster Bay/Cold Spring Harbor are below the maximum 70 MPN per 100 milliliters standard for shellfishing areas. Areas in the vicinity of the Cold Spring Harbor Treatment Plant outfall, the Oyster Bay Treatment Plant outfall, Mill Neck Creek and adjacent to Mill Pond are closed to shellfishing.

2.5.5 Huntington Bay. Approximately 42 percent of the total internal nitrogen loading (1800 pounds per day) to Huntington Bay is estimated to derive from groundwater inflow. An additional twenty percent comes from point sources, twenty-one percent from runoff, eleven percent from direct rainfall and seven percent from stream base flow. Concentrations of total nitrogen within the bay range from 0.1 to 1.4 milligrams nitrogen per liter. Depending on location in the bay, with a boundary nitrogen concentration of 0.32 milligrams nitrogen per liter, three to 50 percent of the observed nitrogen is a result of internal sources. The high values are in Centerport Harbor and Northport Harbor, where point sources discharge to poorly mixed areas. Huntington Harbor receives the Huntington Sewage Treatment Plant discharge.

The generally high nitrogen concentrations result in substantial algal production in those areas that are poorly flushed. Chlorophyll a values up to 50 micrograms per liter have been found in Centerport Harbor and in Huntington Harbor. Dissolved oxygen concentrations ranged from 4.2 to 12.6 milligrams per liter.

Ninety-eight percent of total coliform bacteria loading contributed by sources within the bay is computed to derive from storm runoff. Stream base flow contributes most of the remaining two percent. Treatment plant discharges are minor sources. Total coliform bacteria concentrations within the Bay range from less than three to 1100 MPN per 100 milliliters. Typical coliform concentrations in Long Island Sound, near the entrance to Huntington Bay, are less than 70 MPN per 100 milliliters. As expected, the poorly flushed areas receiving treatment effluent and stream discharges (Northport Harbor, Centerport Harbor and Huntington Harbor) are closed to shellfishing.

2.5.6 Port Jefferson Harbor. Port Jefferson Harbor exhibits the best water quality of all the North Shore bays studied under the 208 Program. The total nitrogen loading from internal sources is approximately 800 pounds per day. Twenty percent of this total is contributed by point sources (Port Jefferson Treatment Plant). Total loads (wet and dry weather) indicate that groundwater inflow contributes 32 percent, stream base flow nine percent, direct rainfall fourteen percent and stormwater runoff 25 percent of the total nitrogen loading to the harbor.

The contribution of Long Island Sound to nitrogen concentrations in the harbor is relatively low. Four observations in the Sound during June and July 1976 ranged from 0.20 milligrams nitrogen per liter to 0.41 milligrams nitrogen per liter with a mean of 0.30 milligrams nitrogen per liter.

Total nitrogen values observed in the harbor during June and July of 1976 ranged from 0.10 to 0.73 milligrams nitrogen per liter. Highest concentrations were observed at the south end of Port Jefferson Harbor, in Little Bay, and in Conscience Bay. In July 1976, point sources and stream base flow accounted for 21 percent of the nitrogen at the south end of Port Jefferson Harbor. Non-point sources alone accounted for over twenty percent of the nitrogen in Little Bay and Conscience Bay. The remaining nitrogen in all areas was contributed at the boundary.

It is estimated that stormwater runoff is responsible for 97 percent of the total coliform input to Port Jefferson Harbor. The remaining three percent is contributed mostly by stream base flow. The treatment plant discharge is only a minor source. This has resulted in the closing to shellfishing of areas near the mouths of the three streams discharging to the Port Jefferson Harbor system. Total coliform concentrations at the Long Island Sound boundary are below the maximum of 70 MPN per 100 milliliters allowable for shellfishing waters.

2.5.7 Peconic-Flanders. The Peconic Estuary-Flanders Bay system, located on the eastern end of Long Island, is characterized by long residence times. The total internal nitrogen loading was approximately 1100 pounds per day in 1976. Approximately 76 percent of this nitrogen loading was from point sources, which included duck farms and the Riverhead Sewage Treatment Plant. Stream flow and direct rainfall each account for an additional eleven percent of nitrogen loads. Bay water quality, under dry weather conditions, is impacted by sewage treatment effluent.

Concentrations of total nitrogen in the system range from 0.1 milligrams per liter to over 9.0 milligrams per liter. The higher concentrations are generally found in the Peconic Estuary and near Meetinghouse Creek. Very high chlorophyll a concentrations were observed in areas with high nitrogen levels. Chlorophyll a concentrations ranged from less than five micrograms per liter to over 370 micrograms per liter. Dissolved oxygen ranged from near zero to over fourteen milligrams per liter.

It was determined that 64 percent of total coliform loadings result from storm runoff. Approximately thirteen percent is from stream base flow.

Total coliform bacteria concentrations in the Peconic/Flanders system ranged from five to 13,000 MPN per 100 milliliters. The Peconic Estuary is closed to shellfishing because of high bacterial concentrations.

2.5.8 Great South Bay. Great South Bay is a large open estuary about 25 miles long and one to two miles wide. The average depth is near six feet. Water quality in the bay is largely affected by stream discharges, groundwater flow, two sewage treatment plants and tidal flushing.

Residence time in portions of Great South Bay is two to three months. This means that a parcel of wastewater requires about two or three months to be flushed out of the bay. It also means that, at any time, the bay contains nearly all the wastes and freshwater discharged to it over the last two or three months.

Total nitrogen loading to the Great South Bay is approximately 6,600 pounds per day. Of this total, approximately 39 percent is from base streamflow, sixteen percent from groundwater inflow, 26 percent from direct rainfall, seventeen percent from storm runoff and only two percent from point sources. Total nitrogen concentrations observed in November 1976 range from 0.12 to 1.72 milligrams nitrogen per liter. The values generally increase from west to east, with highest concentrations found near Bellport Bay (Carmans River).

Chlorophyll a concentrations ranged from one to 90 micrograms per liter. Dissolved oxygen concentrations ranged from 0.2 to fourteen milligrams per liter. The lower values of dissolved oxygen are generally observed toward the western end of the bay and are not found in conjunction with the higher chlorophyll a levels.

The shallow nature of the Great South Bay, the abundance of macrophytes, and the benthic oxygen demand all contribute to the oxygen balance of the Great South Bay. As a result of the long residence time in the bay, phytoplankton abundance is often limited by nitrogen depletion.

Approximately 90 percent of the total coliform bacteria loadings to Great South Bay are from stormwater runoff. The remainder is primarily from base streamflow. Total coliform concentrations in Great South Bay ranged from less than two to greater than 35,000 MPN per 100 milliliters in the vicinity of Bayshore Cove. Portions of the Great South Bay near stream discharges are closed to shellfishing as a result of high bacterial concentrations.

2.5.9 Western South Shore Bays. The western South Shore bays include Hempstead, East, Middle and South Oyster Bay. These bays comprise a series of interconnecting channels, marshes, tidal flats and islands. Hydraulic residence times are relatively short compared to Great South Bay, and flushing is good. However, there are a number of large pollutant sources.

Total nitrogen loading is approximately 22,400 pounds per day, 75 percent of which is from point sources. Groundwater inflow and stream base flow contribute an additional seven and ten percent, respectively. Storm runoff contributes only four percent, and direct rainfall two percent of total nitrogen loading. Total nitrogen concentrations within the bays ranged from 0.03 to 2.4 milligrams nitrogen per liter. Areas in the vicintiy of discharges, particularly the Bay Park Sewage Treatment Plant, showed the highest concentrations.

Chlorophyll a concentrations ranged from less than one to 130 micrograms per liter, illustrating the potential for large phytoplankton production. Dissolved oxygen concentrations ranged from 0.04 to fourteen milligrams per liter. The oxygen concentrations are primarily a result of organic matter oxidation, algal respiration and benthic oxygen demand.

Approximately 83 percent of total coliform loadings to the western South Shore bays comes from storm runoff. Point sources account for approximately fifteen percent. Specifically, in Hempstead Bay, point sources contribute approximately 62 percent of total coliform; 36 percent comes from nonpoint sources. Total coliform bacteria concentrations in the bays ranged from less than two to greater than 24,000 MPN per 100 milliliters. Virtually all of the western South Shore bays are closed to shellfishing because total coliform concentrations exceed the standard. It should be noted, however, that the contribution of fecal coliform loadings is less evenly distributed between runoff and point sources with the former accounting for roughly 96 percent, and the latter for four percent.

2.5.10 Moriches Bay. Moriches Bay lies to the east of Great South Bay on Long Island's South Shore. An estimated 2100 pounds per day of nitrogen are discharged to the bay, mainly from groundwater underflow (33 percent) and stream base flow (30 percent). Point source discharges from duck farms account for fourteen percent of the nitrogen loading, while direct rainfall and runoff together contribute 23 percent. There are no known measurements of nitrogen input from duck sludge deposits, and it is therefore nearly impossible to estimate any present day nutrient loadings.

Virtually 100 percent of total and fecal coliform loadings to Moriches Bay are from stormwater runoff. Total coliform concentrations commonly exceed 70 MPN per 100 milliliters in tributaries of Moriches Bay, with an observed range from less than three to greater than 2,400 MPN per 100 milliliters. Several tributaries and their mouths are closed to shellfishing due to total coliform concentrations in excess of the standard.

The status of Moriches Inlet is a major influence on water quality. The inlet is at present open, providing more tidal flushing than at any other time in the past 40 years. Total nitrogen concentrations in Moriches Bay average around 0.6 milligrams nitrogen per liter. Water quality in the bay has been steadily improving due to stabilization and natural enlargement of the inlet and recent reductions of point source loadings.

2.5.11 Shinnecock Bay. Shinnecock Bay lies to the east of Moriches Bay and receives a relatively small nitrogen loading (500 pounds per day). The largest single source of nitrogen to the bay (48 percent) is direct rainfall. There are no point sources. Coliform loadings to Shinnecock Bay are due solely to stormwater runoff. Observed coliform concentrations throughout

Shinnecock Bay are typically below ten MPN per 100 milliliters. As a result, there are presently no areas closed to shellfishing in Shinnecock Bay. Also, as a result of the small nitrogen loading, Shinnecock exhibits excellent water quality. The average total nitrogen concentration in the bay is approximately 0.32 milligrams nitrogen per liter.

2.5.12 Mecox Bay. Mecox Bay is a shallow coastal embayment located east of Shinnecock Bay on Long Island's South Shore. Mecox Bay receives an estimated 310 pounds per day of nitrogen of which groundwater underflow contributes 49 percent, stream base flow 21 percent, stormwater runoff 21 percent and rainfall nine percent. There are presently no point sources to Mecox Bay. In addition, there is no clear evidence to suggest that duck sludge deposits created by the past operation of the Mecox Bay Duck Farm do or do not contribute nitrogen to the bay. Coliform contamination in excess of the State standard occurs in Mecox Bay due mainly to stormwater runoff. As a result, most of Mecox Bay is closed to shellfishing.

Despite this small loading to the system, Mecox Bay has exhibited water quality problems, especially in its side embayments. Total dissolved inorganic nitrogen concentrations have averaged 0.77 milligrams per liter in Hayground Cove. Coliform concentrations frequently contravene standards in Hayground Cove and Mill Creek, probably as a result of stormwater runoff loads. The only outlet for the bay is an ephemeral channel connecting it to the Atlantic Ocean. This inlet provides limited flushing and drainage to Mecox Bay approximately 50 percent of the time.

2.5.13 Comparison of Bay Water Quality. Any evaluation of surface water quality necessarily requires a consideration of physical, chemical and biological processes. Unfortunately, existing governmental regulations set standards for only two parameters normally considered in marine water quality assessments. Dissolved oxygen and coliform bacteria levels have traditionally been measured for most of the waters on Long Island, and are used by the State as the basis for the classification of areas as to their "best use." Table 2–16 presents data on both dissolved oxygen and total coliforms for each bay system, and the frequency with which State standards for these parameters have been contravened. In addition, data on total nitrogen and chlorophyll a levels are presented. These parameters have been shown to be highly useful in determining the general biological state of the marine waters of Long Island. Analyses of historical and newly acquired 208 data have indicated that total nitrogen values of approximately 0.4 milligrams nitrogen per liter and chlorophyll a levels of about twenty micrograms per liter can be used as guidelines for evaluating the overall biological state of each system.[28]

Table 2–16

SUMMARY OF WATER QUALITY DATA AND FREQUENCY OF STANDARDS CONTRAVENTION FOR LONG ISLAND MARINE WATERS

	Manhasset Bay	Hempstead Harbor	Oyster Bay	Huntington-Northport Complex	Port Jefferson Harbor	Peconic-Flanders Complex	Hempstead Bay	Middle Bay	East Bay	S. Oyster Bay	W. Great South Bay	C. Great South Bay	E. Great South Bay	Moriches Bay	Shinnecock Bay
Diss. O_2 (ppm)+	2–19	2–17	3–18	4–15	4–10	0.2–12	1.2–14.1	0.4–14.0	3.8–15	1–15	0.2–15	2–15	3.6–10	–	–
T. Coli. (MPN/100 ml)+	4–11000	3–11000	2–11000	2–11000	2–1600	2–15000	3–24000	3–11000	2–24000	2–11000	2–35000	2–1600	2–24000	<3–2400	<3–1100
T. Nit. (mgN/l)+	0.1–3.4	0.3–16.8	0.1–0.5	0.1–1.4	01.–0.7	0.1–11.8	0.03–2.38	0.08–1.62	0.09–0.63	0.12–0.76	0.13–1.24	0.12–1.65	0.51–1.72	0.1–1.6	0.1–0.6
Chl. a (μg/l)+	2–308	4–220	10–35	1–49	1–18	1–372	<1–130	<1–40	3–50	3–14	1–50	1–90	1–46	–	–
T. Col. (% exceed 70 MPN/100 ml)	11*	11*	24	26	33	55	16	8	6	33	46	38	40	27	10
Diss. O_2 (% below 5.0 ppm)	17	46	5	36	4†	60	20	24	3	6	45	16	8	–	–
Chl. a (% above 20 μg/l)	59†	60†	57†	21†	<1†	15	14	10	8	<1	61	42	62	–	–

* *range includes historical and newly acquired 208 data.*

** *indicates frequency of contravention calculated based on average of 208 data only—all other frequencies based on historical data.*

*** *criteria is based on 2400 MPN/100 ml—therefore % contravention of 70 MPN/100 ml would be significantly higher.*

Source: Tetra Tech Inc. 1977, "Water Quality Evaluation—Western Long Island Sound," Prepared under contract to the Nassau-Suffolk 208 Program Study.

Several general conclusions can be drawn from the data presented in Table. 2–16.

1. All bays exhibit ranges of dissolved oxygen concentrations that periodically contravene the five milligrams per liter standard. Hempstead Harbor and western Great South Bay show the highest frequency of depressed oxygen values, whereas Oyster Bay and Port Jefferson Harbor on the North Shore, and East Bay and South Oyster Bay on the South Shore, exhibit the lowest frequency of low oxygen levels. (Moriches and Shinnecock Bays were not evaluated for this parameter.)
2. All areas studied show total coliform concentrations above the 70 MPN per 100 milliliters standard set for shellfish areas. Historically, sampling locations are not uniformly distributed, but rather concentrated in areas where contravention of the standard is expected to occur, in order to determine the necessity for closing shellfishing areas. Consequently, the record is biased toward high bacterial values. The percent frequency of contravention seems to indicate that the Peconic-Flanders and Great South Bay systems exhibit the most persistently elevated coliform values. Unfortunately, the only historical data available for Manhasset Bay and Hempstead Harbor were analyzed with respect to the swimming water standard of 2400 MPN per 100 milliliters. Had available data for these areas been based on the 70 MPN per 100 milliliters criterion, both areas would have shown significantly higher frequencies of coliform contamination. The majority of the open water areas of Great South Bay are free of coliform contamination, and indeed, almost all open water areas are certified for commercial shellfishing. Areas closed to shellfishing in August 1977 are shown in Figure 2–8.
3. There are large regional variations in total nitrogen concentrattions. North Shore bays generally exhibit slightly lower values than the South Shore bay systems. The influence of treatment plant locations can be seen in Manhasset Bay, Hempstead Harbor, Peconic-Flanders and the Hempstead Bay system.

   In the Nassau County South Shore systems, values decrease from west to east, reflecting increased flushing and the distance from the Bay Park Sewage Treatment Plant outfall. Values in Great South Bay generally increase from west to east, reflecting the inputs from Carmans River and the decrease in flushing with increasing distance from Fire Island Inlet. All bays periodically exceed 0.4 milligrams nitrogen per liter. This has been suggested as the concentration below which abnormally high fluctuations in dissolved oxygen levels would not be expected. Indeed, all bays exhibit phytoplankton "bloom" conditions from time to time, with concommitant fluctuations in dissolved oxygen levels.
4. Chlorophyll a concentrations are used as an indicator of the standing crop of phytoplankton.[29] Larger fluctuations in this parameter often indicate the probability of associated fluctuations in nitrogen and dissolved oxygen. This is readily apparent in Manhasset Bay, Hempstead Harbor, Peconic-Flanders and the Great South Bay systems. Oyster Bay and Port Jefferson Harbor on the North Shore, and South Oyster Bay on the South Shore, exhibit the narrowest range of chlorophyll a values.

2.6 The Long Island Ecosystem

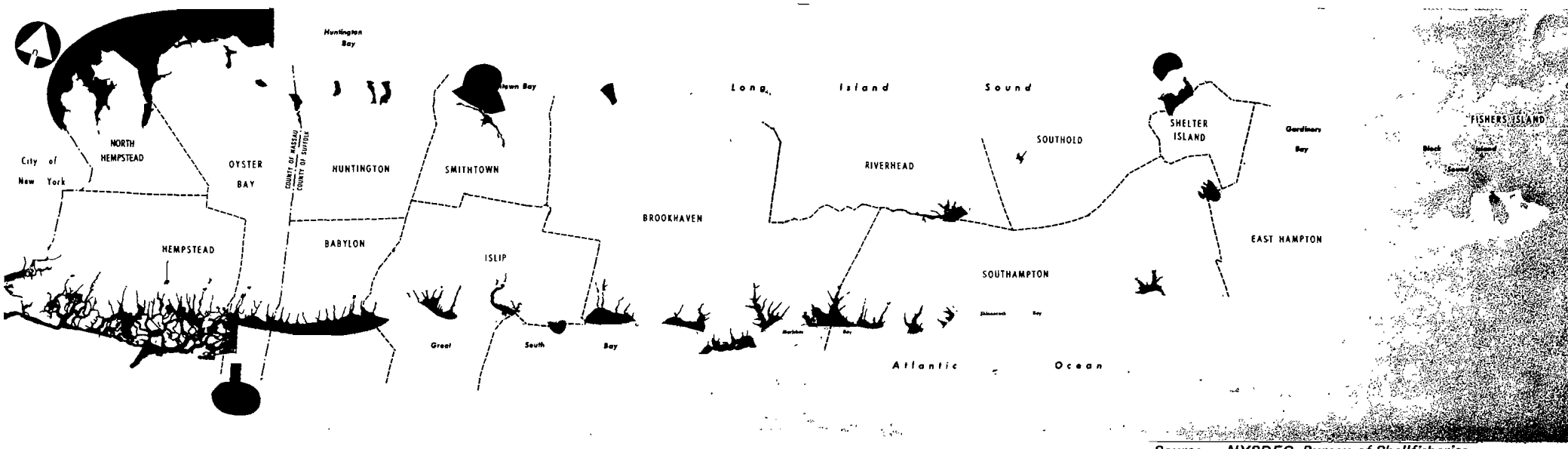
The following discussion on the Long Island ecosystem is based on information taken from a report prepared by Energy Resources Company Inc., and contained in Section P of the Areawide Waste Treatment Management Plan.[30]

2.6.1 Ecological Processes on Long Island. The functioning of the Long Island ecosystem is governed by several processes that integrate the biological elements and cycle and transport material. The major processes affecting the food web include nitrogen cycles, phosphorus cycles, organic matter cycling, land-water interactions and surface-groundwater interactions. The nature of one of these processes on Long Island is indicated in Figure 2–9. Present stresses on the Long Island ecosystem include accumulations of trace contaminants, modification of wetland habitats by point and non-point source inputs, and various chemical discharges. The reduction in shoreline wetlands has eliminated much of the capability of the bays to easily assimilate sediment, and organic and nutrient material loadings. Groundwater-surface water relationships have been altered by development; that is, the substitution of impermeable surfaces for natural vegetation, and, by sewering.

2.6.2 Existing Ecological Communitites. The Nassau-Suffolk Region is characterized by complex ecological systems, of which the chief components are offshore water, bays and estuaries, streams and lakes, wetlands, land, and groundwater. A number of significant types of interactions tie together the six subsystems with respect to the environmental processes affected by waste treatment (nutrient cycles, organic cycles, food web). Most treated and untreated wastes are discharged to offshore areas, bays and land; some are discharged to streams and lakes.

The present conditions and areal extent of the various subsystems can be assessed. In the following discussion, offshore water, bay and estuary, stream and lake, wetland and land systems are discussed in order. Finally, the processes occurring in these systems are considered. A discussion of groundwater has been provided in Section 2.4.

Each of the subsystems presented below can be further divided into smaller systems, which are termed "habitats." Diverse habitats generally permit a variety of life forms to flourish, and provide many predator-prey relationships, which promote system resiliency. Easy access to food sources often allows the development of productive fisheries. The edges of bays



Source: NYSDEC, Bureau of Shellfisheries.

FIGURE 2–8 *Areas Closed to Shellfishing in August 1977*

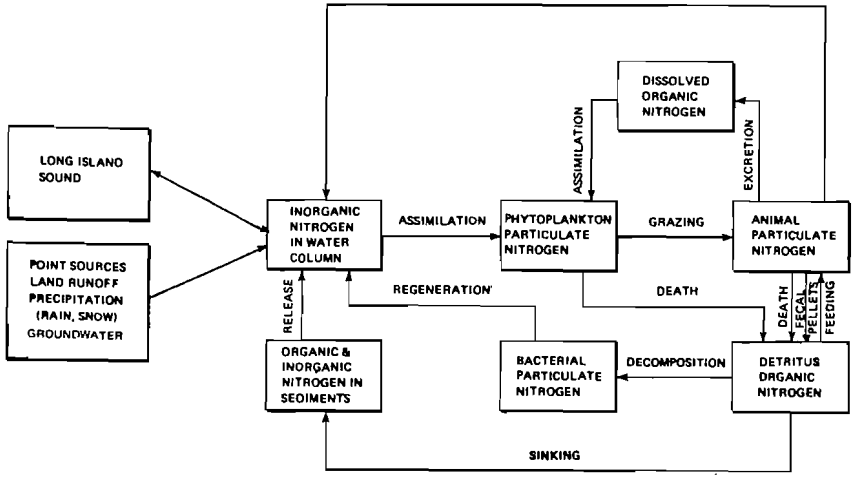


FIGURE 2–9 *Typical Nitrogen Cycle for a Bay Ecosystem*

Source: Energy Resources, Inc., 1977, "Environmental Tradeoffs on Long Island with Respect to Areawide Waste Management," Prepared under Contract to the Nassau-Suffolk 208 Program Study.

provide a simple example of the importance of habitat diversity. The various natural "edge" habitats include *Spartina alterniflora* marshes, *Spartina patens* marshes, sandy beaches, gravel and boulder beaches, bluffs, mudflats, and stream mouths. In many bays, large areas of such habitats have been replaced with uniform, bulkheaded shoreline. These altered areas are generally less ecologically productive except, perhaps, for phytoplankton blooms. Oyster Bay, with a diversity of shoreline habitats, supports a productive community of shoreline uses: waterfowl, sea birds and mammals; Manhasset Bay and Hempstead Harbor, with less diversity of habitat and a great proportion of altered shoreline, mainly support bottom and water column users such as shellfish and finfish.

2.6.2.1 Offshore Subsystems. The offshore ecosystem is composed of several ecological habitats, commonly termed marine zones. These are the surface film, where ultraviolet radiation inhibits productivity; the near-surface layer, which is highly productive; the water column, which is sparsely inhabited; the near-bottom layer, which is productive; and the benthic zone, which is organized around processing of detritus. The offshore waters of Long Island include Block Island Sound, Long Island Sound and the New York Bight.

Open waters are characterized by significant local and regional horizontal and vertical circulation patterns. Thus, materials introduced in a dissolved or suspended state tend to be rapidly dispersed. Despite rapid

dispersion, western Long Island Sound has high pollutant concentrations that are attributable to East River discharges.

2.6.2.2 Bay and Estuarine Subsystems. Bay subsystems include a variety of habitats. Each of the six bays studied in detail has its own particular ecological characteristics.

Manhasset Bay and Hempstead Harbor are the closest to New York City. Hence, they have a relatively developed shoreline, and adjoining Long Island Sound waters tend to be of low quality. The two bays are long and narrow, and are well flushed by tidal action. They are generally characterized by few wetlands, high levels of water pollutants, shellfish populations contaminated by coliform bacteria, and minor fish kills.

Farther east, Oyster Bay has a well protected shoreline, large areas of wetlands, and low pollutant levels, except in a few highly localized problem areas. The bottom substrate is generally suitable for oyster production, and an active oyster mariculture program is carried out. The wetland, creek and pond habitats are suitable for invertebrate and fish spawning.

Huntington Bay is a complicated bay system containing well-flushed bay areas and less well-flushed harbors and creeks. The northeast sections contain shallows and mudflats. The harbors are presently subjected to significant pollutant loads, while the open bay areas exhibit generally low pollutant levels. Wetlands are limited.

Port Jefferson Harbor is the cleanest of the six North Shore bays. This may be attributable to its easterly position on the North Shore. It is a small harbor with limited diversity of habitats. However, the adjoining Conscience and Little Bays are relatively undeveloped, with extensive wetland areas.

Peconic-Flanders is a large bay-estuarine system, which grades from deep and well-flushed in Little Peconic Bay to shallow and poorly-flushed in the Peconic estuary. Many of the creeks tributary to Flanders Bay have been dredged and display eutrophic conditions. Some of these creeks support extensive wetlands. The shallows and wetlands are key fish spawning areas.

The eastern part of the South Shore bay system tends to be very shallow and poorly flushed. The western bays are better flushed. Essentially all of the Nassau County South Shore bays have been closed to shellfishing due to elevated coliform concentrations. On the other hand, in Great South Bay, in Suffolk, the only areas closed to shellfishing are located along the northern shore, at the river mouths. Both systems support a great diversity of estuarine forms and are prime spawning areas for shellfish. Great South Bay provides a suitable habitat for bottom dwellers such as hard clams and flounder.

Phytoplankton are major primary producers in bay systems. They can be sensitive to changes in water quality, particularly with respect to nitrogen levels, nitrogen/phosphorus ratios and turbidity. It is generally agreed that nitrogen/phosphorus ratios of 10:1 or higher are usually correlated with high phytoplankton species diversity, whereas values below 10:1 are generally found in areas associated with elevated algal biomass and low species diversity. Water quality can give an indication of what flora and fauna may be present in a body of water, and conversely, phytoplankton biomass and diversity can give an indication of water quality. Highly turbid waters have a reduced phytoplankton mass. Polluted waters generally have very small diversity. Excess nitrogen can stimulate algal production with the attendant problems associated with eutrophication. Algal blooms shift productivity and species distribution at the lowest level of production. Phytoplankton blooms have been observed in most Long Island bays.

The bays, estuaries and Long Island Sound support large fish populations, many of which have great commercial value. These populations are sensitive to changes in salinity, phytoplankton, and zooplankton levels, and also to the abundance of shellfish and other finfish upon which they feed. The life cycles of some species are dependent upon both the bay and wetland habitats, while some species depend on wetlands mainly as spawning or nursery areas. The important finfish species of Long Island can be conveniently divided into two categories: resident and migratory populations.

Among commercially valuable finfish inhabiting the bays are the winter flounder, menhaden and blackfish; the latter two species, however, move offshore to spawn. Northern pipefish, mummichug and Atlantic silversides are the most important resident forage species in several bay systems, especially Great South Bay.

Bluefish and striped bass are the most abundant of the migratory species that spend a portion of their life cycle in Long Island waters. Northern porgy and weakfish, somewhat less abundant migratory species, spawn in shallow bays and estuaries where the larvae remain for one season.

Shellfish and invertebrates are plentiful; however, the shellfish industry is affected by sewage disposal and non-point runoff since shellfish are generally found in shallow waters close to the shore or in bays. In 1975, 214,000 acres or eighteen percent of the Long Island shellfish beds were closed because of coliform bacteria contamination.

Commercially significant shellfish species include lobster, oyster, many species of clams, blue mussel, bay scallop and, in some years, blue claw crab. Hard clams are particularly abundant in Great South Bay, while oysters are found in large quantities in Oyster Bay.

The bays adjoining wetlands on Long Island serve as wintering grounds for some birds, breeding grounds for others, resting stops for many birds migrating on the Atlantic flyway, and permanent homes for other species. Scoters, Black Ducks, Scaup, Mergansers, Goldeneye and Brant overwinter in many wetlands on Long Island. Black Ducks, Canada Geese, Mallards, Gadwalls and Wood Ducks also breed there. Other species commonly seen in the wetlands of the region include Old-squaws, Canvasbacks, Ringedneck Ducks, Buffleheads, Pintail Ducks, Baldpates, Teal, Ruddy Ducks and Coots. These populations are affected by bay water quality, by changes in wetland areas, and by alterations of beaches and other bird habitats.

2.6.2.3 Streams, Lake and Freshwater Wetlands. Although streams,

lakes and freshwater wetlands are of minor areal importance in the Long Island system, these water bodies are significant. Detailed information concerning the ecology of many Long Island freshwater bodies is minimal. The streams are generally edged with a narrow band of wetlands. These wetlands, together with epibenthic plants, are nutrient cyclers. In those areas where the streams have been channeled or the wetlands have been filled, nutrient and organic cycles are curtailed and pollutants are transported downstream.

The scattered lakes are generally small and shallow. Many are impoundments, formed by damming of streams. Whereas stream water usually exhibits a significant flow, water in impoundments has a high residence time and thus is susceptible to nutrient and coliform inputs. Residence time is related to the rate of stream inflow and outflow. Past sewering and pumping, particularly in Nassau County, have lowered the water table, and hence streamflow, in a number of areas, and have thus increased residence time in some impoundments. Many Long Island lakes and streams display eutrophic conditions and high coliform counts as a result of wild and semi-wild waterfowl pollution and runoff. In addition, coliform die-off rates are extended due to the warmer water temperatures, thus maintaining high levels for longer periods. Swimming is only allowed where an average value of total coliform is below a specified standard, and adequate sanitary and safety facilities are provided.

2.6.2.4 Marine Wetland Subsystem. Wetlands serve as nurseries and spawning grounds for many commercially important fishes and shellfishes. They also protect the shoreline from the intensive erosion that might otherwise occur during storms, and they serve to attenuate many harmful effects of such pollutants as human and animal wastes and wet-weather runoff by assimilating nutrients into a diverse food web. Wetlands and tidal marshes cover 545 square kilometers of Long Island, and their continued viability is a major environmental concern in regional wastewater management.

Wetlands are probably best defined by their locations and elevations within the tidal zone. The NYSDEC has identified the following six tidal wetland zones that are a part of an integrated natural complex:

1. *Coastal Fresh Marsh.* The tidal wetland zone found primarily in the upper tidal limits of riverline systems where significant fresh water inflow dominates the tidal zone. Species normally associated with this zone include narrow-leaved cattail, *Typha angustifolia;* the tall brackish water cordgrasses, *Spartina pectinata* and/or *S. cynosuroides;* and the more typically emergent fresh-water species such as arrow arum, *Peltandra;* pickerel weed, *Pondederia;* and cutgrass, *Leersia.*

2. *Intertidal Marsh.* The vegetated tidal wetland zone lying generally between average high and low tidal elevation. The predominant vegetation in this zone is low-marsh cordgrass, *Spartina alterniflora.*

3. *Coastal Shoals, Bars and Flats.* The tidal wetland zone that (a) at high tide is covered by water, (b) at low tide is exposed or is covered by water to a maximum depth of approximately one foot, and (c) is not vegetated by low-marsh cordgrass, *Spartina alterniflora.*

4. *Littoral Zone.* The tidal wetlands zone that includes all lands under tidal waters which are not included in any other category. Within the limits of Nassau and Suffolk Counties the littoral zone does not extend under waters deeper than six feet at mean low water.

5. *High Marsh or Salt Meadow.* The normal uppermost tidal wetland zone usually dominated by salt meadow grass, *Spartina patens;* and spike grass, *Distichlis spicata.* This zone is periodically flooded by spring and storm tides and is often vegetated by low vigor, *Spartina alterniflora* and Seaside lavender, *Limonium carolinianum.* Upper limits of this zone often include black grass, *Juncus gerardi;* chairmaker's rush, *Scirpus sp.;* marsh elder, *Iva fructescens;* and groundsel bush, *Baccharis halimifolia.*

6. *Formerly Connected Tidal Wetlands.* The tidal wetland zone in which normal tidal flow is restricted by man-made causes. Typical tidal wetland plant species may exist in such areas although they may be infiltrated with common reed, *Phragmites sp.*

Intertidal marshes are highly productive ecosystems that produce essential food and nutrient materials for the coastal estuarine environment. *Spartina alterniflora,* which is the predominant vegetation in intertidal marshes, grows at high densities with large turnover rates, thus exporting with each tide nutrient-laden detritus upon which shellfish and finfish populations depend.

The greater part of Long Island's tidal marshes and wetlands, 314 square kilometers, are in Suffolk County. The remaining 231 square kilometers are in Nassau County, where large areas of salt marsh are located in the sheltered South Shore bays in the Towns of Hempstead and Oyster Bay.

2.6.2.5 The Upland Environment. Five major types of plant cover existed on Long Island prior to development: (1) the red oak forest; (2) pine-oak and pine-dune forest; (3) scarlet oak/black oak forest; (4) Hempstead Plains (grasslands); and (5) downs grassland and dune heath. The extensive red oak forest of the western third of the Island has virtually disappeared and very little remains, even in Suffolk County. The Hempstead Plains have been almost totally destroyed, splinter fragments remain only in the vicinity of Mitchel Field. The pine-oak and pine-dune forest and the scarlet oak/black oak forest still survive in large tracts. Small areas of the downs grasslands and dune heath remain.

Although many other tree and plant species are found scattered, or even in local abundance, at various sites, and although many areas have been cleared and the indigenous vegetation removed, the historically dominant communities still exist in certain areas.

The major types of altered habitats that exist on Long Island include (1) urban or suburban residential and commercial areas, (2) agricultural lands, (3) old fields, and (4) recharge basins. Each of these plays a role in the terrestrial subsystem.

The terrestrial subsystem includes both natural and altered habitats. Generally, Long Island vegetation is a product of the Island's geologic setting. The sandy, glacial soil supports such scrub growth as pitch pine, black pine and black oak. Long Island's chief agricultural activity is the growing of potatoes, which do well in sandy areas. The sandy soil column allows rapid assimilation of precipitation. The leaching of fertilizer tends to be rapid, although vegetative cover slows the process.

There are specific settings in which maintenance of vegetation is of particular ecological importance. As discussed in 2.6.1, a diversity of habitats is generally desirable. This is particularly true of the land/water interface, since aquatic species need the protection of the upland vegetation. The preservation of forested or shrub buffers at the edge of wetlands and ponds, and along streams, is critical.

2.7 Summary

Pollution enters the ground and surface waters of Long Island from both point and non-point sources. Point sources include such discharges as municipal waste treatment plant effluents and industrial wastes, both treated and untreated. Nassau County treats about 107 MGD of domestic and industrial wastes, and discharges all except two MGD to surface waters. The two MGD is recharged and, of this, 40 percent is of industrial origin. In contrast, only 0.4 percent of the flow discharged to surface waters is of industrial origin. Suffolk County currently treats sixteen MGD, although, by 1986, when the Southwest Sewer District plant is operating at capacity, this quantity will rise to 46 MGD. At the present, Suffolk's treated effluent, of which ten to fifteen percent is of industrial origin, is discharged to ground and surface waters in roughly equal amounts. Nassau also generates 90 million gallons per year of waste treatment sludge, mostly disposed of in the Atlantic Ocean. Suffolk generates twenty million, mostly disposed of in landfills.

Non-point sources of pollution comprise stormwater runoff from impervious surfaces, cesspools and septic systems, fertilizers and pesticides and groundwater underflow to streams and bays. Stormwater finds its way into both ground and surface waters. Effluents from domestic on-site waste disposal systems enter the groundwater. Fertilizers and pesticides are applied to the ground surface, and rainfall washes them down into the groundwater. In certain areas, contaminated groundwater carries pollutants into streams and marine waters by underflow.

The concept of "safe" or "permissive" yield is defined as the volume of groundwater that can be withdrawn from the aquifer and used consumptively on an annual basis without producing undesirable results. The safe yield for Nassau County has been estimated at 151 MGD, and that for Suffolk County at 466 MGD. In contrast, although current withdrawal rates are considerably higher, consumptive losses are estimated at 133 MGD for Nassau and 30 MGD in Suffolk. Daily pumpages in Suffolk are well over 110 MGD, and peak days pumpages over 300 MGD, but a substantial portion is returned to the system and not consumed.

Chlorophyll a is an indicator of the standing crop of phytoplankton, and if large fluctuations of chlorophyll a occur, then large fluctuations occur in total nitrogen and dissolved oxygen levels. Such changes are observed frequently in Manhasset Bay, Hempstead Harbor, Peconic Bay and Great South Bay.

Because of pollution in western Long Island Sound, the water quality and marine environment in the North Shore bays show steady improvement with distance from New York City. Superimposed on this pattern are local variations due to runoff and poor flushing in certain creeks and harbors. The amount of development falls off from west to east, so that the easterly bays have better water quality and more extensive wetlands. Most of the South Shore bays in Nassau County are closed to shellfishing. However, in the Great South Bay, in Suffolk County, such closures are confined to river mouths. In the Peconic Estuary-Flanders Bay system, tidal flushing diminishes going from the bay into the estuary. There are extensive wetlands on the tributary creeks, and eutrophication is frequently observed.

All bays support large and valuable fish populations, which are sensitive to changes in salinity and plankton levels. Shellfish and invertebrates are also plentiful. Shellfish are particularly sensitive to sewage disposal and non-point pollution runoff. Marine wetlands and tidal marshes cover 545 square kilometers, and provide habitats and wintering areas for many bird species.

The total surface area of streams and lakes, and their associated wetlands is small. The lakes are generally shallow, and suffer from eutrophication due to waterfowl pollution and surface runoff.

Long Island's sandy glacial soil supports scrub growth, such as pitch pine, black pine and black oak. Much of the original tree cover has been lost to development. The sandy soil allows the rapid seepage of rainfall, which, in turn, carries contaminants rapidly into the groundwater. Vegetative cover helps to slow this process.

In summary, Nassau and Suffolk Counties present a picture of rapid growth and development, in the course of which the area's great natural resources have been seriously impacted. Those that remain are still of the highest quality. Section 3.0 addresses the alternatives for the protection of these resources.

Long Island's geologic system is characterized by three geologic formations, stratified and generally hydraulically connected. The uppermost aquifer usually contains the water table surface, and is most susceptible to contamintion as a result of activities on the land surface. Water quality in the uppermost aquifer is somewhat variable, at times containing objectionable concentrations of iron and manganese, and at times, evidence of the leaching of domestic wastes. Water quality variability in shallower wells is more related to population density and land use. Concentrations of most contaminants are somewhat lower in Suffolk than in Nassau. For example, Nassau County wells show an average nitrate level of 4.5 milligrams per liter compared to

2.3 milligrams per liter in Suffolk. Similarly, Nassau County shallow wells range in chloride concentration from nineteen to 83 milligrams per liter, whereas Suffolk County wells average twelve milligrams per liter.

The next deeper aquifer is the Magothy formation. Its background water quality is excellent, having very low dissolved solids. In the deep recharge area, the Magothy formation is affected by seepage of contaminants from the water table aquifer, as evidenced by nitrates detected deep in the Magothy in the center of Nassau County.

The deepest aquifer is the Lloyd, and this too has excellent background quality, with low dissolved solids. In some locations, the iron content can exceed the drinking water standard. The Lloyd aquifer has not yet been greatly developed for water supply.

Organic chemicals have been appearing in the groundwater in recent years. Their concentrations have been very low, but their presence is a cause for public concern. Fifteen wells have been removed from service because of trace amounts, mostly in industrial areas.

In the marine waters of Long Island, all bays have shown dissolved oxygen concentrations which periodically fall below the standard of five milligrams per liter. Hempstead Bay and western Great South Bay show this periodic drop most frequently. Similarly, all bays show high total coliform counts periodically, at least in some locations. North Shore bay waters generally contain lower total nitrogen concentrations than South Shore bays. Nassau County South Shore bays show a decrease in total nitrogen level from west to east, attributable to the improved tidal flushing as one moves east. In contrast, Great South Bay waters show a decrease in total nitrogen from east to west. Again, this is probably due to improved tidal flushing in the vicinity of Fire Island Inlet.

NOTES

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Section 3 Alternative Wastewater Management Programs

3.0 Introduction

This section outlines alternative wastewater management programs in terms of the following:

1. objectives
2. source control alternatives (both point and non-point), and
3. methods by which objectives may be met, using a combination of traditional and innovative structural and non-structural alternatives.

3.1 Objectives

The various alternative wastewater management programs all have as their general objective the development of a comprehensive management plan for the treatment and disposal of waste to protect the public health and natural resources of the Long Island 208 Region.

3.1.1 Public Health Objectives. The major public health objectives may be met by (a) the continued protection and restoration of the quality of the water-table aquifer, and the deeper aquifers, in order to assure the availability of potable water, and (b) the maintenance and/or improvement of water quality of both fresh and marine surface waters so as to ensure their use for swimming, fishing and other recreational and commercial purposes.

A. Protection of Groundwater. There is a wide range in the types and locations of the sources of groundwater contaminants. Landfills, industrial discharges, sewage treatment plant recharge basins, accidental spills, process and incinerator wastewater, cesspools, rainwater and stormwater recharge are important sources of pollutants for Long Island groundwater.

Just as the sources of contamination vary widely, the materials contributed by each source also vary. Inorganic and organic nitrogen, halogenated hydrocarbons, heavy metals, pesticides, deicing salts, coliform bacteria and viruses are all contributed by these sources. Nitrate and organic chemical contamination are of particular concern in the Long Island area.

Within this category, items that impact the public health include failing cesspools, leakage from faulty or failing sewer collection systems, overloaded treatment systems, physical breakdown of wastewater treatment facilities and inactivation of treatment systems by plant upset. These conditions result in the contamination of ground and surface waters with nitrogen, coliform bacteria, viruses, inorganic ions, heavy metals and organic compounds.

B. Maintenance of Surface Water Quality. Shoreline development places the source of contamination due to human activities immediately adjacent to vital water resources. The erosion of stream banks and the destruction of marsh edges increase surface water contamination from fertilizers, silt, animal wastes and other pollutants. The location of sewage treatment plant outfalls may cause localized degradation of surface waters to levels that prevent their utilization for shellfishing and water-intensive recreational activities. In general, non-point sources contribute the greater part of the pollutant loading that endangers public health.

3.1.2 Natural Resources Objectives. The natural resource objectives include (a) the protection of critical environmental zones such as primary recharge areas, marine and freshwater wetlands, and unique wildlife habitats; and (b) the protection of biological resources, especially fin and shellfish populations in the marine environment and the protection of biological diversity.

A. Protection of Critical Environments. While public health aspects that relate directly to human diseases are obvious concerns to be addressed in a wastewater management plan, the protection of unique environmental zones has often been overlooked, or its importance underestimated. Development or loss of natural recharge areas increases non-point source contaminants in groundwater, such as nitrates, metals and organic chemicals. It also reduces the partial removal of nitrates in rainwater, which normally occurs in naturally vegetated areas. The loss of wetlands such as marshes, swamps and low-lying areas adjacent to streams increases erosion, siltation and the

runoff of nutrients and coliform bacteria to surface waters. Furthermore, these areas are highly productive and of the greatest importance in the food chain. The protection of these unique habitats is required by several Federal and State regulations.

Beyond the effects of the physical dislocation of these critical areas, their degradation due to quality changes resulting from adopted management philosophies must be considered. Strategies that result in the maintenance of public health but allow wholesale changes in the physical or chemical characteristics of surface waters can easily lead to loss or changes in unique natural resources. For example, decreases in groundwater levels can result in changes or losses of marshes, swamps and bottomland zones, with the resulting problem of erosion and runoff. Decreases in the streamflow may affect salinity regimes in the tidal portion of streams and the receiving waters of bays, possibly resulting in changes in spawning and nursery areas for marine organisms.

B. Protection of Biological Resources. The loss or change of existing populations of marine and freshwater organisms, while not necessarily directly affecting man's use of the marine zone, or impacting public health, could indicate a severe alteration in the physical and chemical properties of these waters. Any loss of these resources would also have serious economic consequences affecting the shellfish, sportfish and tourist industries. It must be remembered that, while the natural population of a marine organism such as the hard clam may be maintained, if it cannot be utilized because of contamination by coliform bacteria or viruses, then the population is effectively "lost" to commerce.

The maintenance of existing biological resources implies the prevention of any changes that will affect the normal functioning of the ecosystem. Furthermore, changes in phytoplankton density will result in alterations in dissolved oxygen levels, with subsequent effects on all animal populations in the area. These algal populations are highly dependent upon nutrients such as nitrogen and phosphorus. Any significant increases in nutrient levels may result in large scale changes in phytoplankton.

Decreases in streamflow may result in salinity changes, affecting the growth and reproduction of many marine organisms. Included here are dislocations of finfish populations due to the shifting of optimal salinities in nursery areas. Mid-bay outfalls may give rise to local salinity changes and increases in coliform bacteria levels, which may affect the health and marketability of shellfish. Stormwater runoff contributes coliform bacteria, heavy metals, pesticides, nitrogen and other contaminants to surface bays, and may severely impact the biological resources of these areas.

3.2 Identification of Wastewater Management Needs

Table 3–1 lists the main sources of contaminants and the wastewater management objectives that they impact. Table 3–2 lists the major types of pollutants they contribute to the environment, and the possible types of control options available. A number of conclusions can be drawn from these tables. It is obvious that a number of sources impact both public health and natural resource objectives. It is also apparent that the contaminants that are of major concern are common to a wide variety of sources. State and Federal standards exist for coliform bacteria, certain organics and heavy metals in drinking water. There exists a Federal drinking water standard of ten milligrams NO_3–N per liter. Nitrogen is the only parameter common to almost all public health and natural resource concerns for which total loadings can be calculated. Control of this contaminant from each source will in many cases lead to reduction or elimination of other pollutants. (There are, of course, some specific exceptions to this, as in the case of coliform bacteria,

Table 3–1

CONTAMINANT SOURCES AND IMPACTS ON PUBLIC HEALTH AND NATURAL RESOURCES

	Impacted Factors			
	Health		Resources	
Contaminant Source	**Ground Water**	**Surface Water**	**Critical Environments**	**Biological**
Animal wastes	X	X		X
Cesspools	X	X		X
Stormwater runoff	X	X	X	X
Rainwater	X			X
Leakage from sewer systems	X	X		X
Shoreline development		X	X	X
Development of recharge areas	X		X	X
Loss of wetlands		X	X	X
Changes in streamflow		X	X	X
Landfills	X	X	X	X
Recharge basins	X			
Industrial process water	X	X	X	X
Spills	X	X	X	X
STP* operation	X	X		
Siting of STP*		X	X	X
Siting of outfalls		X	X	X
Siting of collection systems			X	
Residuals	X		X	X
Hazardous wastes	X	X	X	X

X – adverse impact *STP = sewage treatment plant

Table 3–2

WATER CONTAMINANTS, BY SOURCE AND TYPE OF CONTROL

	Contaminant					Control		
Contaminant Source	Coliform Bacteria	Nutrients (Nitrogen)	Organic Chemicals	Metals	Other	Structural	Non-Structural	None
Animal Wastes	X	X			Viruses	X	X	
Cesspools	X	X	X		Viruses	X		
Stormwater runoff	X	X	X	X	Viruses	X	X	
Rainwater		X		X	Acids			X
Leakage from sewer systems	X	X	X	X	Viruses	X		
Shoreline development	X	X	X		Sediments		X	
Development of recharge areas		X	X	X	Viruses	X	X	
Loss of wetlands	X	X	X	X	Sediments		X	
Changes in streamflow					Sediments	X	X	
Landfills	X	X	X	X		X	X	
Recharge basins		X	X	X			X	
Industrial process water	X	X	X	X	Variable	X	X	
Spills					Variable		X	
STP* operation	X	X	X	X			X	
Siting of STP*	X	X			Viruses	X		
Siting of outfalls	X	X			Viruses	X		
Siting of collection systems					Sediments	X		
Residuals	X	X	X	X		X		
Hazardous wastes			X	X	Variable	X	X	

*STP = sewage treatment plant

X — adverse impact

organic chemicals and viruses.) It is for this reason that nitrogen has been selected as the primary parameter upon which the following treatment alternatives have been developed. However, it should be understood that other treatment may be required to remove specific contaminants not directly affected by nitrogen removal processes. In addition, the impacts of parameters not historically monitored, and therefore not specifically treated, require further evaluation.

A primary question is what levels of nitrate-nitrogen are consistent with both the public health and natural resource objectives. As described previously, groundwater is the sole source of drinking water on Long Island. Therefore, if the public health standard is to be satisfied, the nitrate-nitrogen concentration in groundwater should not exceed ten milligrams per liter. Regulations require that, if a water supply reaches this concentration, the purveyor must immediately notify all customers.

Groundwater quality on Long Island is highly variable both in time and from place to place. In order, therefore, to satisfy the drinking water standard, this variation should be accommodated. A statistical analysis of groundwater data, obtained from wells in Nassau and Suffolk Counties, indicated that if the *mean* nitrate-nitrogen concentrations in the Upper Glacial aquifer are six milligrams per liter, then there is a 90 percent chance that well samples will contain levels of nitrate-nitrogen less than ten milligrams per liter.

Although this result is preliminary, it is a useful criterion for managing the Region's nitrogen sources in a manner that ensures that the drinking water standard of ten milligrams per liter will probably not be violated in the Upper Glacial aquifer.

Surface water quality analyses, undertaken within the 208 Program, have demonstrated that levels of oxygen are largely determined by algal respiration and photosynthesis, and by the utilization of oxygen in the bacterial decomposition of dead algal material and other detritus. Large diurnal fluctuations of oxygen are highly undesirable. In particular, larvae of shellfish and other juvenile fish are vulnerable to low levels of oxygen. Given the dependence of algal production on nitrogen, it follows that controls that limit nitrogen will in turn reduce the range of oxygen fluctuations.

From data obtained during the 208 Program, an approximate relationship between nitrogen, chlorophyll a and levels of oxygen was computed, and a nitrogen guideline for the determination of waste load allocations for

marine receiving water was developed. An outline of the method of calculation is given in Section B of the Areawide Waste Treatment Management Plan. The results show that a total nitrogen concentration of 0.4 milligrams per liter or less will generally maintain chlorophyll a levels below 40 micrograms per liter, and will minimize diurnal fluctuations in dissolved oxygen levels. Although this recommended standard can only be regarded as preliminary, the limited data available supports the hypothesis that accelerated eutrophication will not occur where this concentration of chlorophyll a is not exceeded.

3.2.1 The Hydrogeologic Zones. As previously indicated, there are two broad public health objectives, one dealing with groundwater and the other with surface water. The primary objective in protecting the quality of groundwater is to maintain the resource as the regional water supply.

The major patterns of groundwater flow are such that the Region's deep groundwater reservoirs are mainly replenished over a broad area in the central part of the Bi-county Region, as shown in Figure 3—1. Recharge water entering this central area affects the quality of the middle and lower supply. The area outside the central area may be less critical in terms of water supply. On this basis, and considering the use of the groundwater, wastewater management zones can be defined in the Bi-county Region (Table 3—3 and Figure 3—2). It should be recognized that deep flow also occurs to the north of the northern limit of the Magothy in both Nassau and Suffolk. This flow occurs in the deeper portion of the Upper Glacial deposits which are the hydrologic equivalent of the Magothy in this area. In addition, the Upper Glacial aquifer is still utilized as a source of drinking water. Therefore, precautions should be taken to preserve or restore this aquifer as a source of potable water.

One approach to wastewater management is that of identification and protection of critical watersheds. In the Bi-county Region, the greater part of the Magothy aquifer may be identified as the prime source of future water supply. Those areas contributing to this aquifer should be subjected to the strictest management controls.

Zone I covers areas characterized by a deep flow system, which generally contribute water to the middle and lower portions of the Magothy. This zone is a primary source of drinking water in both counties. Point and non-point source controls should be implemented in this zone to protect the public health.

Zone II has experienced serious groundwater quality problems in the Magothy in recent years, primarily due to organic chemicals. Most of the zone is included in Nassau County Sewage Disposal District Three, it is already highly developed, and is presently being sewered. Until the extent of the contamination is determined, all sources of groundwater pollution should be controlled in a manner similar to those in Zone I. Control of non-point sources of pollution will be necessary for reasons of public health.

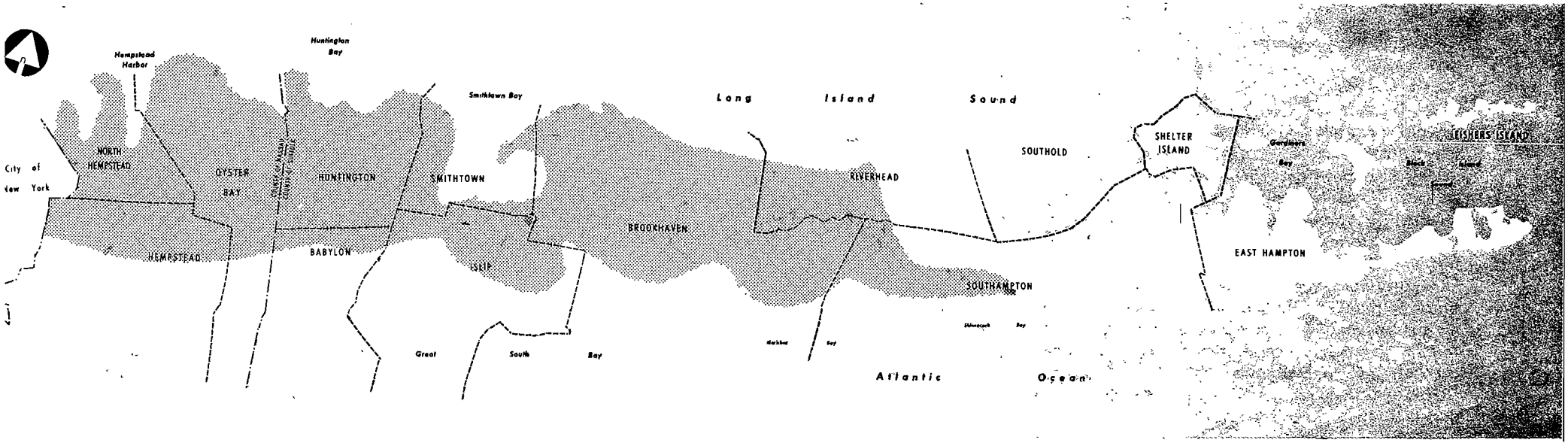


FIGURE 3—1 *Deep Flow Recharge Area*

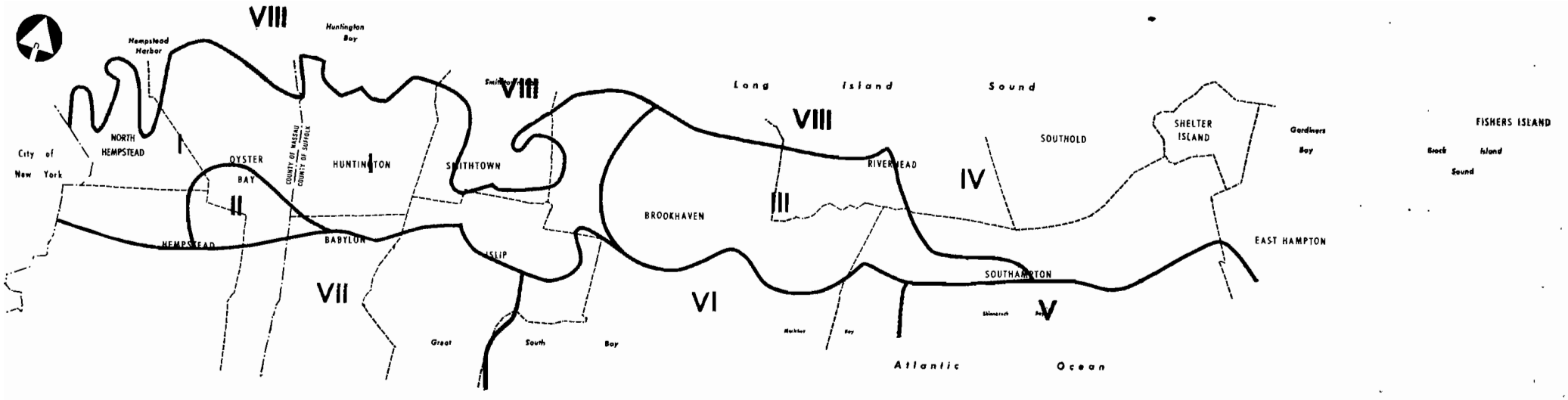


FIGURE 3–2 *Hydrogeologic Zones in the Nassau-Suffolk 208 Study Area*

Zone III is an area that still has good quality groundwater in both the Upper Glacial and Magothy aquifers. Median nitrate-nitrogen concentrations in water from wells in this area have always been low. Moreover, since the hydraulic conductivities of both aquifers are high, there is considerable potential for water supply development in this zone. Much of the area is in low density, primarily non-agricultural, land use. This zone should be protected by applying land use restrictions, as well as strict pollution source controls. In this zone, control of non-point sources is necessary for the protection of the resource itself, and the entire zone should be governed by non-degradation regulations.

Zone IV comprises the North Fork and the eastern part of the South Fork. This area has unique groundwater conditions, and special management alternatives apply to it. Intensive agricultural activities have resulted in nitrate-nitrogen concentrations in wells located in agricultural areas that are above six milligrams per liter, with many observations exceeding ten milligrams per liter. Although groundwater underlying agricultural areas shows definite signs of nitrogen-related contamination, the residential areas still have good quality water, and statistical examination of over 300 analyses from domestic wells located on the North Fork indicates that almost all have nitrate-nitrogen concentrations of less than three milligrams per liter. High chloride concentrations (over 250 milligrams per liter) have been found in a few areas on the North Fork, in New Suffolk, and along both shores of Great Hog Neck and Little Hog Neck. Public supply wells in the Greenport area have experienced saltwater upconing where pumpage was concentrated at one site. While there are many areas with acceptable water quality, any expansion of farming, without the adoption of proper fertilizer management procedures, will lead to increased nitrate contamination of groundwater. However, reduction or elimination of farm acreage and subsequent residential development may result in water supply problems, because most groundwater beneath these agricultural areas already contains very high nitrate concentrations. Based on assessments of the groundwater development potential in each of these areas, there appears to be sufficient available groundwater to support projected land uses, if pumpage is properly developed and managed. This conclusion is supported by the results of a detailed hydrologic model study of the South Fork, conducted as part of the 208 Program. However, because of the limited depth of fresh water on the forks, wastewater management controls must protect those areas that still have acceptable groundwater quality if the areas are to remain self-sufficient in water supply. Failing this, alternative engineering solutions based on water importation or large-scale renovation, will be extremely expensive. Public health questions in Zone IV are related to nitrate concentrations in groundwater. The protection of resources, both natural and recreational, is related to the quality of marine waters. Non-point source controls are relevant to both.

Zone V comprises the southwestern portion of the South Fork not

Table 3–3

HYDROGEOLOGIC ZONES IN NASSAU AND SUFFOLK

Zone No.	Type or Location of System	System Characteristics
I	Deep Flow (Magothy recharge area)	Deep recharge with vertical flow.
II	Deep Flow (Magothy recharge area)	Area of substantially impaired groundwater quality.
III	Deep Flow (Magothy recharge area)	Higher grade reservoir. Exceptionally high quality water with high potential yield.
IV	North Fork and Eastern South Fork	Local water quality problems, but with potential for development, particularly on South Fork.
V	Western South Fork	As previous, but little agricultural input.
VI	Surface Water Impact Area	Polluted groundwater has major impact on surface water, due to long residence time in bays.
VII	South Shore Shallow Flow System	Generally shallow and horizontal flow.
VIII	North Shore Shallow Flow System	Generally shallow and horizontal flow.
	Shelter Island and Fishers Island*	

**Shelter Island and Fishers Island were considered separately.*

included in Zone IV. It differs from Zone IV in having less agricultural activity and, consequently, less of a fertilizer runoff and leaching problem. In all other respects, Zone V shares the characteristics of Zone IV.

Zone VI is that portion of the groundwater system that discharges to Moriches Bay and the eastern portion of Great South Bay. Because the flushing rate in eastern Great South Bay is so low, contaminant concentrations are not sufficiently dispersed and diluted.

The shoreline of Zone VI has valuable recreational resources, and the adjacent bay has important shellfish resources. This zone should be covered by non-degradation regulations.

Zone VII and VIII are areas which are likely to contribute water only to the shallow groundwater flow system. This flow system discharges to streams and saltwater bays, and hence will affect the quality of the surface water. Zone VII groundwater flows into the Nassau County South Shore bays, and has a more significant impact on marine water quality than the groundwater from the areas marked Zone VIII. The latter enters North Shore bays, whose water quality is more dependent on Long Island Sound.

Zones VII and VIII differ geologically. In Zone VIII areas, the Magothy formation has been completely eroded away and replaced by a deep glacial aquifer. The zones are also differentiated on the basis of sewering options. Zone VII is predominantly committed to comprehensive sewering, whereas Zone VIII areas are generally not. Possible exceptions to the shallow flow concept discussed here include those areas of heavy pumping such as in southwestern Nassau, where local reversals of gradient occur. Areas immediately surrounding high capacity supply wells situated in the shallow flow region could also act as local recharge zones. In addition, abandoned wells or wells with faulty construction can serve as conduits for contaminated water and allow movement from shallow to deep systems.

Mean concentrations of nitrates in shallow well water might be allowed to reach six milligrams per liter in Zone I areas, whereas concentrations in Zone VIII might be allowed to approach ten milligrams per liter without contravening surface water standards. In Zone VII, the eastern portion of the zone presently has low groundwater nitrogen concentrations. Increases in groundwater nitrogen in this area will increase the nitrogen loading to eastern Great South Bay. Nitrogen loadings from the western portion of Zone VII do not have as large an effect on eastern Great South Bay, due to the proximity of Fire Island Inlet. The boundary lines separating Zone I and Zones VII and VIII are not meant to be definitive, because there is a lack of data in some areas. The northern boundary of Zones V, VI and VII corresponds roughly to the limit of the Gardiners Clay or equivalent clays. These zones also are areas where available head data between the Magothy and the Upper Glacial indicate essentially horizontal flow in the Upper Glacial aquifer. The southern boundary of Zone VIII on the North Shore was determined using existing information on head distribution near the coastline and interpolating between these points. Flow in the upper aquifer in Zone VIII is, again, essentially horizontal. The area in Zone VIII near Smithtown coincides with the extent of the Smithtown Clay. Further investigation is required to evaluate the flow relationships in most areas before specific management schemes can be implemented. These especially include the Smithtown and Shoreham areas, as well as the southeast portion of Suffolk County.

In some localities, Zones VII and VIII are similar, in that they have a high water table and soils of low permeability.

3.2.2 Surface Waters. Fresh waters in the Nassau-Suffolk Region include several lakes, four major streams and numerous ponds and minor streams. Freshwater quality is a function both of groundwater quality and of the nature and volume of the pollutants carried in runoff originating in the immediate watershed. Freshwater streams contribute locally significant amounts of nitrogen and coliform bacteria to the bays.

These pollutants affect not only public health but also environmental resources. Abnormal changes in the volume of streamflow, such as might be expected to result from sewage collection and discharge of effluent to marine

waters, can be expected to produce changes in stream corridor and bay ecosystems. In the first instance, the changes will occur because of lowered water levels or disappearance of the streams; in the second, because of increased salinities resulting from reduced quantities of fresh water reaching the bays as streamflow and underflow.

In order to protect the marine surface waters and biological resources of Nassau and Suffolk Counties, nitrogen and coliform bacteria have been selected as the two key pollutants to be controlled. Nitrogen is contributed to the bays by point sources (principally municipal treatment plant discharges) and non-point sources. The non-point sources include groundwater underflow, stream base flow, stormwater runoff and direct rainfall. For each Long Island bay, the relative loading of each source varies. The response of each bay to a given loading also varies due to the different flushing rates of each bay. It is also true that the effect of a nitrogen loading to a bay varies, depending on the exact location of the discharge. The individual bays are discussed below, in Section 2.5 of this report and in Section B of the Areawide Waste Treatment Management Plan. Figure 3–3 indicates the areas considered in the natural resource planning alternatives.

Great South Bay. Over 50 percent of the present total nitrogen loading to Great South Bay is from groundwater—sixteen percent from groundwater underflow, and 40 percent from stream base flow. (See Table 2–7 in Section 2.5.) Since nearly 100 percent of stream base flow is derived from groundwater, both sources can be considered together. Groundwater underflow to Great South Bay is approximately 78 cubic feet per second (cfs). This compares to the average stream base flow of 260 cfs.* Nitrogen concentrations in groundwater underflow and stream base flow show similar concentrations. In western Great South Bay (west of the Connetquot River), groundwater nitrogen concentrations average about five milligrams nitrogen per liter. The resulting nitrogen loadings to western Great South Bay are 720 pounds per day from groundwater and 1800 pounds per day from stream base flow.

In eastern Great South Bay (east of the Connetquot River) nitrogen loading is 330 pounds per day from groundwater underflow and 830 pounds per day from stream base flow. The lower loadings are primarily due to lower nitrogen concentrations of 1.4 milligrams nitrogen per liter for streams and one milligram nitrogen per liter for groundwater. Although the nitrogen loadings to eastern Great South Bay are smaller than the loadings to the western Great South Bay, the long residence time (the average length of time for which a parcel of water remains in the bay) of eastern Great South Bay makes it the more critical half of the system. Current nitrogen loading from stream base flow and groundwater underflow in eastern Great South Bay

*Includes groundwater inflow to streams below gauging stations.

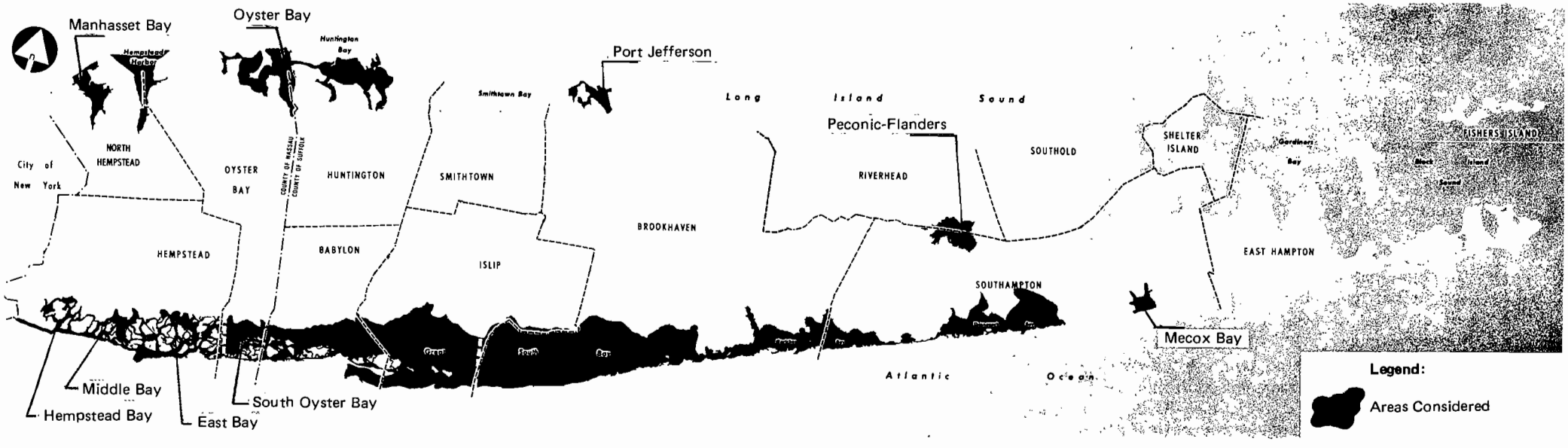


FIGURE 3–3 *Areas of the Nassau-Suffolk 208 Study Area Considered for Natural Resource Planning Alternatives*

produces average receiving water nitrogen concentrations over one milligram nitrogen per liter.

Additional increases in groundwater nitrogen discharging to eastern Great South Bay must be avoided if serious degradation to the bay is to be prevented. If groundwater nitrogen concentrations increase to two milligrams nitrogen per liter or more, nitrogen concentrations in eastern Great South Bay will exceed two milligrams nitrogen per liter.

In western Great South Bay, the residence time is lower and the flushing considerably better than in eastern Great South Bay, except in some canals, where the low flushing rate is a very real problem. Although the loadings are greater, receiving water nitrogen concentrations are currently near acceptable levels. Sewering programs with ocean outfall, currently planned for southwestern Suffolk County, should result in lower groundwater nitrogen concentrations within ten to twenty years.

The two remaining major non-point sources are direct rainfall and stormwater runoff. There are no options available for controlling nitrogen loading from direct rainfall. However, storm runoff into eastern Great South Bay should be controlled. Point sources account for only two percent of the total nitrogen loading to Great South Bay. The major point source, the Patchogue treatment plant, discharges to eastern Great South Bay. This discharge should be removed, or receive denitrification.

Western South Shore Bays. Point source discharges are the major internal source (76 percent) of nitrogen to the western South Shore bays of Nassau County. The point sources are concentrated in Hempstead Bay; an additional source is located at the Jones Beach Sewage Treatment Plant outfall east of Jones Inlet. Flows to the Freeport Sewage Treatment Plant will be diverted to the Cedar Creek plant in 1979. Receiving water nitrogen concentrations are excessive in Hempstead Bay and Middle Bay, and near acceptable levels in East Bay and South Oyster Bay.

The Bay Park Sewage Treatment Plant contributes about 85 percent of the total point source nitrogen loading to the Nassau County South Shore bays. If this outfall were moved to an offshore location, there would be a reduction of the total nitrogen loading (to the western South Shore bays) by 66 percent and the total coliform loading by eleven percent.

Moriches Bay. Moriches Bay has experienced high nutrient and coliform loadings, particularly in the form of wastewater from duck farms in the vicinity of its tributary streams. Point sources account for fourteen percent of the total nitrogen loadings. There are no estimates of the amount of nitrogen trapped in duck waste sludges deposited during past years. However, they are not considered to be significant nitrogen sources at present. Groundwater underflow and streams contribute significant inputs of nitrogen to the system. In order to attain surface water quality goals of 0.4 milligrams nitrogen per liter and 5.0 milligrams per liter dissolved oxygen, these sources must be reduced. Point sources, although only fourteen percent of the total loads, cause localized problems in the poorly flushed streams on which they are located. Any pollutant loads to the Narrows area will affect both Moriches Bay and eastern Great South Bay. Large areas of Moriches Bay are presently closed to shellfishing because of elevated coliform concentrations.

Nitrogen and coliform loads do not occur to the same extent in all the sources. It will be necessary to reduce pollutant contributions from a number of sources in order to attain the required water quality objectives.

Mecox Bay. The inlet from this bay to the Atlantic Ocean is closed approximately half the time. The one duck farm in the area no longer discharges its wastes to the bay.

Shinnecock Bay. Flushing rates, surrounding land use and the absence of point sources have allowed maintenance of high water quality in Shinnecock Bay. For this reason, wastewater management should ensure non-degradation of this resource.

Manhasset Bay. Seventy percent of the nitrogen loading from sources within the bay is discharged from point sources. High nitrogen concentrations in Long Island Sound water are an even larger influence. A waste management plan to maintain recommended nitrogen levels in Manhasset Bay must, therefore, consider control of sources within the bay and possibilities for control of sources outside of the bay (Long Island Sound) and beyond the boundaries of the Nassau-Suffolk study area.

The high nitrogen concentration in Long Island Sound impacts water quality in Manhasset Bay (and Hempstead Harbor). The recommended nitrogen loading to Manhasset Bay assumes future reduction in the concentration of nitrogen in the Sound. This assumption is valid only if New York City ceases its nitrogen discharges to the upper East River. If Long Island Sound water quality does not improve, the attainment of water quality standards in Manhasset Bay (and Hempstead Harbor) cannot be assured even with nitrogen removal or mid-bay discharge. It is therefore very important that the New York State DEC or EPA plan and implement waste controls required to improve water quality in western Long Island Sound.

Hempstead Harbor. Hempstead Harbor, like Manhasset Bay, is subject to high nitrogen loadings from Long Island Sound. Approximately seventy percent of the nitrogen loading from sources within the harbor is from point sources. These point source nitrogen loadings are concentrated in Glen Cove Creek, which receives approximately 1600 pounds per day from the Glen Cove Municipal Treatment Plant and an average of 400 pounds per day from the Powers Chemco plant. (Powers is preparing to treat their wastewater for nitrogen removal.) Although not normally regarded as a point source, the semi-wild duck population on Roslyn Park Pond constitutes one. (The pond discharge frequently requires chlorination because of high bacteria levels.) To avoid localized water quality degradation, the recommended total nitrogen loading to the harbor has been established at 417 pounds per day. At the south end of Hempstead Harbor, the Roslyn Sewage Treatment Plant discharges an average nitrogen loading equal to the total recommended for the entire harbor.

Oyster Bay. Stormwater runoff and stream base flow are currently responsible for contravention of coliform bacteria standards and elevated nitrogen loadings.

Current nitrogen loadings from the Oyster Bay Treatment Plant are well below the maximum recommended loading.

Huntington Bay. Within this embayment, 75 percent of the point source loadings discharged to Northport Harbor and Huntington Harbor originate from sewage treatment plants. Loadings to both harbors exceed the recommended loadings. Therefore, reduction of nitrogen concentrations is required. Stormwater runoff contributes 98 percent of the coliform loading to the bay and requires control.

Port Jefferson Harbor. The Port Jefferson Sewage Treatment Plant is the major nitrogen point source to the harbor. Current loadings are within the recommended maximum of 500 pounds per day. Future loadings greater than 500 pounds per day will result in unacceptable concentrations if the outfall remains in its present location.

Stormwater runoff and stream base flow are currently responsible for violations of shellfish standards in Conscience Bay and Setauket Harbor/ Little Bay; they also contribute to violations in southern Port Jefferson Harbor.

Flanders Bay. Flanders Bay and the Peconic Estuary receive point source nitrogen loadings from duck farms located on tributaries, including the Peconic River, and from the Riverhead Sewage Treatment Plant. Over 50 percent of the present loading is from duck farms. The approximate loading to Flanders Bay from Meetinghouse Creek and the Crescent Duck Farm was 600 pounds per day during the 208 sampling period. The recommended discharge is 464 pounds per day. Thus nitrogen removal would be indicated for the Crescent Duck Farm. However, significant treatment system improvements were made subsequent to the 208 sampling period. These have resulted in no surface discharge from this farm for most of the period beginning February 1977. A re-evaluation of the impact of this discharge point should therefore be made.

The Peconic Estuary receives most of its nitrogen loading from the Riverhead Treatment Plant and the Peconic River. The nitrogen loading of the Peconic River is variable because of the variation of river discharge. From four observations between July 1976 and April 1977, the total nitrogen loading to the Peconic Estuary from the river ranged from 133 pounds per day to 414 pounds per day. In addition to the Peconic River discharge, the Riverhead Treatment Plant discharges an average of 148 pounds per day of total nitrogen.

The maximum allowable nitrogen loading to the estuary is 182 pounds per day. To meet this allowable discharge, the two duck farms on the Peconic River must either institute effluent nitrogen removal, or go to zero discharge. This will reduce the nitrogen loadings of the Peconic River by 40 to 50 percent. No additional nitrogen loading should be allowed from the Brookhaven or Grumman treatment plants. Even with these controls on discharges to the river, the maximum allowable nitrogen loading to the Peconic Estuary may still be exceeded periodically.

3.3 Point Source and Residual Controls

The previous parts of Section Three have described the objectives of the Program and have developed a series of waste management options for different geographic areas. These are general in nature and are meant to provide decisionmakers with an overview of existing problems, their probable causes, and general courses of action for addressing the problems.

This section discusses in more detail structural alternatives to wastewater management. It presents information on various treatment approaches that may be used in the bi-county area, evaluates new technological concepts, and discusses alternative programs for residuals (solid waste, sludges, hazardous wastes) management.

The term "cost-effectiveness" is used throughout this report. It is defined in traditional engineering terminology as those measures that are economically feasible in terms of tangible benefits that accrue from monies spent. Cost-effectiveness, as defined in USEPA "208" Guidelines, refers to the solution, chosen as a result of the systematic comparison of alternatives, that minimizes total costs to society over time, while meeting specified goals and objectives. The total costs should include resource, social, environmental and dollar costs. Effectiveness refers to meeting the 1983 goals of the ACT (PL 92–500), while providing for the highest practical degree of technical reliability in the pollution control alternative that is chosen. This national goal states, in Section 101–a–(2), that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish and wildlife and provides for recreation in and on the water be achieved by July 1, 1983.

3.3.1 Point Source Controls

3.3.1.1 Introduction: Traditional Collection and Treatment Approach Alternatives. This section describes the alternative treatment approaches that have been developed in the 208 Program for Nassau and Suffolk Counties. Because of differences in the degree of development in the two counties, and the inherently fixed nature of the existing Nassau system, treatment emphasis differs not only by the hydrogeologic zone but also by administrative area. In Nassau, the major options concern treatment plant locations and effluent disposal; in Suffolk, the major options concern an identification of those areas that should be sewered as well as the siting of treatment facilities and effluent discharges.

In addition, Nassau and Suffolk are discussed separately because their municipal wastewater treatment needs differ. Nassau County is highly developed; according to the 208 population estimates, the county population is approximately 96 percent of saturation or zoned capacity, and is projected to reach 98 percent by the year 1995. Suffolk's population, on the other hand,

is currently at 52 percent of saturation and is expected to increase to 71 percent by 1995. Nassau County has 23 existing domestic wastewater treatment facilities, and major new construction is not anticipated except where expansion and upgrading of existing facilities is necessary. Suffolk County has 105 small domestic treatment facilities in operation, and one major facility (30 MGD) under construction. Nassau's domestic treatment facilities are generally large scale, treating up to 60 million gallons per day (MGD), but a typical Suffolk County domestic wastewater treatment plant treats less than one MGD, with the largest treating only approximately two MGD.

Surface water quality considerations also dictate different approaches in the Bi-county Region. Marine water quality in Nassau County and western Suffolk is influenced by the effects of New York City discharge. In eastern Suffolk, agricultural uses impact river and bay quality. A final reason for separate consideration of the two counties concerns their degree of urbanization: Nassau and western Suffolk Counties are highly urbanized, while eastern Suffolk is essentially rural and agricultural in nature.

In order to assist in the establishment of potential future sewer service areas and to estimate future domestic wastewater loads for traditional sewering alternatives, an attempt was made to correlate population density with nitrate-nitrogen (NO_3—N) concentrations in the Upper Glacial aquifer. Although the results were not statistically conclusive, they indicated that population density was an important factor that had to be considered in establishing sewer service areas. Several population density criteria were applied in those geographic areas that recharge to the Magothy aquifer to develop alternative geographic limits for potential sewer service areas.

A second reason for establishing areas to be sewered concerns high groundwater tables or low soil permeability, both of which would result in pervasive septic tank/cesspool failures and consequent health hazard. Concern for the protection of surface water quality was a final consideration in delineating potential future sewer service areas.

These criteria—protection of the Magothy, potential for on-lot systems failure and protection of surface waters—were combined to develop the various sewering alternatives. In Suffolk County, these alternatives ranged from the maintenance of the status quo, or no additional sewering, to sewering at a population density of one dwelling unit per acre. The greater part of the Suffolk area is currently unsewered and potential future sewer service areas could be extensive. For this reason, a wide range of alternatives had to be examined in order to delineate these areas, and to develop flow and cost estimates. Potential future service areas were developed for each of the following assumptions:

a. No new sewering; utilize existing service areas only (1975 population).
b. Include land with two dwelling units (D.U.) per acre in high groundwater table areas; five D.U. per acre in Magothy recharge areas (1995 population)
c. Include land with two D.U. per acre in high groundwater table areas; five D.U. per acre everywhere else (1995 population)
d. Include land with two D.U./acre in high groundwater table areas; two D.U./acre in Magothy recharge areas (1995 population)
e. Include land with two D.U. per acre in high groundwater table areas; two D.U. per acre in Magothy recharge areas (1975 population)
f. Include land with two D.U. per acre in high groundwater table areas; two D.U. per acre everywhere else (1995 population)
g. Include land with a density of one D.U. per acre everywhere (1995 population).

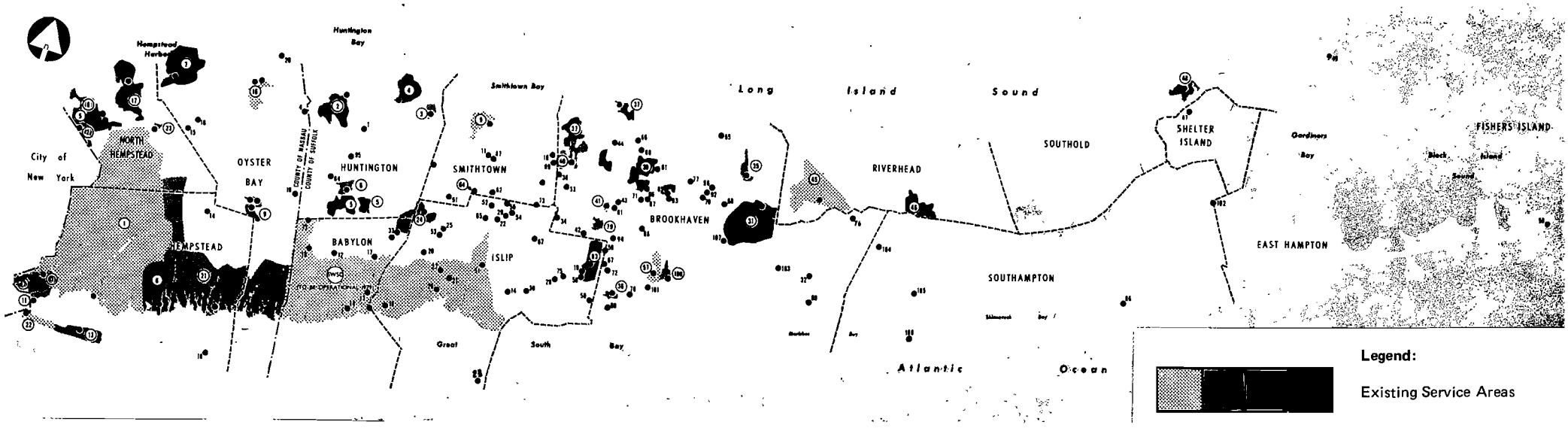
Figures 3—4 through 3—10 indicate the approximate geographic extent of the areas that would be sewered for each alternative. The areas do not include separate commercial/industrial areas because of scale, but they would be included in sewering approaches. Flows from these land uses are included in subsequent estimates.

Two dwelling units per acre was selected as the sewering criterion in areas of high groundwater or low soil permeability because, at lower densities, individual homeowners will normally have sufficient acreage to permit the installation, expansion or construction of new leaching facilities on other parts of the lot. At densities of two or more dwelling units per acre, those options are not as readily available and sewer systems may be the only viable solution.

Five dwelling units per acre was selected as representative of high density land use because, at this density and at higher levels, there is a clear threat to groundwater contamination from individual on-lot systems.

Although protecting groundwater quality provides a major justification for establishing an allowable population density, the geographic limits of the Magothy aquifer recharge area are not precisely defined. It should be recognized that deep flow also occurs to the north of the northern limit of the Magothy in both Nassau and Suffolk. This flow occurs in the deeper portion of the Upper Glacial deposits, which are the hydrologic equivalent of the Magothy in this area. Since this part of the aquifer is also used for water supply, it may be necessary to consider sewering here even in the minimum sewering alternatives. Therefore, criteria for sewering were applied on an Island-wide basis for some of the alternatives. Definition of those areas contributing subsurface flow to the bays was also uncertain, and provided further reason to examine sewering in all areas for some alternatives.

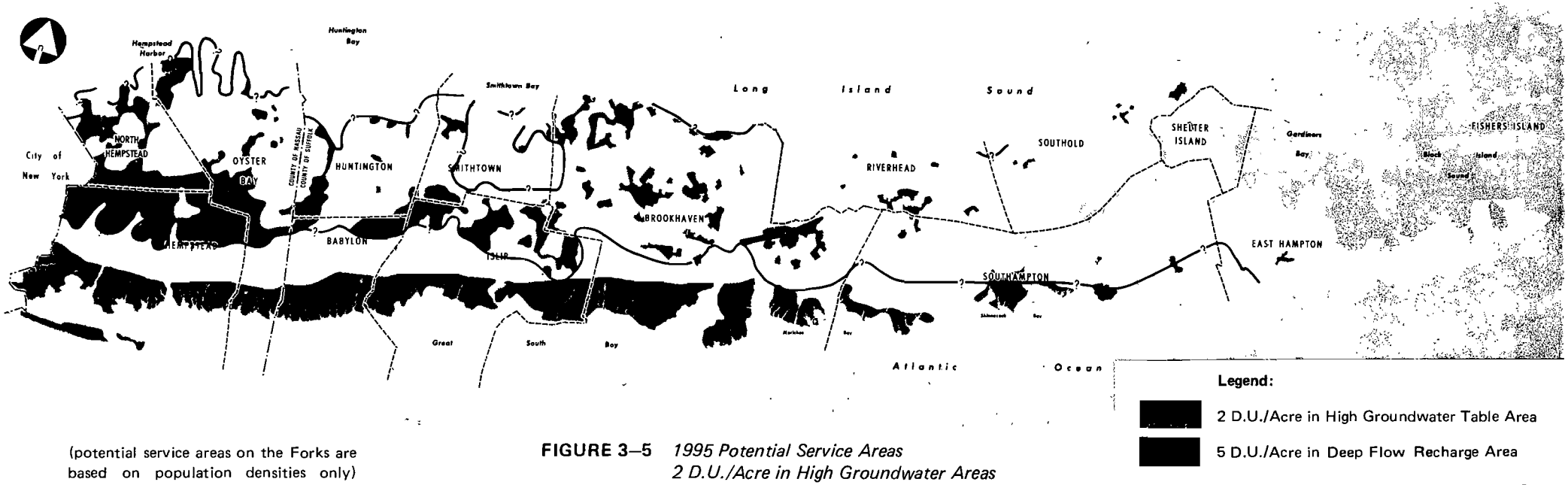
In considering sewering alternatives it should be noted that even the most comprehensive sewering plan will not address all water quality problems. Sewering does not reduce the nitrogen input from fertilizer, which appears to be a major source of elevated nitrate concentrations in groundwater. In addition, sewering an area can lead to land use changes that may actually increase contaminant loading, by encouraging more intense development. This results from more lawn fertilizing, greater volumes of stormwater



NOTE: FOR IDENTIFYING NUMBERS, REFER TO APPENDIX A, ELEMENT H.

FIGURE 3–4 *1975 Existing Service Areas*

Source: Section H of the Areawide Waste Treatment Management Plan.



(potential service areas on the Forks are based on population densities only)

FIGURE 3–5 *1995 Potential Service Areas*
2 D.U./Acre in High Groundwater Areas
5 D.U./Acre in Deep Flow Recharge Area

Source: Section H of the Areawide Waste Treatment Management Plan.

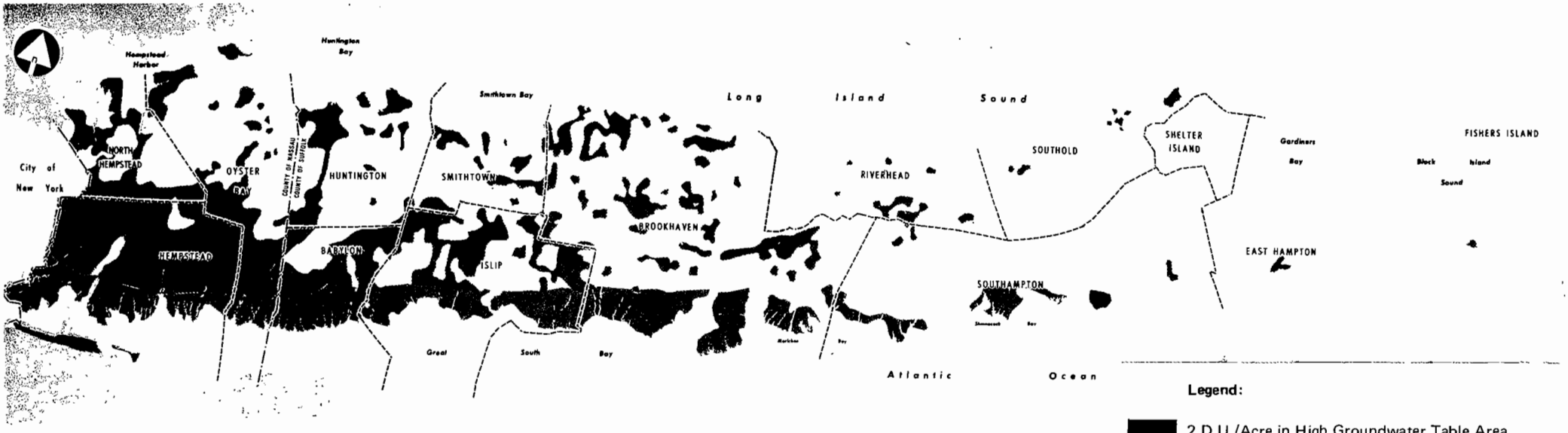


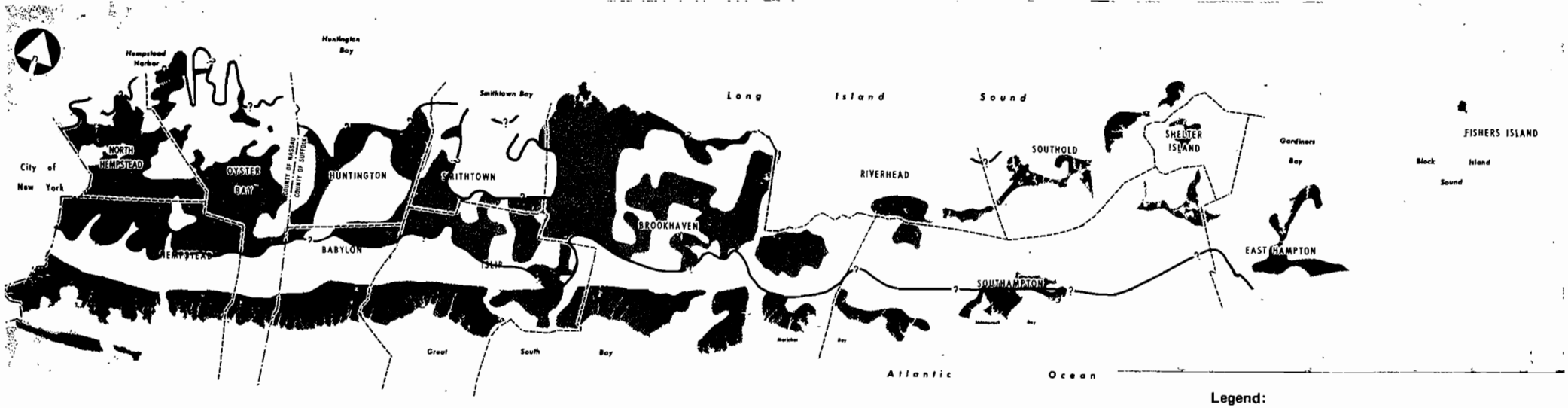
FIGURE 3–6 *1995 Potential Service Areas*
2 D.U./Acre in High Groundwater Areas
5 D.U./Acre Everywhere Else

Legend:

2 D.U./Acre in High Groundwater Table Area

5 D.U./Acre Everywhere Else

Source: Section H of the Areawide Waste Treatment Management Plan.



(potential service areas on the Forks are based on population densities only)

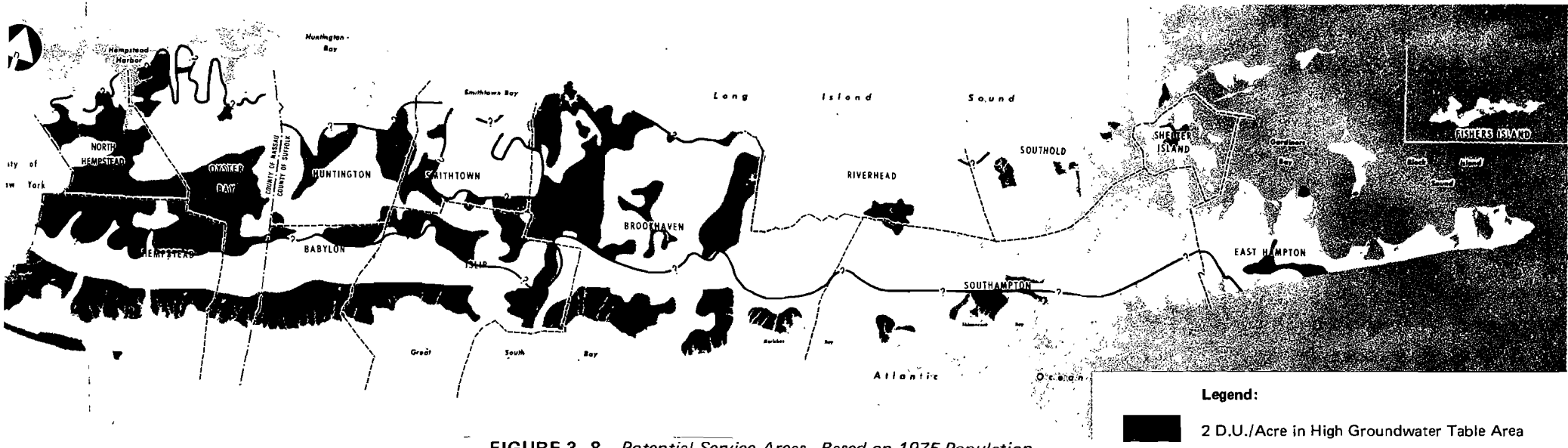
FIGURE 3–7 *1995 Potential Service Areas*
2 D.U./Acre in High Groundwater Areas
2 D.U./Acre in Deep Flow Recharge Area

Legend:

2 D.U./Acre in High Groundwater Table Area

2 D.U./Acre in Deep Flow Recharge Area

Source: Section H of the Areawide Waste Treatment Management Plan.



(potential service areas on the Forks are based on population densities only)

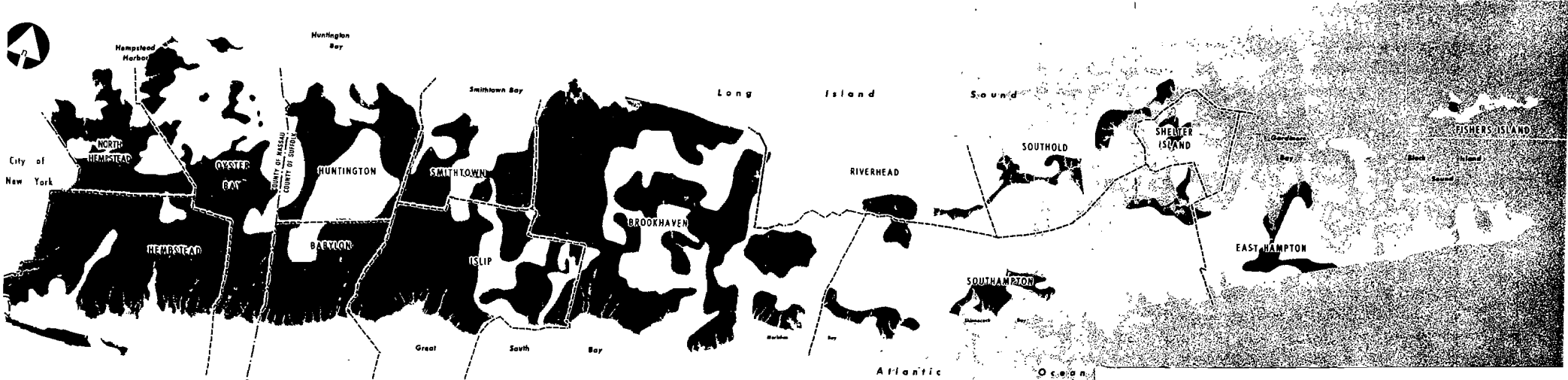
Legend:

2 D.U./Acre in High Groundwater Table Area

2 D.U./Acre in Deep Flow Recharge Area

FIGURE 3–8 *Potential Service Areas—Based on 1975 Population*
2 D.U./Acre in High Groundwater Areas
2 D.U./Acre in Deep Flow Recharge Area

Source: Section H of the Areawide Waste Treatment Management Plan.



Legend:

2 D.U./Acre in High Groundwater Table Area
2 D.U./Acre Everywhere Else

FIGURE 3–9 *1995 Potential Service Areas*
2 D.U./Acre in High Groundwater Areas
2 D.U./Acre Everywhere Else

Source: Section H of the Areawide Waste Treatment Management Plan.

FIGURE 3–10 *1995 Potential Service Areas*
1 D.U./Acre Everywhere

Source: Section H of the Areawide Waste Treatment Management Plan.

runoff from roads, and increased commercial activity with attendant spills and accidental discharges.

The NSRPB projected 1995 population estimates were used to delineate future service areas. In order to study sewerage needs under no-growth policy, alternative (e) was mapped using the same density criteria but substituting the 1975 population for the 1995 population. Figures 3–4 to 3–10 illustrate potential future service areas for those alternatives identified above, including alternative (e) which utilized 1975 population figures.

3.3.1.2 Discussion of Various Sewering Alternatives. Each of the seven sewering alternatives listed in the previous section was developed to test the sensitivity of the study area (particularly Suffolk County) to various degrees of sewering. The first alternative (a) assumes that no new sewering will occur beyond the present sewer service areas (assuming Nassau County District III and Suffolk County Southwest Sewer District are complete). It implies that other technologies or non-structural measures will be employed and will be sufficient to handle the wastewaters of the area. It reflects a no-action alternative in terms of the traditional sewering approach.

As a first approach, it is assumed that sewering is not the most cost effective method for protecting public health and ground and surface water quality. Either water quality will be allowed to degrade and public health threatened, or alternatives will be found to protect public health and water quality that do not require sewers. The major potential problem areas in the first approach will be south of Sunrise Highway, where groundwater elevations are high and on-lot systems fail, and in the Magothy recharge area, where nitrates, organic chemicals and other contaminants from on-lot systems discharge to the Magothy aquifer.

The second sewering alternative (b) attempts to alleviate the major problems cited in the no sewering approach. It provides for sewers in the areas of high groundwater since it assumes that other options are not viable for that area; the alternative would provide sewers in areas of high groundwater when population densities are equal to or greater than two dwelling units per acre. In areas of lower density, septic tanks with additional leaching fields are recommended.

This second approach also assumes that sewers are necessary in the Magothy recharge area to protect the water supply from contamination from on-lot home systems. It reflects a policy that is quite different from past practice in that it assumes sewering at high densities equal to or greater than five dwelling units per acre. Past practice in Suffolk County has required the provision of sewers whenever an area is developed at a density equal to or greater than one dwelling unit per 40,000 square feet. The county currently does not require sewering at lot sizes of 20,000 square feet or more, providing public water supply is available. It is important to note that none of the sewering alternatives assumes that sewers will solve all public health, and surface and groundwater quality problems. Rather, they attack the problems

of domestic sewage and industrial wastewater disposal by traditional means and assume that other pollutant sources (*e.g.,* fertilized areas, stormwater runoff) will also be controlled.

Because the specific Magothy recharge area is difficult to define with accuracy, alternative (c) has been included. It would sewer at densities equal to or greater than two D.U.s per acre in areas of high groundwater and is similar to (b). However, everywhere else, it would sewer at densities of five D.U.s per acre or greater. This approach is included to ensure that the total water supply is protected from wastewater generated by high density areas.

Alternatives (b) and (c) rely on sewering to protect the ground and surface waters and public health only from human and industrial waste. Both the (b) and (c) must be combined with waste management programs for fertilizers, stormwater runoff, landfills and other pollutant sources. Sewering alone cannot be used as a management tool to control all pollutant sources.

Alternatives (d) and (f) are similar to each other and differ from (b) and (c) only in that more protection is given to the Magothy recharge area by sewering at population densities of two D.U.s per acre or greater. In (d) and (f) areas of high groundwater table are sewered at two D.U.s per acre. In (d), areas in the Magothy recharge area are sewered at two D.U.s per acre or more. In (f), all areas of two D.U.s per acre or more are sewered because of the uncertainty of the recharge area boundary lines.

In adopting alternatives (d) or (f), it must be emphasized again that other major sources of pollution must be attacked concurrently as was described in the alternatives (b) and (c).

Alternative (e) has been developed for comparative purposes. It utilizes 1975 population distributions, not 1995 data, and assumes sewering wherever population densities are equal to or greater than two D.U.s per acre. It is similar to alternative (f), except 1975 population is used. Alternative (e) expresses the sewering consequences of a no-growth policy. In other words, if land use and population were controlled to the point where no growth was allowed, a sewering scenario similar to alternative (e) would result. The results of (e) can be visually and statistically compared to the other options, allowing decisionmakers to opt for future growth or no-growth policies.

Alternative (g) is the final traditional sewering approach that has been studied. It assumes that sewers would be provided in all areas where population densities are equal to or greater than one D.U. per acre. Thus, it might be considered the opposite of alternative (a) in that the first alternative assumed all sewering would cease at the present service area boundaries, while (g) assumes sewering will occur wherever subdivision development might occur. Later on in this section, flow estimates are presented for the various alternatives that indicate numerically the relative degree of sewering for each of the alternatives. Cost estimates are also presented.

The study areas used for the development of traditional sewering alternatives represent existing sewer service areas, 201 areas and disposal districts identified in earlier studies. The use of these areas, which are based on surface drainage, does not imply a conflict with the hydrogeologic approach to the selection of wastewater management options.

3.3.1.3 Development of Traditional Sewering Alternatives. In the detailed development of the structural sewering approaches, Nassau County was subdivided into four study areas approximately coinciding with existing or proposed disposal district boundaries as designated by the Nassau County Department of Public Works (NCDPW). In general, Suffolk County was subdivided into the five western towns and five eastern towns. The five western towns are considerably more urbanized and are similar to Nassau County in respect to land use and water quality problems. The five eastern towns are more rural and have extensive agricultural land use and lower population densities. The five western towns were subdivided into seven study areas, which approximate the boundaries of seven 201 planning areas as designated by the Suffolk County Department of Environmental Control (SCDEC). With the exception of those areas in or adjacent to the hamlet of Riverhead and the Village of Greenport, and on Fishers Island, the five eastern towns cannot be conveniently subdivided into proposed 201 study areas and were therefore divided into study areas coinciding with the SCDEC proposed disposal districts as identified by the 1966 Suffolk County Comprehensive Sewerage Disposal Plan (Disposal Districts No. 11 through No. 17). The seven study areas for the five western towns are the Southwest Sewer District (SWSD), West Central excluding the SWSD, Huntington-Northport, Kings Park, South Central, Port Jefferson and Yaphank.

Nassau County treatment alternatives consist of combining a variety of feasible components, including sewage flow diversions and/or the expanssion of particular treatment facilities. Since there are 23 existing domestic facilities in Nassau County, the number of possible permutations is too great to permit examination of all possible diversions between facilities. Instead, only viable options, as determined on the basis of an initial screening, were selected for examination.

In Suffolk County, sewering and treatment alternatives were more numerous than Nassau because many more options were available. Various potential future service areas were delineated utilizing different population density criteria; regional, sub-regional and small plant approaches were analyzed. A regional facility was defined as one treatment plant serving an entire study area such as the SWSD or the Huntington-Northport study area. A sub-regional approach was defined as two to six wastewater treatment facilities serving a study area, and the small plant approach was defined as a proliferation of treatment facilities of approximately one MGD in size, serving localized growth within a study area.

Table 3–4 summarizes the flow projection figures for each of the study areas of the five western towns in Suffolk County. The flows are presented for each of the various sewering criteria and include both domestic and industrial flows for the different scale systems (regional to small plants). Table 3–5 presents similar information for the five eastern towns.

Table 3–4

SEWAGE FLOW BY STUDY AREA FOR VARIOUS SEWERING CRITERIA, FIVE WESTERN TOWNS (MGD) [1]

Study Area	Alternative	Approach	Sewering Criteria					
			2 DU/A high GW [2] 5 DU/A Magothy [3] 1995	2 DU/A high DW 5 DU/A everywhere else 1995	2 DU/A high GW 2 DU/A Magothy 1975	2 DU/A high GW 2 DU/A Magothy 1995	2 DU/A everywhere 1995	1 DU/A everywhere 1995
SWSD								
	I-1	Regional	19.5	28.0	17.0	19.5	30.0	30.0
	I-2	Regional	33.5	52.5	31.5	36.5	54.0	61.0
West Central								
	II-2	Sub-Regional	6.00	7.50	10.5	13.3	17.0	21.0
	II-3	Sub-Regional	11.0	24.0	20.0	24.5	41.0	42.5
	II-4	Small Plants	11.0	24.0	20.0	24.5	41.0	42.5
Huntington-Northport								
	III-2	Regional	0.25	10.5	1.50	2.25	13.0	20.0
	III-3	Regional	0.25	10.5	1.50	2.25	13.0	20.0
	III-4	Sub-Regional	0.25	10.5	1.50	2.25	13.0	20.0
	III-5	Small Plants	0.25	10.5	1.50	2.25	13.0	20.0
Kings Park								
	IV-2	Regional	2.50	7.00	4.00	6.00	14.0	16.0
	IV-3	Sub-Regional	2.50	7.00	4.00	6.00	14.0	16.0
	IV-4	Small Plants	2.50	7.00	4.00	6.00	14.0	16.0
South Central								
	V-2	Regional	19.0	21.5	18.0	25.5	31.0	32.0
	V-3	Sub-Regional	19.0	21.5	18.0	25.5	31.0	32.0
	V-4	Sub-Regional	19.0	21.5	18.5	26.0	32.0	33.0
	V-5	Small Plants	19.0	21.5	18.5	26.0	32.0	33.0
Port Jefferson								
	VI-2	Regional	5.00	4.75	5.00	8.50	8.50	9.00
	VI-3	Regional	5.00	4.75	5.00	8.50	8.50	9.00
	VI-4	Sub-Regional	5.00	4.75	5.00	8.50	8.50	9.00
	VI-5	Sub-Regional	5.00	4.75	5.00	8.50	8.50	9.00
	VI-6	Small Plants	5.00	4.75	5.00	8.50	8.50	9.00
Yaphank								
	VII-2	Sub-Regional	20.5	23.0	15.0	31.0	37.5	38.5
	VII-3	Sub-Regional	20.5	23.0	15.0	31.0	37.5	38.5
	VII-4	Small Plants	20.5	23.0	15.0	31.0	37.5	38.5

(1) Refer to Section H of the Areawide Waste Treatment Management Plan. Numbers include industrial waste flow allocations. Where more than one regional or sub-regional option is listed, different configurations of regional or sub-regional systems were studied. These are discussed in detail in other study reports.

(2) Two dwelling units per acre in high groundwater table areas.

(3) Five dwelling units per acre in the Magothy recharge areas.

Table 3–5

SEWAGE FLOW BY STUDY AREA FOR VARIOUS SEWERING CRITERIA, FIVE EASTERN TOWNS (MGD) [1]

Study Area	Approach	Sewering Criteria					
		2 DU/A high GW [2] 5 DU/A Magothy [3] 1995	2 DU/A high GW 5 DU/A everywhere else 1995	2 DU/A high GW 2 DU/A Magothy 1975	2 DU/A high GW 2 DU/A Magothy 1995	2 DU/A everywhere 1995	1 DU/A everywhere 1995
D.D. No. 11							
	Regional	6.00	5.50	2.50	7.50	8.00	9.75
	Sub-Regional	6.00	5.50	2.50	7.50	8.00	9.75
	Small Plants	6.00	5.50	2.50	7.50	8.00	9.75
D.D. Nos. 12, 15, 16							
(Sag Harbor)		0.00	0.00	–	0.75	0.75	0.75
(Amagansett)		0.35	0.35	–	1.50	1.50	1.50
(Hampton Bay)		1.60	1.65	–	2.00	2.00	2.00
(East Quogue)		1.70	1.70	–	1.75	1.75	1.75
D.D. No. 13							
(Greenport)		1.00	1.00	–	2.00	2.00	2.00
(Mattituck)		0.30	0.30	–	1.50	1.50	1.50
D.D. No. 14							
(Shelter Island)		0.33	0.33	–	1.00	1.00	1.00
D.D. No. 17							
(Fishers Island)		0.00	0.00	–	0.25	0.25	0.25

(1) A more detailed definition of the alternatives for Suffolk County can be found in Section H of the Areawide Waste Treatment Management Plan, Appendix D–Suffolk County Point Source Alternatives.

(2) Two dwelling units per acre in high groundwater table areas.

(3) Five dwelling units per acre in the Magothy recharge area.

Capital, operating and maintenance costs were calculated for the various point source sewering alternatives. Present worth—that is, the current value of all costs incurred over the planning period as the result of the selection of a specific option—was determined for all sewering alternatives to facilitate comparison between them. Present worth includes the total capital cost, plus all of the annual operation and maintenance costs discounted back to the present time. For the various sewering alternative components in Nassau County, a least-cost optimization model was utilized to identify the combination of components that would result in the lowest total cost to Nassau County. A series of possible diversions and/or upgradings was screened based upon engineering feasibility and environmental impacts. In Nassau County, the fourteen existing domestic treatment plants (with one proposed new plant at Bayville) were examined for expansion and/or upgrading to accept additional service area or to be phased out with diversion to a regional facility. To permit selection of the most promising combination, a cost was developed for each component and computer techniques were utilized. (See Section H of the Areawide Waste Treatment Management Plan.)

The optimization results for the north shore plants of Nassau County are dependent upon treatment requirements. If the plants are to continue to discharge at the shorelines or bulkheads, it appears most economical to maintain the individual plants as they presently exist. If, however, the modeling runs indicate that AWT or mid-bay discharges are required to meet bay water quality standards, the cost-effective solution for meeting waste load allocations for the North Shore Nassau County plants appears to be to divert many North Shore facilities to the South Shore Cedar Creek plant to achieve economies of scale. It appears most cost-effective to divert the Great Neck Sewer District, Village of Great Neck, Port Washington Sewer District, Roslyn and Oyster Bay Treatment Plant flows to the Cedar Creek treatment facility, leaving Belgrave and Glen Cove as the major remaining facilities on the North Shore. Belgrave discharges to Little Neck Bay, and was therefore not studied

in detail. In addition, the New York Institute of Technology (NYIT) and C.W. Post treatment plants may be phased out and their flows diverted to the Cedar Creek Sewage Treatment Plant; if not, nitrogen removal should be provided. These concepts must be studied at the 201 level where greater cost estimating accuracy is possible.

The goals of the FWPCA will not be met in every instance in the Nassau-Suffolk study area. Some of the reasons for not attaining water quality goals, particularly those relating to shellfishing, include overriding surface water boundary conditions in western Long Island Sound caused by both treated and untreated sewage discharges, and combined sewer overflows, emanating from New York City; and the impact of internal sources of stormwater runoff to the bays.

Improved groundwater quality may be unattainable in the near-term due to the costs that would have to be incurred in controlling non-point sources of pollution. The actual cost implications of these actions, as well as the effectiveness of the proposed solutions and the probable benefits from attaining the water quality goals as stated in the Act, will require study and evaluation at a much greater level of detail, such as that which is associated with a 201 type of program.

The lowest cost option would maintain existing service area limits. This would involve utilizing on-lot diposal systems, such as septic tanks and cesspools, and could possibly lead to significant groundwater quality contamination in areas of higher population density. Table 3—6 summarizes the impact on costs of the different sewering criteria for Suffolk County. Costs are presented for the various regional, sub-regional and small-plants approaches by study area. The combination of a particular approach (*e.g.,* regional system) with a specific sewering criterion (*e.g.,* one D.U. per acre everywhere) constitutes an alternative. The variability in costs for different sewering criteria depends upon population density patterns in an area, how much of the area is part of the Magothy recharge system, or how much of the area has high groundwater table elevations.

3.3.1.4 Other Structural Alternatives Studied. In addition to the conventional structural sewering alternatives, a variety of newer technologies were examined in the 208 Program. An attempt was made to determine the large scale applicability of a variety of alternatives to the conventional sewering approach. Much of the new technology developed over the past several years is encouraging. However, when evaluating new technology, other factors, such as aesthetics, legal implications, reliability of operation, and implementation feasibility, must also be considered. Once these factors have been examined, recommendations can then be made as to those technologies most applicable to specific Nassau-Suffolk problems.

The approach taken in the evaluation of new technology in the Nassau-Suffolk 208 Program was to first analyze ground and surface water quality problems and their probable causes in the Region. Utilizing a literature review, a variety of new concepts were then described and discussed for applicability to the Nassau-Suffolk area.

The following technologies and concepts, which are described in greater detail in Section H of the Areawide Waste Treatment Management Plan, were initially considered:

- Marsh-Pond System for Treatment of Wastes
- Spray Irrigation with Cropping for Treatment of Wastes
- Black/Grey Water Separation
- Modified On-lot Systems (Aerobic Treatment)
- Septic Tanks with De-nitrification Units
- Waterless Composting Toilets
- Vacuum Collection Systems
- Pressure Collection Systems
- De-nitrification of Water Supply
- Dual Water Systems
- Flow Reduction Measures

New technologies that did not address regional water quality problems were then eliminated from further consideration. For the concepts that did address regional problems, typical capital and operation and maintenance costs were developed. The costs were compared to the costs of the traditional sewering and treatment approach. General conclusions were then reached and recommendations were made on those processes most applicable to Nassau-Suffolk that warrant further evaluation on a 201 level.

After analyzing the above listing of technologies, the following were selected for more detailed cost evaluations: marsh-pond, spray irrigation with cropping, black/grey water separation, subsurface denitrification of septic tank effluent, denitrification at a water supply well (ion exchange/reverse osmosis*), dual water systems (with denitrification of potable water supply), and flow reduction measures. These technologies were compared with the traditional sewering and treatment approach on the basis of costs for a representative development in Suffolk County. The traditional approach utilized a gravity collection network with secondary treatment and biological nitrification and denitrification.

A number of conclusions were reached as part of the analysis:

1. Modified on-lot treatment systems do not address the water quality problems of the Nassau-Suffolk area since they do not remove nitrate or ammonia. The waterless composting toilet concept probably cannot be implemented although it does address the nitrate problem, but the toilet has possible safety and health problems, and a sludge disposal problem. Furthermore, it is extremely expensive to install in existing homes, and therefore, its economic advantages are severely limited.
2. Vacuum and pressure collection systems should be evaluated at a 201 level of study. Their main attribute is capital cost savings but energy costs may eliminate their use in the future.

*Biological denitrification is another alternative but it was not studied in detail.

Table 3–6

SEWERAGE COST BY STUDY AREA FOR VARIOUS SEWERING CRITERIA
(TOTAL PRESENT WORTH IN MILLIONS OF DOLLARS) (1) (2) (3) (4) (5)

Study Area	Approach (6)	Sewering Criteria					
		2 DU/A high GW (7) 5 DU/A Magothy (8) 1995	2 DU/A high GW 5 DU/A everywhere else 1995	2 DU/A high GW 2 DU/A Magothy 1975	2 DU/A high GW 2 DU/A Magothy 1995	2 DU/A everywhere 1995	1 DU/A everywhere 1995
SWSD							
	Regional	358	444	329	358	463	463
	Regional	412	515	379	414	524	564
West Central							
	Sub-Regional	68.0	77.7	95.1	109	127	194
	Sub-Regional	10.4	167	150	169	230	235
	Small Plants	169	270	242	274	373	381
Huntington-Northport							
	Regional	638	59.6	18.5	23.6	67.7	87.7
	Regional	577	54.4	16.9	21.6	61.8	80.0
	Sub-Regional	530	49.9	15.5	19.8	56.7	73.4
	Small Plants	530	49.9	15.5	19.8	56.7	73.4
Kings Park							
	Regional	21.0	38.9	27.8	35.3	58.9	63.8
	Sub-Regional	27.2	50.4	36.0	45.8	76.4	82.8
	Small Plants	38.8	71.9	51.4	65.4	10.9	11.8
South Central							
	Regional	110	119	107	132	148	151
	Sub-Regional	122	132	118	146	164	167
	Sub-Regional	151	161	145	178	202	206
	Small Plants	191	204	184	226	256	261
Port Jefferson							
	Regional	33.8	32.8	33.8	46.5	46.5	48.1
	Regional	45.0	43.7	45.6	61.9	61.9	64.1
	Sub-Regional	36.3	35.2	36.3	49.9	49.9	51.6
	Small Plants	46.0	44.6	46.0	63.3	63.3	65.5
Yaphank							
	Sub-Regional	193	207	160	348	278	282
	Sub-Regional	186	199	154	238	267	271
	Small Plants	228	244	189	292	327	332
Disposal District No. 11							
	Regional	21.7	21.4	13.3	25.8	26.8	30.2
	Sub-Regional	25.2	24.8	15.4	29.8	31.0	34.9
	Small Plants	25.5	24.8	15.4	29.8	31.0	34.9
Disposal District Nos. 12, 15, 16							
	Sag Harbor	0.00	0.00	–	17.1	17.1	17.1
	Amagansett	11.3	11.3	–	27.1	27.1	27.1
	Hampton Bays	17.1	17.1	–	19.6	19.6	19.6
	East Quoque	24.2	24.2	–	24.6	24.6	24.6
Disposal District No. 13							
	Greenport	16.0	16.0	–	24.2	24.2	24.2
	Mattituck	7.01	7.01	–	18.4	18.4	18.4

Table 3–6 . . . Continued

Study Area	Approach (6)	Sewering Criteria					
		2 DU/A high GW (7) 5 DU/A Magothy (8) 1995	2 DU/A high GW 5 DU/A everywhere else 1995	2 DU/A high GW 2 DU/A Magothy 1975	2 DU/A high GW 2 DU/A Magothy 1995	2 DU/A everywhere 1995	1 DU/A everywhere 1995
Disposal District No. 14							
	Shelter Island	7.25	7.25	–	14.1	14.1	14.1
Disposal District No. 17							
	Fishers Island	0.00	0.00	–	6.20	6.20	6.20

(1) Costs do not include recharge, mid-bay or ocean outfalls, or lateral portions of the collection systems.

(2) Present worth at 6 3/8% interest amortized over 20 years, CRF (Capital Recovery Factor) = .08986.

(3) Costs are based on mid-1977 cost data, ENR (Engineering News Record) = 2580; they account for the staging of construction through the 20 year planning period (1975–1995).

(4) All costs in this table reflect secondary treatment.

(5) Cost obtained from Suffolk County Department of Environmental Control.

(6) Where more than one regional or sub-regional option is listed, different configurations of regional or sub-regional systems were studied; they are discussed in detail in Section H of the Areawide Waste Treatment Management Plan, Appendix F—Cost Memoranda.

(7) Two dwelling units per acre in high groundwater table areas.

(8) Five dwelling units per acre in the Magothy recharge area.

3. The marsh-pond and septic tank denitrification systems should be tested in the field under normal operating conditions and without experimentally controlled operation. Both are promising new technologies. (Refer to Section 1.4.3.2.)
4. Spray irrigation and other forms of land application may be viable; the concept should be evaluated in local studies.
5. Black/grey water separation systems may have limited application and should be evaluated in the field under normal operating conditions.
6. Water conservation and flow reduction measures should be generally recommended for implementation. Although the Nassau-Suffolk Region does not have a potable water shortage, water conservation measures are beneficial because they might slightly reduce flows to treatment plants or to on-lot systems. Furthermore, the potential savings in energy from reduced pumpage may be significant.
7. Intentional degradation, which allows for exceeding groundwater discharge and/or drinking water standards, is unacceptable under current State and Federal statutes. Limited or controlled degradation that does not violate standards but leads to water quality that is poorer than baseline conditions is unavoidable in much of the planning region. In other areas, groundwater quality in selected aquifer zones has already violated drinking water standards. Where such aquifers are necessary to meet water supply requirements, treatment of water at the wellhead should be considered as a viable management procedure.
8. Another management option in areas described under seven above is the tapping of unaffected aquifers for specialized uses. For example, the Lloyd aquifer in Nassau County could be developed to supply drinking water needs to limited coastal areas. Dual piping systems can also be employed to isolate drinking water from water used for other purposes.
9. Blending of good quality groundwater with water that has already been degraded is a viable technique for continuing to meet drinking water standards in problem areas. This may extend the life of an affected aquifer while still maintaining water of acceptable quality for consumption.

3.3.1.5 Animal Feedlot Operations. On Long Island, this category of point sources is represented, for the most part, by duck farms. Commercial duck farm operations are generally located close to marine waters and presently contribute bacterial and chemical pollution to surface waters. Commercial duck farms are required to obtain operating permits and to reduce and finally eliminate duck waste pollution. (Refer to Section I of the Plan.)

The following management options are available:

1. Prohibit the location of animal feeding operations where they may pollute surface waters or groundwater.
2. Expand monitoring and surveillance procedures to foster uninterrupted compliance with permit conditions.
3. Provide effective legal remedies for rapid abatement of illegal pollutant discharges.

3.3.2 Residuals Management. In the context of this study, residual wastes are considered to include solid wastes (refuse), hazardous wastes and domestic sludges. Hazardous wastes in the bi-county area generally include concentrated industrial pretreatment or treatment sludges. They may also include other miscellaneous liquid products and small amounts of toxic, solid materials. They do not include radioactive wastes. Disposal of residual wastes represents a potential impact on water quality, primarily as the result

of surface and/or groundwater contamination at the disposal site.

General concepts and specific alternatives are discussed for each of the three types of residual wastes. For solid wastes, concepts necessary to formulate a comprehensive management approach are discussed, including considerations for management and control strategies.

For hazardous wastes, a model hazardous waste treatment disposal facility is recommended and conceptually designed for each county. A discussion of the various processes in the flow scheme and treatment costs are also covered.

For sludges, specific alternative disposal techniques as well as alternative management approaches such as regional, sub-regional and local systems are described for both counties. Capital and annual operation and maintenance costs are developed from generalized cost functions. The purpose of evaluating these alternatives is to identify those disposal techniques and sludge management approaches that should be investigated further. Solution of the sludge disposal problem has become urgent because of the planned discontinuance of ocean dumping. Sludge management studies have been and are being conducted on regional and local levels, in response to this discontinuance.

3.3.2.1 Solid Waste Management Concepts. A review of the present situation in the Nassau-Suffolk Region indicates that present disposal systems (landfills and incineration) in general, do not provide adequate safeguards to prevent environmental degradation as they attempt to handle the approximately 3,000,000 tons per year of solid wastes generated. Also, existing county solid waste management plans do not address controlled landfills and do not present any alternatives to the processes of conventional incineration and landfilling.

Recently, the trend in the Nassau-Suffolk area has been towards the development of regional resource recovery facilities, but each has been an individual effort for a specific geographic area rather than part of a comprehensive county or Nassau-Suffolk area approach. A desirable solid waste management concept is that of resource recovery (such as pyrolysis or co-incineration) with residuals disposal in small, controlled landfills after 1985. The current system of incineration and landfilling, with the addition of those resource recovery facilities currently proposed or under construction, will be expanded to fill the solid waste management requirements through 1985.

Efficient, economical and environmentally sound solid waste management for the Nassau-Suffolk area is the goal; the following sections present generalized concepts, constraints and considerations recommended to aid in achieving that goal.

a. *Landfilling.* Landfilling is the only final method of disposal available. Any other process (incineration, co-incineration, composting or resource recovery) generates secondary residuals that require disposal in a landfill.

Landfilling of solid wastes (processed or unprocessed), even under the best conditions and most stringent constraints, will result in the production of leachates and gases—by-products which can degrade the environment. Historically, these by-products have not been controlled, and there are many cases on Long Island of pollution caused by uncontrolled landfills. Because of geology (predominantly porous materials) and dependence upon groundwater, the Nassau-Suffolk area is particularly susceptible and sensitive to this type of degradation.

Having established the need for landfills, what remains is the establishment of the recommended operating constraints. The intent is the creation of small, easily controlled landfills. Size is a very important constraint. If landfills are kept small, corrective measures can easily be implemented if problems arise. Recommended constraints, which should be followed to the maximum possible extent, are as follows:

- Locate no landfills in the Magothy recharge area or in other areas that contribute to deep groundwater flow, or in areas of high water table.
- Establish a maximum size of 25 to 30 acres.
- Accept processed (shredded, baled, incinerated, etc.) wastes only. This will extend the useful life of the landfills.
- Provide a double lining with adequate and proper materials to ensure isolation of any leachate from the surrounding ground or surface water environment.
- Accept no hazardous materials (except in chemical landfills).
- Establish complete leachate collection and treatment systems.
- Establish gas collection and treatment or venting systems.
- Employ impermeable covers, drainage channels or topographic drainage controls to minimize the amount of leachate that is generated.
- Consider locating new landfills down-gradient of existing landfills if the existing landfills are improperly designed and operated and are generating a pollutant plume in the groundwater.
- Provide an impermeable cover upon completion (*e.g.,* PVC asphaltic membrane, or other impervious non-reactive material, followed by two to four feet of cover material) to isolate the complete landfill from rainfall percolation and the atmospheric environment.
- Establish extensive and continuous monitoring systems (surface water, groundwater and gas).

The above constraints provide the optimum land disposal method known at this time and offer the maximum protection to the environment.

In order to limit the size and required number of controlled landfills, some types of intermediate processes are required.

b. *Intermediate Processes.* An intermediate process serves two functions: first, it reduces the volume and changes the characteristics of the

materials requiring disposal; and second, it usually produces a usable by-product either in the form of energy (*e.g.,* steam or fuel) or recoverable materials (*e.g.,* ferrous metals, non-ferrous metals, glass and compost). For ease of comparison, a very brief description of each process follows.

- Incineration—controlled combustion of solid waste. Achieves significant volume and weight reductions. By-products are gases, quench waters and generally inert residue. Resource recovery is not practiced in conventional incineration (exception ferrous metals).
- Co-incineration and pyrolysis—controlled combustion of solid waste and usually dewatered wastewater treatment plant sludges. Achieves significant volume and weight reduction. By-products are gases, quench waters and a generally inert residue. Usually resource recovery is achieved by passing the off gases through a waste heat boiler to generate steam.
- Composting—the aerobic, biological decomposition of solid waste. Achieves volume reduction. Resource recovery is also possible if the materials are applied to plants in accordance with normal cultivation practices, thus permitting the utilization of nutrients. The compost can be used as a soil conditioner.
- Resource Recovery—processes are divided into two classifications: materials and energy, but a mixture of both is usually present in any one system. Materials recovered are used to replace a portion of the materials normally required in the production of iron, aluminum, glass, etc. Energy in the form of fuels for later use or steam for immediate use is generated by these processes. In general, all processes achieve some form of volume reduction.

c. *Recommended Concepts.* It is recommended that, for the short term through 1985, the following tasks be completed:

- Perform detailed evaluations of existing resource recovery facilities and update as new facilities are constructed and started up, especially those currently proposed for the Nassau-Suffolk area. It is felt that, for the long term, resource recovery should receive primary emphasis in solid waste planning.
- Through the regulatory controls contained in 6 NYCRR Part 360, supervise, monitor and initiate the corrective measures required to insure the proper disposal of solid wastes.
- Require all new landfills to be designed for operation under the suggested constraints.
- Formulate a comprehensive solid waste management plan for implementation as soon as possible.

At this time, the two processes showing the most promise for implementation in the future are co-incineration and pyrolysis. Both processes, which may include resource and materials recovery, can be used for the simultaneous processing of solid wastes and wastewater treatment plant sludges, and both generate a form of energy: co-incineration by passing the gases through a waste heat boiler to generate steam; and pyrolysis by passing the fuel rich gases through an afterburner and then through a waste heat boiler to generate steam. In pyrolysis, the fuel rich gases can either be condensed to form a fuel oil or cleaned to provide a fuel gas.

Two other processes (waterwall incineration and refuse derived fuel) are technically viable, and by 1985 it would be expected that they would have undergone sufficient refinement/upgrading to warrant further consideration. Composting, although workable, is not a viable alternative for mixed solid wastes; it should only be considered for sludges and leaves or other agricultural wastes.

Taking into consideration the rapidly advancing technology and the scale of facilities either on line or under construction, it is almost certain that a number of proven systems will be available by 1985. The system recommended for the post-1985 comprehensive plan consists of a complete materials and energy recovery system(s), with disposal of remaining materials in a controlled landfill.

3.3.2.2 Hazardous Waste Treatment Systems. Hazardous waste disposal is only one part of hazardous waste management. Management of hazardous wastes means awareness and control over the wastes from the time of their generation through their transportation, temporary storage, treatment and disposal. In the past, comprehensive hazardous waste management has not been practiced in the Nassau-Suffolk area. Therefore, a brief description of components that make up a good hazardous waste management system is presented below. (Refer to Section K of the Areawide Waste Treatment Management Plan.)

1. Regulation and Enforcement—at both State and local levels, are necessary if a proper and effective hazardous waste management system is to be formulated and enacted in order to provide adequate protection for the environment.
2. Survey and Inventory—of all firms in the Nassau-Suffolk area (with appropriate Standard Industrial Classification System Codes) is required to identify all generators. In the bi-county area, the existing NYS Department of Environmental Conservation survey and a Nassau County Department of Health survey should establish this data base.
3. Standard and Effective Identification and Labeling System—is essential so that all personnel involved may readily identify the hazardous waste and initiate proper handling and/or treatment procedures.
4. Waste Transportation Control System—is required for continuous monitoring of the waste flow from generator through disposal. This usually consists of some manifest or "trip ticket" system to ensure accountability.

5. Control at the Source
   a. Waste Reduction—through process changes and/or changes in raw materials, is desirable. Restriction of hazardous chemicals utilized in operations, substitution of less hazardous materials, better quality control and material recovery are all alternatives that may reduce the quantity of hazardous wastes generated.
   b. Waste Separation and Concentration—hazardous waste separation early in process stream flows before contamination of other, non-hazardous process stream flow occurs, isolation of similar wastes into separate disposal containers, and concentration by dewatering or some other process will reduce quantities of hazardous wastes that require treatment and disposal.
   c. Waste Exchange—investigate the possibility of reuse by another firm (*e.g.,* one firm's wastes may be another firm's raw materials or process chemical).
   d. Energy or Material Recovery—extraction of materials from hazardous waste streams may be cheaper than to produce them from virgin materials. Combustion to recover energy or heat value for other purposes may result in savings.
6. Treatment and Disposal
   a. Treatment—for those hazardous wastes not suitable to energy/material recovery systems, some form of thermal, biological, physical or chemical treatment should be applied to detoxify and neutralize the wastes to the maximum extent possible.
   b. Encapsulation/Chemical Waste Landfill—for those hazardous wastes not amenable to recovery, treatment or destruction, volume reduction followed by encapsulation or disposal in a chemical waste landfill is recommended.
7. Emergency Hazardous Waste Management Procedures—required in case of spills so that the best means of correcting the situation and protecting the environment will be utilized.
8. Monitoring of Hazardous Waste Treatment Facilities and Chemical Waste Landfills—to insure proper operation.
9. Hazardous Waste Disposal Site Shut-Down Procedures—to insure that disposal sites are properly closed and maintained after closure.
10. Buffer Zones—in addition to sufficient land for all processes to insulate sites from the public.

Description of Recommended Hazardous Waste Treatment System. Public health and environmental considerations suggest that Long Island disposal of hazardous wastes is the least acceptable of several alternatives. The need to protect the deep flow aquifers, in order to maintain a potable water supply, and the shallow flow system, to prevent degradation of productive marine waters, provides a strong argument for out of area disposal.

Export of hazardous wastes to out of area landfills or processing facilities would meet the local objectives of this Waste Treatment Management Plan. The relatively low volume and somewhat diverse nature of the wastes requiring treatment would probably make this option more cost-effective than local treatment. However, should Federal regulations or legal action preclude such export, consideration should be given to the establishment of a single bi-county facility or individual county facilities. The treatment process, described next, would be the same whether for one or two facilities.

A hazardous waste management system for the Nassau-Suffolk area should include a comprehensive regulatory and monitoring program that directs all hazardous wastes generated in the bi-county area to one or two county owned and operated, centrally located treatment facilities, one in Nassau and one in Suffolk. Alternatively, a single facility might be implemented to serve both counties. Disposal of treatment residuals is by transporting and placing them in properly located, constructed, operated, monitored and controlled chemical landfill, one for each treatment facility. This type of comprehensive, controlled system is required to ensure environmentally safe treatment and disposal of hazardous wastes in the area.

Treatment Processes. The treatment system for hazardous wastes should include physical-chemical treatment, sludge dewatering, incineration, effluent polishing and disposal of treatment residues in a chemical landfill. Facilities proposed for each county differ in that batch treatment of cyanide and chromic wastes is provided in Nassau as opposed to the continuous treatment of these wastes in Suffolk. (Batch treatment may also be employed in Suffolk County after a more definitive analysis is made of the types and quantities of wastes to be treated.) Concentrated metal finishing wastes are of a sufficient volume in Suffolk to require equalization for continuous flow-thru processing.

Estimated costs for each county's facilities are presented in Table 3—7. (See Plan Section K.) The treatment plant is designed to accommodate all hazardous wastes generated within the county that were identified during the 208 Study. It is recommended that once the inventories of hazardous wastes are completed, the design flows be adjusted if necessary. A detailed study is required to establish the design basis for the plant.

The ultimate disposal of residues from these plants is to be by chemical landfill. Residue quantities would be small. An estimate of dewatered sludge (30 percent solids), which would be incinerated, would be 1.1 cubic yards per day. The landfill would be protectively lined, with provisions for leachate collection and treatment, and installation of monitoring wells. Special attention is to be given to the location of the landfill because of possible groundwater contamination. The proposed landfill should be located in accordance with the previously discussed criteria.

The effluent from the hazardous waste treatment plants would be discharged through existing or proposed ocean outfalls, as an additional safety measure.

Table 3–7

COSTS FOR HAZARDOUS WASTE DISPOSAL PLANTS [1]

Alternative	Design Flow [2] (GPD)	Capital Cost	Annual O & M Cost	Total Annual Cost [3]
Bi-county Plant	325,000	$ 6,931,000	$ 458,000	$ 1,050,000
County Plants				
Nassau	65,000	$ 4,363,000	$ 247,700	$ 616,000
Suffolk	260,000	4,513,000	357,600	736,000
Total	**325,000**	**$ 8,876,000**	**$ 605,300**	**$ 1,352,000**

(1) Order-of-magnitude cost estimate; based on mid-1977 costs (ENR = 2580)

(2) Less trucked-in sludge volume

(3) Capital cost amortized over 20 year planning period at 6 3/8%

3.3.2.3 Sludge Management Alternatives. Alternative sludge disposal techniques for the Nassau-Suffolk area were identified, developed and evaluated. Various management systems and approaches were formulated and capital and operation and maintenance costs were generated. (See Plan Section K.) Seven sludge handling and reduction techniques were examined and include composting, landfilling, land application, incineration, co-incineration (with solid waste), pyrolysis and thermal drying. The alternative management approaches compared regional, subregional and small treatment plants.

In Nassau County, the regional approach was defined as a single sludge processing facility to handle the approximately 90 MG per year of sludge generated in the county. In Suffolk County, a regional approach was defined to include a central processing facility for each particular study area. Total sludge generated from treatment systems in Suffolk is about eighteen MG per year. The study areas are the same as those defined for point source alternatives.

A preliminary screening of the disposal techniques and management approaches was conducted for each area. In Nassau, it was not deemed feasible to combine incinerators, pyrolysis, or thermal drying units with all the domestic treatment facilities, and a regional or sub-regional approach was examined for these processes. In Suffolk, it was considered unnecessary to haul all sludge to a single wastewater treatment plant for subsequent landfilling, provided there are suitable landfill sites available closer to the sludge source. Landfilling, as a sludge disposal option, was examined on a plant-by-plant basis.

Sludges generated from the implementation of non-point source structural abatement alternatives are negligible in quantity compared to domestic wastewater treatment plant sludges. The non-point source sludges can be dewatered by vacuum filter and transported to the nearest regional or sub-regional sludge processing facility. Sludges currently generated from the periodic scouring and dredging of recharge basins are landfilled. This sludge could be placed in a sanitary landfill directly, or treated at a sludge processing facility. The disposal of contaminated dredge spoil from bays and estuaries was not studied as part of the 208 Program.

In general, the degree of confidence that can be placed in the sludge processing costs is somewhat low (± 50 percent) when compared with actual detailed cost estimates. Documentation in the literature on sludge processing costs is not nearly as extensive as documentation found in conventional wastewater treatment processing. In particular, newer technologies, such as composting, land application, co-incineration, thermal drying and pyrolysis have little available cost information. Costs for the newer technologies were obtained, wherever possible, from documents describing actual operating installations.

Nassau County. In Nassau County, all seven of the alternative disposal techniques were evaluated, some being applicable on a regional and sub-regional basis, and others on a local basis.

For purposes of economic analysis, locations for regional sludge processing facilities were considered to be Bay Park, Cedar Creek or adjacent to a solid waste processing facility, *e.g.,* the Town of Hempstead plant. Potential sub-regional locations included Port Washington and Glen Cove.

For incineration, thermal drying and pyrolysis, dewatering was assumed to achieve a cake solid content of approximately 35 to 40 percent, which is sufficient for autogenous combustion. For composting, land application, landfilling and co-incineration, liquid sludges were assumed to be dewatered by vacuum filters to approximately twenty percent solids, which is sufficient for handling as a semi-solid material rather than a liquid.

Transportation costs within the county were calculated assuming the trucking of dewatered material. For the two largest treatment facilities in Nassau County that currently do not dewater (Cedar Creek and Bay Park), costs for pipeline transportation were utilized because of potentially significant savings over trucking. In addition, there is an existing pipeline between Cedar Creek and Bay Park. Additionally, for the land application alternative, sludge was assumed to be barged to available farm land in Suffolk County for application. The actual acreage required for applying all the sludge generated in Nassau County would not be sufficient within county boundaries.

Apart from economic considerations, processes such as pyrolysis, thermal drying, co-incineration, land application and composting lack a significant operating record. While these processes seem promising in many instances, they have also been prone to failures in full-scale operation. Furthermore, the economic feasibility of such processes as thermal drying or composting for the purpose of recovering a saleable by-product such as soil conditioner is a function of the market for this material. If both counties were to undertake full-scale composting operations or thermal drying operations for soil conditioning, there might not be a readily available local market for all the material that would be generated. Further, should New York City utilize the recommended ISC plan of composting sludge, a great deal of

difficulty could be experienced in finding a market for all the compost that would be generated.

Other considerations besides economics affect the feasibility of implementing the various technologies. For example, in land application, concerns include the possibility of applying excess nutrients, heavy metals or organic chemicals that may be found in the sludge. The intent of applying the sludge to the land is to stimulate plant growth by adding various nutrients. Additional nutrients however could be leached out of the sludge and into the groundwater. This same concern applies in the case of heavy metals since wastewater sludges could leach toxic metals such as cadmium, lead and mercury to the groundwater. Further, cadmium is readily taken up into plants and subsequently concentrated. If these plants are utilized for human consumption they may be toxic. Potential bacteriological contamination is a further concern since pathogens may be conveyed from the sludge to the land and then onto plants or into the groundwater.

Theoretically, complete enforcement and implementation of county and local pretreatment guidelines would prohibit large concentrations of metals from reaching domestic wastewater treatment facilities and subsequently being concentrated in the sludge. Due to the number of metal finishing industries in the county, however, it is difficult to ensure that metals will not reach these domestic facilities. The extreme care required to protect the environment from these potentially hazardous materials reinforces the case for a regional approach to hazardous wastes handling.

Table 3–8 summarizes the costs for various sludge alternatives. Costs ranged from a low of $6.28 million per year for landfilling to a high of $16.0 million per year for land application (exclusive of land costs). High transportation costs ($12.4 million) are incurred in barging Nassau County's sludges to Suffolk County farmland near Riverhead. Nassau County could have difficulty in finding 17,600 acres of suitable land (agricultural or park land) for spreading sludge. While landfilling is the least expensive process, (at an assumed cost of $15 per ton), it is contingent upon the availibility of suitable landfill capacity.

Ranking very close to landfilling, in terms of costs, were composting and co-incineration at $6.7 million to $7.2 million, depending upon management level (regional, sub-regional or small plant). The ten to fifteen percent difference in cost between landfilling and composting (or co-incineration) is well within the accuracy of the cost estimates. Composting appears to be slightly more costly on a regional basis due to the transportation costs and minimal economies of scale. Co-incineration at about $7.0 million per year appears quite promising economically, even at low refuse to sludge ratios (2.67:1).

Incineration, pyrolysis and heat drying represent a third group of costs ranging from about $9.5 million (incineration) to $12.2 million (heat drying). Incineration appears to be slightly less costly on a regional basis, with economies of scale off-setting increased transportation costs. While incineration is

Table 3–8
ESTIMATED ANNUAL COSTS FOR DOMESTIC AND NON-POINT SOURCE SLUDGE DISPOSAL ALTERNATIVES FOR NASSAU COUNTY
(Dollars Per Year)

Management Approach	Transportation Cost[1]	Total Annual Cost[2] [3]
Incineration		
Regional	$ 760,000	$ 9,550,000
Sub-Regional	503,000	9,820,000
Composting [4]		
Regional	$ 760,000	$ 7,070,000
Sub-Regional	503,000	6,740,000
Small Plants	—	6,860,000
Landfilling[5]		
Small Plants	$ 867,000	$ 6,280,000
Pyrolysis		
Regional	$ 760,000	$10,500,000
Sub-Regional	503,000	10,400,000
Heat Drying[4]		
Regional	$ 760,000	$10,400,000
Sub-Regional	503,000	12,200,000
Co-Incineration[6]		
Regional	$ 760,000	$ 6,700,000
Sub-Regional	503,000	7,190,000
Land Application[7]		
Sub-Regional	$12,400,000	$16,000,000

(1) Includes both amortized capital and operation and maintenance costs to transport sludge from existing generation point to central processing facility.

(2) Amortized over 20 years at 6 3/8% interest, CRF = .08986. Total annual costs also include ultimate residue disposal (landfill). Does not include cost of land.

(3) Cost of energy generation or sale is not included in the calculations.

(4) No credit taken for sale of final product.

(5) Assumes utilization of Town of North Hempstead L-4 landfill for North Shore sludges and Oceanside landfill for South Shore.

(6) Assume refuse and sludge are co-incinerated at a refuse:sludge ratio of 2.67. Sludge is dewatered to 20% solids. Costs are allocated to sludge on an "as incinerated" wet ton basis. (See Section K of the Areawide Waste Treatment Management Plan.)

(7) Assumes sludge is barged from Glen Cove and Bay Park to farmland in Suffolk County and applied as a liquid at a dosage of 4 tons per acre per year.

the least expensive of the thermal processes (excluding co-incineration previously discussed), it remains about 50 percent higher than landfilling.

Pyrolysis is approximately ten percent more expensive than conventional incineration. No cost savings were realized in a regional approach as opposed to a sub-regional approach (within one percent). While heat drying to produce a saleable product was comparable to pyrolysis on a regional basis, sub-regional costs were about twenty percent higher. With a sale value of something greater than twenty percent of the cost of processing, heat drying could become less costly than incineration or pyrolysis. This again is a function of marketability.

Land application is feasible only in Suffolk County, since there is little land available for this purpose in Nassau County. While land application ranked the highest in cost, a large portion of the total cost (about 75 percent) is accounted for by transportation costs.

All of these processes can be utilized without significant negative impact on the environment. Composting, heat drying and land application would require guidelines on allowable application rates to avoid potential groundwater contamination by excess nutrients, metals or organic chemicals. Incineration, co-incineration and pyrolysis require suitable emission control devices to protect ambient air quality. Quench water from these processes must also be properly treated prior to release to surface or groundwater.

It is recommended that the cost-effectiveness of some combination of landfilling, incineration, co-incineration and composting be evaluated in further detail in the Nassau County Sludge Management Study. Potential impacts on the environment must be evaluated in detail.

Suffolk County. Table 3–9 summarizes Suffolk County costs for incineration, composting, landfilling, pyrolysis, heat drying, co-incineration and land application. Each table provides costs by study area (or disposal district) for various regional, sub-regional and/or small plant options. Each table facilitates a comparison of costs for different management approaches (regional *versus* sub-regional) for each Study Area (or Disposal District).

In reviewing the previous table, it can be seen that costs change from area to area for the same sludge treatment process. This is a reflection of the quantities of sludge to be handled and economies of scale. In general, as more sludge is handled, the unit costs per ton for handling and disposal decrease. This is also true within a single geographic area as regional, sub-regional and small-plant systems are analyzed. Again, economies of scale affect the final cost estimates.

In costing the landfilling option in Suffolk County, a disposal cost of $15 per ton was assumed and includes liners as well as environmental monitoring and leachate treatment. Sludges from various sources would be hauled to the nearest landfill. The co-incineration alternative assumes that solid wastes are diverted to a particular co-incineration facility.

A second case is costed for each of the co-incineration facilities representing a minimum recommendable ratio of refuse to sludge of 2.67. For example, for the Huntington-Northport co-incineration facility, all of Huntington's refuse (956 tons per day) would represent a refuse to sludge ratio of approximately sixteen to one, whereas the minimum necessary ratio would be 2.67 to one, or 160 tons per day of refuse to 60 wet tons per day of sludge.

For many of the areas, there is an economical preference for land application, landfilling and composting as opposed to pyrolysis, incineration and heat drying. Co-incineration appears competitive, depending upon the refuse to sludge ratio. (Co-incineration becomes less economically feasible at lower solid waste to sludge ratios). However, cost is not the only consideration. Environmental impacts must also be evaluated.

For the Huntington-Northport Study Area, composting and land application are economically preferable at a predicted annual cost of $250,000 to $300,000 per year. Co-incineration, incineration and heat drying comprise another level of costs at about $600,000 to $700,000 per year. Pyrolysis represents the highest cost at as much as $1,500,000 on a regional basis and would seem economically prohibitive. In the land application options, specific land disposal sites were not identified. For cost estimating purposes, it was assumed that dewatered sludge would be hauled by truck to farmland in the eastern portions of the county for final disposal.

In the Southwest Sewer District, methods of sludge disposal have already been investigated. Because of the lack of sufficient space in the immediate area, and because energy recovery was a major objective, incineration was the method selected. The sludge incinerators have been constructed alongside the other treatment facilities on the sewer district treatment plant site.

For the West Central Study Area (exclusive of SWSD), only land application and composting are economically preferable, with landfilling being significantly higher than both, by a factor of almost two, and incineration, heat drying, pyrolysis being substantially higher yet. If sewage is diverted to the SWSD, it would entail expansion of the incineration facilities.

The Port Jefferson Study Area shows land application, landfilling and composting relatively cost-effective, with incineration and heat drying not far behind, and pyrolysis being significantly more expensive than all others. For the South Central Study Area, composting and land application appear to be the most economically feasible, with landfilling almost twice as much in cost, and heat drying and incineration and pyrolysis most costly. Co-incineration does not appear economically competitive with composting and land application.

In Yaphank, the situation is very similar to South Central, except that landfilling is somewhat more economically competitive. Riverhead shows land application as economically attractive due to the location of Riverhead relative to the farmland where sludge may be applied. Composting also appears economical, especially since there may be more of a market for the compost material in the agricultural areas of eastern Suffolk County.

For the small plants of Southold, Shelter Island, Southampton, East Hampton, and Fishers Island, composting generally appears slightly higher than landfilling, with land application being slightly lower than landfilling. Co-incineration, heat drying, incineration and pyrolysis were not examined for the small plants of eastern Suffolk County.

The cost estimates for land application do not include land costs. Therefore, in order for this approach to be economically viable, land must be available on a low-cost rental or purchase basis. Actual land costs are very site-specific and so could not be analyzed herein. However, in more detailed studies, land costs must be identified and included in the analysis.

In summary, it appears that in Suffolk County, landfilling, land applica-

Table 3–9

ESTIMATED ANNUAL COSTS FOR DOMESTIC & NON-POINT SOURCE SLUDGE DISPOSAL ALTERNATIVES FOR SUFFOLK COUNTY: SUMMARY BY PROCESS

Total Annual Cost (Thousands of Dollars)[1]

Study Area / Management Approach	Incineration	Composting	Landfill	Pyrolysis	Heat Drying	Co-incineration [2]	Land Application
Huntington-Northport							
Regional	603	229	394	983	640	619	280
Regional	601	229	388	980	640	619	280
Sub-Regional	758	316	422	1,590	722	–	280
Small Plants	–	316	422	–	–	–	280
SWSD							
Regional [3]	1,320	464	885	1,420	1,370	1,220	521
West Central							
Sub-Regional	2,260	871	1,540	3,610	2,590	–	713
Sub-Regional	1,830	694	1,350	4,040	2,230	–	606
Small Plants	–	3,280	2,540	–	–	–	713
Kings Park							
Regional	650	247	419	1,030	677	743	268
Sub-Regional	868	343	503	1,740	940	–	305
Small Plants	–	1,060	831	–	–	–	325
Port Jefferson							
Regional	520	196	350	935	584	–	207
Regional	466	176	283	830	457	–	173
Sub-Regional	583	258	310	–	518	–	173
Sub-Regional	674	276	356	–	637	–	194
Small Plants	–	584	474	–	–	–	194
South Central							
Regional	1,300	475	942	1,430	1,380	1,210	481
Sub-Regional	1,660	622	1,060	–	1,750	–	521
Sub-Regional	2,050	1,010	1,210	–	2,090	–	574
Small Plants	–	2,580	1,860	–	–	–	632
Yaphank							
Sub-Regional	1,930	824	1,380	3,300	2,220	1,790	615
Sub-Regional	2,330	988	1,380	–	2,320	–	561
Small Plants	–	2,830	2,000	–	–	–	615
Riverhead							
Regional	431	172	256	921	459	–	138
Sub-Regional	566	253	286	–	509	–	138
Small Plants	–	253	286	–	–	–	138

Table 3–9 . . . Continued

Study Area Management Approach	Total Annual Cost (Thousands of Dollars) (1)						
	Incineration	Composting	Landfill	Pyrolysis	Heat Drying	Co-incineration (2)	Land Application
Southold							
Small Plants	–	217	172	–	–	–	109
Shelter Island							
Small Plants	–	75	53	–	–	–	46
Southampton-East Hampton							
Small Plants	–	402	297	–	–	–	127
Fishers Island							
Small Plants	–	24	24	–	–	–	30

(1) Amortized over 20 years at 6 3/8% interest, CRF = .08986.
(2) Costs represent average of two different refuse to sludge ratios shown in Section K of the Plan.
(3) Incineration has already been selected because of limited available space and energy recovery requirements.

tion and composting are economically preferable to pyrolysis, heat drying and incineration. Co-incineration becomes more economically attractive for the five western towns (due to refuse generation in concentrated areas). In the eastern areas of Suffolk, land application and composting of sludges should be given serious consideration by virtue of proximity to agricultural land, and the probable lack of high concentrations of heavy metals in the domestic treatment plant sludges.

All of these processes can be made environmentally safe with proper precautions, and their impacts are evaluated in Section Four of this Summary Plan. Those most economically attractive should be examined in greater detail at the 201 level for application to specific areas.

3.4 Non-Point Source Controls

The 208 Program has identified a number of non-point source problems that contribute to ground and surface water pollution in the Region. For each class of non-point sources, the program identified a series of implementable, cost-effective responses that can be utilized to reduce the non-point problem. These non-point controls should be implemented on a priority basis and must, wherever possible, supplement and strengthen existing programs, regulations and structural alternatives.

3.4.1 Identification of Applicable Non-Point Controls. (Refer to Section J of the Areawide Waste Treatment Management Plan.)

3.4.1.1 Stormwater Runoff Control. Stormwater runoff from impervious surfaces is generally controlled through the use of infiltration basins or allowed to flow through drainage systems or overland to surface waters. Stormwater runoff often contains plant nutrients (*e.g.,* nitrates), heavy metals, organic compounds and bacteria. Pollutants contributed by runoff constitute significant hazards in many parts of the area, and are particularly deleterious to the Great South Bay system. The program has formulated the following control strategies that can aid in minimizing problems attributable to this pollution source:

- Require the immediate recharge or on-site detention of stormwater, where feasible, in order to reduce the volume of runoff.
- Promote the use of storage areas—either specially constructed detention basins, multi-purpose paved areas, natural ponds or other existing or altered landforms—to reduce sediment transport and coliform contamination from runoff.
- Promote or require the imposition of controls to reduce pollution generated by domestic animals.
- Limit, regulate and, where necessary and practicable, prohibit new shoreline development in order to protect the quality of adjacent surface waters.
- Provide adequate buffer zones surrounding tidal and freshwater wetlands.
- Establish and require compliance with Best Management Practices for land clearance and construction in order to minimize erosion and construction-related pollutant discharges.
- Promote or require the institution of municipal street cleaning programs to help minimize the pollution effects of stormwater runoff. Require strict control over the disposal of collected materials in sanitary landfills.

3.4.1.2 Domestic On-Site Disposal Systems. Domestic on-site disposal systems are in widespread use throughout portions of the Nassau-Suffolk area and contribute significant amounts of nitrogen to the area's groundwater. In addition to the usual structural responses, that is, municipal collection and treatment, the Program has identified the following control strategies that can aid in minimizing this pollution source:

- Withhold permits for individual systems in any area where it has been determined that on-site disposal is causing significant deterioration of groundwater or surface waters.
- Promote further investigation into the feasibility of utilizing innovative on-site treatment—disposal techniques including, but not limited to, pressure/vacuum systems, alternate leaching fields and in-ground denitrification systems.
- Prohibit or restrict the use of various classes of products that may contribute to the chemical pollution of the groundwater. Such products include various detergents, dry cleaners and septic system cleaners or reconditioners.
- Establish minimum lot sizes in specific areas subject to hydrologic constraints or, if such areas are already developed, provide for and require hook-up to a collection and treatment system.
- Promote the establishment of municipal or neighborhood programs for the routine preventive maintenance of on-site systems.
- Provide for a monitoring program in areas where pervasive violations of the nitrogen standard or the presence of heavy metals or organic chemicals is considered likely.
- Plan for conversion to alternative disposal techniques in those areas where monitoring indicates unacceptable pollutant concentrations.

3.4.1.3 Subsurface Leakage from Domestic Collection Systems. Sewer systems develop leaks as a result of improper construction, materials failure or aging. These leaks may permit domestic and industrial-commerical waste to be carried to the groundwater. The program has identified the following strategies that can aid in minimizing the pollution problems associated with exfiltration and clogging:

- Continue to apply stringent performance standards for construction materials and practices, accompanied by agency surveillance during construction.
- Require the establishment of regularly scheduled maintenance and cleaning programs.

3.4.1.4 Product Storage Tanks, Pipelines, Accidental Discharges. Leakage of materials from product storage tanks and accidental discharges may introduce hydrocarbons, organic solvents and toxic industrial liquids into surface and groundwaters. The program has identified the following control strategies which can aid in minimizing the pollution source:

- Require construction standards that will minimize the probability of leakage or, in the event of accident, will minimize the entry of pollutants into ground and surface waters.
- Establish siting and location standards that will prohibit the storage of certain materials in areas where leakage and spills will constitute a significant pollution hazard.
- Establish a monitoring program that will enable a management agency to evaluate the performance of storage facilities in relation to baseline ground or surface water quality.
- Require that owners or operators of storage and transmission facilities develop an emergency shut down, containment and clean-up procedure as a permit condition.
- Promote or, where feasible, require changes in clean-up techniques to minimize the flushing or disposition of hazardous spilled materials to groundwater or surface waters.
- Establish and maintain an emergency notification system with a trained emergency response team capable of responding to spill emergencies.
- Provide for criminal and/or civil liability in cases of ground or surface water pollution caused by violation of permit or operating conditions and assume that compliance with these conditions will not affect such liability.
- Require that accurate product records be maintained and made available to regulatory agencies.
- Require that buried tanks be constructed or protected in such a way as to positively prevent the escape of contents due to tank corrosion, both internal and external. Techniques to be considered include, but are not limited to, the use of non-corrosive materials, cathodic protection, coatings and double-walled tanks.
- Prohibit the establishment of waste piles (stock piles) containing potential pollutants within the flood plain of the 100-year flood.
- Prohibit above and below ground storage of potential pollutants in primary recharge or watershed areas except where reasonable safeguards are provided in order to prevent the escape or movement of such pollutants into ground or surface waters.

3.4.1.5 Discharge and Storage of Industrial Wastes. Industrial wastes discharged to municipal treatment facilities and ground/surface waters may contain a variety of toxic organic and inorganic compounds that constitute a public health hazard. The program identified the following control strategies that can aid in minimizing this pollution source:

- Require adequate pretreatment levels as a condition of discharge.
- Prohibit disposal of waste materials on the land surface, or to groundwater, unless permitted or exempted. (Specific classes of materials may be exempted.)
- Prohibit the discharge of specific classes of industrial waste to

groundwater in any prime recharge or watershed area.

- Expand permit conditions relating to an enumeration of chemical constituents and allowable limits to ensure maximum protection of the groundwater resource.
- Promote and, if necessary, require that specified classes of industrial wastes be subject to a materials recovery process prior to discharge.

3.4.1.6 Landfills. The use of the land for the ultimate disposal of solid wastes, sludges and toxic chemicals constitutes a significant threat to groundwater quality and the public health. The program has identified the following control strategies that can aid in minimizing this pollution source:

- Prohibit all landfill operations that rely on natural attenuation as a means of leachate control.
- Prohibit the location of new landfill operations in primary recharge or watershed management areas.
- Require that landfill operators adhere to a cover schedule and maintain a minimally exposed face. Where appropriate, require a cover of relatively impervious material.
- Classify all landfill sites according to the materials that may be placed in them, with toxic wastes assigned to specific disposal sites that are strictly controlled and monitored.
- Promote the use of volume reduction techniques, and resource recovery and reuse, wherever economically feasible.
- Require permits for all landfill operations, regardless of size.
- Require the provision of an underdrain system and an impermeable barrier where the landfill is located in a permeable soil and where it can reasonably be expected that the quantity and quality of the leachate will have a significant adverse effect on ground or surface waters. Provide for treatment and disposal of collected leachate.
- Establish, maintain or supplement groundwater monitoring and surveillance at each landfill site, both open and closed.
- Require surface liners, proper grading and revegetation of completed landfills to minimize infiltration and ensure compatability with the surrounding area.

3.4.1.7 Recharge of Sewage Treatment Effluent. Sewage treatment plant effluent discharged to the ground does not constitute a major threat to the area's groundwater; however, there may be significant local impacts when discharges are concentrated at a few sites. Most of the plants that discharge to the ground are generally treated to the secondary level; some are denitrified. The program has identified the following control strategies that can aid in minimizing this pollution source:

- Establish and/or enforce strict control of treatment plant operating procedures.
- Provide for public take-over in instances where private owners and operators consistently fail to meet permit conditions.
- Require the use of advanced wastewater treatment techniques in primary recharge areas, or prohibit sewage treatment plant discharges to ground in prime recharge or watershed management areas.
- Establish demonstration projects to test alternative treatment and disposal techniques including, but not limited to, the land application of treated effluent, spray irrigation and marsh-pond basins.
- Establish, maintain or supplement monitoring programs to determine baseline water quality and to ensure early detection of any degradation caused by discharges from sewage treatment plants.

3.4.1.8 Construction-Related Erosion. Sediment is the end product of the erosion that occurs when the protective vegetal cover of the land is removed and rain and wind forces can work freely on the exposed soil. Although erosion is not as serious a problem on Long Island as it is elsewhere in New York State, there are areas where the deposition of sediments can severely damage aquatic or wetland ecosystems. In 1974 the Soil Conservation Service reported that erosion from construction sites accounted for approximately half of all erosion losses in Suffolk County. The program has identified the following control strategies that can aid in minimizing pollution from this source:

- Prepare or support the preparation of a handbook for local officials and developers. The handbook would describe Best Management Practices for the control of construction-related erosion.
- Establish or strengthen sub-division ordinance requirements for the reduction of erosion during and after site development.
- Supplement building permit requirements by including provision for submission of a site clearance, interim grading and restoration plan designed to minimize runoff and erosion.

3.4.1.9 Water Well Construction and Abandonment. Improper construction and practices may permit surface pollutants to enter the groundwater aquifer system and may contribute to the movement of contaminated water between groundwater aquifers. Existing controls over this non-point source of groundwater contamination are not particularly stringent. Drillers are licensed and permits are required before wells can be drilled, except for agricultural wells. In addition, Nassau and Suffolk County Health Departments maintain records on public supply wells, but generally do not sample and inspect the numerous agricultural wells. The 208 Program has identified the following control strategies that can minimize this pollution source:

- Extend the NYSDEC regulations governing well construction and abandonment to cover wells presently not subject to regulation.
- Require the registration of all persons and/or firms engaged in well drilling activities with the appropriate county management

agency. Require all drillers to obtain a license and post surety or cash bonds before engaging in activites related to well drilling. The license should provide for revocation wherever regulations are violated.

- Establish a program of well inspection. Inspection priority should be accorded to the classes of wells considered most likely to contribute to groundwater contamination.
- Require a permit for the abandonment, sealing or demolition of any public or private well having a capacity greater than 45 gpm and of any observation well or other well installed for the purposes of scientific investigation.

3.4.1.10 Highway Deicing Materials. The storage and application of highway deicing materials contribute to chloride and sodium contamination of fresh surface and groundwaters. Leachate from inadequately protected salt piles and salt-laden runoff from impermeable road surfaces seeps directly into the ground or is diverted to a storm recharge basin. In some places along the shores of Long Island, street runoff is diverted to storm drains that empty into surface waters. The Program has identified the following control strategies that can minimize pollution from this source:

- Require that salt piles be stored in permanent buildings.
- Require the substitution of inert abrasives, such as sand or cinders, for chemical salts wherever possible.
- Modify application procedures and equipment to allow preferential spreading on high hazard road segments.

3.4.1.11 Well Disposal of Heated Cooling Water to Groundwater (Diffusion Wells). Diffusion wells may cause contamination of groundwater through the introduction of heated water and of chemical additives used in the cooling process or for the maintenance of cooling equipment. The Program has identified the following control strategies that can aid in minimizing pollution from this source:

- Restrict the use of chemical additives in cooling processes or in the maintenance of cooling equipment.
- Require that no cooling waters discharged to the ground differ significantly from ambient water except in respect to temperature.
- Provide adequate surveillance to ensure compliance with diffusion well permit conditions.

3.4.1.12 Control of Domestic Animal Wastes. Data provided by the Soil Conservation Service indicates that the animal population of the Region is sufficiently diverse and numerous to add to the BOD, COD, bacterial, nitrogen and phosphorus content of ground and surface waters. Regulations controlling the disposal of waste from domestic animals are generally designed to prevent public health nuisances and do not protect ground or surface water quality. The Program has identified the following control strategies that can aid in minimizing pollution from this source:

- Promote dog sterilization programs in order to limit the growth of the canine population.
- Require that pet owners assume responsibility for the clean-up and disposal of animal wastes.
- Provide for the repeal of dog curbing ordinances, and promote the adoption of clean-up ordinances.
- Require that persons having ownership or control of numbers of domestic animals obtain a permit specifying the Best Management Practices to be followed, including an approved plan for the disposal of wastes.
- Prohibit the continued sale and/or distribution of White Pekin ducks for pets.

3.4.1.13 Groundwater Development. Optimization of groundwater withdrawal practices is required to assure the long term quality of Nassau-Suffolk groundwaters. Although salt water intrusion does not appear to be a significant areawide problem, there have been instances of local contamination due to saltwater intrusion or upconing in pumping wells. The Program has identified the following control strategies that can aid in minimizing pollution from this source:

- Control pumping patterns, especially of high yield wells, to minimize the interaquifer movements of contaminants.
- Control pumping patterns to minimize local saltwater contamination of supply wells.
- Establish pumping patterns that will minimize the migration of existing contaminants within any aquifer and/or abate existing contamination.
- Formalize interdistrict allocation of public water, where required.
- Encourage use of public lands for groundwater development.
- Amend the New York State law to remove the clause exempting agricultural irrigation wells from operating permit requirements.
- Employ land use controls to limit development in those areas where water supply is restricted.
- Require wellhead treatment of public water supplies in areas where water quality contravenes drinking water standards.

3.4.1.14 Agricultural Chemicals. Large quantities of pesticides and fertilizers are used on Long Island, not only in eastern Suffolk agricultural areas, but also in western Suffolk and in Nassau, where they are applied to lawns, golf courses and nursery stock. Contamination hazards from pesticides are generally controlled by natural physical-chemical biological processes in the soil. Recent developments in pesticide chemistry, however, may yield classes of chemicals that are more persistent and/or toxic. The potential hazard from these chemicals, therefore, cannot be overlooked. Intensive application of fertilizer in domestic, recreational, agricultural and commercial use results in the leaching of a large part of the nitrogen content to groundwater. The Program has identified the following control strategies that can aid in mini-

mizing pollution from these sources:

Pesticides

- Limit or prohibit the distribution and/or use of specific chemicals that are suspected carcinogens.
- Promote the substitution of less persistent or less toxic chemicals for those currently in use.
- Institute measures to control the disposal of used pesticide containers.
- Continue and supplement the licensing of commercial operators.

Fertilizers

- Enlist the active participation of the United States Department of Agriculture, local Soil and Water Conservation Districts, and the Cooperative Extension Service, to conduct information and education programs designed to promote the cost-effective use of fertilizers and erosion/runoff control.
- Limit or prohibit the distribution or sale of those chemical fertilizer formulations that have effective organic substitutes.
- Institute fertilizer use controls in areas with significant hydrologic constraints, *e.g.,* the deep flow Zones I and III. Initial emphasis should be on non-food crops, lawns, golf courses, etc.
- Promote the use of low-maintenance lawns and natural plant materials in order to reduce the need for extensive watering and fertilizing.

3.4.2 Application to Stormwater Control

3.4.2.1 Stormwater Runoff to Bays. A number of factors are considered in formulating and applying control methods to non-point sources. Structural methods (*e.g.,* retention/settling basins) can be used where stormwater is conveyed to the receiving water by a stream or large storm sewer. If the greater portion of flow reaches the water at many diffuse locations, Best Management Practices (usually including street cleaning) are appropriate, if cost-effective. (See Section L of the Areawide Waste Treatment Management Plan.)

Non-point source control in the bi-county area was evaluated on the basis of two factors. The first factor was the presence or absence of a long term problem with bacterial contamination in the receiving water. Closed shellfish areas were used as the indicators for this type of pollution. (It should be noted that, in all but one of the bays studied, the contribution of bacteria from non-point sources far exceeded that from point sources.) The second factor was the relative magnitude of non-point pollution contributed by streamflow as compared with that contributed by diffuse flow. In analyzing this factor, the bays and bay complexes were divided into subdrainage areas, which were then evaluated separately. Also considered was the scale at which the evaluation should be conducted. One approach considers only those streams that have drainage areas of 100 acres or more; another approach considers all streams.

Structural and Best Management Practice techniques for non-point source control were grouped into the following approaches:

Approach I: Bay divided into reaches and controls applied where a problem is indicated (for example, closed shellfish areas). Structural alternatives applied to streams with drainage basins greater than 100 acres where the proportion of stream runoff to areal runoff is relatively high. Best Management Practices applied to suspect overland flow areas and areas downstream of structural facilities.

Approach II: Reliance on Best Management Practices only, throughout the basin.

Approach III: Application of structural alternatives to all streams with drainage basins greater than 100 acres, regardless of the relative proportion of stream and areal flow. In addition, application of Best Management Practice to all other drainage areas.

Approach IV: No action. To be applied to drainage areas contributing to those bay segments where no problem exists or is expected.

The above approaches were applied to the following bays and bay complexes of significance: Great South Bay complex, Manhasset Bay, Hempstead Harbor, Oyster Bay/Cold Spring Harbor complex, Huntington Bay complex, Port Jefferson Harbor and Peconic Estuary.

For each bay, approaches were developed with associated total annual cost, annual pollutant loads and sludge production.

There are a number of natural ponds in the study area that are located on streams near their discharge points. If the settling capability of the ponds is utilized, then only disinfection may be required. This concept should be evaluated in detail when stormwater structural approaches are being considered. The degree of sedimentation taking place in the natural pond should be estimated by comparing influent and effluent water quality. If sedimentation is effective and if effluent water quality is sufficiently good (*i.e.,* low values of suspended solids or turbidity), only disinfection need be applied.

For a comparison of the costs of structural approaches with Best Management Practices, street sweeping was selected as a representative of the latter approach. It is the most commonly applied Best Management Practice; it has been implemented in the past; its costs have been estimated; and it is being studied extensively in other 208 investigations. Other Best Management Practices could also be included but comparable cost-estimating data and operational experience are lacking. In actual applications, a combination of Best Management Practices would probably be applied to an area to achieve maximum effectiveness.

Great South Bay Complex. As illustrated in Figure 2–3, the Great South Bay Complex basin is made up of parts of basins N1, N2, S1, S2 and S3a. The basin is characterized by its extensive tributary system, the discrete location of its streams, a relatively large percentage of impervious surface area (in N1 and N2), and a gradual basin slope with minimum bank runoff.

The percentage of the total drainage area from which runoff reaches

the bays via streams varies for each subdrainage basin.

Sub-Drainage Basin	% Stream Drainage Area
N1	38.9
N2	54.1
S1	60.2
S2	58.5
S3a	53.4

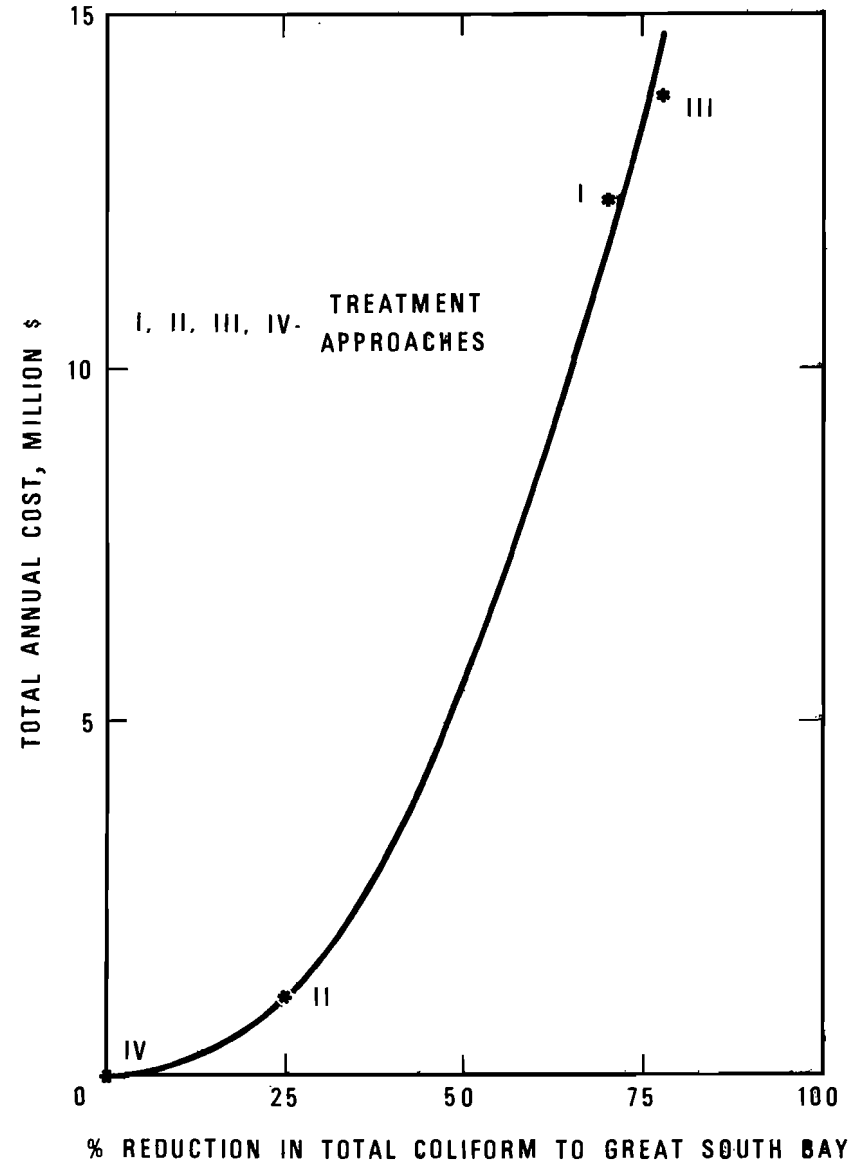
The above drainage area data take on importance when coupled with data indicating areas closed to shellfishing. Figure 2–8 identifies areas of the Great South Bay complex that were closed to shellfishing as of August 1977. Inspection of Figure 2–8 shows that essentially the entire area of the Great South Bay complex below drainage areas N1 and N2 is closed to shellfishing, as are parts of the Bay below S1 and S2, and a small area of the Bay below S3a.

Approach I attempts to identify areas where structural/non-structural methods are more appropriate, based upon the pollution reduction potential of a particular drainage basin and a history of shellfish bed closings. This approach resulted in the following:

1. Best Management Practices were considered for use in N1, because structural methods offer a relatively low pollution reduction potential and because N1 is entirely closed to shellfishing.
2. Since shellfishing closings occur in a large part of the bay below N2, S1 and S2, and since relatively high pollution reduction potential by structural methods exists, structural methods were considered.
3. Although S3a has a high pollution reduction potential, the need for structural abatement facilities is unwarranted because the shellfish closings occur in small isolated areas. For S3a, therefore, Best Management Practices were considered.

In the sub-drainage basins where structural methods were considered (N2, S1 and S2), land availability was checked to determine whether a storage/sedimentation reservoir could fit the available space. If space was not available, then a swirl regulator-concentrator treatment was selected. The total annual cost estimates (amortized capital and operation and maintenance) as well as an estimate of the recent reduction in coliform bacteria (effectiveness) are graphically illustrated in Figure 3–11. The sludge generated from the non-point source structural abatement facilities would be a small quantity in comparison to projected municipal sludges.

Approach II involves the application of Best Management Practices throughout the entire drainage basin of the Great South Bay complex. It represents the minimum treatment level that can be provided from both a cost and treatment efficiency standpoint. The cost for implementing a street sweeping program was estimated at about $97 per curb mile per year. The estimated total annual costs and effectiveness are illustrated in Figure 3–11.



Source: Section L of the Areawide Waste Treatment Management Plan.

FIGURE 3–11 *Cost-Effectiveness of Various Treatment Approaches for the Great South Bay*

Approach III involves the installation of structural abatement facilities on all streams draining areas greater than 100 acres, and implementing Best Management Practices in those areas of the basin not drained by these streams. The only exception to this is that Best Management Practices were considered for applications to the Mill River, the Connetquot River and the Carmans River, since they are too large to control structurally. Approach III represents the highest degree of treatment that can be provided. The estimated total annual costs and effectiveness are illustrated in Figure 3–11.

Approach IV is the no-action alternative. Based on the history of shellfish closings alone, it would appear that some kind of action is warranted and that the no action alternative is not viable.

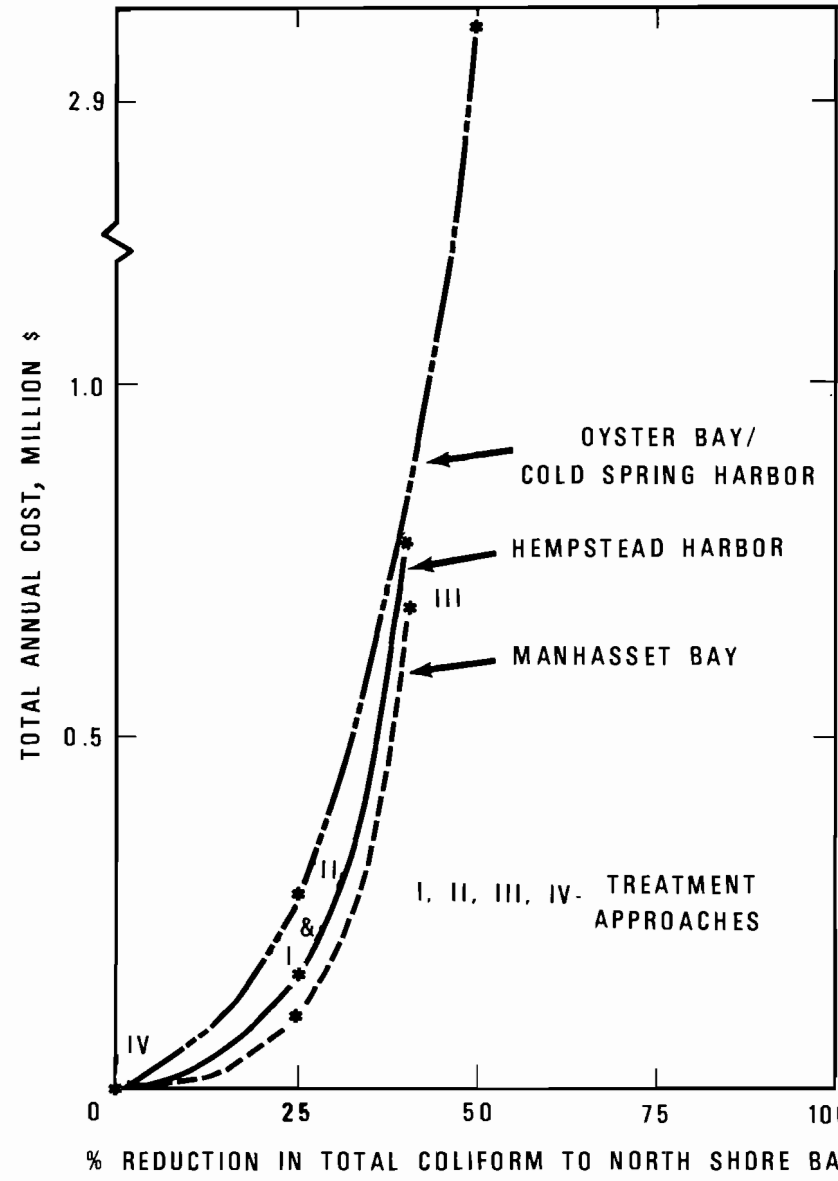
As illustrated in Figure 3–11, the estimated total annual costs differ significantly between Approaches I and III on the one hand, and Approach II on the other. The cost of implementing a street sweeping program (Approach II) throughout the Great South Bay area is about one to two orders-of-magnitude less than the costs of the other approaches. The estimated treatment efficiency, however, of Approach II is less than it is for Approaches I and III. The total coliform reduction of Approach III is 76 percent, while the reduction by Approach II is 25 percent.*

From Figure 3–11 it would appear that, of the four approaches, the most cost-effective solution is Approach II, which yields the greatest estimated efficiency per unit dollar of cost.

North Shore Bays. In general, the basins contributing flow to the North Shore bays are characterized by a minor tributary system, steep basin slope and significant bank runoff. The exception to this is Oyster Bay/Cold Spring Harbor. The drainage area of the streams in that basin accounts for approximately 44 percent of the total drainage area.

As illustrated in Figure 3–12, total annual costs and treatment efficiencies are the same for Approaches I and II for Manhasset Bay, Hempstead Harbor and Oyster Bay. This is because Best Management Practices were used in Approach I after it was decided that structural methods would not appreciably reduce overall non-point source pollution into the bays because of the small drainage area attributable to streams. In the case of Port Jefferson Harbor, Approaches I, II and III are identical because there are no streams where structural control measures would apply. In the case of Huntington Bay, Approaches I and II are identical and III is slightly different. Both of these bays are shown in Table 3–10. Coliform reductions achieved by Approaches I and III differ significantly for the bays illustrated in Figure 3–12. For example, Approach III at Oyster Bay/Cold Spring Harbor results

*Future studies will be required to determine the efficiency of non-structural means of non-point source control. In addition, future modeling studies will be required to correlate the effects of Best Management Practices on receiving water quality.



Source: Section L of the Areawide Waste Treatment Management Plan.

FIGURE 3–12 *Cost-Effectiveness of Various Treatment Approaches for North Shore Bays*

in a coliform reduction of 51 percent (*versus* 25 percent for Approaches I and II). This pattern is generally the same in the other two bays.

Table 3–10 indicates that a structural solution would not achieve much improvement in coliform levels in the Huntington Bay/Northport Bay complex. Port Jefferson Harbor options are limited to Best Management Practices.

Considering Table 3–10 and Figure 3–12, the apparent maximum effectiveness per unit cost of the four approaches for each bay is Approach II. Approach II, therefore, appears to be the most cost-effective alternative for all the North Shore bays, assuming that a 25 percent reduction in BOD_5, suspended solids, nutrients and total coliform bacteria can be achieved by Best Management Practices, and that bay water quality standards can be met.

Table 3–10

ESTIMATED TOTAL ANNUAL COST AND EFFECTIVENESS OF APPROACHES TO CONTROL STORMWATER RUNOFF INTO HUNTINGTON/NORTHPORT BAY AND PORT JEFFERSON HARBOR

Bay/Approach	Estimated Total Annual Cost, $	Estimated % Reduction of Total Coliform Load
Huntington/Northport Bay		
I	151,000	25
II	151,000	25
III	213,000	25
IV	– 0 –	0
Port Jefferson Harbor		
I	98,000	25
II	98,000	25
III	98,000	25
IV	– 0 –	0

Source: Section L of the Areawide Waste Treatment Management Plan.

The dynamic water quality model was used to measure the response to various inputs of stormwater and pollutants to Manhasset Bay and Hempstead Harbor. On the basis of sampling programs and model runs, it is reasonably certain that coliform levels in the outer portions of these bays are dominated by conditions in Long Island Sound, and the inner portions by stormwater runoff from the tributary drainage basin. Coliform levels in these embayments, which are over 70 MPN per 100 milliliters preceding a storm event, can increase to above 2000 MPN per 100 milliliters in response to a "design" storm. The overriding influence of present Long Island Sound water quality will prevent the reduction of coliform levels to below shellfishing standards during storm events, even with a 25 percent reduction of coliform bacteria in runoff. However, Best Management Practices in the control of runoff may insure the suitability of these waters for bathing, following moderate to heavy rainfall.

Peconic Estuary. Flanders Bay-Peconic Estuary is characterized by a major tributary (Peconic River) and a number of much smaller streams. Most of the runoff can be considered bank runoff, with a small portion contributed by the streams. The drainage areas of the streams account for approximately 34.9 percent of the total drainage area of Peconic Estuary. A tabulation of drainage areas of the streams flowing into the Peconic Estuary and the percentage of total drainage area attributable to streams for each subdrainage basin are given as follows:

Sub-Drainage Basin	% Stream Drainage Area
S11b	70
S12a	Negligible
S15a	Negligible
S13b	Negligible

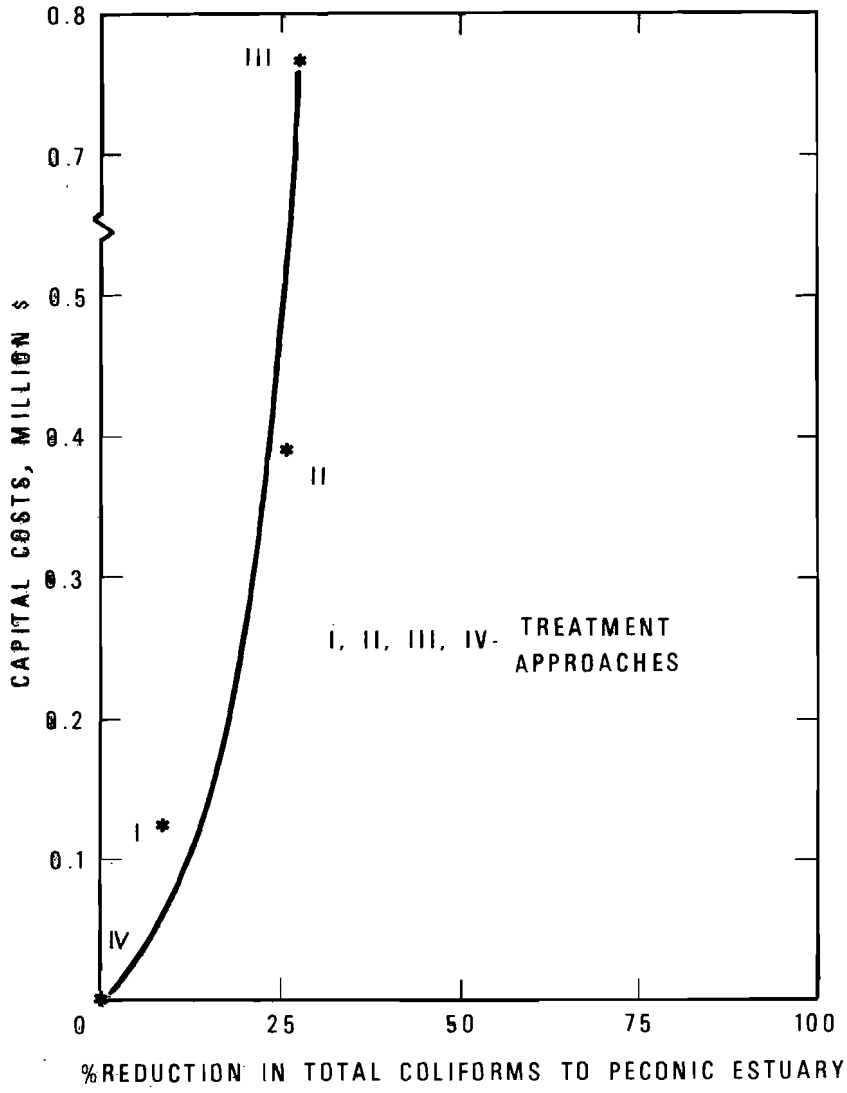
The above drainage area data were compared with the data on areas closed to shellfishing (see Figure 2–8), and the following treatment approaches were developed as part of Approach I:

1. Since Flanders Bay is partially closed to shellfishing, there is a need to reduce the non-point source pollutant loads entering from S11b. It was decided to consider implementation of Best Management Practices in this basin since structural methods are not feasible for large streams such as the Peconic River. Since the southern portion of Flanders Bay has not been closed to shellfishing, the no-action alternative was considered for Mill Creek and Hubbard Creek.
2. For sub-drainage basins S12a, S15a and S13b, no-action was considered acceptable because the bays adjacent to these basins are not closed to shellfishing.

The estimated total annual costs and effectiveness for Approach I are illustrated in Figure 3–13.

Approach II involves the application of Best Management Practices throughout the basin. In the case of Peconic Estuary, this level of treatment seems unnecessary since certain sub-drainage basins (S12a, S15a and S13b) do not appear to contribute to the problem of shellfish closings.

Approach III involves the application of structural abatement facilities on all major streams in S11b and the implementation of Best Management Practices in those areas of the bay not drained by the streams. The exception is that non-point source pollution from the Peconic River is controlled by non-structural measures. Approach III represents the highest degree of treatment that can be provided.



Source: Section L of the Areawide Waste Treatment Management Plan.

FIGURE 3–13 *Cost-Effectiveness of Various Treatment Approaches for Peconic Estuary*

Approach IV is the no-action alternative. It is reasonable to assume that non-point source pollution from sub-drainage basins S12a, S15a and S13b, need not be reduced since the bay areas adjacent to these basins have not been closed to shellfishing.

Estimated total annual costs and effectiveness are illustrated in Figure 3–13. Figure 3–13 suggests that Approach I or II would provide the most cost-effective solution. However, if water quality is improved and the duck farms that discharge to Meetinghouse Creek attain zero discharge, then Approach IV (no action) may be acceptable for the Peconic Estuary.

One of the major questions concerning stormwater control is the effectiveness of street sweeping/vacuuming as a Best Management Practice. There is no experimental or operational data available to describe its effectiveness in the Nassau-Suffolk area. Therefore, in order to evaluate the efficiency of street sweeping, demonstration programs should be established on the basis of topographic and runoff differences. One should be implemented on the North Shore and one on the South Shore. Sampling of stormwater runoff should be conducted in areas where street sweeping/vacuuming is intensively employed and the results compared with samples from areas where minimal amounts or no street cleaning is provided.

Recharge Basin Analysis. There are between 2000–3000 recharge basins on Long Island, recharging approximately 80 MGD of stormwater runoff to the Long Island aquifers. Street surface contamination consists of hydrocarbons (gasoline, oils, grease), organic chemicals (pesticides), heavy metals (lead, copper, zinc) and fecal matter (bacteria and viruses).

At the present time, there are no systems in use to treat the recharge prior to its entering the ground, although use of a marsh-pond approach as well as mechanical systems appears to be feasible. Therefore, unless the contaminants are removed by the natural vegetation and soils, they may eventually reach the groundwater.

The 208 has determined that surface runoff is a source of pollutants and that some form of treatment may have to be implemented. It is suggested that a concept requiring little maintenance, such as the marsh-pond concept, be investigated on a pilot basis to treat stormwater prior to recharge. The marsh-pond concept was selected for the following reasons:

- Runoff comes in contact with the soil and vegetation roots for a maximum amount of time.
- The vegetation removes heavy metals and organics by bio-assimilation.
- Both of the lined sections of such a system act as settling ponds, effectively removing any silt particles that would otherwise plug up the recharge basin.
- The vegetation will act as a nitrogen sink and if cropped will reduce the nitrates reaching the groundwater aquifers. Cropping would also be necessary to avoid accumulation and recycling.

Some disadvantages of this concept are:

- There will not be enough room for a marsh pond installation in all cases.
- The plants will have to be cropped about once per year and disposed of as potential hazardous wastes.
- Water levels in the marsh may have to be maintained during dry periods to prevent the plants from dying off.
- Variable climatological factors may impair the effectiveness of plant and other biological life in removing pollutants.

The estimated cost of such a system depends heavily on the size of each basin and the acreage requirement of the lined sections. For an average-sized recharge basin of 1.5 acres, the capital cost would be approximately $50,000 to $100,000, with an operation and maintenance cost of about $300 to $500 per year.

Summary. The recharge of untreated urban runoff poses a threat to the groundwater quality on Long Island. Many studies have shown that urban runoff may contain organic chemicals, heavy metals, bacteria and viruses, and may reach the subsurface water through recharge basins. (See Plan Section L.)

A review of possible alternatives leads to the recommendation that a marsh-pond pilot treatment plant be constructed in an existing recharge basin in order to test its ability to remove the pollutants in runoff. After a one year trial period, the operating data should be reviewed and a decision made on whether to implement the concept on a large-scale basis or to abandon it altogether.

If the pilot study proves successful, then a plan of phased construction to fit recharge basins in the Magothy recharge area with marsh-ponds can be prepared.

If it proves to be infeasible to treat at the recharge basins, it may be necessary to begin phasing them out in key groundwater areas. If this policy is implemented, substantial quantities of recharge water will be lost. The impact of this loss on groundwater levels and water supply must be carefully analyzed by existing digital and analog mathematical models before such a policy is adopted.

3.5 Planning Options

3.5.0 Introduction. There are a number of ways of achieving any specific wastewater management objective. Common end objectives can be reached generally through point source controls, non-point controls and/or some mix of the two.

In an attempt to keep the array of alternatives and/or complementary ways of achieving a management objective to a reasonable number, the planning process contained herein was designed to subject all alternatives to continuing evaluation, based on technical and economic feasibility, probable environmental effects and legal-statutory requirements. Where an alternative, or set of alternatives was found to violate any of these requirements, it was either modified or eliminated. It is possible to establish a number of area specific water supply alternatives as tradeoffs or second best solutions to wastewater management problems. However, one of the basic constraints, regarding the selection of the more viable wastewater management alternatives, is maintaining the self-sufficiency of the Region's drinking water supply by maintaining the high quality of the reserves. The nature and role of these trade-offs are discussed in Section Six.

This section describes the most viable alternatives as they relate to specific hydrogeologic zones and adjacent marine surface water elements. These alternatives are broken down into two categories: (1) areawide alternatives, or those alternatives that are generally applicable across all Nassau-Suffolk groundwater zones and surface water elements and, (2) area specific alternatives, or those alternatives that are applicable only to designated Nassau-Suffolk groundwater zones and surface water elements. An example of an areawide alternative is the restriction of the use of fertilizer throughout the bi-county area, whereas an example of an area specific alternative is the prohibition of landfills in selected groundwater zones.

The areawide and area specific alternatives follow. The preferred alternatives, or combinations of alternatives, and the reasons for their selection, are described in Section Six.

3.5.1 Areawide Alternatives

3.5.1.1 Provide for Routine Maintenance of On-Site Septic Tank and Leaching Pool Systems. Provisions should be made for routine pumping and maintenance to extend the service life of the leaching facility and ensure its continued efficacy.

3.5.1.2 Prohibit the Use of Certain Chemical Cleaners in On-Lot Systems. The use of organic solvents and other chemical agents that are used in an attempt to clean or extend the life of an on-lot waste disposal system, but that impair or alter groundwater quality, should be prohibited or controlled.

3.5.1.3 Expand Regulations and Enforcement Regarding the Disposal of Industrial Wastes. Where industrial wastes are discharged to municipal sewer systems, strict enforcement of sewer use ordinances should be insured. Where industrial wastes are discharged to the ground, present regulations should be expanded to include greater coverage of specific contaminants and prescribed allowable discharge levels. This applies primarily to organic chemicals.

3.5.1.4 Regulate the Storage and Transportation of Chemical Products. Permits and other controls should be required for the storage and transportation of chemical products that would pose an environmental threat to either the groundwater or surface water. The regulations should include prescribed practices relating to safeguards, inspection and emergency contingency plans. In addition to industrial chemicals, these products include chemical wastes and sludges, deicing salts and petroleum products.

Particular emphasis should be placed on regulating gasoline storage

facilities at automobile service stations and, to a lesser degree, home heating oil storage tanks. The 208 Study has recognized these two types of facilities as major potential pollutant sources but has not been able to define the precise magnitude of the problem.

3.5.1.5 Restrict the Use of Fertilizers. Since fertilizers constitute one of the largest sources of nitrogen applied to the land surface, they are also a significant potential source of ground and surface water impairment. Pending further necessary study to better define their impact on water quality, public education should, and regulation may, be employed to limit or possibly eliminate the use of all or specific types of fertilizers. Included in the Best Management Practices, some of which may also pertain to agriculture, are modification of application rates, discontinuance of reliance on fast-acting inorganic fertilizers, and promotion of low-maintenance lawns, which would require both less fertilizer and less consumptive use of water.

3.5.1.6 Control Stormwater Runoff. To the extent feasible, surface runoff should be intercepted and disposed of as close as possible to the source. Best Management Practices and/or structural systems should be employed to minimize the volume of runoff and the transport of sediments, nutrients, metals, organic chemicals and microorganisms to surface waters. Recharge basins may need to be modified, where feasible, to improve the removal of nutrients, metals and organic chemicals in stormwater runoff that contribute to groundwater contamination. Inasmuch as most of the techniques for both practical and cost-effective treatment of runoff are still relatively untested, the establishment and operation of several pilot projects is recommended prior to consideration for full scale implementation. Street vacuuming and the use of natural or man-made detention systems with marsh-pond application and/or disinfection are recommended for further investigation and testing.

3.5.1.7 Reduce Animal Wastes. Best Management Practices should be employed to minimize the deposition of animal wastes, primarily from dogs and semi-wild ducks, directly into the surface waters or on impermeable areas draining into surface waters. Among these management practices are the reduction of animal populations, regulation of the acquisition and abandonment of certain domestic animals, and proper animal waste disposal by owners.

3.5.1.8 Minimize Pollution from Site Preparation and Development. Regulations should be established requiring the use of Best Management Practices during site clearance, building construction and site restoration in order to control the erosion from development activities and the subsequent transport of sediment to surface waters.

3.5.1.9 Reduce Reliance on Landfills. Regional and/or subregional resource recovery facilities should be constructed as rapidly as feasible in order to minimize the current reliance on landfills for the disposal of domestic and other non-hazardous wastes. In addition, these resource recovery facilities should also provide for the adequate treatment of wastewaters originating at such facilities. The first resource recovery facility on Long Island is presently being constructed in the Town of Hempstead. Until such facilities become available, all new landfills should be interim in nature and should be provided with dual liner systems to prevent leachate contamination of ground and surface waters. Leachate should be collected and treated. This recommendation is consistent with present New York State Department of Environmental Conservation policy. The location of new landfills should conform to recommendations presented as part of the area-specific alternatives. Abandoned and/or completed landfills should also be upgraded when feasible by providing an impervious cover to prevent water infiltration and the continued production of leachate, especially in deep-flow recharge areas.

3.5.1.10 Provide for the Treatment of Hazardous Wastes. Provisions must be made for the safe disposal of hazardous wastes. Because of the types of industries in the Nassau-Suffolk Region and the wastewater treatment processes they employ, two kinds of hazardous wastes are generated: small volumes of strong, toxic industrial wastes, and industrial waste treatment sludges.

In view of the environmental sensitivity of the study area, continued disposal of these types of hazardous wastes outside of the area should be encouraged. However, if this disposal option is not available in the future, treatment facilities and landfills for hazardous wastes and residuals will have to be provided in the bi-county area.

3.5.1.11 Provide Alternatives to Ocean Disposal of Municipal Treatment Plant Sludge. The major municipal treatment plant sludge processing and disposal approaches that appear viable in the Nassau-Suffolk Region include composting, landfilling, land application, incineration, co-incineration with solid waste, pyrolysis and thermal drying. (These approaches also apply to the sludge from scavenger waste treatment plants.) It has been found that any of the conventional approaches can be implemented in parts of the Nassau-Suffolk area without significant environmental degradation if normal safeguards are taken. Final sludge disposal options should be selected after 201-level detail studies have been conducted, since the final decision should be based upon cost-effectiveness, and the 208 Study has not developed sufficiently detailed cost analyses. The 208 has determined that the conventional approaches are regionally acceptable.

Land-based sludge disposal options (land application, composting) must be accompanied by monitoring or other control programs to insure against contamination from heavy metals, organic chemicals and other pollutants. This is particularly important in hydrogeologic Zones I, II and III. Land-based disposal options will require strict enforcement of industrial pretreatment requirements to minimize the amount of toxic materials in municipal treatment plant sludges.

3.5.1.12 Require Nitrogen Removal for Treatment Plants Recharging Effluent. All waste treatment facilities that discharge to either recharge basins or to streams, should be required to provide nitrogen removal. The level

of nitrogen removal required should be in conformance with all applicable groundwater and surface water standards.

3.5.1.13 Minimize Population Density. Minimize population density by encouraging large lot development (one dwelling unit/one or more acres), where possible, to protect the groundwater from future pollutant loadings.

3.5.1.14 Promote Water Conservation. Water conservation is a matter of particular importance on Long Island, where the sole source of the potable water supply is the groundwater. Conservation of water use will help to preserve this water supply, and to maintain aquifer water levels. An additional benefit will be a reduction in energy consumption, also a matter of general concern. It should be noted, however, that insofar as areawide waste treatment management is concerned, water conservation will have limited benefit.

3.5.2 Area Specific Alternatives. The selection of area specific alternatives, whether structural or non-structural or both will influence the character and extent of future collection and treatment service areas.

In order to facilitate the selection of the most appropriate waste management options and the subsequent determination of the areas that should be served by community collection systems and those that should be served by on-site disposal systems, a series of alternatives is offered for each hydrogeologic zone and surface water element. In the case of the hydrogeologic zones, these range from total reliance on non-structural non-point source controls with no additional sewering to comprehensive sewering at densities of one or more units per acre, in combination with the immediate imposition of selected non-structural controls. In the case of the surface water elements, these range from total reliance on non-structural non-point source controls to the upgrading of treatment plants or the relocation of outfalls done in combination with the imposition of selected non-structural controls. A more complete discussion of these alternatives may be found in 3.3 and 3.4 of this section of the Summary Plan, and in Sections B and H of the Areawide Waste Treatment Management Plan.

An outline of the suggested procedure for relating hydrogeologic zone and surface water element alternatives with 201 study area plans is presented in Section Six.

In most cases several alternatives are listed. The rationale for the consideration of these, rather than some of the alternatives presented in 3.3 and Plan Section H, is discussed below.

Based upon an analysis of population densities and Upper Glacial aquifer nitrate-nitrogen (NO_3–N) concentrations in selected unsewered areas with twenty to 30 year old development and vertical groundwater flows, it was concluded that waste loadings generated by development at densities of ten to eleven persons per acre would result in an average NO_3–N concentration of ten milligrams per liter in the shallow groundwater. (An average of ten milligrams per liter implies that approximately 50 percent of the samples will exceed this concentration.) Further statistical analysis of these data indicated that an average level of six milligrams per liter NO_3–N would probably yield concentrations below ten milligrams per liter in 90 percent of the samples. It was calculated that in order to utilize on-site disposal systems, residential density should not exceed five to six persons per acre.

However, since the analyses relating population density to NO_3–N in the groundwater are not conclusive, it was decided that a viable range of alternatives should be offered and that additional study to better define the criteria for delineating service areas be included in a "201" study. In addition to the concern for protecting groundwater quality, consideration was given to factors such as the presence of a high water table or low soil permeability affecting the reliability of individual on-site disposal systems.

The selection of the range of sewering alternatives relating to population density is based upon the analysis of the probabilities of exceeding ten milligrams per liter as indicated from historical data and presented in Table 3–11. (See Section H of the Areawide Waste Treatment Management Plan and Section 4.5.2 of the Summary Plan.)

Table 3–11

POPULATION DENSITY AND OBSERVED NITROGEN CONCENTRATION IN SHALLOW WELLS

Percentage of Individual Well Observations Exceeding 10 mg/l NO_3–N	Predicted Average Concentrations of all Shallow Wells Less Than 100 ft. in a Given Area	Predicted Average Population Density Persons/ Gross Acre
50	10.3	10.9
40	8.7	8.6
30	7.9	7.4
20	7.1	6.3
10	6.0	4.7

Sources: Porter, K.S., et al., 1978, "Nitrogen: Sources and Potential Impact", Cornell University/Cooperative Extension Service. (Draft);
Appendix B, Section H of the Areawide Wastewater Management Plan.

The initial selection of sewering options of one, two and five dwelling units per acre, as discussed earlier in Section Three, was based upon previously recorded and projected residential densities, on which the cost estimates for sewering and waste treatment alternatives were also based. The initial selection of the one and two dwelling units per acre as maximum and intermediate sewering options is still consistent with the statistical data presented above. However, were one to assume a density of five dwelling units per acre and an average household size of four persons, in the area from which the data was obtained, the resulting population density of twenty persons per acre could be expected to produce an average NO_3–N groundwater concen-

tration of approximately twenty milligrams per liter. This would result in a concentration exceeding ten milligrams per liter NO_3–N in about 90 percent of the observations at shallow wells.

Since the violation probability of 90 percent at five dwelling units per acre is extremely high, the minimum sewering option was modified to reflect a lower and more reasonable density at which sewering would be recommended. The options for plan selection are as follows:

1. Minimum Sewering Option. Sewer at six or more persons per gross acre in areas of high water table and low soil permeability in order to provide the necessary space for adequate on-lot disposal systems. Such systems might require relatively extensive tile fields and would therefore require more than the normal amount of space.

   Sewer at nine or more persons per gross acre everywhere else, since it has been shown that, at these densities, groundwater contamination will probably exceed ten milligrams per liter, if sewering is not initiated.
2. Intermediate Sewering Option. Sewer at six or more persons per gross acre everywhere. Based upon the studies conducted during this program and others, this density appears to be the critical point about which both groundwater quality and cost revolve.
3. Maximum Sewering Option. Sewer at three or more persons per gross acre, since this will probably insure that groundwater NO_3–N levels will not exceed ten milligrams per liter, if non-point controls are also implemented. Unsewered areas will then have more than adequate lot sizes to accommodate any on-site sewage disposal system. However, it should be noted, that this maximum sewering option does not necessarily preclude the sewering of any area, if there is a complete failure of on-site systems or if the groundwater is threatened by contamination from on-site systems.

Regardless of the initial sewering alternative selected, it should be accompanied by a groundwater monitoring program in the less densely populated areas to determine the need, if any, for the creation of a new community sewer system or the expansion of the service area of an existing system.

The intensity and scope of the monitoring effort would depend in part on the sewering alternative selected for any given area. For instance, a comprehensive sewering alternative at four or more persons (one dwelling unit) per acre would probably preclude the necessity for an extensive monitoring system. A system perhaps only slightly broader than the one presently in place might be needed. This would allow for limited monitoring of inorganic chemicals, and in the future, organic chemicals. At the other extreme, total reliance on non-structural controls or even sewering at nine or more persons (three dwelling units) per acre would require an extensive monitoring system of many wells, sampled on a regular basis and with data being continually evaluated. This system is described in more detail in Section Six.

Monitoring of the concentrations of nitrogen, metals and organic chemicals, can be used to identify water quality trends in recently developed areas. The presence of average concentrations of six milligrams per liter NO_3–N in the samples from shallow monitoring wells can be used to signal the presence of existing problems in established areas.

A finding of increasing trends in contaminant concentrations or of a critical level of NO_3–N should initiate the necessary response to protect the public health and the long term quality and usefulness of the groundwater aquifer. In recently developed areas, such a response would comprise the stringent control of relevant non-point sources of contamination, followed by the extension of public water supply in order to minimize dependence on untreated water from private wells where applicable. If there is no indication of improvement in water quality, after continued monitoring, and if the degradation can be reasonably assumed to originate from on-lot sewage disposal systems, controls should be implemented.

In developed areas, especially those undergoing 201 study in the near future, time may not allow for a decision to be based upon trends, nor a determination of the effectiveness of Best Management Practices; therefore, the decision to reduce the nitrogen loading may need to rely primarily on structural controls.

3.5.2.1 Hydrogeologic Zone Alternatives. Wastewater management alternatives consisting of structural, non-structural and non-point source control options are given for each of the hydrogeologic Zones I through VIII. In addition, areawide alternatives having particular importance to a zone have been outlined.

Sewering, in the context used below, is defined as communal collection of wastewater and centralized treatment. Methods of treatment must be evaluated (traditional secondary/tertiary, marsh-pond, spray irrigation, and other innovative methods). This is not intended to preclude the future use of effective on-site treatment systems, as these are approved, in areas indicated for sewering.

Many of the pollutants that impact groundwater and surface waters can be expected to persist regardless of the sewering options that are selected. For this reason, non-point source controls must be regarded as an essential part of a comprehensive wastewater treatment management plan.

Zone I: Deep Flow System (Magothy Recharge Area). This zone is an area of recharge to the deep groundwater reservoirs in Nassau and western Suffolk Counties, and constitutes the major source of public water supply.

a. Wastewater Management Alternatives

   Alternative A—Total Reliance on Non-Structural Controls

   i. Permit no additional sewering.

   ii. Determine the acceptability of a given residential lot size and

of commercial and industrial activities on the basis of their impact on groundwater quality.

iii. Strictly control, and possibly upgrade, on-site systems.

iv. Strictly regulate site development and management practices, such as grading and maintenance of vegetation to control runoff.

Alternative B—Minimum Sewering Option

i. Provide sewering for areas with six or more persons (two or more dwelling units) per gross acre in areas of high water table and/or low soil permeability.

ii. Provide sewering for all other areas with nine or more persons (three or more dwelling units) per gross acre.

Alternative C—Intermediate Sewering Option

Provide sewering for all areas with six or more persons (two or more dwelling units) per gross acre.

Alternative D—Maximum Sewering Option

Provide sewering for all areas with three or more persons (one or more dwelling units) per gross acre.

b. Highest Priority Areawide Alternatives

i. Minimize population density by encouraging large lot development (one dwelling unit/one or more acres), where possible, to protect the groundwater from future pollutant loading.

ii. Prohibit the establishment of new landfills, and the expansion of existing ones. Upgrade existing landfills, where possible, to minimize further groundwater contamination.

iii. Restrict the use of inorganic, fast-acting fertilizers. Promote the use of low-maintenance lawns.

iv. Require nitrogen removal for treatment plants recharging effluent.

v. Strengthen and enforce regulations pertaining to industrial waste disposal, product storage and transportation of residuals.

vi. Prohibit the use of certain chemical cleaners in on-lot systems.

Zone II: Impaired Water Quality Area

a. Wastewater Management Alternatives. This zone lies mostly within Nassau County Sewage Disposal District No. 3 (Cedar Creek Facilities Planning Area), and is already scheduled to be sewered. Portions of the water supply have been seriously impaired by organic chemical contamination. For these reasons a single sewering alternative and two water supply alternatives are presented.

i. Convey wastewater to the Cedar Creek Sewage Treatment Plant for subsequent ocean disposal.

ii. Require wellhead treatment (physical/chemical treatment, blending) of public supply water if local water quality does not conform to drinking water standards.

iii. If local water quality does not conform to drinking water standards, or if further pumpage is considered inadvisable, water should be imported.

b. Highest Priority Areawide Alternatives

i. Prohibit the establishment of new landfills, and the expansion of existing ones. Upgrade existing landfills, where possible, to minimize further groundwater contamination.

ii. Restrict the use of inorganic, fast-acting fertilizers. Promote the use of low-maintenance lawns.

iii. Strengthen and enforce regulations pertaining to industrial waste disposal, product storage and transportation of residuals.

Zone III: Highest Grade Reservoir. Groundwater in this zone is generally of excellent quality. The groundwater resource in this zone offers a large potential for further development of public water supplies, provided that measures are taken to ensure the protection of groundwater quality.

a. Wastewater Management Alternatives

Alternative A—Total Reliance on Non-Structural Controls

i. Permit no additional sewering.

ii. Determine the acceptability of a given residential lot size and of commercial and industrial activities on the basis of their impact on groundwater quality.

iii. Strictly control, and possibly upgrade, on-site systems.

iv. Strictly regulate site development and management practices, such as grading and maintenance of vegetation, to control runoff.

Alternative B—Land Use Controls

i. Land use controls should be employed to assure the least intensive use of land wherever possible. Development of this zone for residential, commercial, industrial or agricultural use should be discouraged. However, where residential development cannot be avoided, large lot development should be required. Large land holdings should be maintained and public holdings should be increased to the extent possible.

ii. Institute a water table aquifer monitoring program to provide early warning of incipient degradation of the excellent water quality, and to permit timely action to protect the groundwater.

Alternative C—Maximum Sewering Option

Provide sewering for all areas with three or more persons (one or more dwelling units) per gross acre.

b. Highest Priority Areawide Alternatives

i. Require nitrogen removal for treatment plants recharging effluent.

ii. Provide for the routine maintenance of on-site disposal

systems.

iii. Restrict the use of inorganic, fast-acting fertilizers. Promote the use of low-maintenance lawns.

iv. Prohibit the construction of new landfills or the expansion of existing landfills. Presently operating landfills should be upgraded, insofar as possible, in order to minimize groundwater contamination.

v. Control stormwater runoff to minimize transport of nutrients, metals and organic chemicals to groundwaters.

vi. Strengthen and enforce regulations pertaining to industrial waste disposal, product storage and transportation of residuals.

vii. Prohibit the use of certain chemical cleaners in on-lot systems.

Zone IV: North Fork and Eastern South Fork

a. Wastewater Management Alternatives. This zone is characterized by unique groundwater conditions, especially with respect to local water quality problems such as high nitrate levels in farm areas and saltwater upconing where pumpage is concentrated. One water supply and four sewering alternatives are presented.

Alternative A—Importation of Future Water Supplies

Agricultural usage would be allowed to continue or expand. Groundwater quality controls should be employed only in areas of present residential use. Public water may be imported from Zone III if groundwater contamination becomes pervasive. Even presently adequate water supplies may be replaced with imported and/or renovated water. Wastewater controls will be minimal.

i. Only areas where on-lot disposal systems are subject to failure, or where the surface waters are threatened would be sewered. (This can be equated essentially to the minimum sewering option.)

ii. No new public water supply wells will be installed and existing public water supply wells will be abandoned as concentrations of nitrates or other contaminants exceed drinking water standards.

Alternative B—Total Reliance on Non-Structural Controls

i. Permit no additional sewering.

ii. Determine the acceptability of a given residential lot size and of commercial and industrial activities on the basis of their impact on groundwater quality.

iii. Strictly control, and possibly upgrade, on-site systems.

iv. Strictly regulate site development and management practices, such as grading and maintenance of vegetation to control runoff.

Alternative C—Minimum Sewering Option

i. Provide sewering for areas with six or more persons (two or more dwelling units) per gross acre in areas of high water table and/or low soil permeability.

ii. Provide sewering for all other areas with nine or more persons (three or more dwelling units) per gross acre.

Alternative D—Intermediate Sewering Option

Provide sewering for all areas with six or more persons (two or more dwelling units) per gross acre.

Alternative E—Maximum Sewering Option

Provide sewering for all areas with three or more persons (one or more dwelling units) per gross acre.

b. Highest Priority Areawide Alternatives

i. Reduce excessive use of irrigation water and require the permitting, regulation and monitoring of irrigation wells.

ii. Optimize the timing of agricultural fertilizer applications.

iii. Control the establishment of new landfills, and the expansion of existing ones. Upgrade existing landfills, where possible, to minimize further groundwater contamination. In cases of extreme hardship, new landfills may be permitted if extraordinary measures are taken to protect surface and groundwater. However, the relocation of landfills out of the zone should be encouraged.

iv. Optimize pumping patterns to minimize saltwater intrusion in public water supply wells.

v. Minimize population density by encouraging large lot development (one dwelling unit/one or more acres), where possible to protect the groundwater from future pollutant loadings.

vi. Prohibit the use of certain chemical cleaners in on-lot systems.

Zone V—Western South Fork

a. Wastewater Management Alternatives. The groundwater regime and quality problems resemble those of Zone IV, but agriculture is of less importance; therefore, the same alternatives as listed in Zone IV apply.

b. Highest Priority Areawide Alternatives

i. Minimize population density by encouraging large lot development (one dwelling unit/one or more acres), where possible, to protect the groundwater from future pollutant loading.

ii. Control the establishment of new landfills, and the expansion of existing ones. Upgrade existing landfills, where possible, to minimize further groundwater contamination. In cases of extreme hardship, new landfills may be permitted if extraordinary measures are taken to protect surface and groundwater. However, the relocation of landfills out of the zone should be encouraged.

iii. Reduce excessive use of irrigation water to minimize salt water intrusion.

iv. Optimize pumping patterns to minimize saltwater upconing.
v. Restrict the use of inorganic, fast-acting fertilizers. Promote the use of low-maintenance lawns.

Zone VI—Surface Water Impact Area. This zone is characterized by a shallow flow system, which directly impacts the water quality in eastern Great South Bay and Moriches Bay. In order to protect the important natural resources of the bays, it is necessary to maintain groundwater and stream nitrogen concentrations at, or below, two milligrams per liter. Alternatives developed for this zone stress the protection of the marine surface water quality.

a. Wastewater Management Alternatives

Alternative A—Total Reliance on Non-Structural Controls

i. Permit no additional sewering.
ii. Determine the acceptability of a given residential lot size and of commercial and industrial activities on the basis of their impact on groundwater quality.
iii. Strictly control, and possibly upgrade, on-site systems.
iv. Strictly regulate site development and management practices, such as grading and maintenance of vegetation, to control runoff.

Alternative B—Sewering Option

Provide sewering for all areas with three or more persons (one or more dwelling units) per gross acre.

Alternative C—New Ocean Inlet

If this alternative should prove feasible, it will relax the constraints in the above alternatives and permit the selection of additional options as described for Zone VII. Study the feasibility of constructing a new inlet(s) through the barrier island to control and reduce the nitrogen levels in eastern Great South Bay through improved dilution and dispersion.

b. Highest Priority Areawide Alternatives

i. Minimize population density by encouraging large lot development (one dwelling unit/two or more gross acres), where possible, to protect the groundwater from future pollutant loadings.
ii. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to ground or surface waters.
iii. Control animal populations and animal waste disposal.
iv. New landfills should be permitted under current New York State policy, provided the site is landward of the primary coastal zone* and the depth to groundwater is sufficient to ensure an adequate unsaturated zone below the bottom of the landfill.
v. Restrict the use or inorganic, fast-acting fertilizers. Promote the use of low-maintenance lawns.
vi. Require nitrogen removal for treatment plants recharging effluent.
vii. Prohibit any new development along streams and shorelines. Create buffer zones where possible along all water bodies and protect all remaining marine wetlands.
viii. Prohibit the use of certain chemical cleaners in on-lot systems.
ix. Provide for routine maintenance of on-site disposal systems.

Zone VII—South Shore Shallow Flow System. Hydrogeologically, this zone, which contains parts of Nassau and western Suffolk Counties, is similar to Zone VI. Most of the area, however, is currently sewered or is scheduled for sewering within the near future. The alternatives offered for this zone relate primarily to the protection of surface waters. Whereas the adjacent surface waters are not generally as sensitive to nutrient loading as is eastern Great South Bay, the eastern portion of Zone VII does, however, contribute to the nitrogen loading of eastern Great South Bay.

a. Wastewater Management Alternatives

Alternative A—Minimum Sewering Option

i. Provide sewering for areas with six or more persons (two or more dwelling units) per gross acre in areas of high water table and/or low soil permeability.
ii. Provide sewering for all other areas with nine or more persons (three or more dwelling units) per gross acre.

Alternative B—Intermediate Sewering Option

Sewer as in Alternative A and also in areas where potable water is currently obtained from the Glacial aquifer, and densities reach six or more persons (two or more dwelling units) per gross acre.

Alternative C—Maximum Sewering Option

Implement all presently proposed sewer plans, and expand sewering to cover all areas with three or more persons (one or more dwelling units) per gross acre.

b. Highest Priority Areawide Alternatives

i. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to ground or surface waters.
ii. Control animal populations and animal waste disposal.
iii. New landfills should be permitted under current New York State policy, provided the site is landward of the primary coastal zone* and the depth to groundwater is sufficient to ensure an adequate unsaturated zone below the bottom of the landfill.

*The primary coastal zone extends landward for 1000 feet or to the ten foot elevation whichever includes the greater distance from the shoreline or from any stream flowing into marine waters.

Zone VIII—North Shore Shallow Flow System. Although Zones VII and VIII differ hydrogeologically, both are areas that are likely to contribute recharge only to the shallow groundwater system. This flow discharges primarily to streams and marine surface waters, and hence will have a greater effect on these surface systems than on the deep flow drinking water supply. Since Zones VII and VIII are similar with respect to groundwater and surface water constraints, the same alternatives (both areawide and wastewater management) apply to both. The Glen Cove area presents a special problem in that portions of the water supply have been seriously impaired by organic chemical contamination. Water supply options listed for Zone II are applicable to the Glen Cove sector of Zone VIII.

3.5.2.2 Surface Water Alternatives

A. Western Long Island Sound. Western Long Island Sound waters contain high levels of solids, nitrogen and coliform bacteria. Since most of the suspended solids, nitrogen and coliform bacteria levels in western Long Island Sound can be traced to discharges within New York City, Sound conditions are largely beyond the control of the Nassau-Suffolk 208 Program. Long Island Sound conditions are a dominant influence on Manhasset Bay and Hempstead Harbor. Thus, it is the responsibility of the USEPA and the NYSDEC to require the implementation of waste controls necessary to improve water quality to meet the standards specified for this surface water element. These controls may include nitrogen removal for existing sewage treatment plants and the retention and treatment of combined sewer overflows. Pretreatment for metals and/or organic chemicals may be required if it can be shown that toxic contaminants originating in New York City impact Nassau-Suffolk surface waters.

B. Manhasset Bay. Although the contaminant concentrations in western Long Island Sound dominate the water quality within Manhasset Bay, existing point and non-point sources in this embayment currently produce localized high nitrogen and coliform levels. The following options are available for control of these local conditions.

a. Point Source Control Alternatives:

Alternative i — Upgrade the Port Washington, Great Neck Sewer District and the Great Neck Village Sewage Treatment Plants to include nitrogen removal, with outfalls remaining at their present locations.

Alternative ii — Retain secondary treatment and move present sewage treatment plant outfalls to a mid-bay location.

Alternative iii — Divert sewage influent out of the area to the Cedar Creek treatment facility.

Alternative iv — Divert sewage flows from Great Neck Sewer District and the Village of Great Neck to the Port Washington treatment facility.

Alternative v — Delay upgrading, relocations or diversions until western Long Island Sound improvements are committed. Make no local improvements if minimum sewering is selected for the unsewered portions of the surrounding area.

b. Highest Priority Non-point Source Control Measure:

i. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters.

ii. Strictly enforce existing ordinances prohibiting the discharge of untreated wastes from boats.

C. Hempstead Harbor. The characteristics of this embayment are similar to those of Manhasset Bay. However, the influence of western Long Island Sound is less dominant. The following control options should be considered for Hempstead Harbor.

a. Point Source Control Alternatives:

Alternative i — Implement nitrogen removal for both the Glen Cove and Roslyn Sewage Treatment Plants.

Alternative ii — Retain secondary treatment and relocate outfalls to mid-harbor sites for both the Glen Cove and Roslyn Sewage Treatment Plants.

Alternative iii — Divert the Roslyn influent to Glen Cove, Port Washington or Cedar Creek.

Alternative iv — Delay upgrading, relocations or diversions until western Long Island Sound improvements are committed. Make no local improvements if minimum sewering is selected for the unsewered portions of the surrounding service area.

b. Industrial Point Source Control Alternatives:

Monitor and abate all industrial discharges to Glen Cove Creek.

c. Highest Priority Non-point Source Control Measures:

i. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters.

ii. Encourage the relocation of solid waste handling operations and landfills, which are now sited within the coastal zone, to sites outside it.

D. Oyster Bay. Oyster Bay has relatively good water quality and is surrounded by a large number of wetland areas. Except for the densely developed, unsewered Bayville area, which is affected by on-site treatment system failures, the choices for this surface water body relate to the level of commitment to the maintenance of a pristine Oyster Bay environment. Non-point source controls are especially important for the protection of the local shellfishing industry.

a. Point Source Control Alternatives:

Alternative i — Retain the present method of treatment and outfall for the Oyster Bay Sewage Treatment Plant. If a plant

is constructed at Bayville, locate the outfall in Long Island Sound.

Alternative ii Divert the Oyster Bay influent (and Bayville, if sewered) out of the area to the Cedar Creek treatment facility in order to retain the relatively pristine quality of the embayment.

Alternative iii Implement nitrogen removal at the Oyster Bay treatment facility.

Alternative iv Divert the Oyster Bay influent (and Bayville, if sewered) to the Glen Cove treatment facility.

b. Highest Priority Non-point Source Control Measures:

i. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters.

ii. Prohibit, or severely restrict, all further development in shoreline areas. Establish adequate buffer zones around wetlands. Assign priority to public acquisitions, based on the protection of groundwater quality and natural resources.

iii. Strictly implement existing ordinances prohibiting the discharge of untreated wastes from boats.

E. Huntington Bay. Water quality data shows that the four harbor areas in Huntington Bay exhibit high nitrogen levels and depressed dissolved oxygen levels. Thus, whether or not minimum sewering options are selected, the discharges into those bays require more extensive treatment.

a. Point Source Control Alternatives:

Alternative i Institute nitrogen removal for both the Huntington and Northport Sewage Treatment Plants.

Alternative ii Relocate Huntington and Northport outfalls to mid-bay and allow secondary treatment to be continued.

Alternative iii Institute tertiary treatment and recharge.

Alternative iv Divert all sewage flows to the Huntington treatment facility, or to an alternative regional site.

Alternative v Serve areas outside existing sewered areas by small treatment plants with effluent recharge.

b. Highest Priority Non-point Source Control Measures:

i. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters.

ii. Strictly implement existing ordinances prohibiting the discharge of untreated wastes from boats.

iii. Control animal populations and animal waste disposal.

F. Port Jefferson Harbor. Modeling studies of Port Jefferson Harbor show that sewage treatment plant loads will affect bay water quality only if flows increase significantly.

a. Point Source Control Alternatives:

Alternative i Utilize secondary treatment and present discharge location, provided that there is no significant increase in flow.

Alternative ii Institute nitrogen removal for the Port Jefferson sewage treatment plant.

Alternative iii Relocate the outfall to mid-harbor and allow for secondary treatment.

b. Highest Priority Non-point Source Control Measures:

i. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters.

ii. Strictly implement existing ordinances prohibiting the discharge of untreated wastes from boats.

G. Flanders Bay—Peconic Estuary. The Peconic Estuary, into which the Riverhead Sewage Treatment Plant now empties, shows high chlorophyll counts and frequently low dissolved oxygen levels. A similar condition exists in the numerous creeks that flow into Flanders and Peconic Bays. Thus, discharges into the Peconic Estuary can only be allowed if nitrogen removal is instituted and if flows do not increase significantly.

a. Point Source Control Alternatives:

Alternative i If minimum sewering options are selected for the Riverhead service area, institute nitrogen removal for the Riverhead Sewage Treatment Plant.

Alternative ii If minimum sewering options are selected for the Riverhead service area, then utilize secondary treatment with relocation of the outfall to a mid-bay location.

Alternative iii If one D.U./acre or two D.U./acre sewering options are selected for the Riverhead service area, institute nitrogen removal for the Riverhead Sewage Treatment Plant and relocate the outfall to an open bay location.

Alternative iv If one D.U./acre or two D.U./acre sewering options are selected for the Riverhead service area, relocate the treatment plant outfall to Long Island Sound or Flanders Bay.

Alternative v Institute tertiary treatment and recharge.

b. Highest Priority Non-point Source Control Measures:

i. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters.

ii. Prohibit, or severely restrict, all further development in shoreline areas. Establish adequate buffer zones around wetlands. Assign priority to public acquisition, based on the protection of groundwater quality and natural resources.

iii. Initiate a study to determine the impact of duck sludges as a source of nutrients and bacteria, and the feasibility of their removal.

c. Special Monitoring Requirements:
Provide for further monitoring, specifically for dissolved oxygen nutrients and chlorophyll a to better define and select one of the point source control alternatives.

H. Mecox Bay. The only outlet for Mecox Bay is an ephemeral channel connecting to the Atlantic Ocean. This inlet provides limited flushing and drainage of the bay approximately 50 percent of the time. In order to protect the important natural resources of the bay, it is necessary to maintain groundwater and stream nitrogen concentrations at, or below, two milligrams per liter.

a. Point Source Control Alternatives:
Alternative i Prohibit new point source discharges to the bay.
Alternative ii Provide nitrogen removal or complete effluent recycling for duck farm discharges located in the drainage area.

b. New Inlet Alternatives:
Study the feasibility of stabilizing the inlet from the Atlantic Ocean to provide adequate flushing and dispersion.

c. Highest Priority Non-point Source Control Measures:
i. Prohibit, or severely restrict, all further development in shoreline areas. Establish adequate buffer zones around wetlands. Assign priority to public acquisition, based on the protection of groundwater quality and natural resources.
ii. Provide for routine maintenance of on-site disposal systems.
iii. Restrict the use of inorganic, fast-acting fertilizers. Promote the use of low-maintenance lawns.
iv. Initiate a study to determine the impact of duck sludges as a source of nutrients and bacteria and the feasibility of their removal.

I. Shinnecock Bay. Shinnecock Bay is a shallow bar-built estuary, whose water quality is regulated by tidal flushing through the ocean inlet. The inlet is in a mode of unstable deposition, and it is imperative to keep it open in order to maintain the present water quality conditions.

a. Point Source Control Alternatives:
Alternative i Prohibit new point source discharges to the bay.
Alternative ii Maintain the ocean inlet to provide adequate flushing and dispersion.

b. Highest Priority Non-point Source Control Measures:
i. Prohibit, or severely restrict, all further development in shoreline areas. Establish adequate buffer zones around wetlands. Assign priority to public acquisition, based on the protection of groundwater quality and natural resources.
ii. Provide for the routine maintenance of on-site disposal systems.
iii. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters.

J. Moriches Bay. Moriches Bay is a shallow bar-built estuary, whose water quality is regulated by tidal flushing through the ocean inlet. The inlet is currently subject to an unstable scouring trend, and flushing is increasing. However, it is still desirable to maintain groundwater and stream nitrogen concentrations at, or below, two milligrams per liter in order to protect the bay's important natural resources.

a. Point Source Control Alternatives:
Alternative i Prohibit new point source discharges to the bay.
Alternative ii Provide nitrogen or complete effluent removal from duck farms located in the drainage area.

b. Highest Priority Non-point Source Control Measures:
i. Control animal populations and animal waste disposal.
ii. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters.
iii. Initiate a study to determine the impact of duck sludges as a source of nutrients and bacteria and the feasibility of their removal.

K. Great South Bay. Great South Bay is a large and complex system. Control strategies for specific pollutant loads need to be formulated on a case by case basis using the available data analyses and modeling tools. In general, western Great South Bay is well flushed and eastern Great South Bay is poorly flushed. Strict controls are required for the eastern portions of the bay. In order to protect the important natural resources of the bay, it is necessary to maintain groundwater and stream nitrogen concentrations at, or below, two milligrams per liter.

a. Point Source Control Alternatives:
Alternative i Prohibit new point source discharges into eastern Great South Bay and divert to an ocean outfall.
Alternative ii Prohibit new point source discharges into eastern Great South Bay and recharge tertiary treated effluent.
Alternative iii Provide nitrogen removal for the Patchogue Sewage Treatment Plant.

b. New Inlet Alternative:
Study the feasibility of constructing a new inlet through the barrier island to control and reduce the nitrogen levels in eastern Great South Bay.

c. Highest Priority Non-point Source Control Measures:
i. Control stormwater runoff to minimize the transport of sedi-

ments, nutrients, metals, organic chemicals and bacteria to surface waters.

ii. Control animal populations and animal waste disposal.

iii. Restrict the use of inorganic, fast-acting fertilizers. Promote the use of low-maintenance lawns.

iv. Require nitrogen removal for treatment plants recharging effluent.

v. Prohibit any new development along streams and shorelines. Create buffer zones where possible along all water bodies and protect all remaining marine wetlands.

vi. Strictly implement existing ordinances prohibiting the discharge of untreated wastes from boats.

L. Western South Shore Bays. Western South Shore bays are relatively well flushed but are sensitive to high pollutant loads. The dominant nitrogen and coliform loads requiring control are contributed by the Bay Park Treatment Plant discharge.

a. Point Source Control Alternatives:

Alternative i Locate the Bay Park Sewage Treatment Plant outfall offshore.

Alternative ii Divert the Long Beach Sewage Treatment Plant effluent to the proposed Bay Park ocean outfall.

Alternative iii Institute further study to determine which of the following steps should be selected, if water quality standards are violated in Bannister Creek: divert the Lawrence treatment facility effluent to Reynolds Channel; divert the influent to the Bay Park plant; provide nitrogen removal.

b. Highest Priority Non-point Source Control Measures:

i. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters.

ii. Control animal populations and animal waste disposal.

iii. Strictly implement existing ordinances prohibiting the discharge of untreated wastes from boats.

M. Nearshore Atlantic Ocean. It is the responsibility of the USEPA and NYSDEC to implement the necessary wastewater controls to prevent the discharge of contaminants and floatable material into the New York Bight. Such contaminants and floatables have periodically impaired the use of regional ocean bathing beaches. These regulations should apply to the control and treatment of raw or inadequately treated sewage discharges, industrial discharges and combined sewer overflows from sites located in New York City and New Jersey.

N. Fresh Water Bodies. Non-point pollution is the major source of contamination of streams and lakes. Generally, the water quality problems are caused by excessive nutrient and bacteria loadings. However, the greatest problem is not the effects of these contaminants on the streams themselves, but the contribution they make to the pollution of some of the bays.

a. Point Source Control Alternatives:

Require nitrogen removal for all treatment plants which discharge to streams.

b. Highest Priority Non-point Source Control Measures:

i. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters.

ii. Control animal populations and animal waste disposal.

iii. Prohibit any new development along streams and shorelines. Create buffer zones where possible along all water bodies, and protect all remaining marine wetlands.

iv. Provide for routine maintenance of on-site disposal systems.

3.5.3 Selection of Alternatives for the Areawide Waste Treatment Management Plan. Section Three has marshalled all the significant options available for the management of point and non-point sources, and has identified those which are most pertinent to the hydrogeologic zones and surface water segments of Nassau and Suffolk Counties. The economics have been discussed, wherever useful information is available.

It has been seen that marine surface water quality is closely associated with the quality of groundwater in adjacent areas. Furthermore, the enhancement of both groundwater and surface water quality demands the employment of many of the same point and non-point source controls, both structural and non-structural.

The environmental impacts of all the pertinent options are examined in the following section, Section Four.

On the basis of the information summarized in Section Three and Four (and available, in full, in the reports generated in the course of the 208 Study Program), the final selection of alternatives of the Areawide Waste Treatment Management Plan is made and discussed in Section 5.

Section 4 Environmental Assessment

4.0 Introduction

The Water Quality Management Plan (WQMP) will have a wide range of environmental and health impacts. These include surface water, groundwater, solid waste, land use and air impacts. The design of the Nassau-Suffolk 208 Program has allowed a detailed investigation of surface water and groundwater impacts, an overview of solid waste impacts, and a snapshot of land use and air impacts. Thus, surface and groundwater impacts, which are the most significant, have been emphasized in this assessment.

There are four major types of control available for preservation of surface and groundwater quality; these are structural and non-structural point source and non-point controls. There are uncertainties associated with the impacts of each control type. Structural point source controls have uncertainties of cost burden and of engineering feasibility for organics removal. Structural non-point controls have both cost uncertainties and engineering effectiveness uncertainties (new technologies). Non-structural point source controls have legal/institutional implementability uncertainties. Non-structural non-point controls have implementability uncertainties and also uncertainties as to abatement effectiveness. Non-structural controls are the environmentally preferred approach since they involve the least extensive secondary environmental impacts and are least irreversible. Structural point source controls constitute the least environmentally sound approach since they involve extensive commitment of resources and major rerouting and alterations of natural biogeochemical cycles.[1] This in turn means that structural point source controls impose extensive secondary impacts and are largely irreversible. Costly untested technologically intensive approaches are then required to mitigate secondary impacts.

There are several key water quality problems that have been addressed in this assessment; these are nutrient levels and ratios in bays, pathogens in bay waters and shellfish, salinity gradients in Great South Bay, water table levels, organic chemicals in groundwater, nitrogen in groundwater, hazardous waste loads and sludge loads. Careful control of some of these problems can only be achieved by sacrificing the level of control of some others. Thus, tradeoffs exist between various categories of environmental risks and controls. The tradeoffs have been presented in this assessment and must ultimately be resolved by government and/or citizen decisions.

This section discusses those environmental impacts which are likely to result from the various planning options as set forth in Section 3.5. The impacts are discussed in terms of several types of health-related and ecological effects. These categories of effects are set forth in Section 4.1. Types of effects which can be discussed on an areawide basis are presented in Section 4.2. This section has been organized to correspond to Section 3.5.1, "Areawide Alternatives", as closely as possible. Types of effects specific to the bays and groundwater zones are presented in Section 4.3, which corresponds to Section 3.5.2, "Area Specific Alternatives." Economic costs are discussed in Section 4.4. These four sections are then drawn together in a final section which presents a summary of the overall tradeoffs and recommendations (Section 4.5).

[1] Including H_2O, carbon, nitrogen, phosphorus, potassium and trace nutrient cycles.

4.0.1 Impact Categories. This assessment discusses environmental impacts in the four categories suggested by 40CFR6 (Subpart E):

1. *Short–Term Primary Impacts.* These effects, relevant only to structural options, are generally immediate results of construction that will be abated once the actual construction is completed. Such short-term impacts include those due to dredging, increased erosion, increased turbidity, altered topography, and leaks and spills from construction sites.

2. *Long–Term Primary Impacts.* Such effects are not transitory, but result from the permanent alteration of an environment by an action. Long-term nutrient, bacterial and BOD increases or decreases fall under this category, as does the loss or addition of wetlands and open spaces. Populations of organisms may increase or disappear as a result of such changes. If short-term impacts such as vegetation removal and erosion are not alleviated, they may become long-term impacts.

3. *Secondary Impacts.* Secondary impacts are not a direct result of an activity, but are induced as succeeding links in a chain of effects set off by the initial action. Secondary impacts as a result of water quality management include, for example, induced land use changes and development as a consequence of sewering programs, air quality impacts of sludge generation and disposal, and alterations in salinity gradients in Great South Bay resulting from groundwater table changes; whereas loss of potential public works jobs could be considered a secondary impact of not sewering.

Intermedia tradeoffs and transfers are an important class of secondary impacts that are usually overlooked in resource management and planning because of the technical difficulty in relating causes to effects or to the magnitude of the effects. Intermedia tradeoffs include surface water-groundwater, surface water-air and surface water-solid waste tradeoffs.

4. *Irreversible and Irretrievable Commitment of Resources.* The natural environment is composed of many links and feedbacks, which give the system flexibility to adapt to changes in the physical world. This flexibility is tested whenever natural disasters, such as storms or hurricanes, occur. Changes induced by humans, if done wisely and prudently, may be dealt with in a similar way by an ecosystem. However, as man continues to alter the environment, the ecosystem eventually fails to adapt, and permanent destruction of the previous habitats results. This category includes those actions, such as the extinction of a species or loss of a wetland, that will result in permanent loss of a resource. These actions are beyond the ability of the environment to alleviate, and therefore should be very carefully considered before implementation.

4.0.2 Uncertainties. The evaluation of environmental impacts is complicated by uncertainties as to the effectiveness of control measures. These uncertainties are due to the newness of many of the control technologies. There have been few previous applications of these controls and therefore performance data are largely lacking. Some of the main uncertainties that are encountered are summarized in Table 4–1.

Table 4–1

UNCERTAINTIES IN PROPOSED CONTROL MEASURES

	Type of Uncertainty				
Measure	**Engineering (feasibility of the technology)**	**Performance (effectiveness of the technology)**	**Legal Institutional (implementability**	**Public Cost Burden (cost to taxpayer)**	**Private Cost Burden (cost to industry)**
Best Management Practices, runoff controls		X	X		
Legal/institutional non-point controls		X	X		
Structural non-point controls		X		X	
Industrial pre-treatment	X		X		X
Sewering at 1 to 3 D.U./Gross Acre			X	X	
Stream Augmentation	X	X		X	
Recharge	X	X		X	

Source: ERCO

4.1 Assessment Criteria: Categories of Health and Ecological Effects

The effects of the proposed 208 Plan for Long Island have been evaluated with respect to several types of environmental risk. These include public health problems, natural resource problems, and other environmental problems. These types of problems are set forth below. The evaluations of some of them are straightforward. For example, health risks due to metals are evaluated in terms of drinking water standards. Others are more qualitative. For example, health risks due to viruses have no standards associated with them.

4.1.1 Health Risks. Health risks being considered in this assessment are of three types: first, the effects of toxic chemicals and pathogenic organisms in drinking water; second, the effects of pollutants in fish and shellfish used for human consumption; and third, the carcinogenic effects of organics in drinking water. These various effects have been considered according to pollutant type: metals, organics, nitrates, coliform bacteria and viruses.

4.1.1.1 Metals. Public health standards (NYS Health Standards) for various metals in drinking water are shown in Table 4–2. Standards for metals take into account an individual's overall intake of the metal. Such standards are also applicable to metals in food such as shellfish and fish. These standards can be used to evaluate the acceptability of plan alternatives with respect to trace metals health risks.

A sampling program has been carried out to measure metal concentrations in various water environments. It was carried out as part of a sampling program to measure levels of organic contaminants in groundwater. Thus,

Table 4–2

MAXIMUM CONTAMINANT LEVELS FOR METALS

	NYS[a] Drinking Water Regulations (mg/l)	NYS[b] Groundwater Regulations (mg/l)	Proposed Groundwater[c] Classifications, Quality Standards and Effluent Standards and or Limitations (mg/l)
Arsenic	0.05	0.2	0.05
Barium	1.0	2.0	1.0
Cadmium	0.01	0.02	0.01
Chromium (hexavalent)	0.05	0.1	0.05
Lead	0.05	0.1	0.05
Mercury	0.002	–	0.002
Selenium	0.01	0.02	0.01
Silver	0.05	0.1	0.05
Iron	–	0.6	0.3
Manganese	–	0.6	0.3
Zinc	–	0.6	5.0
Copper	0.1	0.4	–

[a]*Levels allowable in drinking water under the NYS Department of Health Drinking Water Standards. Source: Sanitary Code, Subpart S–1 Public Water Supply.*

[b]*Levels allowable in groundwater under New York State Regulations, Title Six, Section 703.4. Source: NYS, 1967.*

[c]*Title Six, 703.5 Proposed, NYS, May 1977.*

the sampling plan was designed to test water quality of areas likely to be organically contaminated. The set of samples does not necessarily represent the set that would have been selected if the major purpose was to identify metal contaminant problems. However, there are a variety of samples from areas near landfills, scavenger waste lagoons, and effluent discharges, as well as from typical residential areas. Thus the set of samples is reasonably representative of expected areas of contamination by metals. The metals for which the samples were tested (arsenic, barium, cadmium, chromium, lead, mercury and selenium) are those included in the 1976 EPA Interim Primary Drinking Water Regulations. A total of 124 samples were tested. Barium, selenium and silver were low in all samples. Arsenic, cadmium and chromium were low in most samples; however, they were high in certain types of effluent. Lead occurred at a significant level in various types of samples, and further diagnostic sampling would be prudent. Mercury occurred at concentrations in violation of standards in 38 samples with no apparent patterns of occurrence. A further sampling effort is needed to verify the extent of the problem and to identify possible sources. Table 4–3 summarizes the results.

4.1.1.2 Organics. Health risks from organic chemicals include (1) toxic effects, (2) carcinogenesis risk from low levels of organics in drinking water, (3) bioaccumulation in certain organs of shellfish and fish, and (4) tainting of shellfish and fish by hydrocarbons and other odor and taste-inducing organics. Monitoring results have indicated that the first and second of these four types of problems are of real concern (*e.g.*, ERCO; NCDH, 1977a). The third was of concern in the past when DDT and related pesticides were in common use (Porter *et al.*, 1977) and is now mainly of concern with respect to fish that spawn in such areas as the Hudson River where substances such as PCB's occur (ERCO). The fourth has not been shown to be a problem on Long Island.

Table 4–3

SUMMARY STATISTICS FOR COMPLETE SAMPLING PROGRAM
(mg/l unless otherwise noted)

Metal	EPA 1976 Drinking Water Standard	Observed Range	Observed Mean	Observed Median	Percent Violations of Standard	Percent Higher than 50 Percent of Standard Value
Arsenic	0.05	<0.0025–0.14	0.0004	<0.0025	0.8	0.8
Barium	1.0	<0.03–0.5	<0.03	<0.03	0.0	0.8
Cadmium	0.01	<0.00015–0.039	0.0013	<0.0005	2.4	3.2
Chromium	0.05	<0.0002–0.069	0.0015	<0.0002	0.8	1.6
Lead	0.05	<0.0007–0.24	0.01	0.002	6.4	6.4
Mercury (μg/l)	2	<0.13–5.2	1.8	0.44	18.7	37.0
Selenium	0.01	<0.004–0.011	<0.004	<0.004	0.8	2.4
Silver	0.05	<0.00025–0.14	0.002	<0.00025	1.6	2.4

Source: ERCO

SAMPLING PROGRAM

Included in the 208 was a sampling program initially designed to determine in a general way whether or not organic chemicals in domestic wastes or runoff would preclude treated sewage recharge. Early in the sampling effort it became clear that several organics were being identified in significant quantities. However, the techniques available for analysis of volatile organic compounds are still in a state of development (ERCO). Thus, it was difficult to quantify levels of volatile contaminants during the first part of the sampling program. Also, available toxicological literature is sketchy so that it is difficult to establish criterion levels. Since every groundwater sample analyzed showed some contamination, a pollutant hazard was indicated. This result, which did not answer the original question concerning recharge, is very significant from a public health standpoint. The last half of the sampling program was revised in order to address existing contamination from various sources rather than potential recharge effects. The final samples included some designed to help identify contaminant sources. The results for the second half of the sampling program were quantitatively accurate. For example, the final 24 samples were accurate to within twenty percent. The analytical results indicate that there is a significant public health risk. Further sampling programs are required to reduce present uncertainties concerning precision of the data, distribution of the contaminants, and identification of the sources. A summary of the ERCO results is given in Tables 4–4, 4–5 and 4–6. A summary of results of other surveys is given in Tables 4–7 through 4–10.

Table 4–4

SUMMARY STATISTICS–VOLATILE ORGANIC COMPOUNDS

Compound	# stations measured	# stations detected		# stations occurring @ >10 μg/l		# stations occurring @ >50 μg/l	
trichloroethylene	116	93	(80%)	35	(30%)	15	(13%)
chloroform	82	68	(77%)	20	(24%)	4	(5%)
1,1,1 trichloroethane	116	57	(49%)	25	(21%)	6	(5%)
carbon tetrachloride	78	28	(36%)	1	(1%)	0	
tetrachloroethylene	116	38	(33%)	10	(8%)	5	(4%)
dibromochloromethane	78	15	(19%)	0		0	
diethyl ether	38	6	(16%)	0		0	
1,1 dichloroethane	44	5	(11%)	3	(7%)	0	
bromodichloromethane	78	8	(10%)	3	(4%)	1	(1%)
freon–11	44	4	(9%)	0		0	
1,1 dichloroethylene	44	4	(9%)	0		0	
1,2 dichloroethane	44	3	(7%)	0		0	
bromoform	78	5	(6%)	1	(1%)	0	
1 chloropropane	44	1	(2%)	1	(2%)	0	

Source: ERCO

Table 4–5

SUMMARY STATISTICS–NONVOLATILE ORGANIC COMPOUNDS

Compounds detected at >10 μg/l for at least one station	Number of Stations >1 μg/l	Number of Stations >10 μg/l	Number of Stations >50 μg/l
methyl naphthalene	45	2	1
dimethyl naphthalene	37	3	0
dibutyl phthalate	34	20	8
octyl phenols	27	4	1
C_4 benzene	20	4	0
di-tert-butyl phthalate	20	6	2
phthalate (composition undetermined)	19	2	1
naphthalene	19	3	0
phthalate derivative (composition undetermined)	14	1	0
dibutoxy-ethoxy-ethyl methane	13	4	1
phthalate compound (composition undetermined	8	1	0
acenaphthene	6	1	0
C_{16} alkane	6	2	0
C_{28} alkane	6	1	1
tri-t-butyl orthoformate	6	1	0
diethyl benzene	5	2	0
2,3 dimethyl naphthalene	4	1	0
thymol	3	1	0
cyclohexane	3	2	1
o,m xylenes	2	1	1
isopropyl benzene	2	1	1
C_{20} alkane	2	1	0
trimethyl hexanoic acid	1	1	0

Source: ERCO

DISCUSSION OF RESULTS

The sampling results show the following:

a. *Water Media Characteristics*

Glacial Aquifer. Over one third of the sixty wells tested were significantly contaminated by volatiles and over one half by methylene chloride extractables. Of more serious concern, one fifth of the wells contained organic contaminants at the 50 parts per billion level, the level currently in use as the threshold for health risks from potentially carcinogenic organics. The sample size is sufficiently large for there to be little doubt that significant levels of organic contaminants occur in the Glacial aquifer.

Table 4–6

SUMMARY STATISTICS–ORGANIC CONTAMINANTS IN WATER, NASSAU AND SUFFOLK COUNTIES

	Volatiles				Methylene Chloride Extractables			
Medium	# stations	# stations w/at least 1 compound >10 μg/l	# stations w/at least 1 compound >50 μg/l	# stations w/at least 1 compound >100 μg/l	# stations	# stations w/at least 1 compound >10 μg/l	# stations w/at least 1 compound >50 μg/l	# stations w/at least 1 compound >100 μg/l
Effluent	12	6	3	0	12	4	1	1
Magothy	11	4	2	1	12	1	0	0
Glacial	66	31	14	7	69	32	12	3
Water Supply	14	8	3	2	11	4	1	1
Lloyd	1	1	0	0	1	1	0	0
Surface Water	1	1	0	0	1	1	0	0

Source: ERCO

Table 4–7

PESTICIDES IDENTIFIED IN USGS TEST OF WELLS LOCATED IN SUFFOLK COUNTY

Well No.	Pesticides and/or Herbicides (μg/l) identified in general screening process	Levels observed in subsequent resampling event (μg/l)
S43808	Dieldrin = .01	less than .01
S43815	PCB = trace	
S43819	Silvex = .01	less than .01
S45208	PCB = trace	
S46912	DDE = .01 DDT = .02 Dieldrin = .09	all less than .01
S46913	DDD = .04 DDE = .02 DDT = .08 Dieldrin = .11	all less than .01
S46914	Dieldrin = .02	less than .01
S46963	2,4–D = trace	less than .01
S47222	Silvex = trace	less than .01
S47230	Silvex = trace	less than .01
S47235	DDD = trace DDE = trace	both less than .01
S47977	2,4–D = .07	less than .01
S48425	2,4–D = trace	less than .01
S48946	PCB = trace	
S51575	DDD = 8.1	DDD = !.6
S51583	Dieldrin = .01	less than .01

Source: Baier, J.H., 1976.

Magothy Aquifer. Volatile organics appear to have penetrated to the Magothy aquifer. Methylene chloride extractables have not been measured at significant (>10 μg/l) levels. However, the sample size of Magothy wells tested is small; therefore, no firm statistical conclusions as to the extent of the contamination can be presented.

Effluent. Volatile and methylene chloride extractable organics are present in the effluents that have been sampled. Most of these are sewage treatment plant effluents, some of which are presently recharged. The halogenated volatile organics may be resulting from chlorination of effluents; however, comparative sampling of chlorinated and unchlorinated effluents is required to verify this.

Lloyd Aquifer. A single sample was taken from this formation. The sample showed no contamination. However, no conclusions are possible from this data.

b. *Chemical Species Characteristics*

Trichloroethylene, Chloroform, 1,1,1 Trichloroethane, Tetrachloroethylene. Three of these substances are occurring in at least fifty percent of the stations tested. Incidence of 50 parts per billion observations is over four percent. Many of the occurrences noted in this study are in Glacial aquifer wells. However, sampling of Nassau County water wells (NCDH, 1977a) shows a significant level of occurrence of these contaminants in water supply wells, many of which draw from the Magothy. As noted in Section Three, chloroform and trichloroethylene appear on the NAS (1977) list of known animal carcinogens. Thus, the presence of these chemicals in the Magothy aquifer presents a health risk. Identification and control of the sources of these contaminants should be of high priority.

Table 4–8

ORGANICS OBSERVED ON LONG ISLAND IN 1976

		Fractions from the Extraction Procedure				
	Volatile Organics	Neutral Fraction	Acidic Fraction	Acid Esterified Fraction	Basic Fraction	Particulate Extract
Untreated storm-water runoff	benzene toluene ethyl benzene p–xylene n–xylene	ethyl phthalate butyl phthalate isobutyl phthalate (T) ethyl hexyl phthalate dioctyl phthalate 2 additional phthalate compounds	methyl–18 methoxy-abiatata 2–isopropy–1,3-dioxolane ethyl benzaldehyde (T) diethyl phthalate methyl palmitate butyl phthalate dioctyl phthalate	methyl nonanoate phthyl eicosane (T) methyl xyristate methyl palmitate methyl stearate squalene (T)	diethyl phthalate dibutyl phthalate diotyl phthalate	ethyl phthalate ethyl hexyl phthalate dioctyl phthalate 2 additional phthalate compounds
Groundwater percolate of untreated storm-water runoff	methylene chloride benzene toluene 3 additional aromatic BC's	ethyl phthalate ethyl hexyl phthalate phthalate compound dioctyl phthalate	diethyl phthalate butyl phthalate 2–isopropyl–1,3–dioxolane dioctyl phthalate 1–decyne (T)	benzyl–2 (benzyl thio) propionate (T) methyl myristata (T) diethyl phthalate methyl palmitate methyl stearate butyl phthalate dioctyl phthalate squalene (T)	dioctyl phthalate	ethyl phthalate butyl phthalate ethyl hexyl phthalate dioctyl phthalate phthalate compound
Blank	methylene chloride (T)	butyl phthalate isobutyl phthalate butyl isobutyl phthalate	ND	ND	butyl phthalate octyl phthalate	ND
Medford effluent, tertiary treatment	ND	isobutyl phthalate butyl phthalate butyl isobutyl phthalate dibutoxyethane (T) iso-octyl phthalate	ND	ND	isobutyl phthalate	isobutyl phthalate butyl phthalate butyl isobutyl phthalate

Table 4–8 cont'd.

ORGANICS OBSERVED ON LONG ISLAND IN 1976

Groundwater percolate of Medford effluent tertiary treatment	chloroform	isobutyl phthalate butyl phthalate butyl isobutyl phthalate	methyl isoxanoate nor-octyl eicosane nor-decyl docosane b-butyl docosane 11–n decyl docosane n–pentyl beneicosane 10–n–10–n hexyleicosane n–octyl heptadecane methyl tricosane n–nonacosane n–datriaccotane n–octyl tetracosane	ND	ND	ND
Wantagh effluent, secondary treatment	perchloroethylene o–dichlorobenzene	ND	isobutyl phthalate butyl phthalate	butyl phthalate	butyl phthalate methyl undecane methyl decane	butyl phthalate isobutyl phthalate butyl isobutyl phthalate

Key: *(T) = tentative identification.*
ND = no compounds detected in sample
Source: Slimak and Harris, 1976

Carbon Tetrachloride, Dibromochloromethane. These contaminants have been observed in over 15 percent of the samples. Although they are widely present, they are only found at low levels. Thus, although their wide distribution is of concern, they cannot at present be considered to impose significant health risks.

Other Volatile Organic Contaminants. Eight other volatile compounds have been observed. They occur in only a small number of wells at generally small concentrations. However, in the final set of samples, (QA–1 to QA–24) which were analyzed under the best conditions, both 1,1 dichloroethane and bromodichloromethane occur at significant levels. More samples are needed to say anything about the occurrence of those two compounds. The other volatiles detected are not at present of major concern.

Phthalates. This general class of methylene chloride extractable organics occurs ubiquitously. Phthalate compounds were detected at very high levels in about eight percent of the samples. Phthalates occur as plasticizers. Thus, the presence of phthalates may be partially due to use of plastic tubing as part of the sampling devices. Nevertheless, since phthalates occur on the NAS (1977) list of chronic toxins, it is only prudent to consider the observed high phthalate levels as a health risk.

Other Methylene Chloride Extractable Organic Contaminants. A variety of these compounds were found. Some occurred at levels greater than 50 parts per billion. Eighteen substances occurred at levels greater than ten parts per billion. However, information on health risks imposed by these substances is scanty. Thus, the risk levels cannot presently be assessed. be assessed.

c. *Patterns of Occurrence*

The 124 samples taken represent 102 different sample stations. In most cases, only one sample was collected at each station. Thus, there is little statistical validity associated with looking at the contaminant levels of individual sites. Tables 4–11 through 4–13 present the data grouped according to suspected source categories. These data suggest a number of interesting patterns, which at present should be viewed as preliminary hypotheses. Further sampling is warranted with respect to all of the suspected source categories.

Table 4–9

SUMMARY OF VOLATILE ORGANIC SAMPLING OF NASSAU COUNTY MUNICIPAL WATER SUPPLIES[a][b]

Organic Compound	Number of Samples Observed at $\geq 10\ \mu g/l$[c]	Number of Samples Observed at $\geq 50\ \mu g/l$[c]	Number of Samples Observed at $\geq 100\ \mu g/l$[c]
1,1,2 trichloroethylene	25	7	2
1,1,1 trichloroethane	16	7	4
chloroform	11	1	0
tetrachloroethylene	7	5	4
1,2 dichloroethylene	6	0	0
benzene	3	1	0
toluene	2	0	0
bromodichloromethane	1	0	0
vinyl chloride	0	0	0
tri-fluorotrichloroethane	0	0	0
carbon tetrachloride	0	0	0
methylene chloride	0	0	0
ethyl ether	0	0	0

Source: NCDH, (1977a)

(a) All samples collected between June 1975 and May 1977.

(b) Samples analyzed by various labs using various methods.

(c) Total number of samples is 303; not all compounds analyzed for in all samples.

POTENTIAL HEALTH RISKS DUE TO ORGANIC COMPOUNDS IN WATER

Health risks from organic compounds include: (1) toxic effects; (2) carcinogenic effects from low levels in drinking water; (3) bio-accumulation in certain organs of shellfish, fish and other wildlife; and (4) tainting of shellfish and fish by hydrocarbons and other odor and taste inducing organics. Of these problems, the first and second are of major concern; the third was of concern in Long Island in the past when DDT and related pesticides were in common use (Porter *et al.*, 1977) and is now mainly of concern with respect to fish that spawn in areas such as the Hudson River, where substances such as PCB's occur. The fourth has not been shown to be a problem on Long Island. The organic chemicals study was limited to the first and second types of effects.

The National Academy of Sciences (1977) has recently reviewed the existing literature on environmental pollutants, and has divided the organic contaminants of water supplies into four categories: (1) known or suspected carcinogens (Table 4–14); (2) noncarcinogenic toxins (Table 4–15); (3) compounds which have been insufficiently studied with respect to chronic toxicity; and (4) compounds which have not been subjected to chronic toxicity tests.

Table 4–10

SUMMARY OF VOLATILE ORGANIC SAMPLING OF SUFFOLK COUNTY PUBLIC WATER SUPPLIES[a][b]

Organic Compounds	Number of Samples Observed at $\geq 10\ \mu g/l$	Number of Samples Observed at $\geq 50\ \mu g/l$	Number of Samples Observed at $\geq 100\ \mu g/l$	Total Number of Samples Analyzed
1,1,2 trichloroethylene	46	29	19	125
1,1,1 trichloroethane	41	16	7	121
tetrachloroethylene	18	3	1	122
chloroform	8	2	1	123
carbon tetrachloride	4	0	0	105
1,2 dichloroethylene	2	0	0	30
toluene	1	0	0	48
benzene	1	0	0	49
vinyl chloride	0	0	0	29
trichlorotrifluoroethane	0	0	0	45
bromodichloromethane	0	0	0	62
dichloromethane	0	0	0	7
chlorodibromomethane	0	0	0	1

Source: SCHD, 1978

(a) Samples collected between February 1976 and January 1978.

(b) Analyses by the following labs: NYSHD, Stony Brook; NYSHD, Albany; EPA, Ada, Oklahoma; New York Industrial Testing Lab; EPA, Edison, N.J.; H2M. Corp., Melville, N.Y.

"The potential for existing concentrations of organic pesticides and other organic comtaminants in drinking water to adversely affect health, cannot be answered with certainty at this time. The key issue is whether or not certain organic chemicals found in very low concentrations can cause or increase the rate of cancer development in man. Even though several of these chemicals have demonstrated carcinogenicity in laboratory animals, the extrapolation of such results to man remains difficult for a number of reasons" (NAS, 1977).

Phthalates were detected at concentrations equal to or greater than ten $\mu g/l$ in samples on Long Island (mainly from shallow aquifer wells), and in some cases were detected at concentrations greater than 50 $\mu g/l$. These levels were found by the NAS to constitute a toxicity risk, but not a cancer risk. The NAS (Table 4–15) reported that 38.5 $\mu g/l$ is the threshold level for the safe consumption of di-n-butyl phthalate. Therefore, the observed concentrations of di-n-butyl phthalate exceeds these levels in some Long Island shallow aquifer wells.

According to the NAS, many of the groundwater contaminants that are of concern on Long Island have not been sufficiently studied for their toxicity or carcinogenicity, including tetra-chloroethylene; 1, 2-dichloro-

Table 4–11

EFFLUENT AND GLACIAL CONTAMINATION LEVELS RANKED BY FREQUENCY OF OCCURRENCE OF CONTAMINANTS AT $\geq 10\ \mu g/l$. SAMPLE WAS BIASED TOWARD CONTAMINATED AREAS

	No. of Observations at $\geq 10\ \mu g/l$				No. of Observations at $\geq 50\ \mu g/l$				No. of Samples		
	Volatiles	Methylene Chloride Extractions	Volatiles or Methylene Chloride Extractions #	(% of all observ.)	Volatiles	Methylene Chloride Extractions	Volatiles or Methylene Chloride Extractions #	(% of all observ.)	Volatiles	Methylene Chloride Extractions	Volatiles or Methylene Chloride Extractions
Effluent											
Effluent Type:											
Leachate	1	1	2	(100%)	1	1	2	(100%)	2	1	2
Domestic chlorinated STP Effluent	4	2	5	(71%)	3	1	3	(43%)	4	7	7
Runoff Effluent	1	1	1	(50%)	1	0	1	(50%)	2	2	2
Glacial											
Overlying Land Use/ Aquifer Characteristics:											
Leachate Plumes	3	2	4	(100%)	3	0	3	(75%)	3	3	4
Commercial/Industrial Unsewered	2	2	3	(100%)	1	1	1	(33%)	2	3	3
Wooded	3	1	3	(100%)	1	0	1	(33%)	3	3	3
Agricultural	7	3	7	(88%)	3	0	3	(37%)	7	8	8
Runoff Recharge	6	3	6	(75%)	3	1	4	(50%)	8	8	8
Residential Sewered	1	7	8	(73%)	1	3	4	(36%)	1	10	11
Domestic STP Recharge	3	4	5	(63%)	0	0	0		7	8	8
Residential Unsewered	5	6	8	(50%)	4	5	7	(44%)	6	16	16
Mixed Unsewered	3	1	3	(43%)	1	1	2	(29%)	3	7	7

Source: ERCO

ethane; bromoform; bromodichloromethane; and propyl benzene. Others, such as 1, 1, 1-trichloroethane and dibromochloromethane were not included in the NAS study. Thus, despite the existence of information enabling the assessment of health risks for a few of the organic chemicals of concern on Long Island, major uncertainties about the health risks of many others have not been resolved.

4.1.1.3 Nitrates.[1] Nitrates become toxic to humans and other warm-blooded animals only under conditions in which they may be reduced to nitrite. This reduction takes place in the gastrointestinal tract, after which the nitrite may reach the bloodstream and react directly with the blood pigment, hemoglobin, to form methemoglobin. Once altered, the blood pigment can no longer efficiently transport oxygen from the lungs to the tissues and the physiological result is anoxia (lack of oxygen). The direct ingestion of nitrite nitrogen has a more immediate effect on the individual, but nitrite rarely occurs in Long Island drinking waters in sufficient concentrations to cause concern.

The reaction of nitrite with hemoglobin has been documented in approximately 2,000 cases in infants under three months of age in Europe and North America; seven to eight percent of those infants died as a result of the disease.[2] While many infants have not developed methemoglobinemia when fed with well waters having nitrate concentrations greater than ten milligrams per liter (NO_3–N), surveys have demonstrated that a minimal number of cases of infant poisoning were reported when water contained less than ten milligrams per liter (NO_3–N) (USEPA Drinking Water Regulations, 1976). Infants are apparently more susceptible than adults because their fluid

[1]Much of this section is adapted from Porter *et al.* (1978).
[2]This paragraph abstracted from EPA (1976b).

Table 4–12

NINETIETH PERCENTILE OF OBSERVED CONTAMINANT LEVELS ORDERED BY HIGHEST CONTAMINANT LEVEL PER SAMPLE

Sample Type	Sample #	Highest Contaminant Level
Glacial–residential–unsewered	QA 3	592 μg/l bromodichloromethane
Glacial–mixed–unsewered (WS)	QA 17	400 μg/l phthalate compound "a"
Magothy (WS)	QA 13	400 μg/l trichloroethylene
Glacial–agricultural	QA 21	290 μg/l 1,1,1 trichloroethane
Glacial–residential–unsewered	QA 19	285 μg/l trichloroethylene
Glacial–residential–unsewered	QA 2	275 μg/l 1,1,1 trichloroethane
Magothy (WS)	PWG 30	221 μg/l trichloroethylene
Glacial–residential unsewered	JDW 15	171 μg/l dibutyl phthalate
Glacial–Leachate Plume	QA 9	150 μg/l tetrachloroethylene
Glacial–mixed–unsewered (WS)	QA 12	150 μg/l tetrachloroethylene
Magothy (WS)	QA 6	145 μg/l chloroform
Scavenger Waste Lagoon	PWG 44	112 μg/l 1,1,1 trichloroethane
Glacial–residential–unsewered	JDW 14	109 μg/l octyl phenols
Magothy (WS)	QA 10	109 μg/l trichloroethylene

(WS) = water supply well

Source: ERCO

Table 4–13

NINETIETH PERCENTILE OF OBSERVED CONTAMINANT LEVELS ORDERED BY NUMBER OF CHEMICALS OBSERVED AT $\geq$10 μg/l PER SAMPLE

Sample Type	Sample #	Number of Organic Chemicals Observed at $\geq$10 μg/l
Glacial–mixed–unsewered (WS)	QA 17	8
Glacial–residential–unsewered	QA 19	5
Glacial–residential–unsewered	QA 2	5
Glacial–runoff recharge	PWG 1	5
Glacial–runoff recharge	PWG 2	5
Glacial–commercial/industrial–unsewered	JDW 13	5
Glacial–residential–unsewered	QA 3	4
Magothy (WS)	QA 6	4
Glacial–residential–sewered	QA 8	4
Control (Passed through plastic tubing)	PWG 23	4
Runoff	PWG 49	4
Glacial–residential–unsewered	PWG 51	4

(WS) = water supply well

Source: ERCO

Table 4–14

CATEGORIES OF KNOWN OR SUSPECTED ORGANIC CHEMICAL CARCINOGENS FOUND IN DRINKING WATER

Compound	Highest observed concentrations in finished water in U.S. (μg/l)	Upper 95% Confidence estimate of lifetime cancer risk per μg/liter
Human Carcinogen		
Vinyl Chloride	10	5.1×10^{-7}
Suspected Human Carcinogens		
Benzene	10	ID
Benzo (a) pyrene	D	ID
Animal Carcinogens		
Dieldrin	8	2.6×10^{-4}
Kepone	ND	4.4×10^{-4}
Heptachlor	D	4.2×10^{-5}
Chlordane	0.1	1.8×10^{-5}
DDT	D	1.2×10^{-5}
Lindane (γ–BHC)	0.01	9.3×10^{-6}
α–BHC	D	6.5×10^{-6}
β–BHC	D	4.2×10^{-6}
PCB (Aroclor 1260)	3	3.1×10^{-6}
ETU	ND	2.2×10^{-6}
Chloroform	366	3.7×10^{-7}
Carbon tetrachloride	5	1.5×10^{-7}
PCNB	ND	1.4×10^{-7}
Trichloroethylene	0.5	1.3×10^{-7}
Diphenylhydrazine	1	ID
Aldrin	D	ID
Suspected Animal Carcinogens		
Bis (2–chloroethyl) ether	0.42	1.2×10^{-6}
Endrin	0.08	ID
Heptachlor epoxide	D	ID

Source: NAS, 1977
ID = Insufficient data to permit a statistical extrapolation of risk.
ND = Not detected.
D = Detected but not quantified.

Table 4—15

SELECTED ORGANIC PESTICIDES AND OTHER ORGANIC CONTAMINANTS FOUND IN DRINKING WATER, WITH SUPPORTING DATA ON CHRONIC TOXICITY

Compound	Maximum Dose Producing No Observed Adverse Effect (mg/kg/day)	Suggested No-Adverse Effect Level from H_2O (μg/l) 1	2
2, 4-D	12.5	87.5	4.4
2, 4, 5-T	10.0	700	35.0
TCDD	10^{-5}	7×10^{-4}	3.5×10^{-5}
Aldicarb	0.1	7.0	0.35
Paraquat	8.5	59.5	2.98
Methoxychlor	10	700.0	35.0
Toxaphene	1.25	8.75	0.44
Diazinon	0.02	14.0	0.7
Parathion	0.043	30	1.5
Malathion	0.2	140	7.0
di-n-butyl phthalate	110	770	38.5
hexachlorophene	1	7	0.35

Source: ERCO

intake per unit of body weight is greater, and their gastrointestinal tract pH is often high enough to allow nitrate-reducing bacteria to survive. In addition, the predominant hemoglobin at birth (hemoglobin F) is more susceptible to methemoglobin formation, and there is a decrease in the activity of the methemoglobin reducing enzyme.

Recognition of this hazard led the United States Public Health Service in 1962 to adopt a standard for nitrate (measured as N) of ten milligrams per liter in drinking water.[1] The World Health Organization later followed the Public Health Service lead by recommending a similar standard. A survey undertaken by Walton (1951) provided justification for the standard. Subsequently, the standard has been subject to considerable debate. Some have suggested that the standard be relaxed since acute methemoglobinemia is rare in western societies today. For this rarity, however, general acceptance of the standard must be considered a major causative factor. It should also be noted that a large safety factor was not incorporated into the drinking water standard as is the rule with most other contaminants. For example, clinical cases of methemoglobinemia have been reported in areas where the water had less than ten milligrams per liter of nitrate. In addition, new findings have provoked fears that chronic effects also may justify a more stringent standard (U.S. Environmental Protection Agency, 1977). Furthermore, the ten milligram per liter standard should be interpreted in the context of an individual's overall nitrate consumption. The standard assumes that nitrates are being ingested in other forms. Thus, depending on foods eaten, effects may be noted at less than ten milligram per liter or may not be noted until a higher level is reached.

Compared to the acute effect of nitrate, much less is yet known about chronic effects. As in the case with acute toxicity, the actual cause of most chronic effects is due to nitrite produced by the reduction of nitrate. One of the first reports dealing with chronicity of nitrate attributable to drinking water was that of the Russians Petukhov and Ivanov (1970). Russian teenage children who consumed drinking water with a nitrate concentration greater than twenty milligrams per liter were found to have a decreased response to stimuli compared to children whose drinking water met the standard. In a later report (Petukhov *et al.,* 1972) it was claimed that children of various ages whose drinking water contained nitrate concentrations up to 45 milligrams per liter evinced a variety of symptoms, including cyanosis, lowered blood pressure and elevated levels of methemoglobin.

Shuval and Gruener (1975) completed extensive epidemiological studies encompassing nearly 3,000 infants up to two years of age. The study included a survey of babies in the Gaza Strip who consumed water with high levels of nitrate. A particular aim of the research was to determine whether or not cases of subclinical disease could be detected. The results showed that there was a relation between concentrations of nitrate in water used in a powdered milk formula and levels of methemoglobin. Even infants who consumed water containing nitrates only slightly above the standard had significant increases in the percentage of methemoglobin in their blood. In the subsequent U.S. EPA report (1977) it was concluded these results "provided direct epidemiological support for the current standard."

Nitrosamines are organic compounds (N-nitroso compounds) which are now known to be carcinogenic. Some of the compounds are also mutagenic or teratogenic.[2]

N-nitroso compounds are formed by the combination of amines with nitrites. This reaction, called nitrosation, may occur in the environment or in the animal stomach. Amines may originate in water from a wide variety of sources including industrial and domestic waste. Since nitrate is a potential precursor to nitrite, there is the possibility that the presence of amines and nitrates may, under some conditions, produce nitrosation. Much of the research on nitrosamines undertaken so far has investigated the development of cancer in laboratory animals given nitrosamines (for reviews see Crosby and Sawyer, 1976; and Shank, 1975).

Unfortunately, the degree to which amines or nitrosamines represent a public health hazard in drinking water is not presently known. The epidemiological studies so far attempted must be considered inconclusive (see, for example, Armijo and Coulson, 1975; Zaldivar and Wetterstand, 1975; and Hill *et al.,* 1972).

[1] For NO_3 measured as NO_3 rather than as N the standard translates to 44 milligrams per liter.

[2] See the Lancet, December 1. 1973, p. 1,243 for a general review.

4.1.1.4 Coliform and Other Bacteria. The presence of coliform bacteria in water has long been used as an indicator of fecal pollution. While coliforms themselves are generally harmless to man, their presence is used as a surrogate to indicate that pathogenic bacteria and viruses may also be present (EPA, 1976a).

In productive bay ecosystems, excessive contamination by pathogens can render clams, mussels and oysters unfit for consumption. Shellfish tend to concentrate particulate contaminants and associated coliforms when filter-feeding in polluted waters.

A significant portion of the Long Island bays are closed to shellfishing due to violations of the coliform standards. A list of the closed areas is presented in Table 4–16.

The total coliform standard for shellfish harvesting is a median not to exceed 70 MPN per 100 milliliters.[1] The standard for contact recreation is a logarithmic mean of 2,400 MPN per 100 milliliters.[2]

4.1.1.5 Viruses.[3] The major human virus groups known to occur in sewage include (1) Enteroviruses—transient inhabitants of the human alimentary tract consisting of over 100 species including Polioviruses, Coxsackieviruses and ECHO viruses; (2) Adenoviruses—upper respiratory viruses, which are able to withstand the acidity of the human gut and may be shed in feces; (3) Hepatitis virus; and (4) Reoviruses. While only Hepatitis virus and Poliovirus infections have been conclusively proven to have been transmitted by the water route (*i.e.,* sewage pollution of drinking water, shellfish beds, recreational waters, etc.), studies have indicated the likelihood of similar transmission of some or all of the species mentioned above. A listing of the viruses that may be waterborne, and diseases associated with them is presented in Table 4–17.

There is no historical information on viral levels in Long Island waters. Reports of human virus isolations from diverse aquatic systems in various

[1]The median MPN value in any series of samples representative of waters in the shellfish growing area shall not be in excess of seventy (70) per one hundred milliliters.

[2]The monthly median coliform value for one hundred milliliters of sample shall not exceed 2,400 from a minimum of five examinations and provided that not more than twenty percent of the samples shall exceed a coliform value of five thousand for one hundred milliliters of sample and the monthly geometric mean fecal coliform value for one hundred milliliters of sample shall not exceed two hundred (200) from a minimum of five examinations. This standard shall be met during all periods when disinfection is practiced.

[3]This section abstracted from Vaughn and Landry (1977).

Table 4–16

AREAS CLOSED TO SHELLFISHING DUE TO VIOLATIONS OF TOTAL COLIFORM STANDARDS

			Acreage Closed to Shellfishing			
Area	Bay	Total Acreage	Jan. 1, 1970	Jan. 1, 1976	Jan. 1, 1977	Dec. 1, 1977
1	Hempstead Bay	11,850	5,650	11,850	11,850	11,850
2	South Oyster Bay	6,190	700	4,020	4,020	4,620
3	Great South Bay	11,450	970	1,685	1,685	3,155
4	Great South Bay	18,980	705	1,010	1,010	1,110
5	Great South Bay	16,325	555	625	625	635
6	Great South Bay	11,525	285	550	550	550
3–6	Great South Bay	58,280	2,515	3,870	3,870	3,870
7	Bellport Bay	5,595	845	1,030	1,030	495
8	Moriches Bay	10,900	2,545	6,420	6,420	5,485
9	Quantuck Bay and Canal	730	165	165	165	165
10	Shinnecock Bay	9,170	220	220	220	220
1–10	South Shore Bays	102,715	12,640	26,675	26,675	26,675
11	Mecox Bay	1,045	435	320	320	320
12	Napeague Bay	9,135	0	0	0	0
13	Montauk Harbor	1,085	150	150	150	150
14	Acabonack	310	0	0	0	0
15	Three Mile Harbor	1,025	0	0	0	0
16	Gardiners Bay	48,950	0	0	0	0
17	Northwest Harbor	1,550	0	0	0	0

Table 4–16 . . . Cont'd.

Area	Bay	Total Acreage	Acreage Closed to Shellfishing			
			Jan. 1, 1970	Jan. 1, 1976	Jan. 1, 1977	Dec. 1, 1977
18	Shelter Island South	9,450	180	180	180	180
19	Sag Harbor and Cove	575	145	350	350	350
20	West Neck Harbor	625	0	0	0	0
21	Noyack Bay	3,540	0	0	0	0
22	Southold Bay	1,340	0	0	0	0
23	Hashamomuck Pond	170	0	5	5	5
24	Orient Harbor	3,560	0	0	0	0
25	Coecles Harbor	1,205	0	0	0	0
26	Little Peconic Bay	13,725	0	0	0	0
27	Cutchogue Harbor	585	2	2	2	2
28	Great Peconic Bay	19,060	0	0	0	0
29	Flanders Bay	3,090	470	780	780	780
30	Mattituck Creek	125	5	30	30	30
31	Wading River	50	0	50	50	50
32	Mt. Sinai Harbor	455	0	0	0	10
33	Port Jefferson Complex	1,550	815	815	815	900
34	Western Long Island Sound	88,300	20,915	37,150	37,150	37,150
35	Central Long Island Sound	188,000	2,500	0	0	0
36	Eastern Long Island Sound	121,000	300	300	300	300
37	Stony Brook Harbor	855	0	0	0	0
38	Nissequogue River	555	555	555	555	555
39	Smithtown Bay	22,300	500	900	900	900
40	Huntington Bay	2,420	0	0	0	0
41	Northport Bay	1,825	0	0	0	0
42	Northport Harbor	410	200	345	345	345
43	Centerport Harbor	490	125	185	185	185
44	Duck Island Harbor	185	0	0	0	0
45	Lloyd Harbor	600	0	0	0	0
46	Huntington Harbor	340	90	165	165	165
47	Oyster Bay Harbor	5,040	175	375	375	605
48	Cold Spring Harbor	1,325	95	215	215	215
49	Dosoris Pond	105	0	105	105	105
50	Hempstead Harbor	3,465	1,385	3,465	3,465	3,465
51	Fishers Island Sound	7,990	910	910	910	910
52	Stirling Basin	135	135	135	135	135
53	Pipes Cove	370	0	0	0	0
54	Napeague Harbor	885	0	0	0	0
56	Manhasset Bay	2,725	2,725	2,725	2,725	2,725
61	Cold Spring Harbor	220	0	0	0	0
62	Sebonac Creeks	430	0	0	0	0
63	North Sea Harbor	225	0	10	10	10
64	Wooley Pond	30	0	0	0	0

Source: NYSDEC (1977b).

Table 4—17

HUMAN VIRUSES COMMONLY FOUND IN SEWAGE AND DISEASES ASSOCIATED WITH THESE VIRUSES

Group	Subgroup	Number of Serotypes	Type Nucleic Acid	Diseases
Enterovirus	Poliovirus	3	RNA	Mild—Severe Gastroenteritis
				Abortive Poliomyelitis
				Aseptic Meningitis
				Paralytic Poliomyelitis
	Coxsackie-virus			
	A	24	RNA	Summer Minor Illness
				Herpangina
				Aseptic Meningitis
				Common Cold
				Hand, Foot and Mouth Disease
				Infant Diarrhea
	B	6	RNA	Aseptic Meningitis
				Common Cold
				Pleurodynia
				Neonatal Disease
				Sudden Infant Death Syndrome
				Myocarditis
				Pericarditis
	Echovirus	34	RNA	Aseptic Meningitis
				Mild Paralysis
				Febrile Illness
				Conjunctivitis
				Boston Exanthem Disease
				Infant Diarrhea
				Vaginitis and Cervicitis
				Pericarditis and Myocarditis
Hepatitis	A		RNA?	Infectious (viral) Hepatitis
	B		DNA?	Serum Hepatitis
Adenovirus		31	DNA	Acute Respiratory Disease
				Pharyngoconjunctival Fever
				Primary Atypical Pneumonia
				Epidemic Keratoconjunctivitis (shipyard eye)
				Intussusception
				Febrile catarrh
Reovirus		6	RNA	Unknown

Source: Vaughn and Landry (1977).

geographic regions (*e.g.,* rivers, bays, estuaries, treatment plant effluents) have appeared on occasion in the literature. As part of the 208 Program, a viral sampling program was carried out. Sample identifications were limited to enteroviruses. The results, which are summarized in Table 4—18, show that viral contamination is not of major concern in sampled waters.

Generalizing from the numbers in Table 4—18 was not done because of the small sample size and brief duration of the Program. In addition, no information was gathered on non—Enterovirus species, which may also be found in sewage pollution systems (*e.g.,* Adenovirus, Reovirus, Rotavirus (Reo-like), Norwalk-agents).

Viruses in Recharge. Recharge of sewage treatment plant effluent to the groundwater has been suspected of causing viral contamination. An important facet of the 208 Virus Study was the monitoring of several groundwater recharge sites in order to make a qualitative assessment of the effluent and the soil's ability to remove human viruses.[1] While being unable to define all the necessary conditions, it was hoped that the program of monthly viral analysis would be able to indicate the likelihood of returning virus-free effluent to groundwater aquifers.

Although not usually listed among recharge methods, the use of subsurface leaching fields will eventually result in the return of water to the aquifer. It is emphatically recommended that effluents of similarly low quality to those found at the Sunrise Sewage Treatment Plant not be used for such purposes.[2] However, the information gathered at this site may be useful as an index of the efficiency of such recharge systems under "worst possible conditions." Viruses were isolated from 80 percent of the sewage treament plant effluent samples taken, while only a 22.2 percent frequency was noted in the groundwater observation well. The data indicated that this type of disposal of low volume effluents in fairly isolated areas would be practical, providing the effluents were of adequate quality.

Among treatment plants discharging into recharge basins, the best results were obtained from the Stony Brook site where no viruses could be isolated from the eight samples taken and from Meadowbrook, where they showed an isolation frequency of 30.0 percent. Previously cited studies have demonstrated an inability of effluent borne viruses to penetrate appreciable distances through soil columns, depending on soil composition and effluent application rates. The apparent inability to recover significant numbers of viruses at the Stony Brook site was likely a result of the 80 foot soil depth from the bottom of the recharge basin to the aquifer.

The 34 foot soil layer from basin to aquifer at the Meadowbrook site seemed to be a less efficient virus remover. This conclusion does not account for differences in effluent qualities and soil characteristics. Studies of the

[1] Quantitative assessment would require more elaborate programs than those conducted for the 208 Program.

[2] The Sunrise Sewage Treatment Plant effluent quality problem is a well-known problem, and upgrading of the quality of the effluent has been ordered.

Table 4—18

RESULTS OF VIRAL STUDY

Sample	Percent of Samples Containing Virus	Number of Samples
Drinking Water	0	24
Lake Ronkonkoma	28	7
Penataquit Creek	18	11
Closed Shellfishing Areas—Islip	37	8
Water Column—Great South Bay		
Open Shellfishing Areas—Islip	37	8
Closed Shellfishing Areas—hard clams	28	7
Tissue—Great South Bay		
Open Shellfishing Areas—hard clams	40	5
Closed Shellfishing Areas	0	8
Water Column—Oyster Bay		
Open Shellfishing Areas	12	8
Closed Shellfishing Areas—oysters	37	8
Tissue—Oyster Bay		
Open Shellfishing Areas—oysters	12	8
Babylon Landfill—observation well	10	10
Storm Water Recharge—Massapequa observation well	8	12
Stony Brook STP—secondary chlorinated effluent	33	12
Stony Brook STP— groundwater observation well in recharge basin	0	9
Oyster Bay STP—secondary chlorinated effluent	36	11
Meadowbrook STP—secondary chlorinated effluent	25	12
Meadowbrook STP— groundwater observation well in recharge basin	30	10
Parkland III STP—tertiary chlorinated effluent	54	11
Parkland III STP— groundwater observation weill in recharge basin	30	10
Sunrise Garden Apartments STP— secondary chlorinated effluent	80	10
Sunrise Garden Apartments STP— groundwater observation well in leaching field	22	9
SCHD Experimental Septic System—influent	73	11
SCHD Experimental Septic System— effluent nonchlorinated	9	11

Summarized from Vaughn and Landry (1977).

latter may have indicated the presence of small fissures which would have allowed rapid virus infiltration by channeling. Had the observation well been located further down-flow, rather than within the dome of recharge water, some estimate of virus removal during horizontal flow would have been possible. In the absence of this information, it has been assumed (Vaughn and Landry, 1977) that removal rates through the aquifer would be similar to those encountered during percolation through the recharge basin. Based upon this, Vaughn estimated that viral penetration in the aquifer would not be significant after the first 100 to 200 feet of travel. Confirmation of this hypothesis would require an additional study of the site, including the installation of an additional observation well, 150 feet down the hydraulic gradient from the discharge basin.

The quality of effluents discharged from the Parkland III plant did not resemble those of a properly operated tertiary treatment system.[1] In spite of this, encouraging removal rates were noted in observation well waters. Based upon these data, it is conceivable that the recharge of properly treated effluents would contribute no significant viral contamination to the aquifer. The premise could be confirmed with a study similar to that just completed.

Viruses in Shellfish. There has been increasing concern over the likelihood of human virus carriage by shellfish. While there is little epidemiological evidence for the transmission of enteric disease from the consumption of sewage contaminated shellfish (with the notable exception of infectious hepatitis), the potential for infection cannot be ignored. Fugate, Cliver and Gatch (1975) outlined a number of reasons why a potential health hazard exists: (1) shellfish raising waters are continually being subjected to high levels of pollution from sewage sources; (2) shellfish, being filter-feeders, are able to efficiently concentrate viruses from the surrounding waters; (3) a majority of viruses are concentrated in the digestive organ of the mollusk, which is consumed along with all the other edible parts of the animal; and (4) shellfish are frequently consumed raw or with minimal cooking, which may not be sufficient to inactivate the viruses within them.

Oyster Bay was one case study considered by Vaughn and Landry (1977) for the Long Island 208. The "open" and "closed" areas studied in Oyster Bay were probably influenced by separate sources of pollutants. Results showed that 12.5 percent of all water and shellfish samples taken at the open site contained species of human viruses. Likely sources of viral contamination for this area included overland runoff, septic tank or cesspool leaching, and the discharge of treated sewage effluent from the Oyster Bay Sewage Treatment Plant located one to two miles away. While the major viral source could not be determined within the confines of this study, it should be noted that previous work by one of the authors (Vaughn and Metcalf, 1975; Metcalf, Vaughn and Stiles, 1972), conducted in a similar bay system receiving discharge from secondary treatment plants, indicated the presence of human viruses in shellfish beds that were located seven to eight miles from the nearest outfall.

The "closed" site was located several miles west of the "open" area discussed above. Microbial contamination at this site was probably influenced slightly by the sewage outfall, the more likely sources being overland runoff and septic tank seepage from the numerous older homes surrounding the

[1]This problem has been known by the SCDEC and remedial action has been required.

area. The results of sampling in this area yielded no virus isolates in the water column, yet 37.5 percent of the shellfish tested did contain viruses.[1]

Standards. There is as yet no established standard for permissible viral levels in aquatic systems. The reasons for this include the difficulty of sampling, the nonexistence of a single standard method for enumeration and identification, and the lack of concise epidemiological information concerning the waterborne transmission potentials of the virus groups involved. Despite uncertainty concerning an appropriate standard or threshold level, it appears prudent to minimize the occurrence of viruses in waters used for drinking, bathing or shellfish harvest.

4.1.2 Environmental Effects Directly Related to Bay and Groundwater Quality and Quantity

4.1.2.1 Quantity Effects

4.1.2.1.1 Aquifer Quantity. The availability of sufficient fresh water has long been of concern on Long Island. Long Island is surrounded by saltwater that has encroached upon the freshwater aquifer in some locales. Current information suggests that such saltwater intrusion is a localized phenomenon mainly related to local pumping practices and that the freshwater aquifer is not shrinking significantly (Miller and Sgambat, 1977a).

4.1.2.1.2 Water Level of Streams and Freshwater Wetlands.[2] Although the deep Magothy aquifer is not expected to change significantly, the shallow Glacial aquifer is expected to respond quickly to changes in freshwater recharge. Thus, sewering without local recharge can be expected to lower the water table. Significant lowering of the water table and of potentiometric surfaces has occurred over the last few decades in western and southwestern Nassau County. This appears to have resulted in decreased stream flow. The close dependence of streamflow on groundwater was underscored during the 1962–66 drought when record low flows were observed in fourteen of nineteen principal streams in Nassau and Suffolk Counties. The historical record of the combined annual average streamflow of the nineteen streams indicates a flow of 155 cubic feet per second (cfs) in 1966 as compared to the long-term average of 291 cfs.

Reductions in streamflow and declines in water table elevations can result in changes in the vegetation of certain freshwater wetlands. A total freshwater wetland area of over 1,500 acres has been inventoried within the nine major stream systems of southwestern Suffolk County and southern Nassau County. Water table ponds and lakes, such as Lake Ronkonkoma, Hempstead Lake and Southard's Pond (Carll's River) might experience some lowering of water levels. Marsh and meadow species of plants and trees dependent on a shallow water table environment may eventually occupy a greatly reduced area, closer to the remaining streams. A recent study on Long Island by Beitel (1976) suggests a possible sequence of vegetative succession similar to one that occurred at Artist Lake, Middle Island, New York during a lowering of the water table. In that case, nearshore lake habitats changed to marsh, and then to Red Maple swamp habitats. All waterbodies occurring in groundwater Zones VI, VII and VIII may be expected to be altered in the event of sewering with transport of effluent out of the zone. Streams in Zone VI are of particular concern with respect to secondary effects on Great South Bay salinity.

The tidal marshes on Long Island are marked by specific zones of vegetation. This zonation is a reflection of two basic parameters, (1) the degree to which the zones are inundated by the tides, and (2) the salinity gradients to which the vegetation is exposed. The lowest marsh zone, which is generally inundated with saline water twice a day, is dominated by cordgrass, *Spartina alterniflora. S. alterniflora* grows in almost mono-specific stands across extensive areas of low marsh in Long Island. At somewhat higher elevations, there is a high marsh or salt meadow zone, in which salt hay, *Spartina patens,* and spike grass, *Distichlis spicata,* predominate. Inundation is less frequent here, usually occurring only when tides exceed mean high level. Adams (1963), in a study of the North Carolina salt marshes, found that salt marsh species distribution was highly dependent upon elevation. In fact, Adams discovered that the vertical distribution of ten species of salt marsh plants spanned only one foot. Although there are individual differences between the species zonation in different geographical areas, species tend to be found within a well-defined elevation from the mean water level. Adams developed a mathematical relationship to determine the height of a species from mean sea level in a marsh as a function of the tidal range. This value was calculated for the three major species found in both Long Island and North Carolina (Table 4–19).

The sensitivity of marsh vegetation to the frequency and height of inundation has clear implications for any sort of development that affects the level of the water table. Although very little research exists on the effects of lowering the water table in marshes, much has been documented about the results of ditching upon tidal marshes (Bourn and Cottam, 1939, 1950; Cockran, 1938; Stearns, MacCreary and Dargh, 1939, 1940; Florschutz, 1959). Ditching, which effectively lowers the water table in a marsh, creates a higher, drier environment that the low and mud marsh species cannot tolerate. The delicate zonation patterns are altered, and the highly productive, low-marsh species give way to terrestrial and transition zone species such as the salt marsh aster, *Aster subulata,* the high tides bush, *Iva Fructescens,* and the groundsel bush, *Baccharis halimifolia,* (Cottam *et al.,* 1938). These plants are not as productive as low marsh vegetation, nor do they contribute and recycle nutrients in the estuary as effectively as low marsh vegetation, particularly cordgrass, *S. alterniflora.* Since the entire range of tidal marsh vegetation is only approximately one foot, net water level changes greater than an inch or two are expected to have drastic effects upon the species present.

[1] A likely reason for this negative finding was the heavy turbidity of the water.

[2] First two paragraphs abstracted from Miller and Sgambat (1977a).

Table 4–19

ELEVATION LEVELS FOR THREE TIDAL MARSH SPECIES*

	Elevation Above Mean Sea Level (ft)	
	Great South Bay	South Shore Bays
Spartina alterniflora	0.35–1.01	1.01–2.02
Spartina patens	0.51–1.46	1.46–2.92
Distichlis spicata	0.49–1.41	1.41–2.82

**Data is based upon indices calculated by Adams (1963), with tidal range of 1–2 ft for Great South Bay and 2–4 ft for the South Shore Bays*

In addition to impacts on vegetation, changes in the water level will affect the invertebrates that inhabit the marshes. When the water table drops, the soil dries and conditions become more acidic, causing a decline of molluscs and crustaceans, which are dependent upon alkaline conditions for construction and maintenance of their shells and exoskeletons (Nealy, 1962). These invertebrates are the main diet of many birds and animals, particularly waterfowl. As food sources for birds decrease, so eventually will bird populations. Permanent pools on the surface of the marsh may also diminish and dry up as a result of the lowered water table. These pools often support widgeon grass, *Ruppia maritima,* an excellent food for many ducks. The loss of these pools is yet another loss for the bird populations, removing both food and shelter.

The impacts of lowering the water table upon the wetlands in Great South Bay and the western South Shore bays are expected to be great, due to the sensitivity of marsh vegetation to both the height and frequency of inundation, and the water requirements of invertebrate and vertebrate populations. Any development, including sewering, that is expected to alter either the water table level or the height and frequency of inundation of the marsh must be thoroughly examined.

The minimum environmentally acceptable criterion is the maintenance of South Shore streams and wetlands at current flows and inundation levels.[1] The effectiveness of technological measures such as shallow recharge and stream augmentation in preventing ecological change is open to considerable uncertainty.

4.1.2.2 Quality Effects

4.1.2.2.1 Fish. Fish populations are highly mobile within the bay system. They also exhibit a diversity of survival strategies. Some species use the wetland areas of bays as breeding and nursery grounds. A few breed in the bay itself. Many species use the bays only occasionally or as feeding grounds. The various fish which use different parts of the bay system are then affected by changes in those aspects of the system they use. In particular, some may be affected by reduction in wetland areas and salinity changes (Gosselink and Beck, 1977). The accumulation of metals and organics by fish can be toxic to the fish themselves and may also affect their edibility (EPA, 1977).

Fish occupy different habitats during various life stages. Larval stages tend to be very sensitive to physical factors such as dissolved oxygen, turbidity, temperature and salinity (Tables 4–20, 4–21). Significant changes in salinity levels are likely to change the community composition of fish larvae that use the bays and their marsh edges as nursery grounds.

4.1.2.2.2 Shellfish. Shellfish populations have a low mobility and are affected by various types of changes in their habitat. Salinity changes can alter shellfish distributions and productivity (Maurer *et al.,* 1974). Table 4–22 summarizes the data used for determining the salinity ranges of major species of interest in eastern Great South Bay for which data exists. The observations from which the ranges were derived were made in Chesapeake Bay and the nearby estuarine communities that have prevailing conditions similar to those of Great South Bay. Where available, data from the larval stage of the molluscs was included as long-term salinity changes more severely impact the shellfish at this stage. The margins of the salinity ranges can be assumed to be sub-optimal, with some population decrease due to salinity-related mortality, and reductions in sizes of adult individuals. At the extremes of the range, the following sorts of effects could be expected: reductions in size of mature adults, decreased survival of juveniles and increased mortality due to predation and disease.

Severe dissolved oxygen deficits in near bottom water can cause shellfish mortality (Table 4–20). The various shellfish are selective with respect to substrate habitats (Kinner *et al.,* 1975). Substitution of muddy and silty sediments for sandy sediments may decrease the suitability of bottom areas for certain desirable benthic species. An important factor contributing to productivity of the benthic zones is the diversity of benthic micro-habitats. One of the most important effects of siltation may be the reduction in the diversity of rocky, sandy and muddy habitats present in bays. This may then reduce benthic productivity.

It is also possible that the runoff-derived solids, which appear to be responsible for much of the pollution by organic matter, can clog feeding mechanisms. This effect, however, is clearly dependent on the character of solids being discharged.

Coliform contamination affects the harvestability of shellfish. State standards[2] require that areas be closed when the median of a "representative" sample series is greater than 70 MPN per 100 milliliters.

[1] "Current" flows are definable by statistical measures such as twenty year means and variances or by steady-state or statistical hydrologic models.

[2] New York State Chapter X, Title 6, Section 701.5, SA waters.

Table 4–20

SENSITIVITY OF SELECTED FISH AND SHELLFISH TO DISSOLVED OXYGEN BY LIFESTAGE[a][b]

Species	Lifestage[c]	Sensitivity to Dissolved Oxygen
Blueback herring *(Alosa aestivalis)*	A	Susceptible to low dissolved oxygen
Alewife *(Alosa pseudoharengus)*	A	Susceptible to low dissolved oxygen
Bay anchovy *(Anchoa mitchilli)*	A	Intolerant of low dissolved oxygen
Bunker menhaden *(Brevoortia tyrannus)*	J & A	Susceptible to low dissolved oxygen
Weakfish *(Cynosion regalis)*	S & E	Requires >5 ml/l
	L, J, E	Moderate tolerance to low dissolved oxygen
Mummichog *(Fundulus heteroclitus)*	J & A	High tolerance to low dissolved oxygen to 1 ml/l
Striped killifish *(Fundulus majalis)*	E	High O_2 consumption rate
	J & A	High tolerance to low dissolved oxygen to 1 ml/l
Brown bullhead *(Ictalurus nebulosus)*	E	Need high concentrations of dissolved oxygen
	A	Extremely tolerant
Atlantic silverside *(Menidia menidia)*	J & A	High susceptibility to low dissolved oxygen
Hard clam *(Mercenaria mercenaria)*	E	Normal development at .5 mg/l; 100% mortality at 0.2 mg/l
	L	Growth stops below 2–4 mg/l
White perch *(Morone americana)*	A	Moderate tolerance to dissolved oxygen
Striped bass *(Morone saxatilis)*	E	4–5 mg/l reduces hatching success
	L	4–5 mg/l and lower, larval effects
	A	3 mg/l at 16–19° C is probable minimal permissible level
Striped mullet *(Mugel cephalus)*	E	Below 5 ppm decreases survival
	L	Below 4–5 ppm decreases survival
	J & A	Moderate tolerance to low dissolved oxygen
Summer flounder *(Paralichthys dentatus)*	A	High tolerance to low dissolved oxygen
Bluefish *(Pomatomus saltatrix)*	J & A	Highly susceptible to low dissolved oxygen
Winter flounder *(Pseudopleuronectes americanus)*	A	High tolerance to low dissolved oxygen

[a] *ERCO*
[b] *Summarized from Daiber and Thornton, 1976.*
[c] *A = Adult*
J = Juvenile
L = Larval
E = Eggs
S = Spawning Adult

Table 4–21

SENSITIVITY OF SELECTED FISH AND SHELLFISH TO TURBIDITY BY LIFESTATE[a][b]

Species	Lifestage[c]	Sensitivity to Turbidity
Blueback herring *(Alosa aestivalis)*	E	Can take up to 1000 mg/l without apparent effect on hatching
Alewife *(Alosa pseudoharengus)*	E	500 mg/l affected hatching success ($p < .025$)
Anchovy *(Anchoa mitchilli)*	A	Sensitive to turbidity
Bunker menhaden *(Brevoortia tyrannus)*	J	No effect on survival at 1000 mg/l
American oyster *(Crassostrea virginica)*	E	Significant effect on survival and growth at 125 mg/l
	L	Severe mortality at 100 mg/l
	A	Reduction in pumping rates at 100 mg/l
Weakfish *(Cynosion regalis)*	A	Sensitive
Mummichog (Fundulus heteroclitus)	A	Tolerant to high concentrations C_{10} = 23,000 mg/l
Striped killifish *(Fundulus majalis)*	A	High tolerance C_{10} = 23,000
Atlantic silverside *(Menidia menidia)*	A	Highly sensitive LC_{10} = 580 mg/l
White perch *(Morone americana)*	E	1000 mg/l affects hatching success ($p < .005$)
	J	500 to 1000 mg/l has adverse effect on survival ($p < .05$)
	A	Sensitive
Striped bass *(Morone saxitilis)*	E	1000 mg/l affected hatching success; LD_{50} is 3411 ppm
	L	500 to 1000 mg/l affected survival ($p < .005$)
	A	Sensitive
Yellow perch *(Perca flavescens)*	E	Can take up to 1000 mg/l with no effect
	L	500 to 1000 mg/l affected survival adversely ($p < .005$)
Bluefish *(Pomatomus saltatrix)*	J	Sensitive

[a] *ERCO*
[b] *Summarized from Daiber and Thornton, 1976.*
[c] *A = Adult*
J = Juvenile
L = Larval
E = Eggs
S = Spawning Adult

4.1.2.2.3 Contact Recreation. The suitability of waters for contact recreation is evaluated in this report by using the 30-day median 2,400 MPN/100 milliliters total coliform standard.[1]

[1] New York State Chapter X, Title 6, Section 701.5, SB waters.

Table 4–22

SALINITY RANGES OBSERVED FOR VARIOUS MOLLUSCS
(Parts Per Thousand)

Common Name	Scientific Name	Maurer[1]	Others[2]	Thornton[3]
Soft Clam	Mya arenaria	5–20	5–25	
Hard Clam	Mercenaria mercenaria	15–30	10–35	Juvenile 20–32,5
Surf Clam	Spisula solidissima	27–35	10–35	
Razor Clam	Ensis directus	13–28	7–32	
Blue Mussel	Mytilus edulis	20–35	15–35	
Oyster	Crassostrea virginica	Optimum 14–28[4] 5–38		Adult 7–30 Juvenile 15–30
Scallop	Pectin	20–35	17–35	

[1] *Maurer and Watling, "The Distribution and Ecology of Common Marine and Estuarine Pelecypods in the Delaware Bay Area," The Nautilus, (April 1974), 88 (2): pp. 39–45.*
[2] *Reported by Maurer.*
[3] *Thornton, Delaware Coastal Atlas (1976).*
[4] *Maurer and Watling, Studies on the Oyster Community in Delaware, College of Marine Studies, University of Delaware, Newark, Delware (1973).*

4.1.2.2.4 Aesthetics. The effects of the 208 options on aesthetics are evaluated mainly in terms of the aesthetics of three zones: shorelines, marine waters and open space. Of these three, generally the 208 Plan will have little effect on aesthetic quality of shorelines. Rather, shoreline improvements can be expected to result from Coastal Zone Management (CZM) programs. Reductions in pollutant loadings to bays will improve the public perception of the quality of those water bodies. Lowering of the water table as a result of sewering with marine surface discharge will reduce wetland acreage, and the associated aesthetic value that relates to the wetlands' role as a habitat for diverse bird, fish and insect communities, and as nurseries for desirable aquatic species. Reduction of wetland acreage may also degrade existing views and vistas. Table 4–23 summarizes the relationships between recreational uses, aesthetics and water quality. Open space related aesthetic benefits can derive from watershed management approaches in Zones III and IV and stream buffer zone measures in Zones VI and VII.

4.1.2.2.5 Bay Nutrient Cycling. The quantity and composition of nutrient loads are of primary importance in assessing the environmental effects likely to result from wastewater management alternatives in Long Island bays. Nitrogen and phosphorus concentrations in particular are known to regulate the growth of phytoplankton in coastal waters.

In many waters subjected to waste loadings, oxygen-demanding substances depress dissolved oxygen concentrations below saturation. This is generally not a problem in Long Island bay waters where phytoplankton respiration and photosynthesis regulate dissolved oxygen concentrations.

Table 4–23

OVERVIEW OF RELATIONSHIP OF WATER QUALITY AND AESTHETIC QUALITY

Aesthetic Variables	Constituents Causing Aesthetic Degradation	Activity Affected by Aesthetic Degradation
Color	Metals, organics	Contact, noncontact recreation
Turbidity, nuisance algae	Suspended sediment, nutrients	Contact, noncontact recreation
Community diversity	Nutrients, dissolved oxygen	Noncontact recreation

Source: ERCO

The bay ecosystems also depend upon phytoplankton as primary producers. Thus, changes in nitrogen and phosphorus concentrations due to waste disposal can have a profound influence on bay ecosystems. This consideration is especially important in the shallow Long Island bays where relatively small quantities of effluent can cause substantial increases in ambient concentrations of nutrients.

There are two major types of effects—increases in gross levels and changes in atomic ratios among nutrients. Increases in nitrogen concentrations induce increases in phytoplankton productivity and algal blooms. This causes an increased oxygen consumption. Changes in the molar ratio of nitrogen to phosphorus are more critical than the absolute concentrations in determining the dominant species in phytoplankton communities.

Based upon an evaluation of available data from Long Island bays, Tetra Tech has indicated that 0.4 milligrams per liter total nitrogen is the level above which dissolved oxygen deficits violating the state standard of five milligrams per liter can be expected to occur. The actual maximum nitrogen level may vary from bay to bay and should be evaluated specifically for each bay.

Nitrogen (N), phosphate (P) and organic carbon (C) levels are significant indicators of water quality. Their ratio is a reliable indicator of the quality and quantity of flora and fauna supportable by the water. Optimally, the molar P:N:C ratio should be near 1:16:106. Generally C is very much higher than 106; and N is a limiting factor, with steady state N/P ratios in the neighborhood of ten to fifteen for most marine waters. N/P ratios less than ten occur at times in healthy Long Island bays. Persistence of N/P ratios below ten, apt to result from the disposal of some wastes, are generally a sign of an unhealthy ecosystem with a tendency to support phytoplankton populations of a limited number of species. Often the resulting species are not suitable food sources for prey-size selected filter-feeders. These alterations in phytoplankton communities tend to have subsequent effects on the marine food web, such as decreased fish and shellfish production. Interestingly enough, there seems to be no evidence indicating that N/P

ratios higher than sixteen have any adverse effects on an ecosystem (McCarthy, 1977). While N/P steady state ratios control the diversity of species and health of an ecosystem, absolute concentrations of these elements determine the total productivity of that ecosystem. Thus, the N/P ratio should be maintained at a proper level to ensure species diversity, while the absolute concentrations of N and P should also be maintained at some level (possibly 0.4 milligrams Nitrogen per liter) such that phytoplankton production does not cause severe algal blooms and D.O. deficits.

4.1.3 Other Environmental Concerns. Management of ground and surface water quality is best done in concert with several environmental concerns relating to the ecosystem's natural processes, which protect water quality. These concerns, relating to the safeguarding of certain naturally significant areas, are an important aspect of meeting water quality objectives.

4.1.3.1 Open-Space Watershed Management. Much of Long Island Island's precipitation is recharged. The original vegetation-based ecosystems, such as pine and scrub oak barrens, acted as recharge agents; that is, they (1) held water and nutrients in the vegetation and detritus for slow release to the aquifer, (2) contributed a chemical and bacterial setting which gave aquifer waters a particular chemistry, and (3) provided pervious zones that minimized runoff. Thus preservation of or establishment of similar areas relate to management of groundwater quality and of runoff. On Long Island, there are specific areas that are important to the groundwater and others that are important to the surface water environment. There are a range of approaches that can work. Three of these are as follows:

1a. *Acquisition of areas and preservation as open spaces.* Areas such as wetlands, safe zones surrounding pumped areas and selected recharge areas are best protected in such a fashion.

1b. *Acquisition of areas and regulation of use.* This differs from (1a) in that acquired lands are maintained in a multiple-use status. Regions such as watersheds, regional recharge zones and highly transmissive aquifer zones can be partially protected by institution of such measures for selected parcels of land.

2. *Protective regulation of land uses and activities.* Many of the recharge areas, watershed areas and intensively pumped areas are currently developed to a medium or high density. Control of further development of such areas can protect water resources.

4.1.3.2 Estuarine and Bay Wetland Ecosystems. Wetlands border Long Island bays and estuaries. They play an important role in nutrient cycles, organic matter cycles and marine population life cycles. In addition, wetlands act as buffers, filtering the runoff and siltation inputs to bays. Thus, maintenance of these areas is an important aspect of marine water quality management.

Vegetated tidal wetlands[1] cover some 23,000 acres of Nassau and Suffolk Counties. The largest area of wetlands is found on the South Shore, with the western South Shore bays containing some 8,800 acres within South Oyster Bay, East Bay, Middle Bay and Hempstead Bay. Most of this wetland acreage is on small marsh-islands that do not afford access from the mainland except by boat. To the east, Great South Bay is the next largest wetland bay, containing more than 5,500 acres along its shores and rivers and on Fire Island. In terms of total acreage, Peconic and Flanders Bays are ranked next, containing some 1,400 acres. Most of these habitats are small tracts along creeks that feed into the bays, but there are several tracts encompassing more than 100 acres. Oyster Bay is the site of a National Wildlife Refuge covering more than 3,000 acres, about one-tenth of which are vegetated tidal wetlands. Other North Shore bays have scattered wetland tracts along creeks but much of the bay shoreline has been filled and bulkheaded. The Huntington-Northport complex contains some 300 acres, much of it in Caumsett State Park and Lloyd Harbor. Around Port Jefferson Harbor there are approximately 150 acres of wetlands remaining, while Manhasset Bay and Hempstead Harbor together contain some 170 acres.[2]

Between 1964 and 1972, seventeen percent of the wetlands on Long Island were lost due to dredging and filling activities (O'Connor and Terry, 1972). During a 1973–1977 moratorium period, considerably less marsh was lost. The Tidal Wetlands Act (Article 25 of the Environmental Conservation Law of New York) calls for the preservation and protection of tidal wetlands, preventing their despoilation and destruction, giving due consideration to the reasonable economic and social development of the state" (NYSDEC Tidal Wetlands Land Use Regulations, 6 NYCRR, Part 661, 1977). Most activities, including all types of construction and dredging, are regulated by the State, and require a permit. However, for many of the activities associated with residential, commercial and industrial development, as well as sewering, treatment plant expansion, and runoff control, permits continue to be issued, although a significant time delay may be involved. The State of New York (Haje, 1976) calculated that only twenty acres of wetland were legally filled from 1973 to 1976. However, since permits continue to be obtainable, enforcement efforts may not adequately control all types of construction activities which, as discussed below, impact upon wetlands. Although no ecological methodology presently exists to analyze minimum wetland requirements for a bay, the current acreage appears to be critically low for most bays and is probably well below the minimum for a functioning marsh system in Manhasset Bay and Hempstead Harbor. For that reason, special protection of wetlands in those bays with sufficient wetlands, namely Great South Bay, South Shore bays, Peocnic Bay and Oyster Bay, is an essential part of an areawide water quality plan. The level of protection afforded by permit activities should be increased in those areas. Water pollution control facilities should be sited to avoid wetlands, wherever feasible.

[1] Defined as intertidal marsh (IM), high marsh or salt meadow (HM), coastal fresh marsh (FM), and formerly connected tidal (FC) vegetated wetlands.

[2] With the exception of the numbers for Peconic/Flanders Bay, numbers presented in this section were provided as preliminary calculations based on 1976 data by the NYSDEC.

4.2 Impacts of Areawide Alternatives

All control measures proposed for the Water Quality Management Plan that can be discussed on a bi-county basis are included in this section. This includes measures specifically designed to be Island-wide in scope (Section 3.5.1) and aspects on zone-specific measure that are common to all zones (general effects associated with parts of Section 3.5.2).

Table 4–24 is a guide to the organization of this section.

Table 4–24

CORRESPONDENCE OF WQMP OPTIONS WITH IMPACTS DISCUSSIONS

WQMP Option		Impacts Discussion	
Section:	3.5.1	Section:	4.2.1
	3.5.1.1		4.2.2
	3.5.1.2		4.2.3
	3.5.1.3		4.2.4
	3.5.1.4		4.2.5
	3.5.1.5		4.2.6
	3.5.1.6		4.2.14
	3.5.1.7		4.2.7
	3.5.1.8		4.2.15
	3.5.1.9		4.2.8
	3.5.1.10		4.2.9
	3.5.1.11		4.2.10
	3.5.1.12		4.2.15
	3.5.1.13		4.2.11
	3.5.1.14		4.2.12
Sewering Options			4.2.13
Treatment Plants			4.2.15
Outfalls			4.2.16

4.2.1 Effects Associated with Miscellaneous Individual Source Control Measures. The non-point source pollutants that the controls identified in Section 3.5.1 seek to abate, constitute a significant portion of the total load to water bodies. In particular, non-point sources contribute up to 99 percent of the coliform load and about 40 percent of the nitrogen load to the bays that were studied. They contribute to nitrogen, metal and organics groundwater contamination. Despite the significance of these measures with respect to abating health risks, there are major uncertainties associated with a few of them. These uncertainties are of two sorts: questions concerning effectiveness and questions of implementability. If these measures are proven to be effective and if the implementation is commensurate with the need, the net result of various recommended controls will definitely be environmentally beneficial. The measures are discussed individually in Sections 4.2.2 to 4.2.12.

4.2.1.1 Short-Term Primary Impacts. Many of the control options for non-point sources will involve a considerable delay before regulatory programs can be drafted and accepted and before enforcement programs can be organized. Thus, the major short-term impacts will be due to continued pollutant loads until measures are implemented. The short-term impacts can be minimized by giving priority to implementing those measures which control those sources imposing the greatest health and environmental effects.

4.2.1.2 Long-Term Primary Impacts

Metals. None of the proposed controls cause additional metal contamination. Controls of diffusion wells, landfills and discharge and storage of industrial materials and wastes will reduce levels of metals discharged to the environment. Generally, metals in marine, fresh and groundwater are rapidly adsorbed onto sediments. This is suggested by low levels of metals, well below standards, in groundwater sampled in this program. It is also indicated by previous research (*NAS,* 1976). Major metal pollutant problems have tended to arise from accumulation of metals in the food chain where there is a high metal level concentrated in sediment or water column. Such a situation may occur when sediment metal levels are high and members of the food chain are detritus feeders. Sediment metal levels should be monitored since metals data is lacking for the Long Island bays.

Organics. None of the proposed controls causes additional organic chemical contamination. Controls on product storage tanks and pipelines, landfills, groundwater development, discharge and storage of industrial materials and wastes, diffusion wells, fertilizer use and pesticides will all significantly reduce organic chemical discharges. It is difficult to determine which controls would be most effective in reducing organic levels, since all the various sources have not been inventoried or monitored.

However, monitoring of the groundwater has shown organic chemical contamination to be a significant health problem (Section 4.1.1.2). Thus, employment of all available controls would be the most prudent strategy. Also, as noted, there is a major data gap that needs to be eliminated, namely the lack of data on all sources of organic chemical pollution.

Nitrates. None of the proposed controls cause additional nitrates contamination. Control of leakage from sewers, effluent recharge, domestic on-site systems, animal wastes and fertilizer use will all help abate nitrate loads. Modeling work done for this program suggests that animal wastes controls and fertilizer use controls will both help abate nitrate loads. The modeling work also suggests that on-site systems and fertilizers are the major sources. However, the model used did not account for non-conservative transport of nitrates in the groundwater below the root zone. Also, comparison of modeling results showed that some areas display particularly high levels relative to model loading numbers. Variation in monitoring well data may be attributable to local groundwater hydrology and surficial geology. Thus, although control of on-site systems performance and of fertilizer use are of most importance, the effectiveness of controls will vary geograph-

ically. In some locales, a wide range of controls need to be implemented to meet the ten milligrams per liter standard (I and II) or to obtain lower levels (III and VI). Hydrogeological zones can only be specified in a general way at this time. They have been set forth in Chapter Three (see Table 3–3).

Coliforms and Viruses. None of the proposed controls cause additional coliform contamination. Since pathogen transport through soil and aquifer usually is very limited, none of the controls is likely to affect groundwater quality. Control of animal waste could possibly reduce coliform levels in bays. Although it is difficult to link coliform levels in bays to sources, evidence put forth during this project suggests that dog and duck wastes are significant animal waste contributors to bay coliform levels. However, the best management control measures put forth in Section 3.4.1.12 are unlikely to reduce dog and semi-wild duck waste contributions.

Water Quality, Water Level—Streams and Ponds. Control of groundwater pumping patterns will help maintain the water level of streams and ponds. Work done for this study has shown that, regionally, groundwater supply is not a problem, but that water table levels are a problem where recharge is at reduced levels. Locally, both water table and water supply can be depleted in areas that are overpumped. Thus, such controls are highly beneficial.

Fish, Shellfish. The controls being considered in this section mainly affect fish and shellfish in terms of metals, organic chemicals, oils and coliform bacteria. Metals, organics and coliforms have been considered previously in this section. The major impacts of oils on fish and shellfish are likely to be caused by spills and accidental discharges. Control measures are not likely to be of great value in reducing impacts of spills. However, they may slightly reduce the probability of spill occurrence. As of 1977, no major spills have occurred in Long Island bays. However, study of the recent Huntington spill may prove instructive.

Aesthetics, Wetlands, Unique Habitats, Open Space. Land use controls (3.5.1.13) will have a significant benefit in preserving habitats and open space. All of the areawide measures applied to hydrogeologic zones with surface water impacts (Zones IV, V, VI, VII and VIII) will have a positive aesthetic impact due to water quality improvements (see Section 4.1.2.2.4).

4.2.1.3 Secondary Impacts. Most of the proposed controls involve regulation of the use of products, the use of land, or waste disposal. Some proposed regulations will have an impact on consumer practices (for example, pet purchases may be affected). Others will have impacts on industry and agriculture (for example, fertilizer use). All regulations will affect staffing requirements for regulatory agencies. Generally, the trade-offs between positive environmental benefits and negative secondary impacts cannot be analytically resolved. There is no way to optimize between two measures which cannot be expressed in common units. The trade-off must then be resolved politically. Below a list is presented of the key trade-offs related to non-point controls:

1. Control of effectiveness of on-site systems *vs.* cost to homeowners for maintenance.
2. Agricultural fertilizer controls *vs.* requirement for trained personnel to properly carry out scientific application.
3. Residential fertilizer controls *vs.* lawn appearance.
4. Efficient organic controls *vs.* cost to industry and to homeowners.
5. Animal waste controls *vs.* inconvenience to owners.

4.2.1.4 Adverse Environmental Impacts. None.

4.2.1.5 Irreversible and Irretrievable Commitment of Resources. No substantial commitments since most of the measures are legal/institutional in nature.

4.2.2 Provide for Routine Maintenance of On-Site Septic Tank and Leaching Pool Systems. The routine maintenance of septic systems will help them to operate with pollutant removal at or near design efficiency. Such a measure will be environmentally beneficial with respect to groundwater and surface water quality and public health. One result of such a control will be the generation of additional loads of scavenger wastes. However, the additional scavenger wastes would have to be handled at existing or future treatment plants. Any increases in treatment plant design sizes due to scavenger waste flows would induce effects such as those discussed in 4.12.15.

4.2.3 Prohibit the Use of Certain Chemical Cleaners in On-Lot Systems. This measure is intended to control one of the sources of organic chemical contaminants. Due to the lack of a study on relationships of organics sources to groundwater quality, it is difficult to evaluate the impact of the proposed control. From a conservative standpoint, the measure is environmentally beneficial from a public health standpoint since it will have a positive effect on groundwater organic chemical levels.

From an areawide planning standpoint, the benefits of this measure are not clear at the present. A comprehensive plan for organic chemicals control is strongly recommended as an extension of the 208 planning process. This is an interim measure that should be followed by development of an overall organics control plan.

4.2.4 Expand Regulations and Enforcement Regarding the Disposal of Industrial Wastes. The strict enforcement of pretreatment regulations is highly beneficial from the standpoint of operation of waste water treatment plants. Expansion of regulations to cover organic chemicals discharges to the ground will probably result in decreased groundwater organics levels. However, the lack of a study of the relationship between organic chemical sources and groundwater quality leaves considerable uncertainty as to the beneficial impact of implementing controls on industrial sources. An effect of the proposed controls will be increased quantities of hazardous treatment wastes to be disposed of. On an areawide basis, the proposed measures would have environmental benefits.

4.2.5 Regulate the Storage and Transportation of Chemical Products. Measures to minimize spills and other accidental mishaps of hazardous mater-

ials are clearly environmentally beneficial.

4.2.6 Reduce the Use of Fertilizers. Porter *et al.* (1978) showed that fertilizers constitute a major source of nitrates to groundwater on Long Island. Two major sectors to which restrictions can be applied are agricultural use and residential (lawn) use. Figure 4–1 summarizes a Long Island study which shows that scientific fertilizer application in the agricultural sector results in lowered groundwater nitrates. Similar results may be expected for lawn fertilizers, which are largely applied in excess and leach rapidly below the root zone. Other studies have shown that sewage sludge compost, a slow release nitrogen source, results in low nitrate leaching. It is recommended that use of fertilizer be regulated, that low maintenance lawns be planted, and that education relative to scientific fertilizer application be carefully carried out. Such fertilizer controls are environmentally beneficial.

4.2.7 Reduce Animal Wastes. The characteristics of dog, fowl and human wastes are presented in Tables 4–25 and 4–26. The dog population of Long Island is indicated in Table 4–27. These data demonstrate that animal

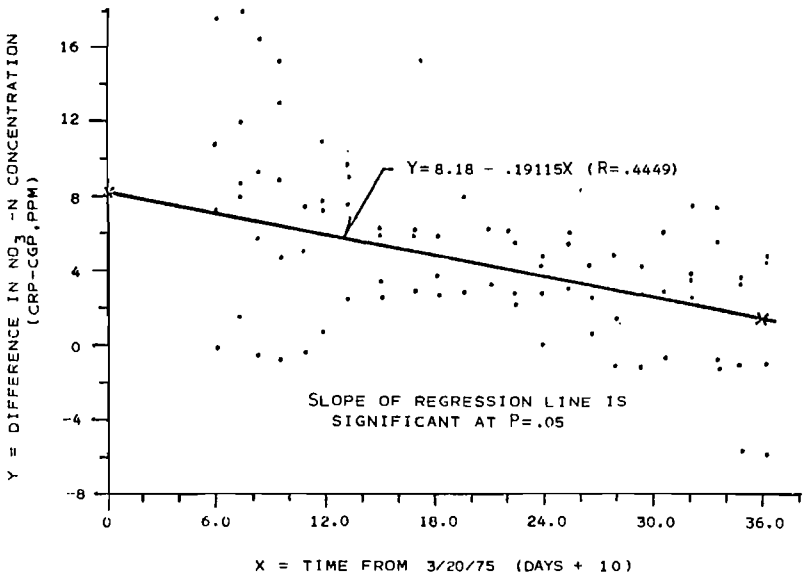


FIGURE 4–1 *Summary of Experimental Data Showing Reductions in Groundwater Nitrates Obtained by Scientific Fertilizer Application (Potato Farm)*

Source: Baier, J. and K. Rykbost, 1976, "The Contribution of Fertilizer to the Groundwater on Long Island," presented at the Third National Groundwater Quality Symposium.

Table 4–25

ANALYSIS OF DOG DROPPINGS: CHICAGO[a]

Constituent	Three Sample Collections		
	1	2	3
Water Soluble, mg/100 ml	16.5	20.2	178.3
Volatile Water Soluble, mg/100 ml	10.3	15.9	145.8
BOD_5, mg/g	78	377.3	300
COD, mg/g	200.7	552	720
Coliform, MPN/g	16,090	16,090	1,400,000

[a]*Source: American Public Works Association (1969).*

wastes contribute both nitrogen and coliform bacteria to surface waters. These contaminants end up in runoff, which enters bays and recharge basins. Thus, animal waste controls that reduce these loads would be clearly beneficial. Effective controls may lessen the need for sewering and may reduce coliform levels in bays sufficiently to permit the reopening of shellfish beds.

4.2.8 Reduce Reliance on Landfills. The proposed measures are clearly of environmental benefit. Organic sampling (1978) demonstrated the hazards to groundwater quality associated with landfills.

4.2.9 Provide for the Treatment of Hazardous Wastes. The collection and treatment of hazardous wastes, discussed in 3.5.1.10 and in Plan Section K "Residual Waste Control Needs" has clear environmental benefits. However, the treatment processes result in hazardous residues and sludges still requiring ultimate disposal. The WQMP recommends (a) removing wastes from the bi-county area or, if that is not feasible, (b) building a bi-county treatment facility, or two county ones. Alternative (a) simply transfers the disposal problem to other areas and does not provide for ultimate disposal of wastes. It is an unacceptable strategy from a Metropolitan Regional standpoint, although it may appear to be adequate from a bi-county perspective. Alternative (b) is the more acceptable option, it being understood that special precautions must still be taken when landfilling treatment residues and sludges. Chemical landfilling may result in accidental discharges to groundwater, with the resulting contamination of the Magothy aquifer if the landfill is in the recharge zone, or of the bays if it is located in a shallow flow zone.

4.2.10 Provide Alternatives to Ocean Disposal of Municipal Treatment Plant Sludge. The alternatives presented in Section 3.5.1.11 as being equally acceptable are not equal in terms of environmental impact. Incineration is the least desirable because of associated air emissions and high energy expenditures. Co-incineration generates the same emissions but provides some energy savings. Pyrolysis produces significantly less harmful air emissions and provides a high energy return. Landfilling and land application probably are not feasible from land use and pathogen contamination standpoints. Thermal

Table 4—26

SUGGESTED HUMAN AND ANIMAL WASTE PRODUCTION VALUES FOR BIOCHEMICAL OXYGEN DEMAND (BOD) AND BACTERIOLOGICAL CONTENT

		Daily Solid Waste Production			Solid Waste Only			Solid Waste Bacteria Content (Million MPN/g)			
								Coliform			
Biotype	Nassau-Suffolk Population (Numbers)	Single Animal (Grams)	Total Population (Pounds)	BOD per Animal Per Day (Pounds)	Human BOD Equivalent	Daily Total Human BOD Equivalent	Total Animal BOD Load (% Human)	Total	Fecal	Fecal Strepto-Cocci	FC/FS*
Human	2,735,637	150	903,000	0.17	1.00	2,735,637	100.0	NA	13.30	3.0	4.43
Dog	425,000	227	212,500	0.13	0.76	323,000	11.81	18.0	18.00	7,300.	0.002
Horse	30,000	16,100	1,063,875	1.40	8.24	247,200	9.04	NA	NA	NA	NA
Duck	750,000	336	400,000**	0.02	0.12	90,000	3.29	NA	32.70	53.6	0.61
Cattle	1,825	26,300	105,721	1.89	11.12	20,294	0.74	NA	0.23	1.3	0.18
Chicken	121,200	182	48,587	0.02	0.12	14,544	0.53	NA	1.30	3.4	0.38
Swine	635	2,700	3,776	0.34	0.20	1,270	0.05	NA	3.30	84.0	0.04

**Fecal coliform-Fecal streptococci ratio*
***Total volume of waste from market ducks adjusted for probable age distribution and does not include wild or semi-wild population.*
Source: NSRPB, 1977, "Animal Waste: Non-point Source Pollution" 208 Program Report Series.

drying produces a usable product but requires a significant energy expenditure. Composting provides a stable product with few negative effects. Thus, any or all of three alternatives—pyrolysis, composting and thermal drying—would be environmentally acceptable.

4.2.11 Minimize Population Density. Land use controls would have several important environmental benefits including: (a) avoidance of high density conditions that appear to be associated with significant degradation of groundwater quality, (b) provision for substantial dilution of on-lot residual discharges, (c) preservation of vegetative cover and habitat areas, which provide the setting for natural cycling of micronutrients, and (d) minimization of human impacts on the hydrologic cycle.

4.2.12 Promote Water Conservation. Water conservation can decrease sewage flows requiring treatment. Conservation practices could assume particular importance under sewering approaches. Sewering, when coupled with marine surface discharges, makes most domestic water uses consumptive. Thus, water conservation is environmentally beneficial.

4.2.13 Effects Associated with Sewering Activities. Comprehensive (1 D.U.) and less extensive Island-wide (2 D.U./gross acre and 3 D.U./gross acre) sewering are options for each of the 208 water management zones of Long Island. As a result of these options, substantial construction of both sewer lines and treatment plants will be required. Such activities will tend to (1) safeguard groundwater from nitrate, organic chemicals, and pathogen contamination (with secondary improvements in surface waters); (2) cause a lower water table if there is no recharge; (3) increase loads of treated effluent to some combination of bays, ocean, and recharge; and (4) increase the sludge load. Effects (2), (3), and (4) are important intermedia impacts that must be considered. Sewering is often judged environmentally beneficial without sufficient consideration of intermedia tradeoffs of groundwater nitrogen and surface water pathogens against surface water quality, air quality, and sludge loads, many of which involve significant health impacts. The major tradeoffs can be summarized as follows:

(a) *Sewering with Surface Outfall.* Limits domestic contributions to groundwater nitrogen; limits public health risks to surface waters resulting from septic tank failures; increases marine/bay nitrogen levels; increases marine/bay coliform levels; decreases streamflows and wetland inundation; involves high costs with high cost uncertainties.

(b) *Sewering with Surface Outfall and Stream Augmentation.* Same as above, although streamflow decreases may (possibly) be mitigated.

(c) *Sewering with Recharge.* Limits domestic contributions to groundwater nitrogen; limits public health risks to surface waters resulting from septic tank failures; may cause groundwater contamination depending on reliability of recharge/treatment technology; may possibly mitigate streamflow and wetland inundation impacts. High cost uncertainties, (engineering uncertainties concerning recharge).

(d) *Sewering only in Selected Areas (high water table, 5 D.U./gross acre densities) with Non-structural Measures.* Limits (with uncertainty) non-point contributions to groundwater nitrogen; limits public health risks to surface waters resulting from septic tank failures; maintains low marine/bay nitrogen levels (with nitrate contributions from groundwater underflow); protects streamflows and wetland inundation levels.

Although, in some areas there may be no presently available alternative for the reduction of groundwater nitrogen, on an areawide basis, sewering should only be used as one of a set of measures to deal with the range of environmental problems.

4.2.13.1 Short-Term Primary Impacts. *Metals, organic chemicals, nitrates, coliforms, virus, water quality, water level, fish, shellfish, contact*

Table 4–27

DOGS ENUMERATED AND LICENSED: NASSAU AND SUFFOLK TOWNS, CITIES AND SELECTED VILLAGES IN 1976

The following municipalities were enumerated and licensed in 1976.

Town	Enumerated	Licensed
Hempstead	59,995	50,682
North Hempstead	21,957	22,573
Oyster Bay	30,525	29,048
Cities		
Glen Cove	2,418	2,064
Long Beach	1,953	1,874
Town		
Babylon	27,515	21,564
Brookhaven	35,324	26,372
East Hampton	1,683	2,302
Huntington	18,175	24,687
Islip	39,811	23,206
Riverhead	2,674	2,824
Shelter Island	378	1,597
Smithtown	12,633	11,894
Southold	2,747	3,066
Southampton	6,500	4,283
Total Enumerations = 287,886		

Village	Enumerated	Licensed
Atlantic Beach	482	222
Bayville	613	613
Bellerose	128	130
Cedarhurst	553	535
Centre Island	113	117
Floral Park	1,629	1,522
Laurel Hollow	320	325
Freeport	3,916	3,336
Garden City	2,002	2,332
Hempstead	3,250	2,593
Hewlett Bay Park	84	79
Hewlett Neck	71	64
Lynbrook	2,258	1,926
Malverne	1,021	1,005
Massapequa Park	3,075	2,727
Mill Neck	291	269
Old Brookville	336	300
Oyster Bay Cove	436	439
Rockville Centre	2,124	2,238
Sea Cliff	896	807
Total Licensed = 249,615		

Village	Enumerated (1974)	Licensed (1975)
East Rockaway	1,535	1,153
Farmingdale	640	621
Hewlett Harbor	208	197
Island Park	526	524
Total Enumerations = 7,973		

Village	Enumerated (1974)	Licensed (1975)
Lawrence	798	693
South Floral Park	131	140
Stewart Manor	267	309
Valley Stream	3,763	3,598
Woodsburgh	105	88
Total Licensed = 7,323		

Source: Esser et al., (1977).

recreation: Dewatering activities in sewer excavations may generate a contaminated waste. This pump water must be carefully monitored and disposed of.

Aesthetics. Construction of sewer lines, interceptors, and associated structures will cause some aesthetic degradation. Such problems can be minimized, if desired, by the use of optimal construction schedules and practices. Short-term aesthetic problems are probably outweighed by other long-term environmental benefits.

Wetlands. Expansion or upgrading of present treatment plants located around the Long Island bays may result in temporary disruption to the flora and fauna of the surrounding wetlands and to fish and shellfish populations. As a site is developed and prepared, the clearing of vegetation

increases land erosion and alters runoff drainage patterns. The hydrocarbons and other chemicals used in construction tend to spill on the ground and are washed into the soil or into the surrounding bays. Although many of the treatment plants are already located on sites that allow expansion, some will need more land for construction and thus may impinge upon neighboring wetlands.

Comprehensive sewering requires pipeline construction, and in some areas this will involve laying pipes through wetlands. Such an activity involves dredging, which, at least temporarily, alters the vegetation and drainage patterns of the area. If dredged material is subsequently replaced and the area is revegetated, these impacts will be minimized.

Although more than 50 percent of Nassau County is presently sewered, including some of the North and most of the South Shore area, less than ten percent of Suffolk County is currently sewered. Most of the areas surrounding Great South Bay remain unsewered, and if plans for sewering are implemented in those areas, great care must be taken to preserve the wetlands and to locate treatment plants away from valuable areas such as the Connetquot River and Bellport Bay. Any construction of pipelines that run through wetlands must be carefully supervised to ensure minimal damage and proper restoration.

Unique habitats. Effects due to sewer and sewage treatment plant construction can be negligible if all structures are built outside habitat areas.

Open spaces. No significant effect.

4.2.13.2 Long-Term Primary Impacts

Metals, organic chemicals. There is a positive effect associated with the hookup of industries to sewers, although pretreatment waste then have to be disposed of.

Nitrates. In most sewered areas, the level of nitrate in the Magothy aquifer is expected to be significantly less than it would have been had those areas not been sewered. This decrease is most likely to be noted in Zones I, II and III. However, it must be noted that the relationship between sewering, fertilizers, aquifer hydrology and nitrogen has not been firmly established. This decrease in groundwater nitrates is a positive effect, both from a groundwater supply standpoint and with respect to underflow to bays.

Coliform and viruses. Coliform and viruses do not appear to travel long distances in the groundwater (Vaughn and Landry, 1977). Thus, the benefits of sewering in this respect may be limited to (1) reductions of pathogen levels in the vicinity of septic systems and (2) reductions in individual discharges of untreated wastes to bays and streams, including discharges due to system failures.

Water quantity and water table. The comprehensive sewering option tends to reduce the quantity of water being recharged unless sewage treatment plant effluent is recharged. Work done during the 208 Study suggests that the effect on the overall water supply reservoir will be insignificant, but that streams and wetlands will have lowered water levels and the salinity of Great South Bay may be altered. This will be a significant negative environmental impact.

Fish, shellfish, contact recreation, aesthetics. See Table 4–28.

Wetlands. Failure to reclaim areas used in construction of treatment plants and pipelines will result in permanent loss of valuable wetlands. Increased erosion and runoff, and a loss of vegetation and resulting increase in detritus, may upset the ecological balance of the wetlands, reducing their value as nutrient sinks and productive habitats for fish, shellfish and wildlife.

Sewering in areas adjacent to wetlands may prove beneficial in terms

Table 4–28

MATRIX DISPLAY OF LONG TERM PRIMARY EFFECTS OF SEWERING

	Sectors Affected						
Changes Due to Sewering	**Freshwater Fish Diversity**	**Marine Fish Community Diversity**	**Shellfish Community Diversity**	**Contact Recreation**	**Shoreline Aesthetics**	**Water Quality Aesthetics**	**Open Space Aesthetics**
Water Table	NE	O	O	O	O	NE*	NE*
Stream Flow	NE	O	O	O	O	NE*	O
Great South Bay Salinity	O	NE	NE*	O	O	NE	O
Groundwater Nutrients	PE	PE	PE	O	O	PE*	O

PE = Significant Positive Effect
NE = Significant Negative Effect
O = No Effect
** = Key Effect*

Source: ERCO

of limiting the sewage that flows into these areas and thence into the bay. The soil in such locations is generally unsuitable for on-site disposal systems because of its vulnerability to high storm tides and its saturation. By installing sewers, one may cause some reduction in the amount of nutrients and bacteria which flow into the wetlands, since on-site systems are reduced in number.

Lower water table elevations due to sewering with marine discharge will reduce freshwater wetland area extent, especially along the South Shore. This is a significant negative effect.

Unique habitats. No significant effect if structures are properly sited.

Open space. A potential threat is posed to terrestrial habitats. Construction agencies must use available municipal land for the treatment plants, and in many communities on Long Island the most available municipal sites are open spaces, potential park sites and forests. Any structural option may represent a tradeoff of water quality against the preservation of terrestrial habitats and the vegetation and wildlife harbored there.

4.2.13.3 Secondary Impacts. There are a number of indirect consequences of sewering activities that are too broad in scope to consider in detail in this study. These can be divided into several categories as follows: (1) effects on other environmental media, (2) social and economic effects, (3) public health effects and (4) natural resource effects.

Those aspects of sewering activities likely to induce secondary effects are changes in water levels, interruptions in natural chemical cycles, changes in development patterns and improved surface and groundwater quality.

Effects induced by changes in water level are discussed in this section as part of direct effects and include changes in wetland vegetation and stream ecology. Induced water level changes are the subject of an in-depth study to be conducted by USEPA and SCDEC. Impacts on natural chemical cycles cannot be determined in this water quality management program because of the lack of data and time-resource constraints. Induced changes in development as a consequence of sewering have been studied at the national level by CEQ (Urban Systems, Inc., 1974). This study concluded that sewering activities will generally induce land development and growth. NSRPB studies indicate that this induced effect has not occurred in the SMSA, and cannot be linked to sewering activities on Long Island. The Urban Systems study contends that sewering provides the vehicle for land subdivision and high rise construction in a fashion similar to the well-known strip development of highways. The NSRPB contends that Long Island sewering activities lag rather than lead development. Suffolk County contends that costs to homeowners of sewering discourages growth. No usable analysis of the Long Island situation is available. Thus, the Urban Systems viewpoint cannot be completely discarded.

4.2.13.4 Adverse Environmental Impacts. All those enumerated under Short-Term Primary Impacts and Secondary Impacts, and those adverse under Long-Term Primary Impacts.

4.2.13.5 Minimize Adverse Impacts. In order to mitigate the effects of construction upon wetlands and aesthetics, certain steps can be taken. These include minimizing the construction area, preventing erosion during construction, and restoring the sites following completion of the activity. Particular care should be taken to restore natural drainage patterns and to maintain buffer strips between the construction area and watercourses. Structures should be sited to avoid important wildlife habitats and valuable open space.

4.2.13.6 Irreversible and Irretrievable Commitment of Resoureces. The permanent loss of some wetlands and the degradation of wetland environments by vegetation loss and erosion are two aspects of comprehensive sewering that result in irreversible and irretrievable commitments of resources. If construction activities are handled so as to minimize adverse effects, this permanent loss will be minimal.

The decline in streamflow and change in water level of wetlands is a very significant environmental effect. The selection of comprehensive sewering options dictates that one be prepared to trade off improvements in groundwater nitrate level against the loss of freshwater wetlands or be prepared to augment streamflow and freshwater wetland levels. Nassau and Suffolk Counties have recently proposed to the EPA that a comprehensive study of the effects of Sewage Disposal Districts Two and Three (Nassau) and the Southwest Sewer District (Suffolk) on stream flow and Great South Bay salinity be performed. Thus, a better judgment of the impact and extent of stream flow changes can be made when that study is complete.

4.2.14 Effects Associated with Stormwater Runoff Controls. Most of the coliform contamination outside of western Long Island Sound, and much of the nutrients, solids, organics and metals in the surface waters, originate in non-point stormwater runoff. Thus, control of this runoff is a key management alternative for the bays, particularly those where shellfish beds have been closed because of high coliform bacteria levels and those which exhibit elevated nitrogen levels. These include Great South Bay, Moriches Bay, Oyster Bay, Port Jefferson Harbor and Huntington/Northport. The nature of runoff contaminants tends to be different for the different areas (Weston, 1977d). For example, in Oyster Bay, coliform bacteria from semi-wild duck and other animal populations frequenting tributary ponds is a key contaminant. However, not enough is known about the runoff to each bay to be able to demonstrate the major differences. In general, nutrients and total coliform bacteria dominate pollutant loadings in runoff in eastern bays, and metals and organics attain a greater significance in western bays.

The control of storm runoff can be accomplished by employing two types of alternatives for pollution abatement, namely structural and non-structural Best Management Practices. Structural alternatives include the following:

1. Sedimentation in storage reservoirs followed by chlorination of the effluent.

2. Sedimentation in storage reservoirs followed by ozonation of the effluent.

3. Primary treatment using swirl regulator/concentrators followed by chlorination of the effluent.

4. Marsh-pond treatment with sedimentation.

5. Natural pond retention and disinfection.

Control by non-structural methodologies involves the following alternatives:

1. Employment of Best Management Practices (BMP) to reduce the volume of runoff reaching surface waters by means of on-site recharge, detention (storage in permanent basins or ponds; temporary ponding on dual-purpose paved areas) and retention (use of natural drainage system; creation of broad channels; employment of flow-retarding devices).

2. Use of Best Management Practices designed to limit availability of pollutants in transport by controlling sediments, and by fertilizer and animal waste controls.

3. Interception and disposal of accumulated pollutants before they reach surface waters by street cleaning and catch basin maintenance.

Non-structural controls have been proposed for Long Island bays. The effectiveness of such controls is not known. Thus, a pilot program has been proposed to evaluate the non-structural approach.

If such a pilot program produces poor results, structural measures will be required. On an areawide basis, extensive runoff controls are environmentally beneficial.

4.2.14.1 Short-Term Primary Impacts. Short-term primary impacts will result primarily from the construction of detention or retention structures, and specialized treatment plants built specifically to treat stormwater runoff.

Metals, organic chemicals. Various contaminants are freed to runoff during construction, including exposed materials (debris, trash), stagnant water, fuel and chemical spillage, vehicle drippings and others. The impacts of runoff and leachate from these materials entering the aquatic ecosystems are varied and relatively unexplored. Synergistic effects of hydrocarbons and heavy metals contamination in shellfish have not been studied, for instance. These effects can be controlled by analysis of soil samples prior to site selection so as to avoid construction in contaminated soils, and by construction of runoff contaminant-control structures.

Nitrates, coliform, virus, water quality, water level. No effect.

Fish, shellfish. The impacts to watercourses and bays associated with construction include the following:

1. Increased volume of water to watercourses from surface runoff.
2. Increased turbidity from loss of natural cover and topsoil.
3. Increased sedimentation and possible shoaling.
4. Peripherally, loss of wetland habitat.

Fish and shellfish are sensitive to increased turbidity and sedimentation, especially in egg, larval and juvenile stages (see assessment of change in outfall location). Benthic shellfish, once covered, are smothered. It may take up to two years before the area is recolonized. These effects can be minimized by prudent construction practices.

Contact recreation, aesthetics. A significant benefit for contact recreation will be due to reductions in coliform levels. Aesthetic benefits will derive from general water quality improvements. (See Section 4.2.1.6.)

Wetlands. Construction of ponds or basins, as well as the building of facilities to treat the runoff, may result in temporary destruction of wetlands through removal of vegetation and soil erosion. The potential dangers due to site preparation and access, and the storage of machinery and supplies, are similar to those for any other type of construction. In this case, however, large areas of land must be altered in order to meet the size requirements of settling basins (on the order of 400 feet by 200 feet by fifteen feet). Thus, the impact on wetlands is potentially greater, possibly including the destruction of extensive tracts of land that may shelter large populations of wildlife.

Unique habitats, open space. No significant effects when properly sited.

4.2.14.2 Long-Term Primary Impacts

Metals. Structural or non-structural controls may significantly reduce metal pollution due to runoff. This is due to adsorption of metals onto settleable material.

Organics. Some reductions may be noted.

Nitrates, coliforms, viruses. The major purpose of these measures is to provide an environmental/health benefit by reduction of these constituents.

Water quantity, water level. No effect.

Fish, shellfish. Long-term impacts of improving structural and non-structural stormwater runoff controls will result in an improvement in general water quality depending on the control alternatives implemented. Sedimentation in storage reservoirs and/or the use of a swirl/concentrator will remove suspended soilds. At peak design flow, the swirl/concentrator system will remove 60 percent of the suspended solids. Disinfection units can also be linked to these systems to eliminate coliform contamination. However, during a typical five year period, thirteen percent of the storms would result in overflows without treatment.

In the long term, storage with sedimentation followed by disinfection will adequately address the suspended sediments and coliform components of stormwater runoff. Thus, impacts on fish and shellfish associated with turbidity, such as gill clogging and smothering, will be decreased. Additionally, lower coliform levels will render shellfish beds harvestable and may also improve bay quality with respect to bathing.

The non-structural alternatives of detention and retention of more diffuse sources of stormwater runoff will also improve water quality in the long run, by reducing turbidity. Peak flows will be modified, reducing suspended sediment concentrations in watercourses. Retention of water will also enhance the settling of suspended sediments.

Non-structural alternatives may not adequately control such sources of pollution from storm runoff as coliform bacteria, pesticides, metals and hydrocarbons, since they deal only (at least directly) with flows and suspended sediments. It is true, for instance, that some phosphorus and heavy metals adsorb onto soil particles, which settle and are thereby removed. However, nitrates are extremely soluble in water and are not removed by alternatives that merely detain or retard flows. Additions of nitrate as oxidized forms of ammonia and nitrite will fertilize plant communities and lead to overproduction and imbalanced food webs, *i.e.,* ecosystem deterioration. A non-structural alternative that is an exception to this is street cleaning, which has been shown to reduce contaminant concentrations. A pilot study of the impact of street cleaning on runoff quality has been proposed for a South Shore locale. The results of that study will show whether or not structural non-point controls will be required.

Contact recreation. Certain areas of the bays that are valuable for both primary and secondary contact recreation are subject to violations of the coliform standards. The implementation of stormwater runoff control measures should result in significant water quality improvements relative to contact recreation potential, since the major coliform source for most bays is runoff.

Aesthetics. Aesthetics can be affected positively if attention is paid to landscaping of runoff detention structures.

Wetlands. The large area requirements of storage ponds will often motivate the developer to use less expensive land, such as wetlands. In addition, the natural drainage patterns may facilitate siting ponds on relatively low land to avoid the need for pumping water. Yet the importance of wetlands in the coastal ecosystem is so great that all attempts should be made to avoid permanent loss of these habitats. This is particularly true of storage reservoirs with or without treatment, since they require very large areas. Other control measures, such as the use of already paved areas and recharge areas with vegetation, put much less demand upon the wetlands. Such alternative measures should be utilized wherever possible in the sensitive areas of Oyster Bay and Great South Bay.

Wetland areas themselves can be used as runoff filters and, in some cases, may be constructed specifically for that purpose. Such construction would be a strong positive benefit. It is suggested that a pilot effort be designed to test the practicability of such a runoff-treatment marsh system.

Unique habitats, open space. Care must be taken to avoid the use of environmentally valuable lands for runoff control structures.

4.2.14.3 Secondary Impacts. Management practices that involve street cleaning, or treatment of water, produce addtional residue that must be disposed of in an environmentally acceptable manner.

4.2.14.4 Adverse Environmental Impacts. Control measures involving the construction of ponds or basins exert adverse effects, as discussed above. Pre-emption of open space areas or wetlands introduces tradeoffs between terrestrial, wetland and marine quality.

4.2.14.5 Minimizing Adverse Effects. Site selection on the basis of the environmental value of land and careful supervision of construction practices will help reduce unnecessary impacts. Specific controls for erosion are a necessity. These should include minimal land clearing, covering of stripped areas with mulch, and then replanting when construction is completed.

To avoid encroachment on valuable terrestrial habitat or wetland areas, all efforts should be expended to find alternate sites for retention ponds. Detention ponds may be located within residential or commercial areas and suitably landscaped to serve an aesthetic and recreational purpose in addition to runoff control. Avoidance of wetland sites and location of the ponds closer to the sources of urban runoff, will permit removal of the sediments at an early point and will prevent siltation of marshlands.

4.2.14.6 Irreversible and Irretrievable Commitment of Resources. The loss of wetland areas and open space through construction of settling basins and ponds threatens the healthy functioning of the coastal ecosystem. Commitment of such land is usually irreversible, and thus all other control measures and sites should be considered before wetlands or valuable habitats are chosen.

4.2.15 Effects Associated with the Upgrading of Treatment Plants. Upgrading the facilities and capabilities of treatment plants to remove contaminants from wastewater deals directly with the point source aspect of the bay and groundwater quality problems in the bi-county area. With respect to fish and shellfish, preserving the natural conditions of the bay ecosystems is the only way to maintain and enhance the productivity and diversity of the indigenous populations; however, mariculture, a special case, is an exception to that rule. Removing excess nitrogen, a critical limiting nutrient in estuarine ecosystems, and maintaining suitable N/P ratios, will help maintain the natural associations of species and the stability of the trophic structure. It should be noted that nitrogen removal would be unnecessary except for a few bays if the non-sewering options were selected, but would be essential under the one dwelling unit per gross acre and three dwelling units per gross acre sewering options. For many bays, upgrading treatment plants is only effective in concert with non-point controls. Upgrading of plants in Manhasset Bay and Hempstead Harbor will be only partially effective for local harbor improvements if Long Island Sound conditions do not improve.

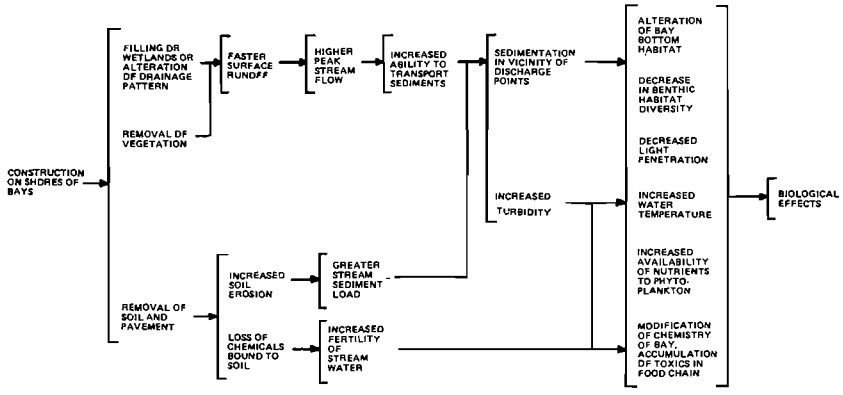
Upgrading of the existing treatment plant facilities with effluent discharge at the present outfall or construction of a mid-bay outfall have been recommended for Manhasset Bay, Hempstead Harbor, Oyster Bay, Huntington Bay, Port Jefferson Harbor, Peconic/Flanders and Patchogue (in Great South Bay). Specific judgments are made in Section 4.3. Some areawide considerations are discussed here.

4.2.15.1 Short-Term Primary Impacts. Short-term primary impacts on aquatic ecosystems due to construction should be minimal, provided treatment plants are not located in proximity to bay shores or wetlands.

Nor should treatment plants be located on watercourses that feed directly into large streams, rivers or wetlands that either empty into, or fringe, the bay ecosystems. Aquatic ecosystems are impacted by construction in the following ways. (See Figure 4–2.)

1. Increased erosion and loss of topsoil leading to:
   - Increased downstream flooding.
   - Increased bottom sedimentation.
   - Increased turbidity.
   - Increased sediment load
2. Construction-related dissolved or suspended leachate contamination such as:
   - Additions of hydrocarbons.
   - Additions of soil minerals.
   - Additions of heavy metals.
   - Additions of fertilizers or pesticides.
   - Additions of stagnant water.
3. Other changes in aquatic water quality:
   - Changed water temperature.
   - Changed pH (estuarine systems are well buffered).
   - Increased BOD.

Measures to mitigate aquatic impact from upland construction will be site-specific. Thus, specific impacts need to be assessed once sites are selected.



Source: ERCO

FIGURE 4–2 *Effects of Construction on Bay Conditions*

4.2.15.2 Long-Term Primary Impacts. In general, the long-term effects are beneficial. Improving the quality of effluent discharged in the bay, Sound, and near shore coastal waters can only improve fish and shellfish productivity and diversity, and bathing water quality. In cases where tertiary treated wastes are recharged, effluents to bays are eliminated. Noxious species will decline, diversity on all trophic levels will increase, and, as a result, ecosystem stability will be enhanced. Algal blooms associated with nutirent overloading will decrease. Coliform counts will be reduced in some bays, opening shellfish areas to production, and consequently increasing water usage. However, there are some tradeoffs involved. First, augmented treatment generates additional sludge, which requires disposal. Sludge disposal then imposes air pollution loads (in the cases of co-incineration, incineration or pyrolysis) or land requirements (in the cases of composting and land application). Also, advanced nitrogen removal may impose lowered N/P ratios, which may affect the phytoplankton community diversity. Another tradeoff relates to increased residual chlorine caused by increased effluent loads. This chlorine is toxic to marine organisms in some cases and may inhibit growth in the vicinity of outfalls. Table 4–29 illustrates present levels of residual chlorine. Future levels are not expected to be significantly higher. At least some dilution will occur in the receiving water. Present EPA criteria levels for toxicity are three micrograms per liter of chlorine for salmonid fish and ten micrograms per liter for other freshwater and marine organisms. Thus, chlorine from treatment plants does not appear to pose a significant threat. Similarly, ammonia levels are expected to remain well below the toxicity threshold. When waste effluent is to be recharged, chlorinated effluent will contain unacceptable levels of chlorinated organics and other disinfectant techniques may be required.

Metals and organics. No significant effect.

Nitrates. No health-related effects for surface discharges. Nitrogen concentrations in groundwater will be lowered by sewering and recharge. The net effect of reduction in nitrogen inputs due to sewering with or without recharge is beneficial.

Coliform and viruses. In cases where shoreline areas are sewered and diverted to treatment plants, some of the non-point pathogen loading may be reduced.

Water quality, stream water levels. Beneficial for nitrogen levels.

Fish, shellfish. See Section 4.3 for a bay-by-bay discussion.

Contact recreation. As a public health measure, bathing is generally prohibited in the vicinity of outfalls.

Aesthetics. All effects are highly dependent on treatment plant design and siting. Effects include the following:

- Visual effect of structures.
- Water quality improvements (color, turbidity).
- Ecological improvements (increased species diversity).

Table 4—29

1976 STP CHLORINE RESIDUAL AVERAGES NASSAU COUNTY

Treatment Plant	Average Cl_2 Residual in PPM	Number of Data Points
Cedar Creek STP	3.2	64
Bay Park STP	1.7	60
Lawrence STP	2.1	30
Long Beach STP	2.9	36
West Long Beach STP	1.3	18
Freeport STP	2.7	24
Jones Beach STP	2.3	8
Cedarhurst STP	1.6	13
Inwood STP	1.7	7
Belgrave STP	2.7	8
Great Neck Sewer District STP	2.2	22
Great Neck Village STP	2.3	17
Port Washington STP	2.6	11
Glen Cove STP	2.3	51
Roslyn STP	1.7	20
Oyster Bay STP	1.9	7
Seawanhaka Yacht Club STP	4.0	7
Cold Spring Harbor STP	3.7	11
C.W. Post STP	2.5	6
Farmingdale STP	3.6	5
Meadowbrook STP	1.6	4
Roslyn Duck Pond Chlorinated Discharge	0.5	7

Source: Nassau County Department of Health, 1978.

4.2.15.3 Secondary Effects. A bay discharge is generally less expensive than an ocean outfall which often requires a long conduit (outfall). Recharge which implies the most stringent treatment requirements is generally the most expensive disposal technique. However, the costs of ocean discharge are more favorable when several plants can be routed to one outfall. With respect to sludge generation, treatment plants impose tradeoffs between bay quality and air quality, land use and groundwater quality.

4.2.15.4 Short-Term Versus Long-Term Environmental Benefits. The long-term environmental benefits of improved effluent quality are clear. However, in the long term, and as technology advances, alternatives to effluent disposal in the bays should be considered. These include flow reduction and land reclamation. As the demand for fresh water from diminishing conventional sources has increased, the interest in land reclamation of industrial and municipal wastewater effluents has expanded concomitantly. In many areas of the country, wastewater effluents are being utilized to supplement freshwater supplies. Wastewater reclamation technologies employing additions from municipal effluent have been used for irrigation (principally agriculture), groundwater recharge, stream augmentation, overland flows (migration and renovation) and for non-potable domestic use.

4.2.16 Effects Associated with Point Source Outfall Relocations. Relocation of the outfalls to mid-bay sites is advanced as an option for Huntington Bay, Hempstead Harbor, Manhasset Bay, Port Jefferson Harbor and Peconic/Flanders Bay; to an offshore site for Peconic-Flanders and South Shore Bays; and/or out of the area for eastern Great South Bay, Manhasset Bay and Oyster Bay. The movement of sewage effluent outfalls does not remove the excess nutrient (N and P) nor the BOD from the ecosystem, but rather ameliorates ecological stress conditions through pollution dilution. In many cases, this is a critical first step towards improving the water quality in the estuarine bays since several of the bays, particularly Great South Bay, have poor flushing rates and consequently tend to accumulate pollutants. When minimum sewering options are selected, such measures are not required. As described in Section 4.20, non-point controls are required in concert with point source controls to achieve water quality improvement. Specific bay situations are discussed in Section 4.3.

4.2.16.1 Short-Term Primary Impacts. Relocation of outfalls to mid-bay or offshore locations requires construction activity through the estuarine and marine benthos (Great South Bay) and possibly through barrier islands (Fire Island, Long Beach) and fringing wetlands. In general, line construction across the bay bottoms requires dredging by mechanical or, more likely, hydraulic means. The short-term impacts associated with dredging include the following (Darnell, 1976):

- Modification of bottom topography
  - Trenching and backfilling involve the removal of some benthic deposits and the smothering of others.
- Modification of water circulation patterns
- Increased turbidity of water
  - Increased oxygen demand
  - Reduced light penetration
  - Reduced photosynthetic oxygen production
  - Release of toxic organic compounds
  - Release of pesticides, heavy metals and hydrogen sulfide
  - Increased temperature
- Bottom siltation with very fine sediments
- Destruction of benthic flora and fauna
- Disturbance of nesting areas in wetlands

If construction of effluent outfall pipelines is managed correctly, the modification of bottom topography can be minimized by replacing extracted sediments over the pipeline and by contouring and grading the benthos. Such procedures can also eliminate modification of circulation patterns. Potentially, the most damaging aspect of construction activity in bays involves the

turbidity generated by dredging. Turbidity (or suspended sediments) impacts fish and shellfish in the following ways:

1. Suspended sediments increase the oxygen demand in the water column due to increased microbial action (consequently community respiration) on detrital particles. This causes dissolved oxygen to decrease, imposing potential hazards on organisms highly susceptible to oxygen deprivation, particularly active, migratory fishes, which have high dissolved oxygen requirements and low tolerance to oxygen deprivation (Thornton, 1975).

2. Suspended sediments inhibit transmission of light through the water column, thus decreasing the standing crop of phytoplankton. Phytoplankton helps form the base of the estuarine food web and is the chief component of the diet of most shellfish. This effect has been documented in the South Shore bays (NCHD, 1977b).

3. Suspended sediments can introduce toxic materials, such as pesticides (chlorinated hydrocarbons), heavy metals and radionuclides, to the water column. These materials are selectively incorporated into fish and shellfish by biological magnification, and cause lethal and sub-lethal effects.

4. Suspended sediments clog the gills of fishes, inhibiting carbon dioxide-oxygen exchange and causing asphyxiation.

5. Suspended sediments clog the mucous membranes of many suspension and filter feeder molluscs by mimicking the size of the host organisms' food particles. This causes inefficient feeding, choking, clogging and in many cases, death.

6. The settling of suspended sediments can physically cover and smother whole benthic organisms.

Turbidity affects juvenile forms of many of the ecologically and commercially important fishes, shellfishes and crustaceans in the South Shore, Manhasset Bay, Hempstead Harbor and Port Jefferson Harbor areas. Monitoring of this effect is already required by the EPA. Some of the more important fish species in these locations include the striped bass *(Morone saxatilis)*, the bluefish *(Pomatomas saltatrix)*, the white perch *(Morone americana)*, menhaden *(Brevoortia tyrannus)* and other herrings, and the silverside *(Menidia menidia)*. Important shellfish are the hard clam *(Mercenaria mercenaria)*, the blue mussel *(Mytilus edulis)*, bay scallops *(Aequipecten sp.)*, and softshell clams *(Mya arenaria)*, and in some cases, the American oyster *(Crassostrea virginica)*. Crustacea of interest include the blue crab *(Callinectes sapidus)*. Offshore, the surf clam *(Spisula solidissima)* and the American lobster *(Homarus americanus)* are a commercially important shellfish and crustacean, respectively.

The specific effect of suspended sediments on the macroscopic biological community has been well studied. In general, the older the life stage, the more tolerant the species. Adult oysters *(Crassostrea virginica)* are extremely tolerant of high silt loads as are other epi- and infauna of the estuary, which must contend with naturally high silt loads at various times of the year. The egg, larval and juvenile stages of estuarine species can be heavily impacted by artificially high concentrations of suspended sediments (Auld and Schubel, 1974; Schubel *et al.*, 1974; Sherk, 1972). The growth and survival of hard clam and oyster eggs and larvae are disrupted at suspended sediment concentrations as low as 125 milligrams per liter (Davis, 1958). Sherk (1972) tested the effects of suspended sediments on various estuarine fishes. Atlantic silversides *(M. menidia)*, juvenile bluefish *(P. saltatrix)*, juvenile menhaden *(B. tyrannus)* and young of the year white perch *(M. americana)* are highly sensitive to suspended sediment loads. At the other end of the spectrum, striped killifish *(Fundulus majalis)* and the mummichog *(F. heteroclitus)* were most tolerant. Deposition of suspended sediment as a result of water disposal of dredge material covers and smothers clams, oysters, crabs, shrimp and other benthic organisms. Benthic communities that are completely covered require two years to re-establish.

Decreases in dissolved oxygen are commonplace with suspended sediments, the oxygen demand in the water column increasing by a factor of as much as eight (Issac, 1965). Decreases in dissolved oxygen impact the more migratory species of fish, such as herrings *(Alosa sp.* and *B. tyrannus)*, silversides *(M. menidia)*, bluefish *(P. saltatrix)*, anchovy *(Anchoa sp.)* and mackerel *(Scomber scombrus)* (Thornton, 1975).

There is evidence to support the claim that suspended dredge material fertilizes the water through nutrient release, although the effect is not an immediate one (Sherk, 1972).

The following is a list of recommendations concerning the deposition of spoil (Clark, 1974; Daiber *et al.*, 1972, 1974, 1976; Marcellus, *et al.*, 1973; Metzgar, 1973; Maurer *et al.*, 1974; Sherk, 1972) as presented in Daiber and Thornton (1976).

1.Prior to full-scale dredging, there should be a determination of the physical and chemical characteristics of the spoil, in order to decide the most appropriate means of dredge spoil disposal.

2. Spoil should not be placed on high value natural habitats that serve as nursery areas for marine species. These include: marshes, beds of submerged vegetation, protected shallows, oyster reefs, tidal flats.

3. Spoil should not be placed back in the water, if possible, but rather on the uplands. Constraints should be placed on types of materials that can be disposed of in open water. However, effects of upland disposal on groundwater must be monitored.

4. Spoil suitable as "fill" for residential, commercial and industrial development should be used for such purposes. This use is subject to groundwater effects. Constructive alternative uses for spoil should be researched.

5. Abandoned sand and gravel pits in proximity to the water should be used as spoil receptacles provided spoil can be restrained from running off or polluting freshwater supplies.

6. Under certain conditions, spoil can be used to enhance existing marsh or to create new marsh.

7. Spoil deposition sites should be planned to allow future mainten-

ance, as in the creation and development of spoil islands, which have been found to be beneficial for terrestrial habitat and migratory waterfowl.

8. Natural channels should not be blocked with spoil.

9. Beach nourishment and spoil are related problems that should be approached jointly.

10. Temporal aspects of spoil deposition should include consideration of biological factors like spawning seasons and schooling patterns, and factors such as the bathing season.

There is a possible impact on wetlands on the South Shore, where the proposed relocation of the Bay Park outfall to permit ocean discharge may disturb wetlands and bay benthos due to dredging, removal of vegetation, and increased turbidity in the area. Caution must be exercised when planning routes and construction methods and times.

Construction activities for an ocean outfall for Bay Park would probably involve a route passing through Long Beach. This would have various effects on the environs of the City of Long Beach.

4.2.16.2 Long-Term Primary Impacts. The long-term impacts of outfall relocation will greatly improve the water quality in the areas from which the outfalls were moved. The BOD, COD, refractory organics, suspended soilds, total nitrogen, total phosphorus, dissolved minerals, and coliform levels should all decrease.

Moving the outfalls offshore will lower the input of nutrients and BOD to the wetland areas, thus increasing the available oxygen in an oxygen-limited environment. This will be beneficial for many fish and will help reverse the eutrophic tendencies of the wetland areas attributable to pollution.

From a dissolved oxygen standpoint, a reduction in BOD would encourage susceptible species as snapper blues *(P. saltatrix),* Atlantic silversides *(M. menidia)* and herrings *(Clupeidae)* to use the formerly impacted areas (Thornton, 1975).

Shellfish such as the hard clam *(Mercenaria mercenaria)* and the oyster *(Crassostrea virginica)* are remarkably tolerant to high concentrations of various nutrients, particularly such nitrogenous compounds as ammonia, nitrite ion, nitrate ion and ortho-phosphate (Epifaunio and Srna, 1976). Effluents of secondarily treated domestic sewage rarely contain levels of these chemicals as high as the 96-hour mean lethal tolerance limits reported in that study. However, sub-lethal toxic concentrations of ammonia (7.2 milligrams per liter) will be encountered around sewage outfalls and will restrict the distribution of molluscs. Consequently, the movement of outfalls to areas of increased flushing will induce a corresponding improvement in shellfish density and diversity in present outfall locales.

Although it is true that wetland areas can serve as nutrient sinks for coastal ecosystems, their capacity is not unlimited and should not be overburdened by anthropogenic wastes. Thus, moving sewage outfalls offshore is a positive step in wetland preservation.

4.2.16.3 Secondary Impacts. Negative secondary impacts include problems associated with spoil disposal, costs associated with monitoring outfall construction and operation, and possible saltwater intrusion into wells hydraulically linked with dredge sites.

Patrick (1949) proposed that moderate pollution would tend to eliminate susceptible species from a community, causing the few that survived to flourish due to reduced competition and greater chance of multiplication. A reduction in pollution should encourage a more healthy, diverse community to evolve.

4.2.16.4 Adverse Environmental Impacts. The risk of leakage from pipelines is always a possibility. If pipes are not properly lined or connected, waste materials may seep into the surrounding soil and alter the vegetation. In the event of violent storms, shifting sands may expose previously buried pipes and perhaps rupture joints. Such an accident would result in great volumes of effluent being discharged directly into the bay and wetland areas, adversely affecting both the vegetation and the wildlife of those areas. Such an event might cause eutrophication and a resulting anoxic area. The leaching of the sewage contaminants to other areas of the bays would then affect water quality and thereby the finfish and shellfish.

4.2.16.5 Minimizing Adverse Impacts. Careful design of pipeline construction is one of the best ways to preclude unnecessary leakage. Siting pipes to avoid wetland areas as well as unstable beaches is vital to safe planning. Geologic conditions should be considered when choosing a route for the line. As mentioned above, proper restoration of the wetland sites affected by pipeline construction is a necessity. Soil must be replaced over the lines, covered with mulch, and planted with marsh vegetation. Precautions must be taken to prevent significant alteration of the drainage patterns due to the soil displacement.

4.2.16.6 Irreversible and Irretrievable Commitment of Resources. None.

4.2.16.7 Relationship Between Short-Term Uses of Environment and Long-Term Environmental Productivity. Moving outfalls to mid-bay or ocean locations, may cause local, temporary perturbations to wetlands and the benthos, but it is beneficial in the long run because of the improvement of water quality and the resulting health of the bay and surrounding wetlands. As long as construction activities are managed in order to minimize habitat destruction, such a project will increase productivity and maintain the healthy ecological functioning of the system.

As was mentioned earlier, relocation of outfalls merely postpones the ultimate resolution of the problem of effluent disposal by physically displacing the outfall to areas of greater water volume and flushing. This is a reasonable temporary measure to immediately improve the water quality in the bays of Nassau and Suffolk Counties, assuming the short-term impacts are kept at a minimum (*i.e.,* restoration of impacted areas is a must). It appears that properly engineered relocation of the outfalls will cause no irreversible or irretrievable commitment of resources. Planners must realize, however, that

the disposal of the effluent in the nearshore Atlantic Ocean, Long Island Sound, or in the middle of the bays may eventually become unacceptable if effluent quality is not improved. Long Island Sound and the New York Bight, although large expanses of water, are already showing some signs of degradation, and increased loads will only exacerbate the situation.

4.3 Area Specific Impacts

The discussions presented below correspond to the subsections of 3.5.2, "Area Specific Alternatives."

Hydrogeologic Zone Alternatives

(Correspond to Subsections of 3.5.2.1.)

4.3.1 Zone I: Deep Flow System (Magothy Recharge Area). Zone I encompasses much of the residential, transport and commercial, and industrial activity areas of Nassau and Suffolk Counties. About ten percent of the area is presently sewered. Other characteristics of Zone I are given in Tables 4–30 to 4–32. The major environmental characteristic of Zone I is that materials released at the surface move downward into the Magothy aquifer. Thus levels of discharge need to be controlled. Zone I is presently well-developed and current land use plans call for continued residential and nonresidential use of the Island's center. Thus, the volume of wastes to be treated and disposed of will grow. Also, pressure to develop existing open spaces will grow. The environmentally favored approach is Alternative IA with possible selective sewering in areas characterized by septic system failures and densities of five or more dwelling units per gross acre, and in other areas indicated by monitoring results. Selection of IA represents a judgement that takes into account the uncertainties concerning implementability and effectiveness of IA and the uncertainties concerning cost-effectiveness and side effects of IB, IC and ID. Both best and worst case situations were considered with respect to the resolution of the various uncertainties.

There are four alternative plans for waste management. These plans represent distinctive approaches; namely, the structural, traditional sewering approach; the non-structural, monitoring, regulatory and non-point source control approach; and intermediate approaches. These approaches have significantly different environmental impacts. One difference relates to the uncertainty of impact. The other relates to secondary problems such as water level and sludge disposal. The sewering approaches (Plans IB, IC and ID) have been in use for years (although the non-point source control aspects of these plans are a new approach). Thus, the impacts are fairly well known. Generally, nitrates, organic chemicals and metals are redistributed from groundwater to waste streams and sludge residues. Water table levels become lower when marine outfalls are employed for ultimate disposal. The effects of Plan ID will be more pronounced than for IB and IC. The non-structural and non-point source control approach (Plan IA) is a fairly untested strategy. Thus, there is a high uncertainty associated with the impacts. Sewage nitrogen is altered by on-site systems to ammonia or nitrates and is diluted in leaching fields. Organic chemicals and metals are controlled at the source and collected as concentrated hazardous wastes. Coliform bacteria in runoff are reduced by management practices or treatment.

There are environmental advantages to each approach. Plans ID and IC, and to a lesser extent, IB, have as their main advantage the predictability of impacts. One can be reasonably confident that the plan will significantly reduce nitrate levels in groundwater and that with a combination of industrial

Table 4–30

DOMESTIC TREATMENT SYSTEMS BY ZONE*,**

Zone***	No. of Systems	Avg. Total Flow (MGD)	BOD Effluent lbs/day	SS Effluent lbs/day	F. Coli N/100 ml	TN lb/day	TP lb/day
I	32	15.978	4,087.1	3,596.2	3,712	3,084	498
II	4	.377	247.2	270.3	217	103	–
III	19	2.285	520	344	1,072	302	74
IV	5	0.455	76.7	176	521	182	9
V	1	0.025	1	1	41	2	–
VI	25	2.557	1,277	397	4,190	558	58
VII	24	90.460	15,255	23,189	2,393	22,619	2,671
VIII	12	7.495	3,966	2,031	3,738	2,179	211

**Source: Weston, 1976.*

***Note: These figures are all based upon the discharge site of the sewer district rather than the areas sewered. For this reason, the coastal zones are particularly high while inland zones may be underestimated. This is especially true of Bay Park STP which has a flow of 63.9 MGD. Although much of the sewer district may be located in Zone I, the outfall flows in Zone VII.*

****See Figure 3–2 for a map of the Zone boundaries.*

Table 4–31

INDUSTRIAL POINT SOURCES BY ZONE*

Zone	Process Flow Rate (gal/day)**
I	675,376,600
II	639,860
III	18,033
IV	87,000
V	35,000
VI	398,600
VII	297,068,000
VIII	396,838,900

Summarized from Weston, 1976
***Includes thermal discharges.*

Table 4–32

MISCELLANEOUS SOURCES BY AREA*

Zone	Landfills Active & Abandoned	Domestic STP's Discharging to Groundwater	Incinerator Effluent To Ground	Duck Farms	Semi-Wild Duck Concentrations
I	12	34	2	0	0
II	2	3	0	0	0
III	0	17	0	0	0
IV	8	2	0	6	2
V	3	0	0	0	1
VI	5	20	1	17	1
VII	5	5	1	0	3
VIII	4	5	0	0	1

Summarized from Miller and Sgambat, 1977.

hook-ups to sewers, and non-point controls, groundwater metal and organic chemical levels will be reduced. Their major disadvantage is the set of environmental side effects. These include lowered water table elevations, if there are surface discharges of effluent (*i.e.,* lowered surface water body levels and flows), increased sludge loads, and a possible catalyst for further development in some areas. (For a discussion of this effect, see Section 4.2.13.3.) Plan IA has as its major advantage the comprehensive minimizing of waste loads with a minimum of side effects and lower cost. Nitrate, metal, organic chemical, pesticide, salt, oil and coliform bacteria levels might all be significantly reduced if controls were to be properly implemented. Its disadvantage is the presently high uncertainty concerning the impact level that will occur. All four plans, if properly implemented, have environmental benefits. The tradeoffs are (a) between a more costly but more certain approach and a less costly approach with higher environmental benefits but higher uncertainty; (b) greater effort to protect surface water quality, air quality and groundwater quantity, versus greater effort to protect groundwater quality (nitrate levels). With respect to sewage, nitrate levels in the Magothy aquifer underlying parts of Area I are high and variable. This can be seen in Table 4–33. Concerning industrial wastes, organics are a problem in the groundwater as mentioned in Section 4.1.1.2. Table 4–34 summarizes data from Zone I. Studies of recharge basins suggest that runoff contributes both organic chemicals and nitrates.

Table 4–33

SELECTED TEST WELL DATA REPRESENTATIVE OF THE HIGH RANGE OF NITRATE LEVELS IN GROUNDWATER UNDERLYING ZONE I*

Well	Date	NO_3–N(mg/l)	Well Depth (feet)	Aquifer
Jericho Turnpike at LIE, Hicksville	9-7-76	2.5	100	Glacial
Round Swamp Road, Huntington	9-1-76	21	168	Magothy
Miller Place, Syosset	9-7-76	9.3	111	Glacial
Garden City Country Club, Garden City	6-2-76	2.4	63	Glacial
	6-23-76	2.4		
	10-6-76	3.6		
Miller Place, Syosset	9-13-76	14	490	Magothy
	10-23-76	15		
Syosset Circle, Jericho	3-3-76	1.6	400	Magothy
	10-27-76	2.6		

Source: Suffolk County Department of Health, 1977.

Plan IA: No Sewering; Emphasis on Individualized Point and Non-point Controls.

Plan IA is considered here in terms of some selective sewering in most areas with population densities of five or more dwelling units per gross acre. Plan IA will reduce nitrate levels somewhat. In general, Zone I is an area of recharge. However, hydrologic characteristics vary locally. Thus there will be locales where higher loads of nitrate will have little effect on ambient levels in the Magothy aquifer. This may be due to direction of aquifer flow, geologic barriers or aquifer chemistry. Proper use of Plan IA should obviate sewering in such areas. Plan IA will maximize the use of the natural nitrogen cycle in the disposal of man-generated nitrates by minimizing structural solutions. Thus, artificial side effects will be minimized.

Land use controls, an important aspect of Plan IA, will be of great benefit in preventing occurence of the conditions of high density residential

Table 4—34

SUMMARY STATISTICS—VOLATILE ORGANIC COMPOUNDS
(Principally Zone 1)

Compound	# stations measured	# stations detected*		# stations occurring @ > 10 μg/l*		# stations occurring @ > 50 μg/l*	
trichloroethylene	116	93	(80%)	35	(30%)	15	(13%)
chloroform	82	68	(77%)	20	(24%)	4	(5%)
1,1,1 trichloroethane	116	57	(49%)	25	(21%)	6	(5%)
carbon tetrachloride	78	28	(36%)	1	(1%)	0	
tetra chloroethlene	116	38	(33%)	10		5	(4%)
dibromochloromethane	78	15	(19%)	0		0	
diethyl ether	38	6	(16%)	0		0	
1,1 dichloroethane	44	5	(11%)	3	(7%)	0	
bromodichloromethane	78	8	(10%)	3	(4%)	1	(1%)
freon—11	44	4	(9%)	0		0	
1,1 dichloroethylene	44	4	(9%)	0		0	
1,2 dichloroethane	44	3	(7%)	0		0	
bromoform	78	5	(6%)	1	(1%)	0	
1 chloropropane	44	1	(2%)	1	(2%)	0	

**percentages given in parenthese.* *Source: ERCO*

and commercial land use that lead to extensive non-point pollution of the Upper Glacial aquifer. In addition, land use controls will act to preserve small undeveloped parcels that constitute the remaining natural habitat. The magnitude of organic chemical loads to be controlled in Plan IA is high, since many industrial wastes will not be diverted to sewers. The loads need to be considerably reduced to keep groundwater organic levels safe from a health standpoint. Each element of the set of non-point and non-structural measures proposed in Plan IA needs to be strictly applied to accomplish that. There is a fairly high uncertainty as to whether the various measures can be applied at a high level of control. Thus, the uncertainty of Plan IA with respect to organic chemicals is high.

Control of metals, nitrogen, organic chemicals and coliform bacteria in runoff is an important aspect of Plan IA. The de-emphasis of sewering must be accompanied by improvement in the quality of runoff to surface waters and to recharge basins. There is a lack of previous experience with implementation of the runoff controls. Thus, there is a high uncertainty as to how effective runoff controls will be in reducing metal, organic chemical, nitrate and coliform bacteria loads. Environmental effects that can be expected from the non-point, non-structural and runoff measures are discussed in Section 4.2.

In summary, Plan IA depends, for a large portion of its effectiveness, on measures such as animal waste control ordinances, fertilizer use ordinances and street cleaning practices, which have a large uncertainty associated with their workability.

Plans IB, IC and ID: Three Dwelling Units Per Gross Acre, with Selective Two Dwelling Units Per Gross Acre and One Dwelling Unit Gross Acre Sewering.

Plan ID, and to a lesser extent, Plans IB and IC, will maintain nitrate levels in groundwater below ten milligrams per liter in locales where nitrates travel downward through the aquifer. However, such locales cannot be mapped in detail. These alternatives may be expected to result in locally high nitrate levels as was suggested by the analysis done for this project, which showed that, in some modeled grid cells, sewering had little correlation with groundwater nitrate (Porter *et al.,* 1978). This approach, however, will result in high nitrogen loading at sewage treatment plants (STPs). Plans IB, IC and ID are designed to avoid violations of groundwater nitrogen standards. They are based on considerable data analysis done during the last two years (Weston, 1977a, 1977b; Porter *et al.,* 1978; Miller and Sgambat, 1977b). Generally, the analyses indicated a large amount of uncertainty as to groundwater nitrogen sources and transport. The data showed that if ten percent violations of standards are an allowable level of nitrate contamination, then sewering at densities of between one dwelling unit per gross acre and three dwelling units per gross acre would result in acceptable nitrate levels with a limited level of enforcement of other controls. Thus, Plan ID is a conservative sewering approach, Plans IC and IB are standard sewering approaches, and Plan IA requires successful implementation and enforcement of other controls for success with respect to nitrogen.

Organic chemicals in industrial effluents will be pretreated and dis-

charged to sewers in Plans IB, IC and ID. Also, the volume of domestically used organics, such as cesspool cleaners, that are introduced to groundwater via on-site systems will be reduced. Thus, a significant fraction of the organics will be controlled by sewering. This leaves a smaller organic load (spills, storage tanks, runoff) subject to the uncertainties associated with non-point measures, which were noted above in the discussion of Plan IA. However, it will be necessary to provide for the disposal of increased quantities of sludges and sewage treatment plant efluents rich in organic chemicals. Effects of sewering, sewerage treatment plants, and outfalls are covered in Section 4.2.

Runoff controls for Plans IB, IC and ID are the same as those proposed for Plan IA. Thus, the same uncertainties discussed with reference to Plan IA apply. However, with respect to nitrates and organic chemicals, the non-point contribution to the total load is less in Plans IB and IC, and least in Plan ID. Thus, the uncertainties are of less consequence.

4.3.2 Zone II: Impaired Water Quality Area. Zone II encompasses a locality of mixed commercial/industrial and residential land, shown in Figure 2–1. Groundwater quality underlying this area is locally unusable and regionally poor, especially with respect to organic chemicals. This zone has displayed the worst groundwater quality in the region. This can be illustrated by groundwater monitoring data from local wells (Table 4–35). The hydrology of this area is similar to that of Zone I; that is, it is a Magothy recharge area. The plume of already contaminated groundwater can be expected to move down into the deeper portions of the Magothy aquifer, then south and up in the South Shore zones.

Zone II is currently being sewered. Thus, there do not appear to be options available with respect to sewering. For non-point source controls, Plan II calls for strict implementation of the whole range of available controls. In addition, industries would connect to sewers and pretreat their waste streams. Such controls would halt significant degradation of the aquifer. Water tables and stream flows will also be reduced as a result of sewering (assuming marine discharge). Implementation of Plan II would generate a sizable quantity of hazardous wastes to be disposed of at the proposed regional facility. Two water supply alternatives, which do not present comparative environmental issues, are also proposed.

In the short term, say a period of up to 50 years, the environmental benefits to be obtained from Plan II would be minimal. No matter how strict the adherence to the plan, the plume of contaminated groundwater would only slowly disperse. Over the long term, environmental benefits could be expected.

4.3.3 Zone III: Highest Grade Reservoir. Zone III encompasses the eastern portion of the Magothy recharge zone, which is generally very high in water quality. The hydrology of this area is similar to that of Zone I; that is, it is a recharge area. It is different from Zone I in that more options for waste management are open. First, less development has occurred. Thus, waste management considerations may have more of a role in determining rational

Table 4–35

RESULTS OF TESTING FOR VOLATILE ORGANICS IN SELECTED WELLS IN ZONE II

NCDH Well #	Date	Compound	Concentration
8941	07-12-76	Chloroform	7.8 μg/l
3876	11-29-76	Trichloroethylene	2.8 μg/l
		Trichloroethane	1.9 μg/l
		Carbon Tetrachloride	2.3 μg/l
3876	12-06-76	Vinyl Chlorides	< 10 μg/l
		Trichloroethylene	60 μg/l
		Tetrachloroethylene	17 μg/l
		Trichlorethane	15 μg/l
		Chloroform	< 1 μg/l
		Benzene	< 2 μg/l
6078	12-06-76	Vinyl Chlorides	< 10 μg/l
		Trichloroethylene	< 1 μg/l
		Tetrachloroethylene	100 μg/l
		Trichloroethane	< 5 μg/l
		Chloroform	< 1 μg/l
		Benzene	< 2 μg/l

Source: Nassau County Department of Health (1977a).

patterns of development. Second, less sewering has occurred. Thus, the option of not sewering is more of a real alternative to be considered.

The plans suggested for protection of the Magothy aquifer in Zone III differ mainly in the extent of the protection that will be provided. Plan IIIB is a "watershed management" plan calling for land acquisition, land use controls and other non-point source controls. Plans IIIA, IIIC, IIID and IIIE are more modest in level of control, calling for a combination of sewering and non-point source controls. Among the environmental advantages of Plan IIIB are (1) control of density of on-site dischargers, thus limiting nitrate loads to groundwater; (2) maintenance of natural recharge sites, thus maintaining water levels and natural treatment of recharge water; and (3) preservation of terrestrial habitats, thus protecting terrestrial populations. However, Plan IIIA with selective sewering is a sound control strategy presenting the same tradeoffs mentioned in Plan IA and is also environmentally acceptable. Plan IIIA has less uncertainty associated with it than IA, since Zone III is further from the New York City industrial center and supports fewer large scale industrial dischargers. Plans IIIC, D and E present many environmental side effects avoided by the other two plans, and previously discussed in connection with Plans IB, C and D. However, recharge of effluent is planned for IIIC, D and E, which would minimize water-table effects and introduce a range of possible groundwater contaminants, such as organic chemical contaminants generated by chlorination.

Long Island's groundwater derives from precipitation, which falls on the ground and percolates through the soil to the aquifers. Since the aquifers are used as the only source of drinking water for the area, the quality of the recharge becomes critical. Urban development, through the clearing of land and the paving of many surfaces, has tended to decrease the amount of recharge to groundwater and to increase the amount of runoff to surface waters. The groundwater recharge basin program, begun in Nassau County in 1935, succeeded in partially alleviating the effects of runoff by providing large unlined basins, where water could seep down to the aquifer. Yet these basins occasionally fail to provide adequate percolation because of poor design, high water table elevation, or inadequate maintenance. The quality of the recharged water also tends to be poor, contributing to the degradation of water supply. The constituents of this poor quality water are many, deriving mainly from urban and industrial development: metals, fertilizers, de-icing compounds, roadway hydrocarbons, air pollutants, pesticides, animal wastes and concrete leachates. Thus, the maintenance of terrestrial open spaces, free of the influences of development, is of prime concern to Zone III. Furthermore, a good deal of open land exists in this zone at the present time, and it would be of great ecological value to preserve some of that land undisturbed. Thus, the watershed management option for Zone III is beneficial from an ecological point of view.

Plan IIIA is similar to IIIB in its approach; however, it is less comprehensive in its level of control. Thus, Plan IIIA presents most of the benefits enumerated above, but does not allow the full range of benefits obtained by implementation of Plan IIIB.

Plans IIIC–E call for sewering developed sections of Zone III. The environmental implications of sewering are discussed in Section 4.2.13. Sewering can be expected to help preserve the water quality of the aquifer at a high level. However, strict fertilizer and animal waste controls are required if the present excellent water quality is to be maintained. Although present data is not detailed enough for analysis to indicate the relative contributions of different sources of nitrate and organic chemicals in various areas, the data shows clearly that each contaminant is contributed by several categories of sources. Thus, the approach of Plan IIIC, which includes a variety of control measures, is an environmentally prudent one. However, side effects such as changes in the water table (alleviated if wastewater is recharged) and sludge generation are introduced.

4.3.4 Zone IV: North Fork and Eastern South Fork. The aquifer underlying the North Fork is of locally marginal water quality, mainly in areas underlying farms (see Table 4–36). Also, there is the potential for saltwater intrusion if pumping patterns are not carefully managed. This is due to adjacent saltwater bodies in the north and south. Modeling done for the South Fork for this project showed that if pumping patterns were carefully controlled, water quantity and salinity would not be a problem. However,

Table 4–36

EXAMPLES OF HIGH NITRATE-N CONCENTRATIONS IN SELECTED GROUNDWATER TEST WELLS UNDERLYING ZONE IV

Well Location	Date Sampled	NO_3–N (mg/l)
Mattituck	10-22-75	16.3
Greenport	10-19-75	8.2
Southold	11-03-75	12.0
East Mattituck	09-16-75	13.1
Test Plot (North Fork Potato Farm)	03-26-75	23.0
Test Plot	03-26-75	21.0
Test Plot (South Fork Potato Farm)	03-26-75	20.0
Test Plot	03-26-75	17.0

Source: Miller and Sgambat (1977b)

existing data suggests that water quality will be a major problem in Zone IV if strict control measures are not implemented.

The alternative plans present several approaches to the problem of water supply on the Forks. Plans IVC to IVE, water quality preservation plans, require sewering in residential areas and/or non-point source controls. Agricultural fertilizers are an important source of nitrates to the groundwater in the North Fork and eastern South Fork. Control of that nitrate source is the central aspect of Plan IVB. Plan IVA, water importation, calls for importation of water for domestic use from areas to the west. Thus, North Fork and eastern South Fork aquifers' water quality would be allowed to degrade despite state and national policies opposing degradation. Sewering would be minimized, allowing water table levels to be maintained. Plans IVC, D and E are sewering approaches which correspond in their impacts to IB, C and D. Plans IVB to E are superior options with respect to public health, since Plan IVA allows irretrievable contamination of the aquifer. Plans IVA and IVB are superior with respect to stream flow and wetland preservation since water table levels can be more easily maintained. Plan IVB is the overall environmentally favored approach involving, again, the same tradeoffs discussed for Zone I.

The environmental impact of Plan IVA would involve writing off a segment of the aquifer as a resource. According to today's knowledge of groundwater, this would be a permanent and irretrievable action, at least on a scale of 100 to 200 years. If Plan IVA were implemented, agricultural fertilzation could proceed at any level and landfills serving a large region could be sited in Zone IV. In addition, sewering could be avoided except in localities with septic tank failures.

The environmental effects of Plan IVB would resemble those of Plan IA. The success of Plan IVB is to a large measure dependent on non-point and non-structural controls. Due to the importance of farm-related sources, fertilizer controls would constitute a key aspect of the plan. The effectiveness of such measures is subject to uncertainty. Thus, although the level of environmental benefits expected to be obtained from Plan IVB are high, the uncertainty associated with that expectation is also high. Since fertilizer nitrogen is the major contributor of nitrates in Zone IV, Plan IVB with selective sewering is clearly the environmentally dominant option.

The effects of Plans IVC to IVE would be similar to those of Plans IB to ID. However, since fertilizer nitrogen is the dominant groundwater pollutant in Zone IV, the benefits of sewering are not proportionately as great as for other zones. If Plans IVC, IVD or IVE are implemented, any sewage treatment plant outfalls should be excluded from the creeks of Peconic/Flanders Bays. Rather, they should be located in the open bay or in the ocean. Recharge or stream augmentation with tertiary treatment would be the most environmentally favorable wastewater treatment plan option because of its positive effect on preserving the present water level of streams and wetlands. Currently existing wetlands in Zone IV are critical to the maintenance of acceptable water quality in the Peconic estuary and in the Peconic/Flanders Bay creeks.

4.3.5 Zone V: Western South Fork. The western South Fork area is very similar to Area IV except that agricultural land use is much reduced and is replaced by residential use. Plans VA to VE correspond with Plans IVA to E and the environmental impacts also correspond. The major difference is that the reduced importance of agriculture reduces the difficulties in implementation that were presented when discussing Plan IVB. Zone V also is presently the site of numerous supply wells. Attention to the regulations of pumping patterns is of environmental importance, since modeling of the South Fork showed that poorly managed pumping could result in local saltwater intrusion problems.

4.3.6 Zone VI: Surface Water Impact Area. See Section 4.3.15.

4.3.7 Zone VII: South Shore Shallow Flow Discharge System. Zone VII is located south of the Magothy recharge zone. Thus, contamination from activities in Zone VII will mainly affect the Glacial aquifer. Zones VII and VIII are alike in being shallow flow zones. Hence, the discussion of the options for Zone VII is also relevant to the Zone VIII options (Section 4.3.8). The significant difference between Zones VII and VIII is that the former contains a number of streams that feed the South Shore bays. These streams are important recreationally, ecologically, and as a freshwater source to South Shore bays (Section 4.1.2.2). Streamflow will diminish if sewering occurs without recharge or streamflow augmentation. The effectiveness of a shallow recharge program to maintain water table levels is untested and uncertain. Thus, a minimum sewering alternative (sewering only in areas of septic tank failure) is the environmentally preferable option unless VIIA to VIIC are accompanied by effective measures for streamflow protection. Plans VIIA to VIIC are likely to be detrimental to the South Shore bays ecosystem due to alterations of the water budget unless water table preservation measures work. Thus, Plan VIIA to C are environmentally less acceptable without stream augmentation (possibly including shallow recharge). The effectiveness of recharge measures is still uncertain. All of the proposed non-point controls will have significant environmental benefit.

4.3.8 Zone VIII: North Shore Shallow Flow System. The land constituting Zone VIII occupies a band of varying width along the North Shore of Long Island. Zone VIII has been restricted to those locales for which extant hydrologic data shows a horizontal or upward movement of groundwater. Zone VIII may be expanded to include more of the North Shore when monitoring activities are extended to other locales. A significant proportion of the precipitation in Zone VIII runs off to bays and to bay tributaries. The fraction of precipitation entering groundwater has not been accurately established but appears to vary locally from zero to 50 percent. A significant portion of the shoreline area is also characterized by a high water table. A saturated zone means that septic system failures are likely.

The three plans for Zone VIII are similar to the three for Zone VII. Plans VIIIB and C are sewering options and Plan VIIIA is a minimum sewering option. The environmental tradeoffs are similar to those for Zone I. Plan VIIIA, if implemented properly, would be environmentally superior, while Plans VIIIB and C may be environmentally acceptable but involve secondary environmental impacts. For Zone VIII, the uncertainties associated with Plan VIIIA and the secondary impacts of Plans VIIIB and C are less important, since the water is not moving into the Magothy aquifer. All three plans call for sewering of areas of septic tank failure. With present technology, that is the only satisfactory option for the saturated zone. Thus, all plans are acceptable from that standpoint.

All three plans call for siting of landfills within Zone VIII. From a groundwater quality standpoint, this is clearly an acceptable strategy. Siting of landfills on sites underlain by horizontally or upward moving groundwater will protect the Magothy aquifer. However, care must be taken to protect the natural resources of the bays. Metals and organics may be transported to the bays from landfills via groundwater underflow. Thus, the siting of landfills involves a tradeoff of groundwater quality versus impacts on natural resources. On the other hand, if landfills are not sited, then there remains a significant waste disposal problem with the likelihood that the wastes would be exported from the region. If disposal sites for hazardous wastes are not allowed, ocean dumping is likely. From a marine resource standpoint, it appears environmentally sounder to site hazardous waste disposal areas and obtain substantial, if not complete, filtering of leachates before they reach bays rather than to deposit hazardous wastes at ocean dumping sites. With

respect to solid wastes, reuse is the environmentally favored alternative.

The control of surface runoff is a key requirement in Zone VIII (see Section 4.2.14). Provisions for substantial removal of coliform bacteria and nitrate from surface runoff is a requirement for an acceptable plan for Zone VIII. Surface runoff control has been discussed for each North Shore bay in Sections 4.3.9, 4.3.10, 4.3.11, 4.3.12 and 4.3.13. Surface runoff is a pollutant source that falls somewhere between the alternatives for land area and alternatives for bays. It is important that the topic be clearly integrated into the final plan.

In addition to the points covered above, Sections 4.2.13, 4.2.15 and 4.2.16 discuss some general issues relevant to minimum sewering Plan VIIIA and 4.2.2 discusses some issues relevant to VIIIA to C. In summary, the three plans are environmentally acceptable. From an environmental standpoint, VIIIB and C may be unnecessarily cautious, resulting mainly in local surface water improvements. Land use controls under a minimum sewering plan would have significant ecological benefits, as was discussed with respect to Plan IIIB.

Surface Water Alternatives. (Corresponds to Section 3.5.2.2.)

4.3.9 Manhasset Bay. Manhasset Bay is located in northwestern Nassau County, adjacent to Long Island Sound. The shore of the bay is lined with commercial facilities. Most of the shoreline has been filled and bulkheaded, leaving just 87 acres of vegetated wetland remaining (NYSDEC, 1977a). This lack of coastal wetlands by itself represents a significant change in the bay ecosystem. This change has probably caused a significant decrease in vertebrate communities in the bay. The shoreline developments contribute a wide range of pollutants to the bay. The bay is reputed to be one of the best pleasure boat areas on the Sound. There are numerous marinas and yacht clubs. In addition to effects that can be linked to extensive development, the quality of the tidally flushed bay is dominated by conditions in Long Island Sound. These two factors, as well as the treatment plant loadings from three sources, contribute to very high nutrient levels and the contamination of shellfish beds by total coliform bacteria. Although the entire bay is rich in hard clams, it has been closed to shellfishing due to high coliform concentrations. In general, barring improvements in Long Island Sound quality, pollution abatement measures [(B) (a) (i)], [(B) (a) (ii)], [(B) (a) (iii)] will have only local effect. The flushing of the southern end of the harbor is poor and upgrading of sewage treatment or relocation of the outfalls could achieve locally significant improvements in water quality. However, even if Sound and bay water quality were to be improved, the lack of wetlands would continue to severely constrain the bay's ecological viability.

Modeling has demonstrated that the boundary conditions from the Sound may sometimes overshadow any effects from pollutant sources within the bay (Johanson *et al.,* 1977a). The Management Plan therefore calls for New York City and southwestern Connecticut to institute effective controls on the many sources contributing loads to the Sound. But since such measures are outside the direct scope of the Nassau-Suffolk 208, specific actions have not been detailed in this Plan. Several specific measures are proposed that may have some local beneficial effect on the bay. However, if Sound conditions are not improved, the benefits of extensive local measures such as centralized collection of domestic wastes or treatment plant upgrading will probably not be significant enough to outweigh the costs. Since benefits are not expressible in dollar units, an absolute judgment cannot be made.

Local measures recommended for the bay include upgrading the treatment plants [(B) (a) (i)], moving the outfalls to mid-bay locations [(B) (a) (ii)] diverting flows out of the area [(B) (a) (iii)], and instituting non-point controls. The negative environmental effects from upgrading the Port Washington and Great Neck plants will be minimal in terms of wetland loss, since the surrounding areas are already developed. If steps are taken to control runoff from any needed construction, then the short-term negative impact upon the bay waters will also be minimal. If advanced treatment is implemented without both phosphorous and nitrogen removal, the N/P ratio may be lowered with detrimental effects upon the phytoplankton. However, due to the tidal exchange in the bay and the dominance of the Sound conditions, changes in the N/P ratio will not be great. The beneficial results of this treatment will be local in nature. Some improvements in the nutrient levels and oxygen demand will be noted in the vicinity of the present outfalls. Model predicted buildups in the southern portion of the bay will be mitigated. General nutrient and coliform bacteria levels in the bay will not be much improved due to Sound conditions. No reduction in the closed shellfish zone is anticipated. Benefits from additional treatment measures will be minimal if non-sewering options for surrounding land areas are selected, since the volume of treated flows will remain near present levels.

Moving the outfall to a mid-bay location will probably do more than advanced treatment to relieve high nutrient buildups in the southern and eastern portions of the bay, as shown in the modeled scenarios. However, such an action requires trenching the bottom and backfilling in order to lay a pipeline, and results in short-term adverse effects upon fish and shellfish from the increased turbidity, as noted in Section 4.2.16. There is also the problem of spoil deposition, and in Manhasset Bay, with its developed shoreline, there may be a tendency to use the last remaining wetlands as dump sites. Such wetland use should be avoided. As with the AWT option, benefits of treatment measures will be small if minimum sewering options are selected.

For one dwelling unit per gross acre to three dwelling units per gross acre sewering scenarios, diversion of the effluent out of the area will go further than [(B) (a) (i)] or [(B) (a) (ii)] to improve local water quality and to benefit the organisms of the bay. Planning must be done carefully to assure that the areas to which the flow is diverted can handle the increased flow. In that regard, it should be kept in mind that the ocean and Long Island Sound are not infinite sinks (see Section 4.2.16). The danger of pipeline leakage or deterioration exists, but can be minimized with proper design and

construction. Even complete removal of point sources by diversion of all wastes out of the bay cannot improve either the baywide nutrient balance or the water quality with respect to bacterial levels because of the overriding influence of Long Island Sound.

Non-point and storm runoff loads constitute a significant problem in Manhasset Bay due to extensive shoreline development and lack of wetland to buffer non-point inputs. For example, they account for 30 percent of local nitrogen inputs to the bay. Thus, a control program that does not effectively control non-point inputs will not be an acceptable strategy. The proposed Best Management Practices approach to storm runoff controls [(B) (b) (i)] has some likelihood of reducing the coliform bacteria, nutrient metal and organic chemical loads to Manhasset Bay. However, it is not known how effective such an approach will be. Hence, it is strongly recommended that a pilot study be implemented to test the effectiveness of Best Managment Practices in reducing non-point runoff.

In summary, a combination of structural measures to control point sources, alternative [(B) (a) (i)] through [(B) (a) (iv)], non-structural measures to control non-point sources, and minimization of sewage flows in surrounding land areas could produce local water quality improvements. The dominating influence of Long Island Sound water on bay water quality makes it impossible for Nassau and Suffolk Counties alone to control the quality of the bay water. However, AWT or mid-bay discharge could have significant local benefits. No action, option [(B) (a) (v)], is another alternative that could be followed at present. If [(B) (a) (v)] were to be selected it would represent a judgment that the local water quality benefits obtainable for other options could not be justified on a cost/benefit basis when compared on an areawide basis with investments in other water quality controls. The onus is clearly on the City of New York to control the large pollutant flows which degrade western Long Island Sound water quality.

4.3.10 Hempstead Harbor. Hempstead Harbor has been highly developed for both industrial and residential use. It has many similarities to Manhasset Bay in terms of loss of wetlands, significance of non-point inputs, and importance of the Sound influence. This harbor handles the largest amount of water-borne commerce on Long Island (Gross *et al.,* 1972) and also shelters many pleasure boats. In general, it is well flushed and subject to substantial influences from Long Island Sound. Although the bay has high potential for production of hard clams, the entire bay has been closed to shellfishing due to coliform contamination. There are also some areas of shoreline and natural woodland, which support beach and upland species, but the wetlands, so vital to nutrient cycling, have all but disappeared. The most recent survey estimates that a total of only about 83 acres of vegetated wetland remains in Hempstead Harbor (NYSDEC, 1977a). Landfill from shoreline development has also changed the character of the bottom sediments and has reduced the harbor area by a small amount. As in the case for Manhasset Bay, local control measures [(C) (a) (i)], [(C) (a) (ii)], [(C) (a) (iii)] or [(C) (b)] will result in only limited, locally observable improvements in water quality. For example, controls on Glen Cove Creek discharges will mainly improve conditions only within that creek, because of the dominance of Sound influence in the open bay. For that reason, the structural measures discussed below are only marginally justifiable from a cost/benefit standpoint, and [(C) (a) (iv)] is an attractive alternative.

Structural controls have been proposed to mitigate pollutants in Glen Cove Creek and the inner harbor. Glen Cove Creek is subject to both municipal and industrial loads. These loads probably contribute significant quantities of nutrients, metals and organic chemicals; however, detailed source inventories are not available. The loads combine to severely degrade local water quality; the industrial loads of metals and organic chemicals constitute the bulk of the problem. Industrial discharges to Hempstead Harbor are specifically considered in alternative [(C) (b)] and it appears that it would be beneficial if such discharges in Glen Cove Creek, which are meeting present standards, were to be pretreated beyond presently required pretreatment or that outfalls be routed out of the area (possibly to the centralized hazardous waste facility). Until treatment measures for the full suite of contaminants are instituted and toxic conditions in the creek abate, implementation of nitrogen controls will have little or no effect on the ecology of Glen Cove Creek.

Currently, the Glen Cove Sewage Treatment Plant is upgrading to include nitrification of wastes and the Powers Chemco plant is ugrading to remove ammonia. However, according to the Tetra Tech model (Johanson *et al.,* 1977b), nitrogen removal is required to alleviate water quality stress. In order to mitigate the localized nutrient concentration in Glen Cove Creek, the Management Plan calls for either nitrogen removal at both the Glen Cove Sewage Treatment Plant and Powers Chemco ammonia removal plant, [(C) (a) (i)], or relocation of both outfalls to mid-bay, [(C) (a) (ii)], the impacts of which are discussed in Sections 4.2.15 and 4.2.16. Either of these actions would substantially improve the nitrogen water quality in Glen Cove Creek, although the harbor as a whole would be only slightly improved because of the overriding influence of Long Island Sound. Upgrading the plants would pose very little threat environmentally, since there are no endangered wetlands or habitats in the vicinity of the plants. Since much of the bottom sediments in the creek have been altered already, and none of the bay is open to shellfishing, the impact of dredging and laying an outfall pipeline is not expected to be adverse if timed to avoid peak periods for spawning and for recreational use.

Similar impacts in Hempstead Harbor can be expected from the various courses of action. The same set of choices as outlined for Glen Cove (upgrade treatment or locate outfall in mid-bay) are applicable to the Roslyn Treatment Plant flows, if one dwelling unit per gross acre or two dwelling units per gross acre sewering is implemented. In particular, the flushing of the southern end of the harbor is poor and upgrading treatment or relocating the

outfall would improve the water quality greatly. Instituting nitrogen removal without phosphorus removal, however, could result in changes in dominant phytoplankton and a consequent perturbation of the marine food web within the southern portion of the harbor. Thus, phosphorus removal with accompanying nitrogen removal should be considered. An estimated nineteen percent of nitrogen loads to the bay are contributed by non-point sources. Metals, organics, coliform bacteria and sediment are also components of the non-point sources. As with Manhasset Bay, wetland edges have largely been filled and runoff directly impacts the bay without the benefit of a buffer. The implementation of non-point controls should accompany point source measures. Non-point controls, for example, could result in lowered coliform levels in water adjoining beaches. However, for this bay, non-point controls alone are clearly not adequate.

In summary, industrial effluent controls [(C) (b)], non-point controls [(C) (c)], and point source controls [(C) (a)] can all produce local improvements in water quality. As with Manhasset Bay, improvement of Long Island Sound conditions is a necessary precursor to the restoration of a healthy nutrient balance and reduction of coliform bacteria in the harbor. Until this can be done, no great improvements in the nutrients, BOD, and finfish and shellfish populations can be expected for Hempstead Harbor as a whole, and local measures will be only marginally cost-effective. As with Manhasset, the onus is on New York City and southwestern Connecticut to implement the measures that will contribute to improvement in western Long Island Sound and Hempstead Harbor. However, AWT or mid-bay discharge could have significant local benefits. No action, option [(C) (a)(iv)], is another alternative that could be followed at present. If [(C)(a) (iv)] were to be selected, it would represent a judgement that the local water quality benefits obtainable for other options could not be justified on a cost/benefit basis when compared on an areawide basis with investments in other water quality controls. Best Management Practices [(C)(b)] should be implemented no matter which of the point source control alternatives is selected.

4.3.11 Oyster Bay. Oyster Bay supports distinctive commercial and recreational resources. These include a major National Wildlife Refuge Area and a significant mariculture industry. The presence of the refuge area dictates that particular caution be exhibited in order to safeguard the protected wildlife habitats. With respect to 208 alternatives, this mainly suggests that (1) trace contaminants (organic chemicals and metals) that may enter the food web be controlled and (2) overall pollutant loads be controlled to maintain the diversity of planktonic and benthic food organisms near the bottom of the food chain pyramid. The presence of the mariculture industry suggests that the bay system should be protected from pollutants that impose shellfish health risks, such as coliform bacteria and trace contaminants (organic chemicals and metals). In addition to their role as an economic resource, these oyster populations may play a significant role in maintaining nutrient and phytoplankton equilibria. It is likely that these populations, in addition to the extensive wetlands, are partly responsible for keeping the nutrient levels low by acting as sinks.

To safeguard the commercial and recreational resources of the bay and its embayments, several potential pollutants need to be controlled. These include metals, organic chemicals, coliform bacteria and suspended solids. There is a paucity of monitoring data for trace contaminant levels in the water columns, sediments or organisms of the bay system. At present, however, point source inputs of trace pollutants to the bay system are limited. The only industrial sources of significance are oil transport facilities, which are the sites of occasional small spills. Suspended solids are also contributed mainly by non-point sources. Thus, the major concern regards future industrial sources and non-point sources, and, therefore, alternative [(D) (a) (i)] is acceptable.

The plan for waste management in Oyster Bay calls for the application of stormwater runoff controls to reduce coliform levels, [(D) (b)]. Non-point sources are estimated to contribute 77 percent of the bay's nitrogen loads. The use of non-structural measures alone may well be insufficient in reducing contamination due to total coliforms and trace contaminants (*i.e.,* metals, organic chemicals) in a situation where pollutants from non-point sources constitute the bulk of the load. The reductions that will be achieved are not predictable prior to a pilot effort. Both total coliform and metal levels directly affect the harvestability of the shellfish in the bay. Thus, structural runoff controls are desirable for maximum protection of bay resources.

A substantial portion of the existing wetlands in and around Oyster Bay are under the purview of the Oyster Bay National Wildlife Refuge. The existence of the refuge protects the wetlands of Oyster Bay, which are an important stopover on the Atlantic Flyway. Thus, the recommended long-term policy position *vis-a-vis* Oyster Bay is to keep the bay system in a relatively pristine state. Several measures are needed: (1) structural non-point control options are important since the effectiveness of non-structural approaches is uncertain; (2) nitrogen and phosphorus removal for any discharges, [(D) (a) (iii)], should be considered even though modeling runs found that secondary treatment would result in "acceptable" ambient levels; removal of discharges from the bay in favor of recharge or Sound discharge could also be considered, [(D) (a) (ii)] or [(D) (a) (iv)]; (3) strict preservation of all wetlands and terrestrial buffer zones is required.

4.3.12 Huntington Bay. Although the waters of this bay complex are relatively well mixed, two of the four harbors, Northport and Huntington, show low dissolved oxygen and high nutrient levels. These two harbors are also the locations of two treatment plant outfalls, and have relatively few wetland areas on their perimeters. Many of the shellfish beds in these harbors, while showing potential for production, have been closed due to coliform contamination.

One of the recommendations for Huntington Bay is nitrogen removal at both sewage treatment plants, alternative [(E) (a) (i)]. This would control

the nutrient level and thus avoid algal blooms; however, the phosphorus would remain high and the steady state N/P ratio in these harbors could decrease. Such an effect can alter the dominant phytoplankton species in the water and thus perturb the feeding shellfish, which depend upon phytoplankton for most of their food. If phosphorus is also removed, the alternative becomes environmentally superior.

A second option for controlling nutrients in these harbors is moving the outfalls to mid-bay locations [(E) (a) (ii)]. This would reduce the nutrient levels within the bay without significantly altering the N/P ratio, and thus would be beneficial to the phytoplankton and shellfish in the waters. The three other options involve routing sewage out of the area, [(E) (a) (iii), (iv) and (v)]. From the standpoint of Huntington Bay quality, these last three options are the best, although no option adding to effluent loads to Oyster Bay should be considered.

In evaluating these structural options, additional environmental impacts must be addressed. First, it must be noted that, if minimum sewering options for surrounding land areas are selected, flows will remain near present levels. Upgrading of treatment is essential even if non-structural non-point measures are implemented. In order to upgrade the treatment plants under option [(E) (a) (i)], construction of new facilities will be required (see Section 4.2.15). Caution must be exercised to avoid erosion and degradation of surrounding areas. Because there is very little wetland in the area surrounding these plants, wetland loss is unlikely in this case. Of more concern is the second option, which requires trenching the bottom and back-filling to lay a pipeline out to the middle of the bay (see Section 4.2.16). This action may impact upon the benthic organisms, particularly the valuable shellfish. Such effects tend to be transitory in nature. Time of year of construction activities becomes critical. Very high rates of sedimentation may result in habitat loss, clogged shellfish feeding mechanisms, and smothering. Other problems include altered bottom topography and circulation patterns. These effects can be minimized by replacing extracted sediments over the pipeline, grading, contouring the substrate and relocating shellfish following construction. The increase in turbidity can be minimized by careful deposition of spoil, but some effects will inevitably remain. The recharge alternatives [(E) (a) (iii) and (v)] have possible health and feasibility drawbacks associated with them and, in Zones I and VIII, present no particular benefits (Miller and Sgambat, 1977a).

Non-point inputs constitute an estimated 80 percent of nitrogen loading and 99 percent of total coliform bacteria loading to Huntington Bay. Thus, control of non-point inputs [(E) (b)] is in some respects more important than point source controls. The non-structural controls that have been proposed are untested. Thus, the results of a pilot effort such as that suggested in Section 4.2.14, above, are needed to determine whether structural non-point controls will be required.

Wetland acreage has been greatly reduced in the Huntington Bay area over the past fifteen years. There are two interpretations of the effect of this reduction. One is that the fewer the remaining wetlands, the more essential is their preservation to the ecology of the area. The other is that once wetlands have been reduced below a critical size, they no longer represent a viable functioning habitat unit in a given system. The authors adhere to the second viewpoint and suggest that strict preservation of wetlands in other bays (Oyster Bay, Peconic Bay) is likely to be much more worthwhile than institution of such measures in Huntington. However, the remaining wetlands in Huntington Bay are clearly a valuable aesthetic resource.

In summary, structural point source controls [(E) (a)] appear to be dominant under maximum sewering (one dwelling unit per acre) schemes for reduction of locally high nitrogen and low dissolved oxygen (D.O.) in Huntington and Northport Harbors. Non-point controls [(E) (b)] are dominant under minimum sewering for nitrogen and D.O. and under all sewering schemes for total coliform bacteria.

4.3.13 Port Jefferson. Port Jefferson Harbor contains valuable shellfish resources, but only some 150 acres of wetland remain. The central harbor, which is a port for commercial shipping, is also the site of the Port Jefferson primary sewage plant treatment outfall. It is this central harbor that is subject to high nutrient levels and contains closed shellfish beds. The embayments, Conscience Bay and Setauket Harbor, are rich in marine and bird resources. Those areas are relatively unaffected by STP outfalls but would benefit from non-point controls. In fact, existing non-point inputs to the embayments contribute to conditions in the open bay.

The structural control plan [(F) (a)] for Port Jefferson does not call for nutrient removal at the treatment plant unless the flow increases dramatically. Since the the sewage treatment plant presently provides only primary treatment, upgrading to secondary treatment, alternative [(F) (a) (i)], is expected to mitigate the impacts of increased flow. The Tetra Tech model predicts that a fifteen million gallon per day (the actual flow increase under one dwelling unit per acre sewering is expected to be only some eight million gallons per day) secondary effluent will only slightly degrade nitrate levels and is actually a positive step for phytoplankton growth with respect to nutrient ratios. The anticipated N/P ratios would be higher than those observed at present and thus there is no cause for concern over dominant phytoplankton species. However, if the plant should be upgraded to advanced treatment alternative [(F) (a) (ii)] then a problem may arise unless phosphorus is removed with the nitrogen. Under minimum sewering, no AWT would be required.

Another proposed structural measure is a mid-bay outfall alternative [(F) (a) (iii)]. This alternative is environmentally acceptable in that steady state nutrient ratios will not be affected and nitrate levels will change minimally. The dredging that will be necessary to lay the pipe will occur in sediments that are silty and may be somewhat polluted. If care is exercised in recontouring the benthos and in disposing of the spoil, the short-term effects

associated with increased turbidity will be minimal. The most productive shellfish areas are located in Conscience Bay and Little Bay-Setauket Harbor, which are removed from the proposed construction area in the main harbor. Thus, effects upon the shellfish may be minimized as well. Again, under minimum sewering options, this measure would not be required.

Another structural solution calls for the recharge of any effluent flows in excess of present levels, alternative [(F) (a) (iv)]. This would require advanced treatment of effluent to minimize nitrogen discharges to groundwater. A health risk of contributing chlorinated organic chemicals to groundwater would exist if the effluent were to be chlorinated, however, further study of this problem is needed and other disinfection procedures may be required. If health risks associated with disinfection procedures can be eliminated, recharge would be acceptable. Organic chemicals contributed to groundwater by recharge would be much less than non-point and industrial inputs. Metal contributions would probably be negligible due to pretreatment of industrial effluent.

The second portion of the Management Plan calls for stormwater runoff controls to reduce coliform and nutrient levels [(F) (b)]. As discussed above, this is a positive measure for the shellfish populations within the embayments, although the nature of Port Jefferson Harbor's sediments suggest that the main harbor may remain an unproductive habitat despite water quality improvements, because of prior pollution and/or the natural state of the sediment.

In summary, the requirements for structural point source measures are moderate under maximum sewering and minimal under minimum sewering strategies. Non-point source controls are needed to maintain and improve the quality of the western embayments. There are no clearly dominant alternatives, although recharge seems to be an attractive choice. In contrast to the western North Shore bays, for which flow diversion to South Shore facilities is feasible, for Port Jefferson recharge is the only presently available option for routing sewage flows away from the North Shore.

4.3.14 Peconic Estuary, Flanders Bay. The Peconic-Flanders system is a particularly sensitive system, since the site is a shallow estuary, with low tidal flushing in the western portion. There are more than 1,400 acres of wetlands, although many areas have been dredged or filled, and wetland destruction continues at a slow rate. Unless such infringement is completely halted and some wetlands reconstructed, the nutrient levels in the estuary will continue to rise, possibly leading to disruption of the ecosystem at some future time. The creeks and Peconic estuary are particularly sensitive, exhibiting high nitrate and low dissolved oxygen.

The wastewater management for Peconic-Flanders requires treatment of the duck farm effluents to remove nitrogen. Some of the farms have already stopped discharging into the river or tributaries; when the three remaining significant dischargers also cease discharging, the nutrient levels will fall to an acceptable level. This will have a beneficial effect upon finfish and shellfish, avoiding algal blooms and maintaining a higher dissolved oxygen concentration. Such an action may, however, have a negative effect on the duck farm industry. Although some local farms have recently closed, a connection between regulatory enforcement and the facility demise has not been established. Such losses may be unavoidable if a healthy bay ecosystem with a balanced nutrient cycle is to be maintained.

The upgrading of the Riverhead Treatment Plant will be necessary even if the effluent load does not increase under the sewering strategies selected. Moving the outfall out of the Peconic estuary to a bay or Sound location, [(G) (a) (ii)], [(G) (a) (iii)], [(G) (a) (iv)], would prove far superior environmentally than maintaining the present outfall [(G) (a) (i)], because of high nitrate and low dissolved oxygen (D.O.) in the estuary. In fact, maintaining the outfall at its present site, [(G) (a) (i)] is environmentally unacceptable. There is more flushing in the bay than in the estuary, so that nutrient buildups are mitigated. As long as the precautions for dredging and construction discussed in Section 4.2.16 are followed, moving the outfall to a Sound location will tend to improve the environmental quality of the estuary and bay. Immediate establishment of a monitoring program [(G) (c)] to measure effects of the present outfall in the Peconic estuary is required under any option, in order to provide information on the nature of D.O. patterns in the estuary.

It is strongly recommended that the D.O. standard for Peconic-Flanders be modified. Historical data show that: (1) the Peconic-Flanders system presently supports productive marine populations, and (2) 23 percent of historical samples are below the present NYSDEC standard. Thus, no matter which options or measures for the Peconic-Flanders system are selected, violations of the present New York State D.O. standard are likely to continue.

It is clear that, due to problems involved in discharging to the Peconic-Flanders system, minimum sewering in Zone IV is a desirable strategy and option [(G) (a) (i)] is unacceptable. Non-point measures [(G) (b)] are needed as well to minimize D.O. and nutrient degradation. Non-point sources contribute 24 percent of nitrogen loadings to Flanders Bay but will contribute a higher percentage when duck farm discharges cease.

4.3.15 South Shore Bays. The South Shore bays, especially Mecox, Moriches and eastern Great South Bay, tend to be sensitive to pollutant inputs. Large portions are shallow, tend to be poorly flushed, and concentrations of nutrients and coliforms readily build up. Such areas support large populations of phytoplankton, which can easily induce dissolved oxygen deficits when nutrient levels rise. They support significant fish and shellfish populations, which are sensitive to salinity changes and which easily accumulate trace levels of metals and organics.

The measures proposed for the South Shore bays are designed to minimize nutrient inputs into the bay. According to Tetra Tech's model, inputs into eastern Great South Bay and the most western of the South Shore bays are already too high and need to be reduced. A similar situation probably

exists for Moriches and Mecox Bays; however, modeling studies and extensive sampling of these bays was not included in the 208 Program. The proposed measures present the most stringent set of controls on nitrogen that could be implemented and are environmentally optimal from nitrogen, phytoplankton and dissolved oxygen standpoints. However, full implementation of the Plan element calling for the reduction of groundwater underflow nitrate-nitrogen concentration to two milligrams per liter will be difficult to achieve.

The strategy of sewering (one, two or three dwelling units per gross acre) gives treatment plant effluent a significant role in the South Shore bays' freshwater budget. The Tetra Tech model suggests that the combination of stream flow reduction and discharge of effluent to the ocean would change the salinity gradients in the bays, especially in eastern Great South Bay. Also, groundwater investigations (Miller and Sgambat, 1977c) show that water table levels and stream flows are reduced along the South Shore in sewered areas. Any change in average bay salinities is likely to impact the distribution of fish and shellfish in the bay. This impact would not necessarily be negative, but in the absence of a good predictive tool with which to assess the probable change, the prudent environmental approach is to assume a negative impact. Reduction in stream flows and wetland levels will adversely impact the area of wetland habitat available to birds and fish populations. Thus, from an environmental standpoint, minimizing sewering is desirable, depending upon the level of nitrogen loadings that must also be controlled. For the Zone VII—western South Shore bays system, minimum sewering (only in areas of septic system failures) is judged preferable, based on measures required for water table maintenance and the ability of the bays to flush nutrients entering in the groundwater flow. There is an appreciable decrease in the effectiveness of tidal flushing, as a means of nitrate dispersal, at the eastern end of Zone VII. For the Zone VI—eastern South Shore bays system, a judgment is based on a tradeoff of wetland levels and bay salinities versus bay nutrient levels. It is a difficult choice, and strict land use controls together with a variety of nutrient contols would be the best option, with sewering avoided when possible. Stream augmentation (with shallow recharge, if feasible) of all effluents in Zones VI and VII is the only acceptable option if sewering occurs. Any effluents recharged or discharged to streams require extensive tertiary treatment beyond nitrogen removal.

Non-point runoff contributes significant amounts of nitrates and coliform bacteria to South Shore bays. It is strongly recommended that a pilot effort at implementation of both the non-structural and structural approaches be instituted for the South Shore. Only after analysis of data from such pilot efforts can it be determined whether non-structural non-point source controls are effective. From an environmental standpoint, structural controls are the currently prudent strategy, due to the uncertainties associated with the Best Management Practices approach.

Specific considerations for each South Shore bay are as follows:

Mecox Bay. Mecox Bay is characterized by violations of dissolved oxygen and coliform bacteria standards (Bigham and Lorenzen, 1977). The bay exhibits poor flushing through an inlet that requires frequent dredging if it is to be kept open. The naturally poor exchange characteristics of the bay suggest that the bay's poor water quality may be at least partially a natural condition. Nevertheless, the surrounding land areas are somewhat developed and the associated human activities have contributed to the violation of standards. Most notably, residuals from duck farming have been historically discharged to the bay. This practice has left a sizeable deposit of organically rich sludge in Hayground Cove. This deposit contributes to nutrient loading and to oxygen consumption.

Mecox Bay exhibits "threshold" levels of various water quality variables; that is, violations of standards occur, but the biological community that can be observed is not one of chronically low diversity. Augmented loadings can be expected to push the bay ecosystem into a polluted state, whereas decreased loadings can be expected to reduce violations of criteria. Thus, the stringent controls recommended as alternatives [(H) (a)] and [(H) (c)] are environmentally prudent and likely to result in easily measurable ecological benefits. From an ecological standpoint, construction of a new inlet [(H) (b)] is likely to significantly alter the bay's ecology. It is as likely to be detrimental as beneficial.

Sewering in the vicinity of Mecox Bay (parts of Zone V) will affect water levels of wetlands and streams connected to Mecox Bay. Such changes are likely to be detrimental to bay ecology. Thus, sewering alternatives imposed without recharge or flow augmentation are not ecologically prudent.

Shinnecock Bay. Shinnecock Bay is connected to Peconic Bay, Moriches Bay and the Atlantic Ocean. All of these connections are by way of narrow inlets and canals. The exchange of bay water with Atlantic Ocean water is via the Shinnecock Inlet and is considerable, as indicated by Shinnecock Bay salinity (Pagenkopf and Bigham, 1976). Shinnecock Bay tends to display lower nitrogen, coliform bacteria and solids levels than Mecox or Moriches Bays. Thus, the need for a full array of strict controls for Shinnecock Bay is less pronounced than for adjoining bay waters. The measures suggested for Shinnecock Bay [(I) (a)], [(I) (b)] will all be ecologically beneficial. However, the present good condition of the bay and the extensive tidal exchange suggest that strict application of the measures, especially of [(I) (b)] are of lower priority than are similar efforts affecting other sections of the South Shore.

In particular, sewering in the vicinity of Shinnecock Bay is not justifiable on surface water nitrogen grounds and is likely to be detrimental to local wetlands and streams.

Moriches Bay. Moriches Bay is similar to Shinnecock Bay in geologic origin and tidal exchange (Pagenkopf and Bigham, 1976). The bay is large in area and contains valuable wildlife, fish and shellfish habitats. High nutrient and coliform bacteria levels have been noted in Moriches Bay. Further additions of nitrogen would pose the threat of serious environmental degradation.

Changes in ambient nutrient levels and in hydrodynamics have historically caused problems in Moriches Bay. In the late 1950's, closing of the Moriches Inlet resulted in significant algal blooms and loss of shellfish productivity. These historical events have demonstrated the ecological necessity of all of the measures [(J) (a)] and [(J) (b)]. Two further considerations, not specifically noted in Section Three, are worth mentioning here. First, an historical study of Moriches Bay nutrient relationships has emphasized the importance of the N/P ratio as an indicator and as a possible controlling factor. Thus, careful monitoring of the ratio is required, if this plan is to be environmentally acceptable. Specific control actions will have to be formulated from time to time, as the ratio shifts. Second, sewering in the area surrounding Moriches Bay (parts of Zones V and VI) will probably be detrimental to the bay ecosystem and will, at a minimum, impose a difficult set of environmental tradeoffs. A benefit of sewering would be decreased nitrogen input to the bay from groundwater underflow; a serious detriment would be lowered wetland water levels and stream flows, unless stream augmentation (with shallow recharge, if feasible) could successfully maintain the water table. Lowered water levels and stream flow would be likely to change the character of the bay's contiguous wetlands and might alter the bay's salinity regimes. The wetland areas are of great importance to the bay's nutrient cycle and marine food web. The specific material flow and ecological community changes cannot be predicted.

Eastern Great South Bay. Eastern Great South Bay is a highly productive system. The ecological community yields large populations of commercially and recreationally important fish and shellfish. Among the most significant resources are hard clams and winter flounder. The area exhibits great sensitivity to long-term changes in freshwater inflows, rainfalls and wind patterns. The system appears to be delicately balanced and quite vulnerable to many sorts of changes. The system has a natural variability, which can be expected to increase or decrease depending on pollutant inputs. Major increases in system variability can be expected to be negative in impact. Among the changes that could seriously alter or destabilize the ecosystem are natural climatic and predator-prey cycles, and alterations in inlet configuration, stream-flow, patterns of nutrient inflow, and sediment makeup.

To minimize changes in inlet configuration, monitoring of the hydrodynamics and periodic dredging are required. Implementation of such a program is an acknowledgement that maintenance of the current ecological community is more desirable than allowing natural evolution of the bay ecosystem to occur. Construction of a new inlet as suggested in [(K) (b)] is undesirable from an ecological standpoint because it is impossible to predict what community shifts would be imposed. The community shifts thus imposed might even include establishment of new, undesirable predator-prey links.

To minimize excess nutrient inputs, measures [(K) (a)] and [(K) (c)] have been proposed. [(K) (a) (iii)] and [(K) (c)] are both needed. [(K) (a) (ii)] is probably preferable to [(K) (a) (i)] because of water table considerations. However, the level of sewering is a critical factor in choosing between the two alternatives. The strict limiting of the extent of sewering with marine surface discharge in Zone VI is ecologically necessary because of the risks imposed if the water table is lowered, although tradeoffs are involved. It is uncertain whether the combination of inundation requirements for wetland plant growth and freshwater inputs for maintenance of Great South Bay salinity regimes will be met by any recharge or flow augmentation scheme. Thus, the marine ecosystem is likely to degrade under comprehensive sewering of Zone VI. However, even with sewering some nitrates will be contributed by groundwater underflow, unless there are strict controls on non-point sources. Thus, careful and extensive land use controls rather than comprehensive sewering are the measures that are environmentally preferable. The studies currently being proposed by Nassau and Suffolk Counties concerning South Shore stream flows are likely to cover these environmental matters in considerably finer detail. Such studies should carefully weigh the uncertainty imposed by water table lowering before any further sewering in Zones V, VI or VII is approved.

Western Great South Bay. These waters are transitional in nature and may require some combination of measures presented under options (K) and (L). Sewering this portion of Zone VII imposes the same risks described for Zone VI and should be avoided for those areas not already sewered.

Western South Shore Bays. These waters are characterized by considerably higher tidal exchange than the bays to the east. They lie directly south of a densely developed region of Long Island. At present, the ability of the western bays to disperse pollutant loads is offset by the excessively high loads currently entering those waters. The major nutrient loading is contributed by effluent from the Bay Park facility. Thus, implementation of measure [(L) (a) (i)] alone will have very significant environmental benefits. Implementation of measures [(L) (a)] and [(L) (b)] will act to protect the valuable resources of these bays and are recommended. If measures [(L) (a)] and [(L) (b)] are fully implemented, groundwater nitrogen inflow will not be of major concern, since the bays will be able to maintain stable nutrient levels by flushing.

4.4 Aggregate Economic Costs

It is impossible to accurately quantify all of the real costs—monetary, indirect and opportunity— of liquid waste disposal systems for the Nassau-Suffolk Region, or for any area. There are costs that can be directly or accurately quantified. Among those are the costs for equipment for water quality monitoring, treatment plants, disposal facilities, pumps, lines, etc. However, accurate comparison of the true economic effect of alternatives for wastewater treatment requires the incorporation of estimates for opportunity costs as well as for any unquantifiable externalities that are imposed upon the area involved. It is very difficult to predict what might have happened in the future had not a particular regulation been imposed or a certain

treatment plant built. Perhaps a flourishing business with employment benefits, profits to the owner, tax revenue, and an increased "quality of life" accruing to the community is prevented from opening. It is extremely difficult to predict the expected return on the aforesaid business opportunity, just as it is extremely difficult to assign a dollar value to the "increased quality of life." However, these effects are all real benefits (or disbenefits) to the community and affect the actual desirability of the option that would cause such changes. Many other examples of opportunity costs being imposed by a particular liquid waste treatment strategy can be constructed. The important point is that while an economically and socially efficient choice of treatment strategies must take opportunity costs and externalities into account, there is no accepted, iron-clad method to reduce such costs to a form where they can be directly compared with other costs.

4.4.1 Discussion of Cost Uncertainties. Costs for various components of the Nassau-Suffolk wastewater quality management program have been estimated (NSRPB, 1978).[1] However, assembling those component costs into aggregate costs is difficult, because many of the cost estimates represent rough order approximations and many options simply defy quantification. Inability to cost out all available options has a tendency to focus attention on those elements for which cost data is known. This often results in decisions weighted toward the known costs while other, equally significant options, may be ignored or dismissed out of hand. It is the purpose of this section to explain the difficulties of specifying certain aspects of cost and to give the reader an understanding of the potential magnitude of unknown costs.

4.4.1.1 Plan Options by Hydrogeologic Zones. Table 4–37 presents a matrix of the various cost elements associated with the options considered by the NSRPB. The cost elements are displayed according to the relative accuracy that can be expected from estimates of the element's cost. The "hardest" estimates can be developed for those cost elements listed as "straight engineering" type costs. Estimates become increasingly "soft" as the reader moves to the right on this matrix and are "softest" for those elements for which the estimation involves specifiying opportunity costs.

The "hardness" of the cost estimates is dependent on the procedure used to estimate them. The procedures for estimating each element are discussed below, by cost type.

Straight Engineering Costs. Straight engineering costs are cost estimates for equipment and operations and maintenance for which the equipment required can be fully specified. Equipment for water quality monitoring at the specific locations; for pumping volume monitoring of irrigation wells required for IV B, C, D and E, as well as the equipment required for additional treatment and disposal facilities can all be completely specified, and cost estimates can be generated using standard cost estimating techniques. These techniques generally yield estimates accurate to within ± 25 percent.

Engineering with Speculation. Costs in this category are similar to those in the first category; cost estimates are based on full specifications of the equipment needed. However, the amount and size of equipment required is only estimated, because it is subject to change over the lengthy planning period involved. The cost for sewering a region once it attains a certain population density (X dwelling units per gross acre) is dependent on (1) how much of the region becomes populated with X dwelling units per gross acre; (2) in what years each of the sewered areas attains such densities; and (3) water consumption rates. Because of the potential for error in forecasting population growth and water consumption rates, sewering costs are subject to larger tolerances than harder "straight engineering" costs.

Similarly, the other element in this category—relocating water supply wells— is subject to the localized growth in water supply demand. This will determine the number of wells required and their locations.

Speculative Cost. Costs in this category are incurred only if certain conditions occur. Therefore, costs for these elements may be as low as zero, but in certain cases they may also be very high. All of the cost elements in this category are contingent on environmental degradation below threshold levels that the other elements seek to preclude. Careful planning should include contingencies such as the proposed additional monitoring if water quality problems arise, contingency water treatment if water supply sources fall below acceptable quality, and contingency pumping plans (that may increase water supply units) should water demand and quality jeopardize water supply.

Difficult to Estimate. Cost elements that fall into this category relate to untested, presently not clearly detailed programs. This would include, for example, educational programs to encourage animal waste control, or possibly other measures in the event that educational programs fail to achieve desired results.

Opportunity Cost. The most difficult elements to estimate are those relating to opportunity costs. For these elements, costs are not dollars spent for equipment and operation, but rather are reflected as savings or revenue foregone because of the loss of opportunity to accrue them. For example, land use controls (*e.g.,* buffer zones or stricter controls forbidding certain forms of development) may prevent an entrepreneur from opening up a certain business in an area. The municipality loses the revenue as well as the employment potential that might have been gained from this business. The entrepreneur may also lose the profits he might have earned by opening in the area. It is extremely difficult to predict the expected return on the foregone business opportunities because the value of the business opportunity is not clear. The problem is further aggravated by the fact that opportunity costs are borne by various groups, not just the municipality. In the example above, the entrepreneurs incur opportunity costs, as do workers who may have prospective jobs foreclosed to them.

[1] Nasau-Suffolk Regional Planning Board, 1. Section H: Municipal Waste Treatment Systems Needs, 2. Section L: Urban and Industrial Stormwater System Needs.

Table 4–37

NATURE OF COST UNCERTAINTIES FOR HYDROGEOLOGIC ZONE ALTERNATIVES

Areawide Alternatives		Straight Engineering	Engineering with Speculation	Difficult to Estimate	Speculative
		Expanded Industrial Waste Disposal Regulations Structural Runoff Controls Provide for Treatment of Hazardous Wastes Provide Sludge Disposal Alternatives Require Nitrogen Removal for Inland Treatment Plants	Promote Water Conservation Storage and Transport of Chemical Products Regulations Minimize Pollution from Site Preparation Reduce Reliance on Landfills	Septic Tank Maintenance Prohibit Use of Chemical Cleaners	Restrict the Use of Fertilizers Nonstructural Runoff Controls Reduce Animal Wastes Minimize Population Density
Hydrogeologic Zone — Specfic Alternatives					
Zone	**Alternative**				
I	A	Permit no Additional Sewering	Strictly Control On-site Systems	Strictly Regulate Site Management Practices	Specify Acceptable Lot Size
	B	Sewering			
	C	Sewering			
	D	Sewering			
II	A	Route Wastes to Cedar Creek Require Wellhead Treatment		Water Importation	
III	A	Permit No Additional Sewering	Strictly Control On-site Systems	Strictly Regulate Site Management Practices	Specify Acceptable Lot Size
	B		Monitoring Program		Land Use Controls
	C	Sewering			
IV,	A	Sewering			Water Importating
V	B	Permit no Additional Sewering	Strictly Control On-site Systems	Strictly Regulate Site Management Practices	Specify Acceptable Lot Size
	C	Sewering			
	D	Sewering			
	E	Sewering			
VI	A	Permit no Additional Sewering	Strictly Control On-site Systems	Strictly Regulate Site Management Practices	Specify Acceptable Lot Size
	B	Sewering			
	C	Sewering			
	D			Construct and Maintain New Inlet	
VII,	A	Sewering			
VIII	B	Sewering			
	C	Sewering			

Source: ERCO

Excluding landfills from various areas will create costs reflected in the higher costs for landfilled waste disposal. Additional transportation to landfills located outside a zone from which landfills are excluded will increase labor (hours for driving) as well as vehicle O & M costs (gas, oil, tune-ups, replacements). It may also preclude local control of landfills by towns within zones excluding landfills.

Excluding the development of water supply wells similarly increases water supply costs. Wells will have to be developed outside of certain zones, thus requiring additional piping and pumping costs.

A fertilizer management program may reduce a farmer's output or raise his costs by forcing him to use more expensive alternative fertilizers. Reduced profit will also reduce income tax revenues.

4.4.1.2 Plan Options by Surface Water Bodies. Table 4–38 presents the elements of the NSRPB plan options for surface water bodies. Here again, the elements are displayed according to the accuracy with which their costs can be estimated. The problems of estimating costs for these elements are subsumed in the previous discussion.

4.4.2 Estimates of "Hard" Cost Components for Representative Alternative Plans. In costing alternatives, it is necessary to quantify as many of the cost components as can be accurately and objectively derived, and to then rely on human value judgements in assigning a relative value to those costs that cannot be quantified. One still remains on shaky ground. This section will present representative calculations on the quantifiable costs for three different wastewater treatment alternatives for Nassau and Suffolk Counties. In addition, those aspects that are basically unquantifiable will be identified and discussed briefly, while the task of placing a value judgement on their relative costs will be left to the 201 level studies.

The present worth cost data has been taken by ERCO from estimates by Roy F. Weston in *Nassau County Wastewater Management,* October 1977. The average (levelized) annual cost for the three alternatives was obtained by dividing the present worth by 11.129, which is the appropriate conversion factor for calculations using a twenty year planning period and a discount rate of 6.375 percent.

Of the annual costs to be incurred, capital costs are subsidized by both the Federal Government and the State of New York, and operating and maintenance (O & M) costs are subsidized by the State. Because the available data did not specify the projected net cost to the counties, it was necessary to select a subsidy rate that would reflect both the capital and O & M subsidies as well as the fact that O & M costs are incurred throughout the period and are thus subject to the discount rate of 6.375 percent. A subsidy rate of 75 percent was estimated for purposes of analysis.

To obtain the average annual cost to the county as a percentage of the tax structure, the estimate of the average annual cost is divided by an estimate of the tax revenues for Nassau and Suffolk Counties. Ideally, this

Table 4–38

NATURE OF COST UNCERTAINTIES FOR SURFACE WATER ALTERNATIVES

Water Body	Alternative	Straight Engineering	Engineering with Speculation	Difficult to Estimate	Speculative
Manhasset Bay	(a) (i)	Nitrogen Removal			
	(a) (ii)	Move Outfall			
	(a) (iii)	Divert to Cedar Creek			
	(a) (iv)	Divert to Port Washington			
	(a) (v)				No Action
Hempstead Harbor	(a) (i)	Nitrogen Removal			
	(a) (ii)	Move Outfall			
	(a) (iii)	Divert to Glen Cove, Port Washington, or Cedar Creek			
	(a) (iv)				No Action
	(b)		Maintain and Abate Industrial Discharges to Glen Cove Creek		
Oyster Bay	(a) (i)	Retain Present Treatment			
	(a) (ii)	Divert to Cedar Creek			
	(a) (iii)	Nitrogen Removal			
	(a) (iv)	Divert to Glen Cove			

Table 4—38 . . . Cont'd

Water Body	Alternative	Straight Engineering	Engineering with Speculation	Difficult to Estimate	Speculative
Huntington Bay	(a) (i)	Nitrogen Removal			
	(a) (ii)	Move Outfall			
	(a) (iii)		Tertiary Treatment and Recharge		
	(a) (iv)	Divert to Regional Site			
Port Jefferson Harbor	(a) (i)	Secondary Treatment			
	(a) (ii)	Nitrogen Removal			
	(a) (iii)	Move Outfall			
Flanders Bay—Peconic Estuary	(a) (i)	Nitrogen Removal			
	(a) (ii)	Move Outfall			
	(a) (iii)	Nitrogen Removal Move Outfall			
	(a) (iv)	Move Outfall			
	(c)		Monitoring		
Mecox Bay	(a) (i)				Prohibit New Discharges
	(a) (ii)	Nitrogen Removal			
	(b)			Stabilize Inlet	
	(c) (i)				Severely Restrict Development
Skinnecock Bay	(a) (i)				Prohibit New Discharges
	(a) (ii)			Maintain Inlet	
	(b) (i)				Severely Restrict Development
Moriches Bay	(a) (i)				Prohibit New Discharges
	(a) (ii)	Nitrogen Removal			
Great South Bay	(a) (i)	Ocean Outfall			Prohibit New Discharges
	(a) (ii)		Tertiary Treatment and Recharge		Prohibit New Discharges
	(a) (iii)	Nitrogen removal			
	(b)			Construct New Inlet	
	(c) (v)				Prohibit New Development
Western South Shore Bays	(a) (i)	Ocean Outfalls			
	(a) (ii)	Divert Outfall			
	(a) (iii)		Upgrade Lawrence Treatment Facility		
Nearshore Atlantic Ocean					Strict Enforcement of Ocean Dumping Regulations
Fresh Water Bodies	(a)	Nitrogen Removal			

estimate of the tax revenue should be an estimate of the forecasted average annualized tax revenues through the twenty year planning period. However, no such estimates have been obtained. Therefore, it was necessary to use historic data for each county. For Nassau County, the tax revenue estimates were obtained from a prospectus for a recent county bond issue that included the average revenue for the period 1970—1974. This figure has been used as a measure of estimated future tax revenue, and is likely to understate tax revenues, which are presumed to grow over time. For Suffolk County, the value used for future estimated tax revenue is the 1976 tax revenue figure given by a prospectus for 1977 Southwest Sewer District Refunding Bonds.

A. *Alternative 1.*[1] One Dwelling Unit (D.U.) Per Gross Acre Sewering for All Groundwater Zones; Non-structural Non-point Controls; All Bay Discharges to Ocean or Sound.

The cost figures developed by Roy F. Weston are formulated for different scenarios. By selecting the costs that correspond to the specifications in Alternative One, a total for the quantifiable costs can be obtained. Table 4—39 presents the total quantifiable costs in both Nassau and Suffolk Counties, assuming a control strategy corresponding to Alternative One. The costs are broken down into costs for sewering and treatment, for non-structural non-point source pollution controls and for hazardous industrial waste treatment. Each of those categories is in turn expressed in terms of average (annualized) cost *to the county* as a percentage of tax revenues based on the estimates discussed earlier. A similar procedure is followed for Alternatives Eight and Twenty-one, which are presented in Tables 4—40 and 4—41 and are as follows:

B. *Alternative 8.* One Dwelling Unit Per Gross Acre Sewering for All Groundwater Zones; Structural Non-point Controls; South Shore Bay Discharges to Ocean; North Shore Bay Discharges to be Secondary Treated Mid-Bay Outfalls.

C. *Alternative 21.* Strict Fertilizer Controls, Five Dwelling Units Per Gross Acre Sewering for All Groundwater Zones; Structural Non-point Controls; South Shore Bay Discharges to Ocean; North Shore Bay Discharges to be AWT Outfalls at Inner Harbor Sites.

For all four categories in each of the three alternatives, the least expensive regional option was selected. Where no regional options were given in the sources, the least expensive existing option was chosen. Therefore, it is quite possible that the costs could be higher if different strategies were adopted for some reason other than cost. Keep in mind also that the costs presented are only those costs borne by the respective counties. The remainder of the burden is covered by Federal and State Government subsidies at a rate of 75 percent of the total cost.

The calculated cost estimates exclude the costs of laterals, which may be on the order of 100 percent of other collection and treatment costs. As can be seen from Tables 4—39 to 4—41, the relative quantifiable costs for all three alternatives are fairly similar, but are more expensive for Suffolk

Table 4—39

WASTEWATER DISPOSAL FINANCIAL BURDEN[1]

Alternative One: One D.U./Gross Acre Sewering for all Groundwater Zones, Non-structural Non-point Controls; All Bay Discharges to Ocean or Sound

Millions of Dollars

Costs To County	Nassau Average Annual	Nassau % Tax Revenue	Suffolk Average Annual	Suffolk % Tax Revenue
Sewering & Treatment*	7.8	3.1	31.525	27.2
Sludge Disposal (Regional Composting)**	1.8	.7	4.2	3.6
Nonstructural Non-point Control Costs†	.2	.07	.38	.33
Hazardous Industrial Waste Treatment Costs†	.1	.04	.16	.14
	9.9	3.9	36.3	31.3

**Source: Roy F. Weston and SUNY at Stony Brook, Nassau County Wastewater Management, October 1977. "Final Output of Recommended Treatment Levels and Sensitivity Runs."*

***Source: Nassau Suffolk Regional Planning Board, 208 Areawide Waste Treatment Management. Section K, "Residual Waste Control Needs," November 1977.*

†Source: Same as above except Section L, "Urban and Industrial Stormwater Systems Needs, November 1977.

[1]Costs exclude costs of laterals which may equal the total of all other collection and treatment costs.

County than for Nassau County, where a considerable portion of the area is already sewered. The magnitude of the costs for Alternatives One, Eight and Twenty-one may range from about 3.9 to 4.3 percent of Nassau's single year tax revenues, while the relevant magnitude of costs in Suffolk may range from about 30.8 to 33.6 percent of the county's single year tax revenues. In other words, if the costs implied in one of the three selected alternatives were incurred in a single year, the cost could total about four percent and 30 percent of Nassau and Suffolk's tax revenues, respectively, for that year. In fact, however, it must be realized that capital costs for water treatment purposes are typically borne through time, and in staged amounts, by means of bonding. Moreover, the gestation period of such investments requires that the construction and the cost of such projects be phased through time.

[1]Alternatives discussed in Section H of the Areawide Waste Treatment Management Plan.

Table 4—40

WASTEWATER DISPOSAL FINANCIAL BURDEN[1]

Alternative Eight: One D.U./Gross Sewering for all Groundwater Zones; Structural Non-point Controls; South Shore Bay Discharges to Ocean; North Shore Bay Discharges to be Secondary Treated Mid-Bay Outfalls

Costs To County	Millions of Dollars			
	Nassau		Suffolk	
	Average Annual	% Tax Revenue	Average Annual	% Tax Revenue
Sewering & Treatment*	6.4	2.5	31.5	27.2
Sludge Disposal (Regional Composting)**	1.8	.7	4.2	3.6
Non-structural Non-point Controls†	1.7	.7	3.1	2.7
Hazardous Industrial Waste Disposal Costs†	.1	.04	.16	.14
	10.0	3.9	38.95	33.64

**Source: Roy F. Weston and SUNY at Stony Brook, Nassau County Wastewater Management, October 1977. "Final Output of Recommended Treatment Levels and Sensitivity Runs."*

***Source: Nassau Suffolk Regional Planning Board, 208 Areawide Waste Treatment Management. Section K, "Residual Waste Control Needs," November 1977.*

†Source: Same as above except Section L, "Urban and Industrial Stormwater Systems Needs, November 1977.

[1]Costs exclude costs of laterals which may equal the total of all other collection and treatment costs.

4.4.2.1 Uncertainties in the Costs. The costs given here should be taken as order of magnitude costs only. A number of factors contribute to this, including the following:

1. The costs are estimates and involve basic uncertainties in their formulation, as do all estimates of future costs.

2. The capital costs have been amortized over a twenty year life span and with a 6.375 percent discount rate. Changing the period of time or the discount rate will change the average annual cost as well.

3. The tax revenues are estimated from actual historic revenue data. Thus, they most likely understate the tax revenues that are expected to increase with time as the area grows.

4. The costs used are for the least expensive of the regional plan estimates. If other waste treatment options are adopted, the cost would increase correspondingly.

Table 4—41

WASTEWATER DISPOSAL FINANCIAL BURDEN[1]

Alternative Twenty-one: Strict Fertilizer Controls; 5 D.U./Acre Sewering for all Groundwater Zones; Structural Non-point Controls, South Shore Bay Discharges to Ocean; North Shore Bay Discharges to be AWT Outfalls at Inner Harbor Sites

Costs To County	Millions of Dollars			
	Nassau		Suffolk	
	Average Annual	% Tax Revenue	Average Annual	% Tax Revenue
Sewering & Treatment*	7.2	2.9	28.3	24.4
Sludge Disposal (Regional Composting)**	1.8	.7	4.2	3.6
Non-structural Non-point Controls†	1.7	.7	3.1	2.7
Hazardous Industrial Waste Disposal Costs†	.1	.04	.16	.14
	10.8	4.3	35.76	30.84

**Source: Roy F. Weston and SUNY at Stony Brook, Nassau County Wastewater Management, October 1977. "Final Output of Recommended Treatment Levels and Sensitivity Runs."*

***Source: Nassau Suffolk Regional Planning Board, 208 Areawide Waste Treatment Management. Section K, "Residual Waste Control Needs," November 1977.*

†Source: Same as above except Section L, "Urban and Industrial Stormwater Systems Needs," November 1977.

[1]Costs exclude costs of laterals which may equal the total of all other collection and treatment costs.

It should be evident, then, that care must be taken when utilizing any of these figures for comparison of the alternatives. It should also be clear that other factors play a part in any decision involving any choice of waste treatment alternatives.

4.4.2.2 Unquantifiable Costs. Some of the other important factors to consider come under the rubric of opportunity costs. For these elements, costs are not dollars spent for equipment and operation, but rather savings or revenues foregone because of the loss of opportunity to accrue them. For example, land use controls (*e.g.*, buffer zones or stricter controls forbidding certain forms of development) may cause the loss of business opportunities

or other alternatives that would have resulted in benefits for the community. Thus, the cost of that land use control is the direct cost of implementing the control *plus* the foregone benefits that would have resulted had the control not been implemented. It is clear that foregone future benefits are virtually impossible to predict, and that it is even more difficult to place a dollar figure on their social and dollar value. However, they embody a cost to society and must not be dismissed out of hand as trivial or inconsequential. Opportunity costs can neither be accurately quantified nor ignored. Therefore, intelligent estimates must be made about the magnitude of the opportunity cost involved and some measure of a subjective judgment must occur as to which alternatives will be chosen. The scope of this report does not extend to such a task; it will be left to the policymakers.

4.4.3 Secondary Impacts of Pretreatment. Pretreatment requirements can be expected to induce secondary economic effects. Adequate pretreatment will be very costly for some industrial dischargers who generate residuals for which simple removal technologies have not been developed. The economic burdens to industrial dischargers will be very unevenly distributed depending on the match of the state-of-the-art of wastewater engineering to particular waste streams. Small industries can be expected to suffer a high burden, percentage-wise. Detailed economic analyses will be required as part of the special studies.

4.5 Overall Impacts and Discussion

4.5.1 Aggregate Bi-County Impacts. This section takes an Island-wide view of the various measures that were discussed in Sections 4.2 to 4.16 on a bay-by-bay and zone-by-zone basis. This Island-wide view lends itself to consideration of intermedia pollutant tradeoffs. Such tradeoffs include the following: groundwater/surface water, surface water/solid waste, and groundwater/wetland quality. These tradeoffs are presented in terms of net residual loadings to the various media for seven alternatives in Tables 4–42 to 4–48.

The residuals loadings have been calculated by use of a residuals allocation procedure developed by ERCO (Beck and Post, 1978). Values of eight variables are calculated for eight bays, eight groundwater zones, Long Island Sound and the Atlantic Ocean. In many cases the values are only order-of-magnitude estimates. However, these estimates are useful for the study of Island-wide patterns and intermedia tradeoffs. This residuals allocation procedure provides a summary and overview of the detailed studies, models and analyses that have constituted the Nassau-Suffolk 208. The values of variables have been specified using data from many of the 208 technical reports.[1]

Twenty-two Island-wide control strategies were considered using this procedure. These twenty-two alternatives cover a wide range of approaches including sewering (one dwelling unit per acre sewering Island-wide), nonstructural groundwater nitrogen control with selective sewering (five dwelling units per gross acre sewering Island-wide), recharge of effluent, ocean disposal of all effluents, and no action. The complete list of alternatives is given in Table 4–49.

The tradeoffs fall into several groups. First, choice of sewering at low densities is expected to lower groundwater nitrogen; add more surface nitrogen; decrease streamflow, unless recharge completely mitigates the effect; and generate additional solid waste. Choice of ocean outfalls preserves bay conditions at the expense of Long Island Sound or ocean nitrogen loading. Choice of recharge may introduce various contaminants into the groundwater, but mitigates streamflow decreases and improves bay nitrogen conditions.

Organic chemicals are not included in the residuals allocation because there is no basis for formulating estimates. Inventories of sources of organic chemical contaminants are still being assembled. Thus any load estimates would be pure guesswork. An assessment of relative contribution of domestic versus industrial loads does not exist. If organic chemicals follow the pattern of other contaminants, non-point and domestic disposal sources can be expected to be proportionately important. Chlorinated effluents may be a dominant load. Due to the uncertainty concerning all sources, the plan elements presented in Section Three can only be assumed to provide control of several specific sources of organic contaminants. Other important sources, such as runoff recharge basins, are not yet included in the plan. Thus, due to the nature of the health risks imposed by the organic chemicals, further work including source inventories and analyses, ambient monitoring, and technology research, is of high priority from an environmental viewpoint.

Air pollutants are also not included in the residual allocation summaries. The major potential for air pollution is in the disposal of treatment plant sludges. The sludge loading numbers give a general picture of air pollution potential if incineration is the selected disposal method. However, there are many alternatives for sludge disposal. Composting and land application involve a minimum of air pollution. Pyrolysis contributes a smaller suite of air residuals than incineration, although the fine particulates contributed by pyrolysis are particularly troublesome. Thus, from an air pollution standpoint, composting and land application are favored approaches.

As can be seen from the residuals loading allocation tables comparing the 22 options, there is no clearly environmentally preferable strategy. Certain classes of risks will have to be tolerated in order to minimize others that are deemed more critical. Among the water quality problems least reversible, and therefore of greatest concern, are high organic chemical

[1] Major sources:
Nitrogen and Coliform: Point source loads for 1995 at one dwelling unit per acre by Weston (1977a). Non-point source loads to bays by Tetra Tech. Non-point source loads to groundwater by Porter *et al.* (1978).
Sludge: 1995 loads for one dwelling unit per acre by Weston (1977b).
Streamflows: ERCO judgements based on Miller and Sgambat (1977a).
Metals: Point Sources, Weston (1977c); *Non-point Sources,* Weston (1977d).

Table 4—42

ALTERNATIVE 1: 1 D.U./GROSS ACRE SEWERING FOR ALL GROUNDWATER ZONES; NON-STRUCTURAL NON-POINT CONTROLS; ALL BAY DISCHARGES TO OCEAN OR SOUND

	Surface Bays								Groundwater Zones							
	Manhasset	Hempstead Harbor	Oyster Bay	Huntington/Northport	Port Jefferson	Peconic/Flanders	Suffolk South Shore	Nassau South Shore	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII
Nitrogen: —surface (lbs/day)	671	1,150	1,290	1,420	612	264	6,350	4,540								
—groundwater (lbs/acre yr)									165	165	175	200	125	165	165	200
Total Coliform (Organisms/day)	$5x10^{13}$	$7x10^{13}$	$1x10^{14}$	$1x10^{14}$	$5x10^{13}$	$6x10^{12}$	$2x10^{14}$	$4x10^{14}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$
Water Table (Change (Δ feet)	0	0	0	0	0	0	0	0	0	0	0	−1	−2.5	−2.5	−2.5	−2.5
Sludge (dry lbs/yr)	0	0	0	0	0	0	0	0	0	0	99,000	35,000	0	140,000	373,000	453,000

	Total Surface Water	Total Groundwater
Cu (lbs/yr)	52,000	42,000
Cr (lbs/yr)	110,000	97,000
Pb (lbs/yr)	290,000	81,000
Ni (lbs/yr)	100,000	75,000

contaminant levels in groundwater, nitrate contamination of groundwater, changes in stream and wetland water levels, and changes in bay salinity patterns. The final choices will rest with the policymakers.

4.5.2 Discussion of Sewering Density and Groundwater Nitrates. This section addresses the relationship between groundwater nitrate levels and sewering practices. In the following subsections analyses of nitrate data are reviewed, observations on interpretation of the data are given, control measure implications are discussed, and the position of nitrate concerns in the general context of intermedia environmental tradeoffs is presented. There is no optimal solution. The environmental tradeoffs are many and each tradeoff is complex. This section seeks to point out the positive and negative impacts of sewering. It is hoped that the planner, armed with this knowledge, will use sewering properly—as only one of many tools to be employed in the complex task of balancing the numerous environmental demands.

There are many public health and ecological objectives that must be weighed against the nitrate standard. In such a complex Water Quality Management Plan, it would be dangerous to base large portions of the Plan on one variable—dangerous in the sense that other variables may not be addressed. The real environmental objective function has many dimensions. Hence, it is environmentally unsound to proceed with comprehensive sewering (one dwelling unit per gross acre), or indeed even less extensive sewering plans (two dwelling units per gross acre or three dwelling units per gross acre

Table 4–43

ALTERNATIVE 8: ONE D.U./ACRE SEWERING FOR ALL GROUNDWATER ZONES; STRUCTURAL NON-POINT CONTROLS; SOUTH SHORE BAY DISCHARGES TO OCEAN; NORTH SHORE BAY DISCHARGES TO BE SECONDARY TREATED MID-BAY OUTFALLS

	Surface Bays								Groundwater Zones							
	Manhasset	Hempstead Harbor	Oyster Bay	Huntington/Northport	Port Jefferson	Peconic/Flanders	Suffolk South Shore	Nassau South Shore	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII
Nitrogen:																
—surface (lbs/day)	5,730	4,110	2,360	9,650	2,660	7,250	5,910	4,180								
—groundwater (lbs/acre/yr)									165	165	175	200	125	165	165	200
Total Coliform (organisms/day)	3×10^{13}	5×10^{13}	7×10^{13}	8×10^{13}	3×10^{13}	4×10^{12}	1×10^{14}	2×10^{14}	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$
Water Table Change (Δ feet)	0	0	0	0	0	0	0	0	0	0	0	−1	−2.5	−2.5	−2.5	−2.5
Sludge (dry lbs/yr)	0	0	0	0	0	0	0	0	99,000	35,000	0	140,000	373,000	453,000	0	0

	Total Surface Water	Total Groundwater
Cu (lbs/yr)	29,400	24,000
Cr (lbs/yr)	63,800	54,800
Pb (lbs/yr)	164,000	44,500
Ni (lbs/yr)	56,900	42,400

Island-wide sewering), which are mainly justifiable only with respect to groundwater nitrogen. Selective sewering is certainly justified. Certain areas with high groundwater elevations, areas with very high population densities (over five dwelling units per gross acre, above which it becomes clear that non-point controls will in very few cases be sufficient) (Weston, 1977a; 1976) and certain other areas that may be identified by monitoring will require sewering; further collection of monitoring data is needed.

A major objective of bi-county 201's or further areawide planning should be collection and analysis of groundwater data for various contaminants. Sewering of large areas, especially along the South Shore, is environmentally unsound with respect to the interruption of hydrological and chemical cycles. Controls of other nitrogen sources and non-structural controls of septic tank performance should be preferentially implemented. One aspect of the water quality management program should be implementation of a permanent mapping and analysis program to lay out and update nitrate and organic chemicals susceptibility zones.

Finally it should be noted that a major cause of nitrate buildups in groundwater is the alteration of natural nutrient cycling by removal of natural forest and marsh ecosystems. The best control strategy is an approach that minimizes such alterations, and includes land use controls, fertilizer controls and runoff controls, such as marsh-pond systems in runoff recharge basins. With this approach, emphasis must be placed on implementation and

Table 4–44

ALTERNATIVE 10: RECHARGE OF SOUTH SHORE TREATMENT PLANT EFFLUENTS (SECONDARY TREATMENT); MAXIMUM LAND USE CONTROLS AND NON-STRUCTURAL CONTROLS IN GROUNDWATER ZONE III; NORTH SHORE BAY DISCHARGES TO BE SECONDARY TREATED MID-BAY OUTFALLS; 1 D.U./GROSS ACRE SEWERING

	Surface Bays								Groundwater Zones							
	Manhasset	Hempstead Harbor	Oyster Bay	Huntington/Northport	Port Jefferson	Peconic/Flanders	Suffolk South Shore	Nassau South Shore	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII
Nitrogen:																
—surface (lbs/day)	5,800	4,200	2,470	9,800	2,740	7,260	6,350	4,540								
—groundwater (lbs/acre/yr)									12,100	165	175	200	125	263	1,170	200
Total Coliform (organisms/day)	6×10^{13}	8×10^{13}	1×10^{14}	1×10^{14}	5×10^{13}	6×10^{12}	2×10^{14}	4×10^{14}	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$
Water Table Change (Δ feet)	0	0	0	0	0	0	0	0	0	0	0	–1	–2.5	–.5	–.5	–2.5
Sludge (dry lbs/yr)	0	0	0	0	0	0	0	0	0	0	99,000	35,000	0	140,000	373,000	453,000

	Total Surface Water	Total Groundwater
Cu (lbs/yr)	9,620	84,800
Cr (lbs/yr)	16,000	195,000
Pb (lbs/yr)	212,000	160,000
Ni (lbs/yr)	25,700	151,000

enforcement of these controls, since their operability is less straightforward than that of sewering.

4.5.2.1 Review of the Data Analyses Done as Part of Water Quality Management Program Planning. Two analyses of observation well data have been done as part of the Nassau-Suffolk 208 Program.[1] One analysis is based on data from 127 samples. The samples selected conform to the following selection criteria: (a) Samples were restricted to wells from unsewered locales with population densities relatively stable over a twenty year period; (b) Samples were from depths less than 100 feet; (c) Samples were restricted to 1970 to the present. These conditions attempted to avoid the time of travel problems between population density input and well measurements. Weston arranged the data into five groups based on school districts. The results of their analysis are presented in Table 4–50.

A separate analysis was done using a larger sample of well measurements (Porter *et al.*, 1978). Porter's analysis proceeded by grouping the data according to uniform sized grid cells, which were smaller in size than the school districts used by Weston. The grid cells used, covered a larger geographic extent than Weston's school districts. Only grid cells covering areas

[1] A third analysis, by the USGS, has not yet been published or released, and is therefore not covered in detail in this discussion.

Table 4–45

ALTERNATIVE 12: 5 D.U./GROSS ACRE SEWERING FOR ALL GROUNDWATER ZONES; NON-STRUCTURAL NON-POINT CONTROLS; SOUTH SHORE BAY DISCHARGES TO OCEAN; NORTH SHORE BAY DISCHARGES TO BE SECONDARY TREATED MID-BAY OUTFALLS

	Surface Bays								Groundwater Zones							
	Manhasset	Hempstead Harbor	Oyster Bay	Huntington/Northport	Port Jefferson	Peconic/Flanders	Suffolk South Shore	Nassau South Shore	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII
Nitrogen: —surface (lbs/day)	3,240	2,680	1,880	5,610	1,670	3,760	6,350	4,540								
—groundwater (lbs/acre/yr)									290	290	300	325	250	290	290	325
Total Coliform (organisms/day)	5×10^{13}	7×10^{13}	1×10^{14}	1×10^{14}	5×10^{14}	5×10^{13}	2×10^{12}	4×10^{14}	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$
Water Table Change (Δ feet)	0	0	0	0	0	0	0	0	0	0	0	0	–.5	–.5	–.5	–.5
Sludge (dry lbs/yr)	0	0	0	0	0	0	0	0	0	0	49,500	17,500	0	70,000	187,000	227,000

	Total Surface Water	Total Groundwater
Cu (lbs/yr)	9,620	84,800
Cr (lbs/yr)	16,000	195,000
Pb (lbs/yr)	212,000	160,000
Ni (lbs/yr)	25,700	151,000

completely sewered or completely unsewered were analyzed. Results of Porter's analysis are given in Tables 4–51 and 4–52.

Both Weston and Porter analyzed their data sets by linear regression. Figure 4–3 presents the derived regression lines. (Table 3–11 presented in Section 3.5.2 is not a data table, but is, rather, a tabular presentation of the linear regression analysis performed by Porter.)

The USGS reports the following provisional findings based on their data:

"When the upper glacial aquifer is treated as a single unit over the entire period of record (1952–76), median nitrate concentrations show no difference over time or between the sewered and unsewered parts of the study area. Care must be exercised when comparing medians from one time interval to another because of bias introduced by the abandonment of wells, changes in samples (analyses) size, changes in sampling frequency, and changes due to hydrologic events (drought, wet periods).

Median ammonium concentrations (as N) of 0.01 milligrams per liter for the sewered area and 1.1 milligrams per liter for the unsewered area for the most recent time interval (1972–76) reflect an improvement in water quality in the sewered area. Of thirteen wells having long-term water quality records (fifteen years or more) in the sewered part of the study area, eight had significant decreasing trends in nitrate concentration with a median value of 0.21 milligrams per liter per year. Two wells had significant increasing

Table 4–46

ALTERNATIVE 14: NO ACTION

	Surface Bays								Groundwater Zones							
	Manhasset	Hempstead Harbor	Oyster Bay	Huntington/Northport	Port Jefferson	Peconic/Flanders	Suffolk South Shore	Nassau South Shore	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII
Nitrogen:																
—surface (lbs/day)	5,870	4,290	2,580	9,950	2,810	7,280	6,800	4,900								
—groundwater (lbs/acre/yr)									290	290	300	325	250	290	290	325
Total Coliform (organisms/day)	8×10^{13}	1×10^{14}	2×10^{14}	2×10^{14}	8×10^{13}	8×10^{12}	3×10^{14}	4×10^{14}	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$
Water Table Change (Δ feet)	0	0	0	0	0	0	0	0	0	0	0	0	$<.5$	$<.5$	$<.5$	$<.5$
Sludge (dry lbs/yr)	0	0	0	0	0	0	0	0	0	0	34,700	12,200	0	49,000	131,000	159,000

	Total Surface Water	Total Groundwater
Cu (lbs/yr)	10,700	94,000
Cr (lbs/yr)	17,800	217,000
Pb (lbs/yr)	235,000	178,000
Ni (lbs/yr)	28,500	167,000

trends and three wells showed no trends. In the unsewered area there was only one well with a long record of nitrate analyses, and this well had a significant increasing trend in nitrate concentrations.

4.5.2.2 Interpretation of Data Analysis. As pointed out in reports by Miller and Sgambat (1977a) and others, the movements and fates of nitrates introduced to the groundwater are very complex. Thus, a conclusive analysis of groundwater nitrate data is very difficult and wholly beyond the scope of the water quality management program. Review of individual well measurements as well as consideration of summarized data indicate the complexity of the nitrate distribution trends.

Some wells have been sampled many times. Hence, some consideration of individual sites and grids is justified. Individual grid cell data from Porter's analysis shows high and low nitrate levels occurring at the full range of population levels. In some grids, high population densities seem to be accompanied by high nitrate levels; but in other grids, such a relationship cannot be discerned.

Summary statistics of Porter's data set show a net lower nitrate level in Upper Glacial groundwater in sewered grids as opposed to unsewered grids. However, the information provided does not fully eliminate the possible effects of sewering from other density-related factors. Some of the other factors contributing to the lower nitrate levels may be (a) less fertilizer use in higher density areas; (b) changed runoff-recharge patterns due to impervious

Table 4–47

ALTERNATIVE 21: STRICT FERTILIZER CONTROLS, 5 D.U./GROSS ACRE SEWERING FOR ALL GROUNDWATER ZONES; STRUCTURAL NON-POINT CONTROLS; SOUTH SHORE BAY DISCHARGES TO OCEAN; NORTH SHORE BAY DISCHARGES TO BE AWT OUTFALLS AT INNER HARBOR SITES

	Surface Bays								Groundwater Zones							
	Manhasset	Hempstead Harbor	Oyster Bay	Huntington/Northport	Port Jefferson	Peconic/Flanders	Suffolk South Shore	Nassau South Shore	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII
Nitrogen: —surface (lbs/day)	862	1,210	1,230	1,690	640	604	5,910	4,180								
—groundwater (lbs/acre/yr)									275	275	225	225	225	275	275	275
Total Coliform (organisms/day)	$3x10^{13}$	$5x10^{14}$	$7x10^{13}$	$8x10^{13}$	$3x10^{13}$	$4x10^{12}$	$1x10^{14}$	$2x10^{14}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$	$<10^{10}$
Water Table Change (Δ feet)	0	0	0	0	0	0	0	0	0	0	0	0	–.5	–.5	–.5	–.5
Sludge (dry lbs/yr)	0	0	0	0	0	0	0	0	0	0	49,500	17,500	0	70,000	187,000	227,000

	Total Surface Water	Total Groundwater
Cu (lbs/yr)	5,430	48,000
Cr (lbs/yr)	9,050	110,000
Pb (lbs/yr)	119,000	89,000
Ni (lbs/yr)	14,500	84,800

surfaces in densely populated areas; (c) less vegetation, with associated organic cycles and root zone activity; (d) changing land uses and, (e) geologic characteristics. The apparent mean difference in groundwater nitrate levels between sewered and unsewered areas is 1.3 milligrams per liter for a 6.8 persons per acre difference in population density.

Porter attempts to take into account variability of nitrate concentrations over time and by locale. His analysis of such variability led to selection of a mean of six milligrams per liter NO_3 as N as a guideline number for achieving 90 percent compliance with the ten milligrams per liter standard.

Porter's regression analysis indicates a statistically significant correlation of a high order. However, Porter has eliminated two data points on the basis of a plausibility screen before running his analysis and these observations may reduce the statistical significance of his result.

Weston's regression analysis is statistically significant at the 95 percent level. The zero population point used in the Weston analysis was taken from a different set of data and does not conform to the screening criteria previously discussed. It is possible that Weston's data base did not cover a wide enough range of population densities and their zero population point did not actually represent "natural" conditions. The sensitivity of groundwater nitrate concentrations to sewering density numbers in populated areas from a zero population data point may not be a wholly relevant

Table 4–48

ALTERNATIVE 22: 5 D.U./GROSS ACRE SEWERING FOR ZONES III, IV, V, VIII; 1 D.U./GROSS ACRE SEWERING FOR ZONES I, II, VI, VII, SECONDARY MID-BAY DISCHARGES ON THE NORTH SHORE; OCEAN OUTFALL ON THE SOUTH SHORE; NON-STRUCTURAL NON-POINT CONTROLS

	Surface Bays								Groundwater Zones							
	Manhasset	Hempstead Harbor	Oyster Bay	Huntington/Northport	Port Jefferson	Peconic/Flanders	Suffolk South Shore	Nassau South Shore	Zone I	Zone II	Zone III	Zone IV	Zone V	Zone VI	Zone VII	Zone VIII
Nitrogen: —surface (lbs/day)	3,240	2,680	1,880	5,610	1,670	3,760	6,350	4,540								
—groundwater (lbs/acre/yr)									290	290	100	200	125	290	290	200
Total Coliform (organisms/day)	7×10^{13}	1×10^{14}	1×10^{14}	5×10^{14}	6×10^{12}	2×10^{14}	4×10^{14}	$< 10^{10}$	$< 10^{10}$	$< 10^{10}$	$< 10^{10}$	$< 10^{10}$	$< 10^{10}$	$< 10^{10}$	$< 10^{10}$	$< 10^{10}$
Water Table Change (Δ feet)	0	0	0	0	0	0	0	0	0	0	0	−1	−2.5	−2.5	−2.5	−.5
Sludge (dry lbs/yr)	0	0	0	0	0	0	0	0	0	0	49,500	17,500	0	140,000	373,000	227,000

	Total Surface Water	Total Groundwater
Cu (lbs/yr)	9,620	84,800
Cr (lbs/yr)	16,000	195,000
Pb (lbs/yr)	212,000	160,000
Ni (lbs/yr)	25,700	151,000

analysis.

Since the purpose of the analysis is to compare sewered versus unsewered areas, the arguments in favor of including "natural" conditions or a "wide" range of population densities may not be particularly relevant. The unsewered areas of concern may also have high population densities. At least two interpretations of the Weston and Porter data are possible: (A) there may, in fact, be a rough cause-effect relationship between population density and groundwater nitrates, or (B) there may be a hyberbolic relationship between the two variables, such that at low populations densities groundwater nitrogen is low, and at densities greater than one half to one dwelling unit per gross acre, nitrate levels are high; they do not increase linearly, and may not be closely related to on-lot systems density. (See Figure 4–4.)

All data is from Upper Glacial wells. Thus, the data analysis does not present conditions of Magothy water supplies. The time horizon for travel of sampled waters to waters tapped for supply may be five to 200 years. Thus, the efficacy of acting on the basis of an Upper Glacial pollution threshold is somewhat uncertain. On the basis of nondegradation arguments, one would take non-point control measures with or without sewering. On the basis of expected net dollar returns on investment through time, expensive control measures may not be called for due to future technological advances in the state of the art,which may make nitrate removal a less costly technique,

Table 4–49

SUMMARY OF ALTERNATIVES CONSIDERED

Alternative	Description
(1)	1 D.U./Gross acre sewering for all grounwater zones; non-structural non-point controls; all bay discharges to ocean and Sound.
(2)	1 D.U./Gross acre sewering for all groundwater zones; non-structural non-point controls; south shore discharges to ocean; north shore bay discharges to be secondary treated, mid-bay outfalls.
(3)	1 D.U./Gross acre sewering for all groundwater zones; non-structural non-point controls; south shore bay discharges to ocean; north shore bay discharges to be AWT, outfalls at the present inner harbor locations.
(4)–(6)	2 D.U./Gross acre sewering for all groundwater zones; the same set of alternatives as (1)–(3) in all other respects.
(7)–(9)	Structural non-point controls; the same set of alternatives as (1)–(3) in all other respects.
(10)	Recharge for south shore treatmnet plants; maximum land use and non-structural controls in Groundwater Zone III; secondary treatment and mid-bay outfalls for north shore bays.
(11)–(13)	5 D.U./Gross acre sewering for all groundwater zones; the same set of alternatives as (7)–(9) in all other respects.
(14)	No action.
(15)–(17)	5 D.U./Gross acre sewering for all groundwater zones; the same set of alternatives as (7)–(9) in all other respects.
(18)	Maximum land use and non-structural controls for Groundwater Zone III; otherwise the same alternatives as (22).
(19)–(21)	Strict fertilizer controls; otherwise the same alternatives as (15)–(18).
(22)	5 D.U./Gross acre sewering for Zones III, VIII, IV, V; 1 D.U./Gross acre sewering for Zones I, II, VI, VII; secondary treatment and mid-bay discharge on the north shore and ocean outfalls on the south shore.

as well as possible economic changes.

USGS analysis of streams suggests that unsewered areas at a given density contribute more nitrogen to surface waters than sewered areas. However, lack of stream ecology surveys limits the usefulness of that result.

USGS aggregate analyses of Upper Glacial groundwater data gave no conclusive indication of differences in nitrogen levels between sewered and

Table 4–50

FINAL DATA SET INDICATING THE RELATIONSHIP BETWEEN POPULATION DENSITY AND RESULTING NITRATE CONTAMINATION BY SCHOOL DISTRICT

School District	Average Population Density Per Acre	Average NO_3–N Concentration 1970–Present
Westbury	8.0	11.3
Hicksville	11.2	9.4
Island Trees	12.4	13.9
East Meadow	10.5	10.2
Levittown	14.5	8.9
Initial Boundary Condition[1]	0.0	1.0

[1] *An initial boundary condition representing no population was chosen as 1.0 mg NO_3–N/1 for the following reasons:*
a. The concentrations of nitrogen in precipitation is approximately 1.0 mg/l.
b. Streams draining undeveloped areas have concentrations of nitrogen close to 1.0 mg/l.
c. Data from wells in rural Suffolk have concentrations less than 1.0 mg/l.
d. The CES regression analysis shown in Figure 4–3 has an intercept of 1.99 mg/l.
Source: Weston (1977a) and Section H of the Areawide Waste Treatment Management Plan.

Table 4–51

POPULATION DENSITIES AND AVERAGE MEDIAN NITRATE-NITROGEN CONCENTRATIONS IN WATER FROM WELLS SCREENED IN THE UPPER GLACIAL AQUIFER 1972–76 IN GRID CELLS WHICH ARE ENTIRELY UNSEWERED

Grid Cell No.	Persons/Acre	Average Median (mg/l)
2	1.5	2.5
55	3.3	6.6
66	0.9	1.9
71	1.5	1.5
81	9.5	19.0
82	4.2	3.1
84	0.7	1.5
104	4.4	2.3
105	10.9	9.6
119	1.6	5.0
120	6.3	9.8
123	11.9	2.3
133	1.3	1.2
140	12.8	13.0
154	2.1	3.2
157	16.6	8.4
174	8.5	7.5
Overall average	5.8	5.8

Source: Porter et al. (1978).

Table 4–52

POPULATION DENSITIES AND AVERAGE MEDIAN NITRATE-NITROGEN CONCENTRATIONS IN WATER FROM WELLS SCREENED IN THE UPPER GLACIAL AQUIFER 1972-76 IN GRID CELLS WHICH ARE ENTIRELY SEWERED

Grid Cell No.	Persons/Acre	Average Median (Mg/l)
18	6.4	5.6
19	12.2	5.9
29	9.1	4.4
30	13.7	1.4
31	11.8	7.2
33	14.1	3.9
34	12.2	5.8
43	10.2	6.8
44	11.0	4.2
46	13.0	4.8
48	14.5	2.6
59	10.7	3.6
60	16.8	2.7
61	9.6	2.0
63	12.4	1.6
75	27.2	7.0
76	12.5	6.7
93	16.5	3.2
94	13.2	1.4
143	9.0	4.9
159	11.2	9.4
Overall Average	12.7	4.5

Source: Porter et al., (1978).

unsewered areas.

Mean nitrate concentrations near the water table are significantly lower in the sewered area than in the unsewered area for both recent time periods (1967–71 and 1972–76). Lower concentrations of total nitrogen were also observed in stream water from the sewered area than in streams draining the unsewered area.

4.5.2.3 Control Measures Implications. Public Health standards (Section 4.1.1.3) dictate that nitrate-nitrogen levels remain below ten milligrams per liter in water supplies. For the 208 Program, this translates to maintenance of the Magothy aquifer NO_3 concentrations below ten milligrams per liter or treatment at the wellhead. The bi-county 208 Program has interpreted the standard level as a tenth percentile rather than an absolute standard. This interpretation appears reasonable. Based on that standard, and assuming treatment at the wellhead is ruled out as the primary basis of control, the analysis of well data suggests a need for widespread controls of nitrate levels. Significant violations of the standards over a twenty year period can be predicted.

The Porter well data show that sewering reduces nitrate levels. The data also shows that in many locales the relationship of population density to nitrate levels is tenuous or nonexistent. Hence, only other controls such as fertilizer regulations, animal waste ordinances, and marsh-pond systems in recharge basins can be expected to reduce nitrate levels in those locales.

A nitrogen budget of the bi-county area by Porter *et al.* (1978) showed the major role of non-point nitrogen sources (see Table 4–53). Detailed nutrient studies of natural ecosystems have shown the important role of vegetation in recycling nitrates from rainfall and some runoff. The lack of

Table 4–53

GROSS SUMMARY OF ESTIMATED SOURCES AND FATE OF NITROGEN IN THE BI-COUNTY REGION (BASED ON 1975 AND 1976 DATA) [1]

Source	Nitrogen Initial Load	(tons/yr.) Load to groundwater	Comment on Sink
Wastewater			
On-site systems	8500	4300	(Denitrification, etc.)
Sewers & sewage treatment			
Sewer leakage	500	200	(Denitrification, etc.)
Effluent discharge to ground	200	100	(Denitrification, etc.)
Effluent discharge to marine bays	4200	–	(Discharge to sea)
Sub-total	13400	4600	
Fertilizers			
Farm (inc. sod farms)	4000	1000	(Crop removal)
Turf (inc. households, golf courses, etc.)	9300	5600	(Volatilization & Denit.)
Animals (primarily dogs & cats)	1600	800	(Volatilization & Denit.)
Ducks	600	300	(Volatilization & Denit.)
Sub-total	15500	7700	
Precipitation	4000	3700	(By difference from totals)
Totals	32900	16000*	(Totals estimated by water/nitrogen model)

[1] *When using this table it should be noted that the numbers represent regional averages and do not refer to specific sites.*

**Assuming an annual recharge of about 500 billion gallons, the resulting concentrations in the leachate equals about 6.8 mg/l.*

Source: Porter et al. (1978).

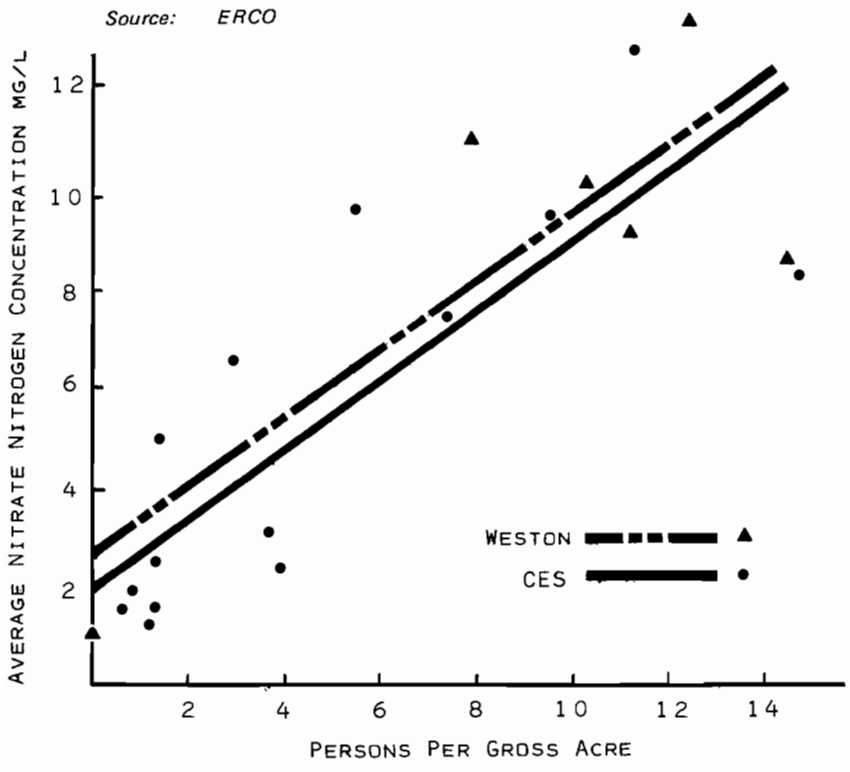


FIGURE 4–3 *Analyses of Two Independent Studies Relating Groundwater Quality to Population Density*

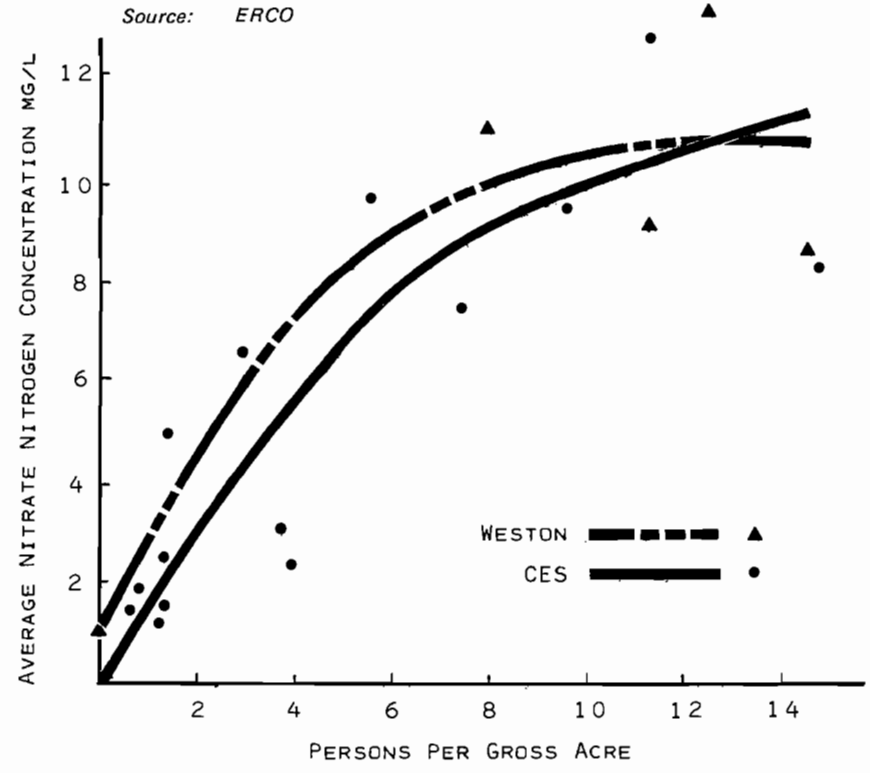


FIGURE 4–4 *Alternative Interpretation of Two Independent Studies Relating Groundwater Quality to Population Density*

natural vegetaion in the residential and urban areas of the Bi-county Region coupled with augmentation of nitrogen loads to groundwater has altered the dynamics of the natural cycles. Measures such as fertilizer controls, which reduce the nitrate loads to be cycled by grasses and crops; land use controls that preserve natural ecosystems; runoff holding ponds and marsh-ponds in recharge basins, which simulate natural ecosystem functions; and animal waste controls and street cleaning, which remove waste from artifical ecologically inactive areas can partially compensate for reduction of natural treatment of runoff and rainwater. Such measures can be expected to significantly reduce nitrate loads to groundwater.

4.5.2.4 Intermedia Tradeoffs. Acceptable groundwater nitrate levels (with associated secondary benefits) is only one of the numerous objectives enumerated in Section 4.1. The following are among the negative impacts of sewering with marine discharges: (1) reduction of streamflows and wetland inundation levels as already observed in southwestern Nassau County; (2) increase in sewage flows that must then be disposed of to bays, oceans or groundwater (Since nitrates also impose a threat to ocean waters, the net result of ocean outfalls is the transfer of a problem from bay to oceans rather than its elimination.) (3) increase in sludge quantities. (Increased sludge quantities may cause negative air quality impact if the sludge is incinerated, co-incinerated or pyrolyzed. The net effect may be positive if sludge is composted.) and (4) induced growth may occur in those areas not already fully developed. (Urban Systems, Inc. (1974) performed a detailed study that demonstrated this impact.)

4.5.2.5 Environmental Judgment with Respect to Sewering Strategy. The many tradeoffs associated with choices for groundwater protection have been carefully and critically studied. These have been considered quantitatively and analytically when possible. This has included use of statistical, graphical and cost-benefit tools. Such investigations have been summarized in this chapter in the various data tables and graphical presentations. In many cases, important aspects of the evaluation have only admitted to qualitative analysis. This has been due to lack of monitoring data or of understanding of environmental functions. Qualitative evaluation has been in the form of expert judgment based on the literature and on ecological, chemical and

hydraulic principals. Those have been presented in this chapter by way of textual explanations and argument.

Based on both quantitative and qualitative evaluation, an environmentally preferred course of action has emerged. This course involves the following:

1. Selection of nonsewering options as a general guideline.

2. Emphasis on providing the regulatory, monitoring and enforcement tools required to implement nonsewering options.

3. Selected sewering in areas where (a) on-site system failures will occur and development is allowed, (b) locally high population densities (over five dwelling units per gross acre) occur, and (c) other areas as indicated by monitoring results. The need for such selected sewering must be clearly demonstrated by 201 studies.

4. Allocate sufficient funds and develop a detailed management plan to adequately implement the watershed management approach in Zone III.

5. Strictly enforce all nonsewering controls, sewer in areas of on-lot system failures, and avoid other sewering to minimize disruption of the water balance. Closely monitor bay N levels in Zones VI and VII. Emphasize land use controls and preservation of buffer zones around water bodies and strictly preserve wetlands to minimize disruption of nitrogen cycling.

6. Only sewer in cases of on-lot system failures or if groundwater flow to bays is clearly demonstrated to present local surface water problems in Zone VIII. Given the range of tradeoffs available, this is ecologically the most sound approach in those zones.

4.5.3 The Major Tradeoffs Involved in Selection of This Course of Action.

1. The choice not to sewer at one dwelling unit per acre, two dwelling units per acre or three dwelling units per acre will allow continuation of nitrate leaching to glacial groundwater in some areas due to on-lot systems. Depending on how the data is interpreted, it appears that domestic nitrate sources will affect mean groundwater nitrate concentrations unfavorably by one to five milligrams per liter. This will involve secondary impacts on bay nitrate levels for Zone VI.

2. Strictly enforced fertilizer controls, on-lot systems maintenance, animal waste controls and land use controls will reduce nitrate leaching to glacial groundwater in some areas. If these controls work, nitrogen balances suggest this will lower mean groundwater nitrate concentrations by three to four milligrams per liter.

3. There is some uncertainty as to how effectively the nonsewering controls can be implemented. This uncertainty gives an error bracket to the figures given in point two above such that the controls may result in as low as only one milligram per liter reduction if they are poorly regulated and enforced, and may result in up to a five milligram per liter reduction if the plan is implemented in a first-class fashion.

4. Selection of nonsewering options will greatly reduce the needs for stream augmentation and recharge. Stream augmentation (with shallow recharge, if feasible), would be a critical part of an acceptable sewering strategy. At present, there is great uncertainty associated with whether or not stream augmentation would work. Changes in inundation levels of wetlands of only a few inches will probably significantly degrade the quality of wetland habitats (see Section 4.1.2.2); changes in stream flows can be expected to change salinity conditions in Great South Bay.

5. Selection of nonsewering strategies would greatly reduce needs for treatment plant expansion and sludge handling facilities. It would eliminate the need for AWT/mid-bay outfalls in bays presently surrounded by unsewered areas and in Port Jefferson Harbor and in Oyster Bay. Based on the above tradeoffs and uncertainties, it is judged that properly implemented nonsewering plan elements, with selective sewering, can be reasonably expected to have results ranging from significant lowering to slight decreases in groundwater nitrates. Comparing this with expected stream flow and marsh inundation declines and increased sewage and sludge loads, the nonsewering options are generally judged environmentally preferable. If sewering options were selected, no further sewering of Zones VI, VII and VIII (except for small treatment facilities involving local recharge of advanced treated effluent) should be undertaken until stream augmentation/shallow recharge is implemented in the Southwest Sewer District and its effectiveness is studied.

4.5.4 Concluding Remarks. Several of the key findings of this environmental assessment are repeated here. They serve as a summary of the environmental portion of the Water Quality Management Plan:

1. *Organic Chemical Contamination* of the aquifer is a critical concern. An acceptable control plan could not be drawn up for the Water Quality Management Plan due to lack of an inventory of sources. Immediate study of organics distribution and formulation of such a plan is required.

2. *Hazardous Wastes* cannot be considered an exportable residual. The proposed measures in the Water Quality Management Plan are adequate with respect to the 208 but not with respect to ultimate disposal of hazardous wastes. However, this is mentioned more as a comment on EPA policy rather than as a conclusion relating to the water quality management program.

3. *Non-point Controls* are implementable and could control a large segment of the residuals of concern. The proposed measures are adequate. Of particular importance are preservation of buffer zones, fertilizer controls, structural measures to treat runoff to bays, marsh-pond type recharge basins, and controls of industrial disposal practices.

4. *Sewering* has numerous environmental drawbacks, as noted in Sections 4.2.12 and 4.5.2.4, and should only be selectively implemented.

5. *Great South Bay's Marine Resources* will be rapidly degraded if the strict control measures proposed are not implemented.

6. *Manhasset Bay and Hempstead Harbor* cannot be expected to improve in quality except for local harbor areas until western Long Island

Sound problems are corrected.

7. *Nutrient Nitrogen/Phosphorus Ratios* will be impacted if nitrogen removal wastewater treatment plants are installed without complementary phosphorus removal. This may cause adverse changes in the marine food web.

8. *The Ocean is Not an Infinite Sink.* Reliance on ocean disposal of sewage and pretreated hazardous wastes may have long-term deleterious effects. This a comment on EPA policy and not a criticism of the water quality management program.

9. *Sludge Disposal* alternatives vary widely in their impacts. Composting, land application, and thermal drying are environmentally beneficial while pyrolysis has significant energy benefits. All other alternatives should be avoided.

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Section 5 Preferred Plan Alternatives

5.0 Introduction

As indicated in the previous sections, the 208 Program has identified Long Island's wastewater management needs and the relevant structural and non-structural alternatives that may be used to ameliorate them. A large number of wastewater management alternatives were defined, all having as their general objective the development of a comprehensive management plan for the treatment and disposal of waste in order to protect the public health and natural resources of the Nassau-Suffolk 208 Region.

During the course of the planning process leading up to the development of the Plan, alternatives were subjected to constant evaluation in terms of engineering and economic feasibility, probable environmental effects and legal or regulatory requirements. Where any alternative or set of alternatives was found to violate environmental, economic, engineering or legal constraints, it was eliminated or modified.

It is well known that the groundwater and marine surface waters of the Bi-county Region were strongly interdependent, as far as quality and quantity were concerned, but that waste management alternatives could conveniently be defined in terms of protecting one or the other. This led to the division of the bi-county land area into a number of hydrogeologic zones distinguished by differences in groundwater flow regime and degree of development. Furthermore, the marine surface waters were divisible into segments having different physical characteristics, tidal flushing patterns, freshwater inputs, and so forth. Waste management alternatives tailored to their specific conditions and requirements were then postulated for each zone and segment.

Water quality problems in Nassau-Suffolk are generally a function of the density of residential development and of the nature of some of the industrial activity. Generally, ground and surface waters are or have been most severely impacted in those areas occupied by the greatest number of persons. Some of these areas are now sewered and groundwater quality appears to be improving.

Long Island's continued ability to meet the regional demand for potable water and for water-based recreation opportunities and commercial fisheries will depend to a great extent on the measures taken to prevent further degradation or to improve the quality of the aquifers, streams and bays.

Inasmuch as the management of domestic and industrial wastes is a primary concern, most of the recommendations for the construction of sewers, or the installation of monitoring wells, are related to existing or proposed residential densities, and to industrial areas.

However, sources of pollution other than sewage must also be controlled in order to achieve and maintain improved water quality. Sources such as stormwater runoff, fertilizers, animal wastes and landfills contribute to the overall problem, and steps must must be taken to mitigate their effects. Since these and other non-point pollution sources are not specific to any locality, measures for mitigation are identified as "Areawide Recommendations."

In 5.1, the Areawide Recommendations are presented, under eight main headings. Next, in 5.2, the array of alternatives for each of the hydrogeologic zones and surface water segments is briefly discussed. In order to provide guidance to present and future 201 Studies in the Region, the 208 Program has related the hydrogeological zone and surface water recommendations to detailed study areas. A map of the detailed study areas was overlaid on the zone and segment maps in order to identify those portions of the various zones and segments located within each study area. It was then possible to develop individual waste treatment management plans for the study areas, and these are presented in 5.3. Together, they constitute the areawide plan.

Finally, inter-jurisdictional matters are discussed in 5.4, and recommendations for future studies in 5.5.

5.1 Areawide Recommendations

The following recommendations should be regarded as applicable throughout the bi-county area wherever the pollutant problems addressed by the proposed measures or practices occur. The recommendations, which have been selected from the more extensive list presented in Section Three and in Section J of the Areawide Waste Treatment Management Plan, focus on key non-point problems: control of stormwater runoff, the functioning of on-lot disposal systems; the use of fertilizers; landfills; animal wastes; on-site industrial waste and chemical products handling, and water conservation.

For the most part, the proposed measures are non-structural in nature and call for the institution or continuation and expansion of Best Management Practices. Furthermore, certain measures require development and demonstration, in order to determine their efficacy. Measures requiring such further study, *e.g.,* marsh-pond treatment, on-lot subsurface denitrification systems, etc., are discussed in Section 6.5.2.

5.1.1 Control Stormwater Runoff. The 208 investigations have indicated that stormwater runoff is a major contributor of non-point pollution to Long Island's surface waters and groundwaters. Best Management Practices should be employed to reduce the volume and velocity of runoff and the consequent diminution of its erosive and transport capabilities. To the extent feasible, surface runoff should be intercepted and disposed of as close as possible to the source. Best Management Practices, including proper grading and the maintenance of vegetation, and/or structural systems should be employed to minimize the volume of runoff and the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters. Recharge basins may need to be modified, where feasible, to improve the removal of nutrients, metals and organic chemicals in stormwater runoff that contribute to groundwater contamination. Inasmuch as the practicality and cost-effectiveness of most of the techniques for the treatment of runoff have not yet been determined, the establishment and operation of several pilot projects is recommended. Further investigation and testing of street vacuuming and the use of natural or man-made detention systems, with marsh-pond treatment and/or disinfection, are proposed.

Land clearance and development tend to accelerate runoff and erosion when the protective vegetal cover of the land is removed. The use of Best Management Practices during clearance, building construction, and site restoration should be required in order to avoid increased runoff and sediment transport from the site.

5.1.2 Ensure the Proper Functioning of On-Lot Waste Disposal Systems.

a. *Provide for Routine Maintenance of On-Site Disposal Systems.* Provision should be made for routine pumping and maintenance of the on-lot systems in order to extend the service life of the leaching facility and to ensure its continued efficacy. Local or county government should be responsible for the provision of scavenger waste treatment and disposal facilities. The numbers and locations of such facilities should be determined at a 201 level of study.

County sponsored public education to encourage voluntary implementation is recommended. The promulgation of legislation mandating routine pumping and maintenance is not proposed at this time.

b. *Prohibit the Use of Certain Chemical Cleaners in On-Lot Systems.* If organic solvents and other chemical agents contain ingredients which might reasonably be expected to impair groundwater quality, their use for cleaning or extending the service life of on-lot sewage disposal systems should be prohibited or controlled. A program to identify such products is presently being conducted by Nassau County Health Department and Suffolk County Departments of Health Services and Environmental Control, and should be continued and emphasized. This should be coupled with specific county legislation banning the local sale of these products within Nassau and Suffolk Counties.

5.1.3 Reduce the Use of Fertilizers. Since fertilizers are one of the largest sources of nitrogen applied to the land surface, they constitute a significant potential source of ground and surface water impairment. Pending further study to better define fertilizer impact on water quality, public education should, and regulation may, be employed to limit, or possibly eliminate, the use of all or specific types of fertilizers. Best Management Practices, some of which may also pertain to agriculture, include modification of application rates, discontinuance of reliance on fast-acting inorganic fertilizers, and promotion of low-maintenance lawns, which would require both less fertilizer and less consumptive use of water.

5.1.4 Minimize Pollution from Landfills.

a. *Reduce Reliance on Landfilling.* Landfills are not a viable long-term solution to Long Island's solid waste disposal problems. Resource recovery systems, at the regional or sub-regional level, are recommended. Feasible methods should be evaluated for local cost-effectiveness and ability to avoid groundwater impairment. Methods for the co-disposal of sewage sludge and solid waste should also be considered. The continued burial of wastes in landfills, with the exception of non-putrescible or non-polluting matter, should be minimized or discontinued, especially in hydrogeological zones that are particularly sensitive. It should be noted however that if land is unavailable in the less sensitive zones and safeguards can be assured that will effectively control the production of leachate and the impairment of the groundwater, landfills may be considered for the more sensitive zones.

b. *Improve Existing Landfills.* Existing and completed landfills should be upgraded in order to effectively control infiltration and direct runoff to surface waters. Methods used should include top covering with impermeable barriers, positive grading with erosion control, and other stormwater diversion systems.

5.1.5 Reduce and Control Animal Waste. In order to minimize the ad-

verse effects of animal wastes on surface waters, a number of Best Management Practices are recommended. These are the following:

1. Repeal dog curbing ordinances, and promote dog waste clean-up ordinances. Also, encourage dog population control.
2. Closely regulate the stabling of horses and other large domestic animals in residential areas. Their numbers should be limited, and the methods of storing and handling of their wastes should be strictly controlled.
3. Prohibit the sale of White Pekin ducks as pets. This practice has resulted in interbreeding with wild species, and the establishment of a semi-wild duck population on inland lakes and ponds. It is necessary that this population be gradually eliminated.

5.1.6 Strengthen and Enforce Regulations Pertaining to Industrial Wastes, Product Storage and Transportation, and Residuals.

a. *Expand Regulations and Enforcement Regarding the Disposal of Industrial Wastes.* Where industrial wastes are discharged to municipal sewer systems, strict enforcement of sewer use ordinances should be insured. Suffolk County is revising its sewer use ordinance to conform to applicable State and Federal guidelines. This revision will be implemented by October, 1978; Nassau County has already adopted such an ordinance. These County ordinances should be the model for all other municipalities or sewer districts within each respective county, and as such should be adopted by each of these entities. Each municipality or sewer district should be responsible for the enforcement of the ordinances and should maintain an adequate staff for such enforcement.

Present regulations covering the discharge of industrial wastes to the ground should be expanded to include greater coverage of specific contaminants and to prescribe allowable discharge levels. This applies primarily to organic chemicals and heavy metals.

b. *Regulate the Storage and Transportation of Chemical Products.* Permits and other controls should be required for the storage and transportation of chemical products that pose a threat to either the groundwater or surface water. The regulations should cover prescribed practices, safety requirements, inspection of equipment and contingency plans for interim storage and clean-up. The county agencies should be responsible for enforcing the permit regulations and control measures; the individual operator should be responsible for maintaining records and monitoring. In addition to industrial chemicals, these products include chemical wastes and sludges, de-icing salts and petroleum products. Salt storage facilities should be designed to prevent leachate contamination of groundwater.

Particular emphasis should be placed on the regulation of gasoline storage facilities at automobile service stations and, to a lesser degree, home heating oil storage tanks. Criteria should be developed and enforced to ensure the integrity of all storage facilities. The 208 Study has recognized these two types of facilities as major potential pollutant sources, but has not been able to define the precise magnitude of the problem.

c. *Provide for the Treatment of Hazardous Wastes.* The industries in the Nassau-Suffolk Region and the wastewater treatment processes they employ generate two kinds of hazardous wastes: small volumes of strong, toxic industrial wastes and industrial waste treatment sludges.

In view of the environmental sensitivity of the study area, continued disposal of these types of hazardous wastes outside of the area should be encouraged. However, if this disposal option is not available in the future, treatment facilities or landfills for the disposal of hazardous wastes will have to be provided in the bi-county area. The 208 recommendation is for a regional hazardous waste treatment facility for both counties. If a single facility cannot be implemented, individual county facilities are then recommended.

Treatment facilities should, wherever possible, be located at a sewage treatment plant with an ocean outfall. The effluent from the hazardous waste treatment facility should be disposed of to the outfall, not to the plant influent. The outfall disposal will provide a temporary discharge in the event of a hazardous waste facility upset.

If a hazardous waste treatment facility cannot be located at a sewage treatment plant with an ocean outfall, it can be located somewhere in the area served by the plant, and can discharge *treated* effluent to the sewer system. Effluent monitoring must then be intensive so that in the event of a plant or process upset, a slug of toxic waste can be prevented from reaching the downstream treatment plant.

If a hazardous waste treatment plant is not connected to a treatment plant ocean outfall, and is located in the deep-flow aquifer recharge area, special provisions must be made to contain any waste spillage. The wastes must not be allowed to percolate into the ground. Consequently, impermeable retention lagoons must be provided, large enough to take the entire plant inventory, in the event of a radical plant failure.

The hazardous waste treatment facilities should provide treatment for both organic and inorganic wastes where feasible. Radioactive wastes should not be handled at the facilities.

5.1.7 Promote Water Conservation. Water conservation is a matter of importance on Long Island for several reasons. First, a reduction in the amount of water use would help reduce the degree of water level declines in the bi-county area. This might also reduce losses in streamflow and underflow to the bays in some areas. Furthermore, in certain cases, lower pumpage from high yield public supply wells as a result of water conservation may help to minimize alteration of natural-flow systems and subsequent migration of contaminants to the deeper aquifer. Moreover, using less water would achieve savings in energy required to pump and heat it. It would also reduce flow to individual disposal systems, which could reduce failures. Finally, in areas requiring sewers, lower water use might permit the development of smaller sewage treatment facilities. Concerted public information programs, and the promotion of flow-reduction devices, can aid in reducing wastage. Recreational, residential and institutional lawn irrigation should be minimized by

the modification of automatic, clock-operated systems to systems that sense the moisture content in the root zone. Public education programs should discourage the use of water-intensive Bluegrass lawns and should encourage the planting of Fescue grasses, which require less water.

Agricultural irrigation water management boards should be organized in the Towns of Brookhaven, Riverhead and Southold. These boards should examine agricultural, residential and recreational irrigation water demands and uses, and should develop water priorities during periods of drought and for areas with saltwater intrusion problems. Irrigation water management plans identifying crop needs and the soil/water holding capacity should be prepared for agricultural operations and lawn areas exceeding five acres. Trickle irrigation and efficient sprinkler irrigation should be encouraged.

5.1.8 Provide Alternatives to Ocean Disposal of Municipal Treatment Plant Sludge. The major municipal treatment plant sludge processing and disposal approaches that appear viable in the Nassau-Suffolk Region include composting, landfilling, land application, incineration, co-incineration with solid waste, pyrolysis and thermal drying. (These approaches also apply to the sludge from scavenger waste treatment plants.) It has been found that any of the conventional approaches can be implemented in the Nassau-Suffolk area without significant environmental degradation if normal safeguards are taken. Final sludge disposal options should be selected after 201 level detail studies have been conducted, since the final decision should be based upon cost-effectiveness and environmental impact. The 208 study has determined that the conventional approaches are regionally acceptable.

Land based sludge disposal options (land application, composting) must be accompanied by monitoring or other control programs to insure against contamination of groundwater with heavy metals, inorganic and organic chemicals, and pathogens. This is particularly important in hydrogeologic zones I, II and III. Land-based disposal options will require strict enforcement of industrial pre-treatment requirements to minimize the amount of toxic materials in municipal treatment plant sludges.

5.2 Recommendations by Hydrogeologic Zone and Surface Water Element

5.2.1 General. Section 5.2 contains a summary table (Table 5—1) indicating the preferred alternatives for each of the eight hydrogeologic zones and the eleven bays described in Sections 3.2 and 3.5, together with brief discussions of recommended groundwater monitoring, the maintenance of groundwater levels, the siting, construction and management of landfills, and the expansion of public water supply systems.

The preferred alternatives for the hydrogeologic zones and surface water elements address public health objectives. The alternatives selected for the hydrogeologic zones characterized by a deep flow system are expected to minimize contaminant concentrations in the primary water supply aquifer, the Magothy, and in the deep Glacial aquifer in northwestern Nassau; those selected for the zones characterized by a shallow flow system are expected to protect the as yet uncontaminated portions of the Glacial aquifer and permit the restoration of previously degraded sectors. The alternatives selected for the surface water elements are expected to minimize coliform levels and maintain dissolved oxygen levels in recreational and shellfish waters.

The pollutants of greatest concern are nutrients, organic chemicals, heavy metals, coliform bacteria and viruses. Nitrogen was selected as the key pollutant for the purpose of developing and selecting alternative waste management options. It is found in most of the important pollutant sources, such as domestic sewage and fertilizers; is analyzed for routinely in all water samples (both potable and waste); and has been identified everywhere in the surface and groundwaters of the Bi-county Region. The selection of nitrogen as a key parameter does not diminish the need for the monitoring of other contaminants, nor does it preclude the possible need for additional treatment measures. A discussion of nitrogen as the key pollutant is to be found in Section 3.2.

The preferred alternatives also address natural resource objectives. These include the maintenance of adequate groundwater levels in order to preclude abnormal changes in stream levels that could affect critical environments or endanger coastal ecosystems, and to assure a sufficient potable water supply. They also include the maintenance of nutrient levels that will minimize eutrophication, and will assure conformance with dissolved oxygen standards and waste load allocations.

Collection and treatment as used in Table 5—1 refers to a variety of possible communal collection systems such as gravity lines, pressure or vacuum. The method of treatment may employ conventional secondary/tertiary, marsh-pond, spray irrigation or other method. This does not preclude the use of innovative on-site treatment systems (*e.g.,* with denitrification capability) in areas, which are candidates for sewering, as such systems are proven to be cost-effective. Note that items listed in Table 5—1 as "Non-Structural Recommendations" may, in part, have structural components. Note also that the order of presentation of recommendations in Table 5—1 does not imply any ranking or prioritization.

5.2.2 Recommended Monitoring of Groundwater Quality. In any area that depends exclusively on groundwater for its potable supply, the wastewater management alternative or alternatives should be accompanied by an extensive program of ambient water quality monitoring. The program described below can provide timely notice of existing and developing problems and of the effectiveness of various countermeasures.

This is a particularly attractive and necessary approach for assessing the effects of diffuse sources of contamination, such as on-lot sewage disposal systems, fertilizers, and stormwater, which cannot be easily monitored using a discharge permit type approach. The present monitoring of ambient shallow groundwater quality in both the unsewered and sewered areas depends on an insufficient number of widely spaced wells. Some wells are shallow, but many are deep (greater than 50 feet below the water table). In general, these deeper

Table 5–1

NASSAU-SUFFOLK 208 STUDY WASTE MANAGEMENT RECOMMENDATIONS BY HYDROGEOLOGIC ZONE AND SURFACE WATER ELEMENT

Hydrogeologic Zone/ Characteristics	Location	Structural Recommendations	Non-Structural Recommendations (Can have structural elements)
Zone I Deep aquifer recharge area. This zone is a primary source of public water supply.	Central and northern Nassau and portions of western Suffolk.	1. In developed areas not presently sewered or scheduled for sewering, plans for collection and treatment where the current density is nine or more persons (three dwelling units) per gross acre should be initiated. 2. At densities less than nine persons (three dwelling units) per gross acre, institute a monitoring program to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where area-average nitrate-nitrogen levels are six milligrams per liter or greater or other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, provide collection and treatment. 3. As currently vacant land is developed, provide collection and treatment at a density of approximately 6 persons or two dwelling units per gross acre. 4. Divert the sewage flow from the C. W. Post College to the Cedar Creek STP or recharge to groundwater following advanced wastewater treatment, with nitrogen removal. 5. The 208 Study has not identified a need, within the twenty year planning period, for groundwater recharge in this area for the purpose of preserving drinking water supply. However, the importance of maintaining the flow and water quality of streams may require action to mitigate the impact of reduced groundwater levels attributable to sewering with marine discharge. 6. In areas that are completely sewered, regulations mandating the hook-up of private disposal systems to district collection systems should be strictly enforced.	1. Minimize population density by encouraging large lot development (one dwelling unit/ one or more acres), where possible, to protect the groundwater from future pollutant loadings. 2. Prohibit the establishment of new landfills, and the expansion of existing ones. Upgrade existing landfills, where possible, to minimize further groundwater contamination. 3. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface and groundwaters. 4. Provide for routine maintenance of on-site disposal systems. 5. Reduce the use of fertilizers on turf. Promote the use of low-maintenance lawns. 6. Strengthen and enforce regulations pertaining to industrial waste disposal, product storage and transportation of residuals. 7. Prohibit the use of certain chemical cleaners in on-lot systems.
Zone II Deep aquifer recharge area. An area of existing water quality problems.	East central Nassau	1. This area is, or will be, essentially completely sewered. Present plans generally conform to recommended 208 guidelines.	1. Prohibit the establishment of new landfills, and the expansion of existing ones. Upgrade existing landfills, where possible, to minimize further groundwater contamination. 2. Reduce the use of fertilizers on turf. Promote the use of low-maintenance lawns. 3. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals, and bacteria to surface and ground waters. 4. Strengthen and enforce regulations pertaining to industrial waste disposal, product storage and transportation of residuals.

Table 5—1 . . . Cont'd.

Hydrogeologic Zone/ Characteristics	Location	Structural Recommendations	Non-Structural Recommendations (Can have structural elements)
Zone III Deep aquifer recharge area. Exceptionally high water quality and high potential yields.	East central Suffolk	1. Require collection and treatment at densities of one or more dwelling units per acre in those areas where large lot development and the preservation of existing large land holdings are infeasible due to existing or planned development. 2. Require advanced wastewater treatment with nitrogen removal for treatment plants recharging effluent to ground or surface waters.	1. Land use controls should be the primary method for protecting this valuable groundwater resource. Where residential development is allowed, require large lot development (two acre zoning or greater). Encourage the preservation of existing large land holdings, and natural vegetation. 2. Establish a groundwater monitoring program to provide early indication of water quality problems and to permit timely institution of corrective measures. 3. Prohibit the establishment of new landfills, and the expansion of existing ones. Upgrade existing landfills, where possible, to minimize further groundwater contamination. 4. Provide for routine maintenance of on-site disposal systems. 5. Reduce the use of fertilizers on turf. Promote the use of low-maintenance lawns. 6. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface and ground waters. 7. Strengthen and enforce regulations pertaining to industrial waste disposal, product storage and transportation of residuals. 8. Prohibit the use of certain chemical cleaners in on-lot systems.
Zone IV Local water quality problems, but potential for groundwater development, particularly on the South Fork; significant agricultural input.	North Fork and eastern part of South Fork	1. In developed areas not presently sewered, plans for collection and treatment should be initiated where the current density is nine or more persons (three dwelling units) per gross acre. 2. At densities less than nine persons (three dwelling units) per gross acre, institute a monitoring program to determine the quality of the water-table aquifer and the efficacy of the non-point source controls. Where area-average nitrate-nitrogen levels are six milligrams per liter or greater or other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, provide collection and treatment. 3. Provide collection and treatment in those areas where on-lot systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other conditions.	1. Minimize population density by encouraging large lot development (one dwelling unit per one or more acres) where possible, to protect the groundwater and surface waters from future pollutant loadings, and to provide additional protection for existing marsh and wetland areas. 2. Control the establishment of new landfills, and the expansion of existing ones. Upgrade existing landfills, where possible, to minimize further groundwater contamination. In cases of extreme hardship, new landfills may be permitted if extra-ordinary measures are taken to protect surface and ground water. 3. Reduce excessive use of irrigation water, to minimize saltwater intrusion.

Table 5–1 . . . Cont'd.

Hydrogeologic Zone/ Characteristics	Location	Structural Recommendations	Non-Structural Recommendations (Can have structural elements)
Zone IV cont'd.		4. Provide collection and treatment in those areas where contaminated underflow may reasonably be expected to contribute pollutants to the surface waters and to result in a contravention of the standards. 5. As currently vacant land is developed, provide collection and treatment at the present Suffolk County Department of Health Services approved density of approximately two dwelling units per acre (greater than 20,000 square foot lot size).	4. Optimize pumping patterns, to minimize saltwater upconing. 5. Optimize the timing of fertilizer application, to reduce nitrate contamination from agriculture. 6. Prohibit the use of certain chemical cleaners in on-lot systems. 7. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface and ground waters. 8. Provide for routine maintenance of on-site disposal systems.
Zone V Local water quality problems, but potential for groundwater development; little agricultural input.	Western South Fork	1. In developed areas not presently sewered, plans for collection and treatment should be initiated where the current density is nine or more persons (three dwelling units) per gross acre. 2. At densities less than nine persons (three dwelling units) per gross acre, institute a monitoring program to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where area-average nitrate-nitrogen levels are six milligrams per liter or greater or other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, provide collection and treatment. 3. Provide collection and treatment in those areas where on-lot systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other conditions. 4. As currently vacant land is developed, provide collection and treatment at the present Suffolk County Department of Health Services approved density of greater than approximately two dwelling units per acre (less than 20,000 square foot lot size). 5. Provide collection and treatment in those areas where contaminated underflow may reasonably be expected to contribute pollutants to the surface waters and to result in a contravention of the standards.	1. Minimize population density by encouraging large lot development (one dwelling unit per one or more acres) where possible, to protect the groundwater and surface waters from future pollutant loadings, and to provide additional protection for existing marsh and wetland areas. 2. Control the establishment of new landfills, and the expansion of existing ones. Upgrade existing landfills, where possible, to minimize further groundwater contamination. In cases of extreme hardship, new landfills may be permitted if extraordinary measures are taken to protect surface and ground water. 3. Optimize pumping patterns to minimize saltwater upconing. 4. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface and ground waters. 5. Prohibit the use of certain chemical cleaners in on-lot systems. 6. Reduce the use of fertilizers on turf. Promote the use of low-maintenance lawns.
Zone VI Generally shallow groundwater levels, with horizontal flow, which has impact on surface water.	South central Suffolk	1. Due to the impact of groundwater underflow and stream flow in this area on the sensitive eastern Great South Bay, collection and treatment is required at densities of one or more dwelling units per acre. 2. Require advanced wastewater treatment with nitrogen removal for treatment plants recharging effluent to ground or surface waters.	1. Minimize population density by encouraging large lot development (one dwelling unit per two or more acres) where possible, to protect the groundwater and surface water from future pollutant loadings, and to provide additional protection for existing marsh and wetland areas.

Table 5–1 . . . Cont'd.

Hydrogeologic Zone/ Characteristics	Location	Structural Recommendations	Non-Structural Recommendations (Can have structural elements)
Zone VI cont'd.		3. Provide collection and treatment in those areas where contaminated groundwater may reasonably be expected to contribute pollutants to the surface waters and to result in a contravention of the standards. 4. Provide collection and treatment in those areas where on-lot sewage systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other considerations.	2. New landfills should be permitted under current New York State policy, provided the site is landward of the primary coastal zone and the depth to groundwater is sufficient to ensure an adequate unsaturated zone below the bottom of the landfill. (The primary coastal zone extends landward for 1,000 feet or to the ten foot elevation, whichever includes the greater distance from the shoreline or from any stream flowing into marine waters.) 3. Stress the future implementation of storm-water runoff controls, if proven feasible, in order to assist in upgrading surface water quality to increase open shellfishing areas. 4. Provide for routine maintenance of on-site disposal systems. 5. Reduce the use of fertilizers on turf. Promote the use of low-maintenance lawns. 6. Control animal populations and animal waste disposal. 7. Prohibit, or severely restrict, all further development in shoreline areas. Establish adequate buffer zones around wetlands. Assign priority to public acquisition, based on the protection of groundwater quality and natural resources. 8. Prohibit the use of certain chemical cleaners in on-lot systems.
Zone VII Generally shallow horizontal groundwater flows.	Southern Nassau and southwestern Suffolk.	1. This area is, or will be, essentially completely sewered. Present plans generally conform to recommended 208 guidelines. 2. In developed areas not presently sewered or scheduled for sewering, plans for collection and treatment where the current density is nine or more persons (three dwelling units) per gross acre should be initiated. 3. Provide collection and treatment in those areas where on-lot systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other conditions. 4. Provide collection and treatment in those areas where contaminated groundwater may reasonably be expected to contribute pollutants to the surface waters and to result in a contravention of the standards.	1. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface and ground waters. 2. New landfills should be permitted under current New York State policy, provided the site is landward of the primary coastal zone and the depth to groundwater is sufficient to ensure an adequate unsaturated zone below the bottom of the landfill. (The primary coastal zone extends landward for 1,000 feet or to the ten foot elevation, whichever includes the greater distance from the shoreline or from any stream flowing into marine waters.)

Table 5–1 . . . Cont'd.

Hydrogeologic Zone/ Characteristics	Location	Structural Recommendations	Non-Structural Recommendations (Can have structural elements)
Zone VII cont'd.		5. The 208 Study has not identified a need, within the twenty year planning period, for groundwater recharge in this area for the purpose of preserving drinking water supply. However, the importance of maintaining the flow and water quality of streams may require action to mitigate the impact of reduced groundwater levels attributable to sewering, with marine surface water discharges.	3. Reduce the use of fertilizers on turf. Promote the use of low-maintenance lawns.
Zone VIII Generally shallow horizontal groundwater flows.	Most of the area bordering Long Island Sound, from Hempstead Harbor to Wading River.	1. Provide collection and treatment in those areas where on-lot sewage systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other considerations. 2. Provide collection and treatment in those areas where contaminated groundwater may reasonably be expected to contribute pollutants to the surface waters and to result in a contravention of the standards.	1. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals, and bacteria to surface and ground water. 2. New landfills should be permitted under current New York State policy, provided the site is landward of the primary coastal zone and the depth to groundwater is sufficient to ensure an adequate unsaturated zone below the bottom of the landfill. (See Zone VII.) 3. Provide for routine maintenance of on-site disposal systems.

Surface Water Elements/ Characteristics	Location	Structural Recommendations	Non-Structural Recommendations (Can have structural elements)
A. Manhasset Bay Important recreational harbor. (Dominated by the influence of Western Long Island Sound, which has been impaired by New York City discharges.)	Northwestern Nassau	1. Based upon preliminary economic and environmental analyses, the diversion of sewage flows from GNSD, Village of Great Neck, and Port Washington, to the Cedar Creek treatment facility is the recommended alternative. 2. If the cost of flow diversion significantly outweighs environmental benefits, the next preferred option would be to consolidate the existing treatment plants into a sub-regional facility. 3. If (1) and (2) above are not feasible, and the present configuration remains as is, then the individual facilities will require either nitrogen removal if the present discharge location is retained, or a mid-bay discharge, if the present level of treatment is maintained. Of these two options, a mid-bay outfall is recommended due to improved dispersion characteristics of the receiving waters, and reduced costs.	1. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters. 2. Enforce existing regulations concerning waste discharge from boats. The towns and/ or counties should provide pumpout stations at all facilities owned and/or operated by them. In addition, "no-discharge" zones should be designated in all areas open to shellfishing and contiguous to bathing beaches. 3. Control animal population and animal waste disposal.

Table 5—1 . . . Cont'd.

Surface Water Elements/ Characteristics	Location	Structural Recommendations	Non-Structural Recommendations (Can have structural elements)
B. Hempstead Harbor Major commercial harbor, with considerable recreation. (Dominated by the influence of Western Long Island Sound, which has been impaired by New York City discharges.)	Northern Nassau	1. Based upon preliminary economic and environmental analyses, the diversion of sewage flows from Roslyn Sewage Treatment Plant to the Cedar Creek treatment facility is the recommended alternative. The Glen Cove treatment plant is excluded from this alternative because it is being reconstructed and upgraded. 2. If the cost of flow diversion significantly outweighs environmental benefits, the next preferred option would be to consolidate the existing plants into a sub-regional facility in the recommended Northwest study area. 3. If (1) and (2) above are not feasible, and the present configuration remains as is, then the individual facilities will require either nitrogen removal if the present discharge location is retained, or a mid-bay discharge, if the present level of treatment is maintained. Of these two options, a mid-harbor outfall is recommended due to improved dispersion characteristics of the receiving waters, and reduced costs.	1. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters. 2. Encourage the relocation of the solid waste handling and landfilling operations in, and adjacent to the Port Washington Sand Pits, to a site outside the coastal zone, at such time as a feasible alternative is available. 3. Control animal populations and animal waste disposal.
C. Oyster Bay Recreational harbor, and important commercial shellfishing area.	Northeastern Nassau	1. Based upon preliminary economic and environmental analyses, the diversion of sewage flows from the Oyster Bay Treatment Plant to the Cedar Creek treatment facility is the recommended alternative. 2. If it is determined that Bayville should be served by its own sewage treatment facility, then final effluent disposal should be to Long Island Sound. 3. If the cost of flow diversion significantly outweighs environmental benefits, the next preferred option would be to consolidate the existing treatment plants into a sub-regional facility in the Northeast study area. 4. Based upon water quality analysis, the Oyster Bay plant, may retain its present treatment level and discharge location without significantly impairing the receiving waters; however, this does not preclude the possibility of diversion to either the Cedar Creek treatment plant or to a sub-regional facility.	1. Due to the valuable shellfishing industry, the extensive wetlands and the excellent water quality in Oyster Bay, non-point source controls to alleviate impact on surface waters should be emphasized. 2. Prohibit, or severely restrict, all further development in shoreline areas. Establish adequate buffer zones around wetlands. Assign priority to public acquisition, based on the protection of groundwater quality and natural resources. 3. Enforce existing regulations concerning waste discharge from boats. The towns and/or counties should provide pumpout stations at all facilities owned and/or operated by them. In addition, "no-discharge" zones should be disignated in all areas open to shellfishing; and contiguous to bathing beaches. 4. Control animal populations and animal waste disposal.
D. Huntington Bay Complex bay system, includes natural, as well as highly developed shorefronts.	Northwestern Suffolk	1. On the basis of preliminary environmental analysis and projected flow, it is recommended that if the Huntington Sewage Treatment Plant is utilized as either a regional or sub-regional facility, secondary treatment with mid-bay effluent discharge appears preferable to AWT and effluent discharge at the present location in Huntington Harbor.	1. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals, and bacteria to surface waters.

Table 5—1 . . . Cont'd.

Surface Water Elements/ Characteristics	Location	Structural Recommendations	Non-Structural Recommendations (Can have structural elements)
D. Huntington Bay cont'd.		2. If the sub-regional alternative is selected, utilize the Huntington and Northport Village STPs.	2. Enforce existing regulations concerning waste discharge from boats. The towns and/or counties should provide pumpout stations at all facilities owned and/or operated by them. In addition, "no-discharge" zones should be designated in all areas open to shellfishing and contiguous to bathing beaches. 3. Control animal populations and animal waste disposal.
E. Port Jefferson Harbor Major industrial, commercial and recreational harbor. Ferry terminal.	Central Suffolk, North Shore	1. There is a 201 study currently underway in this area and the 208 has not selected a recommended alternative for sewage treatment and disposal. It is required that the 201 study select the number and location of facilities by evaluating combinations of existing facilities and other suitable sites. 2. Surface water discharge shall not exceed the waste load allocations established by the 208 study.	1. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters. 2. Enforce existing regulations concerning waste discharge from boats. The towns and/or counties should provide pumpout stations at all facilities owned and/or operated by them. In addition, "no-discharge" zones should be designated in all areas open to shellfishing and contiguous to bathing beaches. 3. Control animal populations and animal waste disposal.
F. Flanders Bay—Peconic Estuary Drains agricultural and natural areas. Hamlet of Riverhead located on the Estuary.	Riverhead—Brookhaven—Southampton Towns	1. Move the Riverhead STP discharge to a location outside the Estuary. 2. The 201 study currently underway should evaluate the regional, sub-regional and small plants alternatives discussed in Section 3.5. Provide for further monitoring, specifically for dissolved oxygen nutrients and chlorophyll a to better define and select one of the point source control alternatives. 3. Require that duck farms' treatment facilities conform to compliance schedules which will call for zero discharge by 1983. 4. No additional loading should be allowed from the Brookhaven National Laboratory Sewage Treatment Plant or from the Grumman Sewage Treatment Plant.	1. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters. 2. Prohibit, or severely restrict, all further development in shoreline areas. Establish adequate buffer zones around wetlands. Assign priority to public acquisition, based on the protection of groundwater quality and natural resources. 3. Determine the impact of duck sludges as a source of nutrients and bacteria, and the feasibility of their removal. 4. Enforce existing regulations concerning waste discharge from boats. The towns and/or counties should provide pumpout stations at all facilities owned and/or operated by them. In addition, "no-discharge" zones should be designated in all areas open to shellfishing and contiguous to bathing beaches.

Table 5—1 . . . Cont'd.

Surface Water Elements/ Characteristics	Location	Structural Recommendations	Non-Structural Recommendations (Can have structural elements)
G. Mecox Bay Small bay, with ephemeral connection to the Atlantic Ocean.	Atlantic shore, Town of Southampton	1. Prohibit new point source discharge to the bay. 2. Provide nitrogen removal, or complete effluent recycling, for duck farm discharges located in the drainage area.	1. Prohibit, or severely restrict, all further development in shoreline areas. Establish adequate buffer zones around wetlands. Assign priority to public acquisition, based on the protection of groundwater quality and natural resources. 2. Reduce the use of fertilizers on turf. Promote the use of low-maintenance lawns. 3. Determine the impact of duck sludges as a source of nutrients and bacteria and the feasibility of their removal. 4. Determine the desirability of stabilizing the inlet from the Atlantic Ocean to provide adequate flushing and dispersion.
H. Shinnecock Bay Shallow bar-built estuary, important commercial and sport fishing facilities.	Between Shinnecock Inlet and Shinnecock Canal, Town of Southampton.	1. Prohibit new point source discharges to the bay. 2. Maintain the ocean inlet to provide adequate flushing and dispersion.	1. Prohibit, or severely restrict, all further development in shoreline areas. Establish adequate buffer zones around wetlands. Assign priority to public acquisition, based on the protection of groundwater quality and natural resources. 2. Provide for the routine maintenance of on-site disposal systems. 3. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters. 4. Enforce existing regulations concerning waste discharge from boats. The towns and/or counties should provide pumpout stations at all facilities owned and/or operated by them. In addition, "no-discharge" zones should be designated in all areas open to shellfishing and contiguous to bathing beaches.
I. Moriches Bay Shallow bar-built estuary, with unstable ocean inlet. Extremely sensitive to groundwater inflow quality.	South shore, between Shinnecock ahd Great South Bays.	1. Prohibit new point source discharges to the bay. 2. Provide nitrogen or complete effluent removal from duck farms located in the drainage area. 3. Maintain the ocean inlet to provide adequate flushing and dispersion. 4. Determine the impact of duck sludge on bay water quality.	1. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters. 2. Determine the impact of duck sludges as a source of nutrients and bacteria and the feasibility of their removal.

Table 5–1 . . . Cont'd.

Surface Water Elements/ Characteristics	Location	Structural Recommendations	Non-Structural Recommendations (Can have structural elements)
I. Moriches Bay cont'd.		5. If duck sludge is *not* the controlling influence on bay water quality, and if the maintenance of the ocean inlet does *not* provide the desired improvement, then collect and treat at one or more D.U./acre in presently developed areas. 6. In order to maintain groundwater nitrogen at or below 2 milligrams per liter, collection and treatment should be provided when densities reach 1 or more D.U./gross acre.	3. Control animal populations and animal waste disposal. 4. Enforce existing regulations concerning waste discharge from boats. The towns and/or counties should provide pumpout stations at all facilities owned and/or operated by them. In addition, "no-discharge" zones should be designated in all areas open to shellfishing and contiguous to bathing beaches.
J. Great South Bay Shallow bay, western portion generally well flushed, eastern portion poorly flushed. Major commercial shellfishing area.	Between the Barrier Beach and the Towns of Babylon, Islip and Brookhaven.	1. Prohibit new point source discharges into Eastern Great South Bay and recharge tertiary treated effluent. 2. Provide nitrogen removal for the Patchogue Sewage Treatment Plant.	1. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters. 2. Control animal populations and animal waste disposal. 3. Reduce the use of fertilizers on turf. Promote the use of low-maintenance lawns. 4. Require nitrogen removal for treatment plants recharging effluent. 5. Prohibit any new development along streams and shorelines. Create buffer zones where possible along all water bodies and protect all remaining marine wetlands. 6. Enforce existing regulations concerning waste discharge from boats. The towns and/or counties should provide pumpout stations at all facilities owned and/or operated by them. In addition, "no-discharge" zones should be designated in all areas open to shellfishing and contiguous to bathing beaches.
K. Western South Shore Bays Relatively well-flushed but sensitive to high pollutant loads.	Between the Barrier Beach and the Towns of Hempstead and Oyster Bay.	1. Locate the Bay Park sewage plant outfall offshore. 2. Divert the Long Beach sewage treatment plant effluent to the proposed Bay Park ocean outfall. 3. Initiate a study to determine whether the Lawrence treatment facility discharge violates water quality standards in Bannister Creek. If so, the discharge options should be as follows: a. Institute AWT with effluent discharge at the present location. b. Continue present treatment with effluent discharge to Reynolds Channel, and c. Divert sewage to the Bay Park treatment facility. 4. Terminate the operation of the Freeport treatment plant and divert the flow to the Cedar Creek facility by December 31, 1979, as presently scheduled.	1. Control stormwater runoff to minimize the transport of sediments, nutrients, metals, organic chemicals and bacteria to surface waters. 2. Institute legislation to control animal populations and animal waste disposal. 3. Enforce existing regulations concerning waste discharge from boats. The towns and/or counties should provide pumpout stations at all facilities owned and/or operated by them. In addition, "no-discharge" zones should be designated in all areas open to shellfishing and contiguous to bathing beaches.

wells are not designed to answer specific types of wastewater management questions.

Present wastewater management decisions concerning non-point sources are based primarily on population density. This is a very easy criterion to use because the distribution of population is readily ascertainable. However, the problem of trying to predict concentrations of various chemicals in groundwater on the basis of present population densities or land uses is a multi-variate one that is not easily solved in a region of varied, changing land use. The application of lawn fertilizer, for instance, is a major source of nitrogen and may be related not only to population density but to other factors such as homeowner income in a particular neighborhood. Predictions of the concentrations of constituents other than nitrate on the basis of population density is even more tenuous because of a general lack of data, particularly for organic chemicals. For instance, the input of organic chemicals may be partially related to certain types of industrial discharges, the use of organic solvents in cesspools, or to the traffic volume in a given area. In fact, because of the complexity of sources over space and time, and because of differences in the soil media, a strictly deterministic basis for wastewater management decisions may not be feasible. There must be some mechanism that allows for the actual monitoring of the groundwater system. Such a program may well result in the discovery of new water quality relationships or trends that were not previously anticipated.

One alternative is to install a number of shallow water table monitor wells throughout the two counties. These wells would provide data on any constituent desired, and permit the making of decisions on the basis of actual data, rather than on the basis of predicted or assumed values. Samples from wells screened in the upper ten feet of the saturated sediments will generally represent water that has recently percolated from the land surface. In addition, this water usually originates in the area immediately upgradient from the well and consequently reflects conditions in that area. Groundwater quality near the water table often represents a worst case situation, since, as the water travels further within the system, contaminants may be diluted and may be attenuated by adsorption on soil particles. For these reasons, adverse water quality conditions measured in these wells can be related to recent land use and/or wastewater disposal practices in the vicinity of the well, and appropriate abatement measures can be taken.

In its simplest form, a grid system would be established throughout the water management zone of interest. A coarse grid, with relatively large spacings between wells, would be established in those areas that appear to be least affected by human activities. Areas of dense residential development, agricultural use, or industrial development would be covered with a fine grid of relatively closely spaced wells. In planning this initial set of wells, sources of nitrate and organic chemicals should be given primary consideration. As water quality data is obtained from these wells it may become apparent that a particular area is receiving contaminants even though it may be located in a coarser section of the grid. This area would then be investigated and additional monitor wells would be drilled. In this way, new information gathered from the wells would be used to refine the monitoring system. As the program continues, the correlation between the presence of certain contaminants in groundwater and different types of land use or population density might become clear. Initially, the present knowledge of contaminant loading from various sources would be used in establishing the location and spacing of the wells. A model can be used to predict a mean concentration of nitrogen in soil water, below the root zone, for each of the land use grid cells used by the NSRPB. This information, along with water quality data from exising wells, would help determine the number of wells needed in any one area. Results of the monitoring could, in turn, help to refine the assumptions made in this model. Thus, two approaches, modeling and the collection of data indicating actual water quality conditions, could be used conjunctively to assess the groundwater quality on a continuing basis.

The number of wells in any particular land use area should be determined with statistical inference in mind. For example, there is usually considerable spatial variability of nitrate in contaminated groundwater, and therefore a sufficient number of samples and wells are necessary before significance can be established. Variation of nitrate in uncontaminated areas is low and fewer samples may be necessary to satisfy the monitoring objectives there. It is expected that many of the approximately 190 Suffolk County DEC and USGS wells, and perhaps a few Nassau County wells could be utilized in this program. Additional wells, perhaps between 50 and 100 wells per county, would be necessary to complete the new system. In addition to the installation of the wells, it will be necessary to carefully describe and catalog the land use in the vicinity, especially upgradient of each well. In this way, water quality data could be related back to these land uses.

Of equal importance to the design of the system is the continuing evaluation and review of the data. In addition to an assessment of existing conditions, shallow monitoring wells can be used to determine trends of a variety of constituents over time. This would be particularly important in areas of changing land use where trends would give an indication of effects of recent development. These wells could also be used to monitor the results of recent large scale sewering, such as that in Sewage Disposal District Three in Nassau, or to supplement the existing monitoring well system of the Southwest Sewer District in Suffolk.

5.2.3 Maintenance of Stream Base Flow and Surface Water Elevations. Fluctuations in groundwater levels (and potentiometric surfaces), stream base flow and surface water elevations have been observed over the past 40 years. These fluctuations result from natural dry/wet year precipitation cycles, and also from groundwater pumping and operation of non-recharging sewage collection systems.

The 208 Study has not identified a need for areawide groundwater recharge of wastewater treatment plant effluent for the purpose of maintaining

drinking water supply. On a regional basis, adequate quantity can be sustained over the entire planning period of twenty years by implementing recommended wastewater and water supply management practices. However, the maintenance of groundwater levels is important and should be addressed. The decline in water levels, which will occur by applying the 208 sewering criteria, and recharge limitations must be analyzed on an individual basis.

While a decline in groundwater level is generally not detrimental to water supply, it can significantly reduce stream base flow and surface waterbody elevations. These reductions can adversely impact water dependent vegetation and ecosystems. In eastern Great South Bay, the limited tidal exchange causes stream base flow to be extremely important in maintaining the bay salinity patterns. Other Long Island bays are not as sensitive to stream base flow or groundwater underflow.

In order to thoroughly ascertain the effects of proper maintenance of streamflow levels, it is recommended that streamflow augmentation studies be conducted by both Nassau and Suffolk Counties, as presently planned. The studies should continue to be comprehensive in nature and deal with the need for augmentation, beneficial impacts, available methods and cost-effectiveness.

It may be feasible to mitigate the effects of groundwater level decline on surface waters without maintaining present average groundwater levels. Information gained from the streamflow augmentation needs studies for the Nassau Sewage Disposal Districts Two and Three and the Suffolk County Southwest Sewer District should be incorporated into the 208 Plan when the studies are completed.

A major concern of the 208 is the potential contamination of the groundwater supply by organic chemicals and other pollutants in the event of system failure, poor operation or other, unforeseen occurrences. It is the recommendation of the 208 to carefully evaluate the results of the Cedar Creek recharge project in terms of process performance, reliability and effluent quality, and then decide if a decision on recharge safety can be reached. It is a further recommendation to continue the sampling and analytical program started under 208, of the impact on groundwater quality of effluent recharge from a secondary treatment plant. The program should be expanded in terms of the number and depth of sampling wells and frequency of sampling.

5.2.4 Recommendations for the Siting, Construction and Management of Landfills. Over the long term, the primary emphasis should be on resource recovery methods for the disposition of most residual wastes. Because of the inherent public health and environmental hazards, especially groundwater pollution, the continued burial of residual wastes in landfills can no longer serve as the Region's primary disposal method. However, some landfills will still be required for (1) the disposal of the relatively small amounts of inert residues remaining after the resource recovery process, (2) non-recoverable and non-putrescible wastes, such as concrete rubble and demolition wastes, and (3) the untreated solid wastes that are generated in rural or resort areas located too far from the resource recovery plants to justify shipment, and in quantities that are too small to warrant the establishment of a resource recovery facility. Various other methods, among them separation, leaf composting, electrical or steam generation, must be evaluated by local and regional agencies for applicability. Smaller political jurisdictions should combine to optimize cost-effectiveness.

The New York State Department of Environmental Conservation's regional policy based in part on the conclusions of the Oyster Bay—Plainview Landfill hearings strongly favors resource recovery for the Region and will require "a thorough examination of alternatives before approving new landfills on Long Island, particularly when they are to be located in areas where the groundwater situation is especially sensitive." (NYSDEC, 1977, Proceedings for the TOB Solid Waste Management Facility, Plainview, N.Y.)

The conclusion does not eliminate landfilling as a means of disposal in the Region, nor rule out the possibility that fail-safe leachate containment systems may be devised, which could allow for the future landfilling in all zones. In the interim, however, DEC's policy will (1) deter the development of large scale landfill sites, issuing only short term permits (three years or less); (2) strictly enforce the newly revised Rules and Regulations of Part 360; and (3) aggressively persuade refuse collecting jurisdictions to evaluate and implement, where justified, resource recovery alternatives.

In considering the following residual waste disposal recommendations for each of the hydrogeological zones, the reader should be aware that the zone boundaries as depicted in Figure 3–2 are merely approximations, and that further investigation is required before their precise location can be determined. It would, therefore, be prudent for any jurisdiction considering the siting of a new landfill to first carefully study the hydrogeology of the area to determine the applicable zone recommendations before proceeding further. Recommendations:

Zone I

1. Existing or abandoned landfills should be covered with impermeable barriers and properly graded to prevent stormwater infiltration, where feasible. Venting or methane recovery should also be considered to prevent lateral subsoil movement of decomposition gases, which will occur subsequent to capping.

2 a. New sanitary landfills, with the exception of landfills used for the disposal of inert wastes under proper management, should be prohibited. Likewise, any other solid waste treatment or disposal facility that might discharge process water to the ground, treated or untreated, should be discouraged from siting in this zone.

2 b. If, however, authorization for the establishment of the landfill was obtained prior to the adoption of the 208 plan, site preparation may proceed, provided that the leachate containment and monitoring systems (double liner—dual leachate collection piping) are designed to prevent all possible exfiltration of leachate and infiltration of stormwater. If leachate

is detected within the monitoring pipes, that area of the site must be immediately surface-sealed with an impermeable barrier, vented and discontinued.

2c. Leachates collected at new or existing sanitary landfills should be pretreated to conform with applicable sewer use ordinances and disposed of at a treatment plant. It has been demonstrated that leachate is not effectively attenuated in typical Long Island glacial tills. Therefore, recharge of even the pretreated effluent is to be prohibited.

Zone II

Even though the groundwaters in this zone have been impaired by past activities, the following recommendations should be implemented to prevent continued degradation, since the zone is within the Magothy recharge area:

1. All existing solid waste facilities, with the exception of controlled composting sites and landfills that dispose of inert wastes, should be graded and top-lined with an impervious barrier to prevent stormwater infiltration. Gas venting or methane recovery systems should also be installed to prevent lateral distribution to areas off site.

2. Whenever an existing landfill is extended into a previously unused area, that area should be double-lined and provided with dual leachate piping systems. Provision should be made for (a) the removal of leachate from the primary liner and (b) monitoring and removal of any leachate that might penetrate the primary liner and accumulate on the secondary liner.

3. New sanitary landfills for the disposal of garbage should be prohibited.

4. Waste and quench waters from other solid waste facilities should be pretreated to conform to sewer use ordinances and then discharged to a municipal facility.

Zone III

The groundwater in this zone is of excellent quality and must be retained for future public water supply.

1. There should be an immediate discontinuance of obsolete operational practices in existing landfills. Older sections of the site should be graded and covered with an impermeable liner to prevent stormwater infiltration and generation of leachate.

The landfill should be redesigned to incorporate the latest techniques for the prevention of groundwater contamination (*i.e.,* double liner—dual leachate collection piping).

2. New sanitary landfills with the exception of those used for the disposal of inert wastes under proper management, should be prohibited. Likewise, any other solid waste treatment or disposal facility that might discharge process water to the ground, treated or untreated, should be discouraged from siting in this zone.

3. Solid wastes generated within this zone should be transported to established waste disposal facilities or landfills located in zones where future sources of drinking water will not be jeopardized.

Zone IV

Heavy agricultural land use in this zone has contaminated the groundwaters with excessive levels of nitrates, and the zone is underlain at various depths with saltwater. The following recommendations should be considered:

1. Where it can be demonstrated that groundwater movement is away from existing or future public water supply resources, the operation of existing landfills should be allowed, in accordance with Part 360. Where leachate might be expected to impact the zone's water resources, existing landfills should be modified, as indicated for Zone II.

2. Where the establishment of new landfills or the expansion of existing landfills cannot be avoided, they should be so sited as to impact already degraded areas. Thus new landfills could be sited downflow of existing landfills where groundwater may already be contaminated and favorable groundwater flow conditions exist, and away from drinking water supply wells. However, proper grading should be incorporated to minimize stormwater infiltration. The establishment of new landfills in a groundwater resource area or immediately adjacent to surface waters should be prohibited.

3. Other types of solid waste facilities that discharge wastewaters may be permitted, provided that they have treatment facilities capable of meeting New York State's groundwater discharge criteria. No type of solid waste facility that requires a wastewater discharge should be permitted in a water resource area.

4. Inasmuch as Shelter Island is isolated and therefore dependent on the local groundwater supply, protection of that supply is particularly important. It should be noted that the cost of importing water may exceed the cost of exporting degradable domestic and commercial solid wastes.

It is recommended that on Shelter Island all landfilling of degradable solid waste be immediately discontinued and the waste exported to a suitable facility elsewhere in Zone IV or Zone V. Unless there are stringent on-site controls, liners may be required even where landfills are designated for the exclusive disposal of inert materials. In addition, the site should be graded to minimize stormwater infiltration.

Zone V

The recommendations for Zone IV also apply throughout all of Zone V.

Zone VI

The recommendations for a zone that provides recharge into the shallow groundwater system may place additional constraints on existing landfilling operations beyond those provided in NYSDEC Rules and Regulations Part 360. New facilities should not be sited in the primary coastal zone or in areas with high groundwater levels. Surface runoff and leachate should be contained and treated to prevent contravention of groundwater standards.

Zone VII

The recommendations for this zone, which also recharges to the shallow groundwater system, are the same as for Zone VI.

Zone VIII

This zone, located on the North Shore, is hydrogeologically similar to Zones VI and VII. Therefore, the recommendations that apply to those

zones also apply to Zone VIII.

5.2.5 Expansion of Public Water Supply Systems. In those hydrogeologic zones where population densities are presently very low and groundwater is near pristine (*e.g.,* Zone III), the concept of "monitoring ambient groundwater quality . . . as a basis for wastewater management decisions," has been adopted as an integral part of the policy of maintaining low population density. In those areas, residences are usually served by individual or private wells. It is also generally true that groundwater quality measured in observation wells screened in the upper ten or twenty feet of the water table aquifer would represent a worse case situation, and most likely reflect the most recent land use and waste disposal practices.

Since it is axiomatic that the major premise for making wastewater mangement decisions, whether they be structural or non-structural controls or monitoring programs, is the protection of the public health, it appears that one of the first responses to a measured degradation in groundwater quality in the water table aquifer should be the extension of public water supply facilities. The rigidly controlled construction standards, and the frequency of quality control monitoring by the public water purveyors, are substantial public heath protective measures in themselves.

5.3 Recommendations by Detailed Study Areas

5.3.1 Detailed Study Areas. The Bi-county Region has been divided into a number of detailed study areas, largely on the basis of surface drainage basins. (See Figure 2–3). Nine of these areas have already been designated in whole or in part as 201 study areas, one is awaiting designation, and the remainder are potential 201 areas.

201 study areas were designated pursuant to Title II of the Federal Water Pollution Control Act (FWPCA), which provides assistance to localities for the development and implementation of waste treatment works. In general, Section 201 has provided financial assistance through a three-tiered program, consisting of alternatives evaluation, detailed project plans and actual construction. Recent amendments (1977) to the FWPCA require applicants for 201 assistance to consider a broad range of alternatives, which may provide for water reclamation and reuse, the need for sewers, improved techniques for waste treatment and various land disposal methods.

Since the hydrogeologic zones are distinguished from each other by their groundwater flow regimes, their boundaries do not coincide with those of the detailed study areas. However, the Areawide Waste Treatment Management Plan has to be based on the latter, rather than the hydrogeologic zones, because the 201 Programs represent the most practical means whereby the management recommendations arising from the 208 Program can be implemented.

5.3.2 Integration of Hydrogeologic Zones and Detailed Study Areas. Figure 5–1 provides a graphic display of the relationship between (1) the detailed study areas and 201 Areas where so designated (each is defined in detail in Section H of the Plan; (2) the potential sewer service areas based on a density of two or more dwelling units per acre and (3) the hydrogeologic zones. The wastewater planning districts are shown as they appear in other 208 outputs, and detailed summary information has been presented for them. The boundaries shown represent the currently anticipated geographic implementation boundaries. It is recommended that the currently designated 201 Programs be implemented according to the boundaries shown in Figure 5–1. An implementation schedule is given in Section Seven. (See Section M of the Areawide Waste Treatment Management Plan.)

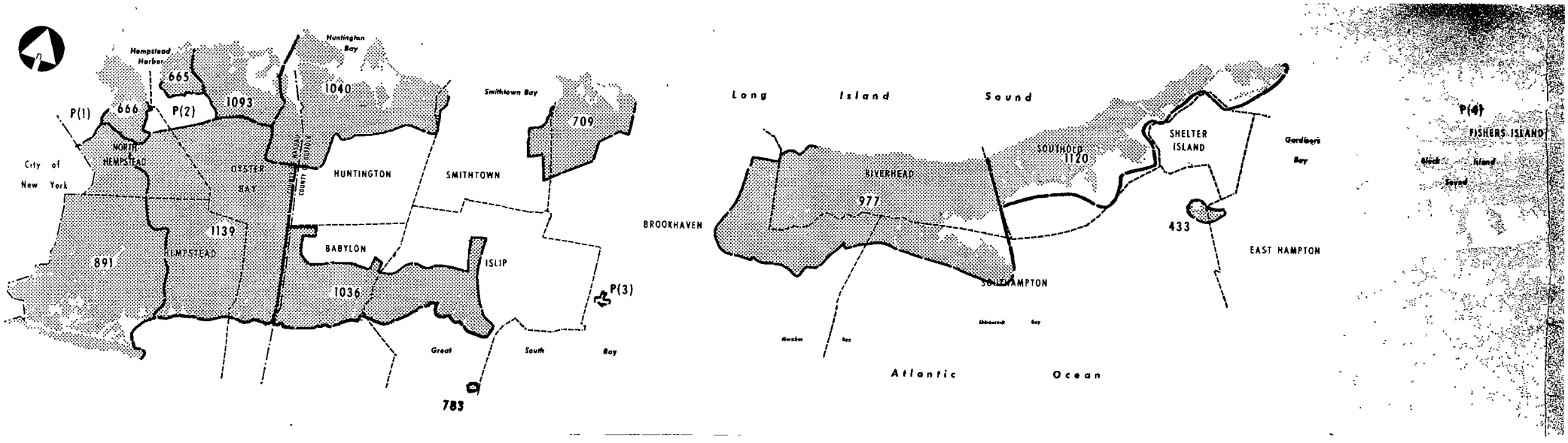
Figure 5–1 illustrates the relationships for one of several sewering options that may be adopted in the future. (See Sections 3.3 and 3.5 for a discussion of the various options.) As previously indicated, sewering at densities of one or more dwelling units per gross acre represents a maximum sewering approach. Sewering at densities of two or more dwelling units per gross acre in areas of high groundwater or low soil permeability and of three or more dwelling units per gross acre elsewhere represents a minimal sewering approach. Sewering at densities of approximately two dwelling units per gross acre, or lot sizes of less than 20,000 square feet for new developments, represents an intermediate approach and reflects current sewering policy in Suffolk County. The three pieces of information have been graphically combined to demonstrate how they should be analyzed and interpreted at a more detailed 201 level of study. The 201 Studies should take cognizance of the regional implications identified at the 208 level of study and interpret and apply the implications at the more detailed level of study.

Within each 201 level study, the hydrogeologic zone boundaries should first be defined in more detail, applying the criteria that were developed in the 208 Program. A similar approach should be taken in mapping areas of different population densities for possible definition as sewer service areas. Areas of high water table and low soil permeability should also be mapped.

For each hydrogeologic zone, the 208 has recommended a specific action or set of options that may be implemented to affect regional waste management goals. These are the alternatives that each 201 Study should develop and evaluate in detail. Each 201 area overlies at least one (and usually more) hydrogeologic zones, and the zone recommendations should be applied individually to the various parts of the 201 study area.

The proposed Yaphank study area in Suffolk provides a good example of the integration procedure. The northern portion is a part of Zone VIII, the central portion includes parts of Zones I and III, and the southern portion is part of Zone VI. Therefore, a 201 Study should be guided by the recommendations provided for the appropriate zones, when selecting alternatives for the various portions of the Yaphank study area.

The North Shore planning area in Nassau County can be similarly analyzed. Those southerly portions of the area that lie in hydrogeologic Zone I should be guided by Zone I recommendations. The northern parts of the area, which lie in Zone VIII, should incorporate the recommendations made, and study the various options listed herein for Zone VIII at a 201 level of detail. The regional, sub-regional or small plants approaches as presented in



(a) Existing and Pending 201 Study Areas

Existing 201 Study Areas

433 – Sag Harbor (V)
665 – Glen Cove (C)
666 – Port Washington
709 – Port Jefferson
783 – Ocean Beach (V)
891 – Nassau County SD No. 2
977 – Riverhead (T)
1036 – Suffolk County SWSD
1040 – Huntington (T)/Northport (V)
1093 – Oyster Bay
1120 – Southold (T)/Greenport (V)
1139 – Nassau County SD No. 3

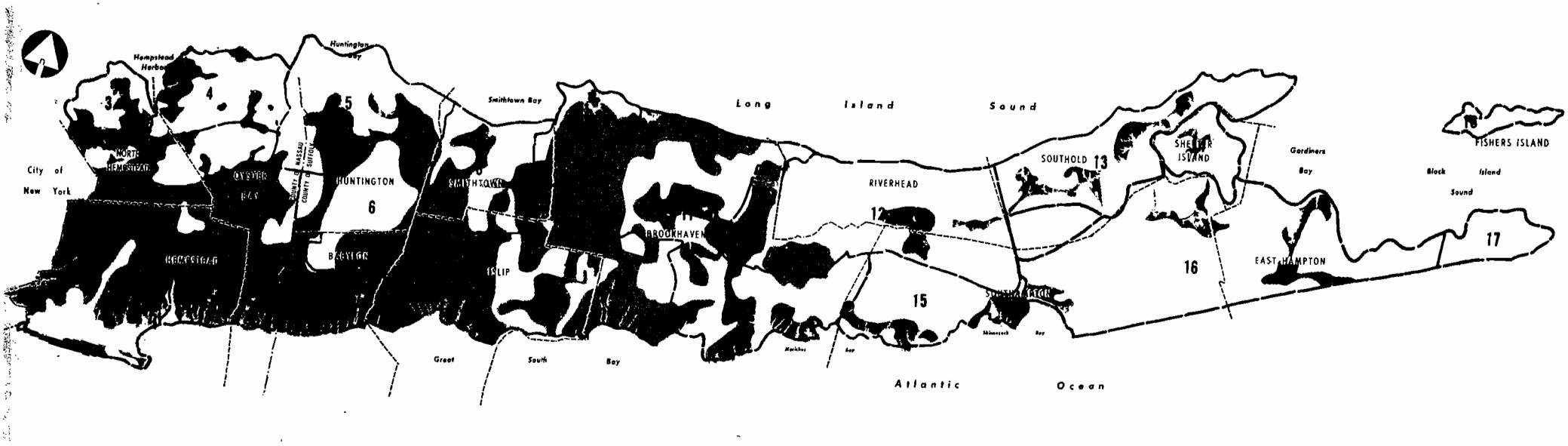
Pending 201 Study Areas

P (1) – Great Neck peninsula
P (2) – north shore undesignated
P (3) – Patchogue SD
P (4) – Fishers Island

Proposed Detailed Study Areas

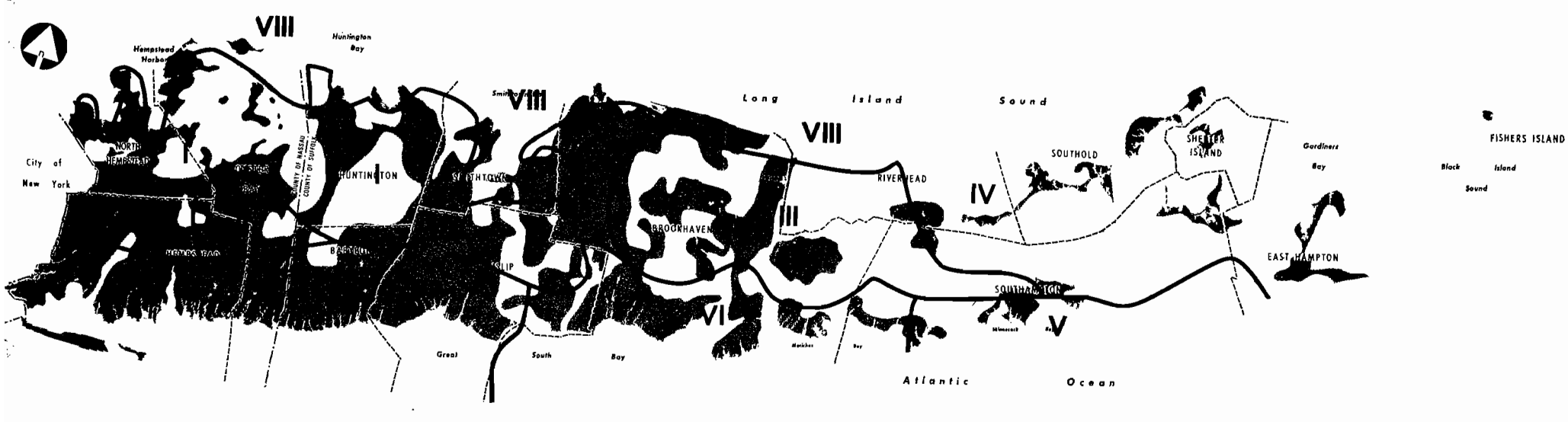
1. Southwestern NC
2. Cedar Creek
3. Northwest NC
4. Northeast NC
5. Huntington/Northport
6. West Central SC
7. Southwest SC
8. Kings Park
9. Port Jefferson
10. South Central SC
11. Yaphank
12. Riverhead
13. Southold/Greenport
14. Shelter Island DD No. 14
15. Southampton DD No. 12
16. South Fork DD No. 15
17. Montauk DD No. 16
18. Fishers Island DD No. 17

FIGURE 5–1 *201 Areas, Detailed Study Areas and Hydrogeologic Zones in Relation to Development of Two or More D.U./Acre*



(b) Proposed Detailed Study Areas

All hydrogeologic zone boundaries are approximate. Further definition of groundwater flow systems at a sub-regional level is required.



(c) Hydrogeologic Zones

— Development at 2 or more D.U.'s/Acre.

Plan Section H, and summarized previously in Section 3.2, should be analyzed in a 201 Study once zone options have been identified. However, the sewage flows and cost estimates presented earlier in this Summary Report (Section 3.3), were presented for detailed study areas and not hydrogeologic zones. Therefore, they are not directly transferrable since study area and zone boundaries do not coincide. Flows, loads and cost estimates will have to be finalized at a 201 level once zone options have been selected and detailed development of alternatives has occurred. In addition, in those 201 facilities planning areas where marine surface water effluent disposal has been recommended, additional detailed study should be conducted to determine the optimal discharge locations.

Groundwater quality monitoring is an integral part of detailed study area planning, and should be routinely employed in situations where there is uncertainty as to the existing quality of the shallow groundwater, or where there is uncertainty as to trends in pollutant concentration. The use of actual groundwater quality data in making wastewater management decisions is an approach that has not been widely used on Long Island. It is a concept that recognizes the limitations of any predictive model, whether it be theoretical or empirical. The planning guidelines recommended for the hydrogeologic zones and surface water elements should be applied in developing plans for relevant portions of the detailed study areas. For example, for those portions of the detailed study areas that are characterized by deep flow recharge regimes, the following planning guidelines should be applied:

1. Guidelines for Determining the Need for Structural and Non-Structural Controls.

a. *Developed Areas.* Since existing data is not sufficient to delineate the spatial extent of needed sewering, and since the effectiveness of selected non-point source controls is not known, the initial minimum density for sewering in developed areas should be nine persons per gross acre (approximately three dwelling units per gross acre). This will provide current 201 facilities planning areas with a threshold density at which to initiate their planning. Statistically, at this density, a nitrate-nitrogen groundwater concentration of ten milligrams per liter may be exceeded in 40 percent of samples drawn from shallow monitoring wells in that locality.

In areas where the density is less than nine persons per gross acre, monitoring should be undertaken during the initial phase of a 201 Study. This effort should be undertaken to define the hydrogeologic system beneath the area and to determine the need for further sewering.

The detection of an average nitrate-nitrogen concentration of six milligrams per liter or greater for the individual analysis of the shallow aquifer monitoring wells during the observation period would indicate the need for control measures to reduce the nitrogen loading.

Statistically, an average value of six milligrams per liter means that a nitrate-nitrogen groundwater concentration of ten milligrams per liter may be exceeded in ten percent of the samples drawn from shallow monitoring wells in that locality.

If it is determined, following analysis, that the source of nitrogen contamination is on-lot disposal systems, the spatial extent of needed sewering will be delineated by the extent of the area where the average nitrate-nitrogen concentrations are six milligrams per liter or greater.

b. *Undeveloped Areas.* For planning purposes, it is desirable to take a more conservative approach regarding the utilization of structural controls because of uncertainty concerning the absolute effectiveness of best management alternatives and the added expense of installing sewers after developments are established. It is recommended that, in undeveloped areas, sewering should be implemented at a population density of six persons per gross acre, which would yield values of nitrate-nitrogen in excess of ten milligrams per liter in approximately twenty percent of the observations in shallow wells. It is assumed that, at six person per gross acre, a large percentage of the violations can be eliminated through Best Management Practices, primarily fertilizer controls. Conversely, it may be assumed that, if non-structural controls are ineffective, or are not stringently applied, sewering may be necessary at lower population densities. At densities less than six persons per gross acre, monitoring of the water table would be undertaken to determine groundwater quality trends and to determine the future need for improved non-structural and structural controls.

At the population density of six persons per gross acre, if one were to assume a household size of 3.5 persons per dwelling unit, this would result in a density of 1.7 dwelling units per acre. Since this recommended sewering criterion for undeveloped areas is very close to the present Suffolk County standard for requiring sewers in new developments at lot sizes less than 20,000 square feet, or 1.6 dwelling units per acre, it is recommended that for planning purposes, the Suffolk County policy remain in effect for undeveloped areas. The additional groundwater quality data, which would be gathered in both 201 and other recommended Studies on the basis of varying geological conditions and population densities as discussed in the recommendations for developed areas, would possibly modify the criterion for structural pollution controls, as recommended herein, in the future.

2. Guidelines for Comprehensive Groundwater Monitoring

Comprehensive monitoring programs to provide data to be used in making wastewater management decisions for both structural and non-structural controls should be initiated or expanded.

The observation well drilling sequence, and the monitoring program should be carefully designed to provide data on representative ambient conditions in previously developed areas, and base data to evaluate trends in concentrations of contaminants in newly developed areas.

The number of wells, locations and depths, and frequency of sampling cannot be determined in a regional study. However, it appears evident that at least monthly samplings must be made for a period sufficient to characterize levels of nitrate-nitrogen and other contaminants with full consideration to the variability imposed by differences in geology, initial conditions, population density and thickness of the unsaturated zone. It

is estimated that sampling would be necessary over a period of six to twelve months. The details of these programs should be based on the demonstration project described in Section 5.5.2.5.

Shallow observation wells, screened in the upper portion of the water table aquifer, would reflect, in the shortest time period, changes in water quality due to activities at the land surface, and the impact on drinking water quality in the area may be predicted, and help to assist in decision-making, especially in areas where 201 Studies are underway or planned.

5.3.3 Structural Recommendations for Nassau County Detailed Study Areas. The following are only structural recommendations for Nassau County 201 study areas. Many of the pollutants that impact groundwater and surface waters can be expected to persist regardless of the structural recommendations that are selected. For this reason, non-structural alternatives must be regarded as an essential part of any comprehensive waste water management plan. For brevity, non-structural and non-point source recommendations have not been reiterated. However, it is necessary to review Table 5—1, in Section 5.2.1, and the Areawide Recommendations in Section 5.1, and apply those recommendations listed for a particular zone to the same zone or zones included in the detailed study area.

5.3.3.1 Southwestern Nassau County Planning Area (Districts No. 1 and No. 2, and the Cedarhurst, Lawrence, Long Beach and West Long Beach Sewer Districts)

Hydrogeologic Zones

Zone I

This area is completely sewered and no further sewering options exist. Regulations mandating the hook-up of private disposal systems to the district collection system should be more strictly enforced.

Zone VII

This area is essentially completely sewered and only one additional sewering option is recommended; that is, to sewer Point Lookout and the unsewered section of Lido Beach. These locations are in areas where on-lot sewage disposal systems are subject to failure and where it may reasonably be expected that these systems contribute pollutants to the surface waters.

Surface Water Elements

1. Relocate the Bay Park Treatment Plant outfall offshore to significantly reduce the nutrient and bacteria loadings to the present receiving waters, which include Hempstead Bay and Reynolds Channel.

2. Reroute the Long Beach Treatment Plant effluent to the proposed Bay Park outfall for ocean disposal. Although the background water quality at the present Long Beach outfall location is marginal, and the impact of the Long Beach discharge on the water quality is relatively minor when compared to that of Bay Park, in the long term, the most environmentally beneficial option is to divert the effluent offshore.

3. Initiate a study to determine whether the Lawrence treatment facility discharge violates water quality standards in Bannister Creek. If so, the discharge options should be as follows:

a. upgrade treatment with effluent discharge at the present location,
b. continue present treatment with effluent discharge to Reynolds Channel, and
c. divert sewage to the Bay Park treatment facility.

5.3.3.2 Cedar Creek Facilities Planning Area (Sewage Disposal District No. 3)

Hydrogeologic Zones

Zone I

1. Continue present plans for sewering this area. These plans generally conform to the recommended 208 guidelines.

2. In developed areas not presently sewered or scheduled for sewering, plans for sewering where the current density is nine or more persons per gross acre (three dwelling units per gross acre) should be initiated.

3. In addition to the planning for sewering at nine or more persons per gross acre, the implementation of non-structural controls should be initiated immediately.

4. In any detailed study area, a monitoring program should be instituted in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

Zone II

The desired goal in this zone is to upgrade groundwater quality and to ensure the continued viability of the aquifer as a source of drinking water.

1. This area is, or will be, essentially completely sewered, and no further sewering options exist. Present plans generally conform to recommended 208 guidelines.

Zone VII

1. This area is completely sewered and no further sewering options exist.

2. It is also recommended that, if sewage flow diversion from the North Shore to the South Shore is determined to be the most cost-effective option, then it should be diverted to the Cedar Creek treatment facility, since land is available at this site.

Surface Water Elements

1. Terminate the operation of the Freeport Treatment Plant and divert the flow to the Cedar Creek facility by December 31, 1979, as presently scheduled.

2. Stress the implementation of those non-point source and stormwater runoff controls proven feasible, to upgrade marine surface water quality to meet shellfishing standards.

5.3.3.3 North Shore Facilities Planning Area. It should be noted that the prioritizing of the wastewater treatment, routing and effluent disposal

alternatives here in this section is not meant to exclude any of these options from further study. The ranking of the treatment alternatives under "Surface Water Elements" is based upon preliminary engineering, environmental and economic analysis, and therefore, it is recommended that all of these wastewater management options discussed below be considered viable and evaluated in greater detail in a "201" level of study.

It is recommended that the northern drainage basin of Nassau County be divided into two 201 level study areas due to drainage patterns, economies of scale, diversion potential, land use characteristics and potential for subregional treatment plants.

1. *The Northwest Study Area* would include the Great Neck peninsula, and the Port Washington peninsula. This would include the following sewer districts and unsewered areas: Belgrave, Great Neck, Great Neck Village, Port Washington, Roslyn, Plandome-Sands Point and Kings Point-Manhasset.

2. *The Northeast Study Area* would comprise the Oyster Bay drainage area and the eastern drainage basin of Hempstead Harbor, including Glen Cove. The study area would include the following sewer districts and unsewered areas: Glen Cove, Oyster Bay, Sea Cliff-Roslyn Harbor, Centre Island, East Norwich, Bayville and Locust Valley.

A 201 facilities planning study has recently been undertaken for Port Washington, and one for Oyster Bay will begin during 1978.

Hydrogeologic Zone

Zone I

1. In developed areas not presently sewered, plans for sewering where the current density is nine or more persons per gross acre (three dwelling units per gross acre) should be initiated.

2. In addition to the planning for sewering at nine or more persons per gross acre, the implementation of non-structural controls should be initiated immediately.

3. In any detailed study area, a monitoring program should be instituted in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

4. Sewage flow from C. W. Post College should be diverted to the Cedar Creek treatment facility for final disposal. If the cost of diversion, however, significantly outweighs the cost of nitrogen removal, as determined in a 201 Study, then this treatment plant may continue to discharge to the ground providing it is upgraded to include nitrogen removal and to meet other applicable groundwater quality standards. This recommendation is consistent with proposed NYSDEC regulations to provide nitrogen removal where the flow exceeds 30,000 gallons per day.

5. All treatment plants discharging to the ground will be required to employ AWT (nitrogen removal).

Zone VIII

1. Sewer in those areas where on-lot sewage disposal systems are subject to failure and cannot be upgraded due to high groundwater table, low soil permeability, small lot size, etc.

2. Sewer in those areas where contaminated groundwater may reasonably be expected to contribute pollutants to the surface waters and to result in a contravention of the standards. This recommendation refers specifically to parts of Plandome-Sands Point, Kings Point-Manhasset, Sea Cliff-Roslyn Harbor, Bayville and Centre Island, which existing and future studies may indicate are critical areas controlling nearby surface water quality.

Surface Water Elements

1. Based upon preliminary economic and environmental analyses, the diversion of sewage flows from the North Shore areas to the Cedar Creek treatment facility is the recommended alternative. The Glen Cove Treatment Plant, however, is excluded from this alternative because it is presently being reconstructed and upgraded.

2. If the cost of flow diversion significantly outweighs environmental benefits, the next preferred option would be to consolidate the existing treatment plants into a sub-regional facility in each recommended Northeast and Northwest study area. The reliance on a number of small treatment plants in this area may fail to capture all the economies of scale available to a larger sub-regional facility.

3. If the benefits of the preferred alternatives cannot be realized due to cost, and the present configuration remains as is, then the individual facilities will require either nitrogen removal if the present discharge location is retained, or a mid-bay discharge, if the present level of treatment is maintained. Of these two options, a mid-bay outfall is recommended due to improved dispersion characteristics of the receiving waters , and reduced costs.

4. Based upon water quality analysis, the Oyster Bay plant may retain its present treatment level and discharge location without significantly impairing the receiving water; however, this does not preclude the possibility of diversion to either the Cedar Creek Treatment Plant or to a sub-regional facility to assure minimal impact on the ecosystem in the area due to the present discharge of both nutrients and bacteria. The potential environmental benefits, achieved through diversion, make this the recommended alternative.

5. If it is determined that Bayville should be served by its own sewage treatment facility, then final effluent disposal should be to Long Island Sound.

6. The presently planned treatment level for the Glen Cove treatment facility will not achieve water quality standards in Glen Cove Creek. To insure compliance with the standards, nitrogen removal or a mid-harbor discharge is required. However, if the removal of a significant source of bacteria in the vicinity of a number of bathing beaches, and the maximum dispersion of effluent is to affected, then a mid-harbor outfall is the preferred alternative.

7. Due to the valuable shellfishing industry, the extensive wetlands and

the excellent water quality in Oyster Bay, non-point source controls to alleviate impacts on surface waters should be emphasized, if proven cost-effective.

5.3.4 Structural Recommendations for Suffolk County Detailed Study Areas. The following are only structural recommendations for Suffolk County 201 study areas. Many of the pollutants that impact groundwater and surface waters can be expected to persist regardless of the structural recommendations that are selected. For this reason, non-structural alternatives must be regarded as an essential part of any comprehensive waste water management plan. For brevity, non-structural and non-point source recommendations have not been reiterated. However, it is necessary to review Table 5—1, in Section 5.2.1, and the Areawide Recommendations in Section 5.1, and apply those recommendations listed for a particular zone to the same zone or zones included in the detailed study area.

5.3.4.1 Huntington/Northport Study Area. A 201 facilities planning study has recently been undertaken for this area, which includes a small portion of northeastern Nassau County. Parts of the area are presently sewered and there are three existing facilities in Suffolk and one in Nassau.

Hydrogeologic Zones

Zone I

1. In developed areas not presently sewered, plans for sewering where the current density is nine or more persons per gross acre (three dwelling units per gross acre) should be initiated.

2. In addition to the planning for sewering at nine or more persons per gross acre, the implementation of non-structural controls should be initiated immediately.

3. In any detailed study area, a monitoring program should be instituted in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

4. As currently vacant land is developed, sewer at the present SCDHS designated density of approximately two dwelling units per acre (less than 20,000 square foot lot size).

Zone VIII

1. Sewer in those areas where on-lot sewage systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other considerations.

2. Sewer in those areas where contaminated underflow may reasonably be expected to contribute pollutants to the surface waters and to result in a contravention of the standards.

3. A need for groundwater recharge for the purpose of maintaining water supply self-sufficiency in the Region has not been identifed by the 208 Study. This does not preclude recharge as an option in any investigation of effluent disposal methods.

Surface Water Elements

1. The following sewage treatment options require further evaluation as part of the 201 plan.

a. Regional Alternative Site
   i. Huntington Sewage Treatment Plant or
   ii. Crab Meadow

b. Sites for the Sub-Regional Alternative
   i. Huntington Sewage Treatment Plant and
   ii. Northport Village Sewage Treatment Plant

c. Small Treatment Plants—All inland treatment plants will be required to employ AWT (nitrogen removal).

2. On the basis of preliminary environmental analysis and projected flow, it is recommended that, should the Huntington Sewage Treatment Plant be utilized as either a regional or sub-regional facility, secondary treatment with mid-bay effluent discharge would be preferable to AWT and effluent discharge at the present location in Huntington Harbor.

5.3.4.2 West Central 201 Study Area. For the purposes of future investigation, this study area may be divided by the Long Island Expressway into a northern and a southern segment, due primarily to the provisions for diversion of flow of the southern portion of this 201 study area to the Southwest Sewer District (Suffolk County Sewer District No. Three).

A. *Northern Area.* This portion of the 201 area north of the L.I.E., which is largely unsewered, has five existing sewage treatment facilities.

Hydrogeologic Zones

Zone I

1. In developed areas not presently sewered, plans for sewering where the current density is nine or more persons per gross acre (three dwelling units per gross acre) should be initiated.

2. In addition to the planning for sewering at nine or more persons per gross acre, the implementation of non-structural controls should be initiated immediately.

3. In any detailed study area, a monitoring program should be instituted in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

4. As currently vacant land is developed, sewer at the present SCDHS designated density of approximately two dwelling units per acre (less than 20,000 square foot lot size).

Further evaluation of the following options is required as part of the 201 plan for selection of the preferred sewage treatment alternative.

a. Sites for the Sub-Regional Alternative
   i. Suffolk State School and
   ii. Facility located in the eastern portion of this area.

b. Small Treatment Plants Alternative—All sewage treatment plants will be required to provide AWT (nitrogen removal).

c. Diversion to the Suffolk County Sewer District No. Three Water Pollution Control Plant (Bergen Point).

B. *Southern Area.* The portion of the 201 area south of the L.I.E. is again predominantly unsewered. There are eight existing sewage treatment facilities.

Hydrogeologic Zones

Zone I

1. In developed areas not presently sewered, plans for sewering where the current density of nine or more persons per gross acre (three dwelling units per gross acre) should be initiated.

2. In addition to the planning for sewering at nine or more persons per gross acre, the implementation of non-structural controls should be initiated immediately.

3. In any detailed study area, a monitoring program should be instituted in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

4. As currently vacant land is developed, sewer at the present SCDHS designated density of approximately two dwelling units per acre (less than 20,000 square foot lot size).

5. This area is included in the study area of the recently initiated Flow Augmentation Needs Study, which will determine the need and, if necessary, the method of mitigating the impact of possible reduced groundwater levels and streamflow resulting from sewering at the Southwest Sewer District (S.W.S.D.). The impact of sewering in this portion of the West Central 201 study area will require further investigation.

6. Interceptor sewers of the S.W.S.D. are sized to accept sewage flow from this area north of the S.W.S.D. Therefore, the recommended means for providing sewer service to this area is to extend those interceptor sewers from the S.W.S.D. which would serve areas of Zone I in accordance with the 208 sewering criteria as substantiated by the prescribed groundwater sampling program. Furthermore, it should be noted that extensions of interceptor sewers from the S.W.S.D. to serve Zone I of the study area must pass through Zone VII. Therefore, service would also be made available to those areas of Zone VII tributary to the interceptors required for Zone I. This recommendation will require further evaluation to assess the impact of effluent disposal alternatives.

Zone VII

1. In developed areas not presently sewered, plans for sewering where the current density is nine or more persons per gross acre (three dwelling units per gross acre) should be initiated.

2. Sewer in those areas where on-lot sewage disposal systems are subject to failure and cannot be upgraded due to high groundwater table, low soil permeability, small lot size, etc.

3. Sewer in those areas where contaminated underflow may reasonably be expected to contribute pollutants to the surface waters and to result in a contravention of the standards.

Pilgrim State Hospital.

A priority has been established for the sub-drainage area that includes Pilgrim State Hospital and AIL (Cutler Hammer) Corporation. Both of these facilities are in violation of their SPDES permits, and require upgrading. In additon, Pilgrim State provides sewage treatment services for Suffolk Community College, West Campus, and the planned Multi-Town Solid Waste Facility, which will also require extensive sewage service. Therefore, a modified 201 Study for this drainage area should begin immediately, with the results required to be consistent with the 208 recommendations for Zones I and VII of the entire West Central 201 study area.

If the 201 Study for the West Central area is begun prior to approval of the 201 facilities plan for the modified area, then the information developed should be used as input for the more comprehensive study area and further work on the modified 201 should terminate.

On the other hand, if 201 planning has not been initiated for the entire area, then the modified area should be considered eligible for necessary funding required for Step II and Step III activities. Also, this procedure would serve as a model for initiating studies for other identified problem areas.

5.3.4.3 Southwest Sewer District (Suffolk County Sewer District No. 3).

Hydrogeologic Zones

Zone VII

1. This area is, or will be, essentially completely sewered, and no further sewering options exist. Present plans generally conform to recommended 208 guidelines.

Surface Water Elements

1. Construction has begun for an ocean outfall for effluent disposal from the Bergen Point Water Pollution Control Plant. The 208 Study has verified that, at design flow, a bay discharge of secondary effluent from this facility would have resulted in unacceptable bay water quality.

2. Stress the future implementation of non-point source controls, if proven feasible, in order to assist in upgrading surface water quality to increase open shellfishing areas.

3. The recently initiated Flow Augmentation Study will determine the need and, if necessary, the method for mitigating the impact of possible reduced stream flow resulting from sewering in the S.W.S.D.

5.3.4.4 Kings Park 201 Study Area. Portions of the study area are

sewered, and there are eight existing treatment facilities.

Hydrogeologic Zones

Zone I

1. In developed areas not presently sewered, plans for sewering where the current density is nine or more persons per gross acre (three dwelling units per gross acre) should be initiated.

2. In addition to the planning for sewering at nine or more persons per gross acre, the implementation of non-structural controls should be initiated immediately.

3. In any detailed study area, a monitoring program should be instituted in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

4. As currently vacant land is developed, sewer at the present SCDHS designated density of approximately two dwelling units per acre (less than 20,000 foot lot size).

5. The 208 Program has not identified a need for groundwater recharge in this area for the purpose of preserving the drinking water supply. However, the importance of maintaining the flow and water quality of the Nissequogue River will require the investigation of possible streamflow augmentation needs.

Zone VIII

1. Sewer in those areas where on-lot sewage systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other considerations.

2. Sewer in those areas where contaminated underflow may reasonably be expected to contribute pollutants to the surface waters and to result in a contravention of the standards.

Surface Water Elements

1. The following sewage treatment options require further evaluation as part of the 201 facilities plan:

a. Site for Regional Alternative
   i. Kings Park Sewage Treatment Plant

b. Sites for Sub-Regional Alternative
   i. Kings Park Sewage Treatment Plant
   ii. Suffolk County Center Sewage Treatment Plant

c. Small Plants—(1) maintain and upgrade existing treatment facilities to AWT. (2) Investigate cost-effective combinations of sewage treatment plants. (3) Provide additional facilities in accordance with sewering criteria.

2. Investigate the need for streamflow augmentation for the Nissequogue River.

5.3.4.5 Port Jefferson 201 Study Area. Significant portions of this study area are presently sewered, and there are two existing treatment facilities.

Hydrogeologic Zones

Zone I

1. Due to the advanced state of 201 facilities planning for this study area, the time schedule does not allow for a substantial groundwater monitoring program. Therefore, additional sewer service beyond that provided by the existing facilities should be based on the minimum sewering guideline, except where existing groundwater data is sufficient to identify a problem area that requires sewering.

2. In developed areas not presently sewered, plans for sewering where the current density is nine or more persons per gross acre (three dwelling units per gross acre) should be initiated.

3. In addition to the planning for sewering at nine or more persons per gross acre, the implementation of non-structural controls should be initiated immediately.

4. In any detailed study area, a monitoring program should be instituted and continued beyond the completion of Phase I of the 201 Facilities Plan in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

5. As currently vacant land is developed, sewer at the present SCDHS designated density of approximately two dwelling units per acre (less than 20,000 square foot lot size).

Zone VIII

1. Sewer in those areas where on-lot sewage systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other considerations.

2. Sewer in those areas where contaminated underflow may reasonably be expected to contribute pollutants to the surface waters and to result in a contravention of the standards.

Surface Water Elements

1. The 208 has not selected a recommended alternative for sewage treatment and disposal. It is required that the 201 Study select the number and location of facilities by evaluating combinations of existing facilities and other suitable sites.

2. Surface water discharge shall not exceed the waste load allocations established by the 208 Study.

5.3.4.6 South Central 201 Study Area. In this study area there are numerous pockets of development that are presently sewered, and there are

thirty-one existing treatment facilities.

Hydrogeologic Zones

Zone 1

1. In developed areas not presently sewered, plans for sewering where the current density is nine or more persons per gross acre (three dwelling units per gross acre) should be initiated.

2. In addition to the planning for sewering at nine or more persons per acre, the implementation of non-structural controls should be initiated immediately.

3. In any detailed study area, a monitoring program should be instituted in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

4. As currently vacant land is developed, sewer at the present SCDHS designated density of approximately two dwelling units per acre (less than 20,000 square foot lot size).

5. The 208 Study has not identified a need for groundwater recharge in this area for the purpose of preserving drinking water supply. However, the importance of maintaining the flow and water quality of streams in this area, especially of the Connetquot River, and the water level of Lake Ronkonkoma, will require the investigation of possible streamflow augmentation and lake level maintenance needs.

Zone III

1. Land use controls should be the primary method for protecting this valuable groundwater resource. Where residential development is allowed, large lot development (two acre zoning or greater) should be required. Encourage the preservation of existing large land holdings and natural vegetation. A groundwater monitoring program should be employed to ensure timeliness of mitigation if degradation is discerned.

2. In the areas of this zone where it is infeasible to implement the preceding recommendation due to existing development of land allocation of planned development, the following actions are recommended:

a. Require sewering at densities of one or more dwelling units per acre.

b. Stress implementation of those non-point source controls proven feasible, in order to protect groundwater quality.

3. The 208 Program has not identified a need for groundwater recharge in this area for the purpose of preserving the drinking water supply. However, the importance of maintaining the flow and water quality of the Carmans River will require the investigation of possible streamflow augmentation needs.

Zone VI

1. Due to the impact of this area on the sensitive eastern Great South Bay, sewering is required at densities of one or more dwelling units per acre.

2. Stress the implementation of those non-point source controls proven feasible, in order to assist in upgrading surface water quality to protect shellfishing areas.

3. The 208 Study has not identified a need for groundwater recharge in this area for the purpose of preserving drinking water supply. However, the importance of maintaining the flow and water quality of streams in this area, especially of the Connetquot River, will require the investigation of possible streamflow augmentation needs.

Surface Water Elements

1. Duck farms are to conform to compliance schedules which require zero discharge by 1983.

2. The following sewage treatment options require further evaluation as part of the 201 facilities plan.

a. Regional Alternative Site
(To be selected)

b. Sites for the Sub-Regional Alternative
i. West of Lake Ronkonkoma
ii. Oakdale vicinity
iii. Sayville vicinity
iv. The Parkland III and S.C.S.D. No. 7 (Medford) facilities would be maintained.

c. Small Plants—(1) Maintain and upgrade existing treatment facilities to AWT (nitrogen removal). (2) Investigate cost-effective combinations of sewage treatment plants. (3) Provide additional facilities in accordance with sewering criteria for the various zones.

Village of Patchogue

A priority has been identified for the Patchogue Village Sewage Treatment Plant, which is presently in violation of its SPDES permit. The following is the recommended course of action to address this immediate need.

1. The "first-stage" 201 Study presently being conducted by the Village should consider the following:

a. Sewering those areas where on-lot sewage disposal systems are subject to failure.

b. Sewering those areas where contaminated underflow may reasonably be expected to contribute pollutants to the surface waters, which results in a contravention of the standards.

c. Upgrading the sewage treatment plant according to the recommendations in this Plan.

d. Implementing the recommendations for Zone VI of the South Central study area, where applicable.

2. If a 201 Study is begun for an area similar to the South Central Study Area before approval of the village's "first-stage" 201 facility report

(estimated for April 1979), the information developed by the village should be fully incorporated into such study so as to avoid duplication of effort and the village's "first-stage" 201 Study should cease.

3. If no 201 Study is begun before approval of the village's "first-stage" 201 facility report, the village should be considered eligible for Section 201 funding for subsequent Step II and Step III work, to carry out its approved 201 facility report.

5.3.4.7 Yaphank 201 Study Area. There are numerous pockets of development in this study area that are presently sewered, and there are twenty-five existing treatment facilities.

Hydrogeologic Zones

Zone I

1. In developed areas not presently sewered, (three dwelling units per gross acre) plans for sewering where the current density is nine persons per gross acre should be initiated.

2. In addition to the planning for sewering at nine or more persons per gross acre, the implementation of non-structural controls should be initiated immediately.

3. In any detailed study area, a monitoring program should be instituted in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

4. As currently vacant land is developed, sewer at present SCDHS designated density of approximately two dwelling units per acre (less than 20,000 square foot lot size).

Zone III

1. Land use controls should be the primary method for protecting this valuable groundwater resource. Where residential development is allowed, large lot development (two acre zoning or greater) should be required. Encourage the preservation of existing large land holdings and natural vegetation. A groundwater monitoring program should be employed to ensure timeliness of mitigation if degradation is discerned.

2. In the areas of this zone where it is infeasible to implement the preceding recommendation due to existing development of land allocation of planned development, the following actions are recommended:

a. Require sewering at densities of one or more dwelling units per acre.

b. Stress implementation of those non-point source controls proven feasible, in order to protect groundwater quality.

3. The 208 Program has not identified a need for groundwater recharge in this area for the purpose of preserving the drinking water supply. However, the importance of maintaining the flow and water quality of the Carmans River will require the investigation of possible streamflow augmentation needs.

Zone VI

1. Due to the impact of this area on the sensitive eastern Great South Bay, sewering is required at densities of one or more dwelling units per acre. In order to maintain groundwater Nitrogen at or below two milligrams per liter, collection and treatment should be provided when densities reach one or more D.U./gross acre.

2. Stress the implementation of those non-point source controls proven feasible in order to assist in upgrading surface water quality to protect shellfishing areas.

3. The 208 Program has not identified a need for groundwater recharge in this area for the purpose of preserving the drinking water supply. However, the importance of maintaining the flow and water quality of the Carmans River will require the investigation of possible streamflow augmentation needs.

Zone VIII

1. Sewer in those areas where on-lot sewage systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other considerations.

2. Sewer in those areas where contaminated underflow may reasonably be expected to contribute pollutants to the surface waters and to result in a contravention of the standards.

Surface Water Element

1. Stabilize or upgrade the ocean inlet of Moriches Bay.

2. Duck farms are to conform to compliance schedules, which require zero discharge by 1983.

3. The following sewage treatment options require further evaluation as part of the 201 facilities plan.

a. Sites for the Sub-Regional Alternative
   i. Three sites:
      (a) Selden Sanitary
      (b) Suffolk County property at Horse Block Road
      (c) Mastic Beach east of William Floyd Parkway
   ii. Six sites:
      (a) utilize the three sites of No.1
      (b) Rocky Point vicinity
      (c) Artist Lake vicinity
      (d) Center Moriches east of Forge River

b. Small Plants
   i. Maintain and upgrade existing treatment facilities to AWT.
   ii. Investigate cost-effective combinations of sewage treatment plants.
   iii. Provide additional facilities in accordance with sewering criteria for the various zones.

5.2.4.8 Riverhead 201 Study Area. The 201 facilities plan for the

study is presently underway. There are currently four treatment facilities in this area including the Town of Riverhead Sewage Treatment Plant.

Hydrogeologic Zones

Zone III

1. Land use controls should be the primary method for protecting this valuable groundwater resource. Where residential development is allowed, large lot development (two acre zoning or greater) should be required. Encourage the preservation of existing large land holdings. A groundwater monitoring program should be employed to ensure timeliness of mitigation if degradation is discerned.

2. In the areas of this zone where it is infeasible to implement recommendation (1) due to existing development or land allocation of planned development, the following actions are recommended:

a. Require sewering at densities of one or more dwelling units per acre.

b. Stress implementation of those non-point source controls proven feasible, in order to protect groundwater quality.

3. The 208 Program has not identified a need for groundwater recharge in this area for the purpose of preserving the drinking water supply. However, the importance of maintaining the flow and water quality of the Peconic River will require the investigation of possible streamflow augmentation needs.

Zone IV

The desired goal is self-sufficiency in respect to water supply, therefore, recommended measures are directed towards obviating the need for importation of drinking water while maintaining the quality and quantity of the groundwater.

1. Due to the advanced state of 201 facilities planning in this study area, the time schedule does not allow for a substantial groundwater monitoring program. Therefore, additional sewer service beyond that provided by the existing facilities should be based on the minimum sewering guideline, except where existing groundwater data is sufficient to identify a problem area that requires sewering.

2. In developed areas not presently sewered, plans for sewering where the current density is nine or more persons per gross acre (three dwelling units per gross acre) should be initiated.

3. Sewer in those areas where on-lot sewage systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other considerations.

4. As currently vacant land is developed, sewer at the present SCDHS designated density of approximately two dwelling units per acre (less than 20,000 square foot lot size).

Zone VIII

1. Sewer in those areas where on-lot sewage systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other considerations.

2. Sewer in those areas where contaminated underflow may reasonably be expected to contribute pollutants to the surface waters and to result in a contravention of the standards.

Surface Water Element

1. Duck farm treatment facilities are to conform to compliance schedules, which will require zero discharge by 1983.

2. No additional waste loading should be allowed from the Brookhaven National Laboratory or Grumman Sewage Treatment Plants.

3. The Riverhead Sewage Treatment Plant discharge should be relocated out of the Peconic Estuary. Monitoring should be conducted to determine when relocation will become necessary.

4. The following treatment options are to be evaluated as part of the 201 facilities plan:

a. Site for Regional Alternative

i. Riverhead Sewage Treatment Plant—expand service area in accordance with sewering criteria

b. Sites for Sub-Regional Alternative

i. Riverhead Sewage Treatment Plant

ii. Manorville

c. Small Plants—Provide facilities as needed in accordance with sewering criteria. All sewage treatment plants with inland disposal will require AWT (nitrogen removal).

5.3.4.9 Village of Greenport/Town of Southold 201 Study Area. A 201 facilities plan is currently being initiated for this study area. There are two existing facilities.

Hydrogeologic Zones

Zone IV

The desired goal is self-sufficiency in respect to water supply; therefore, recommended measures are directed towards obviating the need for importation of drinking water while maintaining the quality and quantity of the groundwater.

1. In developed areas not presently sewered, plans for sewering where the current density is nine or more persons per gross acre (three dwelling units per gross acre) should be initiated.

2. In addition to the planning for sewering at nine or more persons per gross acre, the implementation of non-structural controls should be initiated immediately.

3. In any detailed study area, a monitoring program should be instituted in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

4. Sewer in those areas where on-lot sewage systems are subject to

failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other considerations.

5. As currently vacant land is developed, sewer at the present SCDHS designated density of approximately two dwelling units per acre (less than 20,000 square foot lot size).

Surface Water Elements

1. The following sewage treatment options require further evaluation as part of the 201 facilities plan:

a. Small Treatment Plants

i. Village of Greenport Sewage Treatment Plant—expand service area in accordance with sewering criteria. Investigate the need for recharge to preclude saltwater intrusions. Recharge would require AWT (nitrogen removal).

ii. Additional sites to be selected as needed for areas which satisfy sewering criteria. All sewage treatment plants with inland disposal will require AWT (nitrogen removal).

5.3.4.10 Disposal District Fourteen—Shelter Island. There is currently one primary treatment plant serving Shelter Island Heights.

1. In developed areas not presently sewered or scheduled for sewering, plans for sewering, where the current density is nine or more persons per gross acre (three dwelling units per gross acre), should be initiated.

2. In addition to the planning for sewering at nine or more persons per gross acre, the implementation of non-structural controls should be initiated immediately.

3. In any detailed study area, a monitoring program should be instituted in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

4. As currently vacant land is developed, sewer at the present SCDHS designated density of approximately two dwelling units per acre (less than 20,000 square foot lot size).

Surface Water Elements

1. Shelter Island Heights Sewage Treatment Plant—expand service area in accordance with sewering criteria. Upgrade facility to secondary treatment with discharge to Shelter Island Sound.

5.3.4.11 Disposal District Twelve (Western Portion of the Town of Southampton). There are two existing treatment plants in this study area.

Hydrogeologic Zones

Zone V

1. In developed areas not presently sewered or scheduled for sewering, plans for sewering where the current density is nine or more persons per gross acre (three dwelling units per gross acre) should be initiated.

2. In addition to the planning for sewering at nine or more persons per gross acre, the implementation of non-structural controls should be initiated immediately.

3. In any detailed study area, a monitoring program should be instituted in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

4. Sewer in those areas where on-lot sewage systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other considerations.

5. As currently vacant land is developed, sewer at the present SCDHS designated density of approximately two dwelling units per acre (less than 20,000 square foot lot size).

Zone VI

1. If duck sludge is *not* the controlling influence on bay water quality, and if the maintenance of the ocean inlet does *not* provide the desired improvement, then collect and treat at one or more D.U./acre in presently developed areas.

2. In order to maintain groundwater Nitrogen at or below two milligrams per liter, collection and treatment should be provided when densities reach one or more D.U./gross acre.

3. Stress the implementation of those non-point source controls proven feasible, in order to assist in upgrading surface water quality to protect shellfishing areas.

Surface Water Elements

1. Stabilize or upgrade the existing ocean inlet to Moriches Bay.

2. If recommendation number one is ineffective, then despite the low population density projected for much of this area, the desire to maintain or upgrade the water quality of the Moriches Bay will require the evaluation of the possible need for small treatment facilities. Sites are to be selected as needed for area that satisfy sewering criteria. All sewage treatment plants with inland disposal will require AWT (nitrogen removal).

5.3.4.12 Disposal District Fifteen (Eastern Portion of the Town of Southampton and the Town of East Hampton). There are currently two treatment facilities in this study area.

Hydrogeologic Zones

Zones IV and V

1. In developed areas not presently sewered or scheduled for sewering, plans for sewering where the current density is nine or more persons per gross acre (three dwelling units per gross acre) should be inititated.

2. In addition to the planning for sewering at nine or more persons per gross acre, the implementation of non-structural controls should be initiated

immediately.

3. In any detailed study area, a monitoring program should be instituted in order to determine the quality of the water table aquifer and the efficacy of the non-point source controls. Where it is found that area-average nitrate-nitrogen levels are six milligrams per liter or greater, or when other contaminants are in excess of groundwater standards, and where the pollution may reasonably be expected to result from on-lot systems, sewering should be initiated at densities less than nine persons per gross acre (three dwelling units per gross acre).

4. Sewer in those areas where on-lot systems are subject to failure and cannot be upgraded due to soil conditions, high groundwater, small lot size and other considerations.

5. As currently vacant land is developed, sewer at the present SCDHS designated density of approximately two dwelling units per acre (less than 20,000 square foot lot size).

Surface Water Elements

1. Mecox Bay—restrict the development of shoreline areas abutting the bay.

2. The following small sewage treatment plant options should be evaluated:

a. Maintain existing facilities.

b. Extend Sag Harbor service area in accordance with sewering criteria.

c. Provide new facilities in accordance with sewering criteria.

5.3.4.13 Disposal District 16—(Montauk Area). There is one treatment facility servicing the Air Force base. Due to the low population density projected for this area, no additional sewering appears to be necessary.

5.3.4.14 Disposal District 17—Fishers Island. The collection system discharges raw sewage to Long Island Sound. Therefore, it is recommended that secondary treatment be provided with Long Island Sound discharge.

5.4 Inter-Jurisdictional Recommendations

5.4.1 Western Long Island Sound. Long Island Sound conditions exert a dominant influence on water quality within Manhasset Bay and Hempstead Harbor. Western Long Island Sound waters are characterized by high levels of solids, nitrogen and bacteria. Since most of the high levels of suspended solids, nitrogen and coliform bacteria in western Long Island Sound can be traced to discharges within New York City, Long Island Sound conditions are largely beyond the control of the Nassau-Suffolk 208 Program. It is therefore the responsibility of the USEPA and NYSDEC to require the implementation of waste controls necessary to improve water quality to meet the standards specified for this surface water segment. These controls may include nitrogen removal for existing sewage treatment plants and the retention and treatment of combined sewer overflows. Pretreatment for metals and/or organic chemicals may be in order if it can be shown that toxic contaminants move from New York City into the Sound.

5.4.2 Nearshore Atlantic Ocean. It is the responsibility of the USEPA and NYSDEC to insure that necessary wastewater controls are implemented to prevent the discharge of contaminants and floatable material into the New York Bight. Such contaminants and floatables have particularly impaired the use of regional ocean bathing beaches. These regulations should apply to the control and treatment of raw or inadequately treated sewage discharges, industrial discharges and combined sewer overflows from sites located in New York City and New Jersey.

5.4.3 Western Nassau County. Jamaica Water Company is currently creating significant groundwater movement from western Nassau County to Queens. The company's heavy pumping in Queens has resulted in a significant reduction in the water levels in western Nassau. It is the responsibility of the NYSDEC to implement whatever pumping controls are necessary to prevent the continued underflow to Queens to permit the recovery of water levels and to prevent accelerated saltwater intrusion in western Nassau County.

5.5 The Need for Further Regional Studies, Demonstration Projects and Research

The 208 Program has raised numerous wastewater management questions that are of importance to Long Island and, in many cases, to the Nation as well.

The continuation of studies initiated as part of the 208 Program, including further monitoring and data analysis, is needed to provide essential information in several general areas, including hydrogeologic relationships, correlation between population density and groundwater quality, organic chemical and other contamination of groundwater, and viruses in aquatic systems.

The establishment of demonstration projects is needed to test promising pollution control techniques and to permit the further refinement and development of cost-effective, environmentally acceptable recommendations for incorporation in 208 plans as they are updated in the future. Among these are the water quality impacts associated with street vacuuming and subsurface denitrification.

Research is needed to identify the intermedia impacts of air pollution on wastewater management options and of wastewater management options on air quality, and to permit an evaluation of the nitrate standard for drinking water.

The following brief descriptions indicate the general nature of the proposed studies or projects, the agency or level of government capable of undertaking responsibility for or actually performing the work, and estimated costs, where appropriate.

5.5.1 Continuation of Regional Studies

5.5.1.1 Further Definition of Groundwater Management Zones. The boundaries of the groundwater management zones shown in Figure 3—2 depend, in many cases, on a distinction between areas where recharge from

the land surface generally enters either a shallow or deep flow system. In many areas, recharge to the deep flow system implies recharge to the Magothy aquifer. In the so-called shallow flow systems, the depth of flow is generally restricted to a depth of one to two hundred feet. The zone boundaries as mapped are based on existing data and are only approximate. In many cases, the distinctions between these systems is often not clear and distinct. Since a number of important wastewater management decisions may be based on these flow relationships, it is recommended that further investigations be initiated. The studies of the groundwater flow systems in and around the zone boundary lines should be conducted first on a sub-regional basis in areas where a major wastewater decision is expected in the near future. For example, it would be desirable to investigate those regions where large-scale sewering or development is proposed.

In southwest Suffolk County, it is expected that many of the questions regarding depth, direction and rates of groundwater flow will be answered as part of the proposed stream augmentation feasibility study. In order to answer the critical questions in any area, it will be necessary to drill and construct a series of wells and piezometers screened at different depths. These would be designed to (1) locate and define the extent of any confining clay layers such as the Gardiners Clay, which separate the shallow and deep aquifers; (2) map the direction of groundwater flow under existing conditions by measuring water levels at various depths; and (3) obtain water samples from various depths to see if hydrogeologic factors are providing any protection to the deeper aquifer. In addition, a number of pumping tests would be conducted at various depths to evaluate the hydraulic connection between the shallow and deep aquifer systems and to examine the effect of any confining clay layers.

This approach to the definition of groundwater flow is similar to that attempted in many of the USGS Water Supply Papers of past years. However, the USGS was forced to rely on existing data that, generally, was adequate only to define gross directions of flow. Data from such an investigation could provide considerable insight as to the possible benefits or adverse effects associated with a particular wastewater decision. For instance, it would be very useful to know if groundwater contamination resulting from large-scale development of an area would be likely to affect drinking water supplies or shallow groundwater discharges to streams and bays. In addition, it would be useful to have a clear picture of what portions of the groundwater reservoir might benefit from sewering or non-point source controls.

The regional digital model developed as part of the 208 can be modified, updated and calibrated using the new information developed from the sub-regional investigations. In this way, the model may be used to aid in evaluating 201 wastewater management decisions, especially in relation to overall options for the bi-county area. The extent and cost of such an investigation would vary considerably, depending on the size and location of the area to be studied. It is estimated that for a large sub-region such as the Smithtown-Port Jefferson area, perhaps a dozen or so piezometers or well clusters would be necessary. The cost of such a program, including drilling, testing and hydrogeologic investigation would probably be about $400,000 for a single sub-region. This is a small fraction of the cost of any large sewering or development program. Digital modeling, where necessary, may cost an additional $200,000. The Regional Planning Board and/or the counties should be responsible for this work.

5.5.1.2 Application of the Regional Digital Models to Evaluate Region-Wide Effects of Man-Induced Changes in Groundwater Elevations. Groundwater elevations fluctuate due to natural and man-induced changes in recharge and groundwater pumpage. Declines in groundwater levels can adversely impact water supply, fresh surface waters and groundwater level dependent ecosystems. Some research is currently planned to evaluate these impacts in selected 201 areas. However, evaluations of these impacts is needed on a regional basis.

Specific research needs include utilization of the regional digital groundwater model to determine the regional response of groundwater levels to (1) groundwater pumping alternatives, (2) changes in stormwater recharge, and (3) sewering alternatives. The results of this work should lead to recommendations for groundwater elevations. The estimated cost is $300,000. The Regional Planning Board and/or the counties should be responsible for this work.

5.5.1.3 Detailed Mapping of Land Uses, Natural Resources and Environmental Constraints for the Deep Flow Aquifer Recharge Area. Existing land use maps and tabulations for the deep flow areas, although adequate for general planning purposes, do not provide the detailed resolution most appropriate for local as opposed to areawide wastewater management. Natural resources and environmental constraints maps are currently unavailable. Maps similar to the detailed land use, natural resources and environmental constraints maps already prepared for the coastal zone are needed for further implementation of the chosen wastewater management strategies, particularly those relying on non-structural approaches to the prevention or mitigation of non-point pollution. Data collection, interpretation and mapping should be undertaken by the Nassau-Suffolk Regional Planning Board. The task is expected to take one and one half years. The estimated cost is $400,000.

5.5.1.4 Extent and Causes of Organic Chemical Contamination

a. *Inventory of Organic Chemical Sources.* Organic chemicals are an important contaminant of the Long Island aquifers. Efforts to formulate a control strategy are hampered by a lack of data concerning sources. Thus, a complete inventory is required. This inventory should cover (a) industrial point sources, (b) waste water treatment plant effluents, (c) runoff recharge, (d) landfills and hazardous waste facilities, (e) domestic non-point sources and (f) industrial non-point sources. The inventory must present estimates of mass loading per unit time for all of the contaminants occurring in groundwater at ten micrograms per liter. Nassau and Suffolk Counties should undertake this work. The counties should also continue their sampling for organic

chemicals in the Magothy aquifer. The estimated cost of this work is $350,000.

b. *Organic Chemical Sources—Landfills, Waste Water Treatment Plant Outfalls, Runoff Recharge Basins.* On the basis of preliminary findings, all three of the above listed pollutant sources appear to be significant with respect to organics. The three should be similarly characterized if identified by the organics source inventory. Characterization of sources will require collection of a number of samples, defined by a source-specific sampling plan, with several replicates for each sample. The effort should be undertaken by Nassau and Suffolk Counties. For each source studied, $50,000 is required.

5.5.1.5 Evaluation and Monitoring of the Movement of Heavy Metals and Organic Chemicals in the Aquifer System.

The discharge of untreated and treated industrial and domestic liquid wastes to septic tanks, cesspools and recharge basins has been an accepted disposal practice in Nassau and Suffolk Counties. Many of these waste streams contain small concentrations of heavy metals and organic chemicals that are considered hazardous. In addition, studies undertaken as part of the Long Island 208 investigation have shown that other sources of hazardous substances also exist in the area. Some spills and incidental discharges at industrial and commercial facilities and along transportation routes also contain heavy metals and organic chemicals.

Significant discharge of such pollutants to the ground has been occurring on Long Island for decades. Because of heavy groundwater withdrawals and the resulting pumping patterns, the migration of pollutants from the surface into the deeper aquifers presently used for public water supply may be accelerating. Monitoring to date has already shown their presence in deeper aquifers, and this has led to restriction of the use of some wells in various parts of the two counties.

There is a definite need for more complete evaluation and monitoring of the movement of heavy metals and organic chemicals throughout the aquifer system underlying the Island so that an assessment can be made of the long-term threat to continued use of groundwater in critical water supply areas. At the present time, monitoring programs are incomplete from the standpoint of serving as a warning mechanism on the vertical and lateral migration of hazardous chemicals. It is not known, for example, whether shallow untapped aquifers contain high concentrations of heavy metals and organic chemicals that may in the future move into the deeper, heavily pumped, aquifers. If this were to occur on a broad scale, the results would be a significant reduction in the availability of potable groundwater in the Region.

The Nassau-Suffolk Regional Planning Board and the two counties should be responsible for the work, which is expected to take one and one-half years. The estimated cost is $750,000.

5.5.1.6 Assimilative Capacity of Subsoils. Measure and determine the saturation capacity, and whether a substantial difference exists between assimilative or absorptive capacity of different soils in various formations, and determine the limits of these natural treatment processes. The ability to predict saturation levels of various subsoils would aid greatly in the planning of recharge facilities and water supply systems. The information gathered could become an integral part of the groundwater quality model developed in the 208 Program. The soil columns findings could be used in conjunction with viral, organic chemicals, heavy metal studies, etc. The Suffolk County Department of Health Services should undertake a two year study. The estimated cost is $75,000.

5.5.1.7 Determination of the Impact of Leakage and Spills from Hazardous Materials Storage and Transport, and Identification of Best Means of Control. Sufficient evidence already exists to indicate that leakage of materials such as gasoline, fuel oil, solvents and chemicals into the groundwater from storage and transport facilities constitutes a major pollution problem that must be controlled. A study is needed to further define the problem and to provide the information necessary to develop legislation for control. Once regulations exist, enforcement will proceed involving extensive testing and inspection of tanks and pipelines with repair, improvement or replacement as needed. This will also lead to the discovery of existing pockets of contamination and subsequent clean-up operations. This study and the resulting regulating activities can be carried out by the Nassau County Department of Health in Nassau and by the Suffolk County Department of Environmental Control in Suffolk, with the addition of adequate personnel and equipment. The study will take two to three years. Estimated cost is $320,000.

5.5.1.8 Measurement of Groundwater Underflow Quantity and Quality and Impacts of Duck Sludge Deposits. Groundwater has been shown to be a major source of nitrogen to systems such as Great South Bay and Flanders Bay, where long residence times allow buildup of the nutrients to signifianct levels. Due to the typically good flushing of the North Shore bays, groundwater sources are fairly insignifiant there, compared with the boundary water quality effects of Long Island Sound. Presently, there are no data on actual quantity or quality of groundwater underflow through the bay bottoms. Values for flow quantities used in model calculations were based indirectly on estimates from the USGS groundwater analog modeling efforts, whereas quality was estimated indirectly through historical well sampling landward along the shoreline.

Millions of cubic yards of duck sludge have accumulated in portions of Moriches and Flanders Bays as a result of decades of duck farm operations. Virtually no data exist, however, to establish whether or not the old sludge represents a bacterial or nutrient source. Waste management alternatives currently being formulated for Flanders Bay assume zero discharge from duck farms by 1981. The question of residual loadings from the old sludge deposits remains, however, and cannot be factored into waste load allocations to the bay. In Moriches Bay, where the deposits are most extensive, it has not been possible to estimate nutrient loadings from the sludge deposits.

Recently, a method utilizing enclosed chambers has been devised for directly measuring groundwater seepage rates through the bay bottom and the quality of that groundwater. It is now felt that, since a method for direct measurement is available, such a study would be feasible and practical in assessing groundwater influence and duck sludge influence on bay water quality. Since this type of study should be handled on a regional basis throughout the South Shore bays and in the Peconic Estuary, it is recommended that the Nassau-Suffolk Regional Planning Board and the two counties be responsible. The cost of one summer's field effort for this study would be apporximately $75,000.

5.5.1.9 Determination of the Effects of Inlet Closure on the Water Quality of Moriches, Shinnecock and Mecox Bays and of Inlet Creation on the Water Quality of Eastern Great South Bay. Historically, Moriches, Shinnecock and Mecox Inlets have had a significant impact on water quality within these bays. At present, Moriches Inlet is reported to be closing up, which means that ocean flushing of contaminants will become greatly retarded in Moriches Bay. Considering that water quality conditions are already stressed in Moriches Bay with an open inlet, and in the interest of preserving the high quality of Shinnecock Bay waters, modeling of the two bay systems to allow selection of alternative solutions (such as maintaining the inlets) is recommended. Similar studies should be conducted for Mecox Bay, to determine the water quality benefits of maintaining a permanent inlet.

This modeling study would follow much the same procedure as for the South Shore bays west of Moriches Bay under the Nassau-Suffolk Regional Planning Board 208 Program.

An additional item of interest to wastewater management in this area is the alternative of creating a new inlet through the Fire Island barrier beach in eastern Great South Bay. Such an inlet, if determined feasible, would relax restrictions on point source waste loads within eastern Great South Bay by increasing the ocean flushing of this area. An integral part of this study would include an environmental assessment of the resulting changes in salinity.

Ideally, all of the above problems should be studied simultaneously, since there is considerable hydraulic interface between eastern Great South Bay, Moriches Bay and Shinnecock Bay. A modeling study to address these problems would involve design of monitoring programs, waste source inventory and load estimates, model set up, calibration, verification and calculation of alternatives. Most of this work is completed for the area west of Moriches Bay and could be adapted directly to the study. Such a program could be carried out by the Nassau-Suffolk Regional Planning Board and the two counties. An estimate of the cost for such a program is $300,000.

5.5.1.10 Fertilizer Research. Fertilizers have been identified as significant contributors to Long Island water quality problems. Two research projects should be initiated in order to resolve questions relating to fertilizer use and water quality.

a. *Fertilizer-Nutrient Balance.* The fate of fertilizer nutrients applied to Long Island's agricultural crops (potato, vegetable, nursery, orchard and sod) is understood to some degree. However, there are many variables that influence the movement and ultimate disposition of the nitrogen and phosphorus during and after the growing season. Crop uptake of nutrients varies with the life cycle of the plant. Precipitation patterns during the growing season influence the extent to which nutrients are washed from the surface and leach through the soil profile. Precipitation after the harvest, especially during periods of high runoff when the ground is frozen, may transport the residual nutrients to surface waters. Soil characteristics such as texture, depth and slope also affect the washing and leaching of fertilizers. The timing and method of fertilizer application (broadcast or sub-surface bonding) with respect to the crop requirements, root system and climatic conditions, influences the paths of nutrient transport. Extensive studies to assess the influence of such characteristics on potato crops have already been completed. Further research is now required for other crops and turf to develop a nutrient balance model identifying the nutrient uptake by type of crop, the nutrient leaching through the soil and the nutrient loss associated with stormwater runoff. Investigations using replicate plots to permit evaluation of variations in fertilizer application should be continued year-round for a period of at least three years.

b. *Fertilizer Formulations.* The control of fertilizer-related pollution of ground and surface waters in urban and suburban areas, especially in western Long Island, is largely dependent upon the success of educational efforts since the regulation of lawn fertilizer application practices is not considered feasible at this time. Identification of a relatively non-polluting fertilizer formulation would be a useful adjunct to an educational program.

Organic fertilizers are known to release nitrogen more slowly than inorganic fertilizers. However, local field testing is required to determine whether, and to what extent, the use of organic based nitrogen fertilizers can reduce water pollution on Long Island.

A research program should be developed in which various formulations of fertilizer would be applied to replicate plots of turf. Leachate and stormwater runoff nitrate concentrations, and crop uptake of nitrates, should be determined in order to evaluate the pathways of nitrogen transport and the availability of nitrogen throughout the growing season. Also, the feasibility of recycling existing sources of nitrogen, such as sludge from domestic sewage treatment, should be rigorously explored.

Cornell University should act as lead agency for the above studies, which could be carried out in cooperation with the U. S. Geological Survey and the Suffolk County Department of Environmental Control. Total estimated cost is $100,000.

5.5.1.11 Groundwater Screening for Aldicarb. Aldicarb has been identified as a potential groundwater contaminant. A separate program to look specifically for Aldicarb in groundwater underlying farm areas should be undertaken. New York State should assume responsibility for this work,

which could be carried out by Cornell University-Cooperative Extension Service. Estimated cost is $25,000.

5.5.1.12 Heavy Metals in Sediments. Generally, metals in marine, fresh and groundwater are rapidly adsorbed onto sediments. Major metal pollutant problems have tended to arise from accumulation of metals in the food chain where there is a high metal level concentrated in sediment or water column. Such a situation may occur when sediment metal levels are high and members of the food chain are detritus feeders. Thus, sediment metal levels should be monitored. Such data is lacking for the Long Island bays, and a program should be instituted to obtain it. The work should be undertaken by Nassau County Department of Health, and the Suffolk County Departments of Health Services and Environmental Control, and is expected to cost $125,000.

5.5.2 Demonstration Projects

5.5.2.1 Marsh-Pond Treatment of Sewage. The marsh-pond approach to sewage treatment should be tested at a full-scale installation where it will receive the normal amount of operational attention. The proposed program at Greenport should be encouraged and supported and a similar program instituted elsewhere if the Greenport program is not implemented. The Nassau County Department of Public Works and the Suffolk County Department of Environmental Control should have the responsibility for a two year study. Estimated costs are $100,000.

5.5.2.2 Marsh-Pond Treatment of Runoff. The Nassau-Suffolk 208 Study has identified a number of point sources and non-point source stormwater runoff as significant contributors of pollutants to both surface and groundwaters. The main problem in treating these pollutants arises from the facts that:

a. small point sources are widely dispersed and may involve effluent volumes too small to justify transportation to and disposal at a large regional or subregional wastewater treatment plant; and,

b. stormwater runoff is characterized by highly variable frequencies, volumes, duration and pollutant loadings.

The solution to these problems would be a system that could be scaled for various effluents and volumes, which would be relatively inexpensive to install, have low maintenance and allow discharge of the polished effluents to either ground or surface waters.

Systems such as the marsh-pond form are presently being evaluated on a small scale, primarily for wastewater renovation. However, it appears that they may also provide satisfactory treatment for stormwater runoff prior to recharge or disposal to surface waters. Therefore, projects utilizing the marsh-pond approach should be set up at two existing recharge basins in order to ascertain the degree to which this treatment can improve the efficiency of the basins. Treatment efficiency should be compared to that of two other existing basins that do not employ marsh-pond treatment. Efficiency, in each case, should be determined on the basis of the quality of the recharge water leaving the basin. Particular emphasis should be placed on the removal of heavy metals and organic chemicals. The Nassau County Departments of Health and Public Works, and the Suffolk County Department of Environmental Control should be responsible for the project. Estimated cost is $200,000.

5.5.2.3 Street Cleaning. Two projects should be established to determine the costs and identify the effects of street sweeping/vacuuming programs. A North Shore and South Shore area should be selected in order to permit observation of the effect of topographic influences. Various street sweeping and street vacuuming programs at different frequencies should be studied. The magnitudes of reduction of total annual loads as well as load reductions for individual storm events should be determined. The Nassau County Departments of Health and Public Works and the Suffolk County Department of Environmental Control should be responsible for the project. Estimated cost is $200,000.

5.5.2.4 Structural Treatment of Stormwater Runoff. Structural treatment, employing settling and the swirl-concentrator type of approach, should be evaluated. In addition, the efficiency of treatment by natural impoundments should be analyzed and compared to that of settling basins constructed specifically for the purpose. The Nassau County Departments of Health and Public Works, and the Suffolk County Departments of Environmental Control and Public Works should be responsible for the project. Estimated cost is $2,500,000.

5.5.2.5 Comprehensive Monitoring as an Aid in Making Wastewater Management Decisions. It is recommended that, prior to general implementation of comprehensive monitoring systems, immediate steps be undertaken, in coordination with ongoing 201 investigations, to develop a monitoring system in an area where a decision is pending on sewering and/or non-point source controls. This should be in an unsewered area that has been developed for at least ten years and has a population density of between five and nine persons per acre. The objective of such a demonstration monitoring system would be to establish the sampling frequency, number and spacing of wells and data reduction techniques that could be used as guidelines for subsequent 201 Studies, and for newly developing areas.

In the initial planning of this prototype, considerable attention would be paid to planning the system according to the statistical objectives of the study; that is, to obtain a good estimate of the average shallow groundwater quality and to define the time and spatial variability of selected constituents, particularly nitrates. Analyses have already been conducted within the 208 Program that could aid in planning those systems. The planning, drilling, sampling and analytical techniques developed during this demonstration study could then be used in future programs.

It is estimated that a study of this type would take about one year to complete. Assuming about twenty-five shallow wells were needed, the cost of the total program, including planning, drilling, sampling, analytical work and

data reduction, would probably be about $150,000, and should be conducted by the Nassau County Departments of Health and Public Works, and the Suffolk County Departments of Health Services and Environmental Control.

5.5.2.6 Denitrification of Individual Subsurface Sewage Disposal Facilities. One of the major causes of the increases of nitrate-nitrogen concentrations in groundwater has been attributable to the leaching and subsequent oxidation of ammonium laden wastewaters from the many thousands of cesspools. The Suffolk County Department of Health Services is currently investigating nitrate removal in a subsurface individual sewage disposal system. This program is designed to eliminate nitrates from this source. The experimental unit that has been installed uses methanol in the denitrification phase. The Department is interested in denitrification methods that would not require the homeowner to replenish the methanol, as is required by the present system.

Since it has been demonstrated by the Suffolk County Department of Health Services that denitrification of nitrified septic tank effluent can be achieved under controlled conditions in the ground below a conventional leaching field, steps should now be taken to set up demonstration installations in various parts of the county. Upon the successful completion of these demonstration projects, these systems could be installed as needed throughout the Region. Suffolk County Department of Health Services should undertake a two year project. Estimated cost is $110,000.

5.5.2.7 Removal of Nitrates from Drinking Water Supplies. A number of our public water supplies are experiencing problems as a result of increasing nitrate-nitrogen concentrations in the groundwater supply. The primary cause of these contaminants in some areas has been attributed to the leaching of nitrate fertilizers applied to farms and, possibly, lawns. The Suffolk County Department of Health Services has undertaken a project to perfect means for removal of nitrate contaminants from groundwater to be used for public water supplies. This would be accomplished by a biological denitrification anaerobic filter using methanols or sugar for bacterial activities. This would be treated at the wellhead, followed by rapid sand filters for removal of solids carried over, then followed by disinfection.

The study has progressed to the point of developing laboratory scale systems to investigate various parameters for design. The correlation in the laboratory findings will allow for the development of a pilot scale operating denitrification plant. The construction of a pilot scale operation for denitrification at the wellhead should be continued and, if successful, should provide solutions in areas affected by high nitrates. The Suffolk County Department of Health Services should undertake this project. Estimated cost is $450,000.

5.5.3 Research

5.5.3.1 Viruses in Aquatic Systems. There are no established standards for viral pollution levels in aquatic systems. Reasons for this include sampling difficulty, the lack of a standard method for enumeration and identification of species, and the lack of epidemiological data concerning waterborne transmission of the many viral groups. The study recently undertaken as part of the 208 Program just touched upon the Enterovirus group as it was found in various aquatic systems. However, no information was gathered on non-Enterovirus species, which may also be found in sewage polluted systems.

The following viral studies are needed in order to establish the magnitude of the problem and to permit formulation of appropriate control programs:

a. *Determination of the Significance of Non-Enterovirus Groups such as Adenovirus, Reovirus, Rotavirus and Norwalk Agents in Long Island Aquatic Systems and Wastewaters.* This study will help to quantify non-enterovirus groups, and to identify their sources, in order to assist in the development of control programs.

b. *Determination of the Epidemiological Significance of Human Viral Carriage by Shellfish Taken From Long Island Waters.* Such a study could help to define the problem, identify specific sources and sectors, and permit the formulation of control programs. It might also help to determine whether public health would be better served by the use of shellfish standards, related to the presence of viral agents or other types of indicators, rather than to coliform bacteria.

c. *Determination of the Movement of Virus Particles through Long Island Sub-Soils.* This would assist in the evaluation of standards for the location of wells, recharge basins, etc. and would confirm or refute the current belief that viruses emanating from sewage treatment plants and recharged would not have impact on groundwaters.

These studies should be the responsibility of the Nassau County Department of Health and the Suffolk County Department of Health Services. The cost is estimated to be $450,000.

5.5.3.2 Air Pollution and Wastewater Management (Intermedia Study). Wastewater management is affected by and affects air quality. The following studies can be expected to improve understanding of these relationships and to permit more informed, cost-effective and environmentally acceptable choices among waste management alternatives.

a. *Effects of Air Pollution on Water Quality.* Air pollutants can contaminate rainwater, and thus add non-point pollutant loads to bays and groundwater. To evaluate this problem, a rainwater sampling program is required. A series of samples of rainwater for various recharge areas on Long Island should be studied. These samples should be analyzed for nutrients, metals and organic chemicals.

b. *Effects of Wastewater Treatment on Air Quality.* Incineration, co-incineration, pyrolysis and land application of sludges all have the potential to introduce air pollutants. Standard loading coefficients exist to evaluate expected load per year per quality of sludge. An air quality dispersion model and loading coefficients for other air pollutant sources are both required as

task inputs. The air quality model can then be run for various water quality management and sludge disposal scenarios.

These studies should be undertaken by the Nassau County Department of Health and the Suffolk County Department of Health Services. Total cost is estimated to be $300,000, of which task a. will require $60,000 and task b. $240,000.

5.5.3.3 Evaluation of the Nitrate Standard for Drinking Water. The United States Public Health Services' drinking water standards established in 1962, set a maximum of 45 milligrams per liter nitrate as NO_3 (equivalent ten milligrams per liter as nitrogen). This has been questioned by a great number of eminent scientists. E. F. Winston in 1970 reported that much data did not support the low standards and recommended additional research. In the last five years several studies have been performed which show that relatively high nitrate concentrations in drinking water do not constitute a health hazard. There has not been a reported fatality due to methemoglobinemia in the past seventeen years. Few, if any, cases of methemoglobinemia have been reported in the United States where the water comes from community water supplies. The World Health Organization recommends eleven parts per million nitrate-nitrogen with a maximum of 22 parts per million nitrate-nitrogen. Since a number of researchers have questioned the existing standards and since the World Health Organization has taken steps to change these standards and because of their serious implication on our groundwater supply, we recommend that the EPA systematically review this entire question, taking advantage of all the most recent studies, and update their current standards.

6.0 Introduction

This section is written in two parts. The first part, 6.0–6.5 discusses several generalized approaches to citizen participation, the particular method used in this 208 Study, some of the problems experienced during the conduct of the Program, and a recital of a specific success achieved by the citizens that proved the efficacy of having an active Citizen Advisory Committee (CAC).

The second part, 6.6–6.11, was written by the CAC and is their appraisal of the planning alternatives prepared by the 208 Study.

Governmental decisionmaking in the United States is generally based on the notion that in a federated republic the elected representatives shall act as surrogates for the citizens. The ballot box serves as the arbiter of how well the 'voice of the people' is heard. Even communities with strong attachments to the colonial home-rule town meeting format honor the concept of citizen participation in theory—not in practice. Of course, special interest groups have had access to the process by the use of lobbying, or in more limited instances seeking recourse through litigation. Either of these means is substantially limited to those individuals or organizations with sufficient financial support to wage a successful campaign.

The Johnson Administration formalized the concepts of 'participatory democracy' by mandating citizen participation in much of the domestic legislation.

A recital of the decade's short history of these efforts is one of limited success. Governmental access was made possible to a small number of publicly or politically oriented individuals who were locked out of the traditional political routes to power.

Despite some of the early creakings and groanings of disenchanted citizens, frustrated technicians and concerned politicians, the Congress has been increasingly mindful of the benefits to democratic mythos if workable citizen participation could be achieved. A strong factor was the need to recognize and respond to the growth of consumer, environmental and social planning advocacy organizations. The common thread linking these diverse groups in common allegiance was their adversary posture towards government. The common credo was simple. Each of the loose constituencies affected by governmental actions, or inactions, relative to their interests, argued that they were not able to secure relief because the government represented the "establishment" rather than the citizenry. A solution to such unresponsiveness was to use public interest lawyers to direct litigation against governmental programs and actions.

An obvious alternative to such confrontation politics is to render government more responsive by greater citizen involvement. This choice appears to be the conscious committment of Congress, specifically in domestic legislation relating to community planning, environmental and social issues.

6.1 Participation Models

The regulations prepared to implement the 1972 Amendments to the FWPC Act mandated citizen input in Section 208 planning efforts. The regulations do not, however, describe or define how such participation is to be structured, selected or operated. Unfortunately, there were no earlier examples to rely on.

Historically, professional planners have often acted as the surrogates for the public interest. In this model, technical discretion is assumed to define and prescribe the means of planning actions, but not the ends. This invariably resulted in 'shelved' planning proposals.

A second and perhaps more successful one is one in which the planners select and define the means, and also assume the responsibility of clarifying the ends. In this instance the planner presumes to know the needs of the public, but also the manner in which these needs are to be fulfilled. British town planning and implementation is a notable example of this approach.

A third and more sophisticated model involves the planner in the role of arbiter or mediator, whereby the planner has the discretion to set forth the means and to recommend the ends—so long as a feedback mechanism is operational between the planners and the actual providers and consumers during the plan formulation. In this case the planner mediates between the governmental power structure and the diverse interests among the body politic.

Since planning is essentially a governmental function, it must provide a broad and desirable rationale for attracting and holding the support of political leaders, appointed officials and the general citizenry. The appeal must be broad to cover the multitude of aspirations of such diverse groups. Obviously, the process itself, aside from the technical aspects, is basically a political activity.

6.2 Organizational Activities

The Nassau-Suffolk Regional Planning Board at the onset faced the issue of how best to meet the requirements for citizen participation. The literature and our own experiences were reviewed. It was soon evident that a new approach was needed. The earlier examples of limited or appointed citizen representation could not provide the broad inputs required for a program as complex, as costly, and as potentially unpopular as we expected wastewater management planning to be. The only guidelines were that the effort had to be as open and representative as possible. This meant that some of the approaches such as the appointment of select and elite "citizen" representatives or the hiring of a consultant to "organize the public" were to be avoided. Instead, the Board advertised widely in the press and radio media that this new program was in the organizational stage and that anyone interested in the issues of maintaining the quality of the potable and swimming waters of Long Island should attend an informational session. In addition, over 300 letters were sent to anyone who had ever contacted the Board for information about any matter related to water conservation, pollution, and/or wastewater management. In particular, the Board strove to identify those respondents whose views were antagonistic to prior governmental programs. All local governments were similarly notified about the impending project. At the conclusion of the open meeting attended by over 100 people, approximately 60 persons volunteered to participate.

At the organizational meeting the staff briefly outlined the purposes, duration and anticipated outputs of the program. The citizens were informed that the Board would prefer to have the chairman of the Nassau-Suffolk Regional Marine Resources Council serve as the non-voting chairman for the CAC. This was to insure impartiality in the conduct of the meetings and to avoid jurisdictional maneuvering over the position. The citizens were informed that the rest was entirely up to them. After a brief discussion they concluded that they would prefer a structured organization rather than an open-ended one. They agreed to meet every second week and to form subcommittees as necessary with additional meetings to occur as required. Within one month's time, the formal structure was accomplished. Ten categories of representation were selected. They included: the academic community, agriculture, business and industry, civic associations, disadvantaged citizens, environmental/conservation, government, labor, the Long Island Water Conference, and recreation. Committees were set up in each of these categories from the representatives who agreed to convene a caucus for each grouping on a regional basis, for the purpose of having each group vote for two voting members and alternates for each category. This was accomplished within one month's time. In concept the CAC had the freedom to establish its agenda, prepare and publish a newsletter on 208 activities, and to react and furnish input into the technical work conducted by the Technical Advisory Committee (TAC) as the program was carried out. The CAC, in order to foster the widest possible public information program, also agreed to inform their constituents on a regular basis as to the progress of the planning effort. In theory, the CAC should provide the widest possible dissemination of findings; and receive feedback from the general community. However, as important as *citizen participation is, it must* be kept in mind that the concept of *universal* civic participation should not be over-romanticized nor be expected to be achieved. Anyone with experience with any type of voluntary organization soon realizes that a relatively small number participate in the decisionmaking role beyond the selection of officers. This is but one of the problems inherent in the very nature of participatory democracy. As the activities of the CAC began to mesh with those of the TAC, other problems soon became apparent.

6.3 General Problems

The CAC, being representative of a broad variety of interests and differing levels of technical competence, gave rise to a set of circumstances that surfaced to the frustration of citizens and technicians alike. For example, in

order to assure a working partnership between the TAC and the CAC, it was agreed by the TAC to furnish all technical materials prepared by consultants or staff to the CAC as the material was developed. Theoretically, this was to serve two purposes: to bring the knowledge level of the CAC abreast of the activities of the TAC; and also to receive commentary and input from the citizens' point of view.

It was soon discerned that there was no happy medium in the manner of presentation. Initially, the technicians presented their findings in common language which was resented by those citizens with technical backgrounds who felt they were being talked down to. In response, further presentations were given identical to those presented to the TAC. This produced objections from the non-technicians on the CAC. There also arose a set of problems having to do with role consciousness. Many of the citizen participants joined the CAC because of their very deep and abiding concern with water conservation and wastewater management. They perceived themselves to be knowledgeable and, in fact, were, in most instances. Therefore, there was some chagrin and frustration with the TAC's scientific approach in trying to build the case 'one brick' at a time. Some of the citizens felt that the desired solutions were obvious. Other impatience was evidence of the fear that the technicians would merely produce a "plumbers approach" to wastewater management. They did not quite trust governmental technicians to be truly comprehensive, and to consider the broadest array of alternatives. In fairness, the TAC had as many misgivings about citizen participation as the citizens had about them.

As the program moved foward, another more subtle problem began to appear. The very matter of working together tended to produce an element of co-optation. The TAC perhaps over-reacted in its desire to indicate that nothing was being held back, and strong signs of growing trust between the two groups began to emerge. The potential danger in this growing harmony was that one of the prime roles of the CAC, namely to be objective critics, might have been weakened. This possibility of co-optation, however, was successfully resisted by the citizens.

The process of trying to meld so many personalities into a productive and positive process should not be construed negatively despite the recital of problems. On balance, the problems have been minimal in contrast to the merits and benefits that have already occurred. One of the more noteworthy examples follows.

6.4 A Success Story

Shortly after the inception of the 208 Program on Long Island, the CAC raised the question of why viral studies were not included within the approved scope of services. They were informed by the Director, that in fact the initial application to EPA did include such work prior to the formal establishment of the Program. This segment was not approved, since viral studies were considered to be of a research rather than applied status due to the relative embryonic state of the art. Thus, they were ineligible according to the guidelines for the program, which prohibited research projects.

The concerns voiced by the citizens, who in part joined the Program to promote recharge as a viable alternative to ocean disposal of sewage effluents, included the essential need to understand and assess the potential constraints against recharge.

They did not accept the EPA ruling that viral sampling and analysis was properly categorized as research, and therefore beyond the scope of the Long Island program. They demanded that discussions be held by the CAC and representatives from EPA to demonstrate their support of the expurgated viral section of the original application. A sub-committee was formed to meet with the two County Health Commissioners in the hope of securing professional concurrence and support. These activities took place during June and July, 1975.

By July 7, 1975, the sub-committee reported to the CAC that strong support was guaranteed. They further recommended that the CAC request the scope of services be amended to include virus studies and that funds be ear-marked for this purpose. The resolution adopted by them was forwarded to the TAC who responded favorably, subject to approval by EPA. However, it was stressed that the chances for approval appeared slim.

The CAC then invited Dr. James Vaughn, a noted virologist from the Brookhaven National Laboratory, to address the group. He accepted, and in his presentation he discussed the state of the art referring to work in other parts of the country, and further elaborated on the analytical processes used at the Laboratory to concentrate viruses. At the conclusion of his talk the CAC by resolution directed their chairman to request that a formal application be submitted to EPA.

As a result of their vigorous pursuit of the issue, the EPA agreed to conduct limited viral investigations. This response was received by August 4, 1975. By the following week Dr. Vaughn submitted a proposal to the TAC, with a cost estimate of $60,000. After a number of working sessions between Dr. Vaughn and the TAC with continuous feedback and response from the CAC, and subsequently similar meetings with the TAC/CAC and EPA, a formal application was submitted to EPA on March 12, 1976. An affirmative response was quickly received from EPA on April 27, 1976.

It is absolutely clear that the motivating force in securing approval for this integral portion of the 208 Study must be attributed to the strident efforts of the CAC. Subsequent to this experience, additional modifications have been made to the program at the initiative of the CAC. This included investigations of the presence of heavy metals and trace organics in the aquifers of Long Island. Beyond any question the citizens dared to challenge Federal rulings, and succeeded in doing the undoable. This accomplishment alone merited the difficult marriage between technicians and citizens.

6.5 Conclusion

Planning, as carried out in the context of this discussion, involves mediation between diverse groups and individuals who seek to influence land use and other policy decisions. Planning technicians conduct such mediation within the governmental framework and among the public at large. Thus, planning must be understood to be fundamentally a political activity. It is political in the following ways: It is a governmental process presumably set up to formulate and execute policy on land use activities. Administratively, most planning agencies are part of the executive branch of government. The interactions between planners and private citizens require mediation and compromise—the very essence of politics.

This reality is not necessarily negative. The crass aspects of partisan politics do not have to be the controlling factor. To the contrary, partisanship should be strenuously avoided. Politics herein, is held to be the conduct of the public business in non-partisan fashion, or perhaps more accurately stated, multi-partisan fashion. However it is viewed, planning will be more successful if it is conducted *with* the public involved, rather than *for* the people. The correctness of including public participation in the planning process, as demonstrated by the experiences on Long Island, is seen in several ways. Staff and citizenry have more access to the interests of the general public. This is invaluable for goal formulation, project design, and in selecting the most suitable plans. It should promote greater identification and hopefully a 'pride of authorship' on the part of the public with the plan. It may also help to mobilize resources and support by fostering mutual trust and understanding, particularly in instances where tradeoffs have to be made. In addition, continuous evaluation of the plan and its implementation will be encouraged by all who had a role in the plan's formulation.

Hence, public participation makes the planning process more responsive, more democratic, and often more comprehensive.

6.6 CAC Organization

"Public participation in the development, revision, and enforcement of any . . . plan or program established . . . under this Act (Federal Water Pollution Control Act Amendments of 1972) shall be provided for, encouraged, and assisted by the Administrator (of the U.S. Environmental Protection Agency) and the states." This quotation from Section 101(e) of the FWPCA is not only a statutory mandate that public participation be an integral part of water quality planning, but an opportunity as well for citizens to have a voice in the development and implementation of local wastewater management policies and decisions.

Thus, one of the first steps taken in the Nassau-Suffolk 208 Study was the estbalishment of a means whereby citizens could play a meaningful role in the planning process. This resulted in the creation of a Citizen Advisory Committee, the activities and views of which are the subject of this discussion.

It was decided to establish voting membership positions for ten different interest groups and constituencies as follows:

- —*Academia* (representatives of area colleges and universities)
- —*Business* (representatives of the business-industrial community)
- —*Citizen Associations* (representatives of such organizations as the League of Women Voters)
- —*Environmental Conservation* (representatives of such organizations as the Audubon Society)
- —*Local Government* (elected and appointed representatives of town and village governments, including planning departments)
- —*Labor* (representatives of organized labor unions)
- —*Recreation* (representatives of such recreational interests and activities as boating and fishing)
- —*Disadvantaged and retired citizens* (representatives of such organizations as the Long Island Council of Churches)
- —*Long Island Water Conference* (representatives of the water supply purveyors)
- —*Agriculture* (representatives of the Long Island Farm Bureau)

Each constituency selected two voting representatives and two alternates, with the exception of the Water Conference, which was allocated one voting representative plus two alternates.

The CAC Chairman was appointed by the Nassau-Suffolk Regional Planning Board and a Vice-Chairman was elected by the voting membership. Neither officer was granted voting privilege.

All CAC meetings were conducted in accordance with recognized parliamentary procedure. A quorum was understood to mean twelve voting members or designated alternates for policy issues and ten for non-policy matters. Non-voting members, of which there were about 25 at each meeting, were granted full floor privileges.

The CAC designated the first and third Mondays of each month at 5:00 p.m. in the Conference Room of the Dennison Building in Hauppauge as the time and location of regular meetings. A total of 75 meetings, most encompassing four hours, were held during the 30-month duration of the Study. Each meeting included a half-hour meal break with food provided by the Nassau-Suffolk Regional Planning Board. This break served as a "cooling off" and informal discussion period.

6.7 CAC Activities and Accomplishments

From the beginning, the CAC made its presence felt. It scrutinized every aspect of the Study and insisted on being kept informed of all developments.

1. The CAC reviewed the workplan which had been prepared by the Nassau-Suffolk Regional Planning Board and made meaningful suggestions relative to the direction and emphasis of the Study.

2. Concerned about the environmental and economic impact of any plan that might be proposed, the CAC helped draft the RFP (Request for Proposal) for the environmental/economic consultant.
3. The CAC questioned why the workplan failed to include a study to evaluate the presence of viruses in water and wastewater. The CAC argued that a lack of knowledge about viruses would limit the number of management alternatives, such as recharge, which could be considered. The CAC, with the help of the Regional Planning Board and the Technical Advisory Committee, was able to convince the U. S. Environmental Protection Agency to authorize and fund a viral study.
4. In a related matter, the CAC stressed the need for the analysis of samples for trace organics and heavy metals. Again the CAC succeeded in having these contaminants included in the sampling program.
5. The relationship of the 208 Areawide Planning Program to the 201 facilities planning provisions was yet another issue on which the CAC requested clarification. Concerned that the 201 Studies underway might contradict the recommendations of the 208 Plan being formulated, the CAC urged, without success, a moratorium on all 201 Studies until publication of the 208 Plan.
6. Throughout the 208 Study, the CAC requested and received various briefings from the technical consultants. Representatives of the CAC also attended meetings of the Technical Advisory Committee as observers, reporting back to the CAC.
7. Recognizing the need to keep the public abreast of the 208 Study and to encourage greater participation, the CAC initiated a public information effort early in the Program. Five newsletters, published at regular intervals, were compiled and distributed throughout the Region to local government units, planning boards and community groups. To assist in public understanding of the Plan, the CAC organized a speakers' bureau and prepared educational materials to be used at group presentations including a taped slide program and an informational flyer.
8. As the findings of the technical consultants were compiled, the draft reports were reviewed and discussed by the CAC and comments were forwarded to the authors. As a result of this evaluation, substantial changes were made in several of the interim reports.
9. The CAC also spent several meetings evaluating the concept and recommendations of the actual Plan. In connection with this, the CAC drafted and adopted a series of policy resolutions stating the consensus of the membership on key issues.
10. During the course of the 208 Study, Suffolk County considered discontinuing the annual funding of the groundwater monitoring program conducted by the U. S. Geological Survey. Recognizing the importance of this data for future wastewater management decisions, the CAC urged County officials to restore the funds.
11. Concern over the construction of sewage facilities in the Southwest Sewer District prompted the CAC to urge the funding of a stream augmentation feasibility study for mitigating the impact of reduced streamflows resulting from a lower water table. The CAC, on several occasions, voiced concern about the magnitude of the SWSD project.

6.8 Acknowledgements

The effective participation of citizens in the Nassau-Suffolk 208 Study through the Citizen Advisory Committee has been made possible through the support and efforts of numerous parties which the CAC hereby acknowledges with grateful appreciation.

- *The U. S. Environmental Protection Agency,* especially the Region II office, which funded the study, encouraged public participation and responded to CAC requests for clarification of policy.
- *The New York State Department of Environmental Conservation* which encouraged and supported citizen participation and responded to CAC requests for information and policy clarification.
- *The Nassau-Suffolk Regional Planning Board and staff* for actively encouraging and supporting independent citizen participation; for granting the CAC freedom to organize and function as its members desired; for providing funds to publish newsletters, reproduce articles and carry out a public information program; for arranging presentations to the CAC by technical consultants; for accepting and implementing suggestions made by the CAC; and for making available to the CAC the drafts of all reports and the Plan for evaluation.
- *The technical consultants and the Technical Advisory Committee* for attending CAC meetings to report on their work and to discuss issues.

6.9 CAC Operations: Evaluation and Recommendations

6.9.1 Organization. From an organizational viewpoint, the CAC has generally functioned smoothly and effectively. The designation of voting members representing various constituencies has worked well. The formalizing of committee membership and the instituting of a regular meeting schedule has facilitated good attendance and continuity. It also ensured balanced, broad-based input in a manner that prevented domination by any one interest group. Based on this experience, it is recommended that future citizen participation efforts be formalized in the form of a committee with

membership established on broad-based constituency representation.

6.9.2 Project Deadline. Under the terms of the Federal grant, the deadline for completion of the 208 Plan was December 31, 1977. As this deadline approached, activity intensified, hundreds of pages of technical reports were presented to the CAC for immediate review and comment. With the holiday season beginning in late November, it became very difficult for many CAC members to find the time to attend meetings and to do the necessary reading because of other commitments on their time. The setting of a deadline at a less busy time of the year would have permitted a more thorough and relaxed evaluation of the reports.

6.9.3 Citizen-Government Relations. Throughout the duration of the 208 Study, relations between the citizens serving on the CAC and their government as represented by the agencies involved in the 208 Study have varied from strongly adversary to various degrees of agreement and cooperation. In the final analysis , however, the citizens gained a better understanding of the complexities and frustrations experienced by government bureaucracies which has led to an increased respect for government. Concurrently, the CAC, through the interest and cooperation of its members, gained the appreciation and respect of the government agencies. Based on this successful and mutually beneficial arrangement, it is recommended that citizen advisory committees in general, and this CAC in particular, be continued for the purpose of providing input on future wastewater management decisions in the Nassau-Suffolk Region.

6.10 CAC Policy Positions

Out of the CAC discussions of the past two years there has evolved a consensus on numerous water quality and wastewater management concerns which the CAC has documented in 32 policy recommendations encompassing administrative, research and management issues. The following statements contain the essence of these recommendations. The full text of the concerns and recommendations appears in Section 6.11.

6.10.1 Administration

1. The design of wastewater strategies, the analysis of both monitoring data and strategies, as well as the design of stream augmentation methodologies, should be performed by a bi-county agency. Since the Nassau-Suffolk Regional Planning Board has a staff with both the administrative and technical proficiency to perform water quality management studies, this agency should not only be charged with the above mentioned duties but also be designated as the lead agency for present and future bi-county studies.

2. The NSRPB should seek additional funding to provide cost data for the alternate management strategies in each water quality management zone. In addition, all 201 Studies should be required to include cost-benefit analysis for all alternate strategies. Furthermore, 201 Studies should not be initiated until the final acceptance of the 208 Plan.

3. The provision for meaningful citizen input into water quality management studies should be provided for from the initial stages through a broadly constituted Citizen Advisory Committee. Similarly, any subsequent studies, such as the selection of a wastewater management strategy for a specific area, should receive the same scrutiny by the CAC.

6.10.2 Research

1. In the course of the Bi-county 208 Study, it has been determined that sewering addresses only a portion of the point and/or non-point contaminants entering surface and groundwaters. It is also recognized that nitrogen should be only one of many contaminants considered in water management strategies. Therefore, additional data on other parameters such as virus, metals and trace organics must be gathered and evaluated while research into the actual implications of nitrogen in drinking water must be pursued.

2. These point and non-point source contaminants are not unique to the Nassau-Suffolk Region and therefore water quality and wastewater management studies performed in this region can be applied on a National scale. Since there is a wealth of pre-exisitng data on the Nassau-Suffolk aquifers and surface waters, and this area includes a wide variety of land uses ranging from rural to urban, further Federal funding to expand this data base is recommended.

6.10.3 Management

1. The management of water supply in Nassau and Suffolk Counties should be designed to preclude both the importation and exportation of water. This can be accomplished by managing this regional resource on the basis of the innovative concept of water quality management zones as specified in the Plan. Water management strategies that require the preservation of wetlands and/or Magothy recharge areas as open space should provide for governmental purchase as a fee simple or lesser interest. In addition, a comprehensive land use management program should be Federally funded and developed.

2. Self-sufficiency would be further assured by: (1) providing for the maintenance of existing and future collection systems, treatment plants and on-site systems by dedicated funds; (2) adopting technical specifications and inspection procedures for petroleum and chemical storage tanks; and (3) by the implementation of water conservation measures, wastewater and solid waste reduction methods, and surface water runoff reduction and treatment measures.

6.11 Wastewater Management Concerns and Policy Recommendations

The following is the full text of the 32 key wastewater management concerns identified by the Citizen Advisory Committee and the policy recommendations adopted by a majority of the voting members.

6.11.1 Administration. This encompasses those concerns and recommendations that pertain to the implementation of wastewater management plans, to funding of studies and abatement projects, and to public participation in future management decisions.

1. Concern: An agency that has facility construction and operating authority would increase in size and power from wastewater management decisions that favor the solutions that are implemented by the agency.

Recommendation: The design of wastewater management studies, the analysis of data, the analysis of strategies, and the recommendation of solutions should preferably be done by an agency with only planning authority and never should be done by an agency with wastewater treatment facilities construction and operating authority.

2. Concern: Many structural and non-structural strategies are available that singly or in combination can reduce the volume of pollutants or prevent pollutants from entering the groundwater. However, funding formulas that are area-specific and strategy-specific exclude from active consideration many acceptable strategies.

Recommendation: Funding formulas to implement water quality and wastewater management strategies should equitably reflect the district and regional benefits that accrue and be goal-oriented rather than specific-strategy oriented. A specific strategy that should be examined pursuant to this recommendation follows: A management decision should be made by the responsible 208 management agency as to whether the resources of the bi-county area can be better spent to restore the quality of waters where the nitrogen concentrations exceed ten milligrams per liter such that the resulting nitrogen concentrations meet the ten milligrams per liter standard, or whether those resources should be spent to prevent degradation of high quality groundwaters.

3. Concern: Any effort by Nassau County to unilaterally reduce pollutant levels in North Shore bays near New York City will be frustrated by the high ambient pollutant levels in western Long Island Sound caused by present wastewater disposal practices.

Recommendation: USEPA and NYC are requested to give appropriate consideration to the environmental benefits that will accrue to Nassau's bays as the determination of priorities is made for the various water pollution control projects.

4. Concern: The technical complexity of wastewater management studies, the necessity for background information, and the completion of essential phases of the study prior to the end of the study generally render any technical, procedural or substantive recommendations, however meritorious, made at the conclusion of the study either difficult to integrate or too late to consider.

Recommendation: The provision for meaningful citizen input into water quality management studies should be provided for from the initial stages through a broadly constituted Citizen Advisory Committee (CAC). Similarly, any subsequent studies, such as the selection of a wastewater management strategy for a specific area, should receive the same scrutiny by the CAC.

5. Concern: The recommendations of the 208 Study can be avoided if any 201 facilities study is started prior to the adoption of the 208 Plan.

Recommendation: No additional 201 Studies should be initiated until the final acceptance of the 208 Plan.

6. Concern: Economic cost data is an essential component for a balanced evaluation of alternative wastewater management strategies. The lack of cost data enhances the likelihood of 208 recommendations not being adopted.

Recommendation: The NSRPB should seek additional funding to provide economic cost data for the various alternative wastewater management strategies in each water quality management zone. Any 201 Studies should always have a benefit/cost analysis for all alternative systems and strategies.

7. Concern: The NSRPB has developed a staff with the administrative and technical proficiency to competently manage Water Quality Management Studies (WQMS) and the NSRPB has cooperated in allowing the CAC to participate in the 208 WQMS.

Recommendation: The NSRPB should be designated as the lead management agency for any future WQMS in Nassau-Suffolk.

8. Concern: An agency that has wastewater facility construction and operating authority would be put into the position of being required to evaluate its own effectiveness and competence if that agency also has a monitoring responsibility.

Recommendation: The responsibility for monitoring wastewater quality should not be in the same agency that has facilities construction and operating authority.

9. Concern: The proper management of the environment requires that water quality be managed in coordination with air quality, wildlife, agriculture, recreation, aesthetics,

economic development and energy facilities.

Recommendation: A comprehensive land use management program similar to the Federally funded program for the coastal zone should be developed for inland areas.

10. Concern: The water quality in the aquifers that underlie Nassau-Suffolk varies from unusable, due to contamination by pollutants, to pristine.

Recommendation: Economic growth in Nassau-Suffolk can best be accomodated by managing land uses according to water quality management zones.

6.11.2 Research. This encompasses those concerns and recommendations pertaining to the need for additional studies, sampling/analysis programs, and research.

11. Concern: New research into the health effects of nitrogen in drinking water may require the adoption of more restrictive standards. Therefore, in areas of the groundwater system where nitrogen concentrations are presently less than the present standard of ten milligrams per liter, an effort should be made to maintain lower concentrations.

Recommendation: A technological feasibility study should be made to determine whether the wellhead treatment of water can reduce nitrates to the same level as highest quality water from an aquifer whose recharge areas are undisturbed by housing and agriculture. Until technology achieves such a level of proficiency, in areas of the groundwater system where nitrogen concentrations are presently less than the present standard of ten milligrams per liter, an effort should be made, within the constraints of economic and social factors, to maintain those lower concentrations.

A specific strategy which should be examined is the efficacy of preserving the native vegetative cover in the Magothy recharge areas.

Recommendation: A program for the long term systematic collection and analysis of data on nitrates, chlorides, trace organics, heavy metals, viruses and other pollutants in ground and surface waters should be implemented. The analysis of the data should include the source of each pollutant.

13. Concern: The application of fertilizers and pesticides in agricultural and residential uses may result in a certain amount of leaching of these compounds into the soil and/or runoff into surface waters.

Recommendation: A study should be made to determine the degree of degradation of ground and surface waters that can be attributed to the application of fertilizers and pesticides. Appropriate controls, which are responsive to the scope of the problem and give adequate consideration to the relevant local and regional environmental, economic and social factors, should be implemented.

14. Concern: Certain household, commercial and industrial chemicals, which are disposed of in wastewater or lagoons, are incompatible with quality groundwater.

Recommendation: An inventory of household, commercial and industrial chemicals should be compiled, and the impact of the chemicals on the groundwater should be assessed. Any recommended controls should be evaluated in terms of the relevant environmental, economic and social factors. Research to determine the public health effects of these chemicals should be accelerated in order to establish standards in the near future.

15. Concern: The chloride in de-icing salts that are spread on roads is a groundwater pollutant.

Recommendation: Research should be started to develop environmentally acceptable methods of dealing with ice on roads. In the interim, de-icing salt should always be mixed with aggregates before application, and standards should be set in order that the amount spread will not be in excess of the amount required to do the job.

16. Concern: Stormwater runoff from impermeable surfaces into groundwater and surface water bodies is a major source of pollution.

Recommendation: A pilot program should be developed for decreasing the quantity, as well as the contaminant level of stormwater runoff, if feasible.

17. Concern: The results of certain types of water quality and wastewater management research that is performed in Nassau-Suffolk can be applied to other areas of the country with similar conditions.

Recommendation: The wealth of information on Nassau-Suffolk's aquifers, and the variety of terrestrial activity from rural to urban, should be exploited by a Federally funded program to research pressing water quality problems, such as the transport and fate of trace organics, heavy metals and viruses in the groundwater.

18. Concern: The magnitude of the water quality management decisions, which are based upon the EPA standard for nitrogen in drinking water (ten milligrams per liter), is disproportionate to the confidence that can be placed

in the validity of the standard.

Recommendation: Research into the public health effects of nitrogen in drinking water should be actively pursued.

19. Concern: Improperly constructed or inadequately maintained wells are a potential source of aquifer contamination.

Recommendation: A study should be made to determine if existing wells are a substantial source of aquifer contamination and if the continuation of their present condition will render that portion of the aquifer unsuitable for its present or planned use. If the results are affirmative, then a program should be implemented to correct the conditions.

20. Concern: Commuter automobile use is a significant source of groundwater pollutants.

Recommendation: The degree of environmental degradation attributable to commuter automobile traffic should be determined, and a correspondingly appropriate combination of economic incentives and disincentives should be devised to encourage the use of mass transit systems.

21. Concern: Large quantities of stormwater runoff that transport de-icing sand, oil, grease, fertilizer and sediments are piped directly into stream and bay waters.

Recommendation: A program should be implemented to retrofit with sediment traps the existing stormwater drains that discharge into surface waters. In the interim, wherever practicable, the existing accumulated polluted sediments, which are located at the discharge point of the stormwater drain, should be removed to preclude their dispersion into the adjacent water body.

22. Concern: The environmental changes that will be brought about by the lowering of the water table in the Southwest Sewer District (SWSD), due to the use of a marine outfall, will have a moderate to severe adverse impact on freshwater wetlands, on inland stream-dependent water-related recreation, and on the Great South Bay hard clam fishery.

Recommendation: While acknowledging that the SWSD is an accomplished fact, a study should be made to devise and evaluate strategies, such as stream augmentation, that will counter the effects caused by the water table decline and decrease in average level and flow of our streams and rivers.

23. Concern: Many new concepts are being developed in laboratories to treat domestic wastewater. However, these new technological innovations cannot be considered for use on a large scale until properly conducted small scale field tests provide the basic engineering and cost data.

Recommendation: A Federally funded program to run small field evaluations of innovative wastewater treatment systems should be implemented.

6.11.3 Management. This encompasses those concerns and recommendations pertaining to the legal, institutional, scientific and technical means for implementing wastewater management plans.

24. Concern: The present practice of each public water supply purveyor supplying the entire potable water demand of its customers from wells within its district boundaries will, if continued, decrease the safe yield of the aquifer.

Recommendation: Water supplies in Nassau and Suffolk should be developed with the objective of maximizing the long term safe yield of the aquifer.

25. Concern: The conservation of potable water can reduce the volume of wastewater and decrease the drawdown rate on the potable aquifer.

Recommendation: Potable water should be conserved by initiating a public information program and revising industry standards and building codes that lead to wasteful water practices. Water pricing schedules should be revised to encourage water conservation. A study should be implemented to determine the feasibility of using grey water for industrial and limited commercial uses. Use of shallow wells in a degraded aquifer should be encouraged for irrigation, industrial, fire fighting and other compatible uses.

26. Concern: Current solid waste disposal practices are wasteful of resources, and are a source of leachate.

Recommendation: Municipal composting, recycling, beverage container reuse and other techniques for the reduction of the volume of solid waste should be encouraged with suitable incentives. Water quality monitoring in the vicinity of existing and closed landfills should be conducted, and an assessment should be made of the necessity of implementing interim abatement measures.

27. Concern: The quality of water, rather than the quantity of water, is the relevant problem for the supplying of potable water from Nassau and Suffolk's aquifers.

Recommendation: It is preferable to dispose of treated sewage effluent in areas where flow lines do not enter a potable aquifer unless the effluent is of equal or better quality than the affected aquifer and within the limits of health

standards.

28. Concern: The vast reservoir of potable water that underlies Nassau and Suffolk Counties will through wise management meet all future demands which are predicted for this area.

Recommendation: The management of water supply and wastewater in Nassau and Suffolk Counties should be designed so that the bi-county area need not import any of its potable water supplies from outside of the two counties.

29. Concern: Sewering addresses only some of the sources of pollutants in Nassau and Suffolk's groundwater. Contaminants other than nitrates may be more detrimental to public health.

Recommendation: Nitrogen should be only one of the many contaminants (such as organic and heavy metals) that are considered in water management decisionmaking, and a variety of management alternatives should be considered as abatement techniques.

30. Concern: The proper maintenance of both existing and future sewage collection and treatment systems, and on-site systems is essential for protecting the quality of ground and surface waters.

Recommendation: The maintenance of both existing and future sewage collection systems and treatment plants and on-site systems should be required and provided for by dedicated funds.

31. Concern: The role that wetlands and Magothy recharge areas have in surface water and drinking water quality is knowledge that was not known when these lands were first sold to private owners.

Recommendation: Water quality management strategies that require the preservation of wetlands and Magothy recharge areas as open space should provide as a matter of course for government purchase of a fee simple or lesser interest in the property.

32. Concern: The storage of petroleum products in underground tanks is a potential and, in some cases, an actual source of groundwater pollution.

Recommendation: Technical specifications for underground petroleum storage tanks should be adopted, and all existing tanks should be routinely inspected to determine their integrity. The frequency of the inspections should be based upon the determined likelihood of tank failure and the water quality management zone in which the tank is located.

Section 7 Implementation

7.0 Introduction

The Act and the regulations drafted by EPA thereto, require a commitment from the 208 agencies to indicate how implementation of the planning recommendations will be carried out. Responsible units of local and state governments must agree to support existing or new agencies to do the work and to have sufficient taxing, budgeting and regulatory authority to finance the various tasks.

This implies that technical, fiscal and political objectives can be achieved and that major constraints will somehow be ameliorated. The Areawide 208 Plan developed for Nassau and Suffolk Counties is implementable. The ease of implementation, though, is partially dependent on knowledge of the constraints that inhibit public action, and thorough preparation to cope with them. This is true for minor projects and even generally popular ones, let alone costly and less favored ones. Constraints often are complex and not easily identified or categorized. Attempts must be made to reduce these limits to implementation as though they were singular. For this purpose it is assumed that all barriers fall into three neat classes: technical, fiscal and political. Unfortunately, an apparent technical limit to some observers may justifiably be considered to be really fiscal in origin by others. Such potential definitional disputes are recognized. We dispense with this dilemma by taking a firm grasp of this disclaimer: *The following paragraphs are illustrative and can be re-defined as to category, but are accurate in that they all tend to hinder implementation of public programs.*

7.1 Constraints

7.1.1 Technical Limits. Technical limits include the availability and quality of the data on which technical alternatives are identified, prioritized and chosen; the state of the art of equipment and methodology; and the existence of suitable agencies to design, construct, operate, monitor, maintain and regulate the structural devices and facilities.

One concern that permeated this program was the adequacy of the input data that was used to verify the models and identify the "real world" of Long Island's hydrogeological/ecological system. Serious researchers can never be complacent when considering the relative completeness of technical data. More should be known about organic chemicals, metals and viruses. More wells should have been installed for test purposes. More should be known about the movement of contaminants through the aquifers. More monitoring should be conducted, and on a continuous basis. More has to be known about health and environmental standards. The list is awesome! The unknowns constitute an important set of recommendations for future work and are mentioned in the previous section. Fortunately, sufficient information and experience were available to enable the preparation of this initial 208 Plan. When implementation is considered, however, it must be in the context of a *continuous* planning effort. As the data and knowledge base improve, modifications of the Plan may become necessary.

Waste treatment processes and equipment currently available (from the standpoint of proven reliability and efficient performance) can meet the recommended needs of the Nassau-Suffolk Program. However, some management alternatives, such as large scale recharge to the aquifer, will not become operationally reliable until ongoing demonstration tests at Cedar Creek are completed. Another example of state of the art deficiency is the obvious need for improved means of producing organic-free potable water.

The administrative aspects of technical implementation are perhaps the least difficult set of problems to resolve. Existing county and State agencies in both counties are now implementing many monitoring, regulatory and operational waste treatment programs. Land use controls, to a lesser extent, are also being carried out. Non-point source control measures have to be significantly strengthened. The main administrative questions relate to new opportunities to improve the quality and efficiency of service for the future.

7.1.2 Fiscal Limits

7.1.2.1 Availability of Funding. Fiscal constraints fall into two general classes. One is the availability of money. The other is the legal requirements that must be met prior to spending public funds.

Federal and State transfers of revenue to local governments are the major source of funds for major public works, *e.g.,* highways, sewers, etc. These grants are often the major catalyst in generating local initiation of projects. Yet these monies also deter action due to the following:

1. There might not be an adequate amount to fund all the requests throughout the country or state. Prorated shares would necessitate a larger local contribution, regardless of the aid formulas. Thus, instead of moving local actions, the deficiencies deter them.

2. The funds are often categorical, *i.e.,* monies are earmarked for specific projects and/or specific construction solutions, *e.g.,* at one time, the Federal Government would fund outfalls, but not recharge. (The law has now been changed to make more items eligible.) Local governments are forced to choose between a technology they may not want, but can be funded; or if a different solution is chosen, pay for it with local revenues. This latter case is crucial to 208 implementation, since most non-point pollution abatement techniques and facilities are not currently eligible for Federal grants, except for agricultural areas.

Another fiscal constraint is the low priority accorded the subsidization of sewer lateral construction, which can amount to 90 percent of a sewering program's costs.

3. The condition of the bonding market also affects the availability of funds. Recent experiences in Suffolk County indicate that due to the unstable fiscal situation in New York City, the bond market was reluctant to invest heavily in municipal works, except at exorbitant interest rates. One alternative to this impasse would require the county to partially guarantee the district bonds with earmarked revenues from the county general sales tax. The County Legislature chose this path to avoid default on the partially constructed Southwest Sewer District. The controversy over the financing of this District has already created a strongly negative county-wide attitude towards any further major structural programs for waste treatment.

7.1.2.2 Legal Limits on Spending. State constitutional limits and other State and local statutes related to public spending often slow implementation. Although conceived of as a means of providing fiscal integrity and protection for the citizenry, these laws can impede and sometimes prevent the creation of necessary public works.

1. Most Federal and State grants require that the local governments provide a matching share. If the project is small enough or popular enough, the local share may be obtained by the issuance of bonds for the purpose. This can often be authorized by local legislative resolution after a public hearing is held on the matter. If the local government cannot come up with their share, the grants are cancelled.

2. Projects that are costly and/or controversial are subject to either permissive or mandatory referendum. Permissive means that the legislative body may act in the prior case, but can be challenged by a segment of the public to submit the action to a public vote. It is rare that elected bodies risk permissive actions. This means that the proposal is put to referendum as though it were mandated. In most instances the vote takes place at the next regularly scheduled election. This process alone can delay action for almost one year.

7.1.3 Political Limits. In the last analysis, political limits determine the "go/no-go" real world climate; they are the most complex and, therefore, the most interesting ones to resolve in moving any public program or policy towards successful implementation. Although related to and affected by technical and fiscal issues, political constraints are more reflective of the democratic system, which must be responsive to the public will. There are virtually no limits, technical or fiscal, if the public support is favorable.

The development of an implementation program and schedule is the concluding phase in the preparation of a planning study. It requires that there be a recommended course of action, or at least the identification of resonable alternatives, *e.g.,* the specfic objectives to be attained including timing; the administrative agencies to conduct the initiation and operation of programs, facilities and regulatory procedures; the fiscal resources to fund the effort; the legal provisions to substantiate and protect the program content; and the fostering of citizen interest to assist in making the action politically supportable.

7.1.4 Summary. Secton 3 presented a detailed recital of the many alternatives that may be used for waste management in the two counties. Section 4 commented on the environmental consequences of each alternative. Sections 5 and 6 concentrated on preferred responses. (Section 5 represents the TAC point of view.) The CAC recommendations are in Section 6. Fortunately, there is a strong overlap indicating a healthy, independent consensus on major issues.

The remaining task is to pull the administrative, fiscal, legal and policy elements together into a workable and therefore implementable package. The following pages summarize these matters under the headings of Management Agencies, Fiscal Needs, Legal Needs and Public Informational Program.

7.2 Management Agencies

7.2.1. Introduction. At the present time, all agencies required to implement the various portions of the Nassau-Suffolk Comprehensive Areawide Waste Treatment Management Plan are extant. The Nassau County Department of Public Works and the Suffolk County Department of Environmental Control are statutorily established, with full powers and authority for the planning, design, construction, operation and maintenance of public sewage collection and treatment systems. These agencies, in conjunction with the two County Health Departments, currently can implement the monitoring

and regulatory functions relating to all of the public health matters that are addressed in the Plan.

These four agencies, in conjuction with the powers of the New York State Department of Environmental Conservation, cover the entire gamut of point and non-point concerns called for in the Plan. Land use recommendations contained in the Plan are currently administered by the Nassau and Suffolk County Planning Commissions in accordance with State and/or County Charter provisions.

The Federal law and regulations, which set forth the requirements of 208 planning (40 CFR 131.11 (n) (3) (i), state that, "to the extent practicable, waste treatment management shall be on a statewide and/or areawide basis . . . ." It must be stressed that this goal should be measured in the context of economy of scale. In Nassau and Suffolk Counties, the planning is conducted on an areawide basis (the two counties are an SMSA), and, therefore, meets the general requirements. The operating and regulatory functions, though are carried out by the respective counties. Since the two counties are sufficiently large (almost 3 million people) and have well established agencies that would not gain effectiveness by further centralization, the NSRPB does not recommend any major changes. The areawide 208 planning function can continue to serve as a bridge for the two counties to ensure coordination and cooperation of mutual water quality management objectives.

There are, however, several management agency options that should be considered, since this study would not be complete if it did not analyze the efficacy of existing structures.

The balance of this section contains a discussion of management agency options for the operation and regulation of point and non-point source controls, water development and areawide planning. This is followed by NSRPB recommendations for designated agencies to carry out the various tasks.

7.2.2 Point and Non-point Source Controls. The control of point and non-point sources of pollution involves regulatory and operational activities. Most county units of government that undertake these responsibilities share the task along functional lines. The County Health District (department) assumes the regulatory activities. The County Department of Public Works undertakes the design, construction and operation of structural facilities. This is the pattern in Nassau County.

Suffolk County has developed a more complex approach. Initially, a separate Sewer Agency was created to undertake the planning, design, construction and operation of the Southwest Sewer District. It was never attached to the extant Department of Public Works. Subsequently, a Department of Environmental Control was established, which assumed all the functions of the sewer agency and also included some regulatory and monitoring functions. Some of the prior duties of the Department of Health Services in these fields were transferred to the new agency. However, the Health Department could not relinquish those duties that were mandated to it by virtue of N.Y.S. Public Health Law. Thus, Suffolk County has two agencies whose duties in regulation and monitoring potentially overlap. To address this concern, the two agencies have signed a memorandum of understanding, intended to clarify jurisdictional assignments.

The following pages describe the responsiblities, operations, environmental monitoring, proposed additional functions and advantages of the present administrative structure. This is followed by several questions and observations that may require future action.

7.2.2.1 Suffolk County Department of Environmental Control Responsibilities. The following are the representative examples of the functions performed by the individual units of the SCDEC that fulfill Charter responsibilities: Realty Subdivision, Planning, Engineering, Construction, Operations, Environmental Monitoring (Freshwater Resources, Marine Resources, Air Pollution Control, and Water Pollution Control) and Special Services/ Energy Programs.

7.2.2.2 Suffolk County Department of Health Services Responsibilities. The County Charter, Public Health Law, New York State Sanitary Code and the Suffolk County Sanitary Code have mandated environmental programs to the Health Services Department. This includes the supervision and control of public water supplies, bathing beaches, public swimming pools, individual water supplies and sewage disposal systems, realty subdivision and ionizing radiation. In addition, the Department is responsible for the enforcement of standards regarding operations of county-owned facilities. Thus it appears that the Health Department and Environmental Control Department share duties relative to realty subdivisions and fresh and marine water monitoring and regulation.

7.2.2.3 Administrative Considerations. The present management structure in Suffolk County appears to have created potential impediments to more effective operations. One is philosophical in nature, the others are jurisdictional.

Generally, agencies are assigned either operational or regulatory functions. This is to avoid, to the degree possible, potential internal conflicts of interest. The State and Federal environmental protection agencies' duties include enforcement, monitoring, standard setting and the administration of grant programs. They generally do not build or operate sewage treatment facilities. In New York State this latter function is the responsiblity of a separate New York State Environmental Facilities Corporation.

The opposite argument is that substantial benefits are derived from maintaining within one agency comprehensive, interdisciplinary capabilities for addressing environmental matters. In addition, dual participation of an agency (*e.g.*, SCDEC) in both the 208 Study and 201 facilities planning assists in assuring that the recommendations of the 208 Plan are implemented on the 201 level.

Jurisdictional issues are considered here solely for the objective of understanding where the practice of shared responsibilities breaks down. The main problem appears to be with enforcement. When responsibilities

for enforcement are shared among several agencies (in this case, NYSDEC, SCDHS and SCDEC) disputes are bound to occur. The shortcomings of current enforcement capabilities provide the basis for implementing a local environmental law as described in Section 7.4.11.

7.2.2.4 Administrative Options. There are several models that may be considered for point and non-point management agency assignments. In Suffolk County, they include:

1. a. Assign *all* monitoring and regulatory functions to the Health Department.

b. Assign *all* operational activities to the Department of Public Works.

This model is close to that used in Nassau County. In all other New York State counties, save upstate Erie County, shared responsibilities do not exist. The monitoring and enforcing of environmental control standards is carried out by county health departments.

2. a. Assign *all* monitoring and regulatory functions to the Health Department.

b. Assign *all* operational activities to the Sewer Agency.

3. a. Assign *all* monitoring and regulatory functions to the Department of Environmental Control as an agent of NYSDEC and NYSDH.

b. Enact a local environmental regulatory law with responsibilties assigned to the Department.

c. Assign all operational activities to DPW or an independent Sewer Agency.

4. Maintain the current administrative status quo.

At this time, Nassau County does not have to re-evaluate its agency structures. The county's sewer program is well established and functioning. The areas of responsibility are clear-cut. Finally, the agencies are conducting their respective duties successfully.

In the case of Suffolk County, the NSRPB has offered some models to consider. The Board fully recognizes that ultimately these are decisions to be pondered by the newly formed Citizens Charter Commission, considered by the County Executive and Legislature, and finally, determined by either permissive or mandatory referendum.

7.2.3 Water Development. The 208 Plan indicates that the quantity of groundwater should be adequate through the planning horizon. However, it is possible that a part of this resource may become polluted and, therefore, effectively limit the available potable supply through time. In such event, it may become necessary to ensure the adequacy of supply through the following actions:

- Limit the withdrawals from individual wells or well fields, or establish district-wide limits.
- Require the inter-district allocation of water supply.
- Require the inter-county allocation of water supply.
- Sequence and coordinate the capital investments necessary to provide an adequate distribution network, inside each county, between counties and outside the Region.
- Establish pricing policies throughout the SMSA to achieve significant water conservation.

Provisions for these activites do not now exist throughout the Region. At the present time, each county copes with the problems of water production, quality control, distribution and sale through a variety of administrative mechanisms. Suffolk County has an Authority with county-wide powers to carry out the above mentioned functions. Although individual wells and private and municipal water companies exist, the Authority has powers of condemnation and purchase. Since the mid-1960's, the Authority has striven to build a coordinated system. Some of the municipal water districts purchase water from the Authority, and then retail it to local customers.

Water production and supply in Nassau County is currently managed by 46 separate independent water companies—43 in municipal and three in private ownership. The balkanization of water management obviates the county's ability to efficiently respond to the reality that water is a county-wide resource and concern and should be managed as such.

This observation is neither new nor startling. In 1963, the Greeley-Hansen, *Summary of Report on Water Supply*, recommended the consolidation of Nassau's water supply. In 1971, an updated report by the same consulting firm modified their positions to stress the need for supplemental water. Since this report was published, the NCDH has revised the projected "deficit" from 126 MGD to 47 MGD in 2000. The "deficit" is the estimate of the difference between projected water supply demands and the calculated safe yield of the resource.

The county has partly responded by the creation of a Water Resources Board charged with a review of the 1971 recommendation as a prime responsibility. Their first report urged: (1) the development and adoption of a master plan, (2) creation of a new department or division to implement, when necessary, any part of the Master Plan that calls for the provision and transmission of supplemental water, (3) acquisition by Nassau of the large water main under Conduit Boulevard and Sunrise Highway and (4) action by NYSDEC to reduce the heavy groundwater pumpage in Queens County. Additional actions should now be taken. There are at least three options that the county government should consider.

An obvious option entails the creation of a county-wide authority or department that would have the sole resonsibility for the production, quality control and distribution of water. This would mean the absorption of the county of the 46 existing companies.

A second possibility would be similar to the first for the production of water, *i.e.*, the location and operation of wells, control over pumping rates, and the sole responsibility for water quality monitoring and control. The 46 existing companies would remain for the purpose of local distribution and sale of water. Presumably, the county agency could acquire any of the inde-

pendent companies by purchase as is the case in Suffolk County.

The third alternative would be that water production can be assigned to the Department of Public Works. In this case production of water and construction of a county-wide distribution system would be assigned to the Department, with monitoring and quality control assigned to the Health Department.

Several additional advantages to be considered as a result of centralization include:

1. The ability to foster water conservation through the use of pricing schedules.

2. The establishment of uniform, continuous and sophisticated monitoring surveillance of the groundwater resource.

3. The development of a formal reporting system to ensure that the County Executive and Board of Supervisors receive adequate and timely information regarding the county's water supply situation.

4. The ability to create an administrative mechanism to address intercounty water problems and solutions.

On this last point it must be recognized that Nassau and Suffolk Counties are one region in several senses. There is general understanding that demographically and economically the counties constitute a clearly identifiable Standard Metropolitan Statistical Area (SMSA). Transportation is another obvious regional activity and concern. Certainly, this is also true for water. The aquifer, already designated by the EPA as a "sole source aquifer," does not relate to municipal boundaries. It is a common resource. In fact, if anything defines the unity of Long Island in a physical sense, it would be the groundwater underlying the Region.

Since self-sufficiency of water supply is a good possibility, assuming intelligent management, it is essential that regional policies be formulated and established.

This is an important concern for Nassau County in that it must choose from three possible alternatives of obtaining supplemental water that represent widely divergent approaches. Self-sufficiency may be maintained by (1) recharge of an advanced treated wastewater effluent or (2) by having Suffolk County water made available to Nassau County users.

The third alternative is for Nassau County to consider joining with New York City to implement the U.S. Army Corps of Engineers proposal to skim the floodwaters of the Hudson River. This requires the construction of a new water tunnel and distribution system.

Although this was a wastewater management study, water treatment at the wellhead should not be ignored as a management tool. Public water supply treatment in many areas may, in fact, be required regardless of the structural or non-structural recommendations cited in the Plan. Every effort should be made to prevent further degradation of the resource.

State and/or local legislation that would permit public water supply wells to be located on public lands should be considered. In many cases such locations afford maximum protection for the water supply. These installations can be constructed in a manner that would still preserve the initial integrity and use of the land for which it was originally set aside.

7.2.4 Areawide Planning. Since December 28, 1974 the Nassau-Suffolk Regional Planning Board has been the designated Section 208 areawide planning agency. Between January of 1975 and June 30, 1978, this agency has been responsible for the conduct of the $5.2 million 208 Program. With the completion of the initial plan, questions remain as to continuity of effort for periodic updating and for subsequent work related to any portions of the initial plan subject to conditional approval. Several options exist for the future. They would include:

1. continuance of the Nassau-Suffolk Regional Planning Board as the areawide agency,

2. the designation of Tri-State Regional Planning Commission as the areawide agency, and

3. the assumption of these functions by the New York State Department of Environmental Conservation in accord with the similar responsibilities in other portions of the State of New York.

The first option offers several benefits. The NSRPB and its 208 affiliates—the TAC and CAC—have developed a good working relationship among the responsible agencies and a very active and broad based citizen group. A comprehensive and strongly controversial planning process was conducted relatively on time, and with a remarkable degree of consensus among the participants. Both advisory committees expressed almost unanimous recommendations that the NSRPB continue its 208 planning functions. The administrative mechanisms are in place and functioning, and the decisionmaking process is directly available and open.

The second option is not recommended. The Tri-State Planning Commission has not been involved in 208 planning and would not be able to guarantee smooth continuity.

In view of new EPA/State agreements whereby the relationships between the Federal Government and the State for waste treatment planning purposes are being clarified, one could build a good argument for Option Three to take place. Since the State has the full responsibility for the entire State, it would make sense to coordinate these activities in one agency. Local input could then be achieved through the review process. In short, the Nassau-Suffolk Regional Planning Board would review and comment on the periodic updatings prepared by the State as they affect Nassau and Suffolk Counties.

This would require a significant increase in staff trained in land use planning to handle the land use and other non-structural aspects of 208 work. At the present time, NYSDEC is not responsible for state planning functions. After the demise of the Office of Planning Coordination, modest planning responsibilities were assigned to the Secretary of State. That office is currently specializing in coastal zone management planning.

7.2.5 Designations. One responsibility in the formulation of an areawide water quality management plan is the designation of, and acceptance of, implementation responsibility by regulatory, planning and operating agencies to carry out the adopted plan. The following pages contain the NSRPB recommendations. In general, the NSRPB believes that all management agencies required to implement this water quality management plan are currently in place and have adequate legal and administrative jurisdictions. Agency acceptance of functions designated in this water quality management plan constitutes a moot point, because they already have such responsibilities and their authority is demonstrated to derive from existing legislation, *i.e.*, N.Y. State Public Health Law, N.Y. State Environmental Conservation Law, Federal Law, General Municipal Law of the State of N.Y., regulations of local Health Districts, County Charters, local laws.

The designations are identified for point source control, non-point control, water development and areawide planning. The NSRPB has taken a conservative approach. Although a range of management alternatives has been discussed in previous pages, as required by law, the major focus must be on the successful implementation of the 208 Plan. Thus, the recommendations made now are workable.

Several of the options mentioned in 7.2.2 and 7.2.4 that call for new agencies or shifts in functions between agencies are certainly premature in view of the statutory and/or Charter amendment procedures that must occur and can be quite time consuming.

The NSRPB recommends the following designations:

7.2.5.1 Point Source Control, Operations. The facilities planning, design, construction, operation and maintenance of collection systems, treatment plants and disposal facilities are currently the responsibility of State, county, municipal and private groups. The NYSEFC, NCDPW and SCDEC should be the prime agencies. Municipalities within the two counties that currently operate sewage treatment plants should also be designated. We do not recommend the continued practice of private operation and maintenance of sewage systems.

7.2.5.2 Point Source Control, Regulatory. The NYSDEC, ISC, NCDH, SCDEC and SCDHS be designated the regulatory agencies for each county for the promulgation, monitoring and enforcement of standards, laws and regulations concerning the safe operation of sewage treatment plants for health and environmental control.

7.2.5.3 Residual Waste Disposal, Operations. The NCDPW and the SCDEC be designated for the management of hazardous wastes and sludge waste for county facilities. The municipalities be designated for the management of solid wastes and sludge waste from municipal facilities.

7.2.5.4 Residual Waste Disposal, Regulatory. The NCDH, SCDHS, SCDEC and NYSDEC be designated for the regulation of residual waste disposal.

7.2.5.5 Non-Point Source Control, Operations. Municipalities and county agencies now responsible for street sweeping, catch basin maintenance, storage and use of road salts, and the regulation of Best Management Practices, be designated.

7.2.5.6 Non-Point Source Control, Regulatory. The NYSDEC, NYSDH, NCDH, NCPC, SCDHS, SCDEC and SCPC be designated to carry out the regulatory duties involved in non-point controls.

7.2.5.7 Non-Point Source Control, Advisory. The Suffolk County and Nassau County Soil and Water Conservation Districts, USDA, SCS, NYSDEC, ASCS, Cornell University and CES function in an advisory capacity to the non-point source regulatory and operations agencies in the preparation of regulations and standards, the review of permit applications and inspections of operations relating to industrial discharges, the storage and transportation of chemicals and hazardous materials, storm runoff, erosion control and agricultural chemicals application, as well as continue their function in agricultural non-point source control.

7.2.5.8 Areawide 208 Planning. The NSRPB be designated for continuing land use aspects of waste management planning. The NYSDEC be designated for overall 208 planning.

7.2.5.9 Regulation of Land Use and Zoning. The municipalities be designated for the initiation, local planning, and regulation of land use and zoning, and that the NCPC and SCPC be designated the agencies responsible for review, override and consistency of local land use actions with the 208 Plan.

7.2.5.10 Water Production, Operations. The SCWA be designated for the production and distribution of potable water in Suffolk County. The 46 independent water districts and companies in Nassau County be designated for the local distribution and sale of water. An existing Division within NCDPW could be assigned expanded, county-wide responsibilities for water production policy, including well locations, pumpage rates and design, construction, operation and maintenance of these water production facilities, and for the implementation of any plan adopted by Nassau County for the acquisition, transmission and distribution of water, whether inter- or intra-county. Other administrative options, such as a new department, could also be considered.

7.2.5.11 Water Production, Regulatory. The NYSDH, NCDH and SCDHS be responsible for drinking water quality and be assigned all monitoring and related quality control functions for potable water in the two counties.

7.2.5.12 201 Planning. The NCDPW and SCDEC be designated as the lead agencies for all 201 Programs.

Figure 7–1 depicts the recommended table of organization for planning operations, monitoring and implementation of the Water Quality Plan.

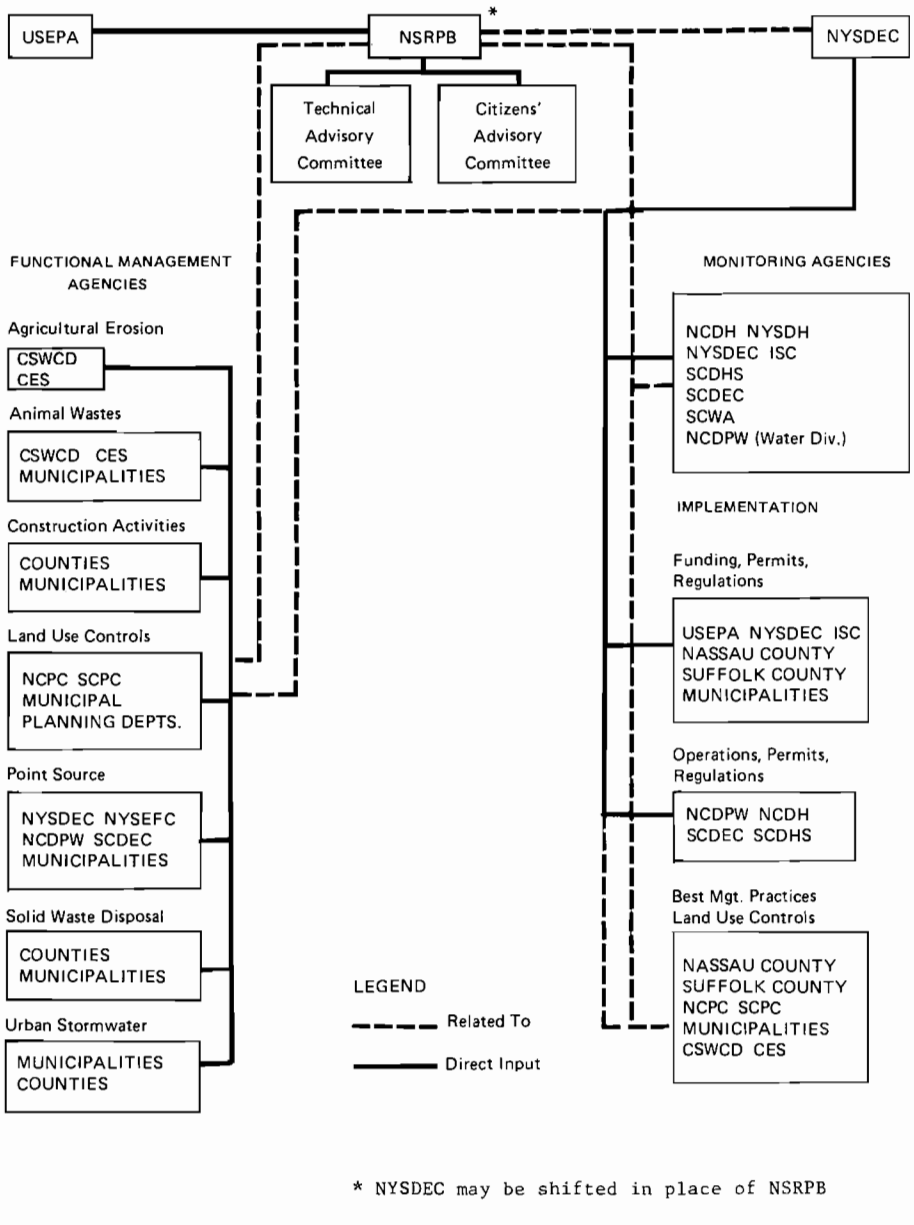


FIGURE 7–1 *Management Organization: Ongoing 208 Planning*

7.3 Fiscal Needs

7.3.1 Introduction. Historically, waste treatment programs centered around engineering solutions. Thus, it is not surprising that the Federal response in terms of intergovernmental relations has been to sponsor major grants for construction. Present sewage construction projects eligible for EPA and state support may receive grants up to 87½ percent of the total project's costs. This is a very necessary and strong support if the communities are to meet the needs for a water pollution-free society. However, in view of the impetus set forth in the Act, which encourages non-point source and planning control measures, it is perhaps timely for Congress to consider adequate funding to achieve these ends as well. For example, the Southwest Sewer District in the Towns of Islip and Babylon, N.Y., is a network of collection systems, treatment facilities and an effluent disposal outfall, that is estimated to eventually cost approximately $1.0 billion, including financing costs. Major segments will receive 87½ percent funding from EPA and the State. Even the 12½ percent balance to be financed by the users places a heavy burden within the district. If this is to be the future pattern, aid will have to be greatly magnified.

In addition to Federal and State funding (87½ percent) for sewage treatment works, which include treatment plant and interceptor construction, permanent provision should be made for the extension of governmental subsidizing for lateral sewer construction, which would greatly reduce the local financial burden. Another obvious alternative would be to limit the density of growth and thereby avoid the need for communal sewage systems. This objective can be partially realized through zoning controls and successful enforcement. In addition, extensive watershed management will be required, including the reservation of significant areas of open space. These types of public programs are virtually dependent on local fiscal resources. Specifically in regard to 201 Programs, Federal and State funding for non-point and non-structural solutions should also be strengthened.

It should be noted that the high cost of providing the facilities of the Southwest Sewer District are directly related to the fact that action was taken after extensive development had occurred, and substantial water quality degradation had been discerned.

A more fiscally sound approach is to install sewerage facilities in accordance with the 208 Plan as development occurs, as one of the preventative measures for protecting water quality. Therefore, in areas where land use controls are not implemented, sewering should be conducted in accordance with the 208 guidelines.

The purchase of development rights and/or the fee simple for open-space lands, or for the maintenance of low density communities should be construed as a modified form of construction project. Wherever land development has not already occurred, this option has to yield a greater return on the public investment. Perhaps fiscal policy improvement can occur if waste treatment programs were written in a format similar to that of the Communi-

ty Development Act, namely, assign block grants to communities with the general requirement to reduce water pollution. Let the local governments decide the most efficacious way of doing this. The states and localities would then have a greater incentive to exercise more stringent land controls.

7.3.2 Estimated Costs of Structural Alternatives. Tables 7–1 and 7–2 present estimates of the costs of the various structural options present in Plan Section H. These costs do not include the construction of interceptors or laterals, and will require update and reevaluation at the 201 study level.

7.3.3 Estimated Costs of Non-Structural Control Measures. The cost of non-structural, non-point source pollution controls will vary with the selection of control measures and the level of effort. It is expected that these controls will be implemented by New York State, the two counties, and the municipalities. Table 7–3 presents estimated annual costs for Nassau and Suffolk County non-point source pollution control efforts. Municipal and State costs are not estimated.

Table 7–1

ESTIMATED COSTS FOR STRUCTURAL RECOMMENDATIONS: NASSAU COUNTY(1)

	Total Present Worth (2) (7) (Millions of Dollars)
Southwestern Nassau County Planning Area	
–Relocate Bay Park Outfall to ocean	52
–Reroute Long Beach to connect with Bay Park outfall	0.5
–Lawrence	
a. AWT with present discharge location	2.1
b. Diversion to Bay Park and incremental cost of treatment at Bay Park	4.7
c. Diversion to Reynolds Channel	See Note(3)
Cedar Creek Facilities Planning Area (Sewer Disposal District No. Three)	
–Terminate Freeport and divert to Cedar Creek	14
Northwest and Northeast Study Areas (North Shore Facilities)	
–Divert North Shore plants to Cedar Creek (Oyster Bay, New York Institute of Technology, C.W. Post, Great Neck Sewer District, Village of Great Neck, Port Washington, Roslyn, including flows generated from high population densities in Plandome, Sands Point, Kings Point and parts of Manhasset). Incremental treatment costs at Cedar Creek included.	54
–Northwest sub-regional facility at Port Washington (divert Great Neck Sewer District, Great Neck Village, Roslyn and Port Washington flows generated from high population densities in Plandome, Sands Point, Kings Point and parts of Manhasset).	33
–Northeast sub-regional facility at Glen Cove (divert Oyster Bay and the following unsewered areas, Sewanhaka, East Norwich, Bayville, Locust Valley and Sea Cliff-Roslyn Harbor to Glen Cove after sewering).	33

Table 7–1 . . . Cont'd.

–Individual treatment plants.	
a. Village of Great Neck: discharge of 1.5 mgd at present location, with AWT (denitrification).	8.7
b. Roslyn: discharge of up to 2 mgd at present location with AWT (denitrification).	7.9
c. Great Neck Sewer District	

Total Present Worth (Millions of Dollars (2) (7) (8)

Possible Flow (mgd)	Secondary Treatment	Mid-Bay Outfall	Total
2.7	5.6	11	16.6
3.5	11	11	22
5.5	15	12	27
7.0	18	12	40

d. Port Washington Sewer District

Total Present Worth (Millions of Dollars) (2) (7)

Possible Flow (mgd)	Option 1 Secondary Treatment	Option 1 Mid-Bay Outfall	Option 2 AWT	Option 2 Existing Outfall
4.50	13	7.5	22	1.9
6.50	18	8.8	30	2.2
13.5	29	9.5	50	2.4
14.45	30	9.7	52	2.5

e. Glen Cove.

Total Present Worth (Millions of Dollars) (2) (7)

Possible Flow (mgd)	Option 1 Secondary Treatment	Option 1 Mid-Bay Outfall	Option 2 AWT	Option 2 Existing Outfall
7.5	19	5.4	33	0.042
11.5	25	5.9	44	0.046
18.5	35	6.3	62	0.046

	Total Present Worth (2) (7) (Millions of Dollars)
Oyster Bay STP(10)	
–Discharge with secondary treatment to present outfall location	13
–Diversion to Cedar Creek including incremental treatment cost at Cedar Creek	11
Bayville	
–Diversion to Oyster Bay, including incremental treatment cost at Oyster Bay	7.5
–Build new facility in Bayville area (Sound outfall)	9.7

See end of Table 7–2 for notes.

Table 7–2

ESTIMATED COSTS FOR STRUCTURAL RECOMMENDATIONS: SUFFOLK COUNTY[1]

	Total Present Worth Cost[2] [7] (Millions of Dollars)
I. Huntington/Northport 201	
Regional Alternative Sites	
1. Huntington Sewage Treatment Plant, or	62
2. Crab Meadow	68
Sub-Regional Alternative Sites	
1. Huntington Sewage Treatment Plant and Northport Village Sewage Treatment Plant	57
Small Treatment Plants	57
II. West Central 201 Study Area	
1. Northern Area	
a. Sub-Regional Alternative Sites	See Note (3)
1. Suffolk State School and	
2. Facility located in the eastern portion of this area	
b. Small treatment plants	See Note (3)
c. Diversion to the Suffolk Co. Sewer District No. 3 Water Pollution Control Plant (Bergen Pt.)	See Note (3)
2. Southern Area—Diversion to SWSD	120
III. SWSD	See Note (9)
IV. Kings Park 201 Study Area	
A. Regional Alternative Site	
1. Kings Park Sewage Treatment Plant	59
B. Sub-Regional Alternative	
1. Kings Park Sewage Treatment Plant and Suffolk County Center	76
C. Small Plants	110
V. Port Jefferson 201 Study Area	See Note (3)
VI. South Central 201 Study Area	
A. Regional	150
B. Sub-Regional Alternative Sites	200
1. West of Lake Ronkonkoma	
2. Oakdale Vicinity	
3. Sayville	
4. Parkland III and SCSD No. 7	
C. Small Plants	260
Village of Patchogue	See Note (3)
VII. Yaphank 201 Study Area	
A. Sub-Regional Alternative Site	
1. Three Sites (Selden, Suffolk County Property at Horse Block Road, and Mastic Beach east of William Floyd Parkway.)	280
2. Six Sites (three sites above plus Rocky Point, Artist Lake vicinity, and Center Moriches east of Forge River)	270
B. Small Plants	330
VIII. Riverhead 201 Study Area	
A. Regional Site	
Riverhead Sewage Treatment Plant	27
B. Sub-Regional Sites	
1. Riverhead Sewage Treatment Plant and Manorville	31
2. Small Plants	31
IX. Greenport/Southold 201 Study Area	
A. Small Treatment Plants	
1. Greenport	24
2. Additional Sites	See Note (3)
X. Disposal District 14—Shelter Island	
Shelter Island	14
XI. Disposal District 12	
Small Treatment Plants	See Note (5)
XII. Disposal District 15	
Sag Harbor	See Note (4)
XIII. Disposal District 16	See Note (6)
XIV. Disposal District 17	
Fishers Island	2.6

(1) Area specific alternatives correspond with those in Chapter 5 of the Summary Plan.

(2) Present worth costs include interceptors, force mains, pump stations, treatment plant, treatment plant outfalls (excluding mid-bay or ocean in Suffolk), and operation and maintenance. The costs are based on a sewering criterion of 2 DU/acre everywhere (1995 population), present worth at 6 3/8% interest amortized over twenty years, CRF = .08986 (ENR = 2580, mid-1977 costs).

(3) To be determined in 201 Study when additional detailed information is available.

Table 7–2 . . . Cont'd.

(4) Plant already constructed. (Further expansion will be a cost.)
(5) Sites to be selected; costs to be determined in future 201.
(6) Sewage treatment to be implemented as need arises.
(7) Costs include 75% replacement of equipment if any wastewater treatment plant greater than fifteen years old was to be utilized in the twenty year planning period.
(8) It was determined with the use of a water quality model that AWT could not meet water quality criteria, hence, only Mid-bay outfall was evaluated.
(9) Total sewerage facilities capital cost (collection and treatment) $601,000,000 (May 1977).
(10) Includes other areas, such as Sewanhaka, East Norwich, Bayville and Locust Valley.

7.3.4 Funding of Comprehensive Structural Programs. The Southwest Sewer District in Suffolk County has undergone severe financing problems in recent years. Litigation, inflation and rising interest rates on bonds have all contributed to sizable increases in the initial cost estimates made over a decade ago. Local shares must currently be raised by benefit taxes charged to residents and commercial/industrial users within the district.

In order to achieve favorable interest rates on construction bonds, the Suffolk County Legislature pledged a portion of the county-wide sales tax revenue as a guarantee of the worthiness of the bonds. County participation should now be evaluated on a more permanent and direct basis. Obviously the theory of cost/benefit taxation, namely, those who benefit should be the ones to pay for the benefit, is logical. The issue though is, who are the beneficiaries? Certainly the users are direct beneficiaries. In addition, the balance of the people in the county are indirect beneficiaries wherever the quality of a segment of the county's ground and surface waters is enhanced. Therefore it is reasonable to propose that a portion of the District costs be assumed as a general county expenditure. In principle, this is analogous to the justification for county acquisition of parks, farmlands and other county facilities as a general obligation, even though the properties are located in specific areas of the county, on the grounds that all residents indirectly benefit even if they never use the facilities. Numerous funding formulas would apply. Perhaps a base charge could be levied against the users to cover the majority of local costs, thus paying respect to the narrow definition of cost/benefit. Any remaining costs in excess of the base could then become a general county charge.

Financing for the various structural recommendations made in this plan can and will be met by existing authorized programs. Sewage treatment plant upgradings, extension of outfalls, improvements in solid waste management and the development of local subdivision sewage treatment plants are generally within the fiscal means of Nassau and Suffolk County governments—assisted by Federal and State grants.

An alternative would be to increase the assesed valuation within the district. The district's transportation system, and the availability of public water facilities and public sewer systems, make this increased density possible. The rezoning of these areas in a prudent, comprehensive fashion should act as a catalyst for the redevelopment of property, with the consequent reduction of the individual tax burden.

7.3.5 Funding of Research Programs. Financing for needed research programs is dependent almost entirely on Federal support. Table 7–4 identifies the recommended research programs and, wherever possible, an estimate of cost has been made.

7.3.6 Funding of Non-Point and Non-Structural Programs. The most difficult to estimate are the non-point and/or non-structural recommendations. Many Best Management Practices, *e.g.,* fertilizer applications, catch basin maintenance, control of animal wastes, depend more on public informational efforts, and financing should not constitute an impediment to implementation. Local governmental controls and current programs can achieve great strides with little or modest budgeting increases. Stormwater runoff control, if requiring structural means, can run as high as $1100/acre according to EPA. (See Section L of the Areawide Waste Treatment Management Plan.) This would be for control of erosion and runoff from construction sites and, presumably, would be borne mainly by the private developer. Local communities should also be able to utilize a portion of their Community Development funds for stormwater control projects. Thus the fiscal impact on local governments should not be significant. Watershed management, however, could engender significant costs. Zone III contains approximately 45,000 deep recharge acres. Much of this is zoned for low density use. If this pattern is maintained, then the need for public funds will be minimized and less crucial. However, in the most severe case, if these lands had to be acquired either by fee simple or purchase of development rights, the per acre cost could range from $3,000 to $10,000. Suffolk County's farm program already represents a sizable county allocation ($21 million for Phase I) and should enable the purchase of the development rights for approximately 6,000 acres. To the extent possible, priority should be given to those farms within the watershed conservation zone. Other land use mechanisms are also available, *e.g.,* agricultural districting, planned unit development (PUD), transfer of development rights and clustering. These mainly represent non-cost techniques for preserving open space. The recommended land use research would be directed towards the detailing of geographically specific plans designed to assist local governments and Suffolk County to maximize water quality improvement and watershed conservation through the proper application of planning techniques.

For agricultural non-point source control, part of PL 95–217 was amended (The Culver Amendment) to provide cost-sharing to owners and operators of rural lands who implement conservation practices that relate to the improvement of off-site water quality. $200 million has been appropriated to the Secretary of Agriculture for this purpose for 1979, and $400 million

Table 7—3

ESTIMATED ADDITIONAL MANPOWER REQUIREMENTS AND COSTS FOR NON-POINT SOURCE POLLUTION CONTROLS[1]

Non-point Pollution Source	Nassau County Dept. of Health: Yearly Control Costs[2]	Nassau County Dept. of Health: Yearly Manpower Requirements (man-years/year)		Suffolk County Dept. of Health: Yearly Control Costs[2]	Suffolk County Dept. of Health: Yearly Manpower Requirements (man-years/year)		Suffolk County Dept. of Env. Control: Yearly Control Costs[2]	Suffolk County Dept. of Env. Control: Yearly Manpower Requirements (man-years/year)	
1. Stormwater Runoff	93	Assist. Eng. Assist. San. Sr. Chemist	(1) (1) (1)	10	Sanitarian Chemist Engineer	(.4) (.1) (.02)	110	Sanitary Eng. Eng. Tech. Sr. Eng. Aide	(1) (2.5) (.5)
2. Domestic Onsite Disposal Systems	60	Assist Eng. Assist. San. Sr. Chemist	(.5) (.5) (.5)	185	Sanitarian Chemist Engineer Eng. Aide Clerk/Steno.	(4) (.9) (2) (2) (1)	24	Eng. Tech. Sr. Eng. Aide	(.5) (.5)
3. Subsurface Leakage from Sewage Collection Systems		(See 10. Misc.)		150	Sanitarian Engineer Eng. Aide	(6) (1) (1)	125	Assist. San. Eng. Labor Foreman STP Helper	(1) (2) (4)
4. Product Storage, Wastepiles, Pipelines, etc.	209	Senior Eng. Assist. Eng. Sr. Sanitarian Assist. San. Sr. Chemist Assist. Chem.	(1) (1) (1) (3) (1) (1)				60	Assist. San. Eng. Environment. II	(1) (2)
5. Industrial Waste Discharges	189	Assoc. Eng. Senior Eng. Sr. Sanitarian Assoc. Chem. Sr. Chem.	(1) (1) (1) (1) (1)				18	Environment. II	(1)
6. Landfills	60	Assist. Eng. Assist. San. Sr. Chemist	(.5) (.5) (.5)	30	Engineer Sanitarian	(1) (.5)	24	Eng. Tech. Sr. Eng. Aide	(.5) (.5)
7. STP's (Groundwater Recharge)		(See 10. Misc.)		5	Engineer	(.4)	99	Sanitary Eng. Eng. Tech. Sr. Eng. Aide Eng. Aide	(1) (1.5) (.5) (1)
8. Well Construction & Abandonment		(See 10. Misc.)		80	Sanitarian Engineer Clerk/Steno.	(4.5) (.6) (1)			
9. Groundwater Development	59	Senior Eng.	(1)					(See 10. Misc.)	
10. Miscellaneous	91[3]	Assist. Eng. Assist. San. Assist. Chem.	(1) (1) (1)				75[4]	Sanitary Eng. Eng. Tech. Sr. Eng. Aide	(1) (1) (1)

Table 7–3 . . . Cont'd.

11. Additional[5]			220	Attorney	(2)
				Sr. Chemist	(1)
				Lab. Tech.	(2)
				Well Driller	(1)
				Heavy Equip. Op.	(1)
				Laborer	(2)
				Clerical	(3)
Total[5]	**761**	**460**	**755**		

[1] *See Section J of the Areawide Waste Treatment Management Plan.*

[2] *In thousands of dollars; includes personnel, fringe benefits, overhead, new equipment, supplies, etc.*

[3] *Includes Subsurface Leakage from Domestic Collection Systems, Sewage Treatment Plants, Construction Related Erosion, Well Construction and Abandonment, Agricultural Chemicals, Highway Deicing, Well Disposal of Cooling Water, and Animal Wastes.*

[4] *Includes costs for Highway Deicing Materials, Groundwater Development, Well Disposal of Cooling Water, and Agricultural Chemicals.*

[5] *Does not include the required initial purchase by each county of one additional well drilling rig at approximately $250,000 per rig.*

These figures do not include manpower and costs presently being applied to non-point pollution source controls. These figures are preliminary estimates and represent minimum requirements; actual manpower requirements will depend on the priorities of selected programs, and the scope of work and scheduling required to accomplish these programs.

Table 7–4

SUMMARY OF ESTIMATED COSTS OF PROPOSED STUDIES AND DEMONSTRATION PROJECTS

	Estimated Cost
Ongoing 208 Studies	
1. Further Definition of Groundwater Management Zones	$ 400,000
2. Application of the Regional Digital Models to Evaluate Regionwide Effects of Man-Induced Changes in Groundwater Elevation	300,000
3. Detailed Mapping of Land Uses, Natural Resources, and Environmental Constraints for the Deep Flow Aquifer Recharge Area	400,000
4. Extent and Causes of Organic Chemical Contamination	400,000
5. Evaluation and Monitoring of the Movement of Metals and Organic Chemicals in the Aquifer System	750,000
6. Assimilative Capacity of Subsoils	75,000
7. Determination of the Impact of Leakage and Spills from Hazardous Materials Storage and Transport; Identification of the Best Means of Control	320,000
8. Measurement of Groundwater Underflow Quantity and Quality and Impacts of Duck Sludge Deposits	75,000
9. Determination of the Effects of Inlet Closure on the Water Quality of Moriches, Shinnecock and Mecox Bays and of Inlet Creation on the Water Quality of Great South Bay	300,000
10. Fertilizer Research	100,000
11. Groundwater Screening for Aldicarb	25,000
12. Heavy Metals in Sediments	125,000
Total	**$ 3,270,000**
Demonstration Projects	
1. Marsh-Pond Treatment of Sewage	$ 100,000
2. Marsh-Pond Treatment of Runoff	200,000
3. Street Sweeping	200,000
4. Structural Treatment of Stormwater	2,500,000
5. Comprehensive Monitoring as an Aid in Making Wastewater Management Decisions	150,000
6. Denitrification of Individual Subsurface Sewage Disposal Facilities	110,000
7. Removal of Nitrates from Drinking Water Supplies	450,000
Total	**$ 3,710,000**
Total Ongoing 208 Studies and Demonstration Projects	**$ 6,980,000**
Research	
1. Viruses in Aquatic Systems	$ 450,000
2. Air Pollution and Wastewater Management	300,000
3. Evaluation of the Nitrate Standard for Drinking Water	N. A.

for 1980. Thus it appears that financial support for erosion and sediment controls will be available for agricultural lands.

However, this will not provide funds for the implementation of other non-point source control measures.

It is therefore recommended that PL 95–217 be amended to provide for the funding of all Best Management Practices that will reduce pollution caused by non-point sources. This should also allow for the funding of such programs as catch basin maintenance, street vacuuming and other measures. The funding level should be commensurate with that provided for structural solutions.

The areawide recommendations for insuring the proper functioning of on-lot waste disposal systems also includes local and county government responsibility for the provision of scavenger waste treatment and disposal facilities. This would be especially necessary where the non-structural land use controls recommended in this Plan have been implemented, thus obviating the need for central collection and treatment of sewage. However, it is presently the State's position that costs for such facilities are not eligible for state construction grant funding.

It is therfore recommended that the State revise its position relative to the funding of such facilities and provide grants similar to those presently given for central collection and treatment facilities.

7.3.7 Funding of Comprehensive and Sub-Regional Groundwater Monitoring Programs. An integral part of the Nassau-Suffolk 208 Plan is that general comprehensive groundwater monitoring and area-specific monitoring programs (such as 201 study areas) be initiated immediately, in order to determine the extent of groundwater contamination and the need for implementation of structural and/or non-structural controls.

These monitoring programs are a key link in the decisionmaking process and are not presently provided for by funding in sub-regional or "201" Studies. In order to integrate the areawide 208 Plan with ongoing and future 201 Studies, funding at all levels (Federal, State and local) is essential and recommended.

7.3.8 Funding of Structural Stormwater Control Programs. The Nassau-Suffolk 208 Program has identified a number of structural stormwater control measures that may provide a cost-effective solution to surface and groundwater pollution problems in certain areas. Site-specific studies are necessary to determine the most cost-effective solution in areas where stormwater discharges have a significant impact on surface and groundwater quality.

Section 211(C) of the Clean Water Act of 1977 (PL 95-217) prohibits the funding of treatment work for the control of pollutant discharges from separate storm sewer systems. This restriction could severely limit the investigation and implementation of stormwater control measures.

Therefore, it is recommended that the Clean Water Act of 1977 be amended to remove the restriction on the funding of stormwater pollution control measures.

7.3.9 Funding of Operation and Maintenance Costs. Operation and maintenance costs for the structural recommendations contained in Tables 7–1 and 7–2 are estimated to be approximately $20–25,000,000 per year. This will be a substantial portion of the total costs of the recommended projects.

Originally, Section 17-1905 of the Environmental Conservation Law provided for State assistance of up to one-third of the approved annual operation and maintenance costs. However, this assistance is subject to the limits of annual appropriations of the State Legislature. In recent years, the rate of reimbursement has varied between 33 percent and 10½ percent. However, Section 17-1905 has been amended to reduce the level of maximum assistance to one-fourth and funding is presently at the 25 percent level. On the Federal level, a similar program does not exist.

It is recommended that a Federal Operation and Maintenance Assistance Program be developed, which is similar to the current New York State program and that funding be provided at least at a 25 percent reimbursement rate.

Such a program would insure protection of the multi-million dollar investment of State, Federal and local funds that have been used to construct sewerage facilities in Nassau and Suffolk Counties.

7.3.10 Funding of Bi-County Hazardous Waste Facility. The U.S. Environmental Protection Agency has indicated an unwillingness to provide funding for a centralized hazardous waste treatment facility to serve the two counties. The recommendation for the creation of this facility was contained in Plan Section K, "Residual Waste Control Needs", and was supported by the Technical Advisory Committee and the Nassau-Suffolk Regional Planning Board.

7.3.11 Caveat. This section discusses costs in order to provide a frame of reference as to the relative scope of water management. It is done with a great deal of reluctance. Structural costs, which are the easiest to estimate based on average prices derived from previous projects, can be in error by a factor of two. First of all, accurate estimating must be based on detailed designs and specifications. This is the province of 201 work. Future costs affected by inflation, bond market responses, new materials, techniques and equipment, and the status of the construction industry are some of the latent factors that affect prices. Indeed, the reader must keep in mind that pricing based on general planning can only lead to the dimension of future investment needs—not the real dollar cost. Consider the difficulty of the defense establishment in building a plane, tank or warship within the estimated budget after the device has been designed in excruciating detail. For that matter—how many homeowners or car buyers pay the "sticker" price.

The advantages of even going through a pricing exercise do exist however. First, it focuses attention on the general magnitude of the Program needs. Second, it alerts State and Federal agencies of future capital support budgets they may have to consider if local governments are to get the job done. Third, it is possible to achieve closer harmony with reality where cost

estimates are made for projects that should be undertaken immediately, *e.g.*, moving an outfall or initiating monitoring or research. Fourth, it clearly indicates that in most cases prevention is less costly than remedial action. Non-structural and land use solutions do require less public expenditure to achieve water quality protection than structural solutions built after pollution occurs. This does not include secondary impact analysis. Fifth, it also provides relative costs for structural alternative comparisons.

7.4 Legal Needs

7.4.1 Introduction. In general, existing laws and regulations are sufficient to cope with the majority of sewage and solid waste management needs. Point and non-point pollution sources are covered under New York State Health and Environmental Conservation laws and, additionally, by Nassau and Suffolk Charter provisions and/or ordinances. Land management and land use planning controls originate with the General Municipal Laws of the State of New York and are amplified by the two counties' charters. Thus, it is currently possible to operate a successful areawide waste treatment program in Nassau and Suffolk Counties in the framework of existing laws. Nevertheless, recommendations are contained herein to strengthen the management agencies' abilities to control non-point sources of pollution. In most instances, local statutes enacted by the counties and/or municipalities will be sufficient.

The initial portion mentions point source control for sewage treatment systems. This is followed by a discussion of legal needs covering water production, erosion and sedimentation, animal wastes and land use control. The last portion contains a proposed county environmental law designed to achieve strong control over non-point pollution sources.

7.4.2 Point Source Control. The NSRPB believes that the existing body of legislation, and administrative control relating to municipal sewage treatment plants and other point sources of pollution is adequate to ensure compliance with the Water Quality Management Plan.

Provisions of New York Environmental Law, Article 17, Title 8 (The SPDES program) are legally adequate to control all significant point sources and can be extended to control many non-point sources of surface water pollution in the Nassau-Suffolk SMSA. Permits are required for the discharge of any pollutant to insure compliance with 306 FWCPA, 1972 and "Any other applicable water quality standards and applicable effluent standards and limitations."

The provisions of SPDES are legally and administratively adequate to control all significant point pollution sources in the Nassau-Suffolk area. The program must be continued, supported and expanded. Limitations in the effectiveness of the program are due to inadequate enforcement and a conservative interpretation of the legal mandates conferred by PL 92–500 and the New York State Conservation Laws. Therefore, the NSRPB recommends that deviations from compliance schedules be minimized.

All schedules should be subject to a thorough review by NYSDEC, the EPA, the permittee and a representative of the Health Commissioner of the appropriate County Health District. Compliance is a permit condition and must be enforced.

7.4.3 Water Production. Existing provisions of Nassau County law provide for the effective centralization of water supply within the county. The relevant sections of this law are Article XII, §1202, 1207, 1208, 1212. Suffolk County has a management agency (Suffolk County Water Authority) that controls water production throughout most of the county. It has sufficient legal authority to continue the absorption of local companies.

The main legal needs apply to the process of well drilling. Proposed revisions to the New York State Environmental Conservation Law (S.3896: A.5311) relating to water well drilling and groundwater protection will fulfill these needs.

The NSRPB recommends that the revisions be fully supported. The Board, however, suggests that this draft be modified as follows:

1. Re §15–1603 and 1625. Large-capacity agricultural wells, or an aggregate number of smaller wells having the same general capacity, must not be exempted, either directly or by implication.

2. Re §15–1623. No well, other than a low-capacity private supply well, shall be permanently sealed, demolished or abandoned by any person, prior to determining the potential usefulness of the well in a groundwater monitoring program. This bill should create the possibility of public access to any well so designated.

3. Re §15–1629. The NSRPB agrees with the logic of establishing critical groundwater areas. However, the bill should recognize the fact that the groundwater resource may be endangered by various chemical contaminants which constitute a real or potential threat to the potable water supply that is equal to, and perhaps greater than, any threat caused by drought and/or overpumping.

In addition, a water supply utility should have the resources available to develop the aquifer containing the best quality water or, if necessary, transport and distribute water from neighboring areas.

Where a public water utility does not have the economic resources or legal authority to finance water main extensions, the same rationale employed in fostering the construction of wastewater collection and treatment systems by Federal and State grants should also be employed in grants for financing water supply expansion. The public health benefit is immediate and directly measurable in contrast to the potential long term benefit assigned to most sewering projects. It is, therefore, strongly urged that legislation be recommended and encouraged to provide this vital protection to the general health and welfare.

7.4.4 Non-Point Source Control, Erosion and Sedimentation. The major source of erosion and the resultant sedimentation in Suffolk County is primarily due to construction activities. Numerous state laws and local

ordinances concerned with land use and water resources can be used to implement some level of erosion control. The Soil and Water Conservation District Law is the only State law that deals specifically with soil erosion and sediment control.

The law states that by January 1, 1980, the Districts will have provided a plan to each owner and occupier of agricultural land within the District boundaries who have requested a plan. The law is deficient on two counts. It only applies to agricultural lands and contains no enforcement procedures to assure compliance.

The NSRPB recommends that the State law be amended to overcome the current deficiencies, thus assuring positive control for the agricultural areas of Long Island. This would be timely and not impose a burden on owners due to the recent passage of the FWPQA amendments of 1977.

Construction related erosion can be managed by extending the Conservation District approach into non-agricultural areas or by strengthening existing development controls, *e.g.,* subdivision ordinances, grading and filling permits, etc. The NSRPB recommends the latter approach with the added requirement that "site clearance and development plans" be part of the approval process. Such plans would identify, step-by-step, all of the activities to be undertaken on a given site and would also indicate the procedures to be followed to minimize runoff and erosion.

7.4.5 Non-Point Source Control, Fertilizers. The NSRPB recommends that the following three steps be implemented.

1. An educational effort be immediately adopted to discourage any excessive use of fertilizers and to promote adoption of low-maintenance lawns;
2. Research to be undertaken to:
   a. Further monitor the use and fate of nitrogen applied to turf;
   b. Investigate the feasibility of developing satisfactory low-maintenance lawns; and
3. Update the New York State law to require a label on turf fertilizers identifying them for use in Nassau and Suffolk.

7.4.6 Non-Point Source Control, Animal Wastes

7.4.6.1 Introduction. Dogs and semi-wild White Pekin ducks were found to be unregulated sources of non-point animal waste pollution. Urban runoff containing dog waste and other animal waste is responsible for most of the recent closures of shellfish growing areas. An information program and new laws are recommended to control dog waste disposal. Semi-wild White Pekin ducks and their descendants are also serious sources of pollution in many ponds and lakes. New laws and public awareness concerning the problem are needed to control these wastes.

Market duck waste has been a pollution hazard in the past and is now regulated by Federal and State laws. Under these laws, duck farmers have been required to achieve very limited discharges of wastewater by July 1, 1977, and zero discharge to any receiving surface waters by 1983.

Zoning ordinances in some municipalities are used to control horse waste and, indirectly, the waste related problems. However, there are many small non-point horse waste pollution sources affecting surface waters. These may require control.

The following discussion offers specific recommendations for new or amended legislation and/or local statutes to control animal wastes.

7.4.6.2 Non-Point Source, Animal Waste, Dogs. Dog curb laws may have a negative effect on the environment. East Hills and Rockville Centre have dog curbing laws requiring that owners walking dogs allow their pets to defecate only at or near the street curb. In theory, animal waste will then be swept up by street cleaning operations. In fact, animal waste in or near the road is easily flushed into the storm drainage system by rainstorm runoff. The drainage system empties into bays and estuaries, recharge basins, etc.

The NSRPB recommends that the following be implemented:

1. That affected municipal governments be encouraged to repeal dog curbing ordinances.
2. That all municipalities on Long Island, either by statute and public informational efforts, prohibit owners from permitting dogs to defecate on roads, sidewalks, parking lots, play areas, parks or other places where people congregate, unless there is prompt cleanup and removal of feces; and prohibit the free roaming of dogs, with or without license and collar.

7.4.6.3 Non-Point Source, Animal Wastes, Ducks. Duck farm animal waste is regulated by Federal and State laws. Under those laws, duck farms are required to achieve zero discharge of wastewater to any receiving surface waters by 1983. A majority of the present Long Island duck farmers now plan to meet this requirement.

Semi-wild ducks are not specifically controlled or protected by law. The State law, authorizing towns and municipalities to establish dog catchers as peace officers with certain police powers, is not clear as to whether such persons can enter properties to capture and remove semi-wild ducks. Property owners can, under this law, have the town or municipality receive and impound the ducks removed by an owner from his property.

This study has found no law or section of a law that can be construed to support the contention that semi-wild ducks are a public nuisance. However, Article 26, Section 354 and Article 25B, Section 35 of the Agriculture and Markets Law do address aspects of the problem. The first, which attempts to discourage the sale of baby ducks for pets, states that, "No person shall sell, offer for sale, barter or give away living baby chicks, ducklings or other fowl under two (2) months of age in any quantity less than six (6)." In attempting to solve the problem of domestic ducks polluting local ponds, these laws may have complicated the issue by encouraging larger purchases. The second, which applies to dogs and other animals as well as ducks, states that, "The owner. . . of an animal, who abandons such animal. . .is guilty of misdemeanor, punishable by imprisonment of not more than one year or by a fine of not more than $500 or both."

The NSRPB recommends that Nassau and Suffolk Counties and/or the municipalities enact local laws authorizing and directing dog wardens, park employees and law enforcement officers to remove White Pekin ducks and their offspring and hybrids from publicly controlled reaches of inland bodies of water.

It is further recommended that local laws be enacted at the county level prohibiting the sale of White Pekin ducks as pets anywhere in the two counties.

7.4.6.4 Non-point Source, Animal Wastes, Horses. The present primary document for statewide control of horse waste is the New York State Public Health Law, which cites animal wastes as sewage when they are waterborne, whether carried by storm runoff or base flow seepage, and as a public nuisance when the waste is offensive to neighboring property owners. Upon complaint, a health department representative may investigate, cause a hearing to be held relative to the nuisance, and require the abatement of the problem.

Zoning ordinances are often used to control the keeping of horses and, indirectly, the related problems. In the more densely populated areas in western Nassau County, such ordinances frequently prohibit the stabling of horses or limit such activities to a few selected locations.

The NSRPB recommends that all municipalities with horse populations adopt local ordinances that provide a limit on the number of horses per acre on residential land, and specify the management of disposal of horse wastes. The following clauses should be included in order to insure adequate waste management:

1. Not less than one half acre of open, unpaved land shall be provided for a single horse or other equine livestock; not less than one fourth acre of open, unpaved land shall be provided for each additional horse.

2. Each premise having less than one half acre of open, unpaved land per horse shall have and meet the provisions of an approved animal waste management plan (agency to be specified), or be in violation.

3. Animal waste, including manure and soiled bedding, shall be kept in weatherproof containers at least 50 feet from adjoining property lines.

4. Paved or otherwise unvegetated or bare soil areas used for horse yards, paddocks, pastures or similar purposes shall be graded or controlled so that no storm runoff wastes from one year frequency rainstorms falling on such areas, shall flow from the horse owner's property to other public or private lands.

7.4.6.5 Conservation Plan for Animal Wastes. Under present State law agricultural producers must develop a plan to reduce sediment and related animal waste pollution by January 1, 1980. This plan is to be developed with the assistance of the Nassau and Suffolk County Soil and Water Conservation Districts. The NSRPB recommends that the present law be amended to require non-agricultural animal owners, who have high concentrations of animals per acre, to develop a plan, with Soil Conservation District assistance, for the control of animal waste. Table 7—5 indicates the maximum number of animals that should be allowed per acre of open land without a conservation plan.

Table 7—5

MAXIMUM ANIMALS PER ACRE OF OPEN LAND WITHOUT A CONSERVATION PLAN

Equine Livestock	2	Hogs	14
Beef Cattle	3	Ducks	400
Dairy Cows	2	Sheep	24
Turkeys	160	Dogs	20
Chickens	500		

or any combination of animals exceeding 2,000 pounds of body weight.

7.4.7 Ensure the Proper Functioning of On-Lot Waste Disposal Systems.

a. *Provide for Routine Maintenance of On-Site Disposal Systems.* Provision should be made for routine pumping and maintenance of on-site systems in order to extend the service life of the leaching facility and to ensure its continued efficacy. Local or county government should be responsible for the provision of scavenger waste treatment and disposal facilities.

County sponsored public education to encourage voluntary implementation is recommended. The promulgation of legislation mandating routine pumping and maintenance is not proposed at this time.

b. *Prohibit the Use of Certain Chemical Cleaners in On-Lot Systems.* If organic solvents and other chemical agents contain ingredients which might reasonably be expected to impair groundwater quality, their use for cleaning or extending the service life of on-lot sewage disposal systems should be prohibited or controlled. A program to identify such products is presently being conducted by Nassau County Health Department and Suffolk County Departments of Health Services and Environmental Control, and should be continued and emphasized. This should be coupled with specific county legislation banning the local sale of these products within Nassau and Suffolk Counties.

7.4.8 Strengthen and Enforce Regulations Pertaining to Industrial Wastes, Product Storage and Transportation, and Residuals.

a. *Expand Regulations and Enforcement Regarding the Disposal of Industrial Wastes.* Where industrial wastes are discharged to municipal sewer systems, strict enforcement of sewer use ordinances should be insured. Suffolk County is revising its sewer use ordinance to conform to applicable State and Federal guidelines. This revision will be implemented by October, 1978. Nassau County has already adopted such an ordinance. These county ordinances should be the model for all other municipalities or sewer districts within each respective county and as such should be adopted by each of these entities. Each municipality or sewer district should be responsible for the

enforcement of the ordinances and should maintain an adequate staff for such enforcement.

Present regulations covering the discharge of industrial wastes to the ground should be expanded to include greater coverage of specific contaminants and to prescribe allowable discharge levels. This applies primarily to organic chemicals and heavy metals.

b. *Regulate the Storage and Transportation of Chemical Products.* Permits and other controls should be required for the storage and transportation of chemical products that pose a threat to either the groundwater or surface water. The regulations should cover prescribed practices, safety requirements, inspection of equipment and contingency plans for interim storage and clean-up. The county agencies should be responsible for enforcing the permit regulations and control measures; the individual operator should be responsible for maintaining records and monitoring. In addition to industrial chemicals, these products include chemical wastes and sludges, de-icing salts and petroleum products. Salt storage facilities should be designed to prevent leachate contamination of groundwater.

Particular emphasis should be placed on the regulation of gasoline storage facilities at automobile service stations and, to a lesser degree, home heating oil storage tanks. Criteria should be developed and enforced to ensure the integrity of all storage facilities. The 208 Study has recognized these two types of facilities as major potential pollutant sources but has not been able to define the precise magnitude of the problem.

c. *Provide for the Treatment of Hazardous Wastes.* The industries in the Nassau-Suffolk region and the wastewater treatment processes they employ generate two kinds of hazardous wastes: small volumes of strong, toxic industrial wastes, and industrial waste treatment sludges.

In view of the environmental sensitivity of the study area, continued disposal of these types of hazardous wastes outside of the area should be encouraged. However, if this disposal option is not available in the future, treatment facilities or landfills for the disposal of hazardous wastes will have to be provided in the bi-county area. The 208 recommendation is for a regional hazardous waste treatment facility for both counties. If a single facility cannot be implemented, individual county facilities are then recommended.

Treatment facilities should, wherever possible, be located at a sewage treatment plant with an ocean outfall. The effluent from the hazardous waste treatment facility should be disposed via the outfall, not to the plant influent. The outfall disposal will provide a temporary discharge in the event of a hazardous waste facility upset.

If a hazardous waste treatment facility cannot be located at a sewage treatment plant with an ocean outfall, it can be located somewhere in the area served by the plant, and can discharge *treated* effluent to the sewer system. Effluent monitoring must then be intensive so that, in the event of a plant or process upset, a slug of toxic waste can be prevented from reaching the downstream treatment plant.

If a hazardous waste treatment plant is not connected to a treatment plant ocean outfall, and is located in the deep-flow aquifer recharge area, special provisions must be made to contain any waste spillage. The wastes must not be allowed to percolate into the ground. Consequently, impermeable retention lagoons must be provided, large enough to take the entire plant inventory, in the event of a radical plant failure.

The hazardous waste treatment facilities should provide treatment for both organic and inorganic wastes where feasible. Radioactive wastes should not be handled at the facilities.

7.4.9 Stormwater Runoff Control. Pollution of surface waters from runoff water can be reduced by controlling the amount of pollutants in the streets, the flow of water transporting the pollutants, natural treatment of the runoff, and mechanical treatment and disinfection of collected stormwater.

It is recommended that a uniform procedure be adopted for estimating the total and peak rates of runoff by all the municipal and county planning agencies. This requires amendments to at least some of the existing subdivision regulations.

It is also recommended that the Conservation Farm Planning Law be amended to provide for enforcing of agricultural stormwater runoff where offsite damage occurs.

In order to implement these recommendations, the NSRPB should establish an ad hoc committee of municipal and county planners, engineers and water resource specialists to prepare a handbook of guidelines and standards for Best Management Practices (BMP) for the control of stormwater erosion and non-point sources of pollution.

7.4.10 Land Management/Land Use Authority. Various sections of the FWPCA (101, 201, 303 and 314) make reference to land use management requirements, the preservation of land resources, and generally indicate that land use regulations should be utilized to control point and non-point sources of pollution.

Section 208 provides that the areawide treatment management plan include "the establishment of a regulatory program to regulate the location, modification and construction of any facilities within such area which may result in any discharge in such area, . . .". This appears to require indirect authority for the 208 Plan to regulate location of all pollutant discharges by seeking appropriate changes in land use plans from the agencies possessing land use control jurisdiction in the 208 area.

A more explicit authority for the 208 Plan to consider land use in the 208 area is provided in Section 208 (b) (2) which states that the plan will set forth procedures and methods, including use requirements, to control to the extent feasible non-point sources of pollution. The term "land use requirements" in Section 208 (b) (2) should be interpreted to include those land use controls (legally permitted uses) and those land management regulations (regulations of activities conducted on land) that contribute to the attain-

ment of water quality standards.

The nature of the "land use authority" that is required by FWPCA is discussed in EPA, Draft Guidelines for Areawide Treatment Management, (May, 1974), Chapter 4. These guidelines provide that:

"primary reliance will be placed on utilizing existing land use plans and controls. In some cases it may be necessary to update these in order to incorporate changes responsive to water quality objectives. In such cases, the 208 planning agency *must work closely with the local governments possessing legal authority* for land use planning and controls. It is also possible that some jurisdiction within the 208 area will not have land use plans and/or controls. In this case, the 208 agency should work with the appropriate jurisdiction to gather enough information about the area so that current and future development patterns and policies can be identified and, if necessary, updated to incorporate water quality objectives."

Acting pursuant to the provisions of the General Municipal Law and County Charter provisions, Nassau and Suffolk have authorized their respective County Planning Commissions to review certain actions. Municipalities are required to submit to the county planning commission: new zoning regulations, amendments to zoning regulations; changes in zoning district classifications, variances from zoning ordinances; special use permits, special exceptions or other special authorizations.

Municipalities are required to refer the zoning actions to the county planning commission when the action will affect real property lying within a distance of 500 feet of: municipal boundary lines; existing or proposed county or state parkways, thruways, expressways or highways; existing or proposed rights-of-way of any stream or drainage channel owned by the county or for which the county has established channel lines; and existing or proposed state and county-owned land on which public buildings or institutions are located.

7.4.10.1 Nassau County. The Nassau County Planning Commission reviews four basic types of zoning actions: (1) amendments to zoning ordinances; (2) variances; (3) zone changes; and (4) special use permits and special exceptions. The Commission evaluates the effects of zoning applications in relation to adjacent properties, arterial highways, public parks and other recreation areas, public institutions, the environment and the projected needs of the community. In this way, the Commission attempts to encourage comprehensive and coordinated planning between all communities in the county.

Depending on circumstances, the Commission adopts resolutions recommending either disapproval or modification of the application. The Commission may also recommend that the matter be determined locally, *i.e.,* when it has no objections, which constitutes a majority of the actions. When the Commission recommends disapproval of the application, the local board may overrule with a majority-plus-one vote, accompanied by a statement as to the reasons of its action within seven days, either overruling or modifying the application.

7.4.10.2 Subdivision Plat Approval. §1610, as amended, of the Nassau County Charter, gives the Planning Commission conclusive authority to approve subdivision plats, establish standards for public improvements such as road, utilities and storm drainage, and to supervise the installation of required improvements in the unincorporated areas of the county, and reviews subdivisions that are located either within a distance of three hundred feet of city and village boundaries, or in unincorporated areas.

7.4.10.3 Suffolk County, Zoning Review. Article XIII of the Suffolk County Charter provides for review by the Suffolk County Planning Commission of zoning actions, special permits, variances and land subdivision plats that are within one mile of a nuclear power plant or airport; or within 500 feet of the boundaries of: villages, towns; county, State or Federal parks; rights-of-way for county or State roads; rights-of-way of county-owned streams or drainage channels; boundaries of other county, State or Federal land; or the Atlantic Ocean, Long Island Sound, any bay in the county or estuary of those waters.

Planning Commission response may be: (1) no recommendation (a matter for local determination); (2) disapproval (or with modification recommended) for stated reasons; or (3) approval for stated reasons. The municipality may override by vote of a majority-plus-one, with a statement of reasons therefore.

§1330 of the Suffolk County Charter provides that any adopted zoning ordinance or amendment thereto (excluding variances and special permits) occurring within 500 feet of a town or village boundary must be submitted for review to the Planning Commission. The Commission has forty-five days in which to act on these referred zoning actions. If an objection is registered within twenty days of receipt, the Commission must schedule a public hearing and render a decision which can only be negated through court action.

If an objection is registered with the Commission by a state agency concerned with environmental protection a public hearing will be scheduled and decision rendered by the Commission within forty-five days. A proposed municipal zoning action disapproved by the Commission may not be adopted by the town or village that referred it, and if an action is approved by the Commission with change, it may not be adopted by the referring body except as amended in accordance with the Commission's report.

7.4.10.4 Subdivision Plat Referral. The Suffolk County Charter also provides for Planning Commission review of proposed subdivisions. Section 1333, Article XIII, of the Suffolk County Charter provides for the referral of certain proposed plats by the authorized municipal agency to the Suffolk County Planning Commission.

Plats must be referred to the Suffolk County Planning Commission if located wholely or partly within one mile of a nuclear plant or airport, or within a distance of five hundred (500) feet from: any municipal boundary, existing or proposed county, State or Federal parks, roadways, other public

lands and the coastal edge including county designated streams.

The Commission response may be: (1) local determination; (2) disapproval; (3) conditional approval; or (4) approval as submitted.

These rules and regulations of the SCPD establish subdivision plat review criteria that are relevant to water quality management. For example, subdivisions are required to provide stormwater collection systems so designed that no water running across or falling on the tract shall reach a county road or roads. Further, stormwater cannot be directly disposed of into any creek, stream, brook, bay, harbor or any other body of water. In the case of waterfront lots in shoreline areas: no buildings can be placed at the top of slope or at the edge of bluff. Additional setbacks are required to compensate for the effects of erosion on the shoreline. No stormwater drainage or concentrated runoff is permitted to flow down the face of the bluff or shoreline slope. All grading and clearing on shorefront lots is restricted to insure stability of the face of slope or bluff against erosion.

Sections 1321 and 1322 of the Suffolk County Charter further provide that the Planning Commission may recommend a comprehensive zoning plan to any town or village in Suffolk County and may make such other recommendations involving the performance of the planning function by towns or villages as the Commission deems appropriate. The Planning Commission may, on request of any town or village in Suffolk County, furnish the town or village with requested planning services.

7.4.10.5 Recommendations. Thus, it is evident that most municipal zoning requests and subdivision designs are already subject to review, advice and/or regulation by the county planning commissions.

Subdivision review is consistent with the requirements of 208 planning and is completely handled by Nassau County and local municipalities. In Suffolk, the preponderance of cases is reviewed by the county.

It is recommended that Section 1333, Article XIII of the Suffolk County Charter be amended to provide that all proposed subdivision plats be referred to the Planning Commission to insure that non-point source runoffs will not occur as a result of subdivision construction activities.

It is also recommended that similar amendments be made to Section 1330, Article XIII of the Suffolk County Charter and Article 12–b, Subsection 239 n of the General Municipal Laws. Obviously, any zone changes that produce use density increases, will have a direct impact on water quality management. Intensification of use may require an increase or the creation of additional collection and treatment facilities. Since the two counties have the lead responsibility for implementation of the 208 Plan, it is imperative that the counties are aware of, and participate in, the total zoning process. It is recommended that NCPC be authorized to implement 239 n.

Realistically, this should be within the current budgetary and staffing capabilities of the two county planning departments, since those agencies now handle well over 90 percent of such actions.

7.4.11 County Environmental Law. This discussion on "Legal Needs" contains a number of recommendations for new or amended legislation and ordinances to augment the existing authorities. However, the passage of laws does not automatically guarantee compliance and implementation. Federal and State environmental laws have often been permissively enforced. Persuasion rather than penalty has been the rule. In Suffolk County there has been discussion of providing a strong comprehensive county environmental law—analogous to the State law, except that it provides for strong local legislative control. It must be stressed that this is a draft and subject to revision.

7.5 Public Informational Program

7.5.1 Introduction. Implementation of planning programs depends on the translation of "good planning" into "good politics." The public must perceive that there is a real crisis confronting them that must be resolved, and this collective perception must be made known to the elected decisionmakers. All too often, public officials are confronted by the "naysayers." Rarely is affirmative general support brought to their attention. Yet this is the key. It is the essence of all successful policies and programs.

The scientific and technical findings of this 208 Program has convinced the participants that a real crisis exists in the two counties about waste treatment management. The quality of the Island's potable and swimming waters, the opportunities for rational growth, the potential for sound economic development, the protection and enhancement of the living resources—in sum the future quality of life on this Island—depends on sound areawide waste treatment management.

We must now expand efforts to share the results of research efforts, findings and recommendations with the broadest array of citizens possible. This will include the dissemination of reading materials, public hearings and a broad-based speaking program.

7.5.2 Publications. The TAC has published a special report on animal wastes, six interim reports, and this Plan Summary. In the aggregate these reports constitute a summary of the more than 150 reports, studies and data memoranda produced during the conduct of the Study. (See Appendix A for a summarization of the data and printed material.)

All public libraries in the two counties will be furnished with the set of TAC reports. The complete set of basic documents and data printouts will continue to be available at the NSRPB office for viewing during regular working hours.

The news media—radio, television and papers—have given fair coverage of the Study during the past two years. Steps have been taken to assure broad coverage of this Plan Summary in the media to aid in the widest distribution possible.

7.5.3 Public Hearings. Formal presentations have been made to the two county legislative bodies this spring. Additional hearings will be held in various locations to afford town and village governments a direct opportunity

to question the technicians. These public hearings will be presented by the NSRPB staff, members of the TAC and the appropriate consultants.

7.5.4 Speaking Program. It is obvious that a region of 1200 square miles and almost three million people will require more than a limited number of public hearings if the general public is also to receive a live explanation of the 208 Plan. The staff will endeavor to also respond to business, civic and environmental groups. We expect to be ably assisted in this opportunity by members of the CAC. They independently established a speakers bureau and prepared their own printed materials and a very ably executed slide presentation.

During 1978, the NSRPB anticipates that the public informational program, which has been in effect since 1976, will reach every interested group in the two counties. Funding for the staff presentations will be a NSRPB responsibility. If continuing 208 funds will not be available for the CAC informational efforts, the NSRPB will cover these costs as well.

Although the campaign to secure implementation will be quite arduous, it is certainly worth the commitment of time, money and energy. The 208 Plan is a sound one, technically and fiscally, often imaginative, and absolutely vital if Long Island's most basic natural resources, its superb potable and marine waters, are to be preserved and enhanced.

7.6 Implementation Schedule

7.6.1 Nassau County Municipal Point Source Abatement Dates

a. *Bay Park—Designated 201 Facilities Planning Area*
(Including the Bay Park, Inwood, Cedarhurst, Lawrence, West Long Beach and the Long Beach Sewage Treatment Plants)

PHASE 1. Expand to 75 million gallons per day with Bay Outfall

Step 1	Approved	2nd quarter 1978
Step 2	Completed and Approved	2nd quarter 1980
Step 3	Completed	1982/83

PHASE 2. Ocean Outfall

Step 1	Approved	1st quarter 1979
Step 2	Completed and Approved	1st quarter 1981
Step 3	Completed	1983/84

Note: a. Lawrence Sewage Treatment Plant—Further investigation recommended as regards diversion or AWT
b. Long Beach Sewage Treatment Plant—Possibility of a 201 Study to be conducted by City and County
c. Unsewered areas (such as Point Lookout) will be considered in this schedule

b. *Cedar Creek—Designated 201 Facilities Planning Area*
(Including the Cedar Creek, Farmingdale, Meadowbrook, Grumman and Freeport Sewage Treatment Plants)

Step 1	Initiated	3rd quarter 1978
Step 1	Completed (including pilot studies)	3rd quarter 1981
Step 2	Completed and Approved	3rd quarter 1983
Step 3	Completed	1986/87

Note: Plants already scheduled to divert flow:

Farmingdale Sanitarium	Cease discharge 1981
Meadowbrook	Cease discharge 1978
Grumman	Cease discharge 1981
Freeport	Cease discharge 1979

c. *Port Washington Peninsula—Designated 201 Facilities Planning Area*
(Including the Port Washington and Village of Roslyn Sewage Treatment Plants)

Step 1	Initiated	4th quarter 1977
Step 1	Completed and Approved	4th quarter 1979/80
Step 2	Completed and Approved	4th quarter 1982/83
Step 3	Completed	4th quarter 1984/85

Note: All unsewered areas will be considered in the above timetable.

d. *Oyster Bay and Surrounding Areas—Designated 201 Facilities Planning Area*
(Including the Oyster Bay and Sewanhaka Yacht Club Sewage Treatment Plants)

Step 1	Initiated	2nd quarter 1978
Step 1	Completed and Approved	4th quarter 1980
Step 2	Completed and Approved	4th quarter 1983
Step 3	Completed	4th quarter 1985/6

Note: All unsewered areas such as Bayville will be considered in the above timetable.

e. *Great Neck Peninsula—Undesignated 201 Facilities Planning Area*
(Including the Belgrave, Village of Great Neck and Great Neck Sewer District Sewage Treatment Plants)

Step 1	Designation	3rd quarter 1978/9
Step 1	Completed and Approved	1st quarter 1981/2
Step 2	Completed and Approved	1st quarter 1984/5
Step 3	Completed	1986/7

f. *Glen Cove—Designated 201 Facilities Planning Area*

Step 1 and Completed		1978
Step 2		
Step 3 Completed		1981/2
AWT (N Removal) or mid-bay outfall		1985/6

Secondary treatment with a nitrification stage is presently being constructed. Due to studies undertaken during the 208 Study it may be necessary to conduct further studies in this area.

g. *Plants not Included in a 201 Designated Area*

New York Institute of Technology	1985/6
AWT or Diversion	
C. W. Post	1985/6
AWT or Diversion	

7.6.2 Suffolk County Municipal Point Source Abatement Dates

a. *Southwest Sewer District*

- commence operations 10/78
- complete construction 1980
- design flow 1986

1. Central Islip State Hospital Sewage Treatment Plant
2. Republic Aviation Sewage Treatment Plant
3. Farmingdale Agricultural and Technical Sewage Treatment Plant
4. Islip Scavenger Waste Sewage Treatment Plant
5. Babylon Scavenger Waste Sewage Treatment Plant

b. *Port Jefferson*

201 Step 1 Complete	4th quarter	1978
201 Step 2 Complete	4th quarter	1980
201 Step 3 Complete		1984

1. Port Jefferson Village Sewage Treatment Plant
2. Strathmore—Stony Brook Sewage Treatment Plant

c. *Yaphank* (assumes county approval in 1978)

201 Designation	1st quarter	1979
201 Step 1 Completed	4th quarter	1980
201 Step 2 Completed	4th quarter	1982
201 Step 3 Completed		1985/1986

1. Selden Sanitary Sewage Treatment Plant
2. Brookhaven Scavenger Waste Sewage Treatment Plant

Permit Compliance	1978

d. *S. Central* (assumes county approval in 1978)

201 Designation	1st quarter	1979
201 Step 1 Completed	4th quarter	1980
201 Step 2 Completed	4th quarter	1982
201 Step 3 Completed		1985/1986

1. Patchogue Village Sewage Treatment Plant

Permit Compliance	March 1983

e. *Kings Park* (assumes county approval in 1978)

201 Designation	1st quarter	1979
201 Step 1 Completed	4th quarter	1980
201 Step 2 Completed	4th quarter	1982
201 Step 3 Completed		1985/1986

1. Kings Park Sewage Treatment Plant

f. *West Central* (assumes county approval in 1978)

201 Designation	1st quarter	1979
201 Step 1 Completed	4th quarter	1980
201 Step 2 Completed	4th quarter	1982
201 Step 3 Completed		1985/1986

1. Suffolk State School Sewage Treatment Plant
2. Strathmore—Huntington Sewage Treatment Plant
3. Pilgrim State Hospital Sewage Treatment Plant

g. *Riverhead*

201 Step 1 Completed	2nd quarter	1978
201 Step 2 Completed	2nd quarter	1980
201 Step 3 Completed		1984

1. Riverhead Sewage Treatment Plant

h. *Huntington*

201 Step 1 Completed	4th quarter	1979
201 Step 2 Completed	4th quarter	1981
201 Step 3 Completed		1985

1. Huntington Sewage Treatment Plant
2. Northport Sewage Treatment Plant

i. *Greenport*

201 Step 1 Completed	4th quarter	1979
201 Step 2 Completed	4th quarter	1981
201 Step 3 Completed		1985

1. Village of Greenport Sewage Treatment Plant

7.6.3 Nassau County Industrial Discharges

- Powers Chemco: 6/78 to meet NPDES permit.
- Fairchild Camera: currently meeting SPDES permit; will connect to sewer by 12/84.
- Grumman: currently meeting SPDES permit; will connect to sewer by 9/81.
- Liberty Industrial: currently meeting SPDES permit; will relocate to Suffolk County by 6/78.
- Metallurgical Processing Corporation: 6/78 to meet SPDES permit; will connect to sewer by 12/84.
- TOD Manufacturing: currently meeting SPDES permit; will connect to sewer by 12/81.
- Li Tungsten: currently meeting NPDES permit.

- Cerro Wire: 12/78 to meet SPDES permit; will connect to sewer by 12/84.
- General Instruments: currently meeting SPDES permit; will connect to sewer by 12/81.

7.6.4 Suffolk County Industrial Discharges

- Circuitron
- Fairchild Republic
- Fairfield Noble
- Deltown Foods
- Suffolk Processing Corporation

The above firms are within the Southwest Sewer District and, are anticipated to be discharging to municipal sewers by 1980.

- Hazeltine Corporation: has converted to a completely closed system.
- Liberty Industrial: will relocate to Suffolk with a closed system.
- Bellport Islip Cleaners
- Bluepoint Laundry
- Strebels Laundry
- Arrow Laundry

Compliance schedule will be modified on NYSDEC approval of engineering report. The above firms currently operate in violation. Full compliance expected by January 1980.

- Entenmann's Bakery: compliance by 6/78.
- Stimson: no abatement date established.
- Q. C. Circuits: compliance by 1/79.
- Oak Tree Farm: schedule modified, compliance by 3/78.

7.6.5 Nassau-Suffolk Industrial Non-Point Discharges. The following programs and schedule dates apply to industrial source control programs in both counties. The majority of the industrial sources have been identified and are being inspected and sampled on a regular basis.

Salt Stockpiles. Identification, inspection and sampling are presently underway and SPDES applications are scheduled for completion by 1/79.

Industrial Storage Practices. Identification, inspection and sampling are presently scheduled to be undertaken by 6/78 and SPDES permit applications are scheduled for completion by 6/79.

Petroleum Storage Practices. Identification, inspection and sampling are presently scheduled to be undertaken by 1/79 and SPDES permit applications are scheduled for completion by 1/81.

7.6.6 Solid Waste Management Facilities

a. *Landfills.* Article 27, title 5 of the New York State Environmental Conservation Law authorizes NYSDEC to regulate the design, construction and operation of all solid waste management facilities to protect the public health and the environment of the State. 6 NYCRR360 was adopted in September 1973 and established a permit system to insure compliance with design and operations standards and provides, in part, as follows:

- that all new solid waste management facilities must comply with the provisions of 360 as a permit/operating condition.
- that existing facilities that do not comply with 360 must furnish an improvement schedule as a permit condition.

The NSRPB Water Quality Management Program incorporates all compliance dates and schedules developed pursuant to Part 360 by reference.

Specific recommendations for solid waste management facilities are contained in Chapter Six of the Plan Summary and Section K of the Water Quality Management Program.

b. *Incinerators*

The Black-Clawson facility is expected to begin shakedown operations by July 1978. At a later date, when the facility is fully operational, the following facilities will cease operations:

- N.C.S.D. No. 1
- Valley Stream
- Garden City
- Long Beach

Target dates for other incinerators are as follows:

• Glen Cove Co-Disposal Facility	operation:	1980
• Patchogue	cease operation:	1980
• Huntington	cease operation:	June 1981*
• Islip	cease operation:	June 1981*
• Babylon	cease operation:	1981*
• Multi-Town Solid Waste Management Facility	operation:	1981

*These facilities will cease operation when the Multi-Town Facility is operational.

c. *Scavenger Waste Treatment Plants*

• Southold	permit compliance:	10/79
• Shelter Island	permit compliance:	10/79
• Riverhead	permit compliance:	10/79
• Southampton	permit compliance:	10/79
• East Hampton	permit compliance:	10/79
• Brookhaven	permit compliance:	10/79

At present, Southold, Shelter Island, Riverhead, Southampton and East Hampton discharge scavenger wastes to disposal pits. The facility at Brookhaven does not meet discharge requirements. Permit compliance will entail providing facilities within each respective municipality, or hauling scavenger waste to other approved facilities in the County.

• Babylon	cease operation:	6/79
• Islip	cease operation:	6/79

These facilities will be phased-out after the Southwest Sewer District facility at Bergen Point commences operation: 10/78

7.6.7 Stormwater Control. The NSRPB does not believe that it is possible to establish definite abatement dates relating to stormwater control. The Nassau-Suffolk Water Quality Management Program, however, can establish a generalized phased approach to stormwater control that will entail a number of sequenced activities. This sequence assumes that USEPA will approve the NSRPB Water Quality Management Program by mid-1978, and that Congressional funding of USEPA will permit the required demonstration.

- Develop a detailed plan of study relating to various stormwater control options in the Nassau-Suffolk SMSA, including, but not necessarily limited to, improved street cleaning, diversion, detention, and treatment. Study dates are outlined below:
  - —Study outline completed—June 1978.
  - —Demonstration projects approval—June 1979.
  - —Demonstration, alternative assessment monitoring program, non-structural approaches—end 1983.
  - —Implementation of selected approaches—1984, depending on nature or extent of construction requirements.

Appendix A Bibliographic Data Summary

A.1 Introduction

In a project as complex as the 208 Program it is extremely difficult to produce a description of all of the efforts which have gone into the acquisition and analysis of the data gathered during the course of the study. This report will outline the major study tasks and the type of data acquired for each. It will also outline those areas where major data collection was performed and a list of all documents produced with cross references to the type of information available in each. Interim 208 Study reports will receive extensive distribution to government, educational and research organizations. It would be almost impossible to publish and make available for general distribution all of the original, historical and newly obtained data which was used in preparing final reports. The latter documents are on file at the Nassau-Suffolk Regional Planning Board and are available to those interested in more detailed information on a particular phase of the project.

In some cases, such as groundwater quality, treatment plant operation and bacteriological quality of surface waters, a substantial amount of historical data existed. Information on nutrient levels in certain bays, organics and viruses in surface and groundwater and non-point sources was lacking in many cases. Even where historical data were available, extensive analyses of these data were required to determine the accuracy due to changing analytical techniques and long-term natural fluctuations in parameters such as runoff, nutrients and flushing characteristics.

It is obvious that in such a complex interdisciplinary study a great deal of information is required to adequately characterize the system under investigation. As in any ecosystem, each functional part is inter-related. In few places is this shown as clearly as on Long Island. Water is not only a major connecting link, but the limiting factor in development and the types of activities which can take place on the Island. Any alteration in the hydrologic regime will have direct or indirect effects on other parts of the system.

The investigations had as their major emphasis the collection and analysis of data required to determine the quality and quantity of surface and groundwaters. Groundwater studies required the use of analog and digital models to predict the effects of pumping rates and patterns and the effects of groundwater contamination by pollutant sources such as landfills. In order to be reliable, these models required the input of large amounts of current information on groundwater elevations, subsurface geology and present and predicted pumpage patterns. Characterization of groundwater quality required design of sampling programs to study the concentration and distribution of viruses, trace metals, organic compounds, pesticides, fertilizers and other chemical constituents related to water quality. In many areas, new test wells were drilled to obtain this information.

Since the surface waters of Long Island are intimately connected with changes in groundwater, field programs were designed to obtain data on the hydrography, chemistry, microbiology and point and non-point sources of pollution in the bays and surrounding marine surface waters. A major data collection effort was required to inventory and characterize all possible point sources in the Nassau-Suffolk area. These included municipal and private wastewater treatment plants, landfills, scavenger plants, industrial sources and incinerators. Data were also compiled on present and projected wastewater flows in order to assess possible structural alternatives in the wastewater management program.

It was initially agreed that to whatever extent possible, the operating and regulating agencies of each county would carry out the field sampling and laboratory analyses. The rationale for this is quite clear:

a. These agencies work with this information on a day-to-day basis and thus exhibit a level of expertise relative to local conditions which an outside consultant could not be expected to have;
b. The operating agencies were already equipped in many cases to undertake various aspects of the field programs; and,
c. Funds provided by the grant would allow the agencies to develop a greater degree of efficiency through purchase of new equipment. This equipment and the experience gained would provide a basis for continued updating of the Program when the initial planning phase was completed.

A.2 Data Collection Program

For each phase of the Program, collection and analyses of existing data were required before field surveys and sampling programs could be formulated. In some cases this meant an extremely long period of searching the files of government, educational and research agencies. In others, voluminous data held by organizations had to be verified as to their relevancy to the Program. Table A–1 lists the agency involved, main topic of investigation and the present repository of the original data. The location of the original data is listed rather than reports comprising reduced data since those interested in pursuing further research on a particular subject generally desire the former type of data over reports containing final analyses of basic research reports.

Table A–2 summarizes the type of data available for each geographical area. The explanation of the table gives examples of data types included under each topic.

Data pertaining to the mainland areas, such as general hydrogeology or organic chemicals in test well samples, are listed as Nassau or Suffolk County "General." No effort has been made to indicate the amount of data for a particular parameter available for a specific location. For example, although hydrogeological data is shown for almost all bays, the only data available in many areas are estimates of subsurface underflow to the bay which are based on indirect evidence from other studies. Conversely there is a great deal of historical and newly acquired data available on the groundwater and subsurface geology of the mainland of the Island.

Table A–3 is a compilation of the types of data collected by each agency or consultant (see Table A–2 for explanation of heading). Again, there has been no attempt to indicate the amount of data held by a particular agency since the data collection effort involved parameters which were of interest to or routinely collected by several agencies. For example, although the Suffolk County Water Authority is especially interested in groundwater quality, it also routinely collects precipitation data. Because of this, a certain degree of interpretation is required in using these tables. For example, suppose we were interested in coliform data for Hempstead Harbor; Table A–2 indicates that such data is available while Table A–3 lists five agencies possessing microbiological data. Since Hempstead Harbor is in Nassau County, the primary contact would be the Nassau County Health Department followed by the general consultants, such as Tetra Tech, Inc.

Table A–4 lists all reports and publications prepared or assembled to date according to subject. Individual reports are listed serially in Section A.3, the Bibliographic Summary. Each report, as received, was assigned an accession number, the data types entered in Table A–4 and the reference added to the end of the Bibliography. Using this system, a reader interested in all reports dealing with a particular topic, such as non-point source pollution, merely has to write down the accession numbers of all reports listed under "Pollutant Sources." One may at the same time make a "first-cut" by eliminating all those except the reports indicated as having "Pollutant Sources" as their major emphasis.

Since planning is a continuous process, it is expected that new information will be generated. Table A–4 and Section A.3 are arranged to allow for additional listings.

Explanation of Tables 2, 3 and 4

Following is a list of major data types included in Tables A–2, A–3 and A–4 with examples of sub-categories within each major heading.

- Reference number (Accession number of each reference)
- Type (Primary [P] or Secondary [S] reference)
- Administrative (proposals, request for proposal, project control plans, contracts, etc.)
- Biology (wildlife, shellfish, productivity, etc.)
- Chemistry (COD, trace metals, inorganics, organics)
- Data Acquisitions (historical data, field sampling, methodology)
- Demography (population, land use, etc.)
- Ecology (natural resources, environmental impacts, etc.)
- Economics (cost/benefit, etc.)
- Geology (surface and subsurface, sediments)
- Hydrogeology (groundwater quality and quantity)
- Legal (present and proposed regulations)
- Meteorology (air quality, wind, precipitation)
- Microbiology (bacteria, viruses, algal species, BOD)
- Modeling (analog and numerical)
- Nutrient Chemistry (nitrogen and phosphorus)
- Physical Oceanography (temperature, salinity, tides, flushing, currents, etc.)
- Toxicology (pesticides, herbicides, organics, etc.)
- Residuals (sludge, solid, hazardous, etc.)
- Point Sources (treatment plants, industrial discharges, duck farms, etc.)
- Non-Point Sources (stormwater runoff, septic tanks)
- Trace organics (in groundwater, rainfall)

Table A–1
LIST OF PARTICIPATING AGENCIES/CONSULTANTS
AND MAJOR AREAS OF STUDY

Agency/Consultant	Main Area of Interest
Nassau-Suffolk Regional Planning Board (NSRPB) H. Lee Dennison Executive Office Building Veterans Memorial Highway Hauppauge, New York 11787 (Dr. Lee E. Koppelman, Executive Director)	Administration Demography Land Use Planning Legal Aspects
United States Geological Survey (USGS) Water Resources Division 5 Aerial Way Syosset, New York 11791 (Grant Kimmel)	Analog Modeling Geology Hydrogeology
Suffolk County Soil and Water Conservation District (SCSWCD) U. S. Department of Agriculture (USDA) Soil Conservation Service 127 East Main Street Riverhead, New York 11901 (Anthony Esser)	Agricultural Runoff Animal Wastes Erosion
New York State Department of Environmental Conservation (NYSDEC) Region I, Building 40 State University of New York Stony Brook, New York 11794 (Philip Barbato)	Administration Advisory Review Lab Analyses
Suffolk County Department of Environmental Control (SCDEC) 65 Jetson Lane Hauppauge, New York 11787 (Vito Minei)	Laboratory Analyses Meteorology Non-Point Sources Sampling Surface and Groundwater Sampling Point Sources Structural Alternatives
Suffolk County Department of Health Services Bureau of Environmental Health (SCDHS) H. Lee Dennison Executive Office Building Veterans Memorial Highway Hauppauge, New York 11787 (Dr. Aldo Andreoli)	Groundwater Quality Trace Organics Sampling Trace Metal Sampling Viruses
Suffolk County Water Authority (SCWA) Water Quality Laboratory Sunrise Highway Oakdale, New York 11769 (August Guerrera)	Groundwater Quality Laboratory Analyses
Nassau County Department of Health (NCDH) Bureau of Water Pollution Control 240 Old Country Road Mineola, New York 11501 (Theodore Burger)	Groundwater Sampling Marina/Boating Effects Point and Non-Point Source Sampling Surface Water Sampling
Nassau County Planning Department (NCPD) Division of Environment and Conservation One Old Country Road Carle Place, New York 11514 (George Andrek)	Intra-Agency Coordination Land Use Planning
Nassau County Department of Public Works (NCDPW) Division of Sanitation and Water Supply Nassau County Executive Building One West Street Mineola, New York 11501 (James Oliva)	Point Sources Structural Alternatives
Town of Islip Department of Environmental Control (IDEC) 577 Main Street Islip, New York 11750 (Barry Andres)	Non-Point Source Sampling Surface Water Sampling Virus Sampling
Cornell University Division of Agricultural Engineering (CES) Ithaca, New York (Dr. Keith Porter)	Fertilizers Hydrogeology Nitrogen Modeling Pesticides
Princeton University Department of Civil Engineering Princeton, New Jersey 08540 (Dr. George Pinder) (Dr. Robert Cleary)	Groundwater Modeling Hydrogeology Landfill Leachates

Table A—1 (cont'd.)

Agency/Consultant	Main Area of Interest
State University of New York Stony Brook, New York (SUNY) (Dr. Edward Beltrami) (Dr. T. Owen Carroll)	Project Control Plan Critical Pathways Program Schedule
Brookhaven National Laboratory (BNL) Division of Applied Sciences Upton, New York 11972 (Dr. James Vaughn)	Viruses
Energy Resources Company, Inc. (ERCO) 185 Alewife Brook Parkway Cambridge, Massachusetts 02138 (Ronald Beck)	Cost/Benefit Analyses Environmental Impacts
Geraghty and Miller, Inc. (G&M) Consulting Hydrogeologists 44 Sintsink Drive East Port Washington, New York 11050 (David Miller)	Groundwater Quality and Quantity Hydrogeology
Tetra Tech, Inc. (TT) 496 Smithtown By-Pass Smithtown, New York 11787 (Gary Bigham)	Analyses of Structural Alternatives Surface Water Modeling Water Quality Assessments
R. F. Weston (RFW) 1044 Northern Boulevard Roslyn, New York 11576 (John DeFilippi)	Cost of Structural Alternatives Point and Non-Point Sampling Program Structural Alternatives Wastewater Management Options
Woodward-Clyde Consultants (W/C) 2909 West 7th Avenue Denver, Colorado 80204 (Daniel Rabinowitz)	Hydrogeology Well Drilling Program

Table A–2

DATA AVAILABILITY vs. GEOGRAPHICAL AREA

Data Type	Western Long Island Sound	Nearshore Atlantic	Manhasset Bay	Hempstead Harbor	Oyster Bay	Huntington Bay	Port Jefferson	Peconic-Flanders System	Moriches Shinnecock System	Mecox Bay	Great South Bay	South Shore Bays (Nassau)	Nassau County (General)	Suffolk County (General)
Alternative Analysis			✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
Administration													✓	✓
Biology	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		
Chemistry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Data Acquisition	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Demography													✓	✓
Ecology			✓	✓	✓	✓	✓	✓			✓	✓		
Economics													✓	✓
Geology			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Hydrogeology			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Legal													✓	✓
Meteorology		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Microbiology	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Modeling			✓	✓	✓	✓	✓	✓			✓	✓		
Nutrient Chemistry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Physical Oceanography	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Toxicology													✓	✓
Residuals													✓	✓
Point Sources	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Non-Point Sources			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Trace Organics													✓	✓
Non-Modeled Areas	✓	✓							✓	✓				
Modeled Areas			✓	✓	✓	✓	✓	✓		✓	✓	✓	•✓	

• – Indicates groudwater models
✓ – Indicates data available

Table A–3

DATA AVAILABILITY vs. AGENCY AND CONSULTANT

Data Type	NSRPB	USGS	SCSWCD	NYDEC	SCDEC	SCDHS	SCWA	NCDH	NCPD	NCDPW	IDEC	CES	Princeton University	SUNY	BNL	ERCO	G&M	TT	RFW	W/C
Alternative Analysis	✓									✓								✓	✓	
Administration				✓					✓	✓				✓						
Biology			✓	✓	✓			✓								✓		✓		
Chemistry			✓	✓	✓	✓	✓	✓				✓	✓				✓	✓		
Data Acquisition	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓	✓	✓	✓	✓	✓
Demography	✓	✓							✓											
Ecology																✓				
Economics	✓				✓					✓						✓			✓	
Geology		✓	✓				✓					✓	✓				✓			✓
Hydrogeology		✓					✓					✓	✓				✓		✓	✓
Legal	✓			✓					✓			✓								
Meteorology					✓		✓						✓		✓					
Microbiology					✓	✓		✓			✓				✓			✓		
Modeling												✓	✓	✓				✓		
Nutrient Chemistry					✓			✓				✓						✓		
Physical Oceanography					✓													✓		
Toxicology												✓								
Residuals					✓	✓													✓	
Point Sources				✓	✓			✓		✓			✓				✓	✓	✓	
Non-Point Sources			✓		✓	✓		✓		✓		✓					✓	✓	✓	
Trace Organics						✓	✓	✓								✓				

✓— Indicates data available

Table A–4

CROSS-REFERENCE OF DATA TYPES CONTAINED IN INDIVIDUAL REPORTS COMPILED IN NSRPB 208 STUDY

Ref. No.	Type	Alternative Analysis	Administration	Biology	Chemistry	Data Acquisition	Demography	Ecology	Economics	Geology	Hydrogeology	Legal	Meteorology	Microbiology	Modeling	Nutrient Chemistry	Physical Oceanography	Pollutant Sources	Toxicology	Residuals
1	P		(x)																	
2	P		x												(x)					
3	S			x										(x)						
4	S			x										(x)						
5	**P**			**x**										**(x)**						
6	**P**				**x**						**x**		**–**						**(x)**	
7	**S**				**x**		**–**				**(x)**			**–**		**–**		**–**		
8	**P**				**–**		**–**			**–**	**x**				**(x)**					
9	P						x												(x)	
10	P				–		–												(x)	
11	P				(x)		x									–				
12	S	(x)				–	–	–							–			–		
13	**S**	**(x)**				**–**	**–**	**–**							**–**			**–**		
14	**P**				**–**		**–**			**–**	**x**				**(x)**					
15	**P**				**–**		**–**			**–**	**x**				**(x)**					
16	**P**				**(x)**	**–**					**x**							**–**		
17	P		(x)																	
18	S	–	–			x		(x)												
19	S											x					(x)			
20	S	x	–			–		(x)												
21	**S**	**–**	**–**					**(x)**												
22	**S**		**–**			**–**														
23	**S**	**–**	**–**			**–**		**(x)**												
24	**S**	**–**	**–**					**(x)**												
25	P				(x)	–					x							x		
26	P				x	(x)														
27	P				x	(x)					x									
28	P				x	(x)					x									
29	**P**	**x**		**x**	**x**			**(x)**	**–**					**x**	**–**	**x**	**x**	**x**		**–**
30	**P**	**x**		**x**	**x**			**(x)**	**–**					**x**	**–**	**x**	**x**	**x**		**–**
31	**P**	**(x)**						**x**	**x**									**x**		**x**
32	**P**					**x**	**x**			**x**	**(x)**	**–**						**–**		**–**
33	P					–	x				(x)									
34	P		(x)								x									
35	P									x	(x)									
36	P		(x)								x							x		x
37	**P**						**–**				**(x)**							**x**		**x**
38	**P**						**–**				**(x)**							**x**		**x**
39	**S**		**x**																	**(x)**
40	**S**		**–**								**(x)**							**x**		
41	S		–									(x)								
42	S		(x)																	
43	S				x	(x)					x									
44	P		–				(x)													
45	**P**		**(x)**																	
46	**P**		**–**												**(x)**					
47	**S**									**–**	**x**	**(x)**								
48	**P**					**x**				**x**	**(x)**				**x**					
49	P					x				x	(x)				x					
50	P					x				x	(x)				x					
51	P									(x)										
52	P			x		x						x						x		(x)

(x) – major emphasis, but may include other minor topics or data
x – data with discussion
– – data presented but discussion minimal or lacking

Table A—4 (cont'd.)

CROSS-REFERENCE OF DATA TYPES CONTAINED IN INDIVIDUAL REPORTS COMPILED IN NSRPB 208 STUDY

Ref. No.	Type	Alternative Analysis	Administration	Biology	Chemistry	Data Acquisition	Demography	Ecology	Economics	Geology	Hydrogeology	Legal	Meteorology	Microbiology	Modeling	Nutrient Chemistry	Physical Oceanography	Pollutant Sources	Toxicology	Residuals
53	S											(x)		x						
54	S																	(x)		x
55	S										x							(x)		x
56	S	(x)									x							—		—
57	S				x	(x)														
58	P	x			x	x							—	x	(x)	x	x	x		
59	P	x			x	x							—	x	(x)	x	x	x		
60	P	x			x	(x)								x		x	x	x		
61	P		(x)												x					
62	P	x			x	(x)								x		x	x	x		
63	P				x	(x)								—	—	—	—	—		
64	P	x			x	x							—	x	(x)	x	x	x		
65	P			(x)																
66	P	x			x	x							—	x	(x)	x	x	x		
67	P		(x)							x					x					
68	P				x	(x)								x		x	x	x		
69	P				x	(x)								x		x	x	x		
70	P				x	(x)								x		x	x	x		
71	P		x		—	—							—	—	(x)	—	—	—		
72	P	x			x	x							—	x	(x)	x	x	x		
73	P	x			x	x							—	x	(x)	x	x	x		
74	P				x	(x)								x		x	x	x		
75	P					x							—		(x)					
76	S											(x)					x			
77	P				x	(x)								x		x	x	x		
78	P				x	(x)								x		x	x	x		
79	P			x		x								x			(x)			
80	P	(x)			x									x		x	x	x		
81	P				x	(x)								x		x	x	x		
82	P				x	(x)							—	x	(x)	x	x	x		
83	P				x	(x)								x		x	x	x		
84	P		—		—	x								—	(x)	—	—	—		
85	P	x			x	x							—	x	(x)	x	x	x		
86	P	x			x	x							—	x	(x)	x	x	x		
87	P	x			x	x							—	x	(x)	x	x	x		
88	P		—			x									(x)					
89	P	(x)			x	x								x	(x)	x	x	x		
90	P				x	(x)								x		x	x	x		
91	P		—		—	—								—	(x)	—	—	—		
92	P	x								x	x				(x)					
93	P	x								x	(x)							x		
94	P	x								x	(x)									
95	P	x								x	(x)				(x)					
96	P				x	x	x											x		x
97	P	(x)			x	x	x											x		x
98	P	(x)			x	x	x											x		x
99	P	(x)			x	x	x											x		x
100	P		(x)																	
101	P						(x)				x					x		(x)		
102	P				x	x	x				—		x	x		x		(x)		
103	P				x	x	—				—			x		x		(x)		
104	P				x	x	—				—			x		x		(x)		

(x) — major emphasis, but may include other minor topics or data
x — data with discussion
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Table A–4 (cont'd.)

CROSS-REFERENCE OF DATA TYPES CONTAINED IN INDIVIDUAL REPORTS COMPILED IN NSRPB 208 STUDY

Ref. No.	Type	Alternative Analysis	Administration	Biology	Chemistry	Data Acquisition	Demography	Ecology	Economics	Geology	Hydrogeology	Legal	Meteorology	Microbiology	Modeling	Nutrient Chemistry	Physical Oceanography	Pollutant Sources	Toxicology	Residuals
105	P													x		x		(x)		
106	S													x		x		(x)		
107	P													x		x		(x)		
108	S	(x)												–		–		–		
109	P													x		x		(x)		
110	P	x																x		(x)
111	P		(x)								–									
112	S		(x)								–									
113	P										x									
114	P		(x)								–									
115	P	(x)							x									x		x
116	P	(x)							x									(x)		
117	P	(x)							x		–							x		x
118	P										–	(x)								
119	S									–	x				(x)	x				
120	S	(x)									x							x		–
121	P											–		x				(x)		
122	S									x	x					x		(x)		
123	P										–					(x)		x		
124	P	(x)							(x)									x		
125	P										x					x		(x)		
126	P									x	(x)									
127	P									x	(x)									
128	P	–												x	–	x	x	x		
129	P													x	–	x	x	x		
130	P																	x		
131	P				x	x							x	x		–		(x)		
132	P					x											(x)			
133	P			x	x	x										–	–	x		
134	P			(x)	x	x										–	x			
135	P					x				x	(x)		x							
136	P					x					x									
137	P				x	x							x	x		x		x		
138	P				–							x		–				(x)		
139	P			x								–		x						
140	S											x								
141	S											x								
142	S											x						–		
143	P			x				x				x								
144	P				x	x								x		x	–			
145	P				x	x								x		x		x		
146	P				x	x								x		x		x		
147	P		x				x					x								
148	P			x	x									x	–	x	–	–		
149	P				–		x					–						x		
150	P				x									x				x		
151	P				–							x		–				–		
152	P				–									–	–	–		x		
153	P				–									–		–		x		
154	P	x	–						–									x	–	
155	P	x							–									x	–	
156	P	x			–				–					–		–		x		

(x) — major emphasis, but may include other minor topics or data
x — data with discussion
– — data presented but discussion minimal or lacking

A.3 BIBLIOGRAPHIC SUMMARY

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   Oyster Bay (8/23)
   Western South Shore Bays (9/14, 9/17, 9/18, 9/19, 9/21, 9/23)

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   Massapequa Creek (2/22, 3/31, 4/1, 4/25, 4/26)
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   Mill Neck Creek [Beaver Lake] (5/19)

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Note: In the text, all Subparts are referred to as Sections, e.g., Section a is Subpart a.

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Map Section

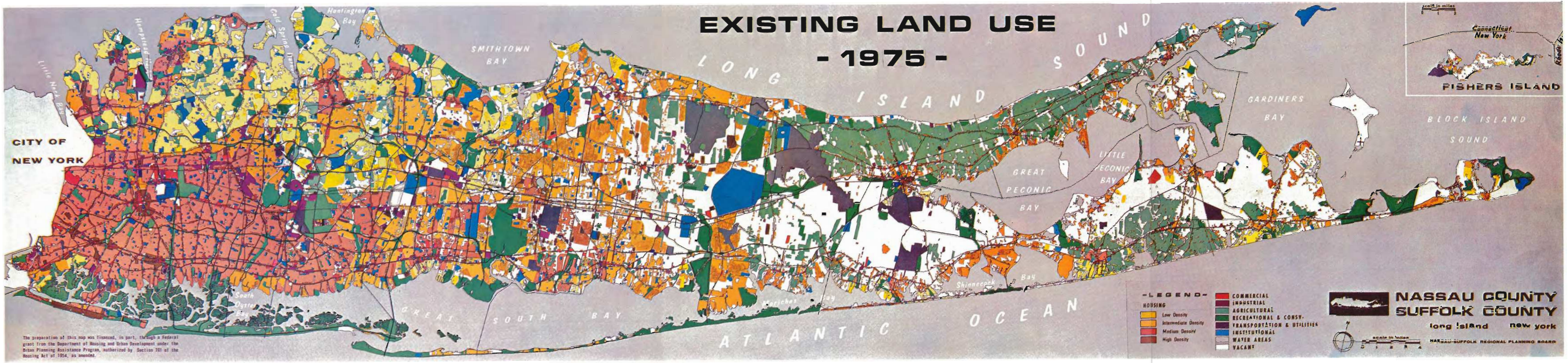
EXISTING LAND USE
- 1975 -
CITY OF NEW YORK
Little Neck Bay
Hempstead Harbor
Cold Spring Harbor
Huntington Bay
SMITHTOWN BAY
LONG ISLAND SOUND
GREAT PECONIC BAY
LITTLE PECONIC BAY
GARDINERS BAY
BLOCK ISLAND SOUND
FISHERS ISLAND
Connecticut
New York
South Oyster Bay
GREAT SOUTH BAY
Patchogue Bay
Shinnecock Bay
ATLANTIC OCEAN
-LEGEND-
HOUSING
Low Density
Intermediate Density
Medium Density
High Density
COMMERCIAL
INDUSTRIAL
AGRICULTURAL
RECREATIONAL & CONSV.
TRANSPORTATION & UTILITIES
INSTITUTIONAL
WATER AREAS
VACANT
NASSAU COUNTY
SUFFOLK COUNTY
long island new york
NASSAU-SUFFOLK REGIONAL PLANNING BOARD
The preparation of this map was financed, in part, through a Federal grant from the Department of Housing and Urban Development under the Urban Planning Assistance Program, authorized by Section 701 of the Housing Act of 1954, as amended.

Figure 2-1

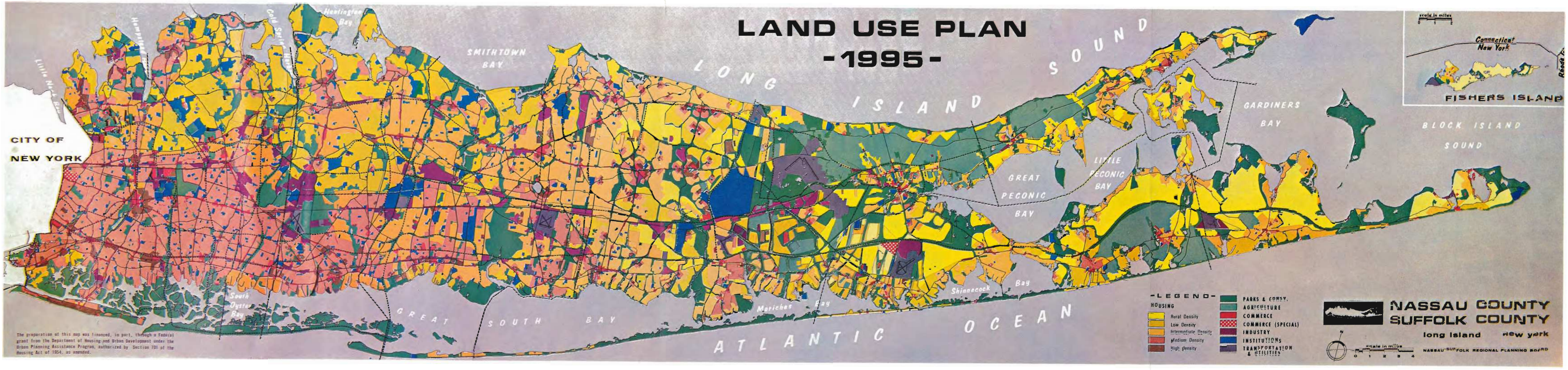
LAND USE PLAN
-1995-
CITY OF NEW YORK
Little Neck Bay
Hempstead Harbor
Cold Spring Harbor
Huntington Bay
SMITHTOWN BAY
LONG ISLAND SOUND
GARDINERS BAY
BLOCK ISLAND SOUND
GREAT PECONIC BAY
LITTLE PECONIC BAY
Shinnecock Bay
Moriches Bay
South Oyster Bay
GREAT SOUTH BAY
ATLANTIC OCEAN
Connecticut
New York
FISHERS ISLAND
Rhode
scale in miles
-LEGEND-
HOUSING
Rural Density
Low Density
Intermediate Density
Medium Density
High Density
PARKS & CONSV.
AGRICULTURE
COMMERCE
COMMERCE (SPECIAL)
INDUSTRY
INSTITUTIONS
TRANSPORTATION & UTILITIES
NASSAU COUNTY
SUFFOLK COUNTY
long island new york
scale in miles
NASSAU-SUFFOLK REGIONAL PLANNING BOARD
The preparation of this map was financed, in part, through a Federal grant from the Department of Housing and Urban Development under the Urban Planning Assistance Program, authorized by Section 701 of the Housing Act of 1954, as amended.

Figure 2-2

THE LONG ISLAND COMPREHENSIVE WASTE TREATMENT MANAGEMENT PLAN

THE LONG ISLAND COMPREHENSIVE WASTE TREATMENT MANAGEMENT PLAN

VOLUME II: SUMMARY DOCUMENTATION

LEE E. KOPPELMAN
Project Director

July 1978

NASSAU-SUFFOLK REGIONAL PLANNING BOARD

Hauppauge, New York

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Dedication

THE HONORABLE H. LEE DENNISON, P.E.

First Suffolk County Executive, first in environmental planning, first in open space preservation, and first in the thoughts of his associates, constituents and friends.

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Newsday Photo

Foreword

Water, life's ultimate indispensible mineral, is no match for its greatest enemy, man. But man's victory is hollow.

"Mommy, my toothbrush tastes funny." This scene could be early morning in Levittown, Lynbrook or Port Jefferson, as a typical Long Island family prepares to begin another day. The circumstances along with others similar in consequence could become reality in the absence of the comprehensive water quality management program contained in this multi-faceted work. Even with this document, they might come to pass. The program only shows the way. Unless implemented, toothbrushes may indeed begin to taste funny and surface waters, commercially and recreationally, may become endangered hydrological species. In this brief context—citing hazards but knowing they can be eliminated—I write this introductory segment with utmost pride. This work, in my opinion, represents excellence unusually distinctive in quality, a demonstration of a public agency's ability to create, produce and execute at the highest level of competency.

Long Island possesses rich and unusual natural bounty: white and pebbleless ocean sands, vast expanses of salt meadow, white-cedar swamps, inland pine barrens, flat plains, colorful downs, fiordlike harbors, bays, ponds, lakes and freshwater bogs. It offers something to suit the taste for nature in each of us. It is a remarkably varied, beautiful and fertile insular tract, lying at the threshold of the greatest urban center in the nation. For 250 years after its first settlement Long Island changed little. From 1812 to the turn of the century Suffolk County's total population increase amounted to only 42,582 souls. Even the railroad did little to alter the generally rural atmosphere. All this serenity came to an abrupt end following World War II when people, equal in number to the population of more than a dozen states, emigrated eastward across the city line. Vast public works were carried out, parkways and expressways laced the largest island on the Atlantic seaboard. But it was not until 1974, two years after passage of the Federal Water Pollution Control Act Amendments, that the fruits of environmental management became apparent and resulted in this far-reaching document. Chronologically it represents the Region's fourth most important plan—following the Nassau County Charter in 1938, the Suffolk County Charter in 1959 and the Bi-county Comprehensive Development Plan in 1970—affecting the lives of all its residents.

There is a valid question concerning the Region's success in developing comprehensive studies. Would they be possible without a regional planning agency? Possibly, yes; anything is. But as timely and of such professional calibre; probably not. Therefore, the underlying wisdom in establishing an areawide regional planning agency has been amply justified. The Nassau-Suffolk Regional Planning Board was created in 1965 by adoption of ordinances and resolutions by the Boards of Supervisors of Nassau and Suffolk, in accordance with provisions of the General Municipal Laws of New York State. As the solutions to economic and social problems become increasingly regionwide in nature, having this agency with a proven track record in performance already in place will serve as a source of assurance to Long Island citizens.

It would be extremely shortsighted to view this plan as just another study—its pages like leaves on trees, deciduous and gone, once fallen to the ground. Its direct value is in its use as a working document, important to the life-styles of future generations and business growth. Indirectly, the applicability of its analyses and findings renders it of national importance and in turn assures national recognition of Long Island as a homogeneous entity with identity well beyond its false reputation as simply a bedroom community.

There is a legal expression, "The evidence speaks for itself." So do the following pages. In the main, Long Island's water supply, derived solely from its own groundwater sources (and not even partially from Connecticut—the erroneous impression lingers) is adequate in terms of quantity. Tunnels from upstate or other outside sources are not only unnecessary, they are equally foolish even to consider. But there is the point-blank question of preserving the quality of our water. This stern challenge must be met by the courage of government supported by an informed constituency, sensitive to parochial interests, yet willing to override them for the common good. Effective implementation will provide bread-and-butter benefits in preserving home values, protecting the quality of life and sustaining economic strength.

Elsewhere in this document the reader will find amply justified expressions of appreciation to the numerous private citizens who served on the technical and citizens advisory committees. Policy was always determined by Board members, past and present. Their cooperation along with that of elected officials was crucial to the completion of this work. In this regard our lasting gratitude is enthusiastically extended to the following: to former founding member and Chairman, Leonard W. Hall; former County Executives Ralph G. Caso and H. Lee Dennison; County Executives John V. N. Klein and Francis T. Purcell; former Board members, Thomas Halsey and Robert Flynn; and present Board members: Vice Chairman Seth Hubbard, Vincent Balletta, Robert Bell, Winfield Fromm and John Wickham. Finally, words are often weak and fruitless when attempting to describe the single most important contribution. For that I simply conclude with where it all began, was and will be, by use of proper noun: Dr. Lee E. Koppelman.

Harold V. Gleason
Chairman

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This program has been a collective endeavor in the best sense of that term. Interdisciplinary skills involving a wide array of scientific talents, and administrative inputs from all levels of government, were required. The program could not have been satisfactorily completed without the enthusiastic participation and support of all persons involved in the development of the Nassau-Suffolk Areawide Waste Treatment Management Plan. The dedication and pride of involvement displayed by the members of the various county departments, consulting firms, and members of the public, were indeed a marvel, and credit for the products of this program must be shared with these people. We have tried to acknowledge their contributions by including their names on the Participation Page. We sincerely hope that we have not inadvertently omitted recognition of anyone. In particular, we owe a debt to our colleagues of the United States Environmental Protection Agency, Region II, who displayed as deep a commitment to the interests of Long Island as any of the local representatives. Mr. Eckardt Beck, Regional Administrator, and his able colleagues, Mr. Conrad Simon, Mr. Charles Durfor, Mr. Anthony Conetta and others, provided invaluable guidance and staff support. They were positive advocates for the program from its inception. Our requests were seriously considered and promptly acted upon—including bringing Federal scientific experts to our agency as specific problems unfolded. We enjoyed similar general support from the New York State Department of Environmental Conservation. Commissioner Peter Berle, Deputy Commissioner Theodore Hullar, Mr. Thomas Eichler, Mr. Michael O'Toole, Jr., Mr. Philip DeGaetano, Mr. Philip Barbato, Mr. Andrew Yerman, Mr. James Redman, and Mr. Wiacheslaw Fedoriw, ably represented the State's interests.

This summary documentation volume is the result of a special effort to afford the reader a solid cross-section of the supporting material used in formulating the Plan. Therefore, it is proper to acknowledge those professionals who were responsible for each of the sections. Section One was prepared by Malcolm Hair using data from field surveys and modeling studies conducted by Tetra Tech, Inc., with the assistance of member agencies. Section Two was written by David W. Miller, assisted by Jeffrey P. Sgambat, Charles A. Rich and Thomas L. Tessier. Section Three was written by James Vaughn, E.F. Landry and the following members of the Brookhaven National Laboratory Virology Group: M.Z. Thomas, Cheryl Ann Beckwith, Lois J. Baranosky, Marilyn Dahl, Neva Delihas, Wayne Penello, Mary Purpura and Thomas Vicale. Section Four was written by Ron Beck with the assistance of William Steinhauer, Mark Scott, John Ehrenfeld, Robert Pojasek, Ann Baxter and Gail Schubert. Section Five was written by Keith Porter assisted by David Bouldin, Christine Shoemaker, Leland Baskin, Douglas Zaeh, Steven Pacenka, Daniel Fricke, Brian Anderson, Albert Hermann, Wendy King, Karen Kottlar and Cynthia McGaw. Section Six was written by Charles Barnett, Anthony Esser and Adelaide Flatau. Section Seven was written by Edward Beltrami and T. Owen Carroll of S.U.N.Y. at Stony Brook. Section Eight was prepared by the Project Director. Section Nine was prepared by Arthur Kunz, Edith Tannenbaum and Carol Moor.

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Prefatory Comments

Introduction

The passage of the Federal Water Pollution Control Act Amendments of 1972 heralded a new era in environmental management. National interest and purpose was stated in the goal to achieve "water quality which provides for the protection and propagation of fish, shellfish and wildlife and provides for recreation in and on the water" by 1983, wherever attainable. It not only set forth a timetable for action but also provided some new approaches to solving the problems of our nation's polluted waters. For the first time there is a clear recognition that improved quality and the prevention of further pollution will also require changes in land use and management of growth in addition to the prevailing practice of building sewage treatment works. Non-point sources of contamination which result from construction and agricultural activities, highway runoff, widespread discarding of the residues of modern society, and the lack of control over animal wastes, etc. must now be considered. The Act is a landmark in three other instances. It provides for a comprehensive planned approach, requires strong citizen participation in the planning process and mandates a commitment from state and local governments to implement the results of the planning effort.

Section 208 of the Act specifically creates a comprehensive water quality management program to deal explicitly with both the treatment and the prevention of water pollution. The plans prepared under this program must include a process for meeting established water quality goals and must show that management institutions exist with sufficient financial and legal authorities to implement the plan; or that new institutional arrangements will be created to achieve this purpose.

The Nassau-Suffolk Regional Planning Board (NSRPB) was designated by Governor Malcolm Wilson in December 1974 as the regional planning entity to carry out Section 208 planning for Nassau and Suffolk Counties. Realizing that a program of this magnitude had to have the support and input from those governmental agencies that either have an interest in, or a mandated role to play in water pollution control, the NSRPB immediately established a Technical Advisory Committee (TAC) to assist it in the preparation of the plan. The initial voting constituency of the TAC included representatives from the Nassau County Departments of Health, Public Works and Planning. The Suffolk County participants were from the Departments of Health and Environmental Control and the Suffolk County Water Authority. The seventh member was the Executive Director of the Nassau-Suffolk Regional Planning Board who served as Chairman of the Technical Advisory Committee and Project Director for the overall program.

In addition to the seven voting members, representatives from the Interstate Sanitation Commission, Region II of the Environmental Protection Agency (EPA), the New York State Department of Environmental Conservation (NYSDEC), the United States Geological Survey (USGS), the Suffolk County Soil and Water Conservation District and the Soil Conservation Service (SCS), the Cooperative Extension Service (CES) and the New York State Department of Health (NYSDH) were invited to participate as resource members.

In accordance with the guidelines for Section 208, and prior practices of the Board in conducting other regional planning studies, the Citizens Advisory Committee (CAC) was created to provide input to the TAC from the general public, and to act as a forum for distributing the findings of the study to the general public.

The Program received a $5.2 million grant from the EPA to carry out the detailed work program necessary to comply with the requirements of the Act.

Between January 1975 and June 1978 the TAC, which was formed prior to the grant award in June 1975, met at least one day a week, first for the design of the Program and selection of consultants, and then for the general conduct of the Program. The CAC met bi-weekly during this period.

The consultants retained to carry out specific technical tasks were selected by national solicitation on the basis of merit. This single factor was one of the key elements in achieving the high level of competence displayed in the Plan.

Report Description

This volume is a consolidation of the six interim reports, and the special report on animal wastes, published during the conduct of the study. It summarizes the almost 200 technical documents used in the preparation of the 208 Plan. In addition, two new sections have been added that discuss the results of the organics sampling program and the nitrates study. This particular information was an integral input into the Plan and appears here in print for the first time.

This volume affords the serious reader a reasonably complete summary of the scientific and planning data used in developing and substantiating the direction of the recommended alternatives in the Summary Plan (Volume I).

The presentation is in nine sections, with two appendices. The first two sections describe surface and groundwater conditions, followed by four sections that provide more detailed information on the four major parameters that impact ground and surface waters, *i.e.,* viruses, organics, nitrates and animal wastes. The next section explains the types of models used for analytical and predictive purposes in assessing ground and surface water conditions. The last two sections present the management alternatives and population projections developed for the Plan. The appendices provide detailed tabular demographic data.

Section One—Surface Water Quality—contains the summarized results of the collection and review of all existing data on marine surface waters; the statistical analysis of, and identification of shortfalls in, the existing data; the design of field sampling programs to complete the data base; and the design, calibration and verification of the mathematical models used to represent and predict surface water quality under various conditions.

Section Two—Groundwater Conditions—is presented in three parts. The first discusses the availability of water in the two counties, and includes a brief explanation of some of the previously proposed water management plans applicable to Long Island. The second part is an assessment of the principal sources of groundwater contamination. The last part characterizes existing groundwater conditions, by aquifer; discusses trends in quality; and summarizes the preliminary findings of the virus study and organics evaluation.

Section Three—Virus Study—proceeds from a literature review to a discussion of the methodology used in site selection, sample collection, virus concentration and isolation, and identification procedures and related tests. This is followed by a discussion of the results of the study in terms of its implications for ground and surface waters.

Section Four—Organics—summarizes the methodology and analytical results of the sampling program, which attempted to determine the types of organic compounds that may already have contaminated portions of the aquifer system. Health implications are discussed.

Section Five—Nitrates—provides an overview of existing data on nitrogen sources to groundwater. The methodologies and results of fertilizer use surveys and field studies are described. The relationship between development and groundwater quality degradation is examined, and a regional nitrogen budget is presented.

Section Six—Animal Wastes—discusses the impact of animal wastes as a major non-point source of pollutants to ground and surface waters. It also contains a series of administrative and legal recommendations for the control and management of animals and their wastes.

Section Seven—Modeling Studies—presents a brief description of the hydrodynamic principles used in the design of water quality models. This is followed by a description and discussion of the surface water and groundwater models used in the 208 Study.

Section Eight—Management Options—addresses non-point pollution sources and stresses non-structural solutions, stormwater runoff control, conservation, and watershed management in the first of two parts. The latter portion addresses point source pollution control, where the emphasis is on structural solutions. Conventional treatment technology is described. The balance of this part mentions alternatives to conventional technology, ranging from sprinkler irrigation and meadow/marsh/pond systems, to on-site facilities.

Section Nine—Population Projections 1975—1995—contains estimates of the 1975 population and of the population at zoned capacity for each of the 108 municipalities, 126 school districts, and 30 drainage basins in the two counties. It also contains population projections in five-year intervals for these areas. Two appendices are included. The first is a complete tabular listing of the projection series. The second discusses the comparison of these projections with projections made earlier by other agencies.

Administrative Observations

The Section 208 effort discussed herein has proven to be challenging and rewarding. Since the Program is entirely new from a national point of view, it can serve as an example for other parts of the nation. An indication of the strengths and weaknesses, successes and failures resulting from this initial effort can assist in the formulation of continuing programs to be carried out in this Region and in other parts of the country.

First among the strengths, we should acknowledge the strong interest and support received from Region II of EPA, which recognized that Nassau and Suffolk Counties are completely dependent on groundwater for potable water supply; have a varied and complex marine environment surrounding the entire Region; and contain areas of human settlement that represent the full triad of planning concerns, *i.e.,* urban, urban-suburban interface, suburban-rural interface. The recognition by EPA that all three impact the natural environment led to the granting of sufficient funds—well beyond the normal allocation formula—to carry out the program.

Second among them was the full cooperation in the best professional sense, of the various members of the TAC who represented organizations

with sometimes strong and differing institutional biases. Third was the very high caliber of talent that exists in public service at all levels of government and which is evidenced in the results of this Study. A fourth source of strength was the impartial selection of consultants by the TAC without any external political or parochial controls to inhibit its national search for the most competent firms; and a fifth was the establishment of a strong CAC, who were self-organized rather than selected by the agency.

The weaknesses of the Program were primarily of an administrative and timing nature. Two major limitations were imposed by the insistence of EPA on plan completion, including approval by the Governor, within a two-year planning period. Although the Act requires Plan development within twenty-four months, provisions existed for project design prior to this phase for up to twelve months. EPA determined to dispense with the pre-planning opportunity. In a sense this fiat is the antithesis of the planning concept itself. The Agency was forced to "learn on the job," thus creating plans by work assignment amendments. The problem was further compounded by the changes in guidelines, regulations and reporting procedures imposed by EPA after the contract and original work program were agreed upon and approved. In essence, EPA was also "learning on the job."

The remedy for these time constraints was either to curtail some of the work efforts or to rigorously manage the productivity of staff and consultants. We chose the latter course, thus placing all of the participants under constant pressure. This in not an optimal administrative choice.

The second shortfall could have developed at the end of the planning period. Implementation, in the full sense of the term, often can take as much time as the Plan development process itself. If the intent is to achieve the sincere acceptance and approval of the general public and various elected and appointed officials—and not be the result of default—then the planners and CAC members must have adequate opportunity to present the case. This was attempted in part during the plan development period. The Project Director delivered nearly 50 presentations to various governmental, professional, civic, environmental and business groups in the two counties. Other members of the TAC, CAC, and consultants also made many presentations. However, the Plan options themselves could only be finalized at the end of the planning process. Thus, the public information phase has to extend beyond the first two years. This is particularly the case in a region of almost three million people. One, or even several, "public hearings" are simply not adequate.

Fortunately, our colleagues at EPA recognized this problem and granted a time extension. Thus far, the Project Director and other TAC members have made formal presentations to almost all of the municipal governments and the two county legislative bodies. In some instances, towns have asked for a second public hearing in order to attract wide citizen attendance. This will be done in the coming weeks. The speakers' bureau, organized by members of the Citizen Advisory Committee, has assumed the responsibility for making similar presentations to non-governmental groups. It is pleasant to note that the result of these efforts have been overwhelmingly positive. Support from government, in the form of formal resolutions of support, has been most gratifying.

Another positive result has been the immediate implementive responses. One of the major towns directed their 201 consultant to conform to the 208 Plan recommendations. In another case, the Attorney General of the State of New York has taken steps to ban or otherwise control the sale and use of certain toxic compounds that can contaminate ground and surface waters. The County of Suffolk is in the process of placing de-icing materials under proper cover, and several municipalities have passed ordinances to control animal wastes. EPA itself has designated the aquifer of Long Island to be a "Sole Source Aquifer." These are encouraging indications that the Long Island 208 Plan will not be a shelved "paper plan."

July 31, 1978

Lee Koppelman
Project Director

Section I Surface Water Quality

1.0 INTRODUCTION

The surface waters of Long Island can be divided into those existing as freshwater flowing across the surface as streams and rivers, and those which comprise the surrounding marine waters. Areas where the waters of Long Island Sound and the Atlantic Ocean mix with, and are noticeably diluted by the freshwater streams, are classified as estuaries. The amount of freshwater inflow, the rate at which the fresh and saline waters mix and the amount of flushing on each tidal cycle determine the relative salinity levels in each bay and the concentration and rate of loss of pollutants carried into them by the streams and subsurface groundwater. In general, because of the wider connection with Long Island Sound and the tidal flushing that takes place, North Shore bays generally demonstrate narrow salinity variations, and their biological and chemical characteristics reflect the quality of the adjacent Sound waters. On the other hand, the South Shore bays are relatively shallow, receive large amounts of freshwater via streams and subsurface flow and have only a few small restrictive inlets to allow mixing of the ocean and bay waters. Consequently, they experience greater salinity ranges, show wide geographical variations in biological and chemical characteristics and have prolonged flushing times. Nutrients or pollutants introduced into these systems will remain for longer periods of time than in North Shore bays.

The physical forces that drive the mixing processes in the North and South Shore bays are also different. In general, tidal mixing is dominant in North Shore bays, whereas a combination of mixing due to tides and wind-driven water currents generally predominates along the South Shore.

As mentioned above, the degree of mixing and the flushing rate determine the salinity levels within a bay system. The salinity of estuarine waters is a major controlling factor of biological processes within the bays, from the type of species of plankton, benthic organisms and fish that can survive to the rate of growth of shellfish and marsh grasses. Since salinity is affected by the proportions of fresh and ocean waters; it can be altered by changes in rainfall, groundwater elevations, stream discharge, inlet characteristics and flushing rates. Consequently, changes in these factors will result in changes in the biological and chemical characteristics of the system.

Just as increased mixing and tidal exchange can increase salinity in an estuarine system, these same processes will generally lead to increased dispersion and loss of pollutants introduced into the bays.

The major components of any ecosystem, whether terrestial or marine, can be divided into four parts:

1. The *abiotic* component, which comprises the non-living factors such as temperature, salinity, oxygen levels, nutrient concentrations, etc.;
2. The *decomposer transformer* component, comprised of bacteria and fungi not capable of carrying out photosynthesis and which, through biochemical processes, breaks down complex organic compounds into simple molecules such as carbon dioxide, water and inorganic nutrients;
3. The *autotrophic* component, which includes all organisms capable of carrying out photosynthesis; that is, using energy from the sun, carbon dioxide, water and inorganic nutrients to produce complex organic compounds; and
4. The *heterotrophic* component, which is made up of all other living organisms that cannot carry out photosynthesis and that require complex pre-formed organic compounds to survive.

These four components will be present in each ecosystem but the types

of organisms that characterize them will differ from system to system. For example, the main autotrophic component of eastern terrestrial Long Island is characterized by scrub oak and pine trees, whereas the main autotrophs of the marine ecosystem are floating and attached algae and marine grasses.

Each species exists and carries on a basic function, which is the transfer of energy from one organism to another. Organisms that receive their energy from the same source, whether they are the same species or not, are on the same trophic or energy level. For example, clams, oysters and mussels are all filter feeders relying on plankton and organic particulate matter for their nutrition, and are therefore on the same trophic level. A highly simplified example of the trophic levels and energy cycling along a salt marsh on Long Island is shown in Figure 1–1. It is obvious that changes in any one component can have both qualitative and quantitative effects on other components. It is because of this that any evalutaion of wastewater treatment alternatives, which will impact one or more of these factors, must be considered in light of their effect on the entire system. It is the intent of the 208 Study to define possible adverse effects from various alternative management schemes and to minimize them as much as possible in the light of existing and newly generated information as outlined in the following sections.

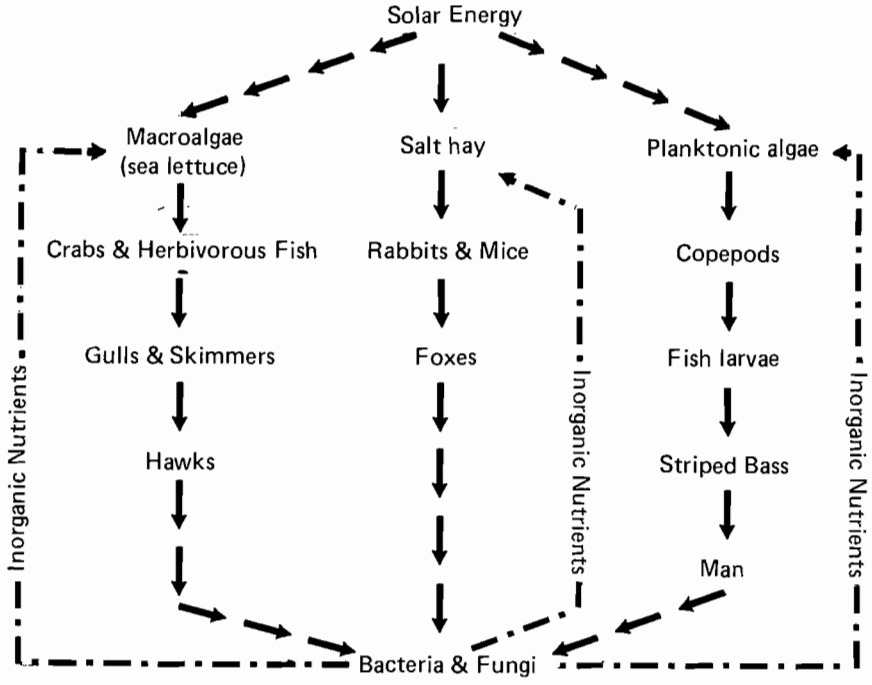


FIGURE 1–1 *Illustration of a Simple Saltmarsh-Estuarine Ecosystem on Long Island.*

1.1 SURFACE WATER QUALITY STUDIES

The surface water quality program of the 208 Study has involved:

1. Collection and inventory of all existing data on marine surface waters of Long Island.
2. Statistical analyses, reduction and identification of shortfalls in existing data.
3. Design of field sampling programs to update historical data and fill in data gaps.
4. Design, calibration and verification of mathematical models capable of representing existing water quality and predicting future changes that may be expected to occur under varying wastewater treatment regimes.

The basis of any scientific study is the detailed gathering and analysis of all existing information concerning the topic under investigation. Tetra Tech, Inc., the prime marine water quality consultant, has amassed data containing more than 400,000 observations on the physical, chemical and biological characteristics of Long Island waters. These data were analyzed as to completeness, length of record and accuracy for each bay system and data gaps identified. Based on these analyses, water quality reports were prepared (see bibliography) and field sampling programs designed to fill in missing data and to calibrate and verify the mathematical models. An example of the procedures used in developing the data base is shown in Figure 1–2.

One of the significant components of the Long Island 208 Study centers on the development and use of appropriate mathematical models. The wastewater management plan for this area ultimately depends on the ability to quantify a preference for one set of structural and non-structural alternatives over another. In the process of doing so, it is necessary to understand in numerical terms just what the impact of these alternatives may be on ground and surface waters in terms of both the changes in movement and quality that result from the options used. The modeling efforts are directed to this end by providing flexible tools to evaluate and predict such impacts without engaging in prohibitive or even impossible trials on the actual water bodies themselves; that is, modeling is a surrogate for reality in which certain basic interrelationships in the real world are captured by mathematical statements. By manipulating these statements one simulates, as it were, the events that actually take place. The models are therefore a conceptual shorthand for organizing the complex interactions which occur between the water bodies and the stresses placed on them. It is possible in this way to carry out "what if" experiments on nature by replacing the actual driving forces (as well as initial and boundary conditions) by altered ones, which presumably would represent new structural and non-structural options. That we can simulate these changes without having to engage in physical alterations is one of the great virtues of models. Also we can look into the future by tracking present conditions to see what eventual effects they may produce on water movement and quality. Finally, one can generate alterations in initial and boundary conditions to find the "best" future scenario.

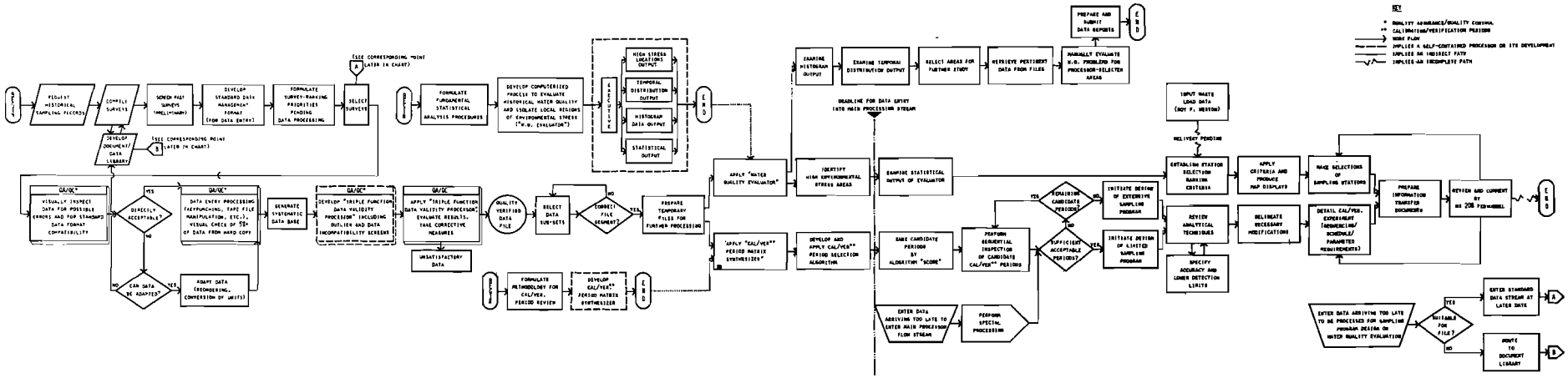


FIGURE 1–2 *Data Evaluation Procedure.*

Water quality modeling for the study involved both two-dimensional estuary and one-dimensional river models. The following parameters are included in both types of models:

- –Conservative substances (such as salinity)
- –Total nitrogen
- –Total phosphorus
- –Total coliform bacteria
- –Fecal coliform bacteria
- –Carbonaceous biochemical oxygen demand (CBOD)
- –Nitrogenous biochemical oxygen demand (NBOD)
- –Dissolved oxygen
- –Temperature

The two dimensional estuary models include three different programs–dynamic estuary, steady-state estuary and time-dependent estuary. The dynamic estuary model uses changing tidal conditions to simulate the hydrodynamics of flow in the estuary. This model is useful for studying short term (one to three days) changes in water quality due to variations in tide stage. The steady-state estuary model takes changes in water mixing and dispersion of the materials under consideration to represent daily average conditions that would prevail if all inputs to the system are kept constant. This model is appropriate for comparing alternative management schemes under typical conditions. The time-dependent estuary model uses dispersion coefficients for the parameters being studied, similar to the steady-state model. However, the boundary conditions and waste load inputs are varied to compute average conditions as a function of time, for example, to determine the effects of a storm. This model is useful when simulations over time (greater than three days) are of interest.

The water quality river models are virtually identical to the steady-state estuarine model except that the movement of water is calculated in one direction only (downstream).

Each of the models represents the estuarine systems as a network of nodes connected by links (See Figure 1–3) where each node represents a

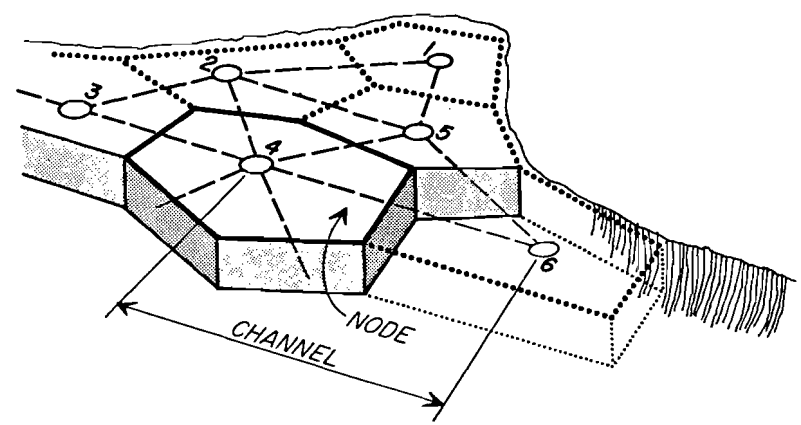


FIGURE 1–3 *Diagram of Link Node System for Bay and Estuarine Models.*

discrete unit of the water body characterized by its surface area, depth and volume. The nodes are interconnected by channels or links characterized by length, width, cross-sectional area, depth, slope and bottom friction. Water masses are modeled as flowing between the nodes along these links resulting in changes in the water quality parameters under study. The reader is directed to Section Seven, outlining the detailed conceptual and mathematical frameworks of the models, for further information.

Detailed modeling and data collection is being carried out for the following marine surface waters (Figure 1–4):

South Shore Bays

–Great South Bay

–Hempstead, Middle, East and South Oyster Bays

North Shore Bays

–Manhasset Bay Complex

–Hempstead Bay Complex

–Port Jefferson

–Peconic Estuary–Flanders Bay

–Huntington–Northport Complex

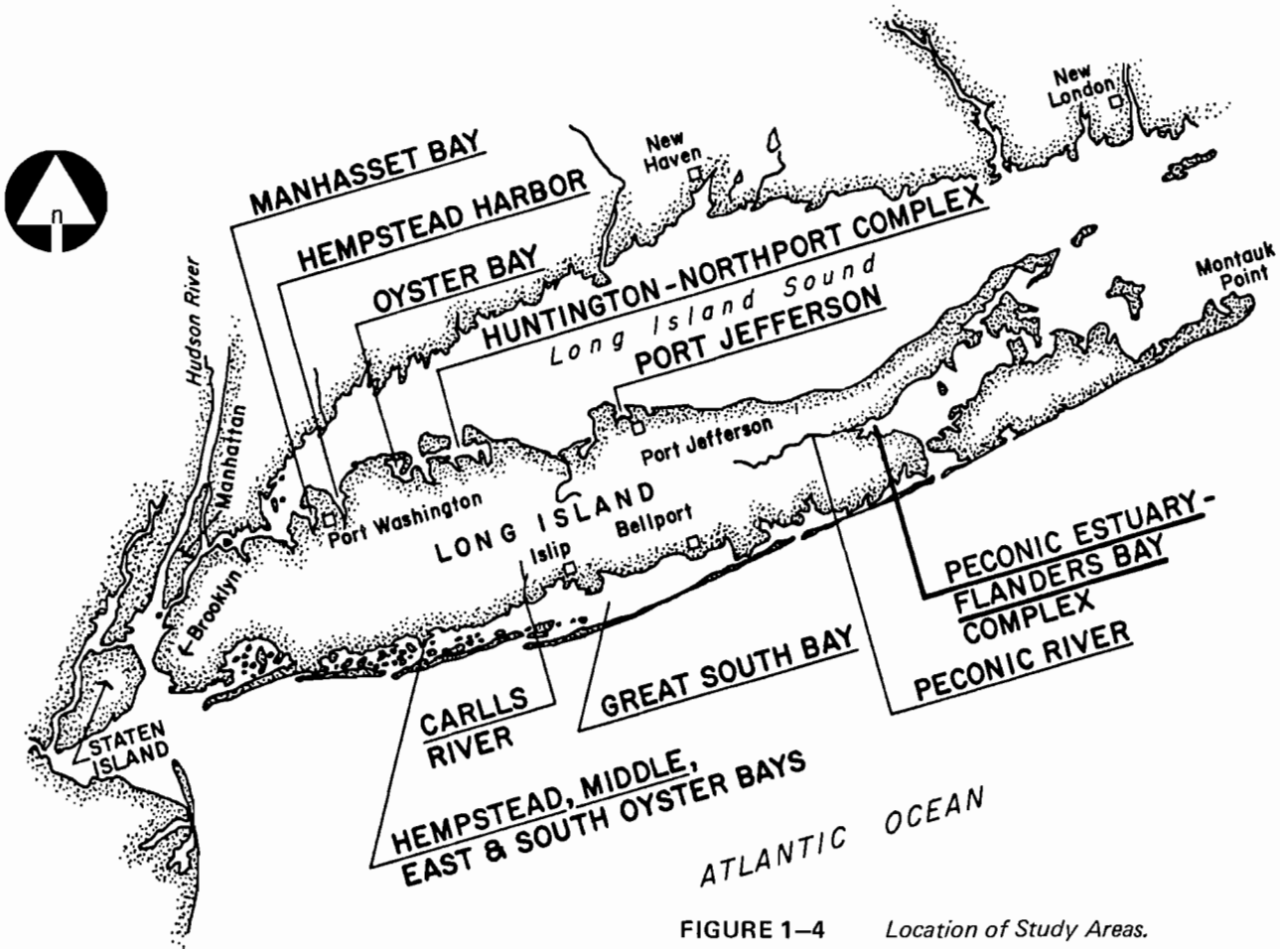
Rivers

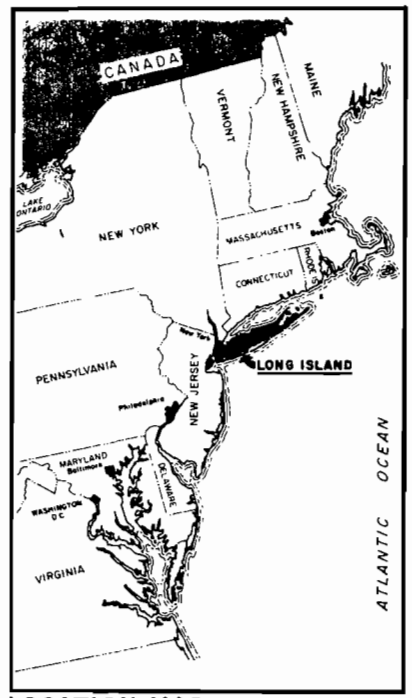
–Carlls River

–Peconic River

In addition to water quality modeling, non-modeling water quality reports are also being prepared for the following areas (Figure 5):

–Western Long Island Sound including Little Neck Bay





LOCATION MAP

GRAPHIC SCALE: Nautical Miles

10 5 0 10

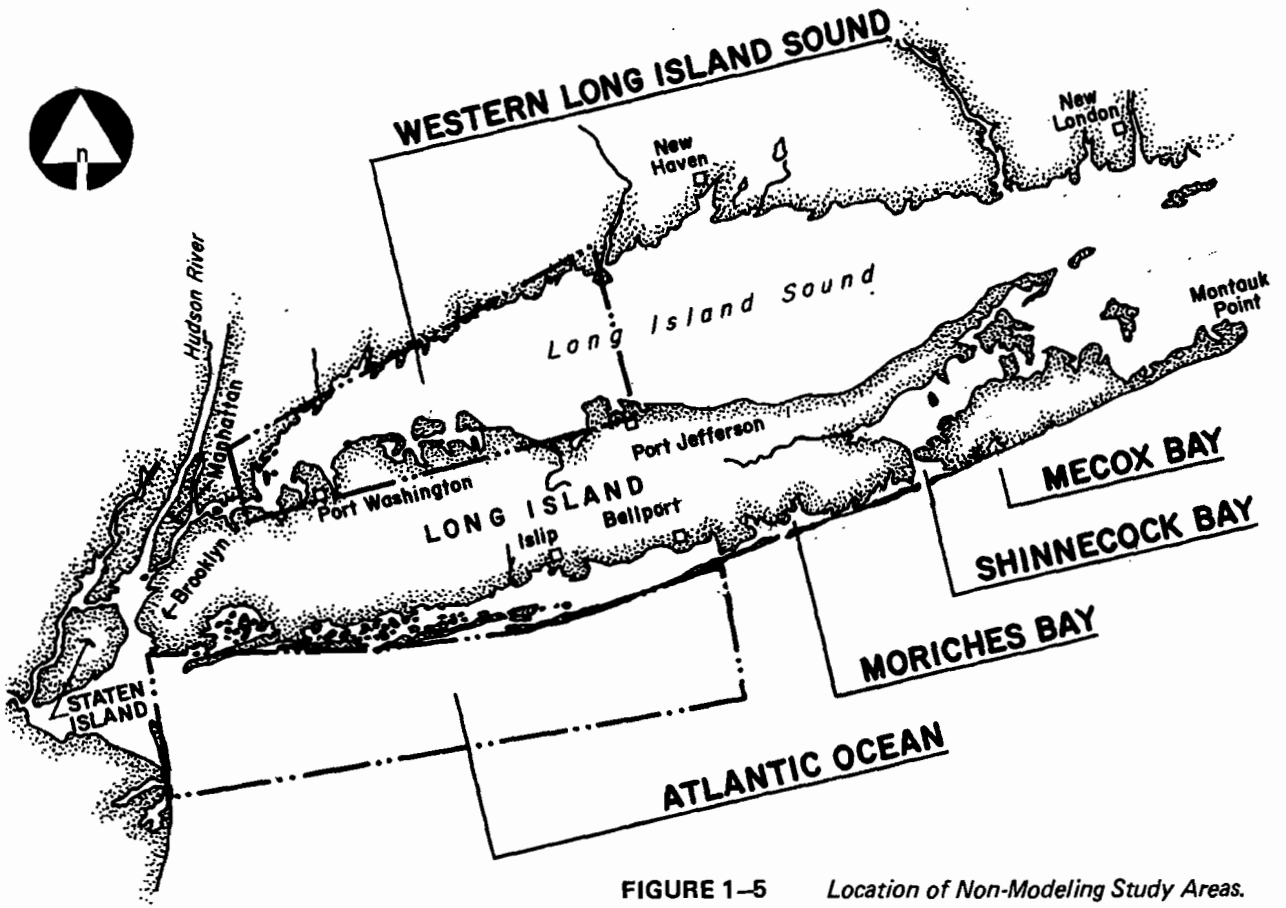
FIGURE 1–4 *Location of Study Areas.*

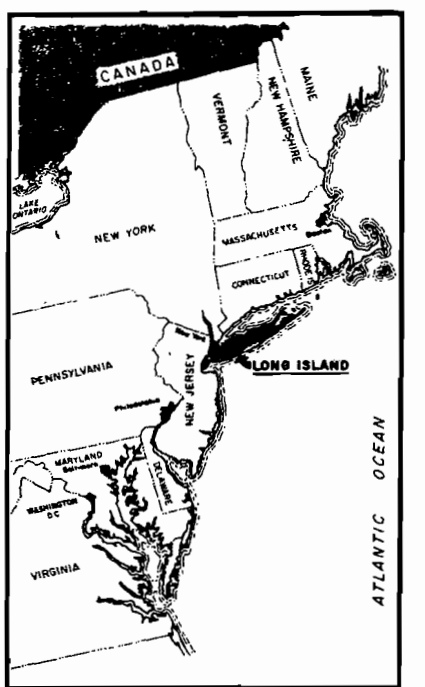
—Cold Spring Harbor and Smithtown Bay
—Nearshore Atlantic Ocean
—Moriches Bay
—Shinnecock Bay
—Mecox Bay

An example of the type of sampling program required to calibrate and verify the models is shown in Figure 1–6. For the Great South Bay Complex alone, six survey vessels with technical personnel were required to sample 42 stations on each of four days. Station locations for each bay system are shown in Figures 1–7 through 1–13b. The reader is referred to the individual technical reports listed in the bibliography for more detailed information on each bay.

At each station, water samples were obtained and analyzed for temperature, salinity, dissolved oxygen, dissolved and total phosphorus, nitrate, ammonia, total nitrogen, chlorophyll pigments and total fecal coliform organisms. Additional information was also recorded for water depth, transparency, wind speed and direction, bottom sediment type and tide stage. The latter information, when combined with temperature and salinity, allows calibration of the hydrodynamic portions of the models. The output of this part of the model is then used in determining the water quality parameters.

Dissolved oxygen is an important biochemical parameter since it is indicative of the relative rates of organic production by marine plants and respiration by bacteria and other marine animals. Depressed oxygen levels are often associated with areas receiving organic waste material, such as that derived from treatment plants. High concentrations of phytoplankton may also lead to low oxygen values due to respiration during evening hours. Severely depressed oxygen levels can lead to large-scale mortalities in organisms unable to migrate from the areas, especially benthic animals such as





LOCATION MAP

GRAPHIC SCALE: Nautical Miles

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FIGURE 1–5 *Location of Non-Modeling Study Areas.*

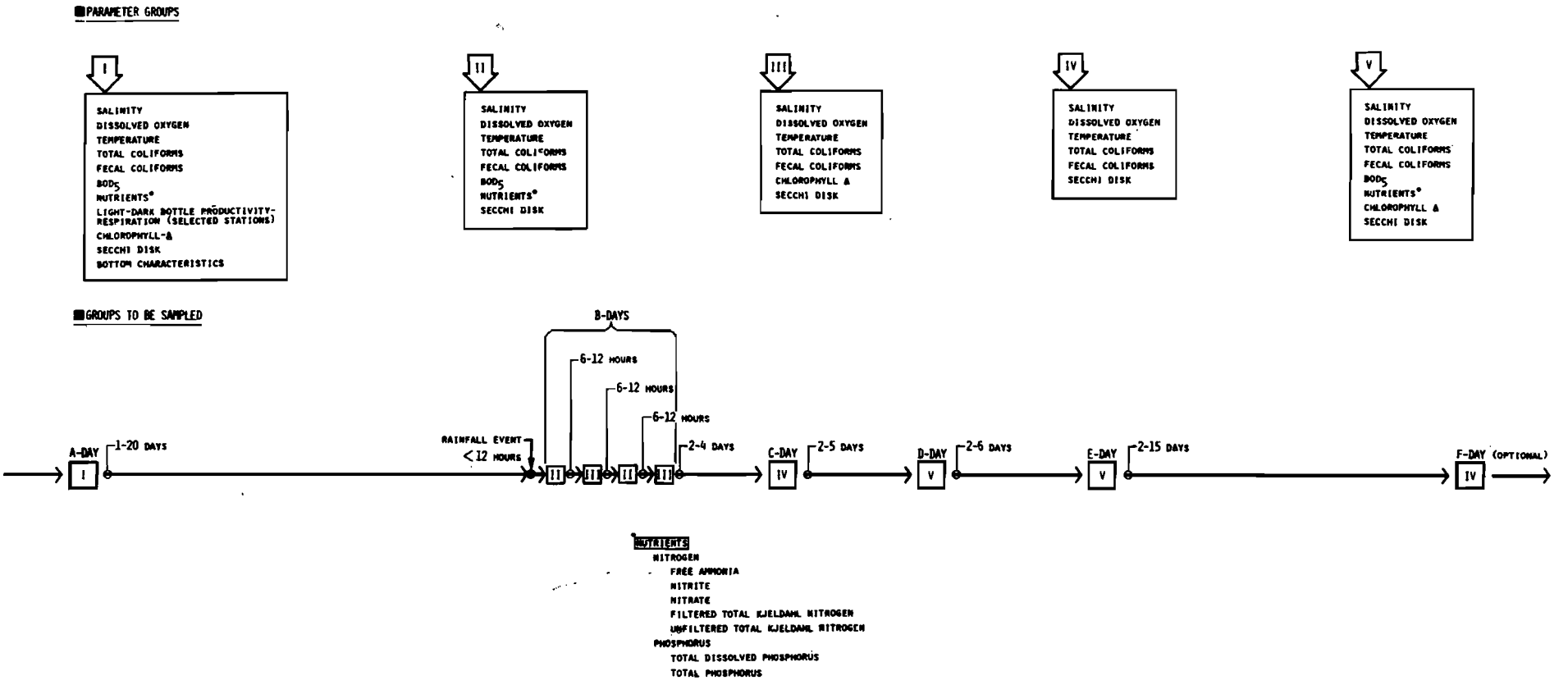


FIGURE 1–6 *Parameter Sampling Schedule.*

clams and oysters.

Dissolved nitrogen and phosphorous are essential plant nutrients. However, elevated concentrations or abnormal ratios of the two nutrients can lead to "bloom" conditions or changes in the normal species composition of the phytoplankton. If these algal blooms grow large enough because of abundant nutrients, they can contribute to the oxygen demand by their respiration and decomposition.

Chlorophyll pigment concentrations are used as indicators of the amount or standing crop of phytoplankton. In some cases, it is possible to correlate chlorophyll and nutrient concentrations and thus make decisions regarding the amount of nutrients that can be allowed to enter a system from sewage treatment plants or other sources.

Total and fecal coliform organisms are bacteria which have long been used as indicators of fecal pollution. The non-fecal coliforms are found normally in the environment and can be derived from a variety of sources, such as stormwater run-off and decomposing organic matter. Fecal coliforms, on the other hand, are found only in the intestines of warm-blooded animals and as such have been used to indicate fecal pollution. They are harmless in themselves but are statistically correlated to the possible presence of pathogenic bacteria.

An example of the type of output obtained from the models is shown in Figure 1–14 for a transect across Port Jefferson Harbor. The curves indicate the effects of discharging 15 million gallons per day at node 1 (head of harbor), node 9 (center of harbor) and node 18 (mouth of harbor). The increase in both nitrogen and phosphorus is easily seen when discharge takes place at the head of the harbor. Model predictions such as these are extremely valuable when considering not only treatment plant size, but also the location of the discharge point. The structural and non-structural wastewater treatment alternatives that were considered in each of the modeling efforts are more fully detailed in an interim report to be published.

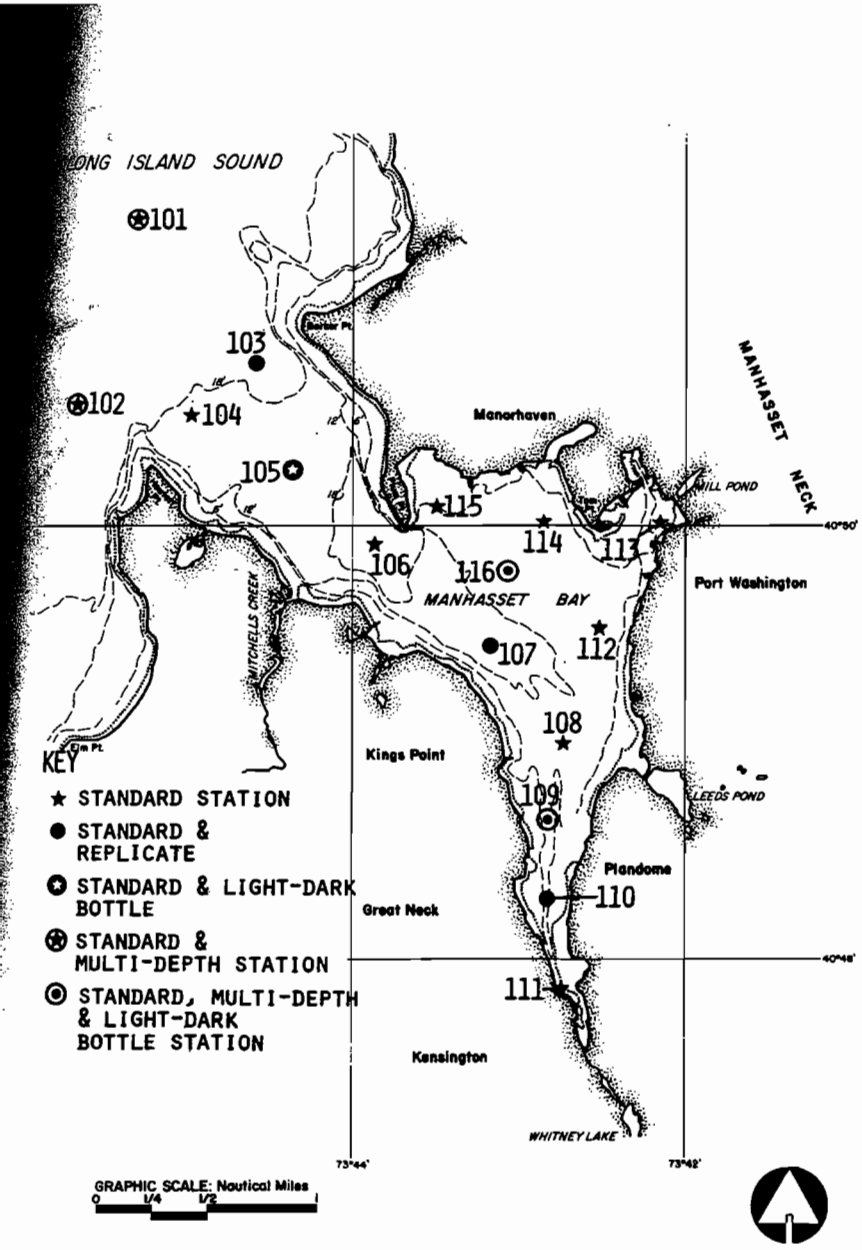


FIGURE 1–7 *Manhasset Bay Sampling Station Locations.*

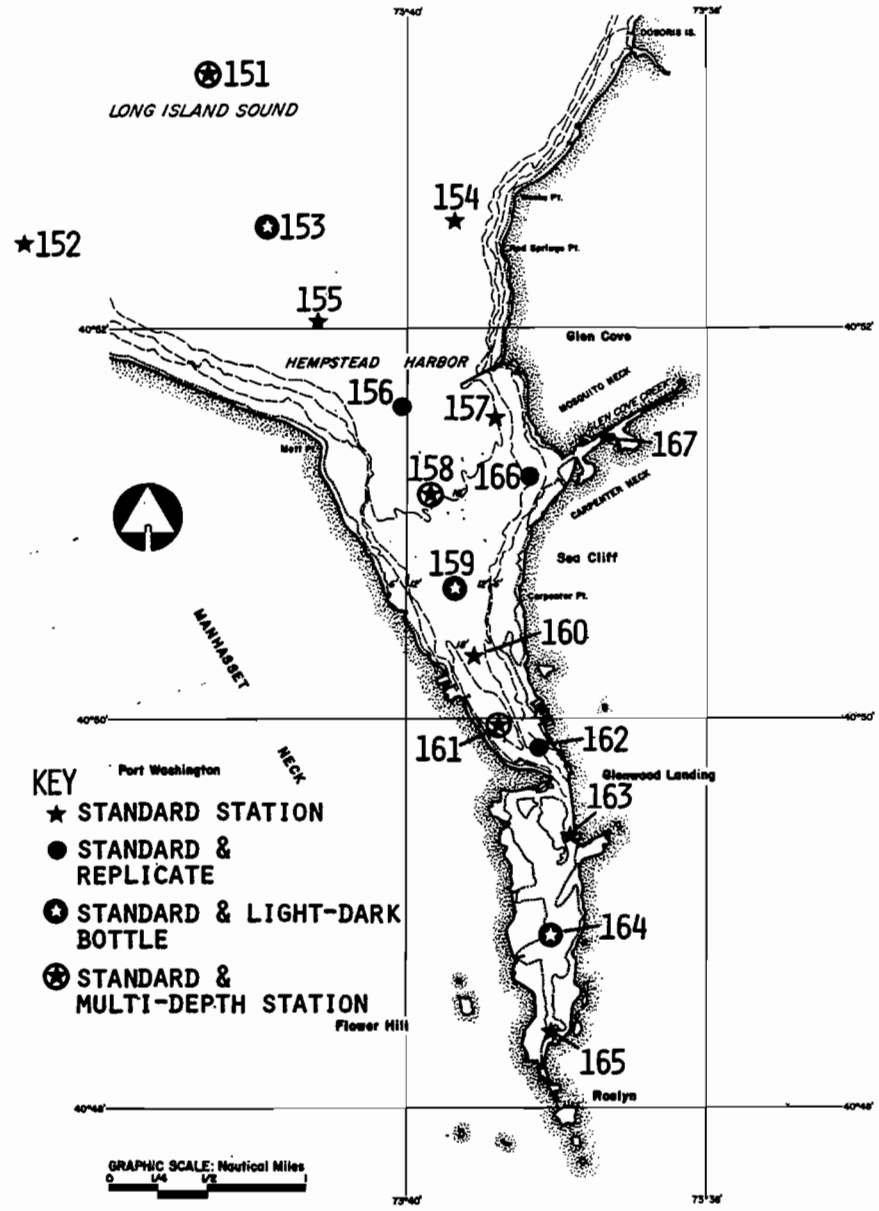


FIGURE 1–8 *Hempstead Harbor Sampling Station Locations.*

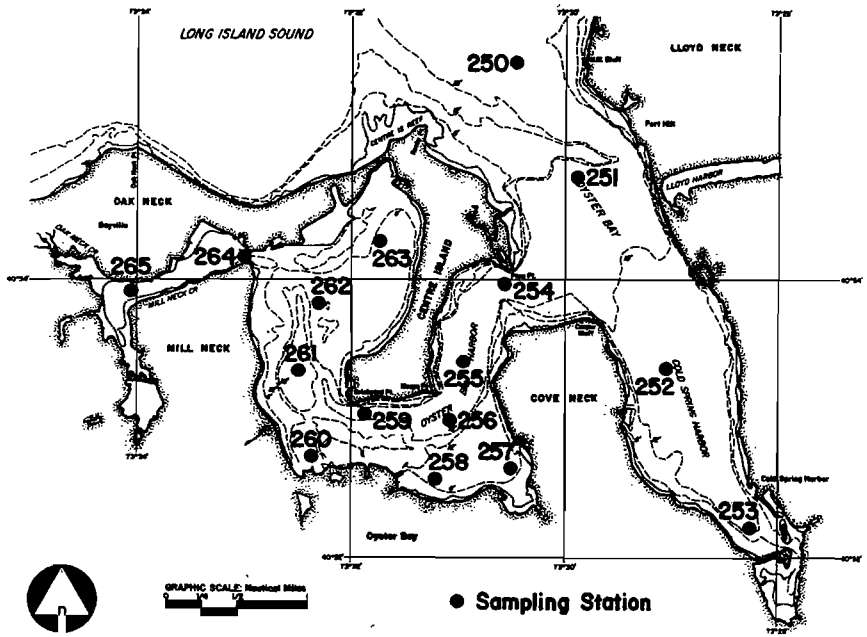


FIGURE 1–9 *Oyster Bay Sampling Station Locations.*

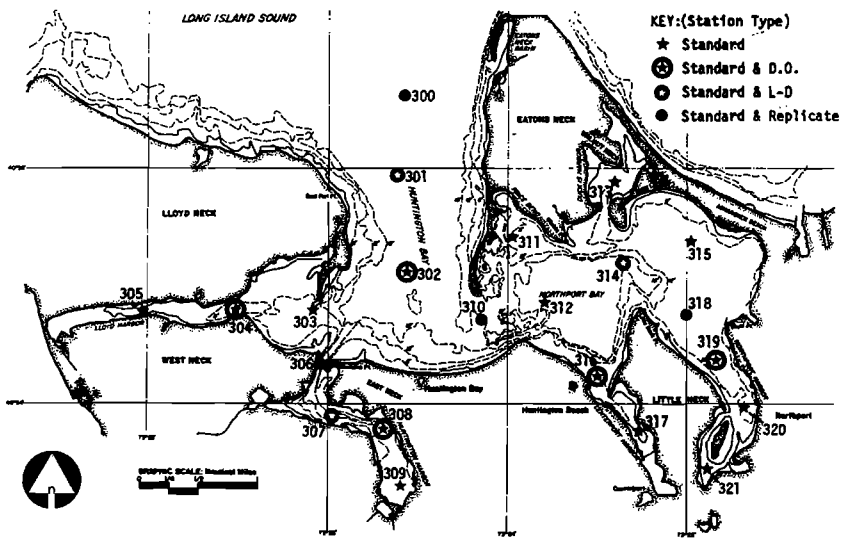


FIGURE 1–10 *Huntington-Northport Complex Sampling Station Locations.*

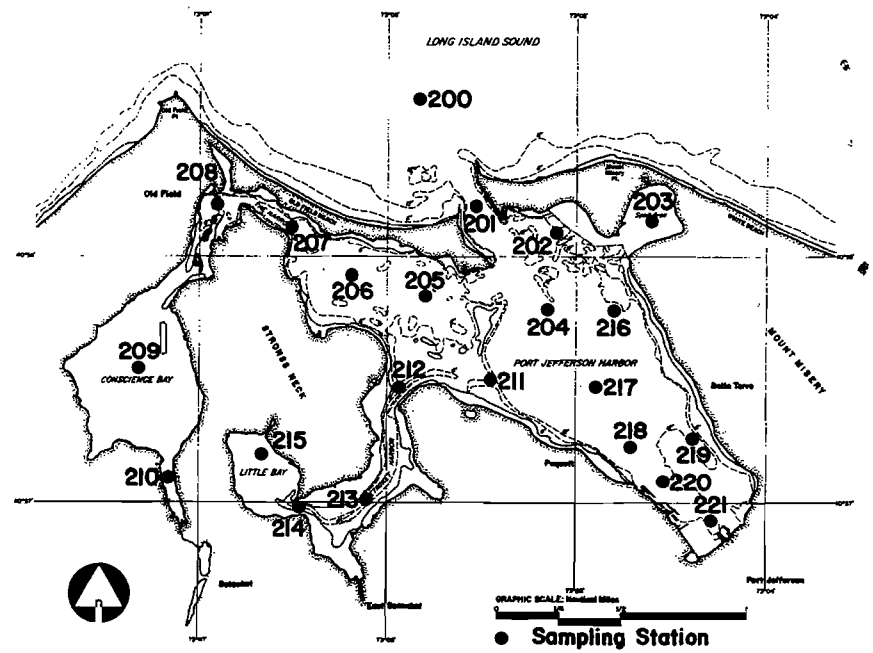


FIGURE 1–11 *Port Jefferson Sampling Station Locations.*

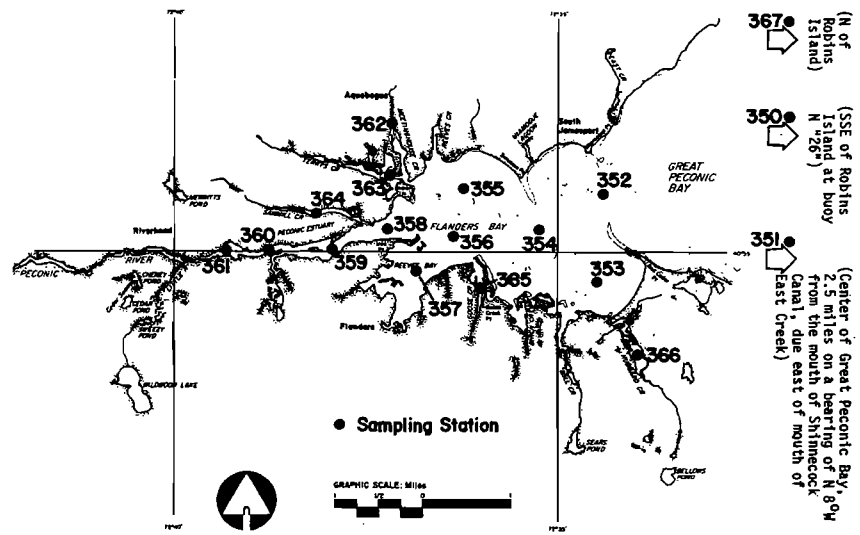


FIGURE 1–12a *Peconic Estuary-Flanders Bay Sampling Station Locations.*

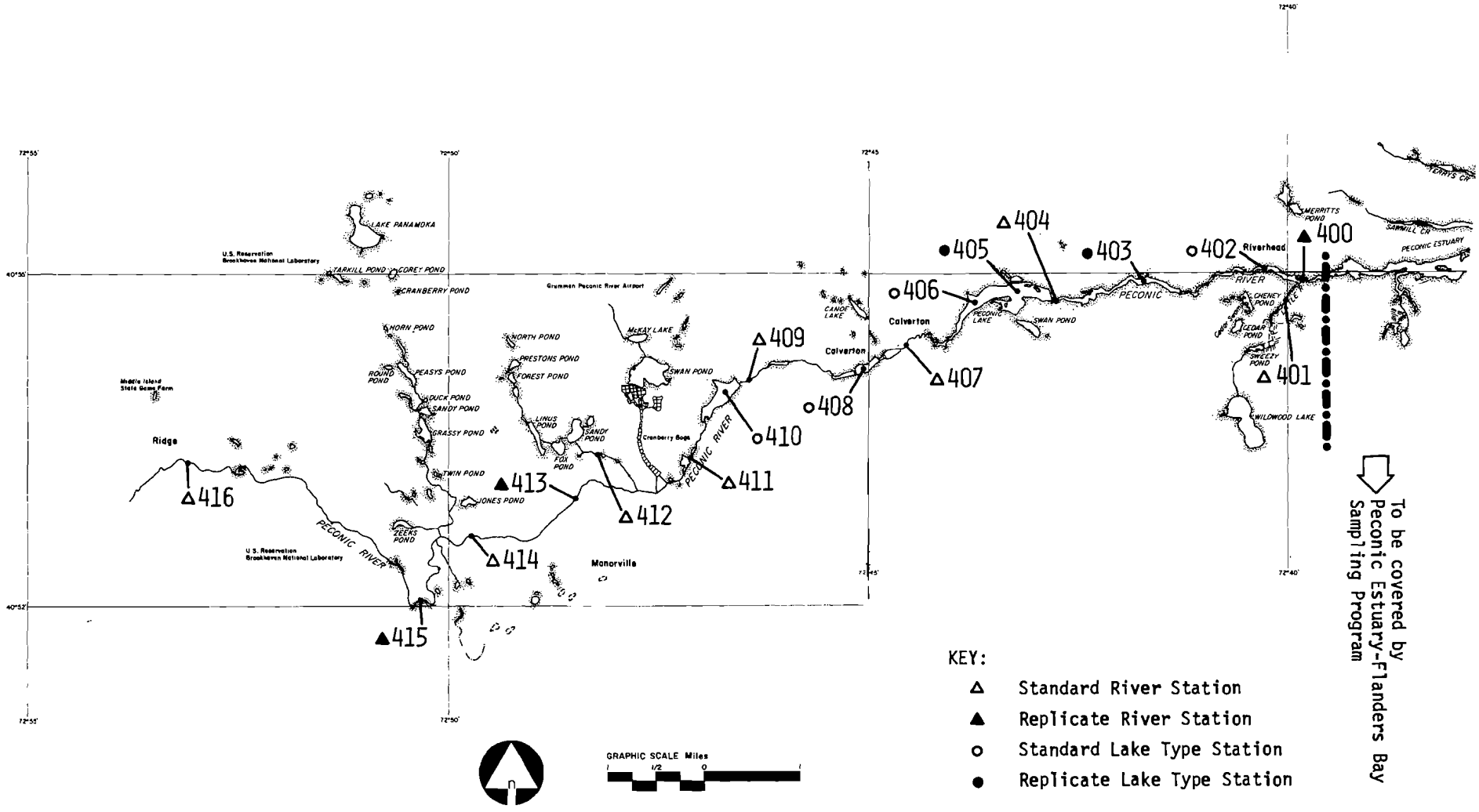


FIGURE 1–12b *Peconic River Sampling Station Locations.*

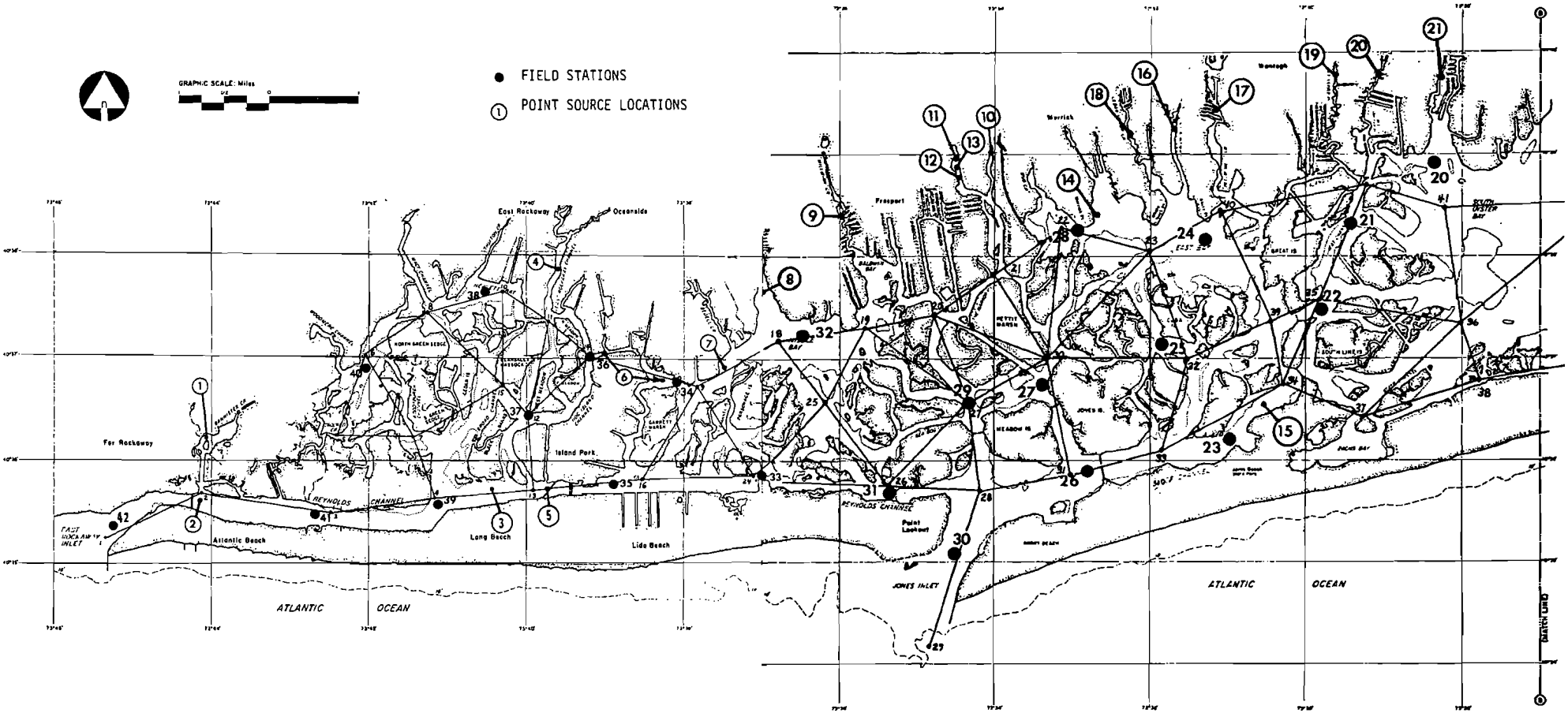


FIGURE 1–13a *Southshore Bays Sampling Station Locations.*

1.2 POINT SOURCE LOAD INVENTORY

In addition to water quality parameters for each receiving body of water, the quantity and quality of all existing point sources have also been fed into the models. The advantage of the modeling exercise is to be able to show how a variety of future conditions such as upgrading existing plants, increasing flow rates or moving plants to different areas will affect water quality by merely changing a few input cards to the computer program.

R.F. Weston has inventoried 411 potential point sources of pollution in the bi-county area. These include 124 domestic (private and municipal) wastewater treatment plants (excluding private septic tanks or cesspools), 170 industrial waste facilities, 29 duck farms, 75 coin-operated laundromats and 13 incinerators. Of the total 124 domestic plants, 22 representative facilities were visited and evaluated in regard to discharge outfall location, potential impact on water quality, service area, service population, operational data, anticipated future flows, potential for plant expansion, effluent limitations, general plant operation, design limitation, infiltration/inflow problems and sludge handling methods. Eleven representative industries, three incinerators and one duck farm were also visited and evaluated with regard to the types and volumes of wastewater generated and treatment methods employed. The reader is directed to "Domestic and Industrial Point Source Inventory and Evaluation, May 1976" prepared by R.F. Weston for detailed information on individual sources.

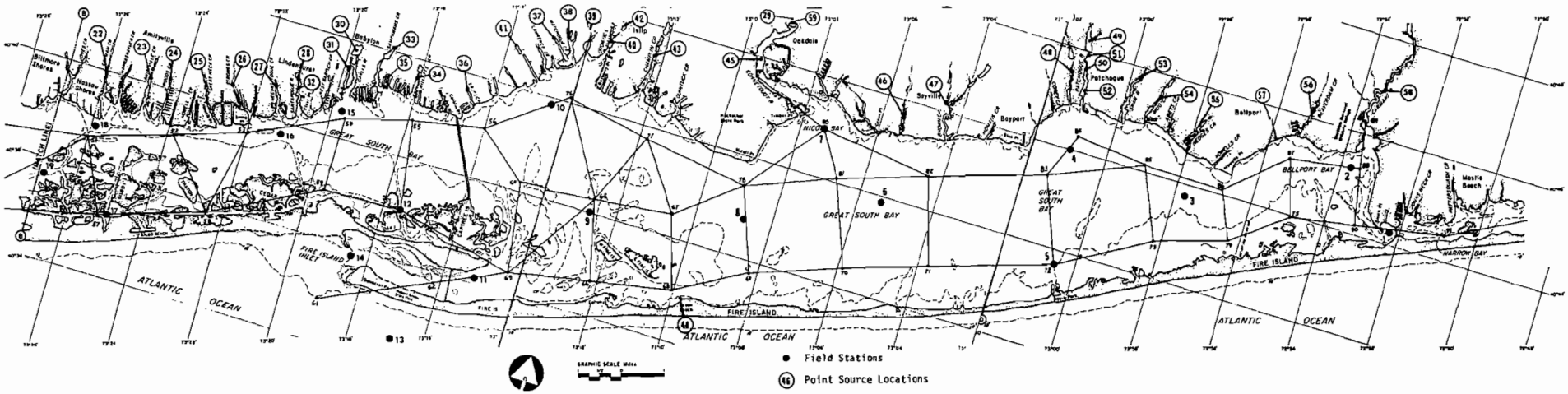


FIGURE 1–13b *Southshore Bays Sampling Station Locations.*

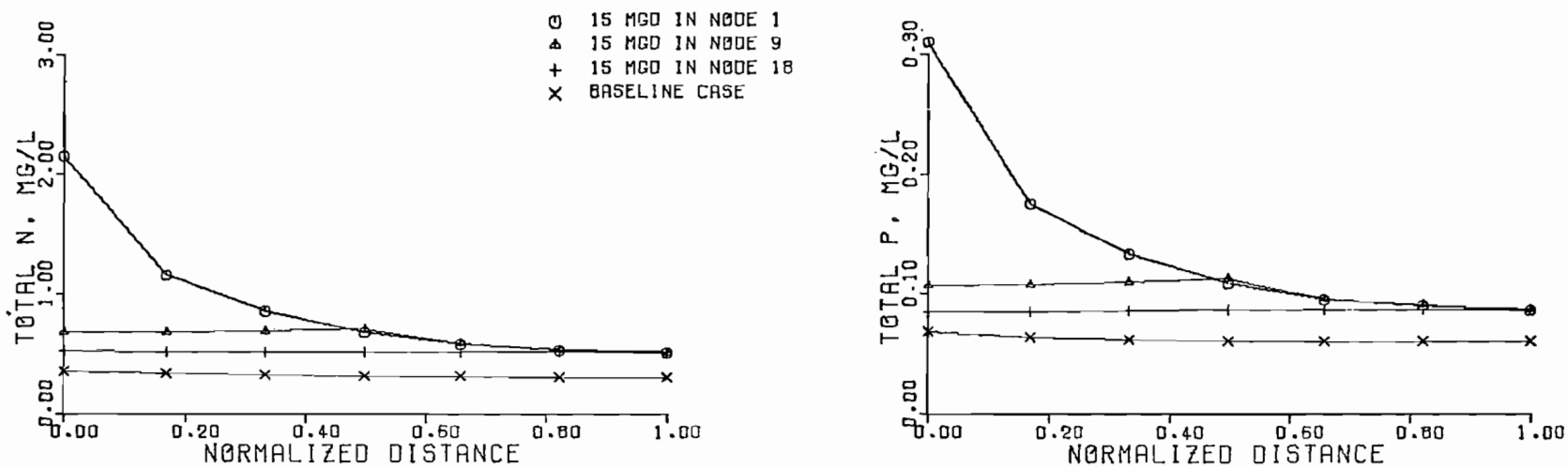


FIGURE 1–14 *Example of Model Output—Transect Across Port Jefferson Harbor Showing 15 Million Gallons Per Day Discharge at Three Outfall Locations.*

1.3 NON-POINT SOURCE POLLUTION

A major source of pollution for both surface and groundwaters has only recently been recognized. Non-point source stormwater run-off may contribute as much as 90% of the total pollutant load entering surface waters. Domestic pets and farm animals contribute large amounts of coliform bacteria, organics and nutrient wastes. Lawns, recreational areas such as golf courses and agricultural lands are sources of herbicides, pesticides and fertilizers. Roadways contribute tars, silt, hydrocarbons and heavy metals such as lead, zinc and nickel.

In contrast to flowing streams and point sources of pollution, such as wastewater discharges, non-point source pollutants enter surface water under highly variable conditions depending on duration and intensity of precipitation and the degree and type of development in an area. One objective of the 208 Study has been to identify and quantify the pollutants entering surface waters and subsurface aquifers under conditions found in the Long Island area. This information has been used as input to the water quality models and to determine the relative contributions of pollutants from point and non-point sources.

Four agencies sampled fifteen areas which are characterized by six different land uses (Table 1–1). Samples obtained were analyzed for the following constituents:

–Biochemical oxygen demand (BOD)
–Chemical oxygen demand (COD)
–Total organic carbon (TOC)
–Suspended solids, volatile solids
– Total nitrogen, nitrate, nitrite, ammonia
–Total phosphorus, ortho-phosphorus
–Dissolved oxygen
–Total coliforms
–Fecal coliforms
–Heavy metals

Because the volume and character of stormwater run-off is highly dependent upon the types and degree of development in an area, the land use for all of Nassau and Suffolk counties had to be determined before non-point source pollution loadings could be calculated. The Nassau-Suffolk Regional Planning Board constructed a network of grids, each approximately one square mile, covering all of the bi-county area. Percentages of land in residential, industrial, agricultural and open space use were assigned for each grid square. Aggregations of squares within each drainage basin then allowed correlation of land use with the stormwater run-off characteristics obtained from the field sampling program.

Computer analysis of the data provided plots of each pollutant entering the streams over the course of each storm as well as the calculations of load factors for each pollutant based on land area. These load factors have been used to obtain stormwater loadings for each bay in relation to the amount of precipitation and for assigning overall yearly loads to surface and groundwater. Table 1–2 lists a summary of average load factors for each of the areas sampled. A number of conclusions can be drawn from this table that are applicable to the Long Island area:

1. There are no appreciable differences in both BOD and suspended solids in run-off from different land uses. That is, all land uses have consistent load factors for both parameters.

2. There is no real difference between medium and low density residential areas with respect to total nitrogen and phosphorus loadings (nutrients); there are no major differences between roads and industrial areas for total nitrogen and phosphorus; residential load factors for nutrients are an order of magnitude higher than loadings for roads and industrial areas.

3. There is no significant difference between low and medium density residential areas with respect to both total and fecal coliforms.

4. The industrial areas have consistently high values for heavy metals. Medium density residential areas exhibit elevated load values.

5. In the first six categories of pollutants, no differences can be discerned between medium and low density residential land uses in terms of run-off characteristics.

Table 1–1

NON-POINT SOURCE SAMPLING LOCATIONS AND LAND USE CLASSIFICATION

Area	Land Use
Valley Stream	Medium density residential
Massapequa Creek	Medium density residential
Cedar Swamp Creek	Mixed land use
Mill Neck Creek	Low density residential
Wildwood	Agricultural
Miller Place	Low density residential
Sagaponic	Agricultural
Baldwin	Medium density residential
Lake Success	Low density residential
Swan River	Mixed land use
Sampawams Creek	Medium density residential
Penataquit Creek	Medium density residential
Heartland Industrial Park	Industrial
Long Island Expressway	Major roads
West Branch Browns River	Medium density residential

1.4 TOTAL ANNUAL LOADS FROM POINT AND NON-POINT SOURCES

Data obtained from the point source and non-point source inventories has been calculated for each drainage basin in the Nassau-Suffolk region. The reader is directed to reports prepared by R. F. Weston listed in the bibliography for detailed discussion of the data and methodology involved. Figure 1–15 shows the individual drainage basins and areas contributing surface run-off directly to streams and salt water bodies, while Table 1–3 lists the total pounds of six pollutants contributed to surface water from each basin per year and the percentage of each pollutant as represented by point

Table 1–2

LOAD FACTORS FOR LAND USES IN THE NASSAU-SUFFOLK REGION[1]

Parameter	Land Use	Average Load Factor Lbs. of Pollutant Per (Acre) (Inch)	Number of Storms Sampled	Standard Deviation	High/Low
BOD	Medium Density Residential	.36	6	.24	.64–.056
	Low Density Residential	(2)	–	–	–
	Roads	.32	4	.24	.67–.16
	Industrial	.35	1	–	.35
SS	Medium Density Residential	3.3	10	4.5	14.7–.3
	Low Density Residential	2.9	3	–	6.5–2.0
	Roads	4.6	4	6.5	14.2–.67
	Industrial	(3)	–	(3)	(3)
TN	Medium Density Residential	.23	12	.25	.79–.002
	Low Density Residential	.14	3	–	.27–.008
	Roads	.06	4	.03	.10–.03
	Industrial	.06	1	–	.06
TP	Medium Density Residential	.091	13	.29	1.04–.00
	Low Density Residential	.018	3	–	0.45–.002
	Roads	.005	4	.004	.01–.002
	Industrial	.007	1	–	.007
F. Coli[4]	Medium Density Residential	1.02×10^{10}	12	1.6×10^{10}	4.9×10^{10}–1.3×10^{7}
	Low Density Residential	4.2×10^{10}	2	–	7.6×10^{10}–$.72 \times 10^{10}$
	Roads	(5)	–	–	–
	Industrial	3.40×10^{6}	1	–	3.4×10^{6}
T. Coli[4]	Medium Density Residential	6.2×10^{10}	12	11.0×10^{10}	35.9×10^{10}–6.5×10^{7}
	Low Density Residential	7.3×10^{10}	2	–	13.3×10^{10}–1.4×10^{10}
	Roads	(5)	–	–	–
	Industrial	2.18×10^{7}	1	–	2.18×10^{7}
Lead	Medium Density Residential	0.024	12	0.03	0.063–0.000
	Low Density Residential	0.006	3	–	0.010–0.000
	Roads	0.008	4	–	0.018–0.000
	Industrial	0.01	–	–	0.01
Chromiun	Medium Density Residential	0.002	9	.002	.007–0.000
	Low Density Residential	0.000	1	–	0.000
	Roads	0.001	4	–	0.001–0.0
	Industrial	0.105	1	–	0.105
Copper	Medium Density Residential	0.009	11	0.02	0.067–0.000
	Low Density Residential	0.003	2	–	0.003–0.002
	Roads	0.011	4	0.009	0.024–0.002
	Industrial	0.014	1	–	0.014
Nickel	Medium Density Residential	0.003	11	0.003	0.008–0.000
	Low Density Residential	0.001	2	–	0.001–0.001
	Roads	0.001	2	–	0.001–0.001
	Industrial	0.064	1	–	0.064

[1] *High density residential and open space were not sampled. Agriculture was sampled and no appreciable runoff resulted.*
[2] *Neither BOD nor TOC was sampled in a low density area.*
[3] *SS was not sampled in this land use category.*
[4] *Units are MPN/(acre) (inch)*
[5] *Coliforms were not analyzed in this land use.*

source, dry-weather stream flow and wet-weather run-off. Long term data on dry-weather stream flow were not available for all areas and are indicated in the Table by the letters NA.

The following conclusions can be drawn from Table 1–3.

Nassau County

1. With reference to BOD, it is quite apparent that except for drainage basin N5, point sources dominate the pollutant contributions. They range from 74 percent of the total loads in N6 to 94 percent in N1. The only exception is N5 where run-off contributes 70 percent of the total load. The influence of the wastewater treatment plant at Bay Park in N1 is readily apparent in Table 3 since point sources contribute 94 percent of BOD,

2. Suspended solids behave opposite to BOD, *i.e.,* run-off contributes more than point sources. Loadings of suspended solids from wet-weather run-off range from 62 to 94 percent of the total annual load from basins N2 to N6 and in only one case, basin N1, do point sources dominate the total load. Again, the impact of Bay Park with its large discharge is readily apparent in N1.

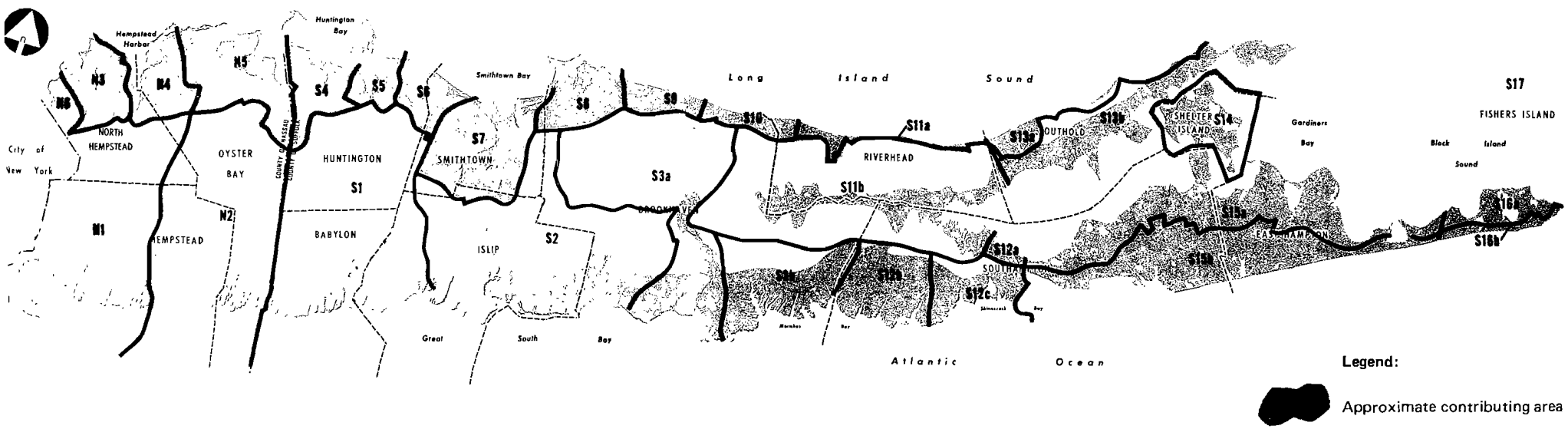
3. Total nitrogen appears to be dominated by point sources. The point sources account for between 48 and 95 percent of the total load in each drainage basin. It should be noted that in drainage basin N1, when stream effects are included, only two percent of total nitrogen is accounted for by the base flow in the streams, while over 95 percent is attributed to point sources. This could reflect the influence of Bay Park. In drainage basin N2, the streams' influence increases to 36 percent, compared to 54 percent for the point sources. The point source percentages reflect the influence of the Cedar Creek Plant. The point source contribution will increase as the Cedar Creek Plant flow increases in the future.

4. Total phosphorus appears to be dominated by point sources in all the basins except for N5; they account for 65 to 93 percent of the total load in each of the basins except N5. The percentage contributed by stream flow in N1 and N2 is only one percent.

5. Fecal coliform load is clearly dominated by run-off rather than point sources. The clear domination of run-off appears in five out of the six Nassau County basins (N2 through N6) and ranges from 72 to 99 percent. Even in basin N1 with the influence of Bay Park, run-off contributes an almost equal amount of coliform as the point sources. Equally important is the zero dry weather contribution from streams indicating dry weather flow is not a major problem.

6. Total coliform is given as a total number rather than a percentage because only six out of 127 treatment plants, in both Nassau and Suffolk, measure and record total coliform. Because complete data does not exist, percentages cannot be compared without distorting the results. However, the results would be similar to fecal coliform, *i.e.,* domination by run-off.

7. By reviewing results by drainage basins, the following conclusions can be drawn: in drainage basin N1, which would correspond to the most heavily populated basins, as well as the most urbanized, domination by point



Legend:

Approximate contributing area

N1, N2, N3... Drainage Basins
S1, S2, S3.....

FIGURE 1–15 *Areas Contributing Surface Runoff Directly to Streams and Saltwater Bodies.*

sources is apparent in all parameters. This is due to the effluent from Bay Park and some of the other treatment plants that discharge in this drainage basin. Drainage basin N5, which is the most rural basin, shows the exact opposite, *i.e.,* the total pollutional load from each of the parameters is dominated by run-off rather than by point sources.

Suffolk County

1. The total loads of the six parameters are almost always dominated by run-off, primarily due to the fact that there are not many large treatment systems in Suffolk County. Only in small drainage basins with a large point source would there be a significant percentage of contribution from point sources (such as in drainage basins S11B, S3 and S4).

2. There is a significant difference between Nassau and Suffolk Counties in terms of which sources contribute the major portion of the total load. In Nassau, point source contributions dominate in most basins. However, in Suffolk, run-off contributes more pollutant material than the point sources. The one exception, in Nassau, is fecal coliform which is predominantly derived from run-off. Between 47 and 100 percent of the fecal coliform load comes from run-off in all drainage basins. In Suffolk County, run-off accounts for between 86 and 100 percent of fecal coliform loads to surface water.

3. Pollutant loadings are substantial in terms of total pounds per year, especially with respect to suspended solids.

4. The major portions of the pollutant loads originated in the western drainage basins, S1 through S8. Assuming impact on water quality is proportional to loads, pollution control efforts should focus on these basins.

1.5 WATER QUALITY AND ALTERNATIVE EVALUATIONS

Using information derived from historical data searches, the marine field sampling programs and point and non-point source loadings, a series of modeling studies were carried out to predict water quality characteristics and to evaluate proposed structural alternatives for certain bay systems. Table 1—4 is a compilation of all water quality data generated in the 208 Study. The values were derived from verified steady-state numerical models where possible. In the case of non-modeled systems, data was obtained from the water quality assessments based on historical data as prepared by Tetra Tech, Inc. Since each bay system undergoes large seasonal variations in chemical and biological processes, only data from the months of July through September were used. This insures that changes due to temperature variations would be minimized. It should also be remembered that the nomenclature used to describe the South Shore bays is artificial in that all bays between Hempstead Bay and eastern Great South Bay are actually one large bay complex. The data for Great South Bay in Table 1—4 has been broken down into three geographical areas: western Great South Bay from the Nassau-Suffolk County line east to the Captree Bridge; central Great South Bay from the Captree Bridge east to Nicolls Bay; and eastern Great South Bay from Nicolls Bay east to Smith's Point. Several conclusions may be drawn from this information:

1. Tidal ranges for all North Shore bays are significantly greater than for the Peconic-Flanders or the South Shore bays.

2. The salinity range for individual North Shore bays is generally much narrower than for the South Shore bay complex. This is mainly due to longer flushing times and greater freshwater input in South Shore bays compared to those of the North Shore.

3. Dissolved oxygen values vary widely between bays. Only Hempstead Bay and Middle Bay showed steady-state values below the state standard of 5.0 milligrams per liter for SB waters. This does not mean that other areas have not or will not experience values below the standard. The values in Table 4 are tidally-averaged, steady-state and as such do not show variations due to changes in seasonal or diurnal respiration and photosynthesis. For example, dissolved oxygen values in Great South Bay are generally above 100% saturation but may fall as low as 30% saturation during the night in summer months.

4. Biochemical oxygen demand values are generally higher for the North Shore Bays than for South Shore Bays. The high North Shore values are generally attributed to Long Island Sound water, which receives loadings from the East River. If the effects of algal respiration are added to the values for South Shore bays, the values for bays east of Middle Bay would increase significantly, bringing them in line with Hempstead and North Shore bays.

5. Nutrient values are generally higher in North Shore areas than in the south bay system. Again, this most likely reflects the effects of enriched Long Island Sound water.

6. Nitrogen/phosphorus (N/P) ratios are calculated based on total values for both constituents except where noted. In the latter case, only data on ammonia, nitrate and phosphate were available. In general, nearshore ocean values for N/P ratios are generally about 10:1. Values lower than this are generally associated with changes in species composition and algal blooms characterized by chlorophyll a levels higher than 20 milligrams per liter.

A comparision of N/P ratios and chlorophyll a values illustrates this point. N/P ratios in the North Shore bays are generally below 10:1 and show elevated chlorophyll values whereas the South Shore bays generally have N/P ratios higher than 10:1 and chlorophyll values below 20 milligrams per liter. Exceptions are seen in Hempstead Harbor and in the central and eastern portions of Great South Bay where upper chlorophyll values exceed twenty. This is most likely due to the increased nitrogen loadings from streams in the South bay areas.

7. The total coliform standard for shellfishing areas is 70 MPN per 100 milliliters (log = 1.85). In general, coliform levels in the North Shore bays bracket this value and indeed all or part of each bay has been closed to shellfishing. The western South Shore bays are generally above the 70 MPN per 100 milliliters standard. However, it should be noted that the transect used in modeling the South Shore bays runs along the north shore of these bays, and is therefore closer to point and non-point sources of pollution. Areas of central and eastern Great South Bay are generally below the 70 MPN standard.

Table 1—3

APPROXIMATE PERCENTAGES OF THE TOTAL POLLUTANT LOADS TO SURFACE WATERS CONTRIBUTED BY POINT SOURCES, DRY-WEATHER STREAM FLOW AND WET-WEATHER NON-POINT SOURCES (1975)

	BOD			SS			TN			
Drainage Basin	Lbs/Yr Total	% Run-off[3]	% Pt. Source[3]	Lbs/Yr Total	% Run-off[3]	% Pt. Source[3]	Lbs/Yr Total	% Run-off	% Stream	% Pt. Source
N-1	4,530,000	6	94	9,500,000	22	78	5,880,000	3	2	95
N-2	1,540,000	20	80	3,400,000	71	29	1,830,000	10	36	54
N-3	699,000	18	82	1,480,000	64	36	645,000	10	NA	90
N-4	1,650,000	10	90	1,960,000	62	38	701,000	12	NA	88
N-5	368,000	70	30	2,000,000	94	6	199,000	52	NA	48
N-6	164,000	26	74	447,000	76	24	110,000	21	NA	79
Nassau Total[2]	**8,951,000**			**18,787,000**			**9,365,000**			
S-1	300,000	97	3	2,240,000	99	1	964,000	16	83	1
S-2	485,000	72	28	2,750,000	98	2	707,000	27	70	3
S-3	329,000	53	47	1,550,000	89	11	180,000	51	49	0
S-4	358,000	55	45	1,690,000	90	10	171,000	52	NA	48
S-5	111,000	92	8	780,000	99	1	69,000	66	NA	34
S-6	104,000	100	—	727,000	100	—	46,000	100	NA	—
S-7	327,000	98	2	2,380,000	99	1	213,000	74	NA	26
S-8	433,000	32	68	1,210,000	84	16	136,000	52	NA	48
S-9	62,000	100	—	510,000	100	—	35,000	100	NA	—
S-10	49,000	100	—	305,000	100	—	23,000	100	NA	—
S-11A	8,500	100	—	57,000	100	—	4,100	100	NA	—
S-11B	472,000	18	82	826,000	44	56	84,000	36	NA	64
S-12A	6,000	100	—	51,000	91	9	2,900	100	NA	—
S-12B	127,000	67	33	483,000	95	5	32,000	100	NA	—
S-12C	45,000	100	—	359,000	100	—	23,000	100	NA	—
S-13A	11,000	100	—	87,000	100	—	5,400	100	NA	—
S-13B	324,000	14	86	424,000	85	15	88,000	26	NA	74
S-14	15,000	100	—	108,000	100	—	6,700	100	NA	—
S-15A	67,000	100	—	477,000	100	—	32,000	100	NA	—
S-15B	24,000	100	—	867,000	100	—	55,000	100	NA	—
S-16A	24,000	100	—	164,000	100	—	11,000	100	NA	—
S-16B	8,200	78	22	42,000	95	5	4,100	64	NA	36
Suffolk Total[2]	**3,690,000**			**18,087,000**			**2,892,000**			
Total[2]	**12,641,000**			**36,874,000**			**12,257,000**			

1 Reflects runoff loading only
2 Rounded total
3 Percent of partial loading; dry weather stream flow not included.

Note: NA = Not Applicable

	TP				F. Coli			T. Coli	
Lbs/Yr Total	% Run-off	% Stream	% Pt. Source	MPN/Yr Total	% Run-off	% Stream	% Pt. Source	MPN/Yr Total[1]	Drainage Basin
866,000	6	1	93	1.6×10^{16}	47	0	53	4.1×10^{16}	N-1
202,000	34	1	65	1.1×10^{16}	72	1	27	4.7×10^{16}	N-2
115,000	16	NA	84	3.5×10^{15}	90	NA	10	2.1×10^{16}	N-3
89,000	27	NA	73	9.9×10^{15}	95	NA	5	2.7×10^{16}	N-4
34,000	58	NA	42	2.4×10^{16}	99	NA	1	4.6×10^{16}	N-5
27,000	29	NA	71	2.1×10^{15}	98	NA	2	7.1×10^{15}	N-6
1,333,000				**6.6×10^{16}**				**1.9×10^{17}**	**Nassau Total[2]**
76,000	80	20	–	8.0×10^{15}	98	1	1	4.4×10^{16}	S-1
146,000	47	49	4	1.2×10^{16}	98	1	1	5.4×10^{16}	S-2
35,200	87	13	–	8.5×10^{15}	100	0	0	2.86×10^{16}	S-3
40,000	58	NA	42	1.5×10^{16}	99	NA	1	3.5×10^{16}	S-4
16,000	72	NA	28	7.8×10^{15}	99	NA	1	1.8×10^{16}	S-5
12,000	100	NA	–	6.7×10^{15}	100	NA	–	1.6×10^{16}	S-6
60,000	83	NA	17	1.6×10^{16}	99	NA	1	5.0×10^{16}	S-7
42,000	57	NA	43	5.8×10^{15}	99	NA	1	2.1×10^{16}	S-8
13,000	100	NA	–	2.5×10^{15}	100	NA	–	1.0×10^{16}	S-9
8,000	100	NA	–	1.3×10^{15}	100	NA	–	6.0×10^{15}	S-10
1,400	100	NA	–	3.1×10^{14}	100	NA	–	1.2×10^{15}	S-11A
33,000	25	NA	75	4.9×10^{15}	99	NA	1	5.6×10^{15}	S-11B
800	100	NA	–	4.0×10^{14}	100	NA	–	1.0×10^{15}	S-12A
7,500	100	NA	–	4.6×10^{15}	100	NA	–	1.1×10^{16}	S-12B
7,600	100	NA	–	2.4×10^{15}	100	NA	–	7.6×10^{15}	S-12C
1,600	100	NA	–	7.2×10^{14}	100	NA	–	1.9×10^{15}	S-13A
11,000	69	NA	31	2.8×10^{15}	98	NA	2	7.8×10^{15}	S-13B
1,800	100	NA	–	2.4×10^{15}	100	NA	–	2.4×10^{15}	S-14
10,000	100	NA	–	3.3×10^{15}	100	NA	–	1.0×10^{16}	S-15A
16,000	100	NA	–	7.4×10^{15}	100	NA	–	1.9×10^{16}	S-15B
3,700	100	NA	–	1.0×10^{15}	100	NA	–	3.4×10^{15}	S-16A
700	100	NA	–	4.0×10^{14}	86	NA	14	8.80×10^{14}	S-16B
543,000				**1.1×10^{17}**				**3.5×10^{17}**	**Suffollk Total[2]**
1,876,000				**1.8×10^{17}**				**5.4×10^{17}**	**Total[2]**

Table 1–4

COMPILATION OF WATER QUALITY DATA DERIVED FROM NUMERICAL MODELS AND HISTORICAL DATA

		North Shore							South Shore	
	Units	Western Long Island Sound	Manhasset Bay	Hempstead Harbor	Oyster Bay	Huntington–Lloyd Complex	Northport–Centerport Complex	Port Jefferson	Peconic–Flanders System	Hempstead Bay
Tidal Range	ft.	6	7.3	8.6	7.3	7.1	7.1	6.6	2.7	2.0–4.0
Salinity	ppt.	24–26	21–26	23–26	24–26	25–28	24–27	26–27	15–27	30–31
Temperature	°C.	19–21	14–19	20–24	19–25	21–23	21–23	21–23	20–22	20–23
Diss. O_2	mg/L.	5.5–8.5	8–12	7–9	8–9	8–10	8–10	7–9	8–10	5–9
BOD_5	mg/L.	2.0–4.0	0.5–3.5	1.5–4.5	0.2–0.9	1.3–2.0	ND*	1.5–1.8	0.2–1.3	0.7–1.1
T. Phos.	mg/L.	0.12–0.15 (PO_4)	0.08–0.39	0.19–0.35	0.12–0.14	0.12–0.16	0.12–0.18	0.04–0.05	0.06–0.16	0.04–0.11
T. Nit.	mg/L.	0.24–0.45 ($NH_4 + NO_3$)	0.13–2.03	0.93–2.43	0.33–0.45	0.32–0.41	0.34–0.78	0.30–0.37	0.31–0.88	0.25–0.73
N/P	atoms	1–3	3–11	10–15	6–7	5–6	6–9	15–16	11–12	13–15
Chl a	mg/L.	10–30	3–51	10–220	10–30	2–28	ND	2–18	5–370	2–15
T. coli.	log	1.15–3.70	0.3–5.8	0.5–1.9	–1.4 to 0.3	0.19–2.25	–1.1 to 1.5	3.1–4.22	0.38–2.25	2.2–2.7
F. coli.	log	0.55–3.5	–0.3 to 5.8	0.0–2.88	–1.35 to –0.19	–0.4 to 1.3	–1.3 to 0.4	2.99–4.22	0.38–2.25	1.4–1.5

		South Shore								
	Units	Middle Bay	East Bay	South Oyster Bay	Great South Bay West	Great South Bay Central	Great South Bay East	Mecox Bay	Moriches Bay	Shinnecock Bay
Tidal Range	ft.	2.5–3.5	2.0–3.0	1.2–2.0	1.0–3.0	0.6–1.0	0.4–0.8	2.0 variable	1.5	2.0
Salinity	ppt.	29–31	29–31	30–31	29–31	26–30	22–27	6–30	25–31	27–32
Temperature	°C.	21–23	20–22	21–22	22–23	22–23	22–23	~20–22	22–24	22–24
Diss. O_2	mg/L.	4–6	5–6	5–7	6–8	7–10	8–10	9–13	ND	ND
BOD_5	mg/L.	0.7–0.8	0.5–0.7	0.3–0.5	0.1–0.3	ND	ND	ND	ND	ND
T. Phos.	mg/L.	0.04–0.11	0.01–0.04	0.01–0.02	0.01–0.02	0.01–0.05	0.05–0.09	0.05–0.20	0.11–0.19	0.01–0.04 (PO_4)
T. Nit.	mg/L.	0.33–0.70	0.33–0.45	0.25–0.38	0.13–0.25	0.13–1.33	1.33–1.65	0.02–1.09	0.28–1.07	0.01–0.15 (NH_4+NO_3+NO_2)
N/P	atoms	14–18	25–78	45–60	30–31	30–60	40–158	0.5–2.0 (dissolved)	5–14	ND
Chl a	mg/L.	5–17	9–12	3–6	4–8	6–28	12–25	26–49	ND	ND
T. coli.	log	2.2–2.6	2.0–2.4	1.9–2.0	1.8–1.9	1.1–2.1	1.1–1.9	0.3–3.4	0.48–3.4	0.48–3.5
F. coli.	log	1.5–1.6	1.5–2.0	1.4–1.5	1.3–1.6	0.8–2.0	0.8–1.5	ND	ND	ND

**ND = No Data*

Note: Only data for months of July through September are included in this table.

1.5.1 Structural Alternatives Examined for Long Island Surface Waters

The following section lists the point sources for each of the modeled bays, the structural alternatives proposed and results of these model evaluations where available.

Point Sources for Manhasset Bay

1. Mill Pond
2. Port Washington Sewage Treatment
3. Baxter Pond
4. Knickerbocker Drain
5. Stannard's Drain
6. Leed's Pond
7. Manhasset Valley Park Pond Creek (Whitney Lake)
8. Great Neck Sewer District STP
9. Great Neck Village STP
10. South Pond (Mann's Creek)
11. Mitchell's Creek
12. Wilson's Pond

Table 1–5

SUMMARY OF ALTERNATIVES EXAMINED FOR MANHASSET BAY COMPLEX

Wastewater Sources

Great Neck STP @ 3.5 MGD
Village of Great Neck STP @ 1.5 MGD
Kings Point–Manhasset Collection District @ 2.0 MGD
Port Washington Sewer District STP @ 4.5 MGD
Plandome–Sands Point Collection District @ 2.0 MGD
Roslyn STP @ 0.7 MGD

Treatment Type and Effluent Characteristics

	BOD_5*	T. Nit.*	T. Phos.*	T. coli.†	F. coli.†
Secondary	30	30	4	400	200
Advanced	10	3	4	400	200

Discharge Locations

Current
Mid-Bay
Long Island Sound

* *values in mg/L*
† *values in MPN/100 ml*

1.5.2 Alternative Analyses For Manhasset Bay Complex

As can be seen from Table 1–5 the number of treatment plants, the estimated future flows, the type of treatment and the outfall locations result in a very large number of possible structural alternatives for wastewater management in this area. In addition to the type of modeling efforts previously described, an entire series of "incremental load values" were calculated for each possible combination of alternatives. These will be used along with environmental analyses to determine the most cost-effective and environmentally sound management plan.

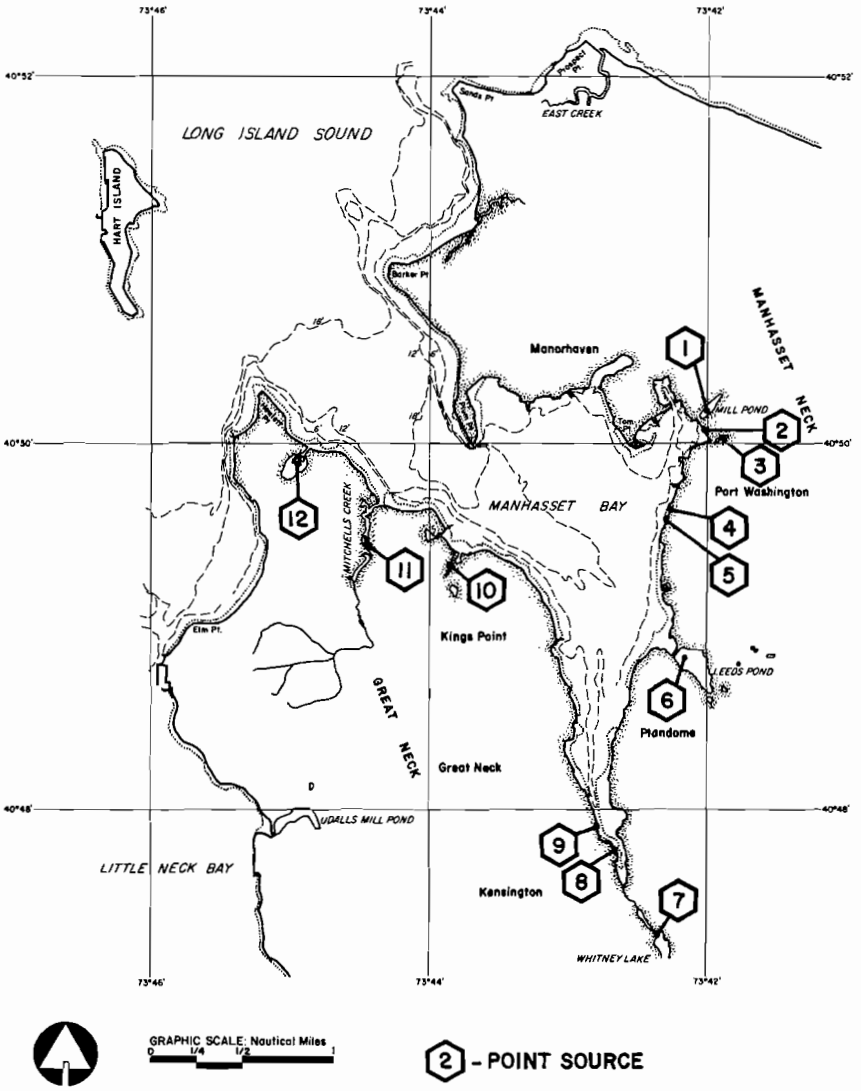


FIGURE 1–16 *Point Source Locations for Manhasset Bay.*

Point Source Locations for Hempstead Harbor

1. Cedar Swamp Creek
2. Powers Chemco
3. Glen Cove STP
4. Scudders Pond
5. N. Tappan Drain
6. S. Tappan Drain
7. Powerhouse Drain
8. Swan Club Pond
9. Drain at Swan Club
10. Drain North of Emmanuel's Pond
11. Emmanuel's Pond
12. Roslyn STP
13. Roslyn Duck Pond
14. Roslyn Viaduct (North Center, S) Pipes
15. Roslyn Incinerator
16. Drain North of Hempstead Harbor Beach

Table 1–6

SUMMARY OF ALTERNATIVES EXAMINED FOR HEMPSTEAD HARBOR

Wastewater Sources

Glen Cove @ 6.5 MGD
Sea Cliff–Roslyn Harbor Collection District @ 5.0 MGD
Oyster Bay STP @ 2.0 MGD
Unsewered Bayville and East Norwich areas @ 2.7 MGD
Port Washington Sewer District @ 4.5 MGD
Unsewered Plandome–Sands Point Collection District @ 2.0 MGD
Great Neck Sewer District @ 3.5 MGD
Unsewered King's Point area @ 2.0 MGD
Roslyn STP @ 0.7 MGD

Treatment Type and Effluent Characteristics

	BOD_5*	T. Nit.*	T. Phos.*	T. coli.†	F. coli.†
Secondary	30	30	4	400	200
Advanced	10	3	4	400	200

Discharge Locations

Current
Mid-Bay
Long Island Sound

** values in mg/L*
† values in MPN/100 ml

1.5.3 Alternative Analyses for Hempstead Harbor

Because of their proximity to one another, many of the structural alternatives examined for Manhasset Bay are also possible alternatives for the Hempstead Bay complex. Again, a series of incremental values (milligrams per liter of constituent per million gallons per day or equivalent units) were calculated for the series of alternative loads, treatment type and discharge location examined. As mentioned previously, boundary conditions (water quality in western Long Island Sound) have a major influence on water quality within Long Island North Shore bays. For this reason, two sets of boundary conditions were chosen for the model runs: yearly averages and "typical worst case" conditions. In addition to these, a "zero discharge" situation (no treatment plants) was also run as a basis for comparison.

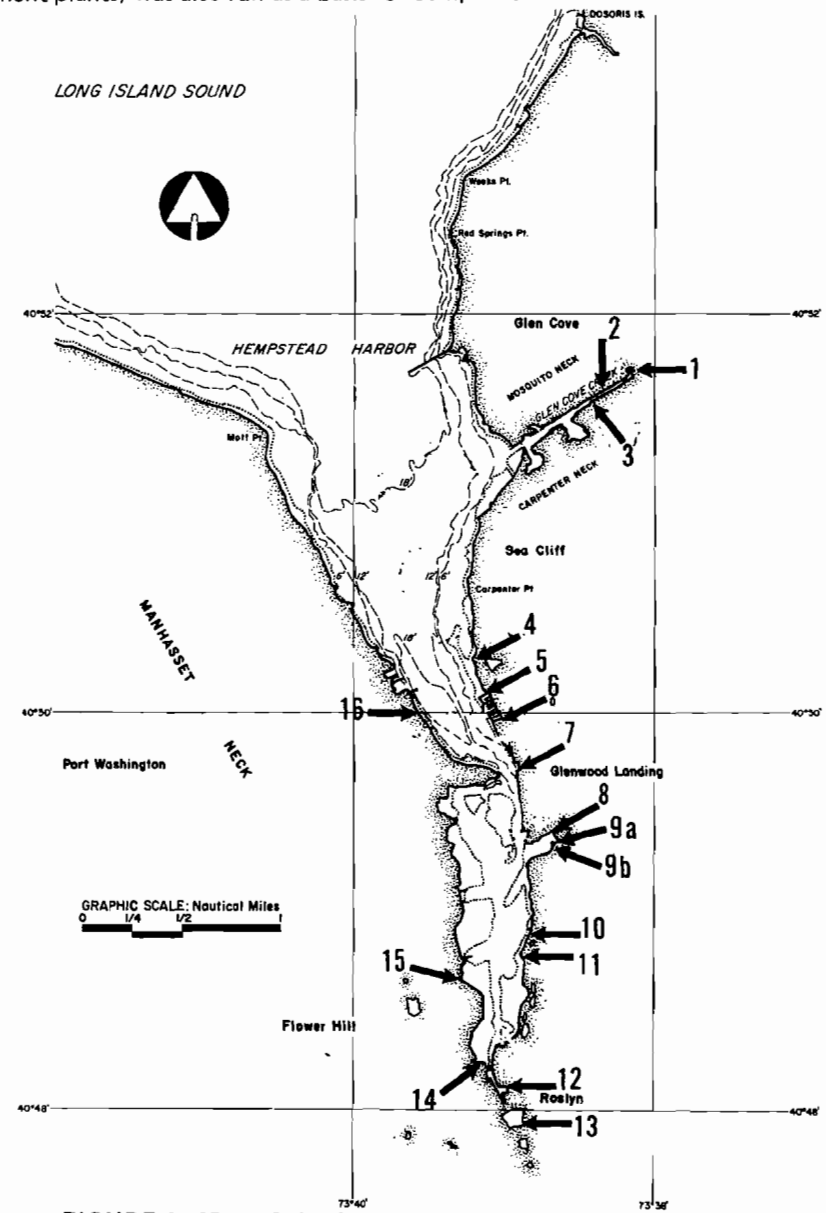


FIGURE 1–17 *Point Source Locations for Hempstead Harbor.*

Point Sources for Oyster Bay–Cold Spring Harbor

1. Oak Neck Creek
2. Mill Neck Creek–Factory Pond
3. Kentuck Pond Creek
4. Mill Pond Creek
5. Oyster Bay STP
6. Center Island STP
7. Tiffany Creek
8. Cold Spring STP
9. Cold Spring Brook

Table 1–7

SUMMARY OF ALTERNATIVES EXAMINED FOR OYSTER BAY–COLD SPRING HARBOR COMPLEX

Wastewater Sources

Oyster Bay @ 3.1 cfs
Oyster Bay with unsewered Bayville area @ 4.96 cfs
Oyster Bay with unsewered East Norwich area @ 5.43 cfs
Oyster Bay with both Bayville and East Norwich @ 7.29 cfs

Treatment Type and Effluent Characteristics

	BOD_5*	T. Nit.*	T. Phos.*	T. coli.†	F. coli.†
Secondary	30	30	4	400	200
Advanced	10	3	4	400	200

Discharge Locations

Current
Mid-Bay
Long Island Sound

** values in mg/L*
† values in MPN/100 ml

1.5.4 Alternative Analyses for Oyster Bay–Cold Spring Harbor

Treatment plant loadings as proposed by the engineering consultants were evaluated as shown in Table 1–7.

The results of modeling studies have shown that there is a relatively minor improvement in surface water quality for all constituents whether receiving secondary or advanced treatment with outfalls located at mid-bay or present locations. For example, an increase of 0.1 milligrams per liter of nitrogen is seen under the highest loading (7.29 cfs) with secondary treatment at the present location. These results are consistent with the high flushing rate of the area and the levels of nutrients in Long Island Sound waters which reflect loadings from the East River.

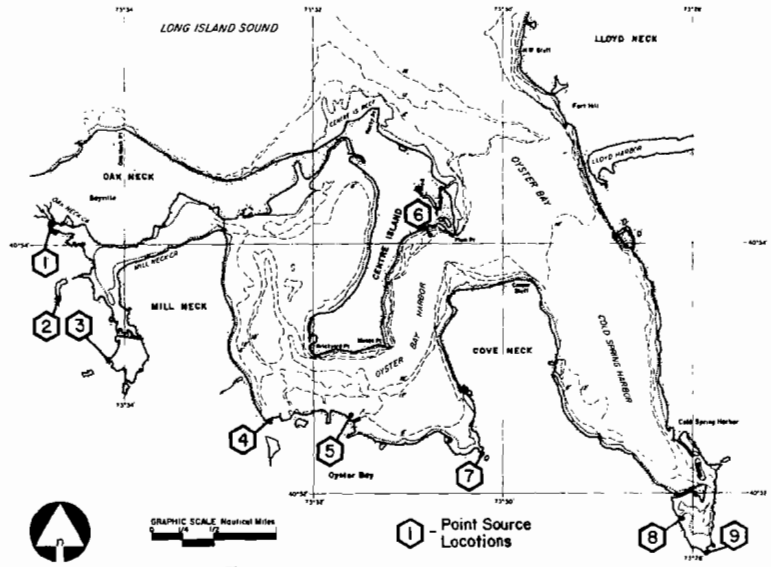


FIGURE 1–18 *Point Source Locations for Oyster Bay–Cold Spring Harbor Complex.*

Point Sources for the Huntington—Northport Complex

1. Mill Road Creek
2. Huntington STP
3. Huntington Harbor Creek
4. Centerport Mill Pond
5. Stony Hollow Run
6. Northport STP
7. Storm drain

Table 1—8

SUMMARY OF ALTERNATIVES EXAMINED FOR HUNTINGTON BAY—NORTHPORT HARBOR COMPLEX

Plant

Huntington @ 13 MGD
Huntington concurrent operation @ 6.5 MGD
Northport concurrent operation @ 6.5 MGD

Treatment Type and Effluent Characteristics

	BOD_5*	T. Nit.*	T. Phos.*	T. coli.†	F. coli.†
Secondary	30	30	4	400	200
Advanced	10	2	4	400	200

Discharge Locations

Huntington

Current
Mid-Bay
Long Island Sound

Northport

Current
Mid-Bay

* *values in mg/L*
† *values in MPN/100 ml*

1.5.5 Structural Alternative Analyses—Huntington-Northport Complex

The objective of this work was to provide quantitative estimates of the effects of projected effluent discharges on receiving water quality using the verified numerical model. A variety of treatment plant loadings as proposed by the engineering consultants was examined and the loadings are listed in Table 1—8.

Comparisons of secondary versus advanced waste treatment with concurrent discharge of 6.5 million gallons per day at two plants indicated that secondary treatment is clearly unacceptable. Nitrogen, phosphorus and BOD concentrations would be approximately one order of magnitude higher than they are at present. The impact of this increase is difficult to quantify but it is reasonable to assume that significant increases in these parameters will result in adverse changes in the system. Coliform counts are presently above the limit set for shellfishing (not more than 70 MPN per 100 milliliters due mainly to the contributions from Huntington Harbor Creek and storm drain inflow. The incremental effect of sewage treatment plant discharge on coliform concentrations is minimal since coliforms are essentially removed in the treatment process.

Comparisons of secondary versus advanced treatment with a single plant discharging 13 million gallons per day at the present Huntington STP location indicate there would be effective nitrogen and BOD removal with advanced treatment but little removal of phosphorus. Again, there appears to be negligible impact with respect to coliform concentrations due to treatment plant discharges.

Comparisons of secondary treatment alternatives with different outfall locations indicate that substantial improvement in water quality would occur by moving the outfalls to the mid-bay area. Under these conditions, neither concurrent discharge of 6.5 million gallons per day at the present Huntington and Northport plants nor 13 million gallons per day discharge from the Huntington plant alone causes appreciable change over the present condition.

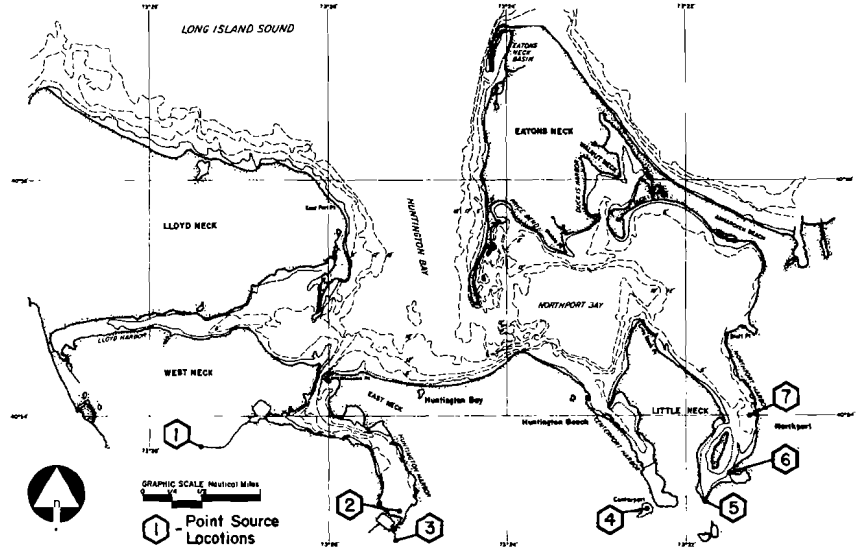


FIGURE 1—19 *Point Source Locations for Huntington-Northport Complex.*

Point Sources for Port Jefferson Harbor Complex

1. Port Jefferson Creek
2. Exxon Storm Sewer
3. Port Jefferson STP
4. Long Island Lighting Company
5. Setauket Creek
6. Conscience Bay Stream

Table 1–9

SUMMARY OF ALTERNATIVES EXAMINED FOR PORT JEFFERSON HARBOR

Plant

Port Jefferson @ 2, 5, 8.5, 10 and 15 MGD discharge rates

Effluent Characteristics

	BOD_5*	T. Nit.*	T. Phos.*	T. coli.†	F. coli.†
Secondary	30	30	4	400	200

Discharge Locations

Current
Mid-Bay
Harbor Entrance

** values in mg/L*
† values in MPN/100 ml
BOD and Fecal coliform values are 7 day arithmetic means

1.5.6 Alternative Analyses for Port Jefferson Harbor

The 208 Study, in response to requests by county agencies involved in the 201 Facilities Plan for Port Jefferson, ran a series of management alternatives using the verified numerical model. Table 1–9 lists the various options examined.

Since tidal cycle and degree of flushing are highly significant in Port Jefferson, the "worst case" tide giving minimum flushing was used in the models.

Discharging 15 million gallons per day to the current location results in a four-fold increase in total nitrogen and a three-fold increase in total phosphorus over baseline conditions or discharge at the harbor entrance.

Modeling results for BOD and coliforms show essentially the same results as found for nutrients; that is, a significant increase over baseline conditions with 15 million gallons per day discharging at the current location and decreasing effects as the outfall is moved closer to the mouth of the harbor. However, there are more localized effects in these parameters especially around the discharge points.

In all cases, differences between baseline and proposed alternatives became increasingly less by moving the outfall closer to the harbor entrance. This is a reflection of the effect of boundary conditions on water quality in the harbor. One might conclude that the presence of contaminants in Long Island Sound could reduce the benefits of relocating a waste discharge nearer the harbor entrance. (However, any marked future improvement in Sound water quality will increase the benefits to be gained from good waste management steps taken now.)

Additional analyses have led to the recommendation to allow secondary treatment at the existing outfall if dissolved oxygen levels are monitored, and to motivate nitrogen removal if dissolved oxygen levels are not maintained above 5.0 milligrams per liter.

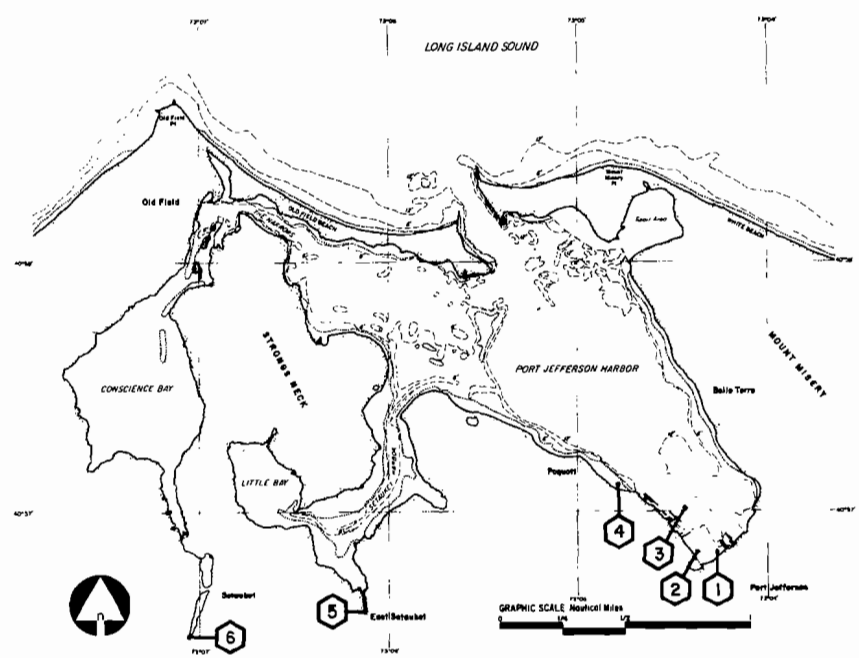


FIGURE 1–20 *Point Source Locations for Port Jefferson Harbor Complex.*

Point Sources for the Peconic Estuary—Flanders Bay System

1. East Creek
2. Reeves Creek
3. Crescent Duck Farm
4. Meetinghouse Creek
5. Broad Cove Duck Farm
6. Terry's Creek
7. Shubert Duck Farm
8. Sawmill Creek
9. Riverhead STP
10. Peconic River
11. Little River
12. White Brook
13. Goose Creek
14. Birch Creek
15. Mill Creek
16. Hubbard Creek

Table 1—10

SUMMARY OF ALTERNATIVES EXAMINED FOR PECONIC ESTUARY—FLANDERS BAY

Plant

Riverhead @ 1, 9 and 20 MGD discharge rates

Treatment and Effluent Characteristics

	BOD_5*	T. Nit.*	T. Phos.*	T. coli.†	F. coli.†
Secondary	30	30	4	400	200

Discharge Locations

Current Site
Mid-Bay
Flanders Bay—Great Peconic Bay Boundary

** values in mg/L*
† values in MPN/100 ml
BOD and Fecal coliform values are 7 day arithmetic means

1.5.7 Alternative Analyses for Peconic Estuary—Flanders Bay

As with each of the other modeled bays, a series of structural management alternatives were proposed. In addition, the 208 Study responded to requests by outside agencies to assist in modeling various alternatives for the 201 Riverhead Facilities Plan. The range of alternatives is given in Table 1—10.

Results of the modeling effort indicate there will be no significant effects on salinity within the area no matter which outfall location is chosen. It should be remembered that the model assumes complete vertical mixing in the water column and therefore predicted values are lower than the values that may occur in localized areas near discharge plumes. This holds for both conservative and non-conservative constitutents.

The one million gallons per day case is representative of the present condition which has often resulted in severe oxygen depletion in the Peconic Estuary during evening hours due to diurnal cycles in photosynthetic activity.

Increases in nutrient concentrations above the present condition may be expected to reach 345% for the nine million gallons per day discharge and 710% for the 20 million gallons per day situation. These estimates are based on nutrient accumulations near the outfall where the impact of the discharges is the greatest. Increases in nutrients at the entrance to Flanders Bay are expected to be 200% (nine million gallons per day) and 400% (2[illegible] million gallons per day) above the present condition.

Model predictions do not show significant changes in coliform concentrations resulting from increased effluent loads. These predictions are based on the assumption that the projected concentrations are truly representative of 24 hour loads from the operating plant and that the coliform decay coefficient of 0.5 per day is appropriate.

Incremental increases in BOD were shown to be similar to increases in nitrogen and phosphorus in areas close to the outfalls. Increases in BOD values at the entrance to Flanders Bay are relatively smaller than nutrient changes due to biological decomposition in diluted discharges. However, while tidally averaged model predictions do not show severe oxygen depletion due to effluent discharges, one should not assume that these situations will not occur at one time or another. Results of the field survey and model sensitivity studies have shown that even under present nutrient loadings, oxygen depletion can be expected to occur from time to time. Dissolved oxygen concentrations in the Peconic Estuary are primarily dependent on phytoplankton photosynthetic-respiration activity. Dissolved oxygen is therefore a function of available nutrients, light intensity and temperature and will vary according to the times of day and season.

Discharge of proposed effluent loads at the mid-bay locations indicates that concentration/gradients are far less pronounced and that better mixing of pollutants would be achieved. Concentration of nutrients at the mouth of the bay with this alternative is much the same as for discharge at the present location, indicating that although the discharge point is closer to the entrance, increased flushing will maintain lower levels of nutrients. Near the outfall, increases over the one million gallons per day case are 163% (nine million gallons per day) and 338% (20 million gallons per day). This represents an improvement in receiving water near the outfall of greater than 50% compared with discharge at the present site.

Discharge at the mouth of the bay results in significantly better mixing and dispersion of nutrients than at the present location. The pollutants are carried out and diluted in Great Peconic Bay so that receiving water nutrient concentrations are believed to be lower than for both other alternatives. While nutrient concentrations in the vicinity of the outfall are essentially the same when discharged at the mouth or at mid-bay locations, nitrogen and

phosphorus concentrations within the bay are generally 20% less for the nine million gallons per day discharge and 30—40% less for the 20 million gallons per day discharge when the outfall is located at the entrance to the bay.

Since dissolved oxygen concentrations are highly sensitive to changes in rates of photosynthesis and respiration, a series of evaluations were carried out to determine the maximum permissible nutrient loadings which would maintain phytoplankton populations at levels not expected to cause oxygen depletion. Results of these analyses indicated that discharge of six million gallons per day with nitrogen removal at the mid-bay site would maintain nutrient concentrations and phytoplankton populations within a range where oxygen depletion would not be expected.

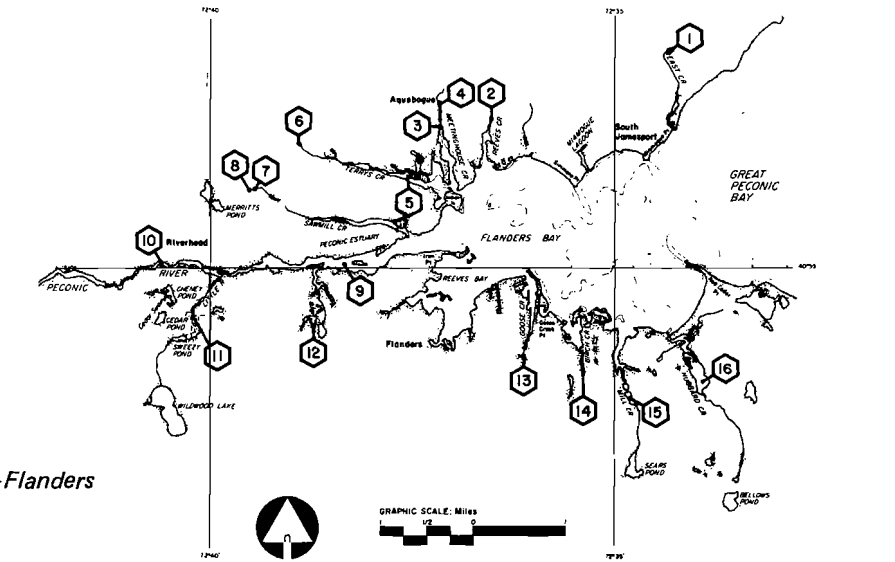
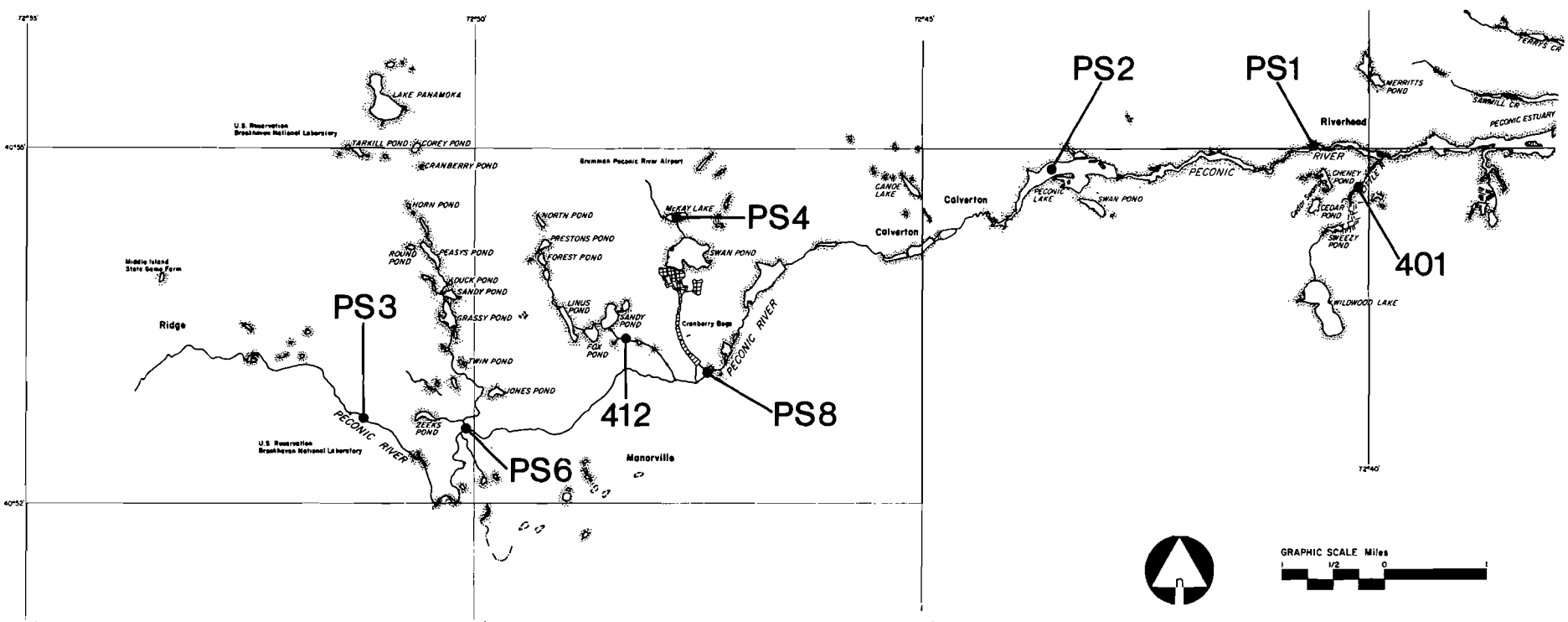


FIGURE 1–21 *Point Source Locations for Peconic Estuary—Flanders Bay System and Peconic River.*



Point Sources For South Shore Bays

	Source Name	Node No.
	Hempstead Bay	
1.	Lawrence STP	2
2.	W. Long Beach STP	2
3.	Bay Park STP	13
4.	Mill River (E + W)	11
5.	Long Beach STP	13
	Middle Bay	
6.	LILCO Power Plant	14→9
7.	Oceanside Incinerator	9
8.	Parsonage Creek	18
9.	Milburn Creek	19
10.	East Meadow Brook	21
11.	Freeport Creek (tidal, fed by East Meadow Brook)	21
12.	Freeport STP	21
13.	Freeport Incinerator	21
	East Bay	
14.	Merrick Incinerator	22
15.	Jones Beach STP	34
16.	Newbridge Creek	23
17.	Bellmore Creek	40
18.	Cedar Swamp Creek	23
	South Oyster Bay	
19.	Seamans Creek	17
20.	Seaford Creek	17
21.	Massapequa River	41
22.	Carman Creek	51
	Great South Bay	
23.	Amityville Creek	52
24.	Woods Creek	52
25.	Great Neck Creek	53
26.	Strongs Creek	53
27.	Neguntatogue Creek	53
28.	Santapogue Creek	54
29.	West Brook	79
30.	Carlls River	54
31.	Park Ave. Apts.	54
32.	Harbor Club Apts.	54
33.	Sampawams Creek	55
34.	Willets Creek	55
35.	Skookwams Creek	55
36.	Trues Creek	56
37.	Watchogue Creek	76
38.	Penataquit Creek	76
39.	Awixa Creek	76
40.	Orowoc Creek	76
41.	Cascade Lakes	76
42.	Pardees Pond	76
43.	Champlin Creek	77
44.	Ocean Beach STP	68
45.	Connetquot River	79
46.	Green Creek	82
47.	Brown Creek	82
48.	Tuthills Creek	84
49.	Patchogue River	84
50.	Patchogue STP	84
51.	Watergate Garden Apts.	84
52.	Justus Roe	84
53.	Swan River	84
54.	Mud Creek	85
55.	Hedges Creek	85
56.	Beaverdam Creek	87
57.	Motts Creek	87
58.	Carmans River	89
59.	Rattlesnake Brook	79

(See Figures 1–13a and 13b for Point Source Locations).

1.5.8 Alternative Analyses for South Shore Bays

Table 1–11 gives a summary of all alternatives examined for the South Shore system. This is by far the most complex of all areas examined both from an ecological viewpoint and from the broad range of structural alternatives to be examined. At least 65 separate model runs have been carried out for this system. It must be remembered that almost all of Nassau County is already sewered, wheareas generally, only the western parts of Suffolk County are presently sewered. This reduces the number of alternatives available for Nassau County while increasing those for Suffolk County. As noted in Table 1–11, a series of regional, sub-regional and small plants are possible in Suffolk County.

Table 1–11

SUMMARY OF ALTERNATIVES EXAMINED FOR SOUTH SHORE BAYS

The Nassau County cases, consisting of several combinations of alternative flows, ocations and diversions were run separately from Suffolk County alternatives. Suffolk County cases were broken down into regional, sub-regional and small plants options and vere run with existing Nassau County average point source loadings as background.

Nassau County Loadings

Lawrence STP @ 1.0 MGD
West Long Beach @ 0.9 MGD
Jones Beach @ 0.2 MGD
Long Beach @ 8.0 MGD
Bay Park @ 75 MGD
Bay Park and Inwood and Cedarhurst and
Great Neck Peninsula @ 84.5 MGD

Suffolk County Loadings

Use Nassau County discharges as background
Regional—Southwest Sewer District @ 30 and 54 MGD
—South Central District @ 31 MGD
Sub-Regional—Oakdale Sub @ 9 MGD
—Southeast Sub @ 5.0, 6.5 and 15 MGD
—Yaphank-South Sub @ 6.5 and 8.5 MGD
—With and without duck farms
Small Plants—Patchogue @ 0.5 MGD
—Watergate Apartments @ 0.02 MGD

Treatment Type and Effluent Characteristics

	BOD_5*	T. Nit.*	T. Phos.*	T. coli†
Secondary	30	30	4	400
Advanced	10	3	4	400

Discharge Locations

Nassau	Suffolk
East Rockaway Inlet	Atlantic Ocean
Long Beach STP	Bergen Point
Jones Beach STP	Nicolls Bay
Atlantic Ocean	Patchogue Bay
30–60 MGD recharge	Bellport Bay

** values in mg/L*
† values in MPN/100 ml

Point Sources for Moriches and Shinnecock Bays*

1. Jergielwiez Processing Plant—Forge River
2. Moriches Duck Farm—Forge River
3. Certified Duck Farm—Terrell River
4. Vigliotta North Farm—Terrell River
5. Vigliotta West Farm—Terrell River
6. Romanowski Duck Farm—Tuthill Cove
7. Vigliotta East Farm—Harts Cove
8. Long Island Co-Op Plant—Seatuck Creek
9. Powell Farm—Seatuck Creek
10. Tuttle Farm—East River

*Duck farms are the principal point sources of pollutant loading for Moriches Bay.

Table 1–12

ESTIMATED LOADINGS FROM DUCK FARMS AND NON-POINT SOURCES FOR MORICHES AND SHINNECOCK BAYS

	Moriches Bay (lbs/day)		Shinnecock Bay (lbs/day)	
Direct rainfall	N	292	N	253
	P	2	P	2
Stormwater run-off	N	188	N	63
	P	53	P	21
Streamflow	N	637*	N	35*
	P	95	P	8
Groundwater seepage	N	698*	N	175*
	P	155	P	39
Duck Farms	N	303	N	0
	P	(150)	P	0
Total	N	2118	N	526
	P	455	P	70

**Total inorganic nitrogen only*
( ) assumes an N/P ratio 0.5 for duck farm effluent

Table 1–13

PROJECTED POINT SOURCE ALTERNATIVES: COMPOSITION OF WASTES

Management Approach	Study Region and Bay	Alternatives	Flow MGD	BOD #/day	TSS #/day	Total-N #/day	Total-P #/day	Total-Coli MPN/day
Sub-Regional	S. E. Sub.	secondary	2.0	500	500	500	67	3.02×10^{10}
	Yaphank to	advanced	2.0	167	167	50	67	3.02×10^{10}
	Moriches	Duck Farms	4.0	double loads				
Small plant	Hampton Bays	secondary	2.0	500	500	500	67	3.03×10^{10}
	to Moriches	advanced	2.0	167	167	50	67	3.03×10^{10}
Small plant	East Hampton	secondary	1.5	375	375	375	50	2.27×10^{10}
	to Shinnecock	advanced	1.5	125	125	38	50	2.27×10^{10}
Small plant	East Quogue	secondary	1.75	438	438	438	58	2.65×10^{10}
	to Shinnecock	advanced	1.75	146	146	44	58	2.65×10^{10}

1.5.9 Alternative Analyses for Moriches–Shinnecock Bays

Treatment plant options and estimated loadings as proposed by the engineering consultants are shown in Table 1–13.

Non-point source loadings for this bay system include direct rainfall, stormwater run-off, streamflow, groundwater seepage and cesspool and septic tank leakage. Table 1–12 lists the relative contributions for both nitrogen and phosphorus from these sources and duck farms. The sources shown fall into two categories, transient and continuous. The continuous sources are of the greatest concern for the bay system. Even though tidal flushing is constantly diluting and removing part of the nutrient load from the system, it is apparent from averaged historical data that the larger continuous nutrient sources from streamflow, groundwater seepage and duck farm point sources are producing elevated nutrient levels in Moriches Bay.

Transient sources such as direct rainfall and stormwater run-off are of less importance to the bay nutrient budget. Since most of Moriches and Shinnecock Bays are well flushed by tidal action, much of the material from these sources will probably be moved out of the system within less than one week.

To reach their full impact, elevated nutrient levels must remain in the system long enough to allow for increased phytoplankton growth and resulting changes in diurnal oxygen concentrations. This phenomenon probably occurs only in the tidal portions of rivers feeding into the Moriches and Shinnecock Bays where flushing rates are lower than the bays'. Obviously, these are the least desirable areas for receiving future point and non-point source loadings.

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Section 2 Groundwater Conditions

2.0 INTRODUCTION

The bi-county 208 region is unique in New York State. Almost three million people depend upon ground water as their sole source of fresh water. The uses are broadly representative of man's need for water in a complex technological society, as well as the need for water for crop growing and domestic supplies.

Section 2.1 discusses the availability of water in Nassau and Suffolk Counties, suggests the need for additional data, and explains problems attributable to heavy withdrawals of ground water. This section also includes a summary of water supply and use for Long Island. A brief explanation of some of the previously proposed local and/or regional water management plans is included.

Section 2.2 is an assessment of the principal sources of ground water contamination in the 208 region, based upon information from a much longer, more technical report which was one product of the overall study.

Section 2.3 characterizes existing ground water conditions by aquifer, discusses trends in ground water quality, and summarizes the preliminary findings of a virus study and organics evaluation made during the course of the 208 investigation.

2.1 GROUNDWATER SUPPLY

2.1.1 Background

Ground water beneath Nassau and Suffolk Counties is the only source of fresh water supply for almost three million people. The quality and quantity of this water is modified by regional and local water supply development policies and waste disposal practices. Water is removed from aquifers, used and, in many cases, recharged back to the ground water reservoir in varying degrees of chemical alteration from its original state. Alternatives which modify how waste water is treated and discharged in the region will each have an effect on the quality and the quantity of drinking water in the future. Therefore, it is important that the current water supply situation in the bi-county area be defined as part of the process for developing the Long Island 208 Areawide Waste Management Plan.

2.1.2 Summary

A number of concepts have been summarized in this section with particular regard to ground water quantity. Potential management plans were reviewed in light of available data and recent projections. Very few of the past studies of Long Island water resources detail the reasons for recommended water management alternatives such as massive water transfers and artificial recharge with reclaimed sewage effluent. Many reports infer that a critical shortage of water may be expected within the next few decades.

Increased consumptive use and declining water levels have been equated with running out of water. The fact is that, on a bi-county basis, there is sufficient available ground water to supply Long Island's future saturation population as projected by NSRPB, providing that provisions are made for solving water quality problems in local areas and for adopting proper management techniques. Regional water shortages within the foreseeable future caused by lowered water levels and/or salt water encroachment cannot be used as the basis for adopting complex and expensive engineering and construction programs. In evaluating waste water management options under 208, emphasis must be placed on determining the impact of proposed plans on ground water quality and the effects on other segments of the environment, such as stream flow and fresh water discharge to the surrounding salt water bodies.

The present ground water situation, from the standpoint of water quantity only, in the Long Island 208 region is characterized by the following:

1. Major concentrations of pumpage have developed near areas of dense population, leaving other portions of the subsurface reservoirs underutilized. This applies particularly to the east-west imbalance in pumpage distribution.
2. The abandonment of shallow wells in favor of withdrawing water from progressively deeper aquifers has been the pattern of development throughout the more urbanized areas.
3. Ground water pumpage in neighboring Queens County along with sewer construction are major factors in the decline of water levels in southwestern Nassau County.
4. Ground water is not developed according to a formal scientific plan or a long-term program with the objectives of protecting water quality, maximizing the available resource, or minimizing the impact on streams and bays.
5. Adoption of water management proposals has been hampered by the fragmentation of responsibility among numerous water supply units, which are controlled by local economic and political factors, divorced from regional needs.
6. Water and waste management schemes can be most effectively implemented if decisions regarding ground water resources are approached on an Island-wide basis.
7. Predicted water level declines due to sewering and increased pumpage will not diminish the overall ability to meet water supply needs in the future but will adversely affect stream flow and fresh water discharge to bays and estuaries.
8. Salt water encroachment is a local problem and not a significant regional threat to ground water availability.
9. Over the long-term, quantity does not represent a serious constraint on water supply self-sufficiency for Nassau and Suffolk. Subsequent sections of this report suggest that water quality degradation resulting from man's activities will be the principal constraint.

Future water supply availability, cost and quality depend on a number of basic policy decisions that must be made now. Of greatest importance are whether or not to (1) regionalize development and distribution, (2) implement water conservation techniques, (3) maintain stream flow and fresh water discharge, (4) enforce protective waste management practices, and (5) control activities that accelerate ground water quality degradation.

2.1.3 Available Water Supply

Two major water-bearing units, the Upper Glacial and Magothy aquifers, are the principal sources of water for the Long Island 208 planning area. The Lloyd aquifer, a relatively unexploited source of water, lies beneath these two upper formations. Together the three aquifers contain over 60 trillion gallons of water, representing the total amount of water in storage beneath the Island (Cohen, 1968).

Past evaluations have placed a number of different limits on the amount of this water available for development. These estimates are usually presented as the "safe" or "permissive" yield of the system. The concept of "safe" or "permissive" yield is normally defined as the amount of ground water which can be withdrawn from the system and used consumptively on an annual basis without producing undesirable results. For the Long Island 208 region, water used "consumptively" simply means that the water is not returned to the ground water system. Determination of what is an undesirable result will be a major factor in the decision-making process that leads to the selection of waste management plans, as required by Section 208 of the Federal Water Pollution Control Act Amendments of 1972.

As consumptive use increases, ground water is taken from storage. There is also a decrease in ground water discharge to streams and to the sea. These stresses on the ground water system result in water level declines and salt water encroachment. If consumptive use stabilizes and total recharge is not exceeded, a new equilibrium is established for water levels and salt water/fresh water boundaries. If, however, consumptive use exceeds total recharge and ground water inflow, water levels will decline indefinitely and salt water will slowly replace the fresh water removed from storage. For Nassau and Suffolk Counties, sewer outfalls discharging to the ocean constitute the principal consumptive use of ground water. The most recent estimates of water availability, or permissive yield, have included consideration of substantial increases in sewering of the study region.

Unfortunately, the term permissive yield is often interpreted in the same way for Nassau and Suffolk Counties' ground water supplies as it is for New York City surface water supplies. The safe yield of New York City surface water supplies is usually defined as the amount of water that would be available under conditions similar to those resulting from the 1962–1966 drought. The Corps of Engineers estimates this yield as insufficient to meet future water demands, and therefore assumes the possibility of a water supply deficiency. In Nassau and Suffolk a drought of this or of even a more severe

nature would cause only a slight diminution of the vast quantity of water in storage, with little prospect of real water shortage. An extended drought period would lead to undesirable conditions of a temporary nature, such as lowered ground water levels and decreased stream flow.

2.1.4 Estimates of Existing Permissive Yield

Both Nassau and Suffolk Counties have had comprehensive water supply studies in recent years. In 1971 Greeley and Hansen estimated a mean permissive yield of 151 million gallons per day for Nassau County (Greeley and Hansen, 1971). This figure was computed by using an extraction ratio* of 75 percent. Holzmacher, McLendon and Murrell computed a "permissive yield" of 466 million gallons per day for Suffolk County using a similar ratio (Holzmacher, 1970). The Nassau County Department of Health (NCDH) computed the average consumptive loss for Nassau County as 133 million gallons per day for the period 1969 to 1973. Annual consumptive loss for Suffolk County was on the order of 40 to 50 million gallons per day for that period.

The studies estimated that large water table declines would occur at the permissive yields. Greeley and Hansen predicted a maximum decline of 30 feet for Nassau County, based upon the assumption of county-wide sewering with effluent discharged by ocean outfalls. The Holzmacher, McLendon and Murrell estimate for Suffolk was for reductions of up to 75 percent of present elevations above sea level prior to the establishment of equilibrium. The water table declines for Nassau are significantly greater than those predicted in recent runs of the U. S. Geological Survey analog model. The authors of both county investigations felt that at the permissive yield the salt water interface off the south shore would move landward to a new equilibrium position, perhaps a mile from its present location.

A 1976 analysis of ground water response to sewerage programs and projected population increases by 1995 forecasts an increase in ground water withdrawals of 9.5 million gallons per day for Nassau County and 46.4 million gallons per day for Suffolk County (Kimmel and Harbaugh, 1976). The total modeled decrease in recharge by 1995 was estimated to be 39.9 million gallons per day and 42.7 million gallons per day for Nassau and Suffolk Counties, respectively. It was concluded that these stresses would result in water table stabilization after declines of as much as sixteen feet in east-central Nassau County, and as much as six feet in central Suffolk County by 1995, with less of a decline forecast for the Magothy aquifer. Stream flow decreases by as much as 55 percent were forecast for southeast Nassau, with slightly higher decreases in the Huntington-Northport Sewer District.

The future of the Jamaica Water Company in Queens adds uncertainty to estimating impacts of sewering in Nassau County. This supplier is pumping about 60 million gallons per day, creating a significant underflow from western Nassau to Queens. It is understood that upon completion of New York City's third water tunnel, distribution of surface water to this area will be possible (Groopman, 1977). However, the lack of additional surface water supply sources upstate will preclude complete replacement of the ground water presently supplied to Queens County, especially during periods of drought. If the Jamaica Water Company pumpage is curtailed, there would be a significant recovery of water levels in western Nassau. The magnitude of the anticipated change may be estimated from the analysis of water level declines attributable to Queens pumpage (Figure 2–1).

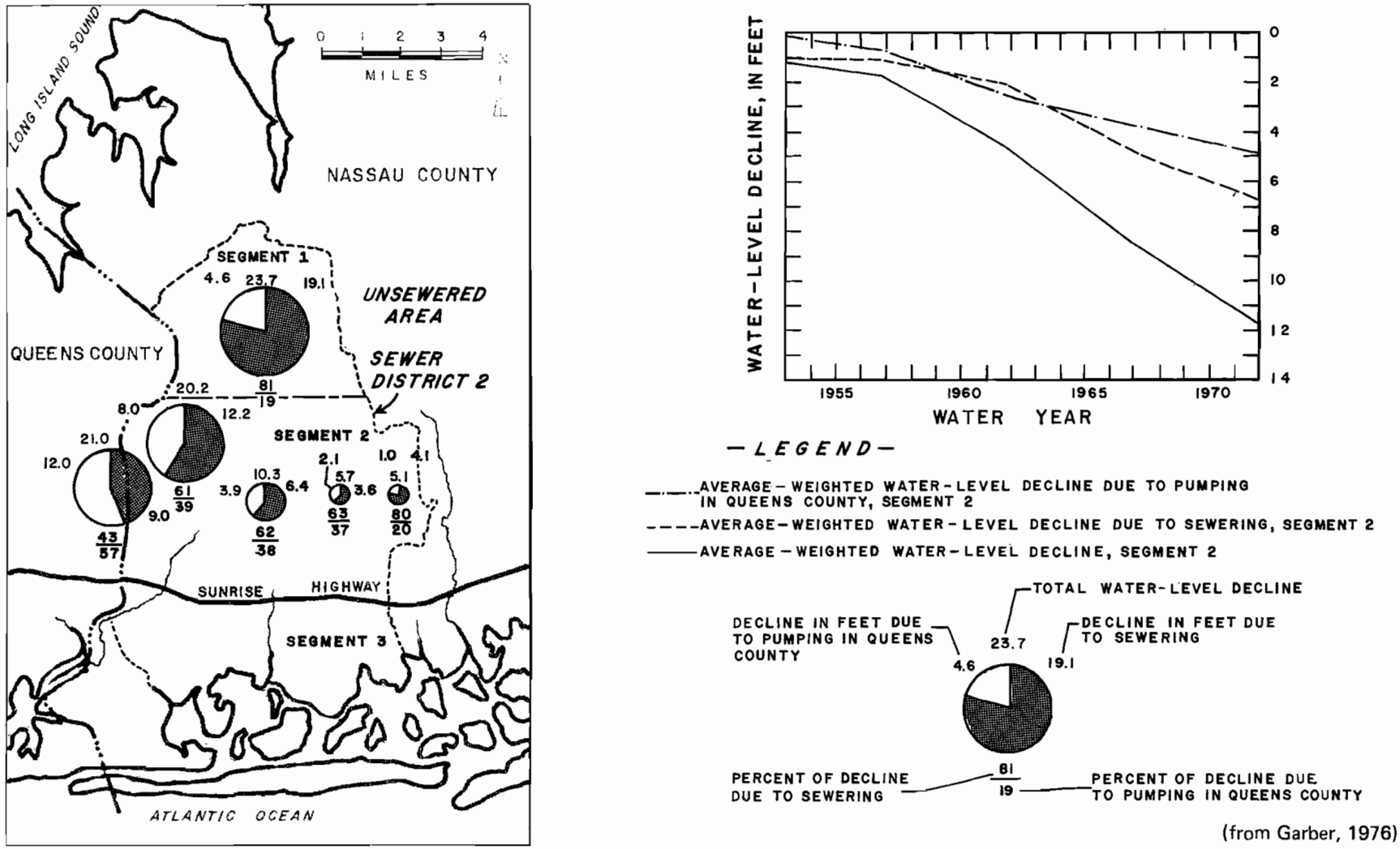
The Queens/Nassau common water level decline illustrates the insignificance of political boundaries with relationship to management of a resource that is common to the entire island. The present flow from Nassau to Queens is estimated at between ten and fifteen million gallons per day. While some of this movement is due to natural conditions, a significant portion is attributable to heavy pumping in Queens, which along with sewering and pumpage in Nassau County, has locally lowered water levels in the three principal aquifers to below sea level (Figures 2–2, 2–3, 2–4). This impact is particularly significant with regard to some of the plans previously proposed for future ground water development in the 208 region, which are discussed in a later section of this report. For instance, one scheme calls for installation of a regional well field in Suffolk County and pumping of water from the field to Nassau County. At present there is little natural exchange of ground water between these two counties. However, if water levels are allowed to decline substantially in Nassau County, natural underflow of ground water from Suffolk will occur.

2.1.5 Salt Water Encroachment

Reliable data concerning the intrusion of sea water into the Island's fresh water supplies are critical to estimates of the future availability of potable ground water for Nassau and Suffolk Counties, and are particularly important to coastal suburban areas. However, the present boundaries of the fresh water reservoir on Long Island are not well defined in many areas. Data on the position of the interface at depth have been gathered mostly as a result of a limited number of U. S. Geological Survey cooperative studies, from wells drilled near the shore which have inadvertently intercepted salt water, and from wells drawing salt water after a period of time, as a result of heavy pumping. Areas of documented cases of salty ground water are shown on Figure 2–5.

A complicating factor is that some of the increases in chloride content attributed to the intrusion of saline water actually may have been caused by sources other than the movement of a principal salt water body within an aquifer. Such sources include leaky casings or openings in the annular space surrounding well casings, which allow salty water in one aquifer to migrate to an overlying or underlying fresh water aquifer. Another contributing local factor is the contamination of fresh water aquifers, caused by the use of salt water in the mining of sand and gravel—as has occurred on the eastern portion

**Extraction ratio = amount of water pumped per year without undesired results divided by the average annual recharge in the water budget area.*



(from Garber, 1976)

FIGURE 2–1 *Ground Water Level Declines in Southwestern Nassau Attributable to Sewering Sewer District Two and to Pumping in Queens.*

of the Port Washington peninsula, where the shallow aquifers have been affected by leakage from artificial ponds containing salt water pumped from Hempstead Harbor. Other activities of man discussed in Section II of this report also contribute chloride to ground water.

The Magothy is known to be fresh for its entire depth throughout most of Nassau County, from its northern boundary extending to an unknown distance south of the barrier beaches. The only salty region is in the extreme southwest corner of the county. In Suffolk, the Magothy is fresh over essentially the entire county, excluding the forks. On the North Fork, the lower Magothy is salty at the western end and probably entirely salty in the central

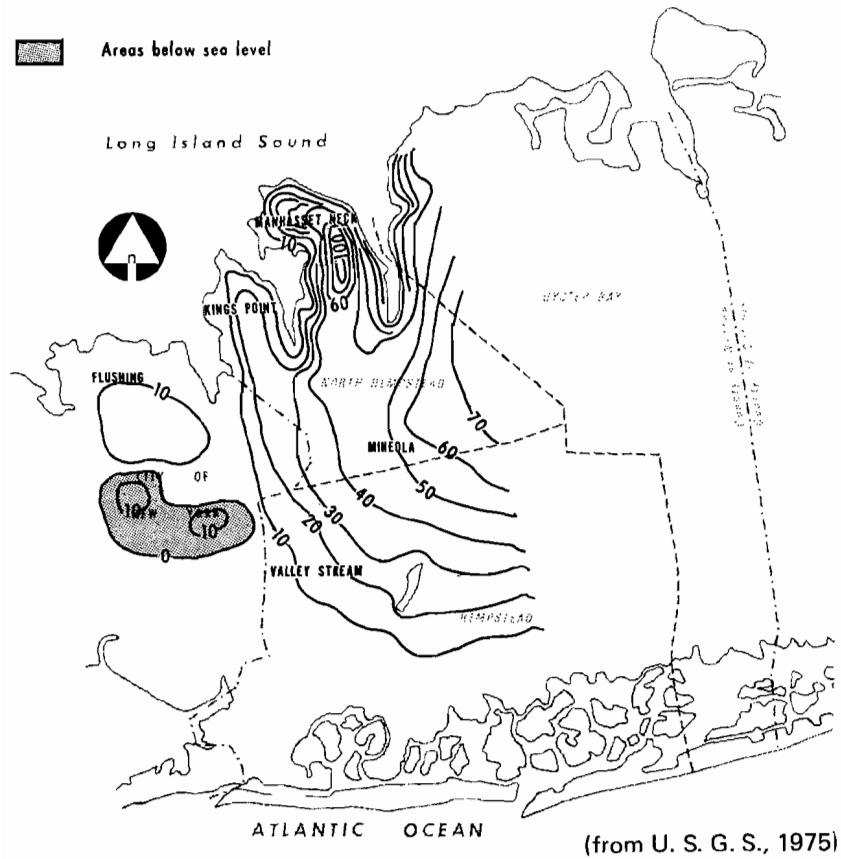


FIGURE 2–2 *Water Table Surface in the Spring of 1975.*

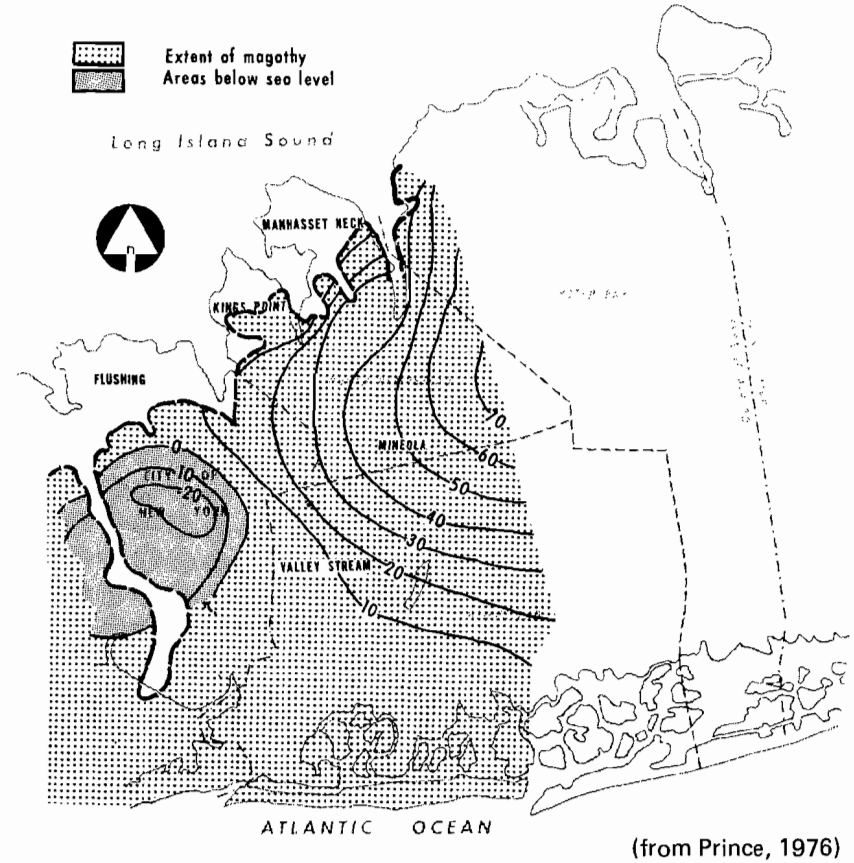


FIGURE 2–3 *Potentiometric Surface of the Magothy Aquifer in March 1975*

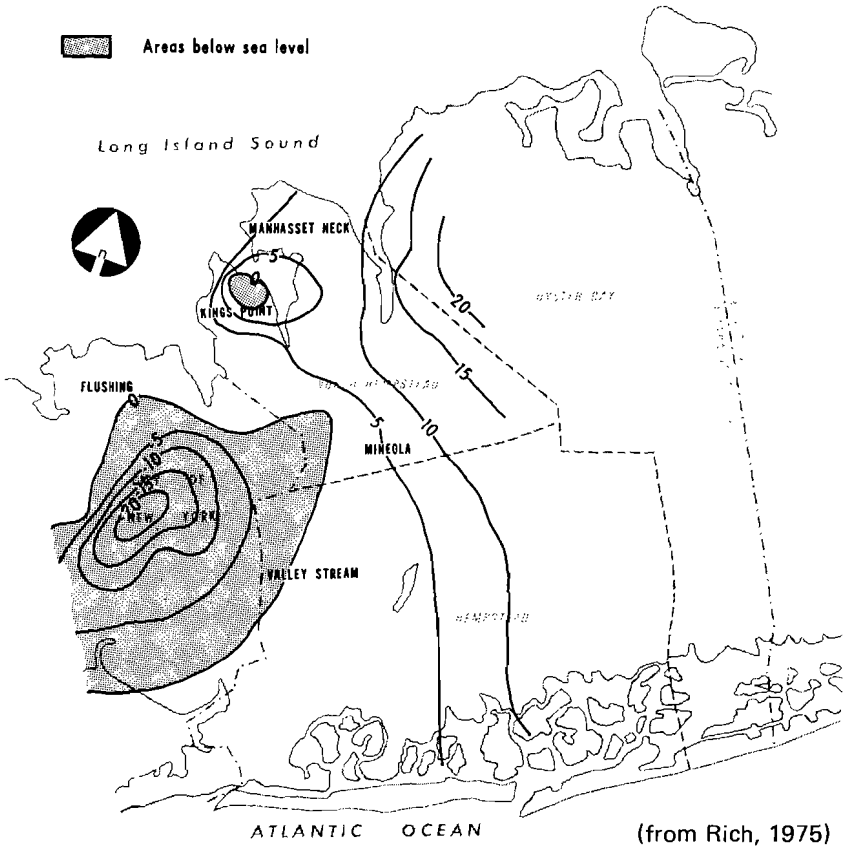
and eastern areas. Maximum depths to fresh water are only 200 to 300 feet (Holzmacher, 1970). Data from the South Fork indicate a similar situation, except that the interface under the widest portion of land area is somewhat deeper.

The Pleistocene (Upper Glacial) sediments on the north shore are thought to be hydraulically equivalent to the Magothy. Deep Pleistocene deposits under Eatons Neck are salty. In recent years, wells 71 to 291 feet deep in the western part of the Kings Point area on the Great Neck peninsula have shown increasing chloride levels (Myott, 1976). The wells are screened in both Pleistocene and Lloyd (or equivalent) sediments. This situation is being studied by the U. S. Geological Survey and may be related to well construction rather than intrusion.

The Upper Glacial aquifer is fresh over most of both counties except for local areas along the coast. The lower portion of the Upper Glacial aquifer beneath the barrier islands and under much of the North Fork is salty. The South Fork has salty water in the Upper Glacial aquifer in the near-shore areas.

The boundaries of fresh water in the Lloyd aquifer extend south of the barrier beaches in most of Nassau and Suffolk Counties. The Lloyd is fresh along the north shore except at Eatons Neck, part of Kings Point, and a small portion of Port Washington. Several wells in the Lido Beach-Long Beach area have shown rapid increases in chloride in the past. However, it has been determined that these isolated cases of salt water are due to leaky well casings rather than general contamination of the aquifer. Parts of the Lloyd in eastern Suffolk, including most of the South and North Forks, are salty.

Detailed investigations in southwestern Nassau and southeastern Queens have provided information on how salt water occurs in an area which is known to be susceptible to encroachment (Perlmutter, 1963 and Lusczynski,



(from Rich, 1975)

FIGURE 2–4 *Potentiometric Surface of the Lloyd Aquifer in January 1975.*

1966). Test data showed that the interface between salty water and fresh water existed in all the permeable sediments, and even within the relatively impermeable clays that interfinger with the water-bearing strata. Shallow, intermediate and deep salty water wedges in the unconsolidated deposits were identified (Figure 2–6). Zones of diffusion containing water less salty than sea water are as much as six miles wide and 500 feet thick.

Of principal concern is the deep wedge which lies primarily in the basal Magothy and in the Raritan clay. This body trends southeast from South Ozone Park, under Woodmere, to a mile or two east of Lido Beach, where it continues south of the shoreline. Salty water may be in the lower beds of the Lloyd several miles offshore. The intermediate wedge, which is in the Gardiners Clay, the Jameco Gravel and the upper part of the Magothy, is found south of the landward extent of the deep wedge.

The intermediate and deep wedges have not been altered significantly

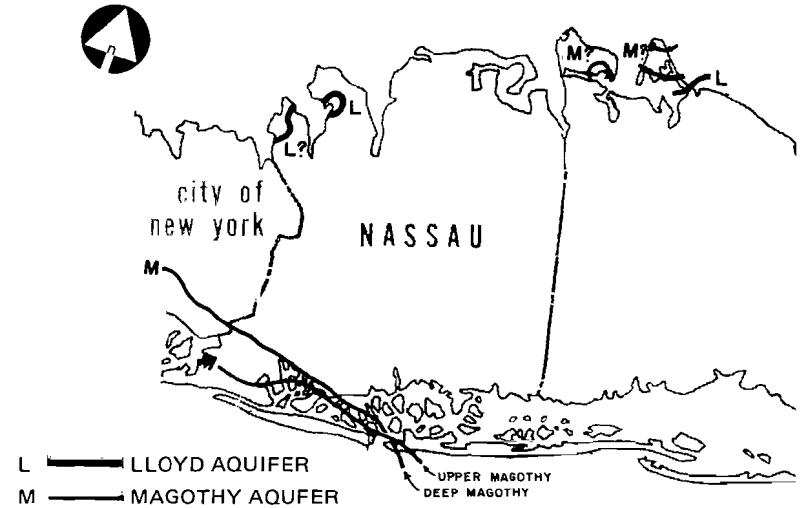
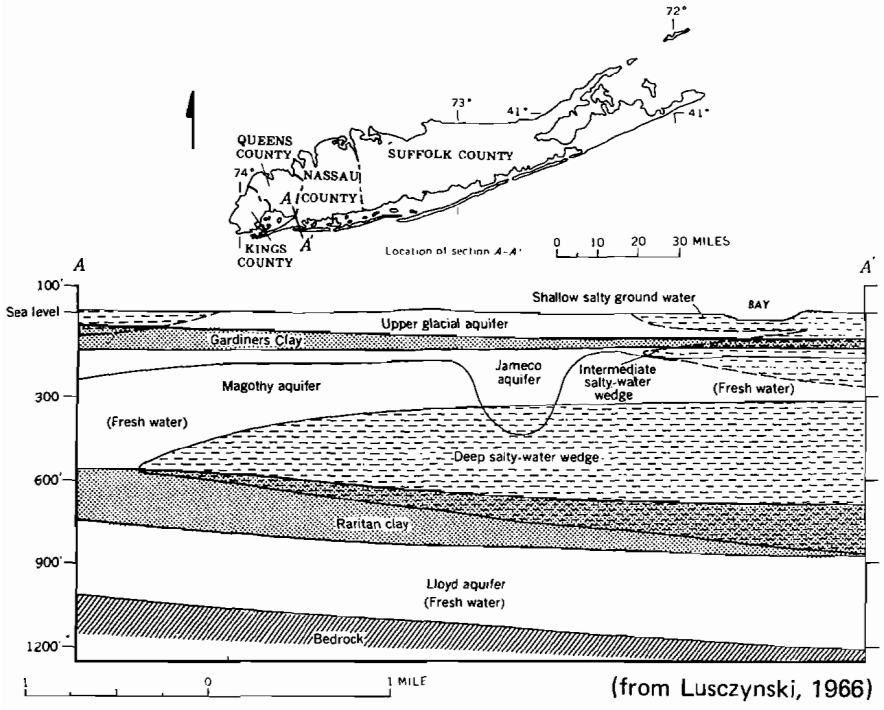


FIGURE 2–5 *Approximate Location of Past and Present Cases of Salty Ground Water in the Deep Aquifers in Nassau and Suffolk Counties, Excluding the North and South Forks.*

from their original position as a result of ground water development or other of man's activities. The deep wedge probably has not advanced more than 1,000 feet since 1900. Regional rates of movement range from less than ten to twenty feet per year. However, tongues of salty water, moving in response to local concentrated pumpage, have encroached at somewhat higher rates in certain areas. It is estimated that the toe of the deep wedge in the South Ozone Park area has intruded at a rate of about 160 feet a year, advancing 3,500 feet between 1938 and 1960. A narrow tongue of salty water moved landward at a rate of about 300 feet a year between 1952 and 1960 in Woodmere. It had advanced about a mile in the preceding 50 or 60 years (Lusczynski, 1966).

A study published in 1970 reviewed data collected over the period 1960–1969 in the same area, in order to further evaluate conclusions reached in the earlier studies. Landward movement of the deep wedge of salty ground water was minimal. Significant changes in chloride content were noted in only three of 30 wells located near the interface (Cohen, 1970).

Predictions of movement of salt water in response to future water development in the 208 region include the Hele-Shaw model studies for Suffolk County, which attempted to estimate the configuration of the interface under assumed initial pre-pumping conditions (Collins, 1972). The boundary along the north shore at Lloyd's Neck was placed near the shoreline. The interface in the Magothy south of Fire Island Inlet, was simulated to be 14 miles south of the southern shorelines of the mainland of Long Island. The results of another analysis showed that if the well withdrawal rate is equal to the total recharge over a period of 50 years, salt water would ad-



(from Lusczynski, 1966)

FIGURE 2–6 *Location of Salty Ground Water in Southwestern Nassau and Southeastern Queens.*

vance at a rate of about twenty feet per year. The magnitude of this rate is similar to that found in the U. S. Geological Survey study of southeastern Queens and southwestern Nassau Counties (Lusczynski, 1966).

The future position and movement of the salt water/fresh water interface is dependent upon the amount and pattern of the seaward flow of fresh water from the aquifers under Long Island. In addition, the hydraulic properties of the geologic units and their relationship in the stratigraphic column affect the rates and manner in which the interface will change in response to new conditions. Clay units, such as the Gardiners and Raritan, help impede the vertical transfer of salt water between aquifers because of their low permeabilities. Intrusion under similar gradients will be faster in sediments of higher permeability, such as those of the Lloyd and certain sections of the Magothy. As consumptive use of water increases in many sections of Long Island, the interface will readjust to a new equilibrium position farther inland. This will probably occur as wedge-shaped tongues, rather than as wide fronts of encroachment. If wells are located away from the immediate position of the present salt water bodies, encroachment will be regional and hence quite slow. Pumping centers near the interface, however, may induce more rapid, local intrusion and certain wells may become contaminated.

If present patterns of use continue, ground water outflow within the Magothy will be reduced along both the north and south shores of Nassau and Suffolk Counties. However, on the basis of past and present cases of salty ground water on Long Island, excluding those on the North and South Forks, it is expected that the regional impact of salt water intrusion will be small. The salt water wedges in the upper and lower Magothy in the southwestern and southern parts of Nassau, an area of historical salt water contamination, will probably not advance much more than a mile locally and less than a mile regionally by the year 2000 (Lusczynski, 1966). This would put the interface of the deep wedge in the vicinity of Sunrise Highway in Valley Stream and Lynbrook. Those few supply wells screened in the lower Magothy would be affected. Significant salt water encroachment along the south shore in eastern Nassau and in Suffolk is unlikely in the foreseeable future.

Salt water along the north shore is probably not far offshore in the Magothy (or equivalent) and Lloyd aquifers. Distances of one to two miles offshore have been postulated for the basal Magothy (or equivalent) in northwestern Nassau (Isbister, 1966). Again, assuming regional rates of encroachment of ten to twenty feet per year, the impact of salt water intrusion would be small. Local problems within the Lloyd aquifer, particularly in parts of the Great Neck and Port Washington peninsulas, could develop if pumping centers are located too close to shorelines. Further east, there is no indication that salt water along the northern shoreline of Suffolk, with the exception of parts of Lloyd Neck and Eatons Neck, and the North Fork, will be a problem in the foreseeable future.

From the standpoint of water supply and waste water management, it is essential that the potential threat of salt water encroachment be viewed in its proper perspective and be fully understood. The loss of usable ground water resources has been minor in comparison to the extensive untapped fresh ground water supplies within the 208 study area. There is insufficient evidence to assume that water level declines due to increased pumpage, sewering, or temporary deficiencies in rainfall will result in massive encroachment of salt water.

2.1.6 Ground Water Pumpage

Withdrawals of ground water from the geologic formations beneath the Long Island 208 planning area now approach 400 million gallons per day. In 1940 and in 1965, pumpage in the bi-county area was 105 and 330 million gallons per day, respectively. The increase corresponds to the rise in population related to suburban expansion eastward from the New York City metropolitan area.

Pumpage and use characteristics within the study region vary from place to place. The divertor may be a single family operating its own domestic well on a small parcel of land; a large water district with a dozen individual high capacity wells located miles apart over several communities; a private water company with a single well field serving one subdivision; or an industry

partially supplied by its own well system and partially dependent upon a local utility. The amount of water withdrawn by these well owners ranges from a few hundred gallons to many millions of gallons per day to satisfy domestic, agricultural, industrial and recreational demands.

Figure 2–7 shows the total pumpage distribution by aquifers for Long Island in 1975. The sizes of the pumpage circles are proportional to the average withdrawal rate within each section drawn on the map. Each circle includes the percentage of water pumped from each aquifer. The proportion of water withdrawn by public water supply systems versus industries and/or irrigators is also indicated.

In Nassau County, the Magothy aquifer is the principal source of potable water, but all three aquifers are pumped in varying degrees from place to place. An additional source, the Jameco Gravel, is of local importance in the southern part of the county and in parts of the northern peninsulas. Drinking water for Suffolk County comes from both the Magothy and the Upper Glacial aquifers. The practice of locating wells within reasonable proximity to the user in order to minimize distribution costs has resulted in uneven distribution of pumpage; major concentrations of pumpage are located near areas of dense populations, leaving portions of the subsurface reservoirs underutilized.

Approximately 133 districts, municipal systems and water companies, either publicly or privately owned, supply water on Long Island. In Nassau County, the largest suppliers are the Long Island Water Coporation, Jamaica Water Supply Company and Utilities and Industries Corporation (formerly

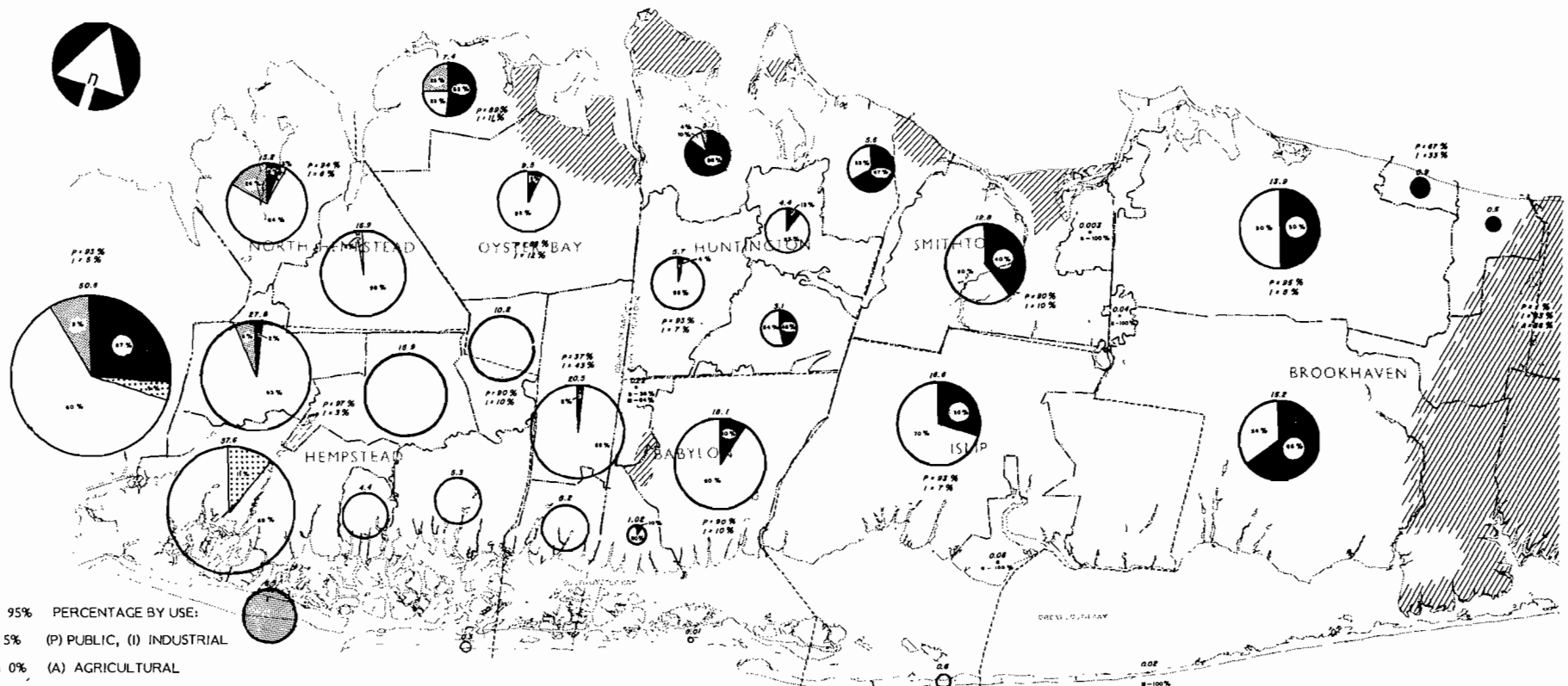
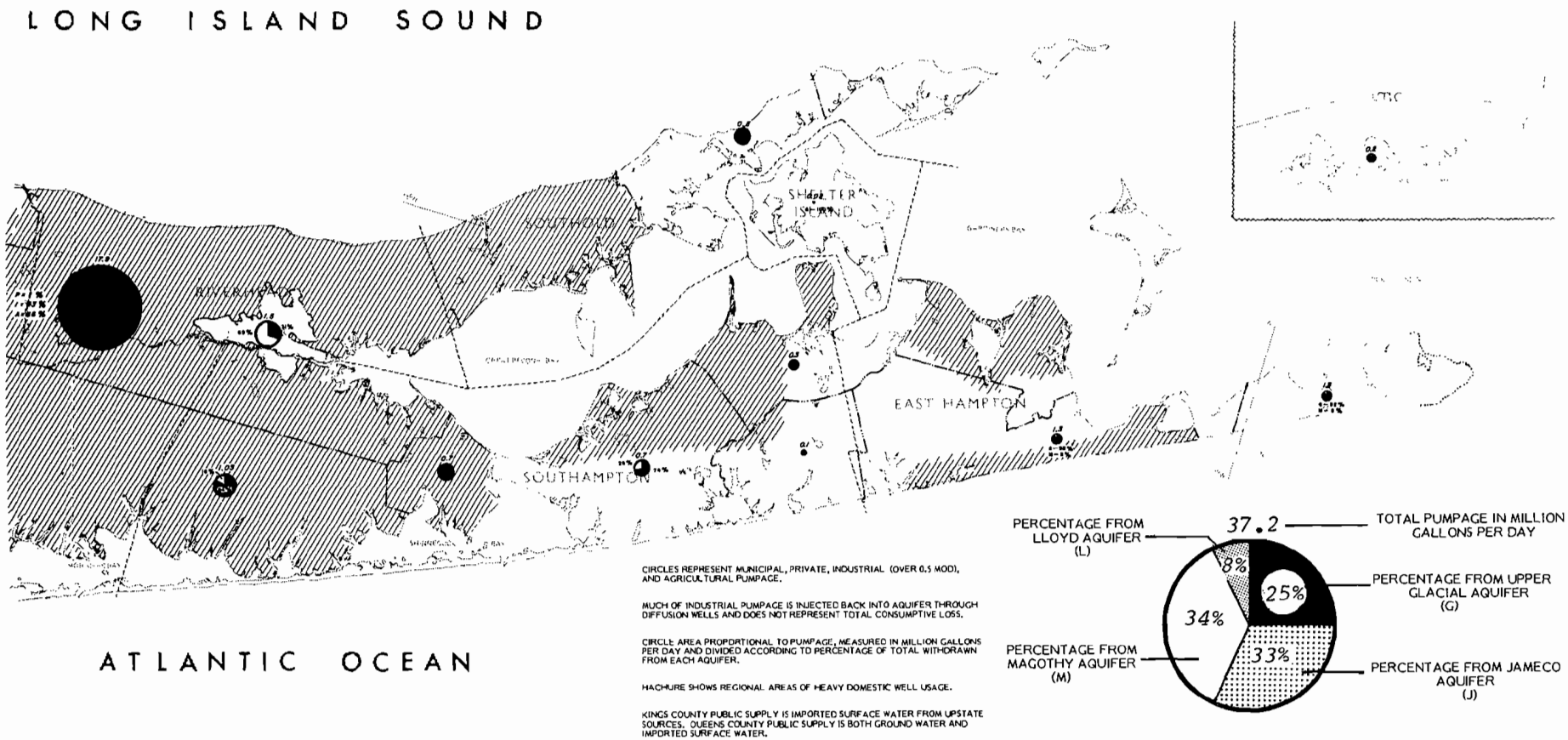


FIGURE 2–7 *Long Island Water Supplies.*

New York Water Service). The publicly owned Suffolk County Water Authority is the major regional purveyor of drinking water in Suffolk County. This system consists of about 12 centralized supply plants, withdrawing water from some 400 wells throughout the county.

The total daily pumpage in Nassau County averages approximately 210 million gallons per day, with 170 million gallons per day of this water supplied by public and private purveyors during 1975. Public supply pumpage in the years 1973, 1974 and 1976 was approximately 178, 179 and 184 million gallons per day, respectively. A recent estimate of the total amount of water pumped by major industrial and commercial users is 36 million gallons per day (Erlichman, 1976). Self-supplied domestic and agricultural pumpage accounts for the remaining four million gallons per day. About 85 percent of the water withdrawn comes from the Magothy aquifer, eight percent from the Lloyd, four percent from the Upper Glacial and three percent from the Jameco Gravel. In a few coastal areas of Nassau County, the threat of salt water encroachment has precluded the use of water from the Magothy aquifer, necessitating the deepening of several public supply wells into the underlying Lloyd strata. The City of Long Beach in southwestern Nassau County is entirely dependent for public water supply upon wells penetrating the Lloyd formation. As much as 30 percent of the supply pumped in the northern portion of the county is also from the Lloyd (or equivalent) aquifer.

Suffolk County draws 108 million gallons per day for public supply (1975 data) of which 40 percent is from the Upper Glacial and 56 percent



from the Magothy aquifer. The five million gallons per day withdrawn from the Lloyd aquifer in Suffolk for water supply purposes is equivalent to about four percent of the total. Industrial pumpage is about 40 million gallons per day, with a few users accounting for a major portion of the total (Erlichman, 1976). For example, Brookhaven National Laboratory alone diverts eighteen percent of the county's industrial pumpage. Most water used by industry in both counties is returned to the ground water system by means of diffusion wells and recharge basins.

About 90 percent of the population of Suffolk County is located in the western half of this region, which includes the Towns of Babylon, Islip, Huntington, Smithtown and Brookhaven. Based on the number of housing units with domestic wells surveyed in the 1970 population census, it is estimated that housing units in Suffolk County not served by central distribution facilities collectively withdraw about twenty million gallons per day of ground water (U. S. Department of Commerce, 1970).

Water pumped for agriculture constitutes an important demand factor in the more rural eastern segment of the county, particularly in the area north of the community of Riverhead. Not all farmers report pumpage, nor are they required to do so, but a conservative estimate of agricultural pumpage rates, based on surveys and returned reports of withdrawals, is about ten million gallons per day. For the most part, this pumpage represents consumptive use and is seasonal.

Although Queens County is not part of the Long Island 208 study area, the amount of ground water pumped there must be considered. As shown on Plate 1, the withdrawal of ground water in Queens averages more than 60 million gallons per day; 27 percent is from the Upper Glacial aquifer and 60 percent from the Magothy aquifer. As discussed in the previous section of this report, the large ground water withdrawal in Queens County has had a significant effect on water levels and salt water intrusion in south-central and southwestern Nassau County.

Deterioration of water quality in parts of the Upper Glacial aquifer has limited the usefulness of this drinking water source in some portions of the 208 planning area. These problems of water quality that are due to man's activities have been aggravated by the rapid urbanization of the region. In addition, the downward migration of degraded water to deeper aquifers compounds the problem. Studies by the U. S. Geological Survey have shown that nitrate-enriched ground water in some portions of east-central Nassau County is moving from shallow to deep aquifers at a rate of as much as five to 25 feet per year (Ku, 1976).

The abandonment of shallow wells in favor of withdrawing water from progressively deeper formations has been a pattern of development in both Nassau and Suffolk Counties. In areas such as Hicksville, Bethpage and Farmingdale, most wells supplying communities and industries 30 to 40 years ago tapped the Upper Glacial aquifer and were 100 to 200 feet deep. Degradation of water quality in this relatively shallow zone, followed by similar problems in the upper portions of the underlying Magothy, caused water districts and other ground water users to install progressively deeper wells. Today, many wells in these areas are 500 to 600 feet deep and tap the basal Magothy. This pattern is continuing under present management and planning policies in many sections of the 208 area. In Suffolk, whenever possible, better quality water in the Magothy is blended with Glacial withdrawals, if the shallow aquifer has become degraded.

The deeper Lloyd aquifer is less susceptible than the Magothy to contamination and is not subject to heavy demand at this time. However, the future potential and use of the Lloyd have not been clearly defined.

As mentioned above, the pattern of ground water diversion matches population densities except in the case of a few large industrial users. Heavy pumping can create a local hydrologic imbalance. If the same area is sewered, high consumptive use results. Water levels in such water deficit areas will decline, causing ground water flow into these regions to increase until a new equilibrium condition is reached. Southeastern Queens and southwestern Nassau represent one region characterized by large diversions. The region is also sewered, and the treated effluent is discharged to the ocean. Consequently, this region and the area immediately north of it have historically experienced large losses in fresh water storage, as indicated by local salt water intrusions and significant water table declines.

Assuming a relatively fixed amount of ground water in storage and a fixed rate of recharge over the long term, the amount of ground water that can be extracted from an aquifer system varies with the distribution of wells within the aquifers. For a system such as Long Island's, with its vast natural underground reservoir, the effects of ground water withdrawal are minimized if wells are distributed uniformly. Diversion which is concentrated in any one area or near the salt water interface results in significant impacts on water levels in the various aquifers, and increases the potential for salt water encroachment. However, in certain cases, properly positioned wells along the coastline can intercept fresh water before it discharges to salt water. Reductions in stream flow can result from concentrated pumpage, particularly if the wells are tapping the shallow aquifer.

It is evident from the preceding discussion of water supply pumpage that Nassau and Suffolk Counties, taken as whole, do not have a uniform distribution of public supply and industrial wells, particularly in an east-west direction. Therefore, water is not being extracted in the most efficient manner. This is because of the way in which water supplies have traditionally been developed, *i.e.,* within separate water districts with a minimum of interdistrict transfer. In most areas, groups of two or three adjoining utilities are interconnected, primarily to handle seasonal fluctuations and peak demands. Thus, there is some capability for response to emergencies caused by major water main breaks, fire or well closure due to contamination. However, there are currently no provisions for large-scale transfer between water systems over any significant distances.

Present patterns of ground water pumpage only reflect patterns of population density. Ground water diversions are not awarded according to a formal scientific plan or long-term program with the objectives of protecting water quality or maximizing the available resource. Interference effects on existing ground water supplies and the potential for salt water encroachment have been the primary considerations in decisions by the state regarding applications for increased pumpage. However, the impact of new withdrawals on the movement of contaminants from potential inland sources of pollution and possible adverse effects on surface streams have not been included in the evaluation of well location, depth or construction. Again, this situation is related to the fragmentation of responsibility for developing ground water resources, with each water supply unit constrained by local economic and political factors that are divorced from regional needs.

2.1.7 Water Level Declines

One of the principal effects of the steadily increasing consumptive use of ground water on Long Island is a general and continuing decline in water levels. Significant lowering of the water table and of potentiometric surfaces has occurred over the last few decades in Nassau and Suffolk Counties. Recently observed imbalances between available water supply and demand in some places are largely the result of greater pumpage, increases in sewage outflow to salt water and the severe drought of 1962–1966. The determination of the effect of each of these factors on the total hydrologic system is critical in attempting to evaluate various management alternatives for the future. Although regional water level declines have been recognized for years, it was not possible to accurately predict future declines until recent advances in electric analog and digital computer simulation techniques were achieved.

Since the mid-1930's, the U. S. Geological Survey has maintained a program of water resources studies on Long Island in cooperation with several county and state agencies. Ground water levels have been measured in fourteen key shallow observation wells on Long Island for over 35 years. Several hundred observation wells throughout Nassau and Suffolk Counties have been monitored over recent years by the U. S. Geological Survey, the Nassau County Department of Public Works, the Suffolk County Department of Environmental Control and the Suffolk County Water Authority. Prior to the late 1950's, water level declines in Nassau and Suffolk Counties were not particularly significant. During the period between 1959 and 1970, declines of the potentiometric surface in Queens and Nassau Counties in the basal part of the Magothy aquifer ranged from about one foot near the shorelines to a little more than twenty feet in parts of east-central Queens and west-central Nassau Counties (Kimmel, 1971). Similar changes occurred in the water table, except near the shorelines where the decline was less. Net changes in water levels are shown in Figures 2–8 and 2–9.

In addition to water level declines caused by increased pumpage on Long Island, extended periods of less than average rainfall also resulted in a decrease in ground water storage as evidenced by the 1962–1966 drought. During that period there was a cumulative deficiency of rainfall of 41.7 inches below the long-term annual average of 44.5 inches per year as measured at Setauket. Figure 2–10 shows ground water response to the drought with declines in ground water levels ranging from somewhat more than ten feet in east-central Nassau County and west-central Suffolk County to less than two feet near the shorelines (Cohen, 1969). The configuration of the contours reflects the nature of the flow system in that the maximum declines took place near the ground water divide. Smaller net losses occurred near the shorelines.

The average altitude of the water levels in the fourteen key monitor wells for the period 1940–1967 was nearly 46.5 feet. By 1966 the average level had declined about six feet below the long-term average (Figure 2–11). The close dependence of stream flow upon ground water was underscored during this period by record low flows in fourteen of nineteen principal streams in the two counties. The combined flow of the nineteen streams (Figure 2–12) was 155 cubic feet per second in 1966 as compared to the long-term average of 291 cubic feet per second (Cohen, 1969).

Since 1967, the water table and water levels in the Magothy aquifer have stabilized and in many cases risen in response to normal and above normal rainfall. The water table in east-central Nassau County rose over twelve feet, and in western and central Suffolk by as much as six feet between 1970 and 1974. However, slight declines occurred in southwestern Nassau County (Figure 2–13).

In addition to stresses caused by increases in withdrawal rates and fluctuations in natural recharge, the ground water system is also affected by sewering, urbanization, lawn sprinkling and other activities. Attempts have been made to evaluate the impact of such factors upon the system, using methods which isolate one response and assign to it a given variable. For instance, a recent double-mass curve analysis of ground water in Nassau County permitted isolation of water level changes due to sewering alone. Declines attributable to sewering in western Nassau County ranged from 3.6 to 19.1 feet (Figure 2–1). Declines due to the influence of pumping in Queens County varied from one to twelve feet. The average weighted water level decline from 1953 to 1972 in southwestern Nassau was 11.8 feet, of which 4.9 feet can be attributed to pumping in Queens County.

With sophisticated methods for evaluating hydrologic systems, such as digital and electric analog models, it is possible to integrate the stresses and responses of a dynamic system by considering the input of many variables at one time. It is evident from recent studies utilizing available models that water level declines will continue in Nassau and western Suffolk as consumptive use increases under the present system of water management. There is considerable uncertainty, however, as to the future rate of this increase, especially in Nassau County where the population appears to have stabilized.

WATER TABLE DECLINE

FIGURE 2–8 *Generalized Net Decline of the Water Table in Nassau and Queens Counties, Long Island, New York from 1959 to 1970.*

BASAL MAGOTHY POTENTIOMETRIC SURFACE DECLINE

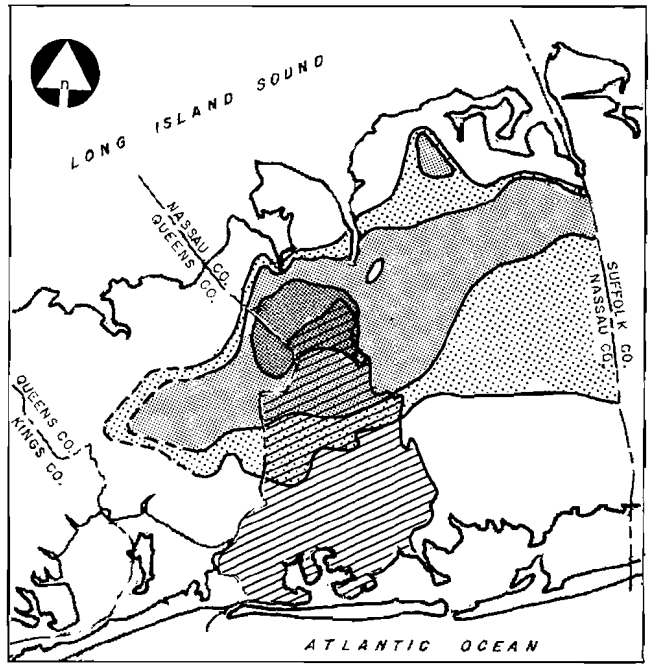


FIGURE 2–9 *Generalized Net Decline in the Basal Magothy Potentiometric Surface in Nassau and Queens Counties, Long Island, New York, from 1959 to 1970.*

5 – 10 10 – 20 20 – 25

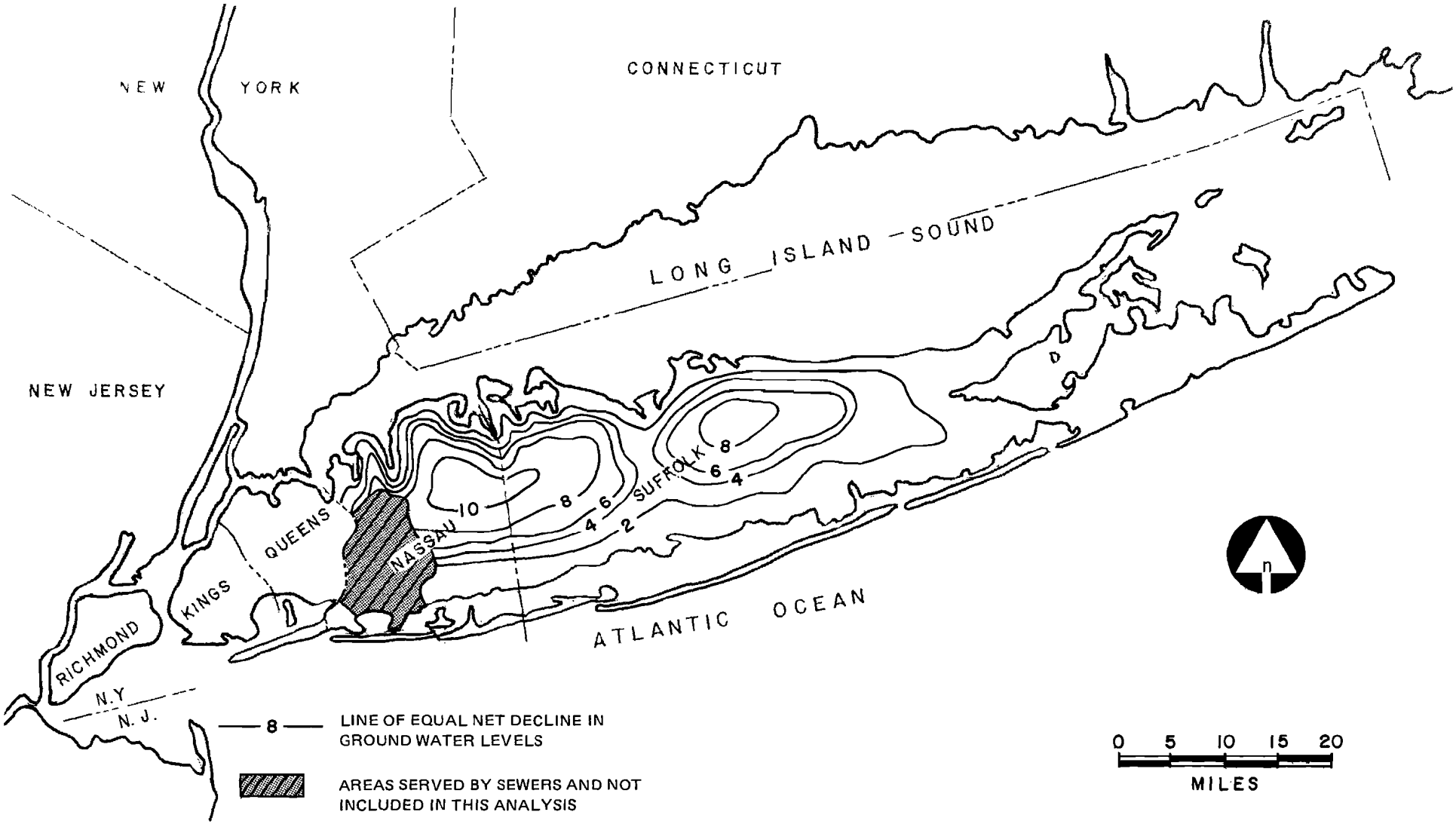
NET DECLINE IN HEAD, IN FEET

– – – – – – – – – – INFERRED DECLINE IN HEAD

AREA UNDERLAIN BY SEWERS IN NASSAU COUNTY IN 1970

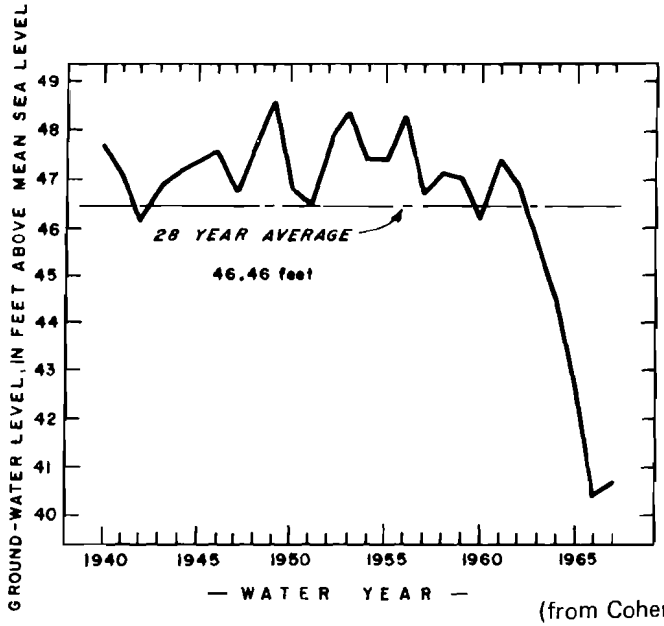
0 5 10 MILES

(from Kimmel, 1971)



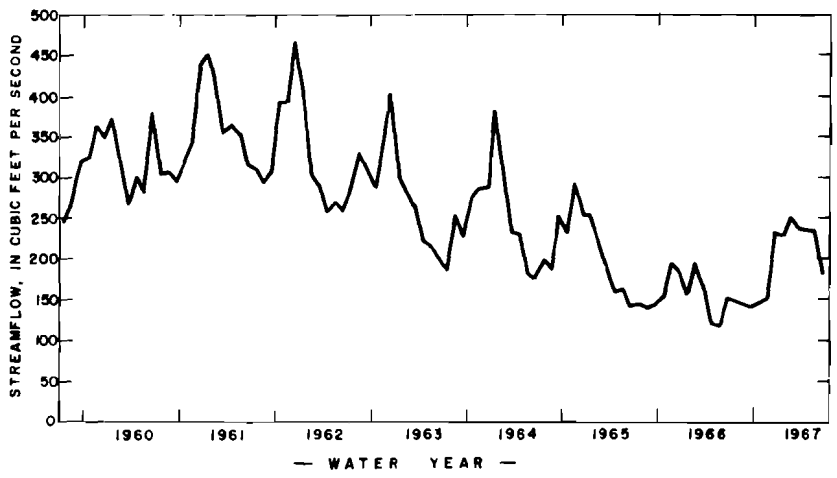
(from Cohen, 1969)

FIGURE 2–10 *Net Decline in Ground Water Levels in the Water Table Aquifer Due to Drought Conditions, 1962–66.*



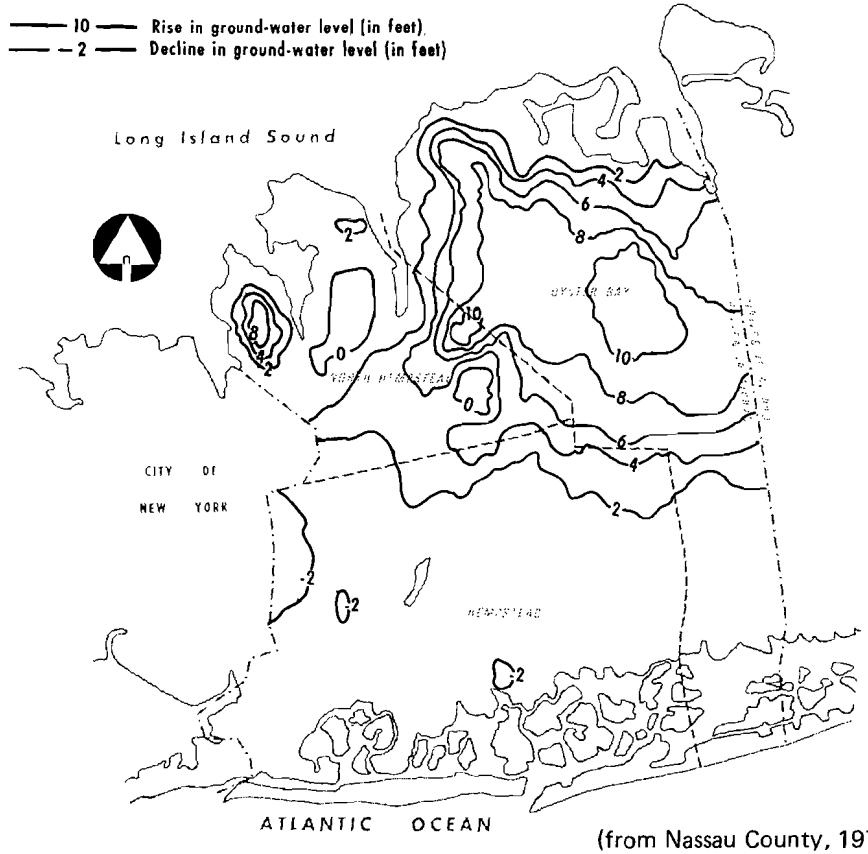
(from Cohen, 1969)

FIGURE 2–11 *Average Annual Ground Water Levels in Fourteen Key Observation Wells in Nassau and Suffolk Counties.*



(from Cohen, 1969)

FIGURE 2–12 *Combined Monthly Average Stream Flow of Nineteen Principal Streams.*



(from Nassau County, 1975)

FIGURE 2–13 *Net Change in Ground Water Levels in the Water Table Aquifer, 1969–73.*

2.1.8 Environmental Considerations

Reduction in stream flow and decline of the water table from increased pumpage and ocean discharge of sewage may cause changes in the vegetation of certain fresh water wetlands. A total fresh water wetland area of over 1,500 acres has been inventoried within the nine major stream systems of southwestern Suffolk County and southern Nassau County (Beitel, 1976). Water table ponds and lakes, such as Lake Ronkonkoma, Hempstead Lake and Southard's Pond (Carlls River) would experience some lowering of water levels from proposed sewering. Marsh and meadow species of plants and trees that are dependent upon a shallow water table environment may eventually be limited to areas closer to remaining streams. The study on Long Island

by Beitel suggests a possible sequence of vegetative succession similar to one that occurred at Artist Lake, Middle Island, New York during a lowering of the water table. In that case, near-shore lake habitats changed to marsh and then to red maple swamp habitats.

Significant long-term reductions in ground water outflow and stream flow to the various salt water bodies surrounding Long Island would alter bay salinities. A study by Moskowitz correlated stream discharge to changes of salinity in Great South Bay (Moskowitz, 1976). Ground water outflow also contributes to the maintenance of bay salinity, but its effect has not been specifically studied. In addition to effects within the water bodies proper, significant impact on the coastal wetlands is possible. In Nassau and Suffolk Counties, two types of wetlands are plentiful, the coastal salt meadows and the regularly flooded salt marshes (Green, 1972). In 1972, a study by the Marine Sciences Research Center reported that tidal marshlands covered 9,400 acres in Nassau County and over 12,000 acres in Suffolk County (O'Connor, 1972). Long Island's wetlands provide habitats for a variety of invertebrates, fishes, birds and mammals. Although descriptive studies exist detailing the functions provided to the environment by wetlands, quantitative analyses of the relative value of these areas are lacking. Thus, it is not clear exactly how reductions in fresh water flow to the bays will alter wetland flora and fauna.

A decrease in fresh water discharge to the bays could be offset in part by: shifting centers of pumping, stream augmentation with sewage effluent or with ground water from surplus areas, artificial recharge of treated waste water, or through planned water conservation programs. The decision on how to protect the remaining streams in heavily pumped areas should be based on a detailed evaluation of the relationship between ground and surface water flow systems. Consideration must be given to the willingness of the public to support the required programs and accept economic impacts.

As indicated previously, ground water pumpage in Queens may eventually be replaced by surface water from upstate New York. A major recovery in water levels can create problems. For example, the rise in the water table from 30 feet below sea level to as much as ten feet above sea level over the past 25 years in Kings County has led to flooding of portions of the New York City subway system and residential and commercial building basements constructed during the period when the water table was artificially depressed (Soren, 1976). Also, the rise in ground water level probably increases flow to sewage treatment plants due to infiltration to sewer lines originally laid in dry sand but now submerged below the water table.

Programs for recharging waste water (sewage effluent or storm water runoff) to replenish ground water supplies are an important water management technique that must be critically evaluated. The proposed 5.5 million gallons per day Cedar Creek Water Reclamation-Recharge Project, which is now under construction, will test the feasibility of replenishing ground water supplies with tertiary treated sewage effluent and also the reliability of producing an effluent suitable for recharge (EPA, 1972 and Consoer, 1973).

In summary, ground water resources have values other than providing water supplies. As pointed out previously, ground water discharge supports stream flow and plays a major role in maintaining an acceptable environment for certain flora and fauna. Thus, although the 208 area may remain self-sufficient in ground water by implementing a number of water management approaches within the bi-county area, this self-sufficiency may be assured at the expense of other significant aspects of the region's environment.

A further constraint to water supply self-sufficiency is water quality. Past and present waste disposal practices modify the purity of a significant portion of the available ground water resource. The presence of nitrate, trace organic chemicals and heavy metals in some portions of the aquifer system may be a much more important constraint to long-term availability of usable water supply than short-term droughts and salt water encroachment.

2.1.9 Proposed Water Management Plans

Development of an effective management plan for the 208 region must include evaluation of the alternative water supply and waste water management schemes proposed in recent years by private consultants and county, state and Federal agencies. These studies have ranged in scope from local to island-wide. Most suffer from technical simplifications, because detailed analysis of the ground water system has only recently been made possible through analog and digital computer simulation techniques.

The planning time spans considered in past water management studies are variable, but most use a 50 year period. Some of the reports simply present and analyze alternatives, while others make specific recommendations. The following is a list of major alternatives for water management on Long Island found in recent literature:

1. Continue present methods of development and management, with some provisions for local problem areas. Modifications might include development of additional well fields or redistribution of water within the present system.
2. Provide recharge to the ground water system with treated waste water via recharge basins or injection wells.
3. Import New York City water to Nassau County.
4. Exchange water with New York City. Water would be pumped from the New York City system to Long Island during periods of normal precipitation and from Long Island to New York City during drought periods.
5. Transfer water from a large well field in east-central Suffolk to areas of hydrologic imbalance in Nassau.
6. Use skimming wells to divert flow from shallow, near-shore aquifer systems to Magothy recharge areas in the center of Long Island.
7. Establish regional or county water authorities to provide for the orderly development of ground water and to oversee its distribution.

Of the plans reviewed, the reports by Greeley and Hansen (1963 and 1971) and Holzmacher, McLendon and Murrell (1970) are the most comprehensive. These studies reach similar conclusions and are generally compatible. Both emphasize bi-county solutions in the next few decades with the possible use of water from the New York City system in the future. However, during the relatively short time span since these reports were written, population projections have changed significantly. In comparing predictions for 1980 made by Greeley and Hansen in 1963 to the current Nassau-Suffolk Regional Planning Board's estimate, the population projection for Nassau County was lowered from 1.80 million to 1.47 million people. Revisions result as new and/or better data become available and as socio-economic factors change in the region. It is apparent that some of the water management plans recommended will have to be re-evaluated.

Another factor that can affect estimates of water supply needs in the 208 region is the future status of programs for conservation of the area's ground water resources. About the only conservation measure presently being encouraged is the installation of meters. There appears to be a real need for investigating the present pricing policies of major water supply systems; the potential for use of recycled waste water as a source of industrial supply; the availability of devices and hardware for reducing flows; and the feasibility of developing plumbing and building codes that may be effective as conservation-related measures. Of particular importance is the possibility of using the pricing mechanism to control demand. The price of water in the 208 region is now far from uniform for residential users, and does not encourage conservation on the part of major commercial users.

Two series of reports are particularly significant in their recommendations. The *Northeastern United States Water Supply Studies* (NEWS), written for the U. S. Army Corps of Engineers, and the studies by the Temporary State Commission on the Water Supply Needs of Southeastern New York, have been considering various water supply proposals for a number of years (Corps of Engineers, 1971–1977 and Temporary State Commission, 1973). Both series of reports view Long Island's water supply needs as approaching the critical point. Both recommend rather immediate action to supplement the bi-county area supply with either imported water or waste water recharge.

Plans for importing water from New York City must be approached cautiously in view of the economic impact on area residents. The boundary between fresh and salt water in the principal aquifers still lies somewhere offshore, which means that vast quantities of fresh water are continuously being lost to the surrounding bays and ocean. Implementation of expensive water supply importation programs may not be justified until the salt water/fresh water interface has moved onshore over a broader area, or at least until the relationship between salt water and fresh water is better defined. Also, the decision as to whether or not to import water from outside the bi-county area should be based on a thorough analysis of the potential success or failure of areawide water management options.

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2.2 GROUND WATER POLLUTION SOURCES

2.2.1 Background

An evaluation of ground water pollution sources is one of the products of the Long Island 208 areawide waste management study. A full report, presented to the 208 Technical Advisory Committee by Geraghty & Miller, Inc. in September 1977, describes eighteen different activities which have or may impair ground water quality in the study area. This section has been prepared to provide easy access to the salient facts contained in the longer, more technical version. The potential impact of the various contamination sources discussed may be subject to reassessment at a later date as more data are made available, or as legal requirements initiate a change in practices.

Although the ground water contamination contribution of several of the sources described may not appear to be significant, it should be borne in mind that the quality of the regional ground water supply is susceptible to the adverse effects of the sum total of man's activities on land. This understanding is particularly crucial to Long Island where activities are diverse, and where a water supply alternative to ground water is not readily or economically available.

There are many sources and causes of ground water contamination in the 208 area. Basically, they can be divided into four categories (Table 2–1). The first two categories represent discharges of contaminants that are derived from solid and liquid wastes. The third category concerns discharges of contaminants that are not wastes, and the fourth category lists those causes of ground water contamination that are not discharges at all.

The variety and type of management options available for each category differ. For example, some Category I sources may require a discharge permit whereas others can be controlled by restrictions on land use. Sources under Category II may require satisfaction of specified construction standards, such as the lining of landfills and the installation of leachate collection systems. Guidelines and manuals (*e.g.,* tons/land-mile limits on highway deicing salts) may be the only type of management option available for Category III. Special regulatory controls are available for the causes of ground water contamination listed under Category IV. An example is the current system of ground water diversion applications and hearings employed to minimize salt water encroachment. Another is the licensing of drilling contractors in order to upgrade water well construction practices.

2.2.2 Domestic On-Site Waste Disposal Systems

Cesspools, septic tanks and leaching fields are a source of ground water contamination on Long Island that has been of great concern to many investigators and regulatory agencies. "The Final Report of the Long Island Ground Water Pollution Study" stated that 800,000 persons in Nassau and 950,000 persons in Suffolk reside in unsewered areas (Nassau-Suffolk Research Task Group, 1969). In addition, facilities serving 24,000 people residing in Nassau

Table 2–1

CLASSIFICATION OF SOURCES AND CAUSES OF GROUND WATER CONTAMINATION USED IN DETERMINING LEVEL AND TYPE OF CONTROL

Category I Systems, facilities or sources designed to discharge waste or waste waters to the land and ground waters.	**Category II** Systems, facilities, or sources not specifically designed to discharge wastes or waste waters to the land and ground waters.	**Category III** Systems, facilities, or sources which may discharge or cause a discharge of contaminants that are not wastes to the land and ground waters.	**Category IV** Causes of ground water contamination which are not discharges.
Domestic on-site waste disposal systems	Sanitary sewers	Highway deicing and salt storage	Airborne pollution
Sewage treatment plant effluent	Landfills	Fertilizers and pesticides	Water well construction and abandonment
Industrial waste discharges	Animal wastes	Product storage tanks and pipelines	Salt water intrustion
Storm water basin recharge	Cemeteries	Spills and incidental discharges	
Incinerator quench water		Sand and gravel mining	
Diffusion wells			
Scavenger waste disposal			

Sewer District No. 2 were reported as not being hooked up to the sewer system. Other reports give different estimates for the number of cesspools and septic tanks in Nassau County (Nassau Environmental Management Council, 1974 and Padar, 1968). The U. S. Geological Survey has estimated that in 1966, 120 million gallons per day of sewage were returned to the ground through cesspools and septic tanks on Long Island (Parker, 1967). A more recent paper from the Nassau County Department of Health reports that 150,000 cesspools in Nassau alone discharge 60 million gallons per day (Smith, 1975).

In on-site disposal systems, bacterial action digests the solid materials, and the liquid effluent is discharged to the ground. In theory, filtration by earth materials provides additional treatment so that the liquid, when it arrives at the water table, is relatively clean. However, many constituents carried by the effluent are introduced to the ground water system. Those which present the greatest threat to ground water quality are excessive concentrations of nitrate, organic chemicals, detergent, metals, bacteria and viruses. Other constituents—previously ignored, but now recognized as a

threat—are halogenated hydrocarbons. Compounds such as chloroform, carbon tetrachloride, trichloroethylene, and others are in common use in industry as degreasers and solvents or are incorporated in plastic products. It has only recently been recognized that these and similar compounds regularly occur in discharges from households. Many products common in the home, such as fabric and rug cleaners, workshop cleaners and solvents, and solutions to clean pipes find their way into on-site disposal systems. Septic tank cleaners are composed almost entirely of active ingredients which are frequently halogenated hydrocarbons. For example, one common cesspool cleaner contains more than 99 percent trichloroethylene. One gallon of this compound could raise the trichloroethylene concentrations of 29 million gallons of water to the State recommended maximum of 0.05 parts per million.

Cesspools and septic tanks are viewed by regulatory agencies as low-cost systems which eliminate surface discharges of raw sewage. There are areas where low housing density and favorable soil conditions make such systems satisfactory alternatives to expensive trunk sewers and treatment plants. However, government agencies have been leaning more and more toward the latter in recent years. Sewer districts have been delineated in both counties and plans for construction are well underway. Figure 2—14 is a nitrogen-loading map, showing the areas in which more than 40 pounds of nitrogen are added annually to each acre by cesspools and septic tanks (Weston, July 1976). This map does not include the nitrogen loading that results from agricultural and domestic fertilizer applications.

2.2.3 Sewage Treatment Plant Effluent

At present, sewage treatment plant effluent is only a minor threat to ground water quality in the bi-county area, as most of the effluent is discharged directly to the sea. According to a study made by Weston in 1976, 23 plants in Nassau County discharge an average of 105.63 million gallons per day, and in Suffolk County 101 plants have an average discharge of 14.26 million gallons per day (Weston, July 1976). These are the total flows of the NPDES and SPDES permitted sewage treatment systems and are believed to include all plants in both counties. Figure 2—15 shows the locations of plants that discharge to the ground.

In Nassau County, only one percent of the total daily flow of treated

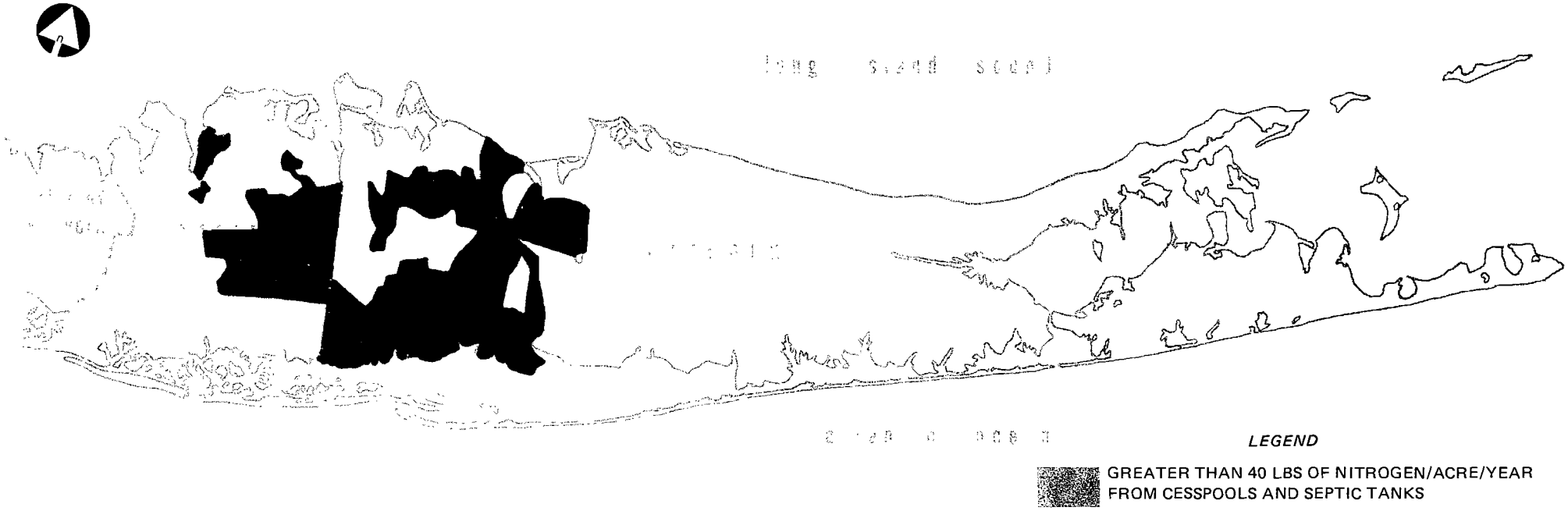

FIGURE 2—14 *Areas of Major Concentrations of On-Site Domestic Waste Disposal Systems.*

effluent (1.2 million gallons per day) and in Suffolk County 50 percent of the total daily flow of treated effluent (7.39 million gallons per day) are discharged to the ground. Thus, a total of 8.59 million gallons per day enters the ground compared to about 800 million gallons per day total recharge of fresh water from precipitation in the bi-county area. Although small, this discharge of effluent to the ground may have a significant effect when concentrated at a few sites. In Nassau County, effluent is discharged at five sites: Meadowbrook Hospital (0.77 million gallons per day), Farmingdale Sanitorium (0.07 million gallons per day), C. W. Post College (0.12 million gallons per day), New York Institute of Technology (0.003 million gallons per day), and Grumman Aerospace Corp. (0.25 million gallons per day).

In Suffolk County, the 85 facilities which discharge treated sewage effluent to the ground are predominantly small residential facilities and some special health and elderly care facilities (Weston, July 1976). Suffolk County is undergoing rapid development and many small sewage treatment plants are being installed to serve areas of 100 or more homes. In developments of less than 100 homes where no sewer system is available, builders are required to install sewers, which will be placed into service after future construction of a nearby interceptor. These homes are permitted to temporarily discharge to cesspools and septic tanks (Pim, 1977).

Some systems receive domestic wastes exclusively; others accept some industrial wastes. Regulatory authorities make every effort to exclude constituents harmful to the treatment plant process or employees, but incidental discharges are not easily controlled. Some chemicals, such as solvents, do not appear to be harmful over the short term, but may damage either the plant or sewer system over a long period of time.

According to a NYSDEC law, effective secondary treatment is the minimum required before effluent can be discharged to surface water. Although this law does not apply to plants discharging to the ground, secondary treatment also is common. Only Farmingdale Sanitorium in Nassau discharges primary treated effluent to the ground (0.07 million gallons per day). In Suffolk, of the 85 plants discharging to the ground, only six do not provide at least secondary treatment. Denitrification of sewage effluent is now required of all new sewage treatment plants which discharge to ground water in Suffolk County.

A recently released report by Roy Gilbert of the SCDEC states that

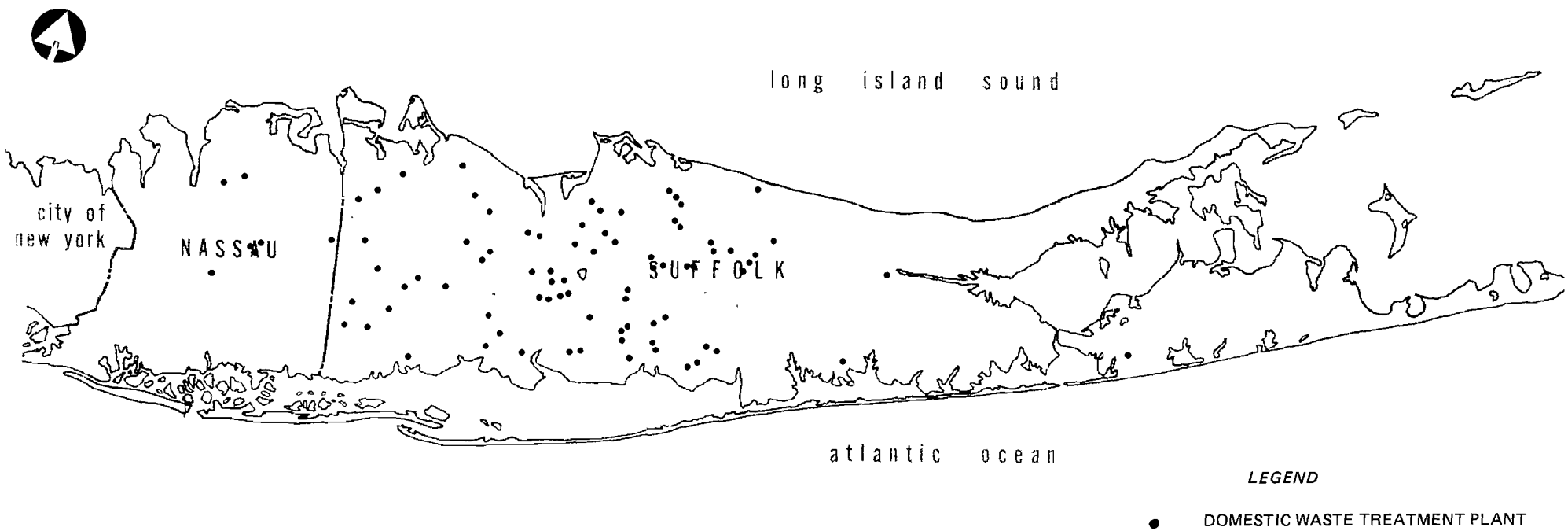

FIGURE 2–15 *Domestic Waste Treatment Plants Discharging to Ground Water.*

a number of organic compounds present in treated sewage are refractory products (not affected by the treatment process) of the biological treatment of the plant, or new compounds formed during chlorination (Gilbert, 1977). It is possible that these products may move through the unsaturated soil to contaminate ground water in places where the effluent is discharged to the ground.

The New York State Environmental Conservation Law of 1967 empowers agencies to regulate sewage treatment plants. This law provides for the classification of state ground water and establishment of quality standards. Violators are assessed penalties under the Federal Water Pollution Control Act (PL 92–500). The NPDES program was established in 1973 and the SPDES program in January 1975; the SCDEC and the NCDH derive their enforcement powers from these.

2.2.4 Sanitary Sewers

Approximately 120 million gallons per day of raw sewage flow through thousands of miles of sewers in the bi-county area. The flow in Nassau averages 105.63 million gallons per day and in Suffolk, 14.26 million gallons per day (Weston, July 1976). Figure 2–16 shows the locations of sewered areas. Sewers frequently leak, and depending upon the type of sewer and its altitude relative to the water table, ground water can infiltrate or sewage can exfiltrate. The contamination that takes place in the latter case is normal domestic sewage, plus those constituents in industrial effluent discharged to sewers.

Since the enactment of the SPDES permit program, the direct discharge of industrial wastes to septic systems has been severely curtailed. Restrictions on industrial discharges to sewers are much less stringent than those covering such discharges to septic systems. Concern over the constituents in industrial effluent is primarily due to their effects on the sewer system, the treatment plant processes, and treatment plant personnel—not their effects on ground water.

Permissible maximum infiltration rates are usually written into sewer specifications and commonly vary from 200 to 500 gallons per day per mile per inch of pipe diameter. Where ground water pollution is of concern, exfiltration rates are also specified. In Suffolk County's Southwest Sewer District, for example, 200 gallons per day per mile per inch of pipe diameter has been

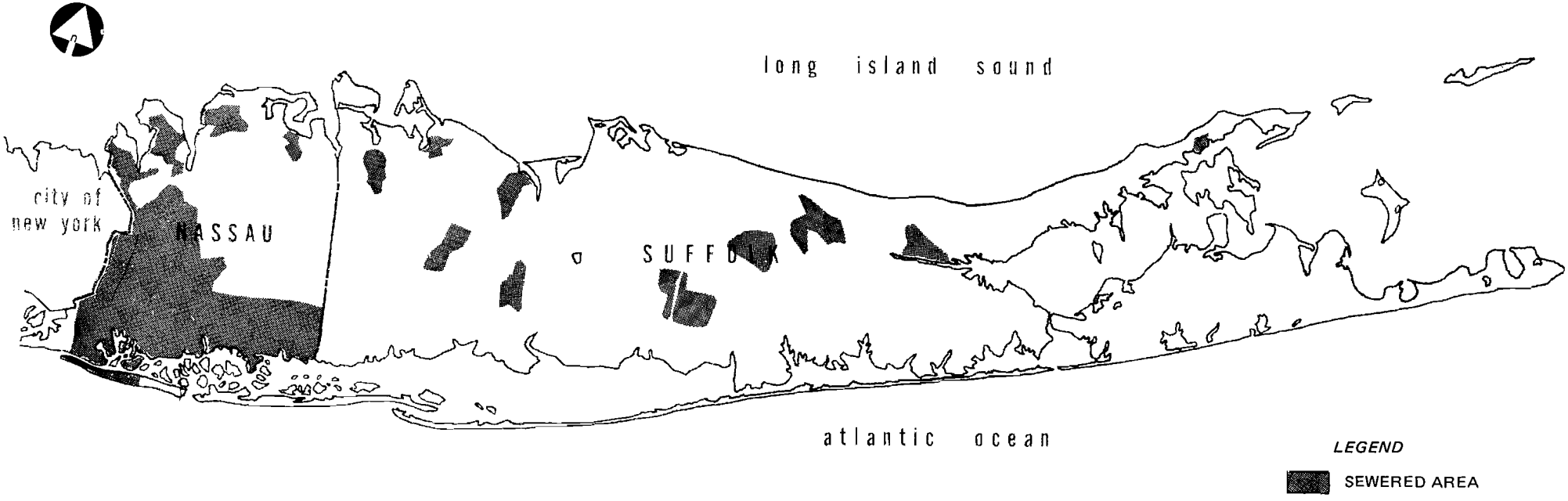

FIGURE 2–16 *Presently Sewered Areas.*

specified as the maximum rate for exfiltration. Projections from tests carried out on existing sewer lines show that leakage has been considerably less than this figure (Graner, 1977).

The potential volume of exfiltration is small when compared to the nearly 100 percent discharge that occurs from cesspools and septic tanks. However, exfiltration may increase over the years as loading produces breaks in the pipes and joints, and as chemical action deteriorates the joints. Exfiltration may also increase if the ground water level was originally above the sewer, but has declined to a point below the sewer.

With present materials and construction techniques, a 50 year sewer life is used as a minimum design estimate. However, a 100 year life may be a more reasonable estimate (Graner, 1977). Some of the older systems in Nassau County are receiving large volumes of ground water (Long Beach, Glen Cove, Oyster Bay and Freeport) (Cameron, 1977). If these systems are infiltrating additional water where the pipes are below the water table, it is reasonable to assume they are also exfiltrating additional sewage where the pipes are above the water table. Similar problems may be occurring in older Suffolk systems, such as Port Jefferson, Huntington, Northport and Patchogue.

Except for monitoring volumes, and to some extent, chemical quality of incoming waste at sewage treatment plants, little control is exerted on sewers once the construction specifications are satisfied. Severe problems involving exfiltration, infiltration or clogging are remedied where they interfere with the operation of the system or cause a public nuisance.

2.2.5 Industrial Waste Discharge

Industrial development and zoning are extensive on Long Island. In 1972, five percent of the Nassau-Suffolk area was zoned for industry. Most of this acreage is inland and includes such heavily industrialized areas as Syosset, Hicksville, Bethpage-Plainview, Melville-Farmingdale, Hauppauge and Deer Park. Except for a small part of the Melville-Farmingdale area, all of these zones and a number of smaller ones in Suffolk County are located in the recharge area of the Magothy aquifer. Areas of known industrial discharge to the ground are shown on Figure 2–17.

Although there are discrepancies in the number of industries reported to have permitted discharges, the nature and volume of NPDES and SPDES discharges are documented in a 1976 report prepared by Roy F. Weston

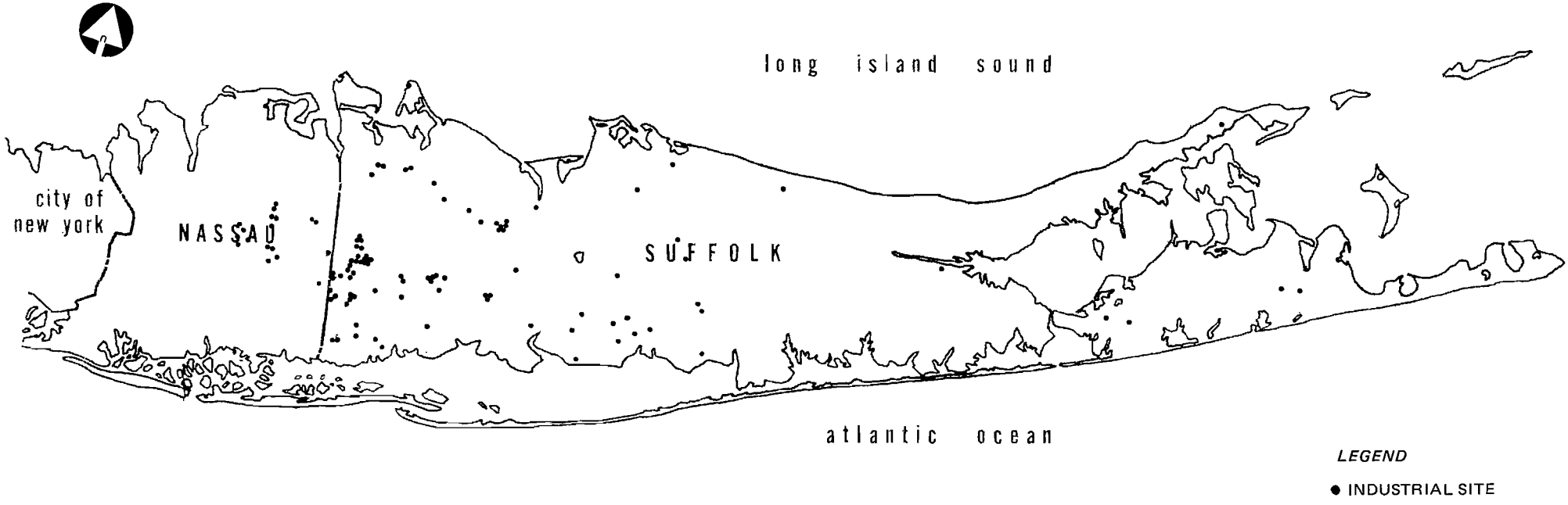

FIGURE 2–17 *Major Industrial Sites Discharging to Ground Water.*

(Weston, July 1976). According to the report, in Nassau 1.2 million gallons per day of waste water are discharged by industry. About 800,000 gallons per day of this amount are discharged to the ground. In Suffolk County, 88 industries discharge a total of 1,325,000 gallons per day, of which 1,278,900 gallons per day are discharged to the ground. Thus, in the bi-county area, about 2.1 million gallons per day of industrial wastes are discharged to the ground in a few industrialized areas.

There are also commercial and industrial discharges in both counties, not included in the permitted inventory. These include car washes, coin-operated laundries and industries discharging waste water with constituents not covered by permitting regulations.

In an attempt to control industrial waste discharges, Nassau County has recently instituted a program to inventory all industries, according to the nature of and receiving body for their discharges. The inventory has revealed a number of industries that are discharging untreated liquid wastes to cesspools (Burger, 1977). Abatement actions have been initiated in these cases. Suffolk County has been conducting industrial surveys for several years.

In Suffolk County, a list of car washes and coin-operated laundries has been compiled. Ten car washes presently discharge to ground water; these predate the State DEC regulation requiring closed systems. There are 135 coin-operated laundries discharging to the ground water; two of these have once-through waste treatment and four others have partial treatment (Gilbert, 1977). Twenty-five percent of Suffolk's coin-operated laundries discharge to sewers and require no pre-treatment (Pim, 1972). Forty-five of the laundries discharging to the ground are in the Southwest Sewer District and will be sewered in the future. Nearly 500,000 gallons per day discharges to ground water from 75 of these laundries.

In Nassau County, permitted discharges to the ground amount to about 800,000 gallons per day. Fourteen metal processing firms discharge 726,000 gallons per day, which is 90 percent of the total. The bottling industry produces an additional 32,000 gallons per day, and the food industry, 24,000 gallons per day. Very small discharges are from metal powder mixing and paper processing industries (Weston, July 1977).

In Suffolk County, 1,278,900 gallons per day of industrial wastes are discharged to the ground. This includes 470,989 gallons per day from metal processing, 356,813 gallons per day from commercial laundries, 164,978 gallons per day from dairies and 152,189 gallons per day from bakeries.

Prior to the passage of the New York State Environmental Conservation Law in 1967, there was no effective law limiting the types of waste water discharged to the land surface. With the enactment of the NPDES and subsequent enactment of the SPDES, a NYSDEC permit is required for non-sewered industrial effluent discharges. The industry must produce treated effluent which meets state water standards. Compliance is monitored by the NCDH and the SCDEC. These agencies also enforce sludge disposal rules.

2.2.6 Storm Water Basins

Investigators have determined that on Long Island approximately half the annual precipitation finds its way to the ground water reservoir as recharge. This averages roughly one million gallons per day per square mile in a 760 square mile recharge area. As the western part of the region has become increasingly urbanized, however, permeable soil areas have been replaced by impermeable roofs and paved areas. The water cannot seep into these surfaces, so it accumulates and runs off.

As a water conservation alternative to offset reductions in ground water recharge and to eliminate the need for expensive trunk sewers leading to the sea, a system of small storm sewers draining to unlined recharge basins was implemented in Nassau County in 1935. At the present time, there are more than 2,000 basins on Long Island, the locations of which are shown on Figure 2–18 (Seaburn, 1973). The basins range from less than one to more than 30 acres in size but most are about one acre. They average ten to twenty feet in depth.

Recharge basins have been considered to be highly beneficial to the overall water conservation program on Long Island, since they account for approximately twenty percent of all recharge to the underlying aquifers (Aronson, 1974). Although the basins restore potentially lost recharge, they are also sources of contamination. Inflow into the basins is a combination of precipitation plus constituents that are dissolved and suspended by the water as it runs over the ground. Typical sources of contaminants are fertilizers, pesticides, deicing salts, organic debris, grease and road oil, rubber, asphaltic materials, hydrocarbons, animal feces and food wastes. Many of the contaminants are not biodegradable and persist in ground water.

As part of the 208 investigation, a number of studies were conducted which have bearing on the amount and types of pollutants that may be entering the ground water system via storm water basins. The Weston non-point source analysis included sampling runoff from small drainage areas and correlation of the runoff quantity and quality with the prevailing land uses. The data and analyses indicated that annual loads of pollutants from non-point sources can be as large as loadings from traditional point sources (Weston, April 1977).

In their program of storm water runoff and ground water sampling at two recharge basins along the Long Island Expressway, the SCDEC detected significant intermittent concentrations of selected heavy metals (*e.g.,* zinc and lead) and total organic carbon (TOC) in discrete samples of storm water runoff during the sampled storm events. Chloride and zinc were observed in elevated concentrations in the ground water samples obtained from wells located in the two recharge basins receiving storm runoff from the Expressway. The SCDEC concluded that further investigation is obviously necessary to determine if runoff quality from the Long Island Expressway is comparable to the often reported major waste load attributed to heavy metals in runoff (Minei,1977).

Guidelines for basin construction have been developed by the Regional Pure Water Staff of the NYSDEC. These guidelines require a preliminary submission review to determine the requirements that the applicant must meet under the New York State subdivision law. It is also determined whether the applicant needs other state permits such as SPDES or tidal and fresh water wetlands permits. This review gives the NYSDEC the opportunity to evaluate design criteria, and departmental requirements (either additions or deletions to design) based on New York State rules and regulations which dictate prevention of runoff to surface water where possible, and recharge of as much storm water as feasible. There is no legislation stipulating storm water quality control.

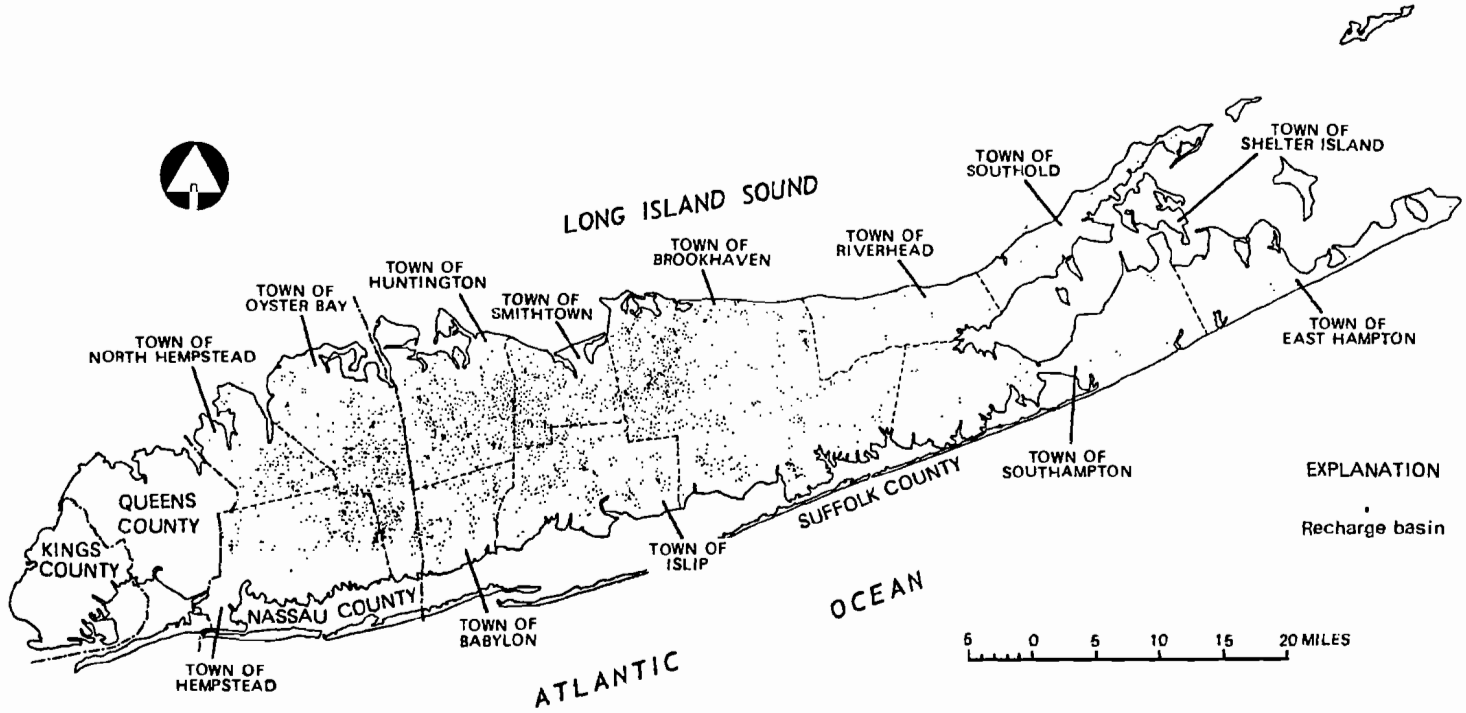

FIGURE 2–18 *Location of Recharge Basins Used for Storm Runoff on Long Island in 1969.*

2.2.7 Landfills

Long Island disposes of its solid wastes by burial in landfills, with incineration of combustible refuse at some of the sites. Based on available information, there are in excess of 40 major active and abandoned solid waste land disposal sites in the 208 planning area. Only a few sites have been studied in detail to determine their effects on ground water quality. Suffolk County has initiated monitoring programs around each major landfill, but a regional inventory of Long Island's landfills defining potential problems of leachate contamination does not exist at this time.

The NCDH currently monitors water quality at the Merrick, Freeport, Port Washington, Oceanside and Old Bethpage sites. Wells installed specifically for ground water monitoring are found only at the Port Washington site. Construction has started at a new disposal location (the Black-Clawson site) just off the Meadowbrook Parkway in the Town of Hempstead. It is a refuse recycling project that reportedly will have a waste-recycling potential of 2,000 tons per day. The project is funded by a private corporation which has agreed to operate the plant for the next twenty years.

Nassau County's annual solid waste output is now more than 1,100,000 tons. This quantity is not expected to change significantly over the next ten years. Annual solid waste generation in Suffolk County (1974) was 1,100,000 tons and is projected to be 2,700,000 by 1990 (Baffa, 1967). An average of between four to five pounds of solid waste per capita per day is generated from domestic and residential sources in the bi-county region. Industrial, commercial, agricultural, demolition and incinerator wastes have been landfilled along with residential refuse. Until recently, they were combined and dumped together as one unit at the same site.

One of the most important problems associated with Long Island landfills is the generation of leachate. The amount of leachate produced depends upon the landfill's overall extent, volume, absorptive capacity and the amount of recharge water infiltrating it. In theory, 100 acres of landfill can generate 40 million gallons of leachate per year under climatic conditions similar to Long Island's. Thus, in Suffolk County, 320 million gallons per year of leachate could be generated from the 800 acres used for solid waste disposal.

The largest landfill sites are shown on Figure 2–19. Additional data on old landfills for Nassau County are available from a report compiled by the Long Island Sanitary Commission on refuse collection in 1931. Some of the disposal sites inventoried in the 1931 survey are still active. A survey of aban-

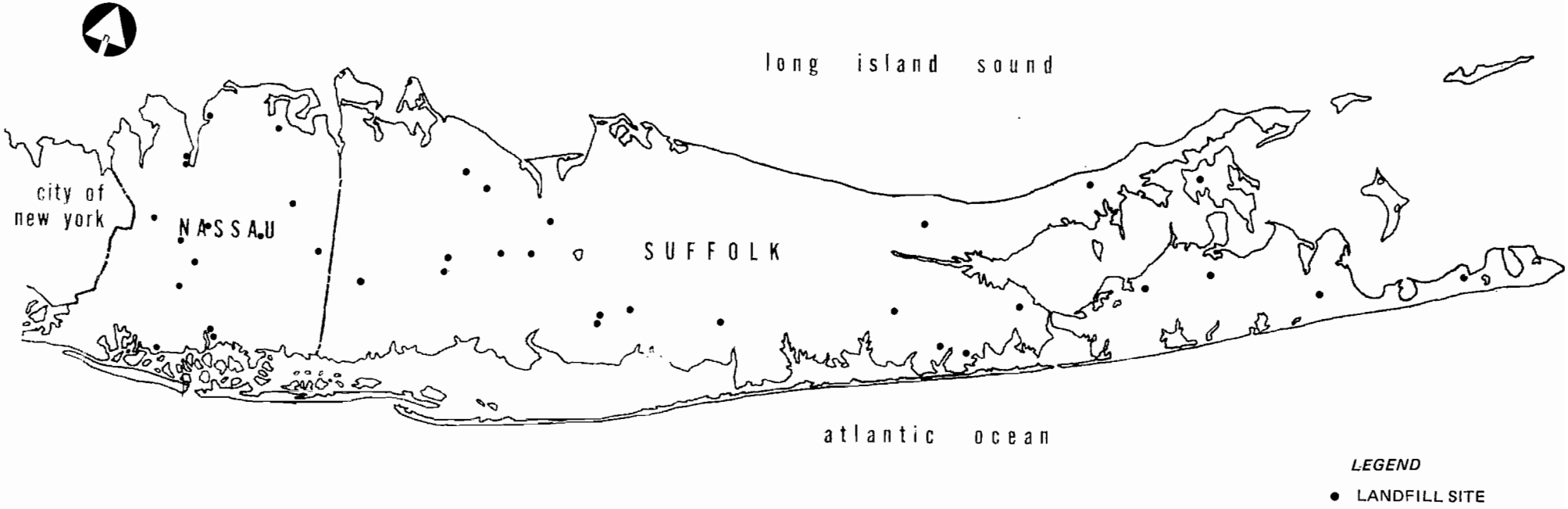

FIGURE 2–19 *Principal Active and Abandoned Landfills.*

doned municipal landfills in Nassau County is being undertaken by the NCDH; 34 sites have been reported to date.

The older landfills in the 208 region typically range in size from twenty to 60 acres. Most are in mined-out sand and gravel pits and are unlined. Some have received or still receive septage from septic tanks and cesspools. Two recently constructed landfills, one in Nassau and another in Suffolk, are lined.

Landfills receive a wide range of materials including paper products, food wastes, septic tank sludge, construction debris, tires, autos, leaves, plastics, glass, chemicals, textiles, cans, oils and hydrocarbons, street and building sweepings, dead animals and waste water and water treatment sludges. The type and concentration of contaminants in leachate is of great importance in determining potential effects on ground and surface water quality. Table 2–2 lists pollutants expected from municipal waste sites. Significant pollutants in landfill leachate on Long Island are BOD, COD, iron, chloride, ammonia, heavy metals and organic chemicals.

Landfilling of solid waste is the typical disposal method employed on a nationwide basis, and has the lowest cost of the various waste management options available. Until passage of the Resource Recovery and Conservation Act in late 1976, there was no effective Federal regulatory control over land disposal of solid waste. Regulations for the Resource Recovery and Conservation Act are now being prepared by EPA. On Long Island, the NYSDEC, in cooperation with the NCDH and the SCDEC, has jurisdiction over applications for new landfill sites and the expansion of old sites. Current trends in landfill regulation include lining all new sites, installing leachate collection systems, encouraging resource recovery and monitoring ground water quality.

2.2.8 Highway Deicing

The application of salt to highway surfaces in freezing weather can cause ground water contamination. The salt melts snow and ice, and the resulting solution of brine, combined with other pavement contamination, runs off the impermeable road surface and most of it either seeps directly into the ground or is diverted to a storm water recharge basin. In some places along the shores of Long Island, street runoff is diverted to sewers which discharge to the sea. However, the bulk of the runoff enters the ground where it seeps down to the water table and migrates through the ground water system

Contamination can also take place around salt storage piles if they are not adequately protected. Rain falls on the pile, dissolves the salt and runs onto the ground. Increasingly, salt piles are being stored under cover on paved impermeable surfaces to prevent dissolution.

It is obvious that road salting cannot be discontinued without a drastic increase in traffic accidents and inconvenience to motorists. What can be done, however, is to decrease the amount of salt used to the minimum required to do the job, mixing it with sand so that the cars can maintain good traction with the road surface. About 80 percent of all deicing salt pollution

Table 2–2

LEACHATE CHARACTERISTICS BASED ON TWENTY SAMPLES FROM MUNICIPAL SOLID WASTES
(Constituents given in parts per million, where applicable)

Constituent	Median Value	Ranges of all Values
Alkalinity ($CaCO_3$)	3,050	0 – 20,850
Biochemical Oxygen Demand (5 days)	5,700	81 – 33,360
Calcium (Ca)	438	60 – 7,200
Chemical Oxygen Demand (COD)	8,100	40 – 89,520
Copper (Cu)	0.5	0 – 9.9
Chloride (Cl)	700	4.7 – 2,500
Hardness ($CaCO_3$)	2,750	0 – 22,800
Iron, Total (Fe)	94	0 – 2,820
Lead (Pb)	0.75	<0.1 – 2.0
Magnesium (Mg)	230	17 – 15,600
Manganese (Mn)	0.22	0.06 – 125
Nitrogen (NH_4)	218	0 – 1,106
Potassium (K)	371	28 – 3,770
Sodium (Na)	767	0 – 7,700
Sulfate (SO_4)	47	1 – 1,558
Total Dissolved Solids (TDS)	8,955	584 – 44,900
Total Suspended Solids (TSS)	220	10 – 26,500
Total Phosphate (PO_4)	10.1	0 – 130
Zinc (Zn)	3.5	0 – 370
pH	5.8	3.7 – 8.5

is caused by improper storage practices and the remainder by improper spreading techniques (U. S. Salt Institute, 1976).

Nassau County maintains ten salt stockpiles; nine are open and one is enclosed. All of them are mixtures of sand and salt, and in 1976 they had a total storage volume of 18,250 tons. They are located in Manhasset, Glen Cove, Oyster Bay, Hicksville, Mitchell Field, Mineola, Inwood, Franklin Square, Wantagh and Hempstead. The ages of these sites range from two to 21 years. The three towns in Nassau County maintain ten additional sites,

totaling 10,360 tons, and 31 storage sites are located in 29 villages, representing 4,500 tons of salt. New York State has two large salt piles in the Duffy Avenue landfill in Hicksville and at the Planting Fields Arboretum landfill in Oyster Bay.

There are sixteen Suffolk County Department of Public Works storage piles in the following towns: Huntington, Hauppauge, Babylon, Bay Shore, Brentwood, Farmingville, Medford, Yaphank, East Moriches, Riverhead, Peconic (two), Westhampton, Hampton Bays, East Hampton and Montauk. Only two of these county piles are indoors, one in Riverhead, and the other in Peconic. Numerous storage piles exist at the town and village level. Brookhaven has submitted plans for twelve brine collection pads (to be installed beneath their outdoor piles) and four of their piles are within buildings. Six Suffolk towns are currently complying with the SPDES permitting system; one is partially complying, one has promised to comply, and two are not complying, with subsequent legal action pending. By 1978, 80 to 90 percent compliance is expected from the towns and the County Department of Public Works. The smaller villages generally comply with the building and pad requests because they can obtain multiple usage from such facilities.

Some of the NYSDOT piles come under the jurisdiction of the Long Island State Park Commission. They are not, for the most part, considered to be in compliance with SPDES. Most of the piles are uncovered and without curbs or catch basins. Some piles have impervious pads, but others do not, and the result is leaching and uncontrolled runoff. As funding is made available, NYSDOT constructs storage facilities for its piles. The first was built in 1959 and nine more have been built since then.

An average of about 32,500 tons of road salt is applied to 9,000 lane-miles of road in Nassau County yearly. Averaging the state, county and municipal applications, about 5.2 tons of salt is applied per lane-mile. This average annual application rate is calculated from Nassau salt usage data in Table 2–3. In Suffolk County, with greater road area, about 60,000 to 65,000 tons are applied annually. One hundred thousand tons of road salt would contribute some 60,500 tons of chloride, plus large amounts of calcium and sodium to the environment. The runoff dissolving these salts seeps into the shallow water table aquifer, usually within the immediate vicinity of the treated road surfaces or is discharged to a nearby recharge basin designed to receive highway runoff.

Substances have been added to deicing salts to prevent caking and to inhibit corrosion. For example, sodium ferrocyanide has been added to deicing salts in the past to prevent caking. Not enough is known about the present use of additives, their toxicity, nor their fate in the soil and ground water system to comment on potential hazard.

On Long Island, no regulations exist for deicing practices but certain policies, similar to those described by USEPA, are commonly used (U. S. Environmental Protection Agency, 1974). The SCDEC issued an order in 1974 requiring more substantial protection for stored salt used by highway departments. The order called for construction of buildings to store the salt/sand piles, and in 1975, most of the townships and incorporated villages began to comply. Suffolk County salt storage piles must now comply with the SPDES permitting system as required by SCDEC.

Table 2–3

SALT USAGE IN NASSAU COUNTY (from NCDH)

Agency	Lane-Miles Maintained	Average Annual Salt Usage (tons)	Tons per Lane Mile
New York State	950	7,000	7.4
Nassau County	1,400	14,900	10.7
Town of Oyster Bay	1,600	1,500	0.9
Town of North Hempstead	540	3,000	5.6
Town of Hempstead	4,500	6,000	1.3
Total:	8,990	32,400	5.2 (average)

2.2.9 Fertilizers and Pesticides

About 45,000 acres in the bi-county area are devoted solely to crop raising. Figure 2–20 shows areas being used for agriculture. In Suffolk County alone 64,000 acres are considered available for present and future agricultural use (Nassau Suffolk RPB, 1975). In Nassau County, agricultural land is minimal. Most of the land, although previously farmed, is now used for residential, commercial, industrial and recreational purposes.

In the bi-county area, as a whole, most fertilizers and pesticides are applied for non-agricultural uses including home lawns, golf courses and nurseries. Increasing evidence from Long Island ground water quality testing programs supports the association between fertilizer use and nitrate in ground water. Studies being conducted for the 208 by Cornell University indicate that lawn fertilizers applied by home owners may be as significant a source of nitrogen contamination of ground water as discharges from septic tanks, particularly in Nassau and western Suffolk (Porter, 1977) However, further work is required to more effectively quantify the use and relative environmental impact of fertilizers.

There is no evidence to suggest that pesticides have posed a serious threat to ground water resources on Long Island, despite the heavy use of the chemicals on intensely farmed agricultural land. Metallic base pesticides and hydrocarbons were used until quite recently. The "first generation" pesticides are very persistent and substantial residues may still be found in the soil. However, the residues are strongly retained by soil forces and do not usually leach to ground water. In the past decade new generation pesticides have been widely used. Some of these, including certain herbicides which are now used

very extensively, are more soluble in water and have higher acute toxicities. Most, however, are broken down rapidly in soil or water and, therefore, are not regarded as a ground water hazard. Some evidence indicates that a few recently developed pesticides may be more persistent under some conditions. Unfortunately, there are virtually no data available from monitoring for these pesticides in ground water. These pesticides include some of the carbamates which are both highly toxic and soluble in water.

There has been no legislation enacted to regulate the rate of fertilizer application. The Federal Insecticide, Fungicide and Rodenticide Act of 1975 (PL 92-516) deals principally with control of compounds through registration of both pesticides themselves and commercial operations by pesticide firms, and through monitoring procedures. By law, pesticide users must apply the product according to prescribed dosages provided by the manufacturer.

2.2.10 Product Storage Tanks and Pipelines

A number of products are stored in surface and subsurface tanks and are transmitted in pipelines on Long Island. Among the most frequently stored fluids are liquid petroleum products; gases, both liquefied and gaseous under pressure; industrial chemicals; and water. Among these products, industrial chemicals are not commonly transmitted long distances through pipelines, and water poses little contamination threat to ground water. The other products, however, have all been reported to cause ground water contamination on Long Island or elsewhere in the United States.

A major ground water contamination threat is posed by liquid petroleum products stored in tanks and transmitted through pipelines. Three types of petroleum products and their means of storage are common in Nassau and Suffolk Counties. Gasoline service stations store various grades of gasoline in two or more subsurface storage tanks with capacities of 2,000 to 12,000 gallons. Many individual homes and businesses store heating oil indoors, below ground or at the surface. Oil depots store one or more grades of fuel oil in surface tanks of various sizes. These various sources are described below.

2.2.10.1 Service Stations. For a number of reasons, service stations are of most concern as a threat to ground water, and many case histories of ground water contamination from this source have been reported. First, they are spread over the entire bi-county area. The greatest concentration of service stations occurs in the most densely populated areas which are also the

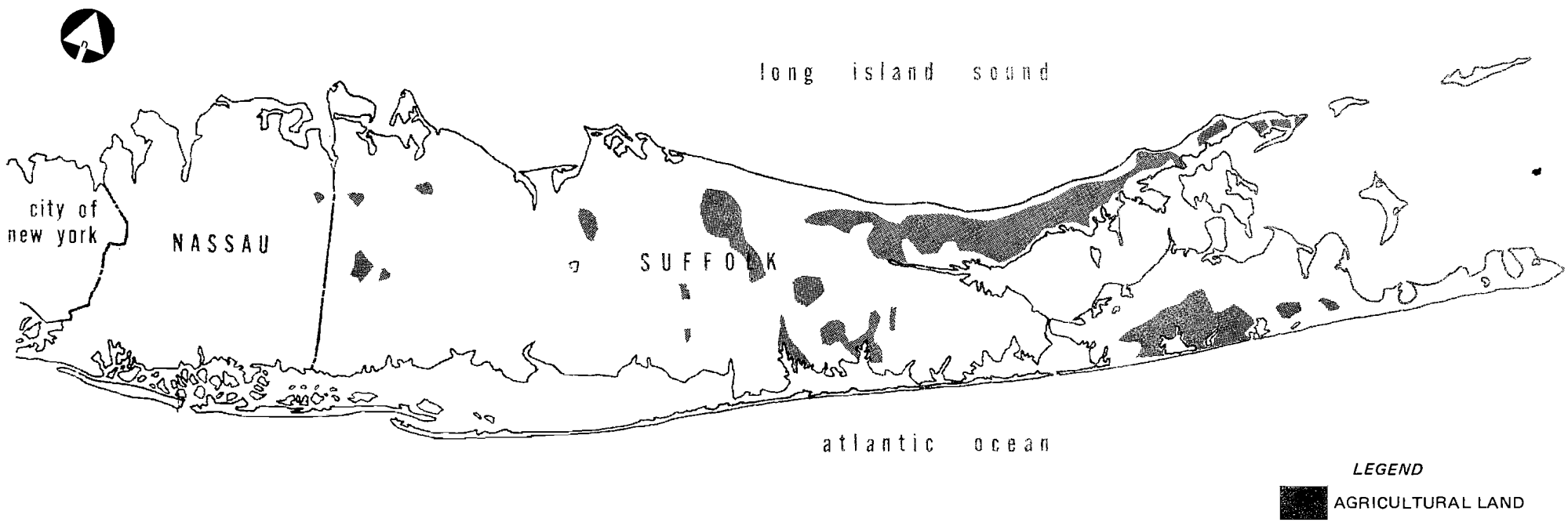

FIGURE 2—20 *Agricultural land*

areas of greatest ground water pumpage. The Nassau County Fire Marshal's Office estimates that more than 1,200 gasoline and diesel service stations exist in Nassau County (Bartow, 1977). The Suffolk County Bureau of Weights and Measures records over 1,400 service stations and marinas which have storage tanks (Kerbs, 1977). These numbers do not reflect the numerous facilities which dispense products on a non-profit basis, such as construction companies or major trucking firms which fuel their own vehicles. In total, it is estimated that 3,000 sites which store vehicle fuel exist in Nassau and Suffolk (L.I. Gas Retailers Association, 1977).

The volume of storage is enormous. Personnel of the Long Island Oil Heat Institute estimate that over one billion gallons per year of gasoline and diesel fuel are used in Nassau and Suffolk. Most of this fuel is initially delivered by tank trucks, and almost all of it is stored underground for some period of time (Byrne, 1977).

Most service stations have steel tanks, although fiberglass tanks (first marketed in the early 1960's) are slowly gaining in popularity. The steel tank, usually of welded construction, is highly susceptible to corrosion, especially at the welds. In order to inhibit corrosion, steel tanks are often coated on the outside with tar. With care, the coating may be temporarily effective, but many tar-coated tanks develop leaks at the point where the tar was scratched away during installation. Gasoline additives often accelerate tank corrosion from the inside. Fiberglass tanks have effectively alleviated the corrosion problem, but they can crack when exposed to cold temperatures and excessive surface loads.

2.2.10.2 Home and Industrial Heating and Power Generation. According to personnel of the Long Island Oil Heat Institute, Nassau and Suffolk homes and industries use 1.5 billion gallons of No. 2 oil (the most common home heating fuel) and two billion gallons of No. 6 oil. Less than ten percent enters over the road, with the remainder shipped to the bi-county area by barge (Byrne, 1977).

Oil heated homes on Long Island number 640,000. Popular home storage tank sizes are 275, 550 or 1,050 gallons. Basements can accommodate one or more 275-gallon tanks, but larger, underground tanks are more common. Welded steel tanks are the most popular.

Underground steel tanks at homes and industries are as susceptible to leaks as tanks beneath service stations. However, their contamination potential is less for several reasons.

1. Stored volumes are smaller so a single loss of product would have less of an impact on ground water.

2. The loss of a few hundred gallons of fuel oil should be more obvious to a homeowner than the loss of a similar amount by a gasoline retailer.

3. Because the tanks are smaller, the bottom of the home fuel oil tank will likely be at a shallower depth and, therefore, less likely to be installed below the water table where corrosion could be accelerated.

2.2.10.3 Oil Storage Depots. The distribution and number of depots on Long Island which store petroleum products are significant. Several cases of leakage into ground water have been documented from this source. Most depots store fuel oil for home and business use, although many also store gasoline, kerosene and diesel fuel. Except for Long Island Lighting Company which stores its own oil, all but about ten percent of the fuel oil consumed in Nassau and Suffolk is stored in depots in the bi-county area. Nearly all tanks are above ground and outdoors. In fact, New York State law prohibits indoor storage of large volumes of flammable products (Early, 1977).

The Nassau County Fire Marshal's office has inventoried nearly 100 oil storage depots in the county. Although the largest facilities are generally near the shore where they can be supplied by barges and tankers, the greatest number of facilities are found inland.

A complete inventory of Suffolk County depots is not available at this time. However, a listing made available by the SCDEC reveals that more than 41 storage tanks exist at six major storage terminals (Maloney, 1977). The largest of these terminals, at Northville, has a storage capacity of nearly 120 million gallons (Nassau County Environmental Management Council, 1974). Two large inland terminals at Holtsville and Setauket have more than 25 storage tanks between them (Maloney, 1977).

2.2.10.4 Other Storage Facilities. Most industrial chemicals are stored in tanks on or above the ground. It is unlikely that the locations of many of those containing hazardous substances are known to regulatory agencies, because most are small and unobtrusive. However, many of those containing flammable products are known to fire departments. For example, in the Town of Huntington, any facility which stores combustible material must be permitted by the district fire inspector (Early, 1977).

2.2.10.5 Pipelines. The four major pipelines on Long Island transport fuel oil; these are the Consolidated Petroleum pipeline from Port Jefferson to Setauket, and three Northville Industries pipelines—from Port Jefferson to Holtsville, from Northville to Riverhead, and from Holtsville to Plainview.

Regulatory controls applicable to oil product storage tanks and pipelines are diverse, ranging from local ordinances to USEPA regulations. There are also guidelines and recommendations for siting and construction designed to ensure safe encapsulation of the stored or transported product. In addition, compliance with the New York State Environmental Conservation Law, Section 23, is required. This legislation is concerned with the storage and transportation of liquefied natural gas and petroleum products.

2.2.11 Incinerator Quench Water

A typical 600-ton-per-day municipal incinerator requires about 10,000 gallons of water each day to dissipate heat from fuel gases and gas residue. Some of this quench water is retained in the ash, but most of the unevaporated water, which may contain hazardous constituents, is siphoned away for discharge.

Of the eleven active municipal incinerator sites in the bi-county area,

eight are in Nassau and three in Suffolk (Weston, 1976). Four dispose of quench water directly to the ground; the others discharge to surface water.

Contaminants of concern are similar to those found in landfill leachate. The quality of quench water from one incinerator in the study area did not meet sewage treatment effluent discharge standards for pH, suspended solids and turbidity. At another site several constituents were in excess of the concentrations permitted under SPDES regulations. Owners of incinerators are in the process of applying for SPDES permits, a relatively recent requirement because the potential for contamination from this source was not previously regulated.

2.2.12 Airborne Pollution

Both the atmosphere over Long Island and precipitation contain appreciable amounts of ground water contaminants. For instance, emissions from motor vehicles in the bi-county area may amount to 4,000 tons per day of carbon monoxide, 800 tons of hydrocarbons and 740 tons of nitrogen oxides (Frizzola, 1975). Other sources of air contamination and potential incorporation of chemicals into precipitation include incinerators, power generators, aircraft, railroads, industrial emissions and open burning of refuse.

Table 2–4 shows the average values of selected chemical constituents in rain water reaching Long Island. The samples collected by the U. S. Geological Survey show higher concentrations of all constituents at the suburban sites at Mineola and Medford, while lower levels were registered for the rural environment at Upton. The results of recent studies show an average sulfate content in rain water of 3.60 milligrams per liter, total nitrogen 1.36 milligrams per liter, sodium 1.89 milligrams per liter and chloride 3.22 milligrams per liter (Frizzola, 1975).

Amendments to the Clean Air Act in 1970 established national ambient air quality standards for six common classes of air pollutants; sulphur oxides, particulate matter, carbon monoxide, photochemical oxidants, nitrogen oxides and hydrocarbons. In addition, national emission standards for hazardous substances, including asbestos, beryllium and mercury were established. To date, no studies of organic chemicals in rainwater have been conducted on Long Island, although several are now being proposed. Since 1970 air pollution control has been a responsibility of the NYSDEC, with Nassau and Suffolk Counties acting as agents of the State and assisting in any necessary enforcement of regulations and standards.

Table 2–4

AVERAGE RAIN WATER QUALITY ON LONG ISLAND (MILLIGRAMS/PER LITER) – FIVE YEAR RECORD 1969 TO 1974
(Nassau County Environmental Planning Report, 1974)

Parameter	Mineola (average)	Upton (average)	Medford (average)
Nitrate-nitrogen	0.66	0.34	0.67
Ammonia as N	0.48	0.17	0.43
Total N as N	1.14	0.51	1.10
Sulfate	6.67	3.54	3.43
pH	5.08	4.41	4.44
Chloride	2.00	1.65	3.04
Sodium	1.17	1.08	1.68

2.2.13 Sand and Gravel Mining

The extent of sand and gravel mining on Long Island is uncertain. Although figures for presently mined acreage are available, an inestimable acreage of small pits exists which were mined for a short period and then abandoned.

For the most part, large sand and gravel operations are located in the hilly areas of Long Island, where mining can proceed laterally into the hillside. Vertical pit mining is prevalent only where a significant depth can be attained before the water table is reached. Large sand and gravel mining operations exist in Port Washington, Oyster Bay, Plainview, Melville, East Commack, Nesconset and Half Hollow Hills.

The practice of sand and gravel mining does not in itself present a significant ground water pollution threat. The few cases reported elsewhere in which pollution actually occurred involved noticeable changes in turbidity in wells at or adjacent to the mined site. One of the most desirable traits of ground water is its generally low turbidity.

A greater threat to ground water at sand and gravel mining sites is from pollutants which have been introduced into the pits. Abandoned pits serve as attractive but illegal disposal sites for domestic, industrial and scavenger wastes. Although no reported cases of ground water pollution from illegal dumping have been reported on Long Island, such dumping is suspected to occur. Careless handling of materials at sand and gravel sites, for example, where road salt or petroleum fuels are stored, can cause these materials to enter the ground water.

The principal cause of ground water pollution at sand and gravel pits has been the use of brackish and salty water to wash the fines from the mined material. Salt water pumped from bays is spread on the land surface or stored in ponds where it can leach to the underlying fresh ground water (Swarzenski, 1963).

Under the recently enacted New York State "Mineral Resources (Mine Reclamation) Act" (1975), a mining operator removing more than 1,000 tons of minerals in a month is required to have a permit to operate. In the application for a permit, the operator must describe his plans for reclamation at the site. A bond, posted upon issuance of the permit, assures NYSDEC that reclamation is executed.

2.2.14 Scavenger Waste

Scavenger waste pits are open, unlined seepage ponds for disposal of liquid and sludge waste from septic tanks, cesspools, and municipal and industrial sources. On Long Island, each town has a designated location for scavenger waste; most usually near landfill sites or sewage treatment plants. Suffolk County has eight major waste pit areas discharging directly to ground water. However, a large percentage of the sludge generated by the County's municipal treatment plants is trucked to five scavenger waste treatment plants, located in Islip, Huntington, Babylon, Kings Park and Brookhaven. Nassau County septic tank waste goes directly to municipal treatment plants, while coastal treatment plants usually dispose of sludge at a prescribed disposal area in the ocean.

These sludges and liquid wastes are most frequently a problem when high loading rates exceed the lagoon's holding capacity, resulting in clogging of the lagoon's surface and overflows. Misdemeanor charges have been filed against one Suffolk County town which failed to correct the overloading of a scavenger waste disposal site under its jurisdiction.

SPDES permits must be obtained for authorized treatment plants, but as yet there are no controls over random scavenger waste dumping into pits.

2.2.15 Diffusion Wells

On Long Island, the NYSDEC requires all water used for cooling to be pumped through a completely closed system and then returned to the source aquifer through one or more diffusion wells or equivalent structures. Depending upon the cooling system, the water is raised 10° to 40° F above the natural ground water temperature (DeLuca, 1975).

Ground water temperatures to a depth of about 200 feet are usually 3° to 6° F warmer than the average annual air temperature. Below that depth, the natural gradient is approximately 1° F increase for each 60 to 125 feet of depth (Hoffman, 1958). In the bi-county area, natural ground water temperatures range from about 50° to 70° F.

In the 208 area, thermal loading has been observed in a number of industrial areas where large quantities of hot water are returned to the ground. Observations have been documented in Hicksville, Lake Success, Syosset and Smith Haven. Undoubtedly, there are many other occurences that are not documented.

NYSDEC data on diffusion wells are reported by a number of installations, and each installation may include more than one diffusion well. In 1976, 306 installations in Nassau County returned 4,500 million gallons of cooling water through wells.
In 1974, 183 installations in Suffolk County returned 3,000 million gallons (NYSDEC, 1977). The total is approximately 7,500 million gallons per year or 20.5 million gallons per day.

The return of cooling water to the ground as a source of recharge has been considered an environmentally beneficial practice and not a source of pollution on Long Island. Consequently, institutional activity has been directed toward encouraging the use of diffusion wells rather than their control. More water quality data is needed to determine whether this policy is justified.

2.2.16 Water Wells

Water wells themselves are not normally sources of contamination, except in cases of improper construction, well failure, and in a few instances, use of the well. Some of the most common conditions that might result in contamination of ground water are given in Table 2–5.

Table 2–5

EXAMPLES OF CONDITIONS UNDER WHICH WATER WELLS CAN CAUSE GROUND WATER CONTAMINATION

Imperfect Construction	Inadequate surface protection Poor or no grouting Well finished at or below land surface Open annulus around casing
Illegal Construction	Poor location Split screen where prohibited by situation Improper abandonment of well Improper backfill of test holes
Well Failure	Casing corrosion Casing electrolysis (chemical) Stray currents in ground Accidental holing of casing during construction or maintenance
Well Use	Direct recharge of contaminant Movement of contaminants caused by pumping Salt water intrusion

Since 1940, there have been 9,040 permits issued by the NYSDEC to drill wells in Nassau County and 60,280 in Suffolk (NYSDEC, 1977). Most of the wells, however, were drilled since 1960. In the bi-county area, there are an estimated 750 public-supply wells, 840 industrial and commercial wells, and 440 agricultural wells.

Domestic wells are usually of a small capacity (45 gallons per minute or less) and six inches or less in diameter. Typically they are installed as shallow as water table conditions and local regulations permit. Agricultural wells, on the other hand, are usually of a high capacity (500 to 1,500 gallons per minute), but are also constructed as cheaply as possible and as shallow as possible. Since cost is often of prime importance, little is done to secure these

wells from contamination. Both domestic and agricultural wells are rarely, if ever, cemented in place or sealed at the land surface. Consequently, surface and ground water percolation outside the casing to the water table may take place. Such percolation may introduce pesticides, fertilizers, septic effluent or other contaminants to the ground water.

Industrial and commercial wells are normally constructed more carefully, although the water is used principally for cooling. Diffusion wells, discussed in another section, are wells designed to return cooling water to the ground and are constructed to less stringent standards than most industrial pumping wells. Public supply wells are the best constructed, in some cases with double casings combined with cement grout.

Modern construction and proper inspection during installation generally minimize the chance of contamination due to improper design or structural failure. The gravel packing and backfill are sterilized with chlorine compounds, and upon completion the entire well is disinfected. Casings and wells are inspected for structural integrity, and the volume of gravel or grout used is carefully checked to avoid the creation of voids or openings that might allow vertical migration of contaminated water. In many cases, however, the annular space between the outside wall of the drilled hole and the inside casing are backfilled with the natural material that was removed from the hole, and grouted only near the surface. Migration of contaminants along this annular space between the well casing and natural sediments may be an important source of contamination for deeper wells in Long Island.

Separate screens in the same well are generally prohibited in permitted wells on Long Island if the screens are set opposite different aquifers. However, it is possible for a single formation to have beds of different permeabilities. The Magothy, for example, is considered a single aquifer, but contains a number of water-bearing zones separated by confining layers. If one such zone were contaminated, the pollutants could move through a well with mutiple screens to contaminate other zones.

Another way in which a well can become a vehicle for contamination is through improper abandonment. If the well is not filled with impermeable or low permeability materials, the open casing can provide easy access for contamination to move down to the aquifer tapped by the well. Contaminants can enter at the surface or through a break in the casing. When a well is unused, flooding with surface water and even deliberate dumping of various, sometimes toxic, substances into the well can occur. Once in the well, contaminants can enter the ground water either through the well screen or other breaks in the casing.

The Safe Drinking Water Act shall ultimately ensure stricter surveillance of public supply wells and those industrial or commercial wells providing potable water, principally through increased sampling requirements. However, there exists little opportunity for surveillance of construction of private, domestic and agricultural wells other than the requirement that they be constructed by a licensed well driller.

2.2.17 Spills and Incidental Discharges

Carelessness and poor housekeeping account for a large percentage of the spills and incidental discharges of contaminants that occur in the bi-county area. Their occurrence is random and frequently not recorded. In most cases failure to confine the spilled material, and even cleanup methods themselves, increase the probability of ground water contamination.

For instance, when accidents occur, especially when hazardous flammable products are involved, the fire department normally washes down the road. This procedure moves the flammable substance from the road surface to unpaved surfaces or sewers, or catch basins where it may seep into the ground.

The principal causes of spills are summarized below:

Industry	Mishandling of delivered or stored chemicals on-site
	Spills or accidents involving trucks containing industrial chemicals
	Miscellaneous discharges to the ground of waste products that cannot be disposed of in other ways
	Surface discharge of blowdown water from stacks and boilers that contain chemical additives which inhibit corrosion and scaling, but are otherwise harmful
Sewage	Major breaks in sewer lines (particularly force mains) which would allow rapid incidental discharges to the land surface
	Handling accidents or lagoon breaks and overflows at sewage treatment plants or scavenger waste plants
	Dumping by scavenger waste trucks in deserted areas because it is inconvenient to haul to a designated area
	Sewage discharges in violation of the Sanitary Code
	Railroad cars
Agriculture	Mishandling of chemical fertilizers and pesticides on the farm
	Disposal of chemical fertilizers and pesticides on the farm
Petroleum Products	Spills during loading/unloading of truck tankers
	Incidental discharges which result at the completion of the filling of service station tanks

Spillage during home heating deliveries when the tank is overfilled or when the hose is rolled up
Mishandling and disposal of waste crankcase oil
Dumping of sludge on-site after tanks are cleaned
Spills from carelessly attended motor vehicles in service stations

At the county level there is little opportunity for direct regulatory control over spills; the SCDEC reports that efforts to introduce legislation to improve the situation have not been successful. Procedures associated with state regulations are such that up to six months may be required to prepare documents needed for enforcement. Locally, the Nassau County Fire Marshal and individual fire districts adhere to guidelines developed by the National Fire Protection Association, which provide only limited controls in the event that a spill directly endangers public safety.

2.2.18 Animal Wastes

Statistics provided by the U. S. Department of Agriculture Soil Conservation Service in its 208 report "Animal Waste Control Alternatives, Nassau and Suffolk Counties, New York," show that the animal population of the region is sufficiently diverse and numerous to add to the BOD, COD, bacterial, nitrogen and phosphorus content of ground water (U. S. Soil Conservation Service, 1977).

SCS estimates that in the bi-county area there are approximately 258,000 cats; 425,000 dogs; 30,000 horses; 121,000 chickens; 1,800 cattle; and numbers of turkeys, swine and sheep. In addition, there may be as many as 750,000 market ducks.

The SCS report emphasized the effect that this animal and bird population has on surface water. However, it should be noted that dog waste carried in street runoff may finally end up as available for infiltration through storm water basins rather than in bodies of surface water.

Regulations controlling disposal of animal wastes, other than those associated with cattle feedlots, are non-existent in the United States. Some cities have established restrictions aimed at curbing dog owners from allowing their pets to defecate on sidewalks, but these ordinances are largely ineffective and do not protect ground water.

2.2.19 Cemeteries

There are 94 cemeteries larger than two acres, and many smaller ones scattered through the bi-county area. Of the 94 larger cemeteries, 25 are in Nassau County, covering about 1,510 acres, and 69 are in Suffolk County, covering about 2,920 acres. Combined, both counties have about seven square miles of land used for cemetery purposes.

Most of the larger cemeteries in Nassau and Suffolk are situated inland where substantial depths to ground water exist. Ground water percolating downward, therefore, receives considerable filtration prior to reaching the water table. Also, the potential threat to ground water depends upon the type of burial, *i.e.,* casket construction and use of vaults. There are no known field studies involving drilling and sampling on Long Island to determine the effects of cemeteries on ground water quality.

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2.3 GROUND WATER QUALITY

2.3.1 Background

This section of the interim report characterizes present ground water quality conditions by aquifer, with major emphasis on nitrate. Nitrate is used as an indicator of water quality trends because of the availability of historical data. Also, nitrate is a potential contaminant that is associated with almost all of the waste disposal practices that have been of prime importance in the Long Island 208 area. Trends of other selected constituents are presented if there is sufficient information for analysis. Available heavy metal data are examined with a preliminary evaluation of the distribution of these contaminants.

Heavy reliance has been placed on the data presented in many previous reports describing ground water conditions in the bi-county region. It is beyond the scope or purpose of this document to evaluate the validity of the data used in each of these reports. Instead, it is the intent to summarize and build upon those studies which after examination appear to reach reasonable and significant conclusions. Many investigations of the U. S. Geological Survey are cited, especially the water quality study which was done as part of the 208 program (Ragone, 1976a). In that report, thousands of analyses are organized according to such factors as depth of the well sampled and its location in a sewered or non-sewered area.

2.3.2 Summary

1. For the period 1972–76, median concentrations of nitrate-nitrogen exceeded eight milligrams per liter in water from nineteen of 127 selected Upper Glacial wells in Nassau. Wells yielding water with relatively high nitrate are fairly widely distributed throughout the county, with the exception of the northwest portion where values are slightly lower. In western Suffolk, nine of 85 selected Upper Glacial wells yielded water with median concentrations above eight milligrams per liter. In Upper Glacial wells on the North Fork, water from six of seven selected wells had nitrate exceeding eight milligrams per liter, and on the South Fork, water from thirteen of 92 selected wells had nitrate greater than this level. These well ratios give a general indication of the magnitude of the nitrate problem in the respective areas.

2. Water quality data from streams and shallow wells, as well as from the infiltration galleries in Wantagh and Massapequa, indicate that elevated concentrations of nitrate in the shallow ground waters of Nassau and western Suffolk are widespread. However, nitrate concentrations in most of the shallow aquifers are below the ten milligrams per liter standard for drinking water.

3. Changes in overall medians, as well as statistical analyses of nitrate trends in water from selected wells in the shallow ground water aquifer, indicate that concentrations are generally decreasing in Sewer District Two. There is some evidence that this decrease is due to sewering, but this relationship is not clear cut. Despite generally decreasing trends, the actual concentrations in some wells are still quite high. Using the criteria established in this report, there is insufficient data to make a determination regarding nitrate trends in eastern Nassau. However, a recent study of the quality of water from the infiltration galleries in eastern Nassau County indicates that nitrate concentrations have stabilized or are decreasing in concentration. Nitrate concentrations in shallow wells in southwestern Suffolk are generally increasing.

4. For the period 1972–76, median concentration of nitrate-nitrogen in Nassau exceeded eight milligrams per liter in the Magothy aquifer in six of 40 selected wells at depths of less than 200 feet; in five of 115 wells at 200 to 399 feet; in four of 174 wells at 400 to 599 feet; and in zero of 38 wells below 599 feet. Most well water exceeding eight milligrams per liter nitrate-nitrogen is in central Nassau.

5. On the basis of other recent studies, nitrate in water from most Magothy wells in Nassau appears to be increasing.

6. Evidence suggests that regional hydrologic and geologic factors are important in controlling the movement of contaminants from the surface to the Magothy aquifer. The present distribution of nitrate and chloride levels in the Magothy indicates that certain broad areas are more susceptible to pollution from the surface than other areas. In general, the southern portion of much of both counties appears to be an area in which shallow ground water flow helps protect the middle and lower Magothy from sources of contamination by restricting downward movement of water into the Magothy.

7. Despite the relatively low mobility of heavy metals in soils, low concentrations of such constituents (below EPA Interim Primary Drinking Water Standards) are widespread in shallow ground water. Elevated levels of some metals also exist in certain Magothy wells.

8. In most areas, the Lloyd aquifer is protected from contamination within any reasonable planning period by the overlying Raritan clay. There is water quality evidence, however, that suggests some degree of hydraulic connection with shallow deposits in portions of the north shore of Nassau County.

9. Special studies conducted as part of the Long Island 208 program included a virus survey and an investigation of the presence or probable absence of organic chemicals in ground water. Enterovirus species were not isolated in the few samples of ground water obtained from public supply wells. Sampling for organic chemicals, however, has revealed the presence in ground water of substituted benzene compounds, napthalenes and various butyl-phthalates. Volatile organic compounds were also detected at parts-per-billion concentrations.

10. Evaluation of water quality conditions in the Long Island 208 region is difficult because of the lack of monitoring programs designed to answer specific waste water management questions pertaining to such subjects as the inter-aquifer migration of organic and inorganic chemicals, the local and regional impact of various densities of domestic waste disposal systems on ground water quality, and the position of the fresh water/salt water interface offshore.

2.3.3 Water Table Aquifer

2.3.3.1 Geology and Aquifer Characteristics. The water table or uppermost aquifer on Long Island receives most of the contaminants originating at the land surface. This aquifer consists primarily of Upper Glacial deposits and includes some sediments of the Magothy formation, the Manetto gravel and recent deposits. Because it is shallow, the aquifer has become contaminated to various degrees and, in some places, is unsuitable for use as a source of potable water supply. The ground water found in these sediments is of special importance because in many areas it supplies water to the deeper Magothy formation, and over a long period of time recharges the Lloyd aquifer. In addition, streams in Nassau and Suffolk Counties are largely dependent on flow from shallow ground water and closely reflect its quantity. Significant input to the bays and to salt water bodies is also derived from the water table aquifer by underflow.

To a large degree, the surficial geology influences the rate at which water infiltrates into the ground and percolates down to the water table. For example, outwash deposits make up most of the southern portion of the island. These sediments are very permeable sands and gravels, with an estimated average horizontal hydraulic conductivity of about 270 feet per day (Franke, 1972). Vertical permeability is estimated to average about 27 feet per day. Specific capacities of wells are usually more than 50 gallons per minute per foot of drawdown. In contrast, where deposits of clay and till are found, they impede infiltration and downward percolation of water, and locally may create perched water conditions. Two documented cases of widespread perched conditions include the Glen Cove-Brookville-Syosset area (Isbister, 1966), and parts of the Huntington-Smithtown area (Lubke, 1964).

Once the water enters the saturated section of the aquifer, movement is controlled by natural and artifical flow operating in the system. In general, water in the shallowest aquifer near the ground water divide of the island has potential gradients which tend to carry some of the water vertically downward to the deepest part of the Magothy. South and north of this zone, water in the shallow deposits flows with vertical and horizontal components that result in some water moving into the middle portion of the Magothy. Farther toward the coastlines, circulation becomes shallower until, at some point, flow is essentially horizontal in the water table aquifer. A detailed study of the shallow ground water flow system or subsystem of East Meadow Brook showed that it might take 25 to 30 years to fully flush this subsystem of the water in storage (Franke, 1972). Ground water flowing between stream subsystems could take somewhat longer to reach salt water bodies.

Based on estimated flow rates in the Upper Glacial aquifer, the quality of water yielded by many shallow wells now reflects the quality of water that has entered the ground water system since the late 1940's. The exact age of water at these wells is probably extremely variable, depending on depth, location, permeability of the sediments at the particular site and the influence of pumping.

2.3.3.2 Ground Water Quality. Recharge to the water table aquifer is dependent upon precipitation, which has chemical characteristics of its own by the time it reaches the land surface. A study in 1974 reported values of selected constituents in rainwater at Upton, Mineola and Medford (Frizzola, 1974). Of particular interest are pH, with average values of 4.41 to 5.08, and total nitrogen, with average values of 0.51 to 1.14 milligrams per liter. Average values of the major constituents are given in Table 2–4.

Background or non-degraded quality of fresh ground water in the shallow sediments of Nassau and Suffolk Counties is very good. In general, the water can be characterized as soft, mildly corrosive, and in some cases, somewhat high in iron and manganese. A study conducted at Brookhaven National Laboratory, which classified various types of ground water and surface water at that site, reported the chemical composition for background shallow ground water (see Table 2–6).

Table 2–6

CHEMICAL COMPOSITION OF BACKGROUND SHALLOW GROUND WATER AT BROOKHAVEN NATIONAL LABORATORY (DeLaguna, 1966)

(All concentrations except pH and conductance in milligrams per liter).

Silica	8
Iron	0.2
Calcium	2
Magnesium	1.5
Sodium	4
Potassium	0.6
Bicarbonate	9
Sulfate	8
Chloride	5
Nitrate (as N)	0.11
Dissolved solids	36
Specific conductance	50
pH	6.0

Over the past few decades, widespread effects of urbanization have considerably altered the quality of ground water in the water table aquifer. Many studies have detailed the extent and magnitude of these effects with particular attention paid to nitrate, detergent, chloride and to a lesser extent, sulfate. These constituents are generally good indicators of contamination, particularly from two very common sources: sewage and fertilizers. Median concentrations of these parameters, with the exception of detergents, in Nassau and Suffolk for the period 1972–76 are given in Table 2–7. DeLaguna reported the range of sulfate and chloride in "normal" water at Brookhaven

CONCENTRATIONS OF SELECTED CONSTITUENTS IN WELLS IN THE UPPER GLACIAL AQUIFER, 1972–76
(Based on Ragone, 1976)

	Median		Mean	Range		
Southwestern Nassau						
Nitrate (as N)	4.9	(159)	4.8	0.04	–	14
Chloride	28	(164)	43	6.6	–	950
Sulfate	44	(128)	47	5.0	–	120
Northern and Eastern Nassau						
Nitrate (as N)	3.0	(259)	4.3	0.00	–	36
Chloride	19	(309)	83	1.3	–	14,000
Sulfate	30	(259)	30	0.00	–	450
Suffolk						
Nitrate (as N)	1.4	(1,273)	2.3	0.00	–	23
Chloride	12	(2,047)	20	0.10	–	2,600
Sulfate	9.2		19	0.00	–	470

Note: The number in parenthesis indicates the number of analyses, concentrations in milligrams per liter.

to be 2.6 to 19 milligrams per liter, and 3.8 to 8.9 milligrams per liter, respectively (DeLaguna, 1964). It is likely, however, that these ranges include some slightly contaminated water.

Wells in the water table aquifer, which yield water showing distinct effects of contamination, are widely distributed throughout Nassau County and over much of Suffolk. The regional distribution of nitrate in central and southern Nassau during the period 1966–70, as reported by Perlmutter and Koch, is shown in Figure 2–21. Particularly high levels (greater than nine milligrams per liter nitrate-nitrogen) were found in the Elmont-New Hyde Park-Williston Park area, the Bellmore-East Meadow-Levittown-Hicksville area, and in several other locations. An examination of nitrate concentrations in the northern part of the county for the 1972–76 period, as reported by Ragone, shows high median values (greater than five milligrams per liter nitrate-nitrogen) in Bayville, in Syosset and in the area just east of Hempstead Harbor (Ragone, 1976a). During the period 1966–70, the average nitrate-nitrogen content of ground water in the shallow aquifer in central and southern Nassau was found to be 6.3 milligrams per liter in the sewered area, and 8.1 milligrams per liter in the unsewered area. The discrepancy between this data and that presented in Table 2–7 is probably due to the fact that the 1976 study included many deep Upper Glacial wells from the north shore in the unsewered area.

Nitrate in Suffolk County is well above background concentrations in the western portion of the county and elsewhere in the vicinity of densely populated areas. (Data in the central portion of western Suffolk, near Half Hollow Hills, however, is scarce.) Median concentrations of nitrate-nitrogen in the Babylon-Islip area, for instance, typically ranged from about two to ten milligrams per liter during the period 1972–76. Areas of present and past agricultural use, including the area north of Riverhead, the North Fork and parts of the South Fork, show high concentrations of nitrate. Many wells in these areas have median concentrations in the five to ten milligrams per liter range or greater for the period 1972–76. DeLaguna found that nitrate-nitrogen in private wells in potato farming areas of East Marion, Southold, Cutchogue, Mattituck, Riverhead, East Hampton and Sagaponack were betweeen 4.5 milligrams per liter and 27.1 milligrams per liter, with an average of about nine milligrams per liter.

Of special interest are those wells that recently have yielded water containing nitrate-nitrogen concentrations that exceed or are very close to exceeding the EPA standard of ten milligrams per liter. An examination of median levels in wells reported by Ragone for the period 1972–76 shows that nineteen wells of a total of 127 Upper Glacial wells sampled in Nassau County have median nitrate-nitrogen levels greater than eight milligrams per liter. Wells with high nitrate values are fairly widely distributed throughout the county, with the exception of the northwest portion where levels are slightly lower (Figure 2–22). During the period 1967–71, 42 wells sampled in Nassau County had median nitrate-nitrogen concentrations exceeding eight milligrams per liter.

In western Suffolk (west of Smithtown), nine wells of a total of 85 wells sampled yielded water with median concentrations above eight milligrams per liter. Most of these wells are in the southwest portion of the county (Figure 2–23). On the North Fork, six wells of a total of seven wells, and on the South Fork thirteen wells of 92 wells exceed eight milligrams per liter nitrate. Well water with a five year median nitrate greater than eight milligrams per liter has probably exceeded the ten milligrams per liter drinking water standard at some time during that period. Portions of the aquifer in the immediate vicinity of these wells, and possibly over broad areas around the wells, are unsuitable for development of potable water supplies without treatment.

It should be noted that nitrate-nitrogen in shallow ground water is not necessarily the same as total nitrogen. Significant amounts of ammonia may be present in certain areas, especially those with numerous septic systems and a high water table. In these cases, there has been insufficient time and travel for ammonia to become fully oxidized to the nitrate form.

Chloride and sulfate distributions in the water table aquifer have not been studied as extensively as nitrate. In many cases, they show similar

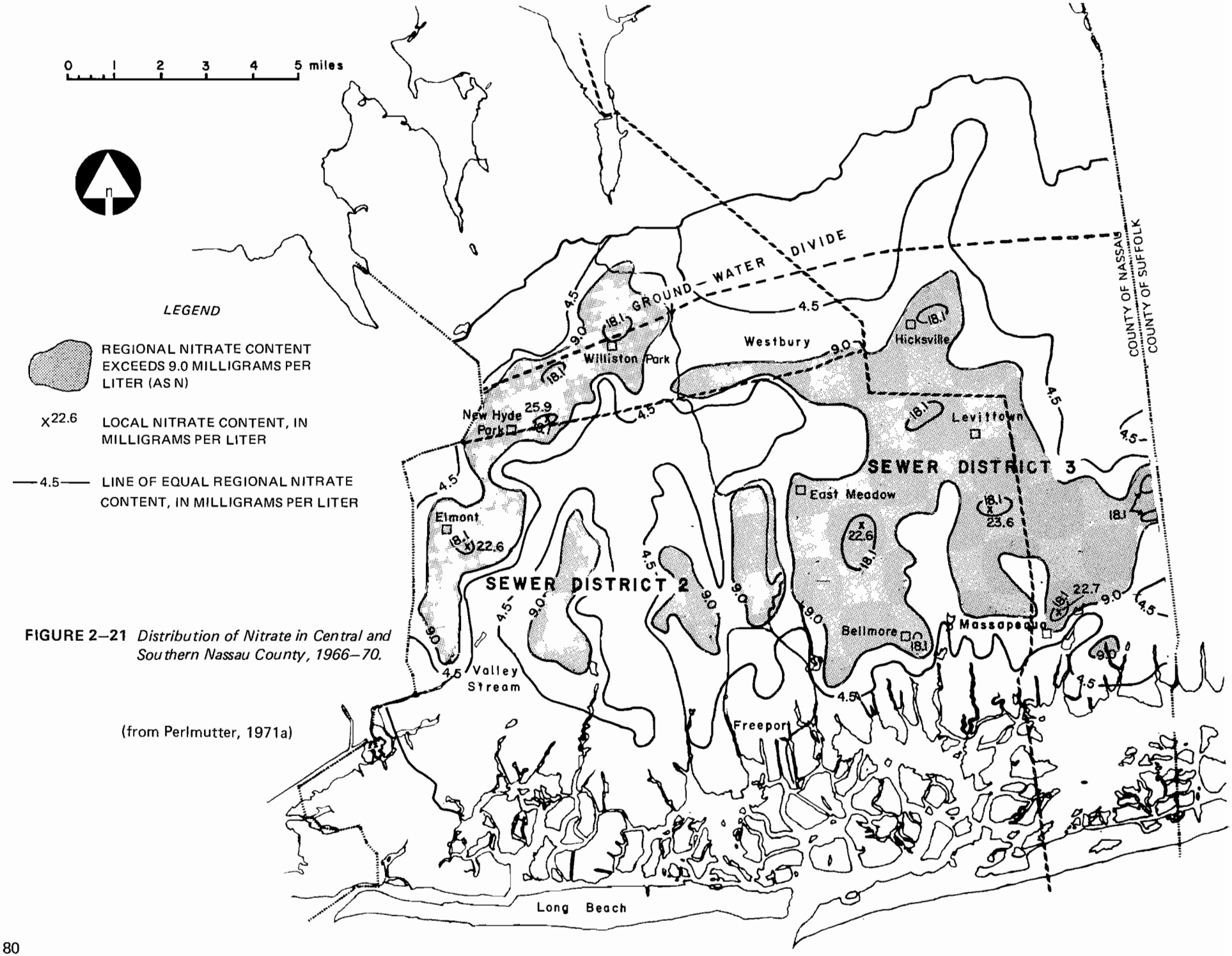


FIGURE 2–21 *Distribution of Nitrate in Central and Southern Nassau County, 1966–70.*

(from Perlmutter, 1971a)

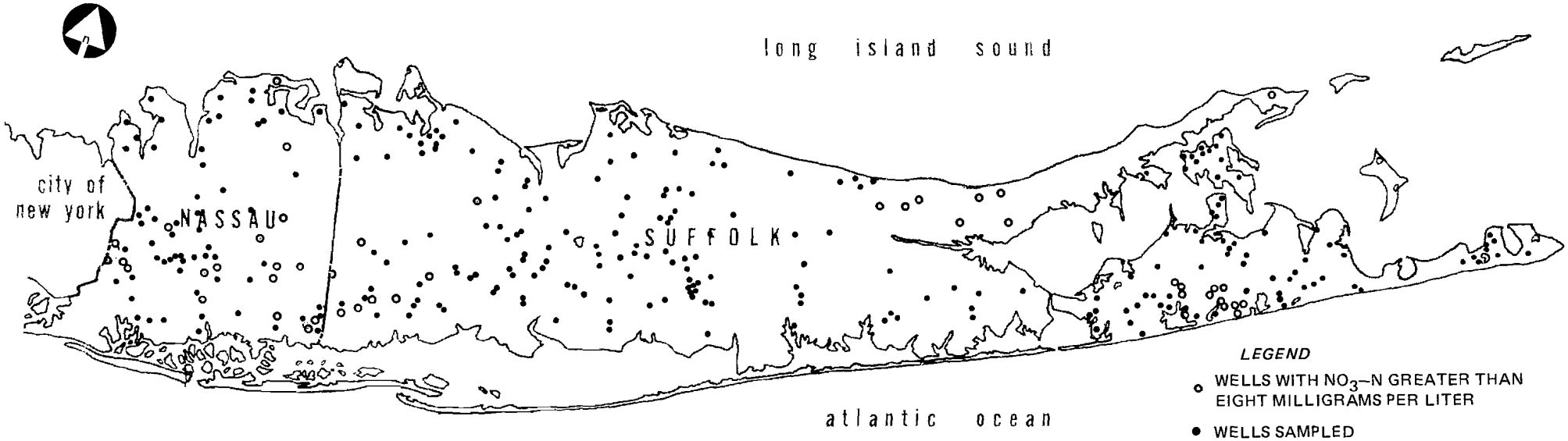
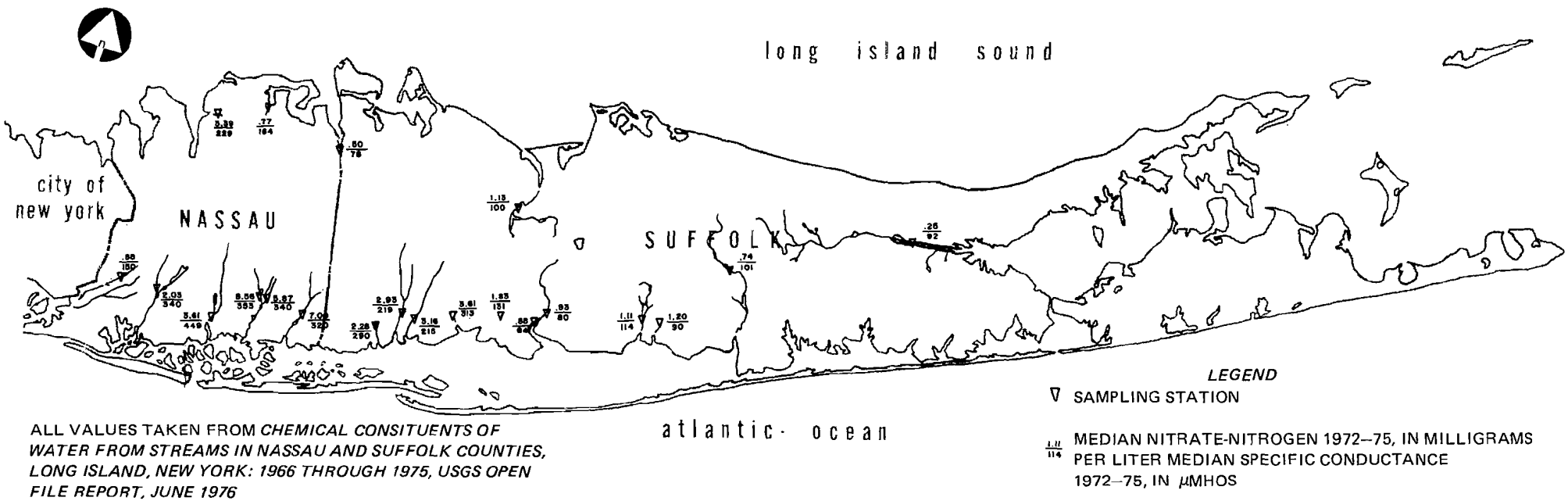


FIGURE 2–22 *Upper Glacial Wells with Median Nitrate Levels Greater than Eight Milligrams per Liter 1972–76.*



ALL VALUES TAKEN FROM *CHEMICAL CONSITUENTS OF WATER FROM STREAMS IN NASSAU AND SUFFOLK COUNTIES, LONG ISLAND, NEW YORK: 1966 THROUGH 1975, USGS OPEN FILE REPORT, JUNE 1976*

FIGURE 2–23 *Median Nitrate-Nitrogen and Specific Conductance Concentrations in Streams in Nassau and Suffolk Counties, 1972–75*

increases in areas where nitrate concentrations have also risen. Their ratios, however, may differ, depending on the pollution source. Unaltered water in the Babylon-Islip area has a chloride content of five to six milligrams per liter in areas more than about two miles inland from Great South Bay (Pluhowski, 1964). Closer to the bay, concentrations of ten to fifteen milligrams per liter are common. This general relationship probably applies to many areas in Nassau and Suffolk Counties.

An especially good indication of the quality of shallow ground water in southeastern Nassau is reflected by the chemical analyses of water from the infiltration galleries in Wantagh and Massapequa. These galleries make up part of New York City's Ridgewood System which extends along southern Nassau County. During the period 1961–75 the range in concentrations of selected constituents was found to be as follows (Sulam, 1977b):

	Wantagh Area	Massapequa Area
Nitrate (as N)	6.9 – 9.2	4.2 – 7.8
Chloride	23 – 44	22 – 43
Total Solids	190 – 249	188 – 228
Hardness (as $CaCO_3$)	73 – 94	44 – 88
Alkalinity (as $CaCO_3$)	38 – 87	32 – 64

Sulam and Ku report a recent leveling or decrease in nitrate trends in the Wantagh and Massapequa infiltration galleries located in unsewered southeastern Nassau County (Sulam, 1977b).

2.3.3.3 Trends of Ground Water Quality. Trends in nitrate from well water in the water table aquifer in Nassau are difficult to characterize on a broad basis because of the many sources and variables involved. Perlmutter and Koch (1971a) examined long-term trends of ten public supply wells in the Upper Glacial aquifer for the period 1955 to 1970 in Sewer District Two. Seven of the ten wells showed net nitrate-nitrogen declines ranging from 0.9 to 5.9 milligrams per liter, and averaging 3.8 milligrams per liter. The nitrate content of water in the other three wells showed no significant net change during the same period.

Statistical analyses of nitrate in selected wells throughout Nassau and Suffolk Counties were performed as part of the 208 program. Trends in nitrate are important not only in themselves, but also because associated contaminants may follow similar trends. The characteristics of wells selected for analysis were as follows:

a) relatively shallow depth, near the top of the saturated section
b) at least ten chemical analyses available
c) at least four years of analyses available (many of the wells have been sampled for ten to twenty years).

The nitrate-nitrogen levels for each well versus the time of sampling were plotted. This data was then matched to a polynominal regression up to and including a cubic equation. The equations were tested for statistical significance using the F Test (Fisher Index) beginning with the linear first, the quadratic second and the cubic third. In over half the cases, the test was significant at the 0.05 level, and the regression line explained the observed data reasonably well. The line was then examined for trends. Those wells showing statistically significant trends are given in Tables 2–8, 2–9, 2–10 and 2–11. Their locations are shown on Figure 2–24. Boundaries of sewered areas are included on this figure for reference.

Of 21 wells in Sewer District Two in Nassau, thirteen show decreasing trends of nitrate. Four have increasing trends. The median change in nitrate per year for all seventeen wells that have trends is –0.34 milligrams per liter. Eight of the wells indicate a similar pattern of increasing and then decreasing concentrations. The time of inflection, or change, from negative to positive

Table 2–8
NITRATE TRENDS IN WELLS IN SEWER DISTRICT TWO

Well	Depth	Number of Analyses	Period of Trends	ΔN (mg/l)	ΔN Year	Degree of Regression	Last N of Regression Line (year)
N–14	103	24	52–59	+ 2.1			
			59–74	– 9.2	– 0.61	2	3.8(1974)
N–15	101	21	52–60	+ 2.1			
			60–74	– 7.4	– 0.53	2	4.7(1974)
N–75	24	24	52–58	+ 1.7			
			58–75	– 4.7	– 0.28	3	1.6(1975)
N–91	82	10	57–65	– 1.5	– 0.19	1	1.0(1965)
N–693	98	41	52–75	– 4.4	– 0.19	1	9.2(1975)
N–1167	25	19	66–72	+ 1.7			
			72–76	– 1.4	– 0.35	2	2.8(1976)
N–1428	24	13	66–72	+ 2.4	+ 0.40	1	5.1(1972)
N–2115	87	18	52–69	– 6.3			
			69–74	+ 0.7	+ 0.14	2	8.9(1974)
N–2414	89	22	52–59	+ 0.6			
			59–73	– 2.6	– 0.19	2	6.0(1973)
N–3722	80	21	52–61	+ 2.7			
			61–73	– 4.8			
			73–74	+ 0.8	+ 0.80	3	5.4(1974)
N–4077	90	25	54–62	+ 2.4			
			62–74	– 6.2	– 0.44	2	0.2(1974)
N–5155	90	17	55–66	+ 2.9			
			66–74	– 4.3	– 0.54	2	4.4(1974)
N–6744	94	15	60–74	– 4.8	– 0.34	1	5.3(1974)
N–8149	40	12	66–71	+ 11.7	+ 2.34	1	12.9(1971)
N–8235	53	13	66–76	– 4.8	– 0.60	1	7.3(1976)
N–8396	41	13	67–75	– 5.9	– 0.74	1	6.8(1975)
N–8395	23	12	67–71	– 8.2	– 2.10	1	4.5(1971)

Note: Four wells did not have statistically significant trends.

Table 2–9
NITRATE TRENDS IN WELLS IN SEWER DISTRICT THREE

Well	Depth	Number of Analyses	Period of Trends	ΔN (mg/l)	ΔN Year	Degree of Regression	Last N of Regression Line (year)
N–1201	29	11	66–72	– 14.7			
			72–76	+ 0.6	+ 0.15	2	0.6(1976)
N–2402	85	18	52–54	– 1.3			
			54–63	+ 7.5			
			63–68	– 8.1	– 1.62	3	2.8(1968)
N–3564	69	19	52–59	– 1.3			
			59–71	+ 6.4	+ 0.53	2	14.4(1971)
N–7696	29	15	64–72	– 3.9	– 0.49	1	3.3(1972)
N–7699	30	14	66–70	– 4.8			
			70–72	+ 2.1	+ 1.05	2	1.0(1972)

Note: Six wells did not have statistically valid trends.

Table 2–10
NITRATE TRENDS IN WELLS IN NORTHERN NASSAU COUNTY

Well	Depth	Number of Analyses	Period of Trends	ΔN (mg/l)	ΔN Year	Degree of Regression	Last N of Regression Line (year)
N–28	136	21	57–75	– 0.4	– 0.02	1	0.5(1975)
N–29	207	21	57–75	+ 0.9	+ 0.05	1	1.0(1975)
N–37	140	27	54–56	– 0.5			
			56–71	+ 3.7			
			71–76	– 1.8	– 0.36	3	3.8(1976)
N–585	78	18	54–60	+ 0.9			
			60–72	– 1.2			
			72–74	+ 0.3	+ 0.15	3	1.8(1974)
N–901	68	12	52–74	+ 5.6	+ 0.25	1	9.0(1974)
N–3486	102	16	54–61	+ 0.1			
			61–67	– 0.2			
			67–71	+ 0.6	+ 0.15	3	2.0(1971)
N–3540	207	21	57–73	– 2.5	+ 0.16	1	3.2(1973)
N–4860	93	25	57–75	+ 2.4	+ 0.13	2	3.1(1975)
N–6087	95	23	57–72	+ 2.3			
			72–75	– 0.3	– 0.10	2	3.2(1975)
N–7643	218	26	65–75	+ 13.5	+ 1.35	1	20.1(1975)
N–735	100	12	60–67	– 0.7			
			67–74	+ 1.2	+ 0.17	2	2.5(1974)

Note: Two wells did not have statistically valid trends.

Table 2–11
NITRATE TRENDS IN WELLS IN SUFFOLK COUNTY

Well	Depth	Number of Analyses	Period of Trends	ΔN (mg/l)	ΔN Year	Degree of Regression	Last N of Regression Line (year)
S–871	104	20	63–69	– 0.4			
			69–76	+ 0.5	+ 0.07	2	0.7(1976)
S–2405	88	11	72–76	+ 1.5	+ 0.38	1	1.6(1976)
S–3813	83	23	63–76	+ 2.1	+ 0.16	1	2.3(1976)
S–3814	90	23	63–76	+ 1.9	+ 1.50	1	2.2(1976)
S–10641	62	17	63–76	+ 3.1	+ 0.24	1	3.8(1976)
S–12143	116	12	61–64	– 0.54			
			64–73	+ 3.9	+ 0.43	2	4.1(1973)
S–13558	106	13	63–73	+ 3.2	+ 0.32	1	3.2(1973)
S–14218	85	20	63–73	+ 2.1			
			73–76	– 0.2	– 0.01	2	2.3(1976)
S–15500	149	19	63–76	+ 1.5	+ 0.12	1	1.5(1976)
S–15501	160	19	63–76	+ 0.6	+ 0.05	1	0.8(1976)
S–18621	201	22	60–76	+ 0.8	+ 0.05	1	0.8(1976)
S–19554	105	22	62–66	– 0.4			
			66–76	+ 7.3	+ 0.73	2	7.7(1976)
S–20045	140	10	61–75	+ 0.5	+ 0.03	1	0.8(1976)
S–20057	200	19	65–76	+ 0.1	+ 0.01	1	0.1(1976)
S–20479	128	16	62–67	+ 4.0			
			67–72	– 0.6			
			72–76	+ 0.6	+ 0.15	3	4.0(1976)
S–20591	150	13	72–76	– 9.4	– 2.35	1	9.4(1976)
S–22494	118	10	72–74	+ 2.0			
			74–76	– 3.8	– 1.90	2	1.2(1976)
S–24047	132	16	65–76	+ 3.1	+ 0.28	1	3.2(1976)
S–26490	110	22	62–76	+ 4.8	+ 0.34	1	3.8(1976)
S–31913	160	13	68–76	+ 0.8	+ 0.10	1	1.2(1976)
S–34522	149	12	70–76	+ 0.8	+ 0.13	1	0.9(1976)
S–38917	–	10	72–76	0.0	0.0	1	0.1(1976)
S–47226	27	13	73–75	– 0.2			
			75–76	+ 0.1	+ 0.10	2	0.05(1976)
S–48946	45	13	73–76	– 5.3	– 1.77	1	1.5(1976)

Note: Wells S–20057 and S–38917 yield water at background concentrations. Nineteen wells did not have statistically valid trends.

slope occurred during the late 1950's or early 1960's in most of these wells and does not appear to be a drought related phenomenon. The change corresponds with large scale sewer construction which started in the early 1950's and was completed in 1964. Well 8149 shows an anomalous increasing trend, probably the result of a nearby source of contamination.

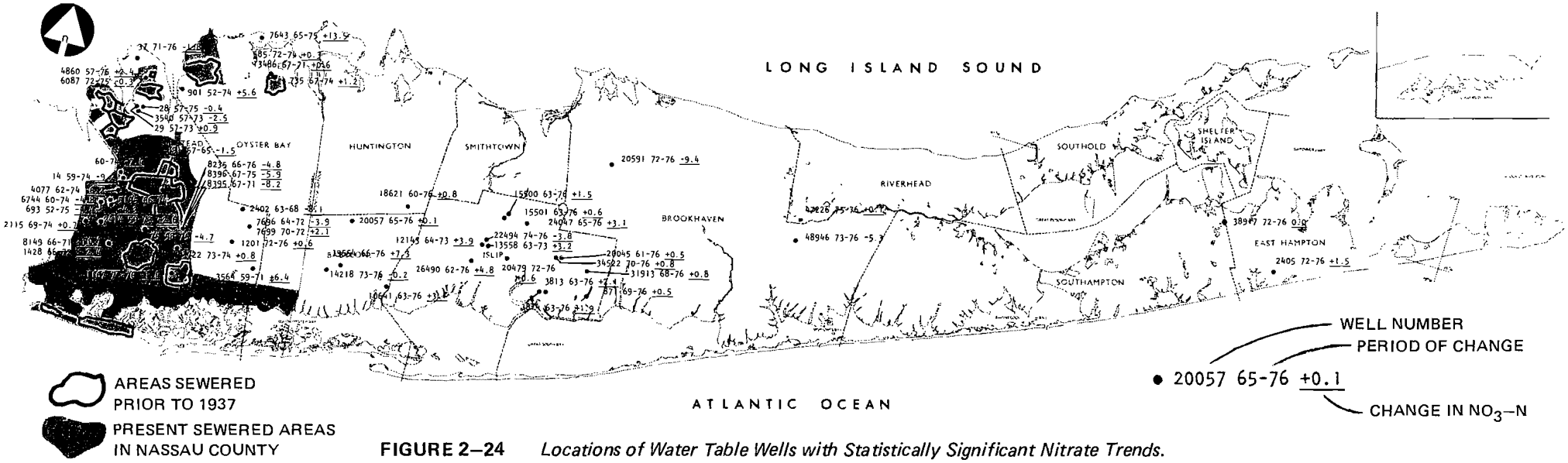


FIGURE 2–24 *Locations of Water Table Wells with Statistically Significant Nitrate Trends.*

Despite generally decreasing trends of nitrate in wells in Sewer District Two, the actual concentrations in some wells are still quite high. Possible explanations for this are (1) the sewers are leaking, (2) the use of home fertilizers is such an important input that removal of on-lot disposal systems alone results in only a slow decrease in nitrate levels, or (3) insufficient time has elapsed for even shallow wells to be flushed of high nitrate water. Detailed studies presently underway by the Cooperative Extension Service of Cornell University suggest that the fertilizer explanation is a strong probability. Studies on sewer leakage are not available.

Applying the criteria used in this report, the data in eastern Nassau County (Sewer District Three) are not sufficient to reach any conclusions regarding nitrate trends. Water analyses from three wells show increasing trends; analyses from two show decreasing trends. Wells in northern Nassau County generally show either small increases or small decreases in nitrate concentration.

An indication of the effects of sewering on ground water quality is provided by ongoing studies of the U. S. Geological Survey (USGS, 1977). Preliminary findings of continued evaluation of the information obtained during the preparation of the Ragone report for the 208 program (Ragone, 1976a) reveals significantly lower median concentrations of ammonia in shallow ground water underlying Sewer District Two compared to shallow ground water in Sewer District Three in Nassau County. Again, sewering was undertaken in District Two during the 1950's, whereas the installation of sewers in District Three is still underway. In addition, an evaluation of water quality trends in only the very shallow glacial deposits in Sewer District Two and Sewer District Three indicates stronger decreasing trends of nitrate in the former. These preliminary findings are indications of the results of a reduction in nitrate loading, apparently due to sewering.

Analyses of samples from 22 out of 43 water table wells in Suffolk that yield water with nitrate-nitrogen concentrations above background levels show significant nitrate trends. Of eighteen wells that show trends in south western Suffolk (Babylon and Islip), sixteen show increasing trends of nitrate – an indication of deteriorating water quality. The period of record for most of these wells started in the 1960's. For purposes of comparison, southwestern Suffolk is of interest because it is hydrologically similar to Sewer District Two. Recent land use is also similar, although development took place some years later. The 1960 census for the Town of Babylon indicates population densities ranging from 1.24 to 10.5, with an average of 4.5 persons per acre. The median change in nitrate per year in the eighteen wells in this part of Suffolk is +0.13 milligrams per liter. This suggests that the transition from a rural, partly agricultural area to an unsewered residential area may result in increasing nitrate in the shallow ground water.

2.3.3.4 Stream Quality. The quality of stream flow is a general indicator of the chemical nature of shallow ground water, since it is estimated that in many cases over 90 percent of the total discharge is actually ground water (Seaburn, 1969). Possible exceptions to this are streams in southwestern Nassau which receive more than ten percent of their flow from surface runoff as a result of urbanization (Vaupel, 1968). As part of the 208 program, median nitrate and specific conductance concentrations from 1972 to 1975 for many streams were computed and compared. Specific conductance is an indirect measure of the sum total of the major cations and anions, including nitrate, in the water. Its level is typically less than 50 μmhos in uncontaminated water on Long Island. A number of general conclusions can be drawn as a result of this analysis (see Table 2–12 and Figure 2–23):

1. Streams with the highest nitrogen and total dissolved solids are in southeastern Nassau County.
2. Stream water quality in southwestern Nassau County may indicate beneficial effects of sewering.
3. The general stream quality becomes better as one moves from southwestern to eastern Suffolk.
4. The ratios of nitrate-nitrogen to specific conductance vary considerably for different streams and indicate that different sources of pollution, in addition to sewage or fertilizer, are likely in certain areas.

Detailed examination of the data and correlation to given drainage areas could lead to more specific conclusions. For instance, the specific conductance in East Meadow Brook is unusually high and indicates a source of dissolved solids, possibly from road salt contamination. Other streams with fairly high specific conductance, but quite low ratios of nitrate to conductance, include Mill Neck Creek, Valley Stream and Pines Brook. It should be noted, however, that a small portion of nitrogen species in certain streams may be in the form of ammonia.

A qualitative assessment of trends of stream quality, in terms of nitrate and specific conductance, for the period 1966 to 1975, leads to several conclusions (Ragone, 1976b). Almost all streams in Nassau County show either no or very minor apparent trends. A number of streams, mostly in Suffolk, show minor or variable trends in nitrate, but slight to strong positive (upward) apparent trends in specific conductance. These streams include the Santapogue Creek, Carlls River, Sampawams Creek, Penataquit Creek, Champlin Creek, Connetquot River distributary, Lake Ronkonkoma, Nissequogue River and Cold Spring Brook. The Connetquot River shows an upward apparent trend in nitrate, but no or low apparent trend in specific conductance. The Patchogue River, Swan River and Carmans River show apparent upward trends in nitrate and specific conductance. The Peconic River shows no or low apparent trends of both constituents.

2.3.3.5 Detergents. Detergents have been widely studied in Nassau and Suffolk Counties, particularly with regard to domestic sewage. Prior to mid-

Table 2–12

QUALITY OF NASSAU AND SUFFOLK STREAMS

Stream	Median Nitrate-Nitrogen (mg/l) 1972–75	Median Specific Conductance (μmhos) 1972–75
North Shore (Nassau and Suffolk)		
Glen Cove Creek	3.39 (11)	228 (14)
Mill Neck Creek	0.77 (26)	164 (35)
Cold Spring Brook	0.50 (12)	76 (13)
Nissequogue River	1.13 (8)	100 (12)
Southwestern Nassau		
Valley Stream	0.88 (6)	150 (9)
Pines Brook	2.03 (9)	340 (11)
Southeastern Nassau		
East Meadow Brook (tributary)	3.61 (28)	449 (38)
Bellmore Creek (tributary)	8.58 (10)	353 (14)
Bellmore Creek	5.87 (12)	340 (14)
Massapequa Creek	7.00 (31)	320 (36)
Southwestern Suffolk		
Santapogue Creek	2.26 (13)	290 (15)
Carll's River	2.93 (14)	215 (16)
Sampawams Creek	3.16 (15)	215 (17)
Penataquit Creek	3.61 (14)	313 (17)
Champlin Creek (Oakdale)	1.85 (14)	151 (16)
Connetquot River	0.93 (12)	80 (15)
Connetquot River (North Great River)	0.88 (12)	84 (14)
Southeastern and Eastern Suffolk		
Patchogue River	1.11 (10)	114 (4)
Swan River	1.20 (10)	90 (12)
Carman's River	0.74 (29)	101 (36)
Peconic River	0.25 (12)	92 (24)

Note: The number in parenthesis indicates the number of analyses.

1965, ABS (alkyl benzene sulfonates) were a principal ingredient of detergents. They were replaced in household detergents by LAS (linear alkyl sulfonates), surfactants that are more biodegradable. In March 1971, Suffolk County prohibited the sale of most detergent products. Both LAS and ABS are detected by the methylene-blue test and are reported as MBAS (methylene blue active substance). Detergents, in themselves, are not known to be harmful, but serve as a good indicator of sewage related contamination and may render water supplies aesthetically undesirable. Concentrations of 0.7 to 1.0 may cause foaming of water, especially if pH is adjusted upward. The U. S. Public Health Service (1962) recommends that the concentration of MBAS not exceed 0.5 milligrams per liter.

A study of detergents in the central and southern parts of Nassau during the period 1966–70 showed that the area comprising the southern quarter of the county had detergent levels of 0.3 to two milligrams per liter (Perlmutter, 1971). The region to the north of this had a range of 0.0 to 0.3 milligrams per liter. Similar ranges of synthetic detergents were found in detailed studies in southwestern Suffolk County (Perlmutter, 1970).

An analysis of linear trends of both detergents and ammonia in water from eighteen Upper Glacial and shallow Magothy wells in Nassau County during the period 1960 to 1972 (Myott, 1975), showed that a decrease in detergents in both unsewered and sewered areas had occurred with a more negative trend for detergents in the sewered area. The trend line of ammonia was negative in the sewered area but was slightly positive in the unsewered area. Apparently, only the detergent trend line in the unsewered area was statistically significant. This analysis concluded that (1) both ammonia and detergents are decreasing in the sewered area as a result of sewering, and (2) detergents are decreasing in the unsewered area because the newer types of detergents are more biodegradable.

A similar study in the southwest portion of Suffolk County for the period 1968–74 showed an indication of decreasing detergents in shallow supply wells and streams while chloride was generally increasing (Baier, 1976). This decrease may be due to the detergent ban and increased biodegradability of newer detergents. Ragone found a general increase in chloride concentration in the last fifteen years in almost every stream examined in Suffolk County (Ragone, 1976c). Conversely, concentrations of MBAS decreased in many cases. Again, this difference is generally attributed to the change in the type of detergent and the 1971 detergent ban.

2.3.3.6 Heavy Metals and Pesticides. Investigations of heavy metals in ground water on Long Island have been much less extensive than those of the standard constituents. The 208 program summarized the available data to identify the occurrence and distribution of heavy metals. All ground water samples analyzed for heavy metals and listed in the U. S. Geological Survey STORET System as of February 1977, were reviewed at two levels of significance. The first is the EPA Interim Primary Drinking Water Standards recommended limits, for those constituents with established limits. The second is a much lower concentration, arbitrarily chosen to represent a very low level that is significantly above background concentrations in the majority of wells. At least 90 percent of the analyses are at concentrations below the lower limit.

The metals included in this analysis and their respective concentrations used as limits are as follows:

	Lower Limit (mg/l)	EPA Interim Standards (Primary and/or Secondary) Upper Limit (mg/l)
Cadmium	0.001	0.010
Chromium	0.010	0.050
Cobalt	0.001	no standard
Copper	0.200	1.00
Lead	0.010	0.050
Mercury	0.0007	0.002
Selenium	0.001	0.010
Zinc	0.300	5.00

The lower limits range from four percent to 35 percent of the upper limits. The samples were reportedly all taken at the well head, prior to entering the distribution system. Copper and zinc contamination from pipes and fittings, which may occur from movement in the distribution system, should be at a minimum.

Extensive conclusions regarding the sources and distribution cannot be made on the basis of present data because the wells sampled are not equally distributed, and many have only been sampled once. In addition, a number of wells, such as the "I" wells drilled near the Town of Islip landfill, were purposely located near a source of contamination. It is apparent that despite the relatively low mobility of metals in soils, low concentrations of such constituents are present in the shallow ground water (see Figure 2–25). In Nassau, several well locations have low levels of a number of metals. In Suffolk, there is a greater number of analyses showing low levels. This is perhaps related to the greater number of samples taken. Several low levels of mercury are evident in southwestern Suffolk. Low levels of arsenic, selenium and other metals are common in eastern Suffolk. These may possibly be due to past use of inorganic pesticides and herbicides. Preliminary results of a 208 study by Energy Resources Company (ERCO) have shown that very low levels of most heavy metals are found in ground water within the bi-county area. Lead and mercury were the only heavy metals that were found in a number of samples at concentrations near or above EPA Interim Standards. However, zinc and copper were not included in the ERCO evaluation.

There are numerous sources of metals in the environment. Obvious sources are certain industrial discharges, landfills and storm water runoff. In addition, there is evidence that sewage from residential areas also contrib-

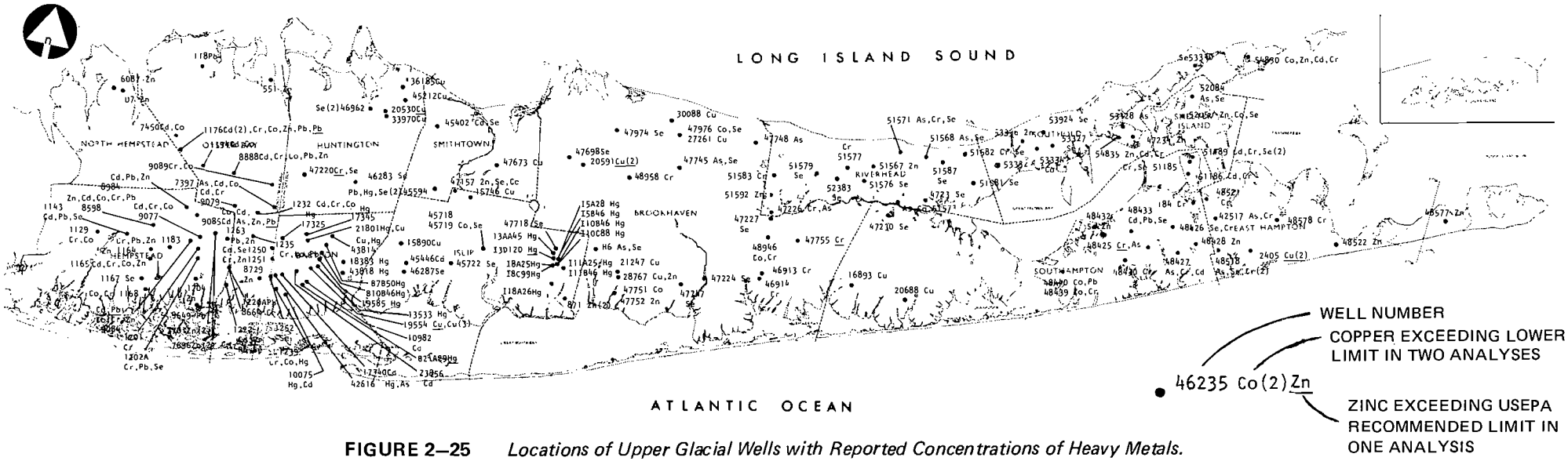


FIGURE 2–25 *Locations of Upper Glacial Wells with Reported Concentrations of Heavy Metals.*

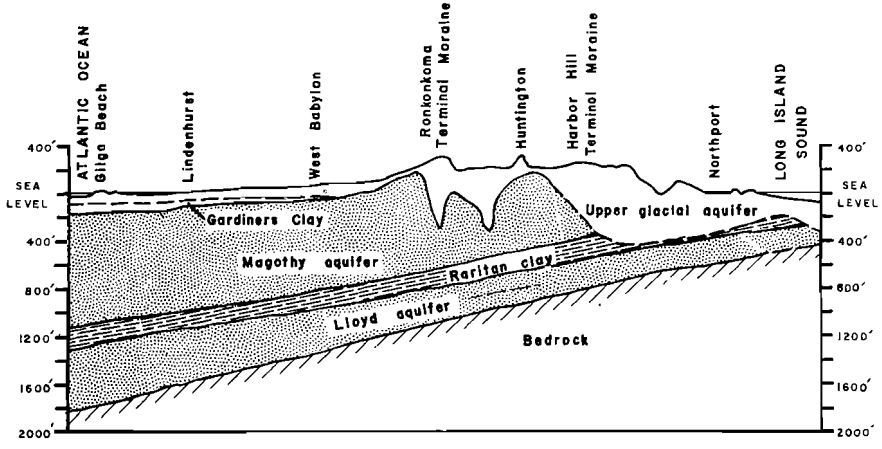
utes significant amounts of certain metals to the ground (Maher, 1974). Undoubtedly, some of these metals, such as copper and zinc, are dissolved from the water supply and waste water distribution system itself.

Several limited investigations of pesticides in ground water on Long Island have been undertaken in recent years. Harr presented analyses of 40 samples taken from selected wells in Nassau and Suffolk Counties in 1972 (Harr, 1972). Commonly used insecticides, herbicides and polychlorinated biphenyls were analyzed. Although no conclusions were reached, it is evident that the great majority of samples did not contain constituents in concentrations above the detectable limits. Another more comprehensive study investigated pesticides in 191 shallow test wells in Suffolk County (Baier, 1976a). Very few samples contained pesticides at detectable limits. Only one of these wells showed evidence of pesticides in replicate samples. It was concluded that pesticides should not be considered a major ground water pollution problem; although new products with higher solubilities, greater mobility or greater persistence, could be a problem in the future. It has also become apparent that some of the pesticides used on Long Island, such as aldicarb, may not have been included in the prior analyses.

2.3.4 Magothy Aquifer

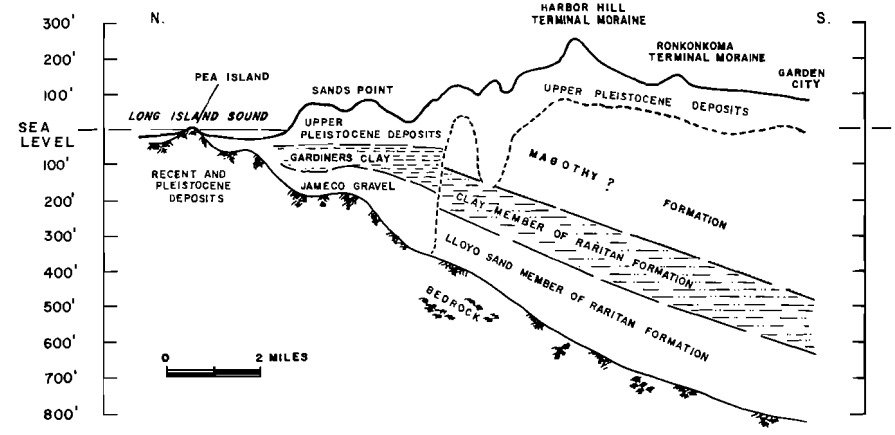
2.3.4.1 Geology and Aquifer Characteristics. The Magothy aquifer generally underlies the Upper Glacial aquifer with some outcropping at the surface. Magothy sediments are Cretaceous in age and of fluvial or deltaic origin. The aquifer is chiefly composed of undifferentiated deposits of coarse to fine sand and gravels with lenses of interbedded silts, clays and lignite. Its surface is highly irregular due to erosion by streams and glaciers. North-south trending buried valleys occur from Queens County eastward, verifying the idea that a substantial surficial drainage system existed some time after deposition occurred. The geology of the Magothy on Long Island has been mapped in greatest detail in Nassau County and western Suffolk County. A cross section through western Suffolk, illustrating several important regional geologic relationships is given in Figure 2–26.

The Magothy is absent in northwest Nassau County but increases in thickness to over 1,000 feet in the southern part of Suffolk County. Hydraulic conductivities vary widely, with the average horizontal conductivity estimated to be about 50 feet per day, while the average vertical conductivity is about 1.4 feet per day (Jensen, 1976). Consequently, specific capacities of wells also vary widely, from one to about 40 gallons per minute per foot of drawdown. Wells in the Magothy commonly yield in excess of 1,000 gallons per minute. Ground water in the aquifer may be poorly or well confined, depending on location. In areas where the overlying clays, such as the Gardiners clay, are laterally continuous and of substantial thickness, vertical movement between the water table aquifer and the Magothy is reduced. There are also many local clay lenses both above and within the Magothy which affect ground water flow. For instance, well logs in western Suffolk, north of the Ronkonkoma moraine, show several occurrences of thick, discontinuous clay



(from Jensen, 1976)

FIGURE 2–26 *Generalized Geologic Cross Section through Western Suffolk County.*



(from Swarzenski, 1963)

FIGURE 2–27 *Generalized Geologic Cross Section through Northwestern Nassau County.*

lenses up to 300 feet thick.

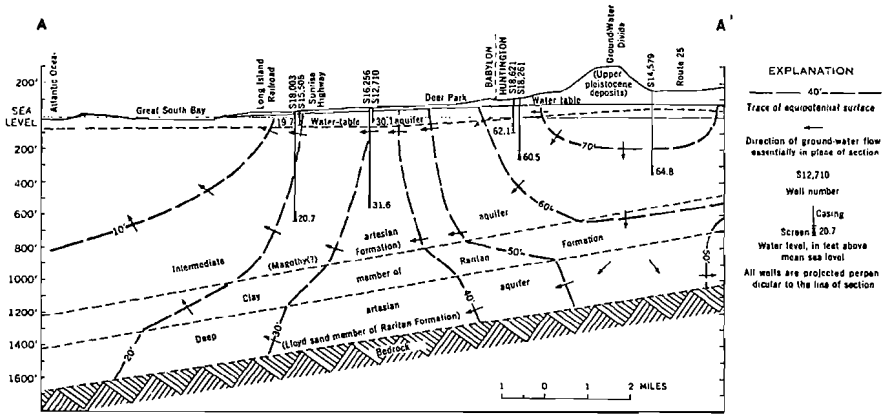
Along much of the north shore, the Magothy is entirely absent and has been replaced by Pleistocene deposits. In these areas, the Pleistocene deposits are often hydraulically connected to the Magothy aquifer at similar depths to the south. On Manhasset Neck and Great Neck, the Jameco gravel and Gardiners clay are thought to have replaced the Lloyd sand and Raritan clay, respectively (see Figure 2–27). However, it is unclear how extensive the Gardiners clay is in these areas. Swarzenski reports that, since little downward movement of water from the shallow unconfined aquifer seems probable on Manhasset Neck, because of highly impervious clay bodies, the principal aquifer (Magothy or equivalent) apparently receives much of its recharge by ground water from the south (Swarzenski, 1963).

In the central portion of Long Island, recharge to the Magothy from the water table aquifer occurs over a large area. The definition of this region is critical in trying to assess how chemical contaminants, introduced to the water table from the land surface, will tend to move in the ground water system.

Because of its shape, structure and geographic setting, Long Island has a rather unique ground water flow system, which can be broadly described on a regional basis. Ground water in the water table aquifer, near the spine of the island, is subject to hydraulic gradients which tend to carry some of the water vertically downward to the deepest part of the Magothy. To the south and north of this zone, water from the shallow deposit flows with vertical and horizontal components that result in some water moving into the middle portion of the Magothy. Farther toward the coastlines, circulation becomes shallower until, at some point, flow is essentially horizontal in both the water table and the Magothy aquifers. Beyond this area, water in the Magothy has a vertically upward component, while the water in the shallow deposits flows essentially horizontally until it discharges to streams or salt water bodies.

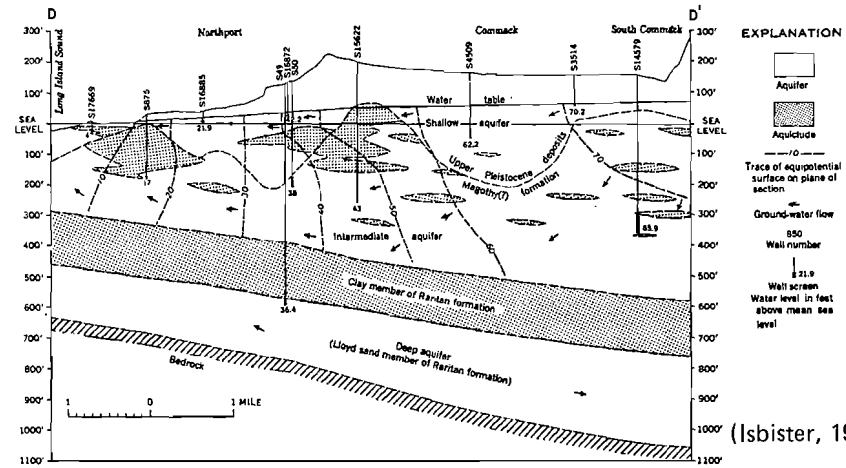
This general relationship is borne out in many of the more detailed studies undetaken by the U. S. Geological Survey over the past 30 years, and reported in Water-Supply Papers (see Figures 2–28, 2–29, 2–30 and 2–31). Under natural conditions, it takes about 100 years for water from the surface to reach the lower portion of the Magothy in the center of the island. The travel time to the barrier beach is about 800 years and to the north shore, about 400 years.

In order to further examine the concept of defining Magothy recharge and discharge areas, maps of the potentiometric water level surfaces in the lower Magothy and maps of the water table were overlain and compared for head differences. U. S. Geological Survey maps for 1966, 1972, 1974 and 1975 (Vaupel, 1977 and Kosalka, 1975) were examined, and the approximate areas of regional Magothy recharge and discharge for those years were interpreted and plotted (see Figure 2–32). The areas of generally negative head difference shown in Figure 2–32 are, for the most part, negative for each of the years examined, although the shape and size of these areas change some-



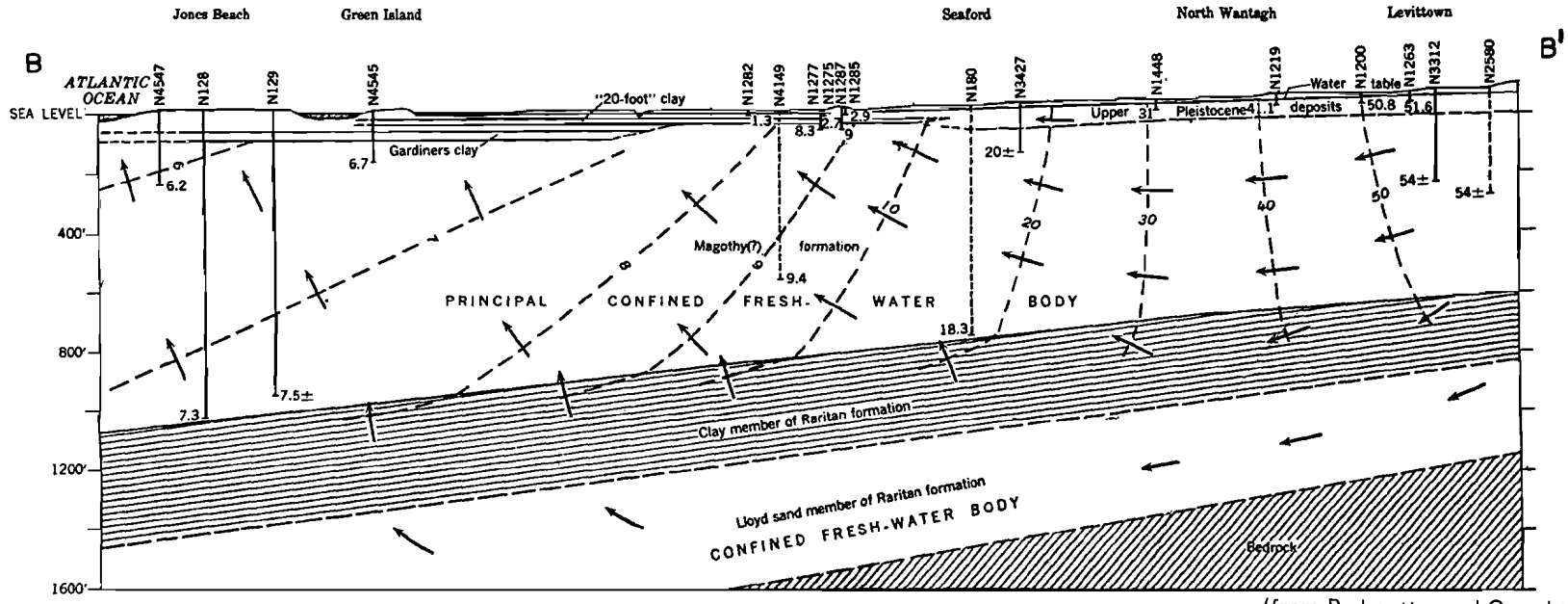
Source: Pluhowski, E.J. and I.H. Kantrowitz, 1964, "Hydrology of the Babylon–Islip Area, Suffolk County, Long Island, New York," USGS Water Supply Paper 1968.

FIGURE 2–28 *Approximate Hydraulic Profile of the Ground Water Reservoir Underlying the Babylon–Islip Area, October 1960.*



(Isbister, 1966)

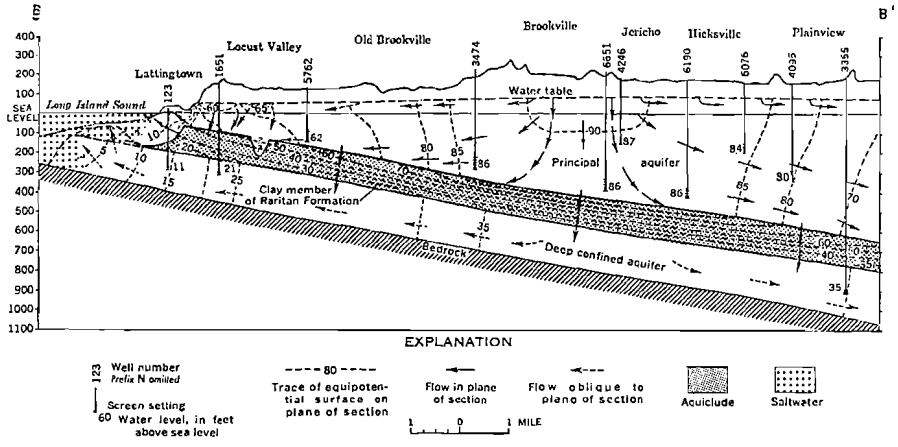
FIGURE 2–30 *Hydraulic Profile through Ground Water Reservoir from Northport to South Commack, New York, in May 1959.*



(from Perlmutter and Geraghty, 1963)

— — 40' — —	←		⊥	18.3	
TRACE OF EQUIPOTENTIAL SURFACE	DIRECTION OF GROUND WATER FLOW ESSENTIALLY IN PLANE OF SECTION	N180 WELL NUMBER	CASING	WATER LEVEL, IN FEET ABOVE MEAN SEA LEVEL	ALL WELLS ARE PROJECTED PERPINDICULAR TO THE LINE OF SECTION

FIGURE 2–29 *Hydraulic Profile Showing Probable Flow of Water in Magothy Aquifer in Southeastern Nassau County, New York, in 1954–55.*



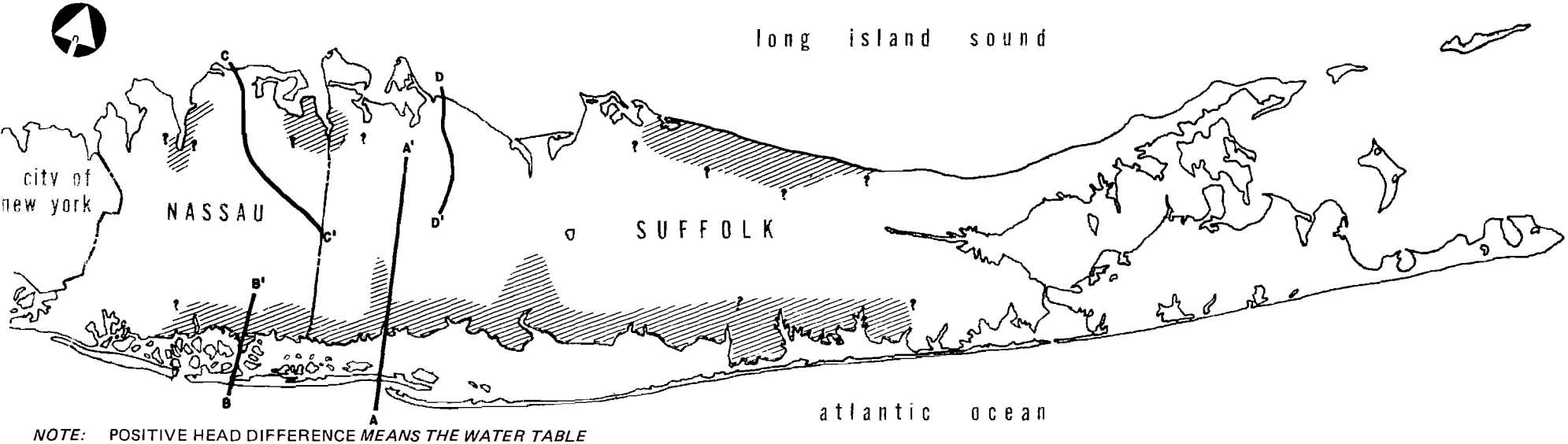
Source: Franke, O.L. and P. Cohen, 1972, "Regional Rates of Ground Water Movement on Long Island, New York," USGS Professional Paper 800–C.

FIGURE 2–31 *Hydraulic Profile through the Ground Water Reservoir from Lattingtown to Plainview, in March 1961.*

what from year to year. More detailed drilling and investigation of head relationships could define these areas further. Heads in the southwest corner of Nassau are very variable because of heavy local pumpage in Nassau and Queens. Undoubtedly, some other local reversals of gradient between the water table and Magothy occur in the immediate vicinity of supply wells in the discharge area.

Instances of hydraulic head relationships studied as part of two U. S. Geological Survey Water-Supply Papers, illustrate the type of data that can be obtained to specifically evaluate particular areas. In northwestern Nassau, heads in the lower part of the Magothy were found to be six to ten feet higher than the water table at corresponding sites near the southern ends of Little Neck Bay, Manhasset Bay and Hempstead Harbor (Swarzenski, 1963). This indicates upward flow from the Magothy is occurring in these areas.

In another study, head relationships between deep and shallow wells in southwestern Suffolk at a well station, near Sunrise Highway, were investigated (Perlmutter, 1976). The Upper Glacial and Magothy aquifers are reportedly not separated by distinct confining layers at this site. Under natural conditions, vertical components of flow betweeen the aquifers were found to be negligible, indicating that movement of significant quantities of water between aquifers is minimal. While pumping a deep Magothy well (495 feet deep) at 800 gallons per minute, observations were taken in two



NOTE: POSITIVE HEAD DIFFERENCE *MEANS THE WATER TABLE ELEVATION IS HIGHER THAN THE ELEVATION OF THE BASAL MAGOTHY POTENTIOMETRIC SURFACE AT A GIVEN POINT*

FIGURE 2–32 *Areas of Generally Positive or Negative Head Differences between Wells Screened in the Water Table and Lower Magothy Aquifers, Based on USGS Maps for 1966, 1972, 1974 and 1975.*

observation wells, an Upper Glacial well 23 feet deep and a well in the upper part of the Magothy 97 feet deep. Over several days of observations, there was no recorded drawdown in the 23 foot well. Therefore, little or no water was being induced downward from this depth as a result of pumping. Drawdown in the 97 foot well was less than 0.5 foot.

Geologic factors, such as the presence of confining clay layers, can influence head differences between the two aquifers and play an important role in determining whether there can be relatively easy inter-aquifer exchange of water. Deposits of low permeability, such as those found under the Port Washington peninsula and much of the Town of Smithtown, tend to impede downward flow, resulting in large head differences. The Gardiners clay, for instance, is a marine deposit of clay and silt, with some interbedded sand and gravel, which is quite extensive throughout the southern portion of both Nassau and Suffolk Counties (Figure 2–33). It is commonly found at depths of 50 or more feet below sea level. The thickness of the clay varies, but it is as much as 40 feet in Nassau (Ku, 1975) and 75 feet in Suffolk (Jensen, 1974). In addition, several other less extensive clay deposits are found above and below the Gardiners clay. The "20 foot" clay is found in parts of southern Nassau County at elevations of about 20 feet below sea level. Where there is a relatively good hydraulic connection between the aquifers, as in the Plainview and Bethpage areas, head differences are lower, but greater volumes of water from the water table aquifer reach the Magothy.

It should be noted that head differences between the water table and the lower Magothy at the same location differ somewhat from year to year. This is because the water level maps represent conditions at one point in time and not necessarily steady-state conditions. Thus, the magnitude of potential head differences within the Magothy recharge or discharge zones can not be evaluated by themselves to indicate their degree of importance, but must include the effects of other variables, principally geology and pumpage.

2.3.4.2 Ground Water Quality. The natural chemical quality of water within the Magothy is excellent and characterized by a very low dissolved solids content. Contamination of the Magothy is of great concern, since many public supply wells are screened in this formation. Past water quality investigations have dealt primarily with the distribution and trends of nitrate. From these studies, it has been established that many wells within the Magothy are pumping chemically altered, or contaminated, water.

The 1972–76 median concentrations of nitrate, chloride and sulfate in the various portions of the study area illustrate the relative degree of alteration (Table 2–13). Differences in concentrations of these constituents between the two specified areas of Nassau are probably not due to sewering. except possibly at the shallower depths. Other factors, such as location of wells with respect to past land uses, are probably more important. Those water quality

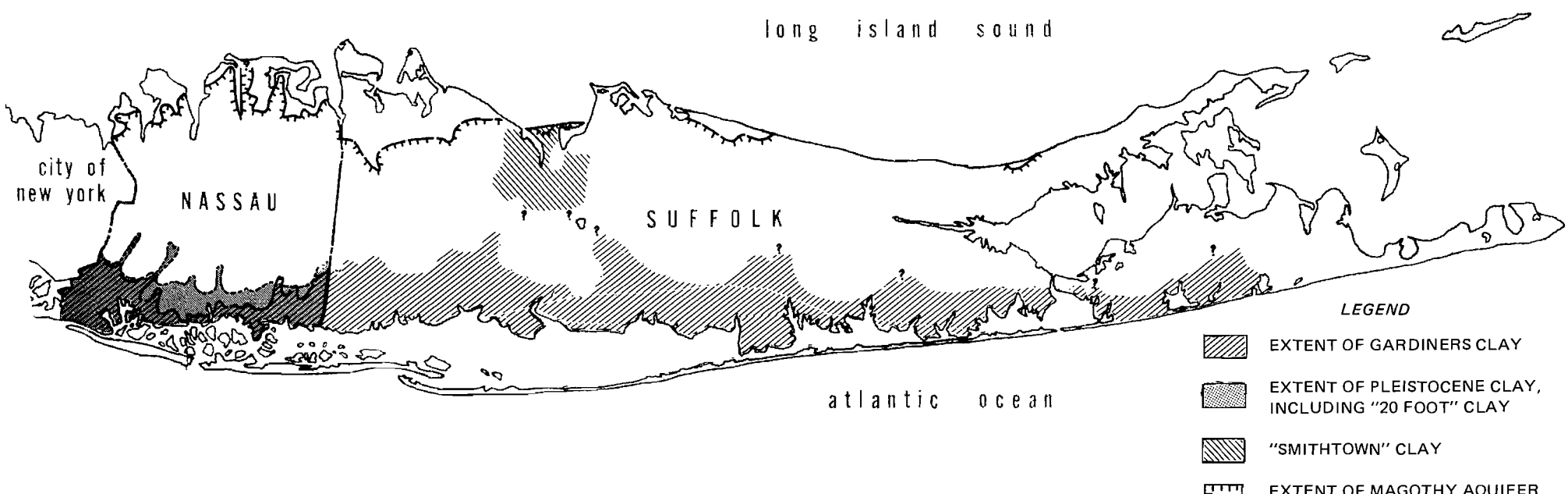


FIGURE 2–33 *Location of Selected Extensive Subsurface Clays.*

Table 2–13

1972–76 MEDIAN WATER QUALITY DATA IN THE MAGOTHY AQUIFER (Ragone, 1976)

Depth (feet)	Southwest Nassau		East and North Nassau		Suffolk	
Nitrate as N						
Less than 200	0.88	(18)	2.8	(104)	2.6	(4)
200 to 399	2.5	(130)	2.8	(443)	0.10	(263)
400 to 599	0.2	(526)	1.1	(515)	0.10	(391)
Greater than 600	0.01	(42)	0.13	(177)	0.01	(322)
Chloride						
Less than 200	18	(18)	13	(108)	14	(13)
200 to 399	12	(136)	10	(453)	5.0	(270)
400 to 599	6.4	(542)	5.8	(532)	4.5	(400)
Greater than 600	4.6	(42)	4.4	(179)	4.0	(355)
Sulfate						
Less than 200	32	(14)	22	(93)	2.6	(11)
200 to 399	13	(122)	7.0	(392)	3.2	(264)
400 to 599	5.0	(500)	2.0	(403)	3.2	(388)
Greater than 600	3.0	(39)	1.0	(159)	3.4	(399)

Note: Numbers in parentheses are the number of analyses. All concentrations in milligrams per liter.

trends now occurring in the water table aquifer, as discussed in the previous section, will undoubtedly be reflected in some way in the Magothy in future years. In general, the levels of contaminants decrease with depth until near-background concentrations are found in most wells greater than 600 feet deep. The apparent smaller value of nitrate reflected in the analysis of less than 200 foot deep wells of the sewered area may be due to insufficient sampling.

A question of principal interest is the extent to which the Magothy has been made essentially unusable by contamination. Organic chemicals, heavy metals and nitrate are of special interest because of their health implications, and also because standards exist or are pending that would preclude use of water exceeding certain limits. At the present time, however, extensive data are available only for nitrate. Basic data on the distribution of nitrate, chloride and sulfate in other parts of Nassau and Suffolk Counties are presented by Ragone (1976a). As part of the present investigation, wells in which the median nitrate-nitrogen level has exceeded eight milligrams per liter at some time in the past were plotted for each depth zone. These are presented in Figures 2–34, 2–35 and 2–36. Water in these wells either exceeds or is very close to the EPA standard of ten milligrams per liter for nitrate-nitrogen. Most are in the central portion of Nassau County. The proportion of wells in Nassau exceeding eight milligrams per liter to the total number of wells sampled for the period 1972–76 is as follows:

Depth (feet)	Number of Wells with 1972–76 Median Nitrate-Nitrogen Greater than 8 mg/l	Number of Wells Sampled
Less than 200	6	40
200 to 399	5	115
400 to 599	4	174
Greater than 599	0	38

These proportions give only a general idea of the extent of high nitrate water and would be representative of the true conditions of the aquifer only if the distribution of sampled wells was random. Some sampling bias has probably been introduced, however, because contaminated public supply wells are abandoned and sampling is discontinued.

In general, the distribution of known contamination is consistent with the flow patterns previously described. In order to illustrate this, an analysis intended to delineate the maximum extent of contaminated water in the Magothy, as indicated by nitrate and chloride, was performed. For this analysis, constituents that serve as good indicators of pollution were chosen. The criteria for selection include (1) widespread occurrence in the water table aquifer in Nassau and western Suffolk, (2) nearly conservative transport within ground water systems, and (3) sufficient analytical data to map areal distributions. The nitrate and chloride ions were selected for this analysis. The median concentrations of these constituents for the period 1972–76 for selected Magothy wells were plotted. Wells screened deeper than 200 feet below land surface and with frequent water analyses were included.

Perlmutter and Koch (1972) consider concentrations of nitrate in excess of 0.23 milligrams per liter nitrate-nitrogen in the Magothy as an indication of man's activities. Perlmutter and Geraghty (1963) state that, in general, altered ground water on Long Island has a chloride concentration of less than ten milligrams per liter. They also report that the fresh water in the Magothy formation in most of southern Nassau County during the period 1953–57, ordinarily contained between four and eight parts per million of chloride. Median chloride data from Magothy wells over 600 feet deep in Nassau County for the period 1952–72 was examined during the 208 program (Ragone, 1976a). Water from most of these wells is thought to reflect unaltered, background quality. Figure 2–37 indicates the distinction between background and above background concentrations. Values of 0.20 nitrate-nitrogen and seven milligrams per liter chloride, were chosen for purposes of this report and although these levels are very low, they can be used to dis-

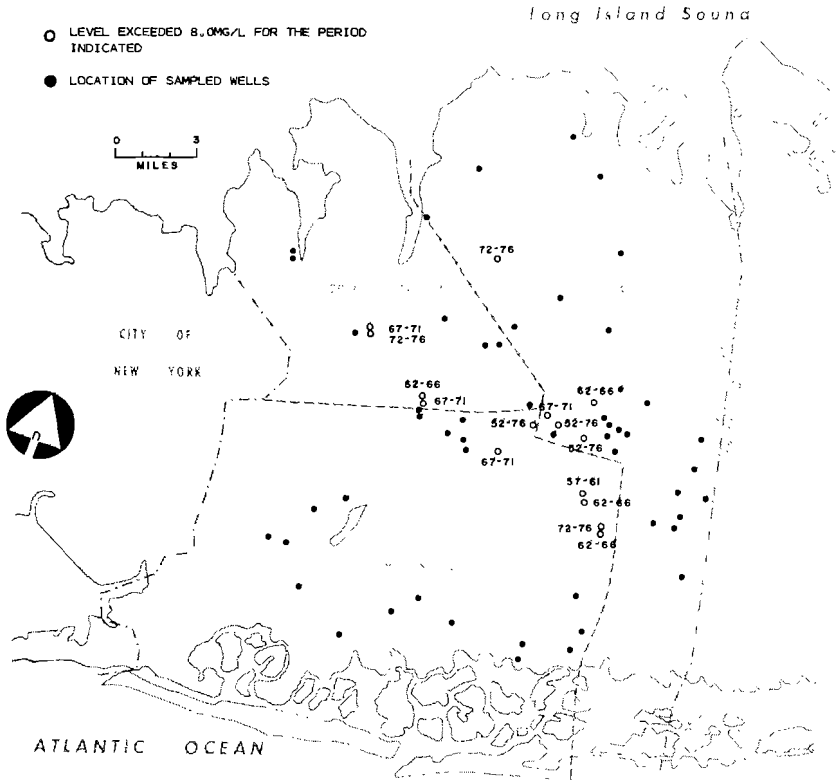


FIGURE 2–34 *Magothy Wells Less than 200 Feet Deep which have had Median Nitrate Concentrations Greater than Eight Milligrams Per Liter.*

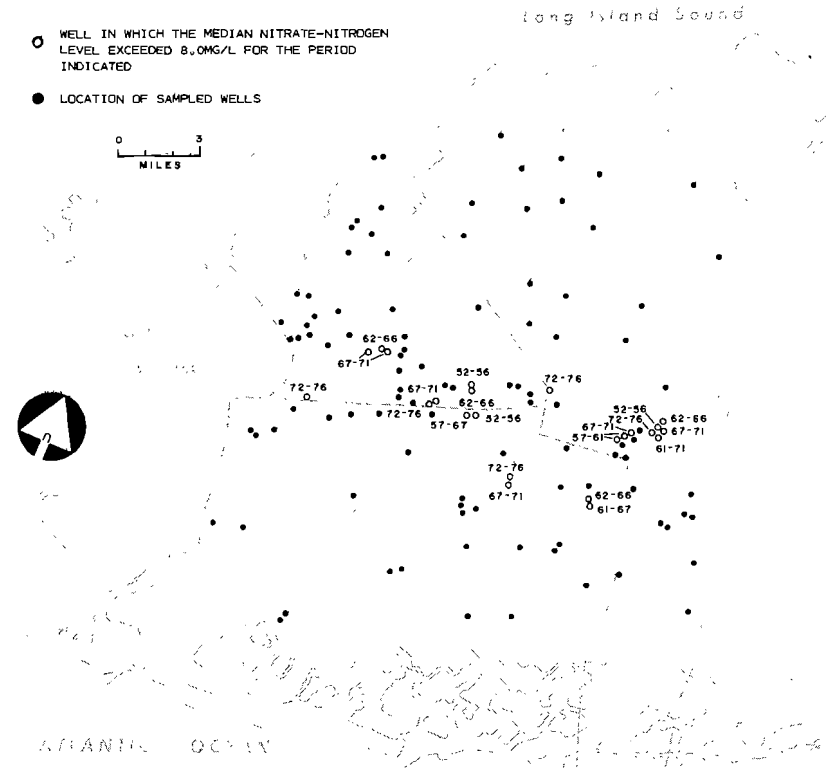


FIGURE 2–35 *Magothy Wells Between 200 and 399 Feet Deep which have had Median Nitrate Concentrations Greater than Eight Milligrams Per Liter.*

tinguish natural water from that which has been altered by man's activities. Using this criteria, Figure 2–38 indicates the pattern of water quality distribution.

The area of generally greater than 0.20 milligrams per liter nitrate-nitrogen in Nassau includes almost all of the central and northern parts of the county. South of a line extending from Franklin Square through Hempstead, East Meadow and Levittown to Farmingdale, concentrations in the middle and lower Magothy are below 0.20 milligrams per liter. In Suffolk County less data are available, but a similar pattern is suggested. South and east of a line extending from Farmingdale through Half Hollow Hills, South Commack and up to Kings Park, nitrate-nitrogen is less than 0.20 milligrams per liter. This analysis was not extended to central or eastern Suffolk because of the generally higher quality of water in the shallow aquifer and a lack of data.

The area in which the same depth zone of the Magothy has levels of chloride generally greater than seven milligrams per liter extends slightly farther south than the nitrate line in Nassau County. This may be due to the fact that chloride acts more conservatively than nitrate under many subsurface conditions. The isochlor line extends from Lynbrook through Baldwin and over to South Farmingdale.

The probable source of high nitrate in the Magothy aquifer, particularly in Nassau County, has been the subject of much speculation. In this century, the two major nitrogen loading sources in Nassau and Suffolk Counties are probably agricultural and home fertilizers and cesspools. Data on patterns of agricultural use and practices prior to 1950 are very poor. A report describ-

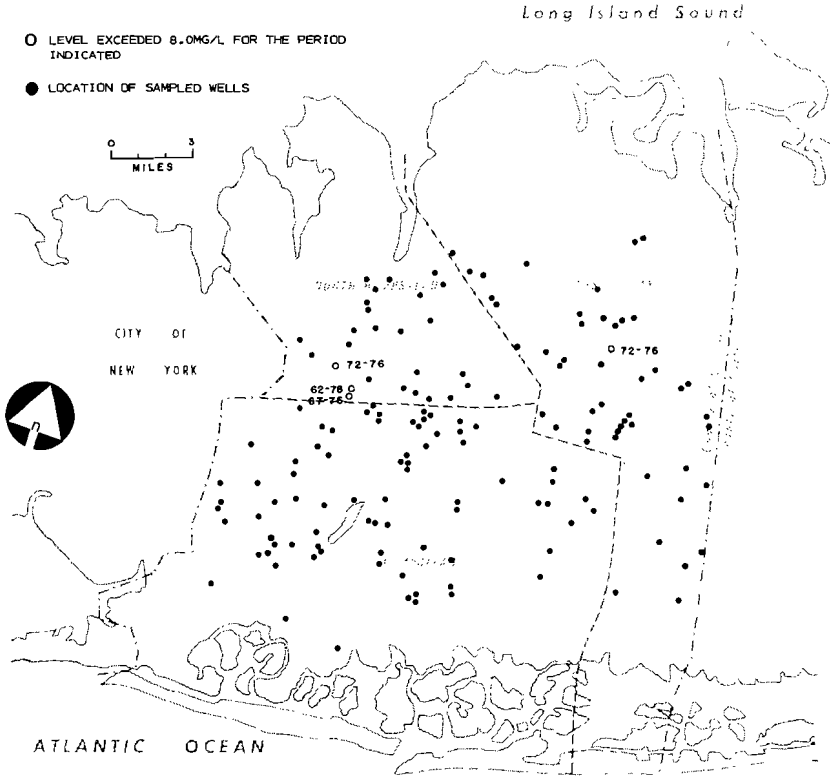


FIGURE 2–36 *Magothy Wells Between 400 and 599 Feet Deep which have had Median Nitrate Concentrations Greater than Eight Milligrams Per Liter.*

ing agricultural use in 1949 (Warren, 1954) indicates the total approximate acreage of commercial vegetable and potato farming in Nassau County as follows:

	Vegetables	Potatoes
North Hempstead	0	100
Hempstead	2,000	1,500
Oyster Bay	3,600	4,200

Although the exact amount of farmed acreage prior to this date is unknown, it was undoubtedly greater. Farming began in colonial time, and it is estimated that by 1919 approximately 27,000 acres of land in Nassau County was used for farming (Bond, 1953). Much of the nitrogen loading from cesspools and individual home fertilizers began in the late 1930's and 1940's. The time of travel for water entering the water table to reach the lower portion of the Magothy in the central portions of the island, under natural conditions, is estimated to be between 50 to 100 years (Franke, 1972). Pumping in the Magothy, of course, will decrease this time considerably. It seems reasonable to assume then, that much of the nitrogen content now found in the middle and lower portions of the Magothy is from past agricultural fertilizer sources.

This conclusion is partially confirmed by nitrogen isotope studies done by the U. S. Geological Survey. A 1975 report concluded that, on the basis of preliminary data, nitrate in the water from the Magothy aquifer appears to be either organic nitrogen of soil humus or nitrogen fertilizer (Kreitler, 1975). The nitrate from the Upper Glacial aquifer in Queens appears to be of animal waste origin, possibly stemming from leaky sewers. In a recent study of nitrogen isotopes, water from a broader range of samples was analyzed (Kreitler, 1977). Nitrate in the Magothy of Nassau and Suffolk Counties was found to probably reflect a mixture of animal waste and agricultural sources.

2.3.4.3 Ground Water Quality Trends. A recent study in southeast Nassau County provides an analysis of vertical and horizontal distributions of nitrate, chloride and dissolved solids. The following conclusions were reached (Ku, 1976):

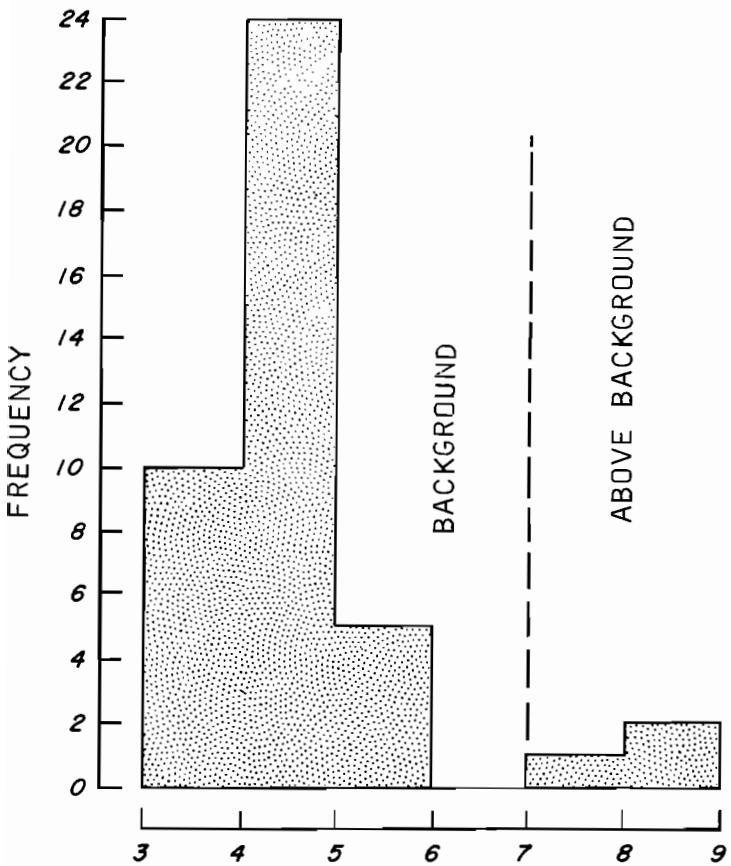
1. Downward movement of nitrate in the Magothy between the early 1950's and 1973 ranged from no significant movement in the area south of North Merrick and South Farmingdale to a maximum movement of a few hundred feet in the areas of Westbury, Hicksville and Plainview. There also seems to be a definite horizontal movement of equal nitrate concentration lines through the aquifer.

2. There has been a more rapid downward movement of nitrate in the eastern part of the study area than in the central and western parts. The rapid movement in this eastern part may be partly due to a large increase in population in and adjacent to the Plainview area.

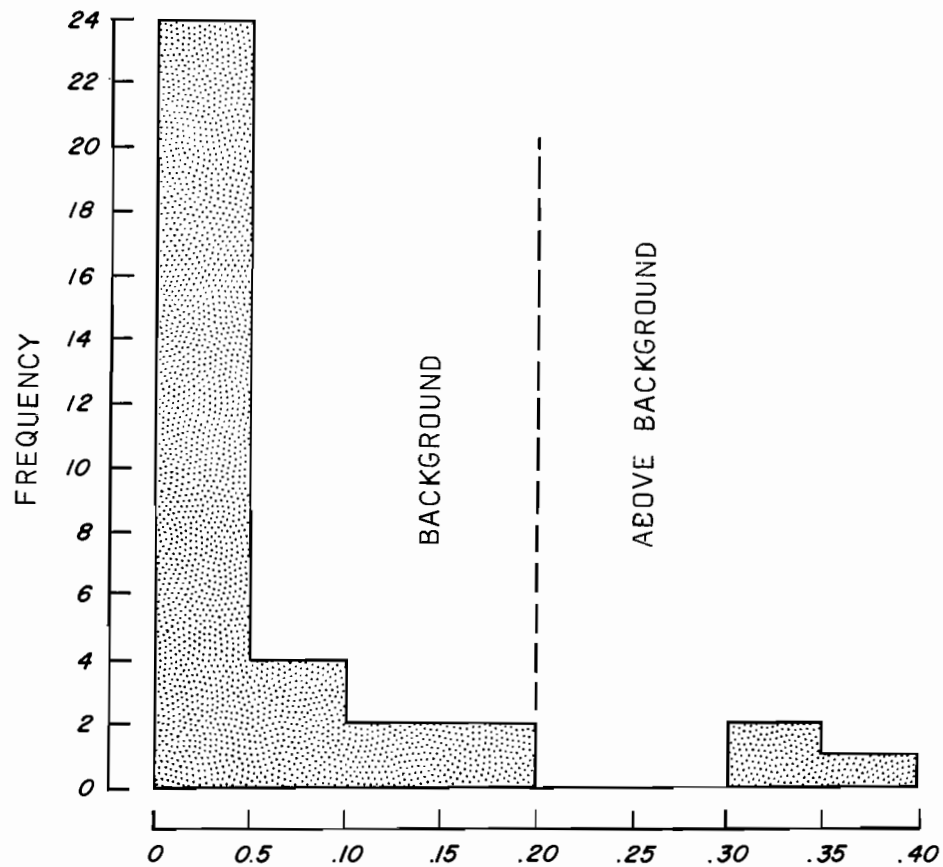
3. There is a zone of high-nitrate water in the Magothy aquifer in the areas of Westbury, Hicksville and Plainview. Some of these increases may be attributable to past large-scale farming and associated use of fertilizers in the Hicksville and Levittown areas.

4. The downward movement of chloride covers a broader area than does that of nitrate.

5. There has been significant downward movement of higher than normal total solids concentration between the 1950's and 1973. Overall downward movement ranges from a few feet to approximately 300 feet. A zone of high total solids concentration of more than 200 milligrams per liter is found in the Hicksville and Plainview area. The total solids concentration in ground water in the Plainview area approximately doubled in twenty years.

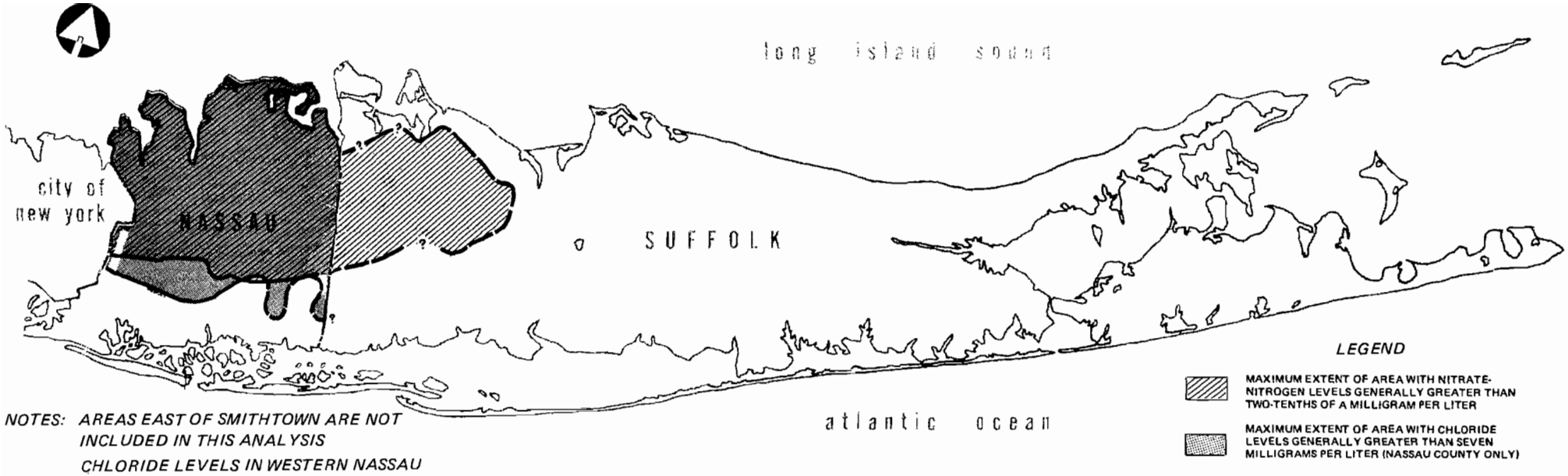


MEDIAN CHLORIDE VALUES IN MAGOTHY WELLS
OVER 600 FEET DEEP IN NASSAU COUNTY - 1952-76.



MEDIAN NITRATE-NITROGEN VALUES IN MAGOTHY WELLS
OVER 600 FEET DEEP IN NASSAU COUNTY - 1952-76.

FIGURE 2–37 *Frequency Distributions of Median Nitrate and Chloride Values in Deep Magothy Wells.*



NOTES: AREAS EAST OF SMITHTOWN ARE NOT INCLUDED IN THIS ANALYSIS
CHLORIDE LEVELS IN WESTERN NASSAU ARE FOR PERIOD 1969–71

FIGURE 2–38 *Areas in Nassau and Western Suffolk Where Ground Water in the Magothy at Depths Greater Than 200 Feet Below Land Surface Shows Evidence of Alteration Based on Median Nitrate and Chloride Levels in Wells During Period 1972–76.*

A study completed in 1969 reviews the trend of nitrate in 373 public supply wells in Nassau County (Smith, 1972). Most of the wells analyzed were deep wells, screened in the Magothy. Eighty wells showed statistically significant increasing linear trends; nine showed decreasing trends. A general upward trend of nitrate in most Magothy wells is also confirmed by a study presently under way by the U. S. Geological Survey (Ragone, 1977). In this investigation, trends of nitrate in most Magothy wells in Nassau showed statistically significant increasing trends.

2.3.4.4 Heavy Metals. Heavy metals in the Magothy aquifer have not been extensively investigated to date. In most cases, they are not part of the routine analysis done on well water samples. Copper and zinc are the most frequently analyzed of the group.

As part of the present investigation, all ground water samples that were analyzed for heavy metals and listed in the U. S. Geological Survey STORET System as of February 1977 were reviewed. A screening of the data, identical to that performed on data from the water table aquifer, was performed; the results are plotted on Figure 2–39. As with the previous analysis, most wells were only sampled once and any conclusions drawn from these data are very preliminary.

As expected, the frequency of occurrence of metals found in the Magothy is lower than in the shallower, water table aquifer. Copper and zinc are most prevalent, although this may be a function of the greater number of analyses done for these constituents. In only two sample locations did metals exceed the 1972 EPA recommended limits. One sample, at Well S–42762, showed a high level of copper. Subsequent samples from this well showed negligible concentrations, indicating a possible sampling or analytical error. At the other location, samples from adjacent wells screened at different depths (Wells S–29776 and S–29778) showed high levels of zinc.

2.3.5 Lloyd Aquifer

The Lloyd aquifer is the least altered by man's activities. This is due primarily to the thick confining bed of Raritan clay which overlies the Lloyd in most places and impedes the exchange of water with the Magothy. On the north shore, however, the Raritan clay is truncated in places and is in lateral, and possibly vertical, hydraulic connection with Pleistocene deposits which have replaced the Magothy deposits. Regionally, the Lloyd is recharged through the clay over a broad area covering most of Nassau and Suffolk Counties. Discharge in the western part of the study area is primarily through wells, while in the eastern part discharge is mostly to the bays and to the ocean (Kimmel, 1973).

The median concentrations of selected constituents in the Lloyd in Nassau County for the period 1972–76 are as follows (Ragone, 1976):

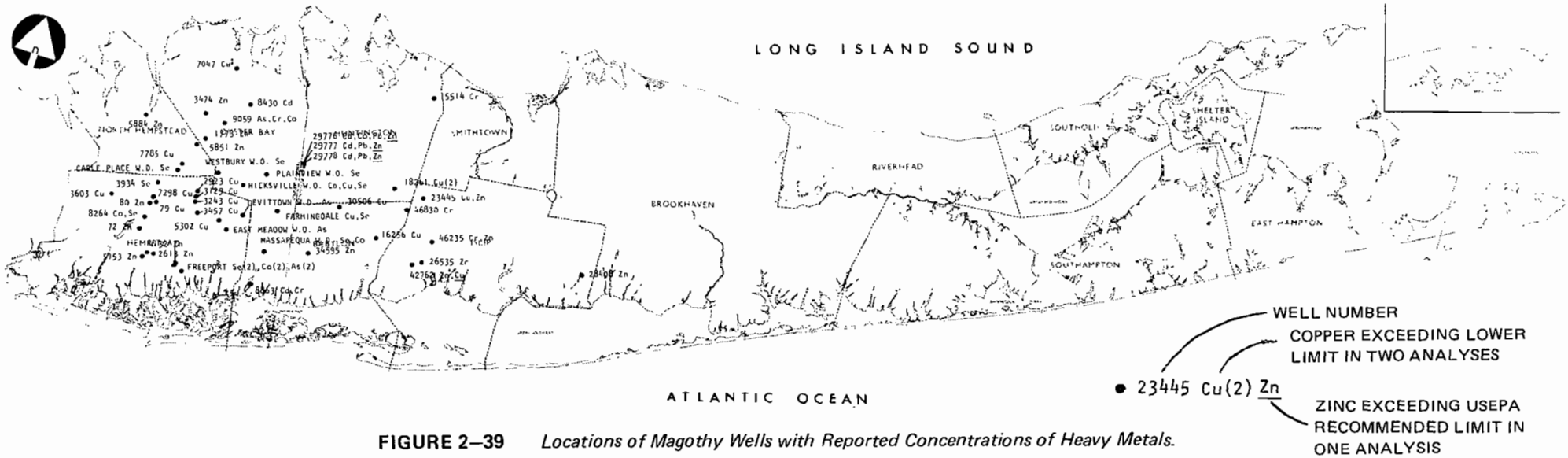


FIGURE 2–39 *Locations of Magothy Wells with Reported Concentrations of Heavy Metals.*

	Southwest Nassau		North and East Nassau	
Nitrate as N	0.07	(13)	0.21	(100)
Chloride	5.1	(12)	5.2	(106)
Sulfate	6.0	(13)	3.0	(94)

Note: Concentrations in milligrams per liter; numbers in parentheses are number of analyses.

Many of the wells in the north and east area are located on Manhasset Neck, Great Neck and in the northern part of the Town of Oyster Bay. Some of the wells in these areas show elevated levels of nitrate which indicate contamination from the surface. This suggests some degree of hydraulic connection with overlying sediments, probably in areas where the Raritan clay has been eroded and replaced by more permeable deposits. High chloride due to salt water intrusion has occurred in certain locations in the Lloyd aquifer. Uncontaminated water in the Lloyd is characterized by low dissolved solids (less than 50 millgrams per liter). Iron, however, commonly occurs at levels considerably above the U. S. Public Health Service recommended limit of 0.3 milligrams per liter.

Regional rates of ground water movement in central Nassau County have been estimated by Franke and Cohen (Franke, 1972). From these rates, the age of water moving in the Lloyd at the ground water divide is estimated to be at least 200 years old. Closer to the barrier beaches on the south shore, the age of water is estimated to be about 3,000 years old. Water in the Lloyd near the north shore may be on the order of 1,000 years old. If these rates are correct and if the confining layers above the Lloyd are indeed continuous, then the quality of water in the aquifer in most areas is in little danger of contamination in the near future.

2.3.6 Special Studies

2.3.6.1 Virus Study. During the period June 1976 to June 1977, Brookhaven National Laboratory conducted a virus survey as part of the 208 program. This survey involved the concentration, enumeration and identification of species of human Enteroviruses from selected aquatic systems on Long Island including embayments, lakes, creeks, public drinking water supplies (ground water), ground water under influences of waste water recharge basins, and effluents from secondary and tertiary sewage treatment plants.

Enterovirus species were isolated from all systems studied, with the exception of public water supplies. Virsues were most often encountered in the chlorinated effluents of sewage treatment plants. In three instances, wild type Poliovirus was tentatively identified from one of the treatment plants.

The limited sampling conducted at each site (one per month) precluded any extensive interpretation of the data for the purpose of identifying the precise hazard posed by enteric viruses in Long Island waters. The results of the virus study are presented in detail in one of the 208 interim report series.

2.3.6.2 Organics Study. Concern over the presence and concentration

of trace amounts of certain organic compounds came into sharp focus in mid–1974 with the publication of results of an EPA study of water quality in the Mississippi River at New Orleans. This study detected 66 organic chemicals including some suspected of being carcinogenic to animals. Concentrations found ranged from less than one part per billion for most of those detected, to a high of 133 parts per billion for chloroform. The potential for the formation of chloroform as a result of disinfection procedures was recognized.

In 1975, a survey of the water supplies of 80 cities nationwide was conducted for six specific compounds including the four trihalomethanes (chloroform, bromoform, dibromochloromethane, dichlorobromomethane), carbon tetrachloride and 1,2 dichloroethane. In 30 of the 80 supplies surveyed, none of these compounds were detected, indicating that the quality of the raw water source including the presence of precursor compounds was of paramount importance. A subsequent survey of ten cities' water supplies for a broad range of compounds identified as many as 76 compounds in one source.

In late 1974, Bellar and Lichtenberg of the EPA at Cincinnati published a procedure for the determination of volatile organic compounds at the microgram per liter level (parts per billion) in water by gas chromatography. This methodology proved a breakthrough in evaluating the presence of volatile organic compounds (defined as less than two percent solubility and boiling at less than 150° Centigrade) in waters at very low concentrations. Many of the compounds are suspected of being animal carcinogens and are listed on the "Master List of Non-Pesticide Organics of Carcinogenic or Other Harmful Potential" published by the National Academy of Science. Some of the compounds on the "Master List" were listed as ingredients in some 65 commercial products on the shelves of supermarkets and hardware stores in a one-day survey conducted by the NCHD.

In March 1975, an incident of suspected ground water contamination was reported near an industrial complex in Nassau County. Subsequent sampling and analysis of wells within the complex indicated significant concentrations of vinyl chloride, which is a known human carcinogen in occupational environments, and industrial degreasers such as tri- and tetra- chloroethylene. The wells containing these contaminants were removed from service as sources of potable water.

An intensive survey of all public drinking water supply wells in both Nassau and Suffolk Counties has been underway for the past two years. The overall extent of contamination of drinking water by organic chemicals in Nassau County is demonstrated by the number of wells sampled and the various ranges in concentrations of organic compounds detected. Based on data representing 336 wells sampled, 310 wells yield water with concentrations less than ten micrograms per liter of organic compounds (of these approximately 80 percent show no organic compounds), nine wells yield water containing between ten and twenty micrograms per liter, six wells yield water containing between twenty and 50 micrograms per liter, and eleven wells yield water containing greater than 50 micrograms per liter. Wells yielding water containing one or more organic compounds range in depth from 89 to 691 feet deep.

As of December 1977, a total of 367 of the 437 drinking water supply wells have been sampled at least once. Of these, eleven wells have been restricted, based upon the New York State Health Department's guideline (50 micrograms per liter of any single organic compound or a total of 100 micrograms per liter for all organic compounds detected in the water sample). Each public supply well within Nassau County will have been sampled at least once, by March 1978.

In addition to establishing the extent of organic chemical contamination by assessing drinking water, a survey of industrial and commercial establishments was undertaken to identify and abate sources of organic compounds. To date (December 1977), 2,300 establishments have been surveyed of which 243 were found to be utilizing organic chemicals, and 61 were discharging to the ground. Thus far, 48 sources have been abated and the remaining are in the process of being curtailed.

Other actions have also been implemented by the Nassau County Health Department:

- proposed legislation to prohibit the use of organic solvent cesspool and drainer cleaners
- identification of consumer products containing organic compounds
- initiation of SPDES permits to regulate the storage and removal of organic chemicals
- initiation of a licensing program to regulate industrial waste scavengers.

A similar effort has been underway in Suffolk County where more than 400 water samples from public supply wells, observation wells and distribution systems have been analyzed for the presence of organic compounds. Seven supply wells have been restricted based on New York State guidelines. Constituents of major concern are trichloroethylene, tetrachloroethylene and trichloroethane. Also encountered during the sampling were trace amounts of chloroform, other trihalomethanes and a few aromatic compounds.

The Nassau-Suffolk Regional Planning Board's 208 Program responded to requests from its TAC and CAC and engaged the firm of Energy Resources Company to analyze samples from ground waters, storm waters, domestic waste discharges and landfill leachates for the presence of volatile and non-volatile organic compounds. The survey of non-volatile compounds resulted in the detection of substituted benzene compounds, naphthalenes and various butyl-phthalates. Some of these compounds are common constituents of plasticizers, but some are on the list of suspected carcinogens to animals. Volatile organic compounds were also detected at parts per billion concentrations with their sources yet to be determined or evaluated.

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Section 3 Virus Study

3.0 INTRODUCTION

Growing public concern over the fate of dwindling natural aquatic resources has resulted in a nationwide commitment for the re-evaluation of water management practices, especially those related to domestic wastewater disposal. Efforts to evaluate the relevance of various treatment schemes have often been stymied by the lack of adequate information with which to predict the movements and ultimate fates of the potentially pathogenic biological organisms commonly associated with human fecal material. Among these organisms much attention has been given to the final disposition of human viruses. The major human virus groups known to occur in sewage include: (1) *Enteroviruses*—transient members of the human alimentary tract consisting of over 100 species including Polioviruses, Coxsackieviruses, and ECHOviruses; (2) *Adenoviruses*—upper respiratory viruses which are able to withstand the acidity of the human gut and may be shed in the feces; (3) *Hepatitis virus*; and (4) *Reoviruses*. While only Hepatitis virus and Poliovirus infections have been conclusively proven as being transmitted by the water route (*i.e.*, sewage pollution of drinking water, shellfish beds, recreational waters, etc.), studies have indicated the likelihood of similar transmission of some or all of the species mentioned above. A listing of the viruses which may be water-borne and the diseases associated with them is presented in Table 3–1.

Reports of human virus isolations from diverse aquatic systems (*e.g.*, rivers, bays, estuaries, treatment plant effluents, etc.), which have appeared on occasion in the literature, have underscored the need for more extensive virus monitoring programs. Such a need was realized by the Nassau-Suffolk advisory committees, which included a virus study as part of their federally-funded 208 program. The study, initiated in June of 1976, was designed to survey the occurrence of human enteric viruses in a number of routinely monitored aquatic systems. Enteroviruses were specifically chosen as a model system because of their predominance in sewage-associated systems, and the relative ease of their isolation and identification in the laboratory.

The ultimate goal of the virus survey was to provide previously unavailable background information on the presence of these unique organisms in various Long Island aquatic resources. Information generated from the study would then be utilized by those involved in water management planning decisions. In this regard, the virus data was not meant to stand alone, but in conjunction with existing physical and chemical information. In addition, virus results would be used to define trends in specific treatment systems and to delineate areas for future study.

3.1 LITERATURE REVIEW—HUMAN VIRUSES IN AQUATIC SYSTEMS

Because of the great diversity among the kinds of samples taken during the 208 virus study, it will be necessary to review each as a separate unit (*e.g.*, surface waters, sewage treatment plant effluents, drinking water, etc.).

3.1.1 Drinking Water

The likely presence of virus in drinking water has been a difficult, often perplexing problem to evaluate. Among questions facing environmental scientists in this area are those concerning: (1) the minimum infective dose necessary for the establishment of an infection; (2) the documented transmission of virus diseases via the water route and (3) the confirmed occurrence of virus in public drinking water supplies.

Table 3–1

HUMAN VIRUSES COMMONLY FOUND IN SEWAGE AND DISEASES ASSOCIATED WITH THESE VIRUSES.

Group	Subgroup	No. of Serotypes	Type Nucleic Acid	Diseases
Enterovirus	Poliovirus	3	RNA	Mild—Severe Gastroenteritis Abortive Poliomyelitis Aseptic Meningitis Paralytic Poliomyelitis
	Coxsackie-virus			
	A	24	RNA	Summer Minor Illness Herpangina Aseptic Meningitis Common Cold Hand, Foot and Mouth Disease Infant Diarrhea
	B	6	RNA	Aseptic Meningitis Common Cold Pleurodynia Neonatal Disease Sudden Infant Death Syndrome Myocarditis Pericarditis
	Echovirus	34	RNA	Aseptic Meningitis Mild Paralysis Febrile Illness Conjunctivitis Boston Exanthem Disease Infant Diarrhea Vaginitis and Cervicities Pericarditis and Myocarditis
Hepatitis				
	A		RNA?	Infectious (viral) Hepatitis
	B		DNA?	Serum Hepatitis
Adenovirus		31	DNA	Acute Respiratory Disease Pharyngoconjunctival Fever Primary Atypical Pneumonia Epidemic Keratoconjunctivitis (shipyard eye) Intussusception Febrile catarrh
Reovirus		6	RNA	?

While many disagree on the question of how many virus particles are necessary for the establishment of infection in humans, laboratory experiments in tissue culture cells have indicated that one virus is sufficient to produce an infection in human cells (Plotkin and Katz, 1967; Katz and Plotkin, 1967). The infection may or may not lead to disease depending upon a wide range of host-related factors. Hypothetical calculations done by Gerba, Wallis and Melnick (1975a) suggested that where one infectious unit is present per 50 gallons of finished water, a community utilizing 50 million gallons per day would have a minimum of 600 of its residents exposed to possible infection each day (assuming 0.2% use of water for drinking purposes, and an infection rate of 30%).

A second problem in the assessment of virus in drinking water relates to the lack of epidemiological evidence on the transmission of disease by the water route. To date, the only documentation for water transmission of human disease by sewage-borne viruses is that pertaining to the Hepatitis type A virus, and possibly Poliovirus. In 1955, a sewage-contaminated municipal water supply was blamed for over 30,000 cases of infectious hepatitis in New Delhi (Viswanathan, 1957). Between 1961 and 1970, over 30 outbreaks of water-borne hepatitis were recorded in the United States, with a majority being caused by sewage contamination of private or semi-public water supplies (Sobsey, 1975; Taylor *et al.*, 1966). Sobsey (1975) pointed out that the lack of epidemiological evidence for water-borne transmission of other enteric diseases does not mean that transmission of such disease is impossible. Goldfield (1976) suggested that usual epidemiological procedures could not be used to determine water-borne transmission of most enteric diseases citing a number of reasons including prior immunity of individuals leading to subclinical infection; the broad spectrum of disease syndromes common to many virus types; and the secondary spread of disease by person-to-person contact obscuring the role of water. Sobsey (1975) concluded that alternative investigative approaches must be utilized to determine the transmission of water-borne enteric disease.

The third problem in evaluating the virus assessment in drinking water centers on controversial isolations and difficult virus testing procedures. As mentioned previously, Hepatitis virus was responsible for a massive disease outbreak in New Delhi in 1955. In 1964, Coin *et al.* isolated enteric virus in 18% of the drinking water samples analyzed in Paris. Among the isolates he identified were Poliovirus types 1 and 3, Coxsackievirus and ECHOvirus, with an average concentration of one plaqueforming unit (PFU) per 300 liters of water. Enteric viruses were also found in ten liter volumes of drinking water in South Africa (Nupin, Bateman and McKinney, 1974). In the United States, enteric virus isolations from drinking water have been sporadic and sometimes questionable. In 1970, Poliovirus type 2 was isolated from an unchlorinated drinking water well in southeast Michigan (Mack, 1973). After chlorine treatment was initiated, the virus could not be detected. Also in 1970, a national controversy arose when the Northeast Water Supply Research Laboratory reported the isolation of enteric virus from the finished drinking water supplies of two Massachusetts communities (Potable Water Senate Hearings). Almost immediately, the Water Supply Research Laboratory of the EPA National Environmental Research Center initiated studies in order to confirm these findings and evaluate the isolation methods used. The investigators concluded that techniques used by the Northeast Lab required excessive manipulations and were therefore subject to the possibility of extraneous viral contamination. A similar situation recently occurred when Hoehn (1975) reported the presence of Poliovirus in the Virginia's Occoquan Reservoir. Subsequent studies by Akin and Jakubowski (1976) of the

Environmental Protection Agency failed to confirm the presence of virus in the system and again raised the question of possible laboratory contamination.

Extensive studies of drinking-water systems in communities located in Ohio, Indiana and Missouri have shown these water supplies to be free of enteric virus (Akin *et al.*, 1975a). In these studies, the authors sampled large volumes of drinking water (1900 liters) using sensitive virus concentration techniques designed to recover three to five PFU per 380 liters. In the absence of positive findings, the authors concluded that good conventional treatment was adequate for virus removal from public drinking water supplies.

3.1.2 Surface Waters

The possible transmission of diseases of viral etiology in surface waters (lakes, streams, bays, estuaries and coastal waters) has been the topic of numerous studies. Concern has been amplified by the recent interest in the conservation of the aquatic environment for both recreational and economic purposes. The latter is of particular importance in an area such as Long Island where coastal waters and embayments serve as important shellfish-growing areas.

The virus hazard has been created by the release of sewage material either directly into the larger water masses, or indirectly via wastewater contamination of their tributary streams and rivers.

Human viruses have been isolated from almost all types of surface water. Simkova and Wallnerova (1973a) isolated Coxsackie virus from waters of the Danube River. Nestor and Costin (1976) reported similar findings in sewage-contaminated river waters in Roumania. Human enteric virus have been isolated in estuaries (Metcalf and Stiles, 1967; Vaughn and Metcalf, 1975), as well as in seawater and coastal marine sediments (DeFlora, DeRenzi and Badolati, 1975). In the latter study, the concentration of viruses isolated from marine waters ranged from 0.1 PFU per 100 milliliters in moderately polluted waters, to 40 PFU per 100 milliliters in heavily polluted waters near sewage outfalls. The authors found that viruses readily adsorbed to marine sediments and could be released into the water column by simple mechanical shaking similar to the agitation occurring in natural waters.

The survival capacity of enteric viruses in marine environments is quite unpredictable, even though seawater has been shown to contain antiviral properties. Seawater constituents such as organic matter, particulates and heavy metal ions have been shown to be antagonistic to the action of non-specific antiviral components, ultimately resulting in the extension of virus survival (Vaughn, 1974). Initial virus inactivation studies were conducted using Poliovirus type 3 in Baltic and North Sea waters by Lycke *et al.* (1965). The authors found that marine waters had a virus inactivating capacity (VIC) capable of inactivating 99% of the virus in eight days at 23 Celsius. Since the inactivating agent or agents were not heat-labile or filterable, the authors suspected that marine bacterium might have been involved in the virus inactivation process. In a similar study, Shuval, Thompson, Fattal, Cymbalista and Wiener (1971) found antiviral activity in Mediterranean and Red Sea waters. Heating and filter sterilization reduced the inactivating capacities of the water, leading the authors to also conclude that marine bacteria might play a role in viral inactivation. Laboratory studies by Metcalf and Stiles (1968) and Vaughn and Metcalf (1975) demonstrated that inactivation of Coxsackie type B3, ECHOvirus type 6 and Poliovirus type 1 was dependent primarily upon water temperature, autoclaved and ultraviolet light-sterilized waters showing similar VIC. Follow-up studies in the field indicated, however, that viruses could be inactivated at an even faster rate in natural environments, suggesting that factors other than temperature were involved. By using a flow-through system, Akin *et. al.* (1976) found that autoclaving and filtration had little effect on the virus inactivating capacity of waters from the Gulf of Mexico. They found water temperature to be the most important factor in virus survival but cited the very complex nature of virus inactivation in an aquatic environment. Temperature was again found to be an important factor in a study by Lo *et. al.* (1976). The study revealed that while Poliovirus could survive six weeks at 25 Celsius, survival could be extended to 40 weeks by reducing the temperature to 4 Celsius. Their field studies indicated that while viruses were more sensitive to inactivation in natural environments than in laboratory environments, water temperature still played an important role in survival rate. Poliovirus was shown to survive 27 days during the summer months at temperatures of 21 to 26 Celsius, but was still viable for periods of up to 65 days during the winter (0–12 Celsius). The authors demonstrated that survival rate varied greatly with the type of virus being studied. ECHOvirus type 6 was more stable than Poliovirus in both field and laboratory studies. Coxsackievirus type 5 was the most stable, capable of surviving up to 53 weeks at 4 Celsius in laboratory experiments, and over 80 days in field studies.

The survival of enteric virus in non-marine aquatic environments has not been extensively studied. Simkova and Wallnerova (1973b) found that Coxsackievirus A4 could survive for 45 days at a temperature of 22 Celsius and up to 154 days at 4 Celsius in Danube River water. Using membrane dialysis chambers, O'Brien and Newman (1977) observed inactivation rates of Poliovirus types 1 and 3, and Coxsackievirus types B1 and A13 in the Rio Grande River. They found inactivation to be a function of both water temperature and the virus type. All viruses were more readily inactivated at 23–27 Celsius than at 4 Celsius, with Polio 1 and Coxsackie B1 showing greater stability than Polio 3 and Coxsackie A13. Lycke *et al.* (1965) found river and lake waters to be devoid of inactivating capacity for Poliovirus type 1, but Hermann *et al.* (1974) demonstrated that Polio type 1 and Coxsackie type A9 could be inactivated by water from a Wisconsin lake. The viruses were inactivated more rapidly in natural-lake water than in sterilized-lake water.

The mechanism for the viricidal action of marine and other surface

waters remains complicated. The role of powerful oxidants, sunlight, salinity, metals, detrital material and marine organisms has been suggested as contributing to viricidal capacities of natural waters (Won and Ross, 1973), but there is considerable conflicting evidence concerning the effect of heat-labile filterable agents or toxins. All studies seem to agree that water temperature appears to be of primary importance with greatest viral inactivation occurring at higher temperatures. Recent studies by O'Brien and Newman (1977) have indicated viral inactivation at temperatures lower than 37 Celsius might be due to damage of the nucleic acid core of the virus. They found that inactivated virus was still capable of adsorbing to host cells even after exposure to river water, indicating no major alteration of external structures. They theorized that inactivation resulted as a consequence of an exposure of the viral nucleic acid to some inactivating agent in the water, damage to the nucleic acid likely resulting in an inability for the virus to replicate, rendering it functionally "dead." While nucleic acid degradation appears to be the primary mechanism for viral inactivation at a temperature of 25 Celsius and below, it appears that oxidation of the viral protein coat is the most likely mechanism for inactivation at temperatures of 37 Celsius and above (Lund, 1973).

3.1.3 Shellfish

There has been increasing concern over the likelihood of human virus carriage by shellfish. While there is little epidemiological evidence for the transmission of enteric disease from the consumption of sewage-contaminated shellfish (with the notable exception of infectious hepatitis), the potential for infection cannot be ignored. Fugate, Cliver and Hatch (1975) outlined a number of reasons why a potential health hazard exists: (1) shellfish-raising waters are continually being subjected to high levels of pollution from sewage sources; (2) shellfish, being filter-feeders, are able to efficiently concentrate viruses from the surrounding waters; (3) a majority of viruses are concentrated in the digestive organ of the mollusk, which is consumed along with all the other parts of the animal; (4) shellfish are frequently consumed raw or with minimal cooking that may not be sufficient to inactivate all of the viruses within them.

The occurrence of human virus (*i.e.* enterovirus) in various shellfish species is well documented. Morris, Mearns and Kim (1976), while studying the presence of virus in the California mussel found that 18 of the 39 samples tested contained virus. The mussels had been taken from beds located near outfalls which were discharging primary and secondary treated sewage effluent. Viral enumerations revealed concentrations ranging from 25 to 1475 PFU per kilograms of meat. Fugate *et. al.* (1975) found virus in two of 17 oyster samples in Texas and in one of 24 samples taken from the Louisiana Gulf Coast. Oysters had been taken from areas that met the approved coliform standard. Virus isolates were identified as ECHOvirus type 4 and Poliovirus type 1 from the Texas oysters, and Poliovirus type 3 from the Louisiana oysters.

In 1968, Metcalf and Stiles isolated Poliovirus, Coxsackie B-3 and Reovirus from shellfish growing in a sewage-polluted estuary in New Hampshire. Coxsackie type A was isolated from seven of 70 oyster samples and two out of ten mussel samples found in a French market (Denis, 1973). Serological assays in suckling mice identified the majority of the French isolates as being Coxsackie virus type A16.

Although many enteric virus isolates have been found in shellfish, there is no epidemiological evidence to indicate that consumption of contaminated shellfish would lead to infection. There is, however, well-documented evidence for the shellfish-mediated transmission of disease by Hepatitis virus. The first reported shellfish-related outbreak occurred in Sweden in 1955 resulting in 629 cases of infectious hepatitis (Roos, 1956). Since then, outbreaks have occurred in 1961 in New Jersey, Mississippi and Alabama; in Philadelphia and Connecticut in 1963; in North Carolina in 1964; in New Jersey in 1966; and in Rhode Island and Massachusetts in 1971 (Portnoy *et al.,* 1975). An outbreak occurred in October and November 1973 (Portnoy *et. al.,* 1975) affecting 263 individuals from Houston and 15 from Calhoun, Georgia, who were infected with hepatitis following the consumption of raw oysters from Louisiana Bay. After eliminating the possibility of contamination during transportation and storage, investigation concluded that the oysters were contaminated prior to, or at the time of harvesting. The area from which the oysters were harvested had been closed six weeks earlier due to contamination by polluted flood waters from the Mississippi Valley. On September 1, the area was re-certified by means of a coliform standard. The authors concluded that the Hepatitis virus had been retained within the oysters for periods as long as six weeks. More recently, Mahoney *et. al.* (1974) detected the presence of Australia antigen (Au), indicative of the presence of type B Hepatitis virus, in Maine clams. The clams were taken from waters known to be contaminated with untreated sewage from a local hospital. It was found that the antigen could be transmitted to previously uninfected clams, and they concluded that shellfish could act both as a vector and a reservoir for Au antigen and type B Hepatitis virus.

Shellfish obtain their food through a filter-feeding process in which they selectively ingest small particles of organic matter from large volumes of seawater. Food particles become attached to the mucous secretions of the shellfish and are directed by ciliary action to the mouth region where they are either swept into the mouth, or rejected and passed out as pseudofeces. Since viruses are often attached to small particles of organic material, they readily gain entrance to the inner portion of shellfish.

DiGirolamo *et al.* (1977) proposed a mechanism for the attachment of virus to shellfish mucus during feeding. Utilizing a number of enteric viruses in seeded laboratory experiments, they found that virus particles became ionically bound to secretions. The binding sites were found to be the sulfate radicals in the mucopolysaccharides of the shellfish mucus. The uptake of virus particles by shellfish occurs very rapidly resulting in the accumulation of large numbers of viruses in the digestive glands of the animal. Liu, Seraichekas

and Murphy (1966a) found 70% of the poliovirus seeded into seawater tanks was accumulated in species of the Northern Quahaug in 48 hours. DiGirolamo, Liston and Matches (1975) reported a similar rate of uptake in the West Coast oyster with 80 to 90% of the seeded viruses being accumulated within 24 hours. Liu, Seraichekas and Murphy (1966b) found that maximum efficiency of virus uptake occurred when virus concentrations in the surrounding water were at low levels. Hamblet *et al.* (1969) reported that oysters subjected to low turbidity water accumulated three times as many Poliovirus as oysters in high turbidity seawater.

Although high titers of virus can be accumulated within shellfish in a relatively short period of time, the animal's filtering system can work to remove virus when placed in clean water through a process called depuration. Laboratory studies have shown that contaminated shellfish, when placed in fresh running seawater, can be rendered virus-free. Depuration rates have been found to be dependent on the temperature as well as the salinity of the seawater (Liu, Seraichekas and Murphy, 1967). Studies have found removal of virus occurring in 48 hours at 18 C. Reducing the temperature to 13 Celsius resulted in an increase in the depuration time. Little or no depuration occurred at 8 Celsius, a temperature at which the shellfish ceased pumping. The authors also demonstrated that a reduction of 50% in the salinity of the water in the oyster tanks was sufficient to halt the virus depuration process. Studies conducted in an estuarine environment by Vaughn and Metcalf (1975) showed that complete virus removal from seeded oysters required a period of 21–30 days in summer (17–22 Celsius) and 60–80 days during winter months (-1–12 Celsius). These results tended to confirm those of several earlier studies. Hamblet *et. al.* (1969) concluded that under controlled environmental conditions, oysters can effectively eliminate virus irrespective of turbidity levels. The optimal conditions for depuration were judged to be continuously flowing virus-free seawater of either high or low turbidity; a temperature optimum of 20 Celsius; and a salinity of greater than 18 parts per thousand.

In addition to determination of uptake and depuration rates, the question of virus survival within the shellfish has also been addressed. Morris *et al.* (1976) calculated that enteric viruses could survive in mussel tissue three to six times longer than coliform bacteria. Hedstrom and Lycke (1964) found Poliovirus to be more stable in oyster tissue than in the surrounding waters. DiGirolamo *et al.* (1970) went one step further in testing the survival of Poliovirus in shellfish during various food preparation procedures. They found a marked stability during refrigeration for periods up to 30 days. Studies with heat processing showed surprising results. The authors were unable to inactivate all of the shellfish-bound Poliovirus after frying or stewing for 8 minutes, baking for 30 minutes, or steaming for 30 minutes. They concluded that none of the procedures were of sufficient duration to generate enough internal heat to bring about total virus inactivation. Later studies conducted by the same authors concluded that total virus inactivation required a 30-minute exposure to temperatures in excess of 70 Celsius.

3.1.4 Sanitary Landfills

Sanitary landfills contain a mass of heterogeneous solid waste materials including those generated by households, such as animal (pet) feces and fecally soiled disposable diapers. Since fecal material is known to contain potential human pathogens, the possibility exists that such organisms may be collected and passed via the landfill leachates to groundwater aquifers (Pohland and Engelbrecht, 1976).

While a number of studies have investigated landfills for pathogenic bacteria, few have concerned themselves with the fate of human enteric virus in landfill leachate and leachate-contaminated groundwater. Peterson (1971) examined raw municipal solid wastes and found human enteric virus in 4 of 12 samples in concentrations of 192 to 684 PFU per 200 grams of solid waste. The viral isolates were identified as Poliovirus types 1, 2 and 3. Among the waste items most commonly present in the municipal waste were disposable diapers. Further studies by Peterson (1974) demonstrated that enteric viruses could be found in 10% of the soiled disposable diapers analyzed.

The potential hazard of enteric viruses in sanitary landfills depends upon the amount of viruses in the landfill, their survival in the landfill environment, and the ability of the viruses to pass through the landfill into the surrounding environment (Engelbrecht *et al.* 1974). As with most microorganisms, the fate of enteric virus in landfill environments is contingent upon a number of factors including temperature, pH, moisture, duration of storage and the presence of chemical and biological antagonists. A majority of survival studies conducted thus far has dealt with the survival of virus in landfill leachate. Peterson (1971) failed to recover virus after seeding solid waste with Poliovirus in a sanitary landfill. Cooper *et al.* (1975) reported sporadic recovery of seeded Poliovirus for periods of up to 20 weeks from the leachates of simulated sanitary landfills whose chemical and physical properties were similar to those of natural sanitary landfill leachates. The authors felt that the sporadic occurrence was due to the irregular distribution of the fill, and the non-uniform flow of water over the fill. They were able to show, however, that the leachate had no detrimental effect on Poliovirus over a 48 hour period. Sobsey *et al.* (1975) was unable to recover Poliovirus or ECHOvirus in a simulated sanitary landfill seeded with high concentrations of each virus. They conceded that their lysimeters might not have been operating for a sufficient amount of time to allow viruses to travel the length of the refuse column. Engelbrecht *et. al.* (1974) studied the stability of Poliovirus in landfill leachates at various temperatures and pH. They found that naturally occurring leachate (22 Celsius) at a pH of 5.3 was more viricidal than at a pH of 7.0. Additional studies on the effect of temperature showed an almost immediate viral inactivation at 55 Celsius. Similar work by Sobsey *et. al.* (1975) showed 95% virus inactivation in two weeks at 20 Celsius, in six days at 37 Celsius and in 27 days at 4 Celsius.

From the above, it can be determined that the rate of viral inactivation will vary greatly depending on the type of leachate studied. In an effort to

determine which specific chemical characteristics were responsible for viral inactivation in leachates, Engelbrecht and Amirhor (1975) fractionated a landfill leachate by ultrafiltration and tested the various subfractions for virus inactivating capacity. They observed that most of the inactivation was found in a 500 molecular weight (MW) permeate. Chemical analysis of the permeate revealed that it contained high concentrations of short chain fatty acids as well as iron (120–190 milligrams per liter) and zinc (30–48 milligrams per liter).

Little information is available on the passage of viruses from landfills leachates to groundwater aquifers. Existing data on removal of virus in sewage material via adsorption to soil columns cannot be extrapolated to a virus-in leachate situation (Pohland and Engelbrecht, 1976). A single study conducted by Novello (1974) showed an 80% or less retention of Poliovirus in landfill leachate by soil. To date, no follow-up studies have been reported.

3.1.5 Stormwater Recharge Basins

There is little or no information available concerning the presence of human viruses in stormwater recharge basins, or the groundwater beneath them. It can be speculated that the most likely source of viruses in such basins would be from surface run-off (provided such waters would have access to basins). Viruses on entering basins would be subjected to the same removal systems discussed for sewage recharge basins in section E-2 (*i.e.,* adsorption to soil, etc.).

The presence of virus in groundwater beneath stormwater recharge basins could also be indicative of other pollution sources. Such a condition might occur in an area where the basins are in the midst of a heavily developed area making use of septic tanks. In such an area, viruses might enter the groundwater through septic leachates with no direct involvement of the basin.

3.1.6 Sewage Treatment Plants

The occurrence of virus in human domestic wastewater is well-documented. Poliovirus was first found in raw sewage by Levaditi (1940) and by Paul, Trask and Gard (1940). Melnick (1954) found Poliovirus in secondary treated sewage effluents. Although outbreaks of poliomyelitis were reported shortly thereafter (Little, 1954), the evidence incriminating the outbreak as water-borne was circumstantial. Other enteric viruses have been isolated from sewage, such as Coxsackie (Clarke, Knowles, Shimada, Rhodes, Ritchie and Donahue, 1951) and ECHOvirus (Kelly and Sanderson, 1957). More recently, Shuval (1970) found high concentrations of enteric virus in raw sewage ranging from five to 11,000 PFU per liter. In a two-year study of Israeli wastewaters, Buras (1976) found virus were present throughout the year in both raw sewage and secondarily treated effluents. The highest concentrations reported were during the summer months with average concentrations of 28,000 PFU per 100 milliliters in raw influent and 20,000 PFU per 100 milliliters in the treated effluent. There were considerably less virus found during the winter months. During a period of epidemic poliomyelitis, seven strains of Poliovirus 1, 2 and 3 were recovered from Madrid wastewaters (Olivares, 1974). Studies have demonstrated the high number of solid-associated virus in sludge (Wellings, Lewis and Mountain, 1976; Cliver, 1975) that is removed by primary settling during the initial phases of wastewater treatment. Although the raw sludge is rich in nutrients, it cannot be utilized in this form due to the high concentrations and long-term survival of both bacterial and viral pathogens. Investigations have shown that virus associated with sludge solids is still capable of causing infection (Moore, Sagik and Malina, 1975). A common treatment for raw sludge is anaerobic digestion. Studies have elucidated the mechanism of viral inactivation during anaerobic digestion. Using raw sludge seeded with different serotypes of Poliovirus, Ward and Ashley (1976) found that virus could be recovered intact from digested sludge, but the concentration varied with temperature and time. They observed a 90% reduction in viral infectivity in one day at 28 Celsius, but required a digestion period of five days for the same reduction at 4 Celsius. Since raw sludge exhibited no viricidal activity, they concluded in a later study that the viricidal agent was a product of the digestion process (Ward, Ashley and Moseley, 1976). Fractionation of the digested sludge indicated that the anti-viral activity was associated with the liquid portion of the sludge. When this fraction was added to raw sludge viral inactivation occurred. Analysis of the liquid indicated the agent responsible for the inactivation was ammonia (Ward and Ashley, 1977). Inactivation was found to occur only when the pH of the digested sludge was 8.0 or higher where the ammonia would be in the uncharged state. Inactivation was observed for several viruses belonging to the Picornavirus family (Polio, ECHO, Coxsackie) while Reovirus was resistant to the effects of ammonia. The mechanism of inactivation appeared to be cleavage of the major capsid proteins followed by destruction of the viral RNA.

A number of studies have been conducted that were designed to determine the efficiency of virus inactivation at each step of the wastewater treatment process.

3.1.6.1 Primary Settling. The data on virus removal by primary settling is confusing and incomplete. After seeding Poliovirus in raw influent, Clarke *et al.* (1961) reported that virus failed to settle out within three to six hours after seeding. Only 40 to 70% of the virus had settled after 24 hours even though 75% of the solids had settled. Berg (1973b) pointed out that there was no way of measuring those viruses imbedded and adsorbed within the fecal material. Presumably, a large portion of these viruses would settle out with the solids.

3.1.6.2 Storage. Long-term storage has been suggested as a simple method for destroying virus. The survival of virus, however, is directly related to the water quality and the temperature (Berg, 1973b). In his study, Berg reported that 99% inactivation of Polio 1 and ECHO 12 required 60 days of storage at 10 Celsius, and 30 days at 30 Celsius. ECHOvirus type 7 required twice as long for the same inactivation. Survival was found to be longer in clean water than moderately or grossly polluted water (Clarke and Chang, 1959). Because of the lengthy detention times and the large storage facilities

required, this method of virus removal is not considered to be practical.

3.1.6.3 Biological Treatment. Several methods of biological treatment have been utilized to remove virus from wastewater including: trickling filters, stabilization ponds and activated sludge. Trickling filters show erratic virus removal rates. Shuval (1970) reported 16 to 100% recovery of virus from wastewater passed through trickling filters. Results from experiments utilizing stabilization ponds to remove virus were equally varied and erratic. In a series of repeated experiments, Shuval (1970) reported that virus removal ranged from 0 to 96% in ponds with a 20 day retention time.

Activated sludge appears to be the best method of biological treatment available for virus removal or inactivation. In laboratory studies, Berg (1971) reported that 96 to 99% of Coxsackie type A9 was removed after a 6 to 8.5 hour treatment period. When Polio 1 was seeded into activated sludge, 88 to 94% was removed within 7.5 hours. Similar studies conducted at treatment plants yielded reductions of 53–71%.

3.1.6.4 Chemical and Physical Treatment. Coagulation appears to be the most effective chemical procedure for removal of viruses from wastewater. The reaction involves a metal cation-protein interaction forming a metal-virus complex that aggregates to form a precipitate (Clark and Chang, 1959). Aluminum sulfate, calcium hydroxide and polyelectrolytes have been most often used in the coagulation process. Chang *et al.* (1958) obtained virus reduction up to 99% using 60 to 100 milligrams per liter of alum. By using ten milligrams per liter of alum as a coagulant, Thorup *et al.* (1970) removed 85 to 90% of seeded Poliovirus type 1. Virus is generally not inactivated by coagulation but precipitated in the sludge. A number of investigators have isolated viable virus from alum sludge and expressed concern over the disposal of such sludge (Berg, 1973b). Lime [$Ca(OH)_2$] is an effective coagulant at concentrations of 400 to 500 milligrams per liter. When the higher concentrations of lime were used, a pH of 11.1 resulted. This pH level was sufficient to destroy or inactivate 90 to 99% of the virus during a 90-minute contact period (Berg, 1973b). Effective virus removal was also reported using $FeCl_3$ as a coagulant (Chang *et al.*, 1958). Cationic polyelectrolytes have been found to be more efficient in virus removal than nonionic or anionic polyelectrolytes (Berg, 1973a). In deionized water up to 99% removal of virus was observed with these polyelectrolytes.

3.1.6.5 Disinfection. Since the majority of sewage treatment plants cannot effectively remove all the potentially harmful microorganisms during biological, physical and chemical treatment, a terminal disinfection stage is necessary for wastewaters. However, due to the complex nature of the effluent wastewaters, there is ample evidence to indicate that routine disinfection used in most treatments is not sufficient to destroy viruses. There is no one agent which can effectively disinfect all types of wastewaters due to the varying quality of the effluents.

Chlorine is widely used as a terminal disinfectant. The viricidal effectiveness of chlorine is dependent upon pH, retention time, temperature, chlorine concentration and overall quality of the water being treated. There is some disagreement in the literature as to which form of chlorine is the most effective viricidal agent. Between acidic and neutral pH levels chlorine hydrolyzes to yield hypochlorous acid (HOCl), while under alkaline conditions, it exists as hypochlorite ion (OCl^-). Kott, Nupen and Ross (1975) indicated that hypochlorous acid at pH 6.0 was a more effective viricidal agent against Poliovirus. Clarke and Kabler had previously reported (1954) that the hypochlorous acid form at a residual concentration of one milligram per liter was sufficient to inactivate 99.6% of Coxsackie type A2 in 100 seconds at 27 Celsius, while similar concentrations of hypochlorite ion required 3.5 minutes to attain the same level of inactivation. Temperature reduction was shown to lengthen the inactivation time, but the same difference was noted with HOCl inactivating 99.6% in seven minutes and OCl^- in 30 minutes. Other investigators have found OCl^- to be the more effective viricidal agent (Scarpino *et al.*, 1972). The effectiveness of chlorine as a disinfecting agent is complicated by its reactions with other wastewater components leading to the formation of a variety of compounds. The presence of ammonia, for example, results in the production of chloramines. Not only are chloramines less efficient in their viral inactivating capacity, but at a concentration of 0.06 milligrams per liter are toxic to fish and other aquatic life. Species within the Enterovirus group have varying sensitivities to chlorine as seen in Table 3–2 (Liu and McGowan, 1973). Reovirus type 1 was inactivated in 2.7 minutes, but Coxsackie type A6 virus required over 120 minutes of contact time to reach the same level of inactivation. The inactivation time among members of the same group can vary significantly.

Table 3–2

TIME TO INACTIVATE 99.99 PERCENT OF TWENTY-FIVE HUMAN ENTERIC VIRUSES WITH 0.5 MG/L FREE CHLORINE IN POTOMAC WATER (pH 7.8 and 2 C)

	Virus	Minutes		Virus	Minutes
1	Reo 1	2.7	14	ECHO 11	14.0
2	Reo 3	<4.0	15	Polio 1	16.2
3	Reo 2	4.2	16	ECHO 29	20.0
4	Adeno 3	<4.3	17	Adeno 12	23.5
5	Cox B2	6.5	18	ECHO 1	27.0
6	Cox A9	6.8	19	Polio 3	30.0
7	Cox B4	7.0	20	Cox B3	35.0
8	ECHO 7	7.1	21	Cox A5	35.3
9	ECHO 5	8.0	22	Cox B5	39.5
10	Cox B1	8.5	23	Polio 2	40.0
11	ECHO 9	12.0	24	ECHO 12	>60.0
12	Adeno 7a	12.5	25	Cox A6	>120.0
13	ECHO 8	13.0			

Shuval (1970) reported that viruses were more resistant to the effects of chlorine than bacteria. Chlorine concentrations of 40 milligrams per liter were required to inactivate 99.9% of Poliovirus in sewage in ten minutes. To reach the same level of inactivation, only nine milligrams per liter of

chlorine were needed to inactivate coliform organisms. Kott *et al.* (1975) also demonstrated Poliovirus to be more resistant to chlorination treatment than E. coli.

Other agents have been used to disinfect wastewaters. Ozone appears to have excellent potential value as a terminal disinfecting agent particularly in waters containing organics (Berg, 1973b). It has been shown to inactivate Polio type 3 and Coxsackie B3 in ten minutes. Iodine has also been used in small water supplies. While being slower in virus inactivation than HOCl, I_2 has the advantage of not forming amines and may be useful in wastewaters containing ammonia (Berg, 1973a). Studies of the use of bromine have yielded results comparable to those for I_2. While all above methods have shown promise in experimental or small scale operations, none has proven to be totally reliable in sewage disinfection processes.

Efforts to produce virus-free sewage effluents have thus far met with little success (Sproul, 1974). The major problem appears to rest not with the type disinfectant used, but the quality of the water being disinfected (Berg, 1971).

3.1.7 Sewage Effluent Recharge

Most effluents from wastewater treatment plants contain populations of enteric viruses. The presence of these viruses constitutes a potential threat to wastewater recharge procedures should viruses be carried through soil and contaminate the groundwater aquifers. The fate of viruses in soil, their adsorption, movement and survival, should be carefully studied in order to determine if potential health hazards exist.

A number of field studies have been discussed in the literature which indicated that viruses can be effectively removed from sewage effluents by percolation through soil. At the Santee Water Reclamation Project, chlorinated sewage effluent, percolated through 400 feet of sand and gravel, was used to supply waters for a recreational lake (Merrell and Ward, 1968). Out of 128 samplings, two showed positive viral isolations. After seeding treated wastewater with high concentrations of Polio type 3, no virus could be found after passage through 200 feet of sand reclamation bed. It should be noted that the authors used swabs and gauze pads as water sampling devices. These methods do not represent very effective means of recovering viruses under field conditions. Gilbert *et al.* (1976b) found that percolation through 60–90 centimeters of fine loamy sand was sufficient to remove 99.99% of the viruses found in secondary sewage effluents. Sand filtration was also found to be sufficient to remove over 99% of total coliforms, fecal coliforms and fecal streptococci (Gilbert *et al.*, 1976a).

A number of studies have detected the presence of viruses in groundwater following the recharge of sewage effluents through sand basins. Hori *et al.* (1970), studying the fate of Poliovirus type 2 recharged through Oahu Island soils, found instances of viral contamination of groundwater despite the good removal characteristics of the soil. The authors concluded that the possibility of groundwater contamination existed if the underlying soil was interrupted by fissures and fractures that would result in channeling of the percolating waters. In a study of the rapid infiltration of viruses through silty sand and fine gravel, Schaub and Sorber (1977) demonstrated the sporadic occurrence of enterovirus in groundwater. Laboratory experiments confirmed the poor removal qualities of the test soil used in their field experiments.

The probable mechanism of virus removal during percolation through sand or soils is adsorption rather than filtration or sieving (Drewry and Eliassen, 1968). The adsorption process is strongly influenced by a number of factors including the pH of the recharged water, the chemical composition of the soil, the moisture content of the soil and the rate of recharge (Gerba *et. al.*, 1975). Since viruses are electrically charged, colloidal particles consisting of an inner core of nucleic acid surrounded by a protein coat, the pH and ionic strength of the surrounding medium greatly influence the ability of the virus to adsorb to soil particles. Drewry and Eliassen (1968) demonstrated this pH dependence in a study of the ability of bacteriophage to adsorb to different types of soils. They found that maximum adsorption occurred when pH values were below the isoelectric point of the virus particle. Under these conditions, the virus would be positively charged and act as a cation, freely adsorbing to the negatively charged soil.

The ionic strength of the adsorbing environment was also found to be an important factor in the attachment of virus particles. Wellings *et. al.* (1975) studied the ability of a cypress dome to remove enteric viruses present in treated sewage effluent. No isolations were observed during the first five months, however, three isolations of virus from groundwater were later reported following a period of heavy rainfall. The authors concluded that the rainfall resulted in an increase in the water/soil ratio, which acted to desorb the viruses allowing them to move vertically towards the aquifer. A similar desorption effect was seen when deionized water was added to 250 centimeter calcareous sand columns used to recharge sewage effluent (Lance *et al.*, 1976). The virus, which had been previously adsorbed to the top five centimeters of the soil column, moved down the column readsorbing at a lower level. Desorption was minimized by drying the columns one day between applications of the sewage, or by addition of cations to the effluent. The investigators concluded that desorption was due to a reduction in the ionic strength of the soil. In a similar study Duboise *et al.* (1976) reported that a specific conductance of 700–800 micro-ohms per centimeter was necessary for maximum retention of virus to soil. The addition of distilled water to simulate rainfall diluted the ionic capacity of the soil and freed the virus.

Robeck *et. al.* (1962) reported that the rate of recharge was important in the removal of Poliovirus type 1 in a sand recharge basin. At recharge rates of 0.6 to 1.2 liters per minute per meter squared ($l/min/m^2$), 99% of the virus was removed during passage through sand columns. At higher flow rates of 38 to 76 $l/min/m^2$, viruses were commonly found in the sand column effluent. Gilcreas and Kelly (1955) reported similar results using Coxsackie A5. A flow rate of 7.5 $l/min/m^2$ allowed removal of 99% of the virus while a

75 l/min/m^2 recharge rate resulted in the removal of only 10% of the virus.

Clean dry sand has been shown to have little or no capability for removing virus (Berg, 1973a). Moistened sand showed a better removal efficiency (Nestor and Costin, 1971). Drewry and Eliassen (1968) reported that soils with a high clay and silt content (composed of .5 to 1% organic matter) were effective in removing viruses. Clay particles were found to possess a larger surface area than sand which provided numerous sites for viral adsorption (Britton, 1975).

Although viruses are readily adsorbed to soils during the process of recharge, they can remain viable for significant periods of time. Moore *et al* (1975) found that Poliovirus adsorbed to organic and inorganic particulates was still infective. Schaub and Sagik (1975) reported that clay-adsorbed virus retained its infectivity in tissue culture monolayers and in mice. Bagdasaryan (1964) studied the survival of enteric viruses in soil and concluded that survival was dependent on the pH of the soil, its moisture content, the nature of the soil and its temperature. Sandy soil at a pH of 7.5 provided the best conditions for virus survival, with Polio type 1 surviving for 170 days at 3–10 Celsius. Wellings *et al.* (1975) reported isolating Poliovirus in a groundwater well below a recharge basin 28 days after application of sewage effluent was terminated. Duboise et al. (1976) found Poliovirus capable of surviving 84 days in soil at 3 Celisus. Increasing the temperature to 20 Celsius resulted in a 99% inactivation rate in 84 days. A similar study by Tierney *et al.* (1977) detected Poliovirus after 96 days in irrigated soils during the winter. Summer survival in soil was significantly shorter, lasting only 11 days.

3.1.8 Septic Systems

Little information is available on the fate of human enteric viruses in septic systems. Since large numbers of human viruses can be shed in feces, there is little doubt of their presence in the system. What is needed is more information concerning the amount of virus removed during the initial stages of settling, the mechanisms and rate of viral inactivation during this period and the ultimate fate of viruses discharged in septic tank effluents.

Due to the lack of scientific study, the answers to the first two questions have not been determined. One can, however, speculate based upon similar processes occurring during the initial stages of conventional wastewater treatment. As found in primary settling, some viruses will be removed with the solids, the survival depending upon the presence of non-specific viricidal agents present in the sludge or the toxic metabolic by-products of the resident microbial population.

The fate of viruses discharged in septic tank effluents has been the subject of a few laboratory studies, but little or no data has been gathered from field trials. The studies have concerned themselves with the removal of viruses from effluents by percolation through soils, a subject which has been reviewed in Section E-2. Sproul (1975) reported that viruses discharged from leaking septic tanks could be efficiently removed from the leachates depending on the type of subsoil, the flow rate and the overall quality of the effluent itself. He recommended using soils which contain a high percentage of silt or clay, with a minimum depth of within five to ten feet of the fractured ledge. The recommended flow rate for such a system was 0.4 to 0.7 gallons per day per foot squared (gpd/ft^2). Citing the number of viral isolations from groundwater following recharge, Sproul warned that the soil adsorbing layer should be free from fissures or fractures that would lead to channeling and possible contamination of the groundwater. Green and Cliver (1974) reported on laboratory studies involving the removal of virus by sand columns. Using Poliovirus type 1 seeded into septic tank effluent, they found that a majority of the viruses were removed in 60 centimeter sand columns. The sand columns were the most efficient when the column was unsaturated. Drewry and Eliassen (1968) found soil to be an effective virus adsorbing medium except where channeling occurred. Their recommendations for an ideal subsurface soil percolation system included a minimum infiltration rate of 2.54 centimeters per hour with a loading rate of three gallons per day per foot squared (gpd/ft^2) and a high adsorptive soil containing 1 to 2% silt or clay and 0.5 to 1% organic matter. They concluded that incorporation of the above criteria, in addition to placement of the septic system 100–150 feet from the nearest well, would be sufficient to avoid viral contamination of groundwater used for domestic purposes.

3.2 METHODS AND MATERIALS

3.2.1 Sample Site Selection

Sites for virus sampling were chosen by a sub-group of the Technical Advisory Committee which represented a diversity of professional disciplines. The sites selected and the frequency with which they were sampled are described below and reviewed in Table 3–3.

1. Sites Located in Nassau County

(a) Meadowbrook Hospital. The site included a 1,000,000 gallon per day (GPD) capacity secondary sewage treatment plant (trickling filter) which services the hospital complex of the Nassau County Medical Center and Nassau County Jail. Chlorinated effluent was discharged into a series of recharge basins that were located approximately 34 feet above the groundwater table. Sampling at this site consisted of a 25 gallon sewage effluent sample and a 100 gallon groundwater sample taken from an observation well that was located within ten lateral feet (downflow) of the primary recharge basin (sample designated as "Meadowbrook Well"). Samples were taken on a monthly basis.

(b) Oyster Bay STP. The site consisted of a secondary sewage treatment facility (trickling filter) that disinfected its effluents via chlorination. Treated effluent was discharged directly into Oyster Bay. Twenty-five gallon samples were taken on a monthly basis from this site.

(c) Oyster Bay Waters and Shellfish. Water (100 gallons) and shellfish (oyster) samples were taken from areas of Oyster Bay that had been designated as "open" or "closed" to shellfishing by the New York State

Table 3–3

SITES CHOSEN FOR VIRAL ANALYSES

Site	Location (County)	Type Sample	Frequency
1. Meadowbrook STP	Nassau	Chlorinated sewage effluent	Monthly
2. Meadowbrook Well	Nassau	Groundwater from observation well located down flow from sewage effluent recharge basin	Monthly
3. Oyster Bay STP[a]	Nassau	Chlorinated secondary sewage effluent	Monthly
4. Oyster Bay—closed waters	Nassau	Bay water (area closed to shellfishing)	Monthly-June-Sept, March-May Bi-monthly-Oct-Feb
5. Oyster Bay—open waters	Nassau	Bay water (area open to shellfishing)	Monthly-June-Sept, March-May Bi-monthly-Oct-Feb
6. Oyster Bay—closed oysters	Nassau	Oysters from closed area	Monthly-June-Sept March-May Bi-monthly-Oct-Feb
7. Oyster Bay—open oysters	Nassau	Oysters from open area	Monthly-June-Sept March-May Bi-monthly-Oct-Feb
8. No. Massapequa recharge basin	Nassau	Water from observation well located within recharge basin receiving storm water run-off	Monthly
9. Bayport Well	Suffolk	SCWA[b] well water	Monthly
10. Oakdale Well	Suffolk	SCWA well water	Monthly
11. Stony Brook STP	Suffolk	Chlorinated secondary Sewage effluent	Monthly
12. Stony Brook Well	Suffolk	Groundwater from observation well located down flow from sewage effluent recharge basin	Monthly
13. Penataquit Creek	Suffolk	Salt water creek receiving freshwater run-off	Monthly
14. Great South Bay—open waters	Suffolk	Bay water (area open to shellfishing)	Monthly-June-Sept, March-May Bi-monthly-Oct-Feb
15. Great South Bay—open clams	Suffolk	Clams from open area	Monthly-June-Sept, March-May Bi-monthly-Oct-Feb
16. Great South Bay—Closed waters	Suffolk	Bay water (area closed to shellfishing)	Monthly-June-Sept, March-May Bi-monthly-Oct-Feb
17. Great Soutn Bay—closed clams	Suffolk	Clams from closed area	Monthly-June-Sept, March-May Bi-monthly-Oct-Feb
18. Babylon Well	Suffolk	Groundwater from observation well located down flow from sanitary landfill site	Monthly
19. Sunrise STP	Suffolk	Chlorinated secondary sewage effluent	Monthly
20. Sunrise Well	Suffolk	Groundwater from observation well located down flow from sewage effluent leaching pools	Monthly
21. Parkland III STP	Suffolk	Chlorinated sewage effluent	Monthly
22. Parkland III Well	Suffolk	Groundwater from observation well located down flow from recharge basin receiving sewage effluent	Monthly
23. Lake Ronkonkoma	Suffolk	Lake Water	Monthly-June-Sept, Bi-monthly-Oct-May
24. SCHD(c) Experimental wastewater septic system (located at Brookhaven National Laboratory)—Influent	Suffolk	Raw wastewater	Monthly
25. SCHD experimental septic system—effluent	Suffolk	Treated non-chlorinated effluent	Monthly

(a) Sewage Treatment Plant
(b) Suffolk County Water Authority
(c) Suffolk County Health Department

APPENDIX TO TABLE 3–3

All "well" samples listed were collected from observation wells which had been driven a few feet below the upper surface of the groundwater aquifer.

Department of Environmental Conservation on the basis of coliform data. The sites were sampled monthly from June–September, and again from March–May, and on a bi-monthly basis from October–February.

(d) North Massapequa. The site was chosen as a representative stormwater recharge basin located in a thickly settled area. Sampling consisted of 100-gallon volumes collected monthly from a United States Geological Survey observation well located in the bottom of the basin.

2. Sites Located in Suffolk County

(a) Bayport Well, Oakdale Well. Both sites were Suffolk County Water Authority public drinking water supply wells located in the hamlets of Bayport and Oakdale respectively. Samples, taken at monthly intervals, consisted of 100 gallons each. Both areas had been in service for a number of years with neither having any past problems with high coliform counts.

(b) Stony Brook. This site included a 300,000 gallon per day capacity secondary sewage treatment plant (contact stabilization) and a series of recharge basins into which chlorinated effluent was discharged. At monthly intervals, 25 gallon treated effluent samples were taken along with 100 gallons of water taken from an observation well located some eight lateral feet downflow from the nearest recharge basin. The basins themselves were some 80 feet above the water table.

(c) Penataquit Creek. The creek, located in the hamlet of Bay Shore is a tributary to Great South Bay. In making its way to the bay, the water passes through a residential area and by a hospital. The actual sampling point was the Town of Islip boathouse located well below the above areas.

(d) Great South Bay Waters and Shellfish. Located within the Town of Islip, sites for collection of water (100 gallons) and shellfish (clam) samples included areas designated as "open" and "closed" to shellfishing by the New York State Department of Environmental Conservation. Samples were taken monthly from June–September, and March–May, and on a bi-monthly basis from October–February.

(e) Babylon. The sampling area was a groundwater observation well located within one quarter mile down groundwater flow from the Babylon landfill site. The landfill includes regular rubbish disposal and pits for scavenger-waste disposal, and is located approximately 75 feet above the glacial aquifer. Monthly samples of 100 gallons each were taken from a United States Geological Survey observation well.

(f) Sunrise Garden Apartments. This site, located in the hamlet of Sayville, included a secondary sewage treatment facility (contact stabilization) with a 38,000 gallon per day measured operating capacity. Chlorinated effluent from the plant was discharged to a leaching field that was located some five to eight feet above the groundwater table. Twenty-five gallon effluent samples were taken at monthly intervals, along with 100 gallon volumes from an observation well that was sunk within ten feet downflow from the leaching field.

(g) Parkland III. The site consisted of a 260,000 gallon per day capacity tertiary treatment plant (extended aeration, denitrification, gravity, sand filtration) with recharge basins located some 18 feet above the water table. Twenty-five gallon samples of the chlorinated effluent were taken on a monthly basis along with a 100 gallon volume from an observation well located some 50 lateral yards down water flow from the recharge basins.

(h) Lake Ronkonkoma. The site constitutes the largest fresh water lake on Long Island. The area is thickly settled by both residential and commercial concerns, and contains several public bathing areas. Virus sampling was confined to an area within the Islip Town Beach. One-hundred gallon volumes were taken from a depth of five feet (approximately ten to 15 feet off shore) on a monthly basis from June–September, and bi-monthly from October–May.

(i) Septic System. The site, located at the Brookhaven National Laboratory, contains an experimental septic system that has been constructed by the Suffolk County Health Department in collaboration with William F. Cosulich Associates. The subsurface system consists of a tile field, which has been constructed over an aerobic soil zone. Below this is an anaerobic soil zone—the principle function of which is denitrification. Final effluent from the system is collected in a sampling shaft. Samples of this system's raw influent (one gallon) and final effluent (100 gallon—undisinfected water) were collected for viral analysis on a monthly basis.

3.2.2 Sample Collection

Sample volumes of 100–125 gallons each were taken from public water supply wells, groundwater wells near recharge basins and sanitary landfills, embayments, lakes and streams. Twenty-five gallon samples were usually collected from wastewater treatment plants while one gallon samples were taken when raw influent was required.

All samples (with exception of raw influents) were collected in plastic 55 gallon tanks (Plast-i-cube, Greif Brothers Corp.). Between sample collections, tanks were thoroughly rinsed with tap water, sanitized with 0.12 N hydrochloric acid (30 minutes), and rinsed once again with tap water. Upon arrival at each site, tanks were initially rinsed with 10–20 gallons of sample water before being filled with sample material. Brookhaven National Laboratory pumping equipment (*i.e.,* impeller pumps, hosing) was also rinsed with 20–30 gallons of sample water prior to collection. Brookhaven National Laboratory equipment was routinely used for all sampling, with the exception of waters from Oyster Bay (open and closed). In these instances, water samples were taken by means of pumps available on oyster boats belonging to Flowers Inc. of Bayville. Before collection of these samples, water from the designated area was rinsed through the pumping system for five to ten minutes.

The above precautions were taken in order to obviate any chance of virus cross-contamination between samples.

Great South Bay clam samples were collected by tonging, while oysters from Oyster Bay were obtained by dredging. Shellfish samples were stored in ice during transport to the laboratory where processing was carried out immediately whenever possible.

3.2.3 Virus Concentration Procedures

1. Water Samples

Viruses in large volume water samples were initially concentrated by means of an Aquella Virus Concentrator (Carborundum Corporation). Appropriate sample volumes were pumped through a series of prefilters to remove debris. Sample pH was then adjusted to 3.5 and aluminum chloride was added to a final concentration of 0.0005 M. The water then flowed through virus concentrating filters, where virus was adsorbed to the surface of the filters. Elution of adsorbed virus was carried out with 0.1 M glycine at pH 11.5. Samples were then neutralized to pH 7.5. The concentration procedure routinely yielded a final volume of 4.1, which was further concentrated in the laboratory. The procedure involved the formation of an aluminum hydroxide floc to which virus particles became adsorbed. After concentration of the floc by centrifugation, viral particles were eluted with 0.1 M glycine (pH 11.5) to a final volume of approximately 50 milliliters. After the addition of 10% fetal calf serum to each reconcentrate, samples were stored at −72 Celsius until needed.

2. Shellfish Samples

Shellfish (clams and oysters) were shucked and placed in 100 gram aliquots. Following homogenization, samples were acidified causing formation of a virus-containing precipitate which could be centrifuged and collected. Viruses were eluted from the precipitate with a glycine-saline solution, then separated from the rest of the precipitate by centrifugation. Virus-laden supernates were then filtered through a series of 47 millimeter membrane filters (0.8, 0.45 and 0.22 micrometers porosity respectively) and concentrated by ultrafiltration to a final volume of five milliliters. Processed samples were frozen at −72 Celsius while awaiting tissue culture assay.

3.2.4 Isolation and Identification

Virus enumerations from field samples were carried on monolayers of Buffalo Green Monkey Kidney Cells (BGM—Microbiological Associates). Quintuplicate 0.5 milliliter sample volumes were placed on prepared cell sheets and incubated for one hour to facilitate virus attachment. After decanting excess sample material, cells were covered with a four milliliter neutral red agar overlay media and incubated at 36 Celsius under 5% CO_2 for a period of eight days. Daily readings were taken to determine the presence of viruses that appeared as "plaques" (clearings in the normally red stained background indicating cell death as a result of virus infection). After eight days each plaque was "picked" and the isolated viruses were enriched for one week on a monolayer of BGM cells. Isolates were identified in microtiter plates by serum neutralization techniques using enterovirus typing pools made available by the National Institute of Allergy and Infectious Disease.

3.2.5 Poliovirus T—Marker Studies

Isolates identified as being members of the Poliovirus group were further tested to determine whether they were vaccine strain or wild type virus. This was accomplished through T—marker tests which differentiate between vaccine strain and wild type based upon the latter's ability to grow at 40 Celsius. T—marker tests were carried out in response to a request by health officials who realized the public health significance of the isolation of non-vaccine Polioviruses from Long Island aquatic systems.

3.2.6 Coliform Studies

In order to correlate virus data with a recognizable biological pollution indicator, total and fecal coliform numbers were determined from all sites tested for virus. Coliform enumerations derived from standard "most probable numbers" methods were carried out by the staff of the New York State Department of Environmental Conservation Microbiology Section (Stony Brook), under the direction of Mr. James Redman..

3.2.7 Other Chemical and Physical Tests

PH determinations were carried out on all samples with the exception of shellfish. Residual chlorine and turbidity measurements were made on sewage treatment plant effluents (turbidity monitoring began in February 1977).

3.3 RESULTS

3.3.1 Limitation of Study

Before proceeding with the presentation of the results of the 208 Virus Study, it is appropriate to discuss the major limiting factors that were inherent in the program.

The use of virus concentrating units, such as the Carborundum concentrators used in our study, has greatly facilitated the isolation and enumeration of human enteric viruses from large volumes of water. However, because of the variables involved, *(e.g.,* turbidity, salinity, presence of organics, etc.) it is not reasonable to expect a 100% efficiency of concentration. Similarly, methods for virus extraction from shellfish do not release all of the virus particles bound up within the tissues of the animal. Budgetary considerations required our use of a single host cell type (BGM), which has been shown to be sensitive to a great variety of enteroviruses (Dahling *et al.,* 1974), but not to all known members of the group. Extending the range would have required the use of additional cell strains, an action which would have involved considerable expense.

As a result of the above limitations, the viral enumerations reported in the following pages must be construed as being representative of the *minimum* numbers of virus in each sample. It is likely that in most cases there were more than we were able to report. Samples in which no viruses were detected have been labeled NI (no isolates) in the tables rather than with a zero. The NI designation refers to the inability to detect viruses within the constraints of our testing systems, but cannot preclude the possibility of viral presence in very low concentrations.

Isolate identification procedures utilize serum pools that can accurately

identify 42 members of the Enterovirus group. These include those species most often encountered in domestic wastewater. As there are over 100 known Enteroviruses, it was impossible to identify all isolates derived from the 208 study. Untypable isolates will be designated by a U in the tabulated listings of virus identification.

3.3.2 Results of Field Samplings

1. Public Water Supply Wells

All samples from both the Bayport and the Oakdale drinking water installations yielded no positive virus results (Table 3–4 and 3–5). Corresponding coliform counts were at the lowest limits of detection (Figures 3–1 and 3–2).

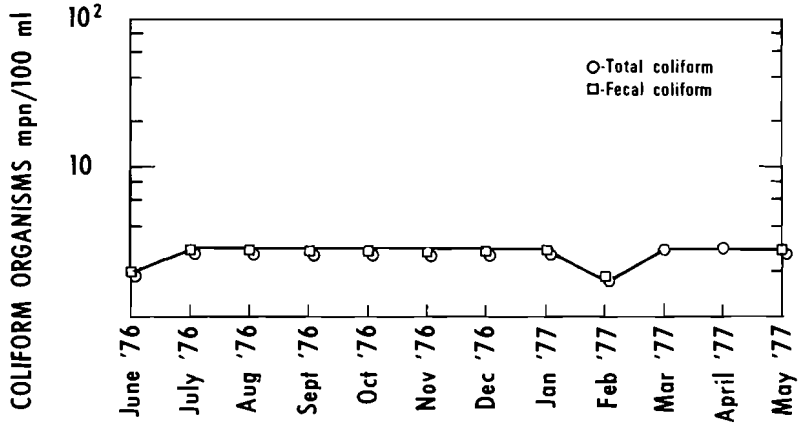

FIGURE 3–1 *Total and Fecal Coliform Counts (Per 100 Milliliters) Bayport Well.*

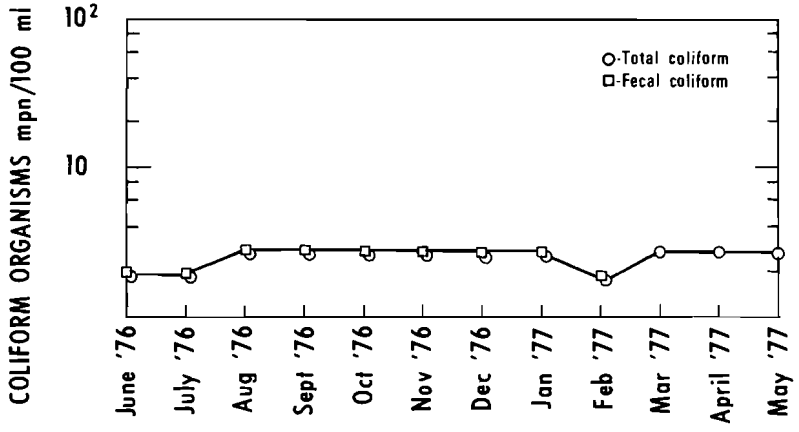

FIGURE 3–2 *Total and Fecal Coliform Counts (Per 100 Milliliters) Oakdale Well.*

Drinking water sample reconcentrates were assayed on tissue culture more extensively than any other sample type. The resulting data are therefore more representative of the entire sample volume.

Table 3–4

COLIFORM AND VIRUS ISOLATION

Bayport Well

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
June 1976	<2	<2	ni
July 1976	<3	<3	ni
August 1976	<3	<3	ni
September 1976	<3	<3	ni
October 1976	<3	<3	ni
November 1976	<3	<3	ni
December 1976	<3	<3	ni
January 1977	<3	<3	ni
February 1977	<2	<2	ni
March 1977	<3	nt	ni
April 1977	<3	nt	ni
May 1977	<3	<3	ni

ni = No Isolates
nt = Not Tested

Table 3–5

COLIFORM AND VIRUS ISOLATION

Oakdale Well

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
June 1976	<2	<2	ni
July 1976	<2	<2	ni
August 1976	<3	<3	ni
September 1976	<3	<3	ni
October 1976	<3	<3	ni
November 1976	<3	<3	ni
December 1976	<3	<3	ni
January 1977	<3	<3	ni
February 1977	<2	<2	ni
March 1977	<3	nt	ni
April 1977	<3	nt	ni
May 1977	<3	<3	ni

ni = No Isolates
nt = Not Tested

2. Surface Waters

(a) Lake Ronkonkoma. Viruses were recovered from the lake on two occasions, September and March. Isolations occurred at times when coliform numbers were not at particularly appreciable levels (Table 3–6, Figure 3–3).

The area from which the samples were taken is used extensively during summer months as a bathing beach. With this in mind, it would not be unreasonable to expect a certain level of enteric viruses to be present in the near shore waters in early September, the likely viral source being the bathers themselves, especially young children. Sampling problems arising from the presence of algal blooms during July and August may have inhibited the isolation of viruses whose presence could also have been linked to bathers. September isolates were confirmed but could not be specifically identified as they were insensitive to our typing antisera (Table 3–7).

Table 3–6

COLIFORM AND VIRUS ISOLATION

Lake Ronkonkoma

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
July 1976	230	230	ni
August 1976	2,300	930	ni
September 1976	43	43	2.3
October 1976	nt	nt	nt
November 1976	930	930	ni
December 1976	nt	nt	nt
January 1977	14	9	ni
February 1977	nt	nt	nt
March 1977	7	nt	6.5
April 1977	nt	nt	nt
May 1977	150	75	ni

ni = No Isolates
nt = Not Tested

Isolations made in March cannot easily be linked to bathers unless it is proven that viruses can over-winter in lake bottoms. Since there are supposedly no direct sewage discharges into the lake, the source possibilities are logically narrowed to runoff and contamination from the septic systems (via seepage or overflow) of homes situated around or near the lake. The latter possibility is strengthened by the isolation of a vaccine strain of Poliovirus type 2 (Table 3–7) normally shed by young children who have recently been immunized against poliomyelitis. The remainder of the confirmed March isolates could not be identified.

Table 3–7

VIRUS ISOLATE IDENTIFICATIONS

Lake Ronkonkoma

Date	Identifications Include
September 7, 1976	U*
March 9, 1977	Poliovirus Type 2 (Vaccine strain) U*

**U = Identity Unknown*

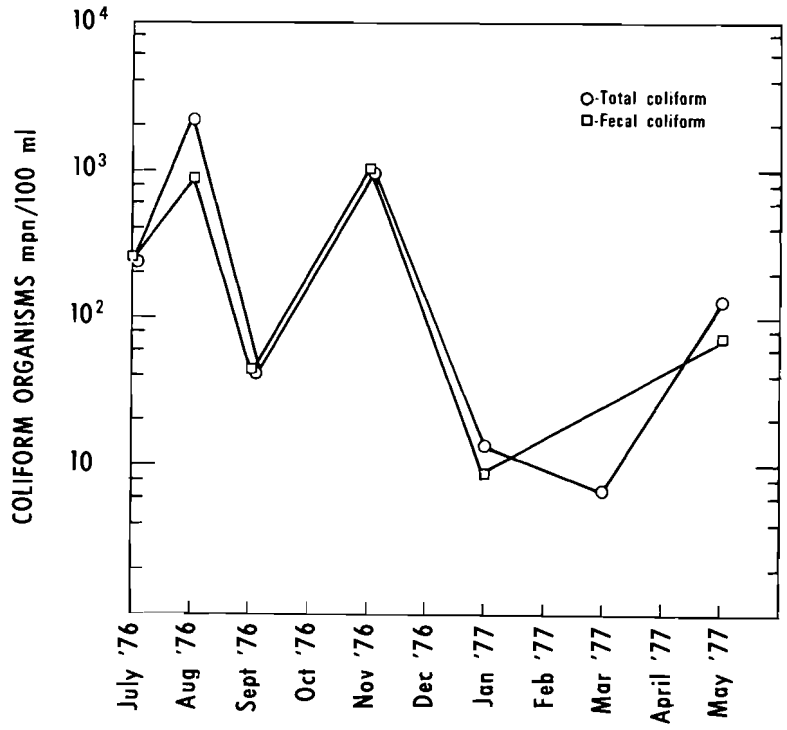

FIGURE 3–3 *Total and Fecal Coliform Counts (Per 100 Milliliters) Lake Ronkonkoma.*

(b) Penataquit Creek. Viral isolations were made in the creek in June and July during periods when total and fecal coliform counts were moderately high (Table 3–8, Figure 3–4), but not when total coliform counts reached their highest point in August. It is possible that the August counts were representative of a non-human fecal source (*i.e.,* ducks, seagulls, etc.).

The major sources of contamination in the creek likely occurred from points above our sampling area, rather than from the bay. The consistently high coliform counts suggested a fairly constant source of pollutants, such as runoff, and leakage from the septic systems located along the banks of the creek. The likelihood that contamination arose from a number of sources, rather than a single one, was further supported by the wide variety of isolates identified from the two samples (Table 3–9). No Poliovirus species were recovered from any creek samples.

Table 3–8

COLIFORM AND VIRUS ISOLATION

Penataquit Creek

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
June 1976	43,000	43,000	25.0
July 1976	1,100	460	8.0
August 1976	230,000	9,300	ni
September 1976	nt	nt	nt
October 1976	9,300	2,300	ni
November 1976	1,500	390	ni
December 1976	930	93	ni
January 1977	9,300	4,300	ni
February 1977	9,300	nt	ni
March 1977	15,000	nt	ni
April 1977	4,300	4,300	ni
May 1977	4,300	430	ni

ni = No Isolates
nt = Not Tested

Table 3–9

VIRUS ISOLATE IDENTIFICATIONS

Penataquit Creek

Date	Identifications Include:
June 29, 1976	ECHOvirus Type 6
	U*
	ECHOvirus Type 2
	Coxsackievirus Type A-9
	U*
	U*
	ECHOvirus Type 15
	Coxsackievirus Type B-3
July 15, 1976	ECHOvirus Type 25
	ECHOvirus Type 32

**U = Identity Unknown*

(c) *Great South Bay Waters and Shellfish*

i. OPEN AREA. Virus recoveries in water occurred twice during the summer, and once in the spring (Table 3–10). With the exception of the July sample, virus isolations were made during times when coliform counts were at their maximum (Figure 3–5). Isolations from clam samples occurred in April, when recoveries were also made in the water column, and in June (Table 3–11). Some moderate correlation was noted between virus isolations

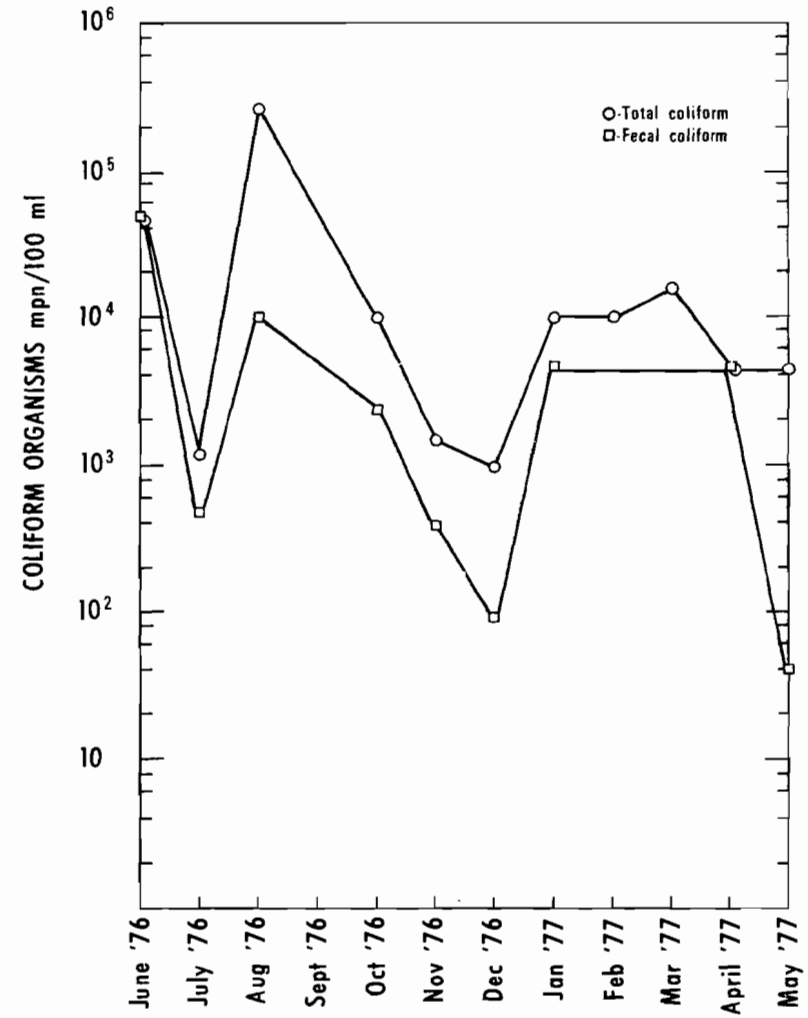

FIGURE 3–4 *Total and Fecal Coliform Counts (Per 100 Milliliters) Pentataquit Creek.*

and coliform counts (Figure 3–6) during these months. Difficulties in obtaining shellfish severely limited the total number of samples taken during the study period.

The possible sources of pollution to this region include land runoff, leakage from domestic septic systems located along the bay, and the discharges of previously contaminated tributary rivers and creeks. (*Note:* Penataquit Creek, which was previously shown to contain virus during summer months, empties into Great South Bay at a point just north of where "closed" and "open" water sampling was carried out.)

Table 3–10

COLIFORM AND VIRUS ISOLATION

Great South Bay, Open Shellfish Waters—Islip

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
July 1976	4	4	8.0
August 1976	460	4	1.2
September 1976	93	<3	ni
October 1976	nt	nt	nt
November 1976	43	nt	ni
December 1976	nt	nt	nt
January 1977	nt	nt	nt
February 1977	93	nt	ni
March 1977	23	<3	ni
April 1977	150	15	2.9
May 1977	nt	nt	nt
June 1977	93	<3	ni

ni = No Isolates
nt = Not Tested

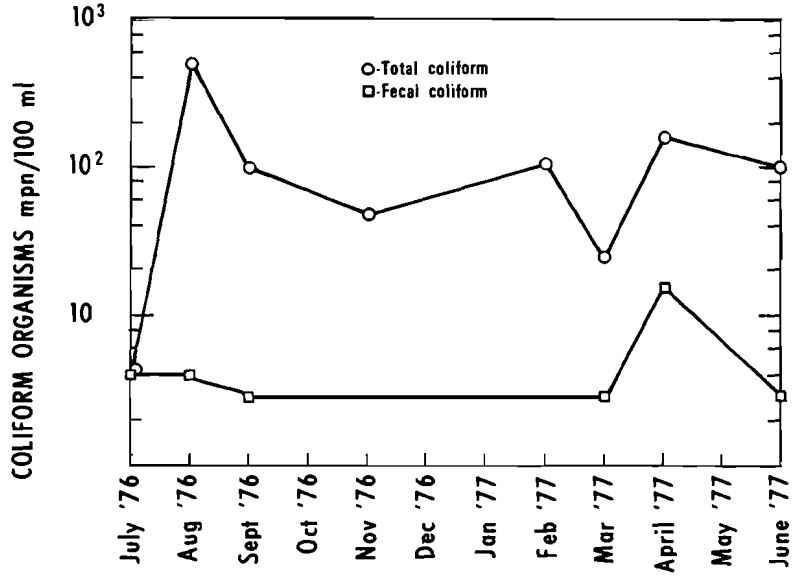

FIGURE 3–5 *Total and Fecal Coliform Counts (Per 100 Milliliters) Great South Bay, Open Shellfish Waters—Islip.*

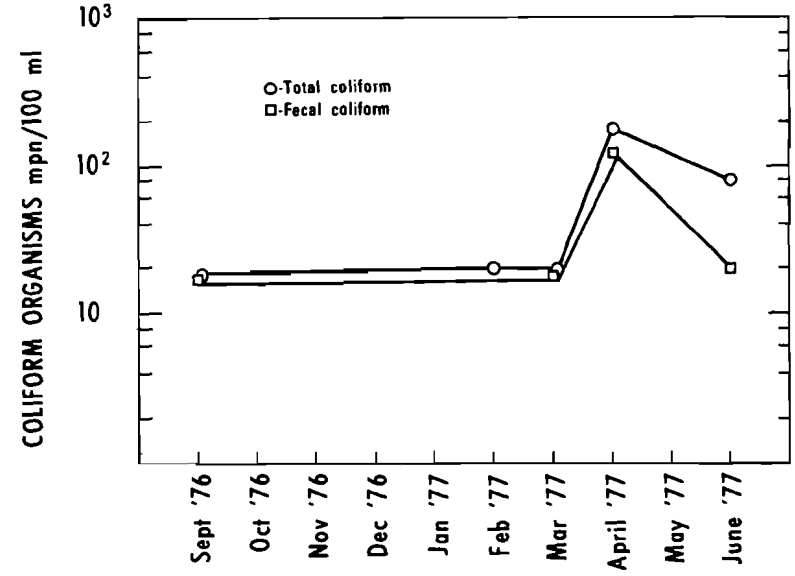

FIGURE 3–6 *Total and Fecal Coliform Counts (Per 100 Milliliters) Great South Bay, Open Shellfish—Clams.*

Table 3–11

COLIFORM AND VIRUS ISOLATION

Great South Bay, Open Shellfish—Clams

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
September 1976	<20	<20	ni
October 1976	nt	nt	nt
November 1976	nt	nt	nt
December 1976	nt	nt	nt
January 1977	nt	nt	nt
February 1977	20	nt	ni
March 1977	<20	<20	ni
April 1977	170	130	0.3
May 1977	nt	nt	nt
June 1977	70	<20	0.1

ni = No Isolates
nt = Not Tested

With the exception of the July sample, most of the water and shellfish isolates could not be specifically typed (Table 3–12). The Poliovirus type 2 isolate occurring in July was later shown to be a vaccine strain.

Table 3–12

VIRUS ISOLATE IDENTIFICATIONS

Great South Bay

"Open" Water and Shellfish

Date	Sample Type	Identifications Include:
July 7, 1976	Water	U*
		U*
		Poliovirus Type 2 (Vaccine strain)
		ECHOvirus Type 22
		ECHOvirus Type 11
August 18, 1976	Water	U*
April 25, 1977	Water	U*
April 25, 1977	Shellfish	U*
June 2, 1977	Shellfish	U*

U = Identity Unknown*

ii. CLOSED AREA. The area sampled was located within one mile in-shore from the "open" area, and was therefore closer to those potential pollution sources previously discussed.

Viral isolations from closed waters and shellfish were made in July (1976) and June (1977), with an additional isolation made in water alone in February (Tables 3–13 and 3–14). In general, viral isolation did not correlate well with coliform counts (Figures 3–7 and 3–8), with the exception of the July clam sample.

Isolate identifications, shown in Table 3–15, included several Polio and ECHO virus types. Of particular interest were the June 2 samples in which Poliovirus type 1 was isolated from both shellfish and the overlying water column.

Extrapolation of data collected from Penataquit Creek suggests that this and other local creeks were contributing to the "viral pollution" observed in this immediate region of the bay.

Based on the limited information collected, there was apparently little virological difference between the waters and shellfish of the "open" and "closed" areas. It must be noted, however, that the distance between the sites was not sufficient to expect any meaningful virus removal from the water column. A significant difference may have been seen, had the "open" testing site been located several miles from the "closed" area.

Table 3–13

COLIFORM AND VIRUS ISOLATION

Great South Bay, Closed Shellfish Waters—Islip

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
July 1976	430	75	4.0
August 1976	110	23	ni
September 1976	93	4	ni
October 1976	nt	nt	nt
November 1976	2,300	43	ni
December 1976	nt	nt	nt
January 1977	nt	nt	nt
February 1977	150	nt	4.4
March 1977	45	15	ni
April 1977	2,400	460	ni
May 1977	nt	nt	nt
June 1977	23	4	1.1

ni = No Isolates
nt = Not Tested

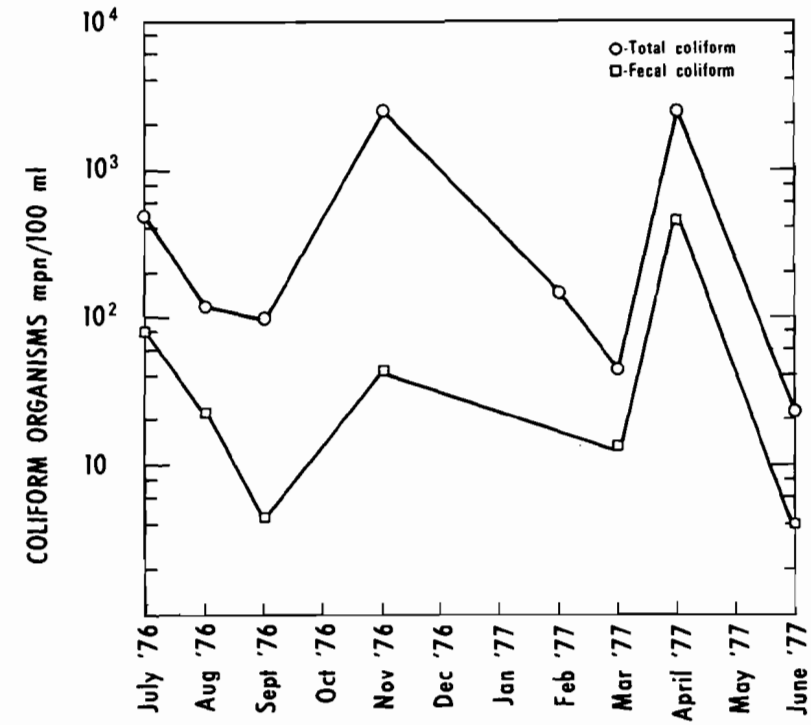

FIGURE 3–7 *Total and Fecal Coliform Counts (Per 100 Milliliters) Great South Bay, Closed Shellfish Waters—Islip.*

Table 3–14

COLIFORM AND VIRUS ISOLATION

Great South Bay Closed Shellfish—Clams

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
July 1976	16,000	16,000	0.16
August 1976	20	<20	ni
September 1976	1,300	<20	ni
October 1976	nt	nt	nt
November 1976	nt	nt	nt
December 1976	nt	nt	nt
January 1977	nt	nt	nt
February 1977	<20	nt	ni
March 1977	50	<20	ni
April 1977	630	20	ni
May 1977	nt	nt	nt
June 1977	220	20	0.1

ni = No Isolates
nt = Not Tested

Table 3–15

VIRUS ISOLATE IDENTIFICATIONS

Great South Bay "Closed" Waters and Shellfish

Date	Sample Type	Identifications Include:
July 7, 1976	Water	U*
July 29, 1976	Shellfish	ECHOvirus Type 20 ECHOvirus Type 23
February 28, 1977	Water	Poliovirus Type 2 (Vaccine strain)
June 2, 1977	Water	Poliovirus Type 1 (Vaccine strain)
June 2, 1977	Shellfish	Poliovirus Type 1 (Vaccine strain)

**U = Identity Unknown*

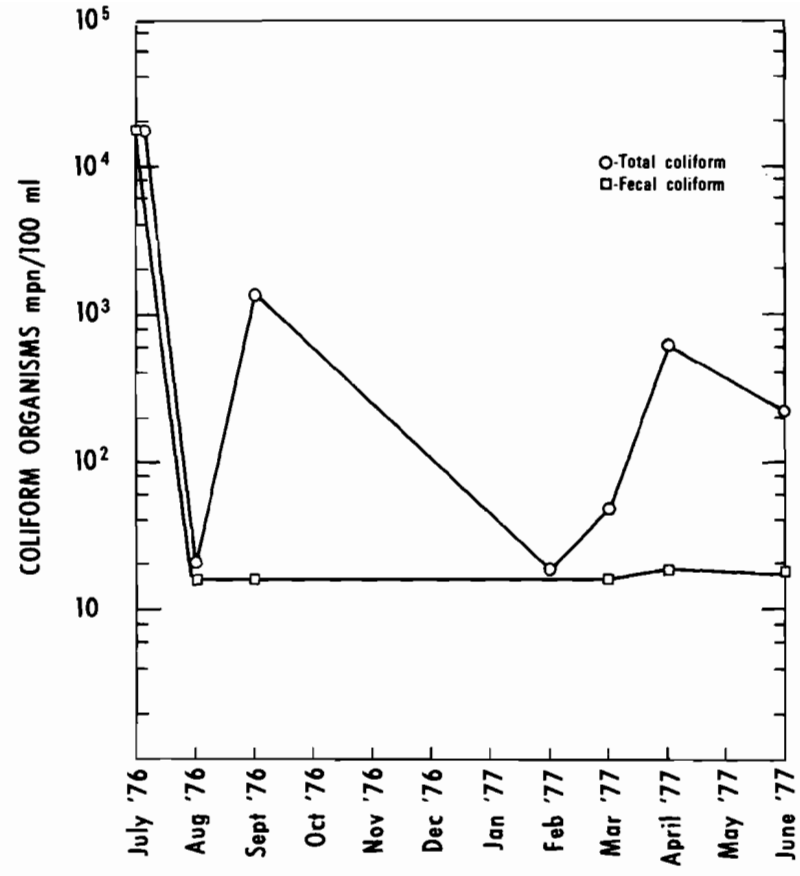

FIGURE 3–8 *Total and Fecal Coliform Counts (Per 100 Milliliters) Great South Bay, Closed Shellfish—Clams.*

(d) *Oyster Bay Waters and Shellfish*

i. OPEN AREA. Virus isolations from "open" waters and shellfish were infrequent (Tables 3–16 and 3–17). Corresponding coliform counts also tended to be quite low with the exception of some of the summer readings (Figures 3–9 and 3–10). Virus isolates which were recovered in July and March, could not be identified using typing pools (Table 3–18).

The study area in question, which had been open to shellfishing for many years, was located several miles from the nearest major pollution source, a secondary effluent outfall. The relative infrequency with which viruses were isolated was probably related to the viricidal properties of the waters, in conjunction with the distance required to reach the "open" area.

Table 3–16

COLIFORM AND VIRUS ISOLATION

Oyster Bay, Open Shellfish Waters

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
July 1976	1,100	9	2.8
August 1976	230	93	ni
September 1976	930	43	ni
October 1976	nt	nt	nt
November 1976	23	23	ni
December 1976	nt	nt	nt
January 1977	nt	nt	nt
February 1977	23	nt	ni
March 1977	4	nt	ni
April 1977	<3	<3	ni
May 1977	nt	nt	nt
June 1977	15	<3	ni

ni = No Isolates
nt = Not Tested

Table 3–17

COLIFORM AND VIRUS ISOLATION

Oyster Bay, Open Area—Oysters

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
July 1976	80	20	ni
August 1976	2,400	<20	ni
September 1976	1,100	60	ni
October 1976	nt	nt	nt
November 1976	<20	<20	ni
December 1976	nt	nt	nt
January 1977	nt	nt	nt
February 1977	<20	nt	ni
March 1977	50	nt	0.48
April 1977	70	<20	ni
May 1977	nt	nt	nt
June 1977	210	<20	ni

ni = No Isolates
nt = Not Tested

Table 3–18

VIRUS ISOLATE IDENTIFICATIONS

Oyster Bay

"Open" Water and Shellfish

Date	Sample Type	Identifications Include:
July 20, 1976	Water	U*
March 30, 1977	Shellfish	U*

**U = Identity Unknown*

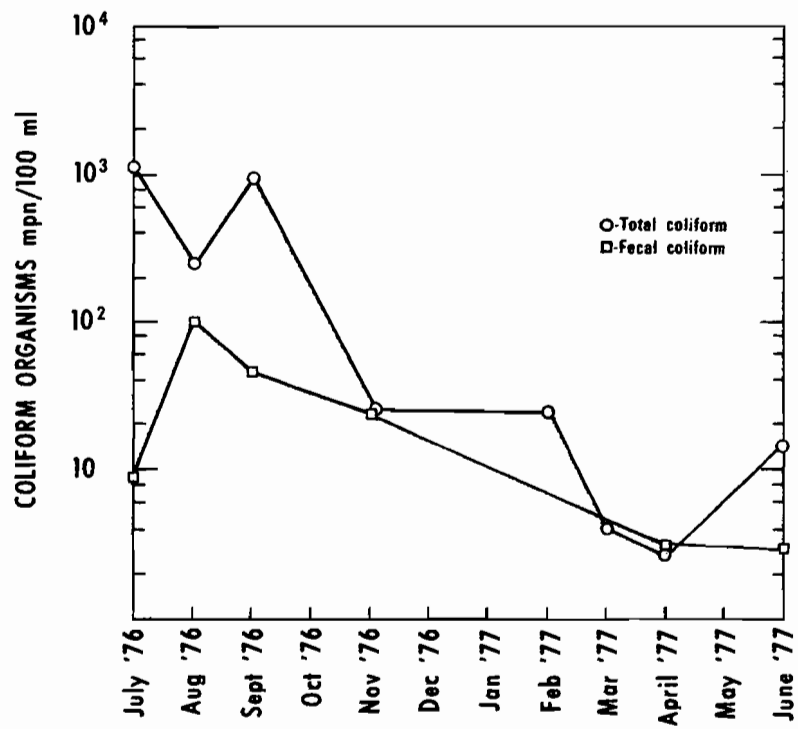

FIGURE 3–9 *Total and Fecal Coliform Counts (Per 100 Milliliters) Oyster Bay, Open Shellfish Waters.*

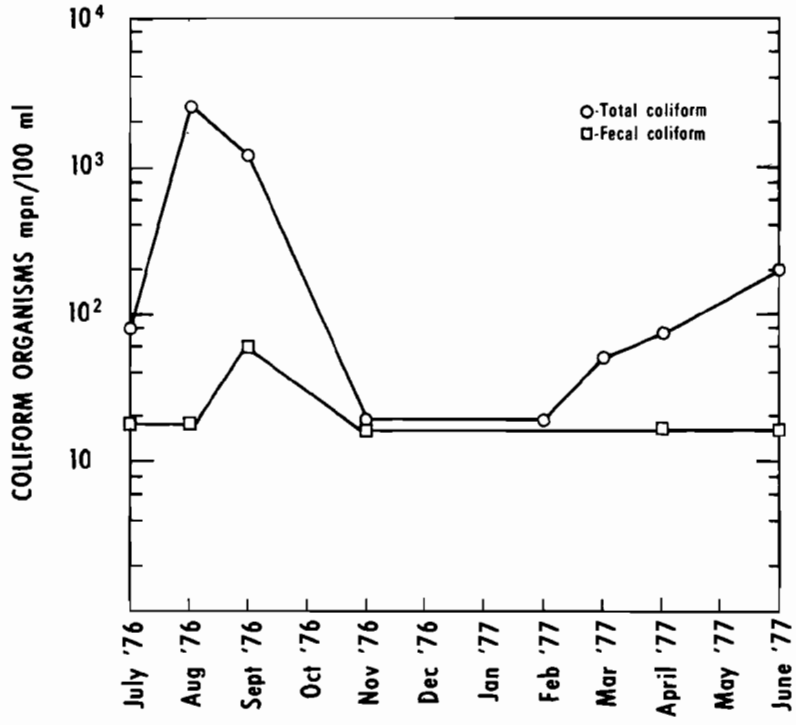

FIGURE 3–10 *Total and Fecal Coliform Counts (Per 100 Milliliters) Oyster Bay, Open Area—Oysters.*

ii. CLOSED AREA. The bay area studied had been closed to shellfishing for several years. The surrounding banks were extensively developed with single family dwellings.

Viral isolations were not made from any of the water samples tested (Table 3–19). With the exception of the June 1977 sample, coliform counts in this area were quite low (Figure 3–11). These findings were difficult to reconcile with shellfish data from the same area which revealed a number of virus isolations and high coliform counts in three of the eight times the area was sampled (Table 3–20, Figure 3–12). There are two possible explanations for this discrepancy: (1) the waters in the "closed" area contained heavy concentrations of suspended material (*i.e.,* algae, detritis). It has been shown that such conditions, especially when in a marine or estuarine environment, can severely limit the efficiencies of virus concentration methods; and (2) in extremely turbid estuarine waters, human viruses will not usually remain in a free state. Studies have shown that viruses in the water column readily bind to particulates which later become sedimented. A number of workers have shown greater numbers of virus in sediments than in the surrounding waters. If this was occurring in the "closed" area of Oyster Bay, viruses would be difficult to find in water samples, but would still be available for uptake by shellfish (Table 3–2).

Little value would be obtained from any attempt to compare data from "open" and "closed" areas based upon so few sampling events.

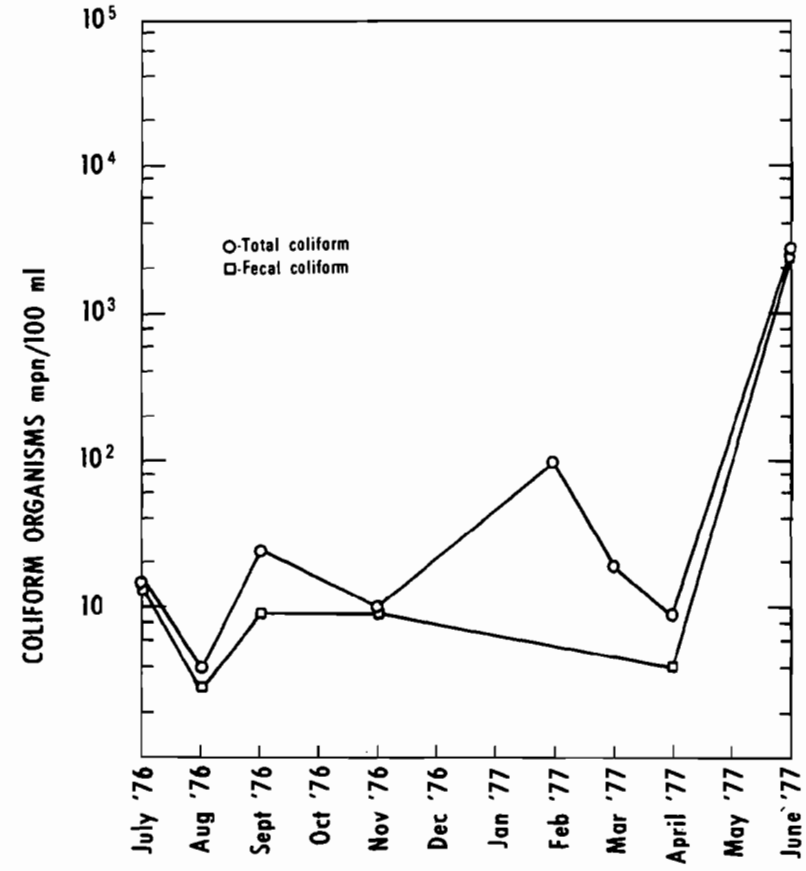

FIGURE 3–11 *Total and Fecal Coliform Counts (Per 100 Milliliters) Oyster Bay, Closed Shellfish Waters.*

Table 3–19

COLIFORM AND VIRUS ISOLATION

Oyster Bay, Closed Shellfish Waters

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
July 1976	15	15	ni
August 1976	4	<3	ni
September 1976	23	9	ni
October 1976	nt	nt	nt
November 1976	9	9	ni
December 1976	nt	nt	nt
January 1977	nt	nt	nt
February 1977	93	nt	ni
March 1977	<20	nt	ni
April 1977	9	4	ni
May 1977	nt	nt	nt
June 1977	2,400	2,400	ni

ni = No Isolates
nt = Not Tested

Table 3–20

COLIFORM AND VIRUS ISOLATION

Oyster Bay, Closed Area–Oysters

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
July 1976	50	20	0.48
August 1976	5,400	270	ni
September 1976	1,400	90	ni
October 1976	nt	nt	nt
November 1976	<20	<20	0.08
December 1976	nt	nt	nt
January 1977	nt	nt	nt
February 1977	<20	nt	ni
March 1977	70	nt	ni
April 1977	<20	<20	0.2
May 1977	nt	nt	nt
June 1977	1,300	220	ni

ni = No Isolates
nt = Not Tested

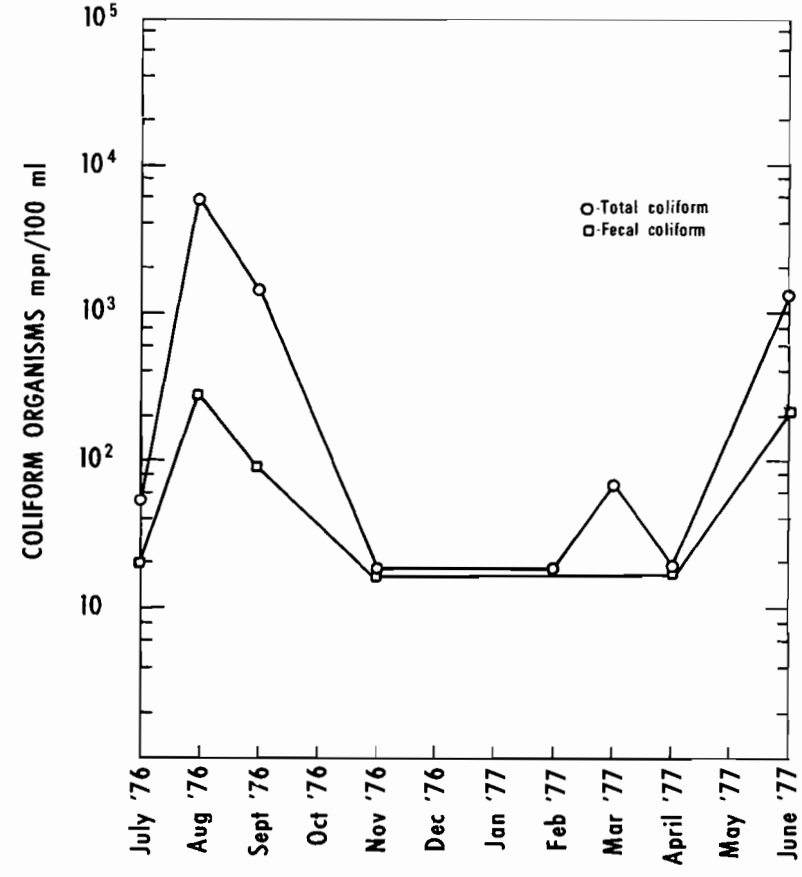

FIGURE 3–12 *Total and Fecal Coliform Counts (Per 100 Milliliters) Oyster Bay, Closed Area–Oysters.*

3. Landfill Site

Groundwater samples taken near the Babylon landfill yielded a single positive result (Table 3–22) during the month of November. Coliform counts during the entire sampling program tended to be quite low (Figure 3–13). The likely virus source was the scavenger waste pits located at the landfill site. Since no tests were performed on the scavenger waste, it is not possible to comment on removal rates.

Water samples from the Babylon site had a light orange color, and gave off a "chemical" smell. It is possible that the extremely poor quality of the water inhibited additional virus isolations.

The only confirmed isolate identification was a Coxsackievirus type B-3 (Table 3–23).

Table 3–21

VIRUS ISOLATE IDENTIFICATIONS

Oyster Bay

"Closed" Area, Shellfish

Date	Identifications Include:
July 27, 1976	ECHOvirus Type 15 ECHOvirus Type 2 U*
November 22, 1976	Coxsackievirus Type B-3
April 27, 1977	U*

U = Identity Unknown

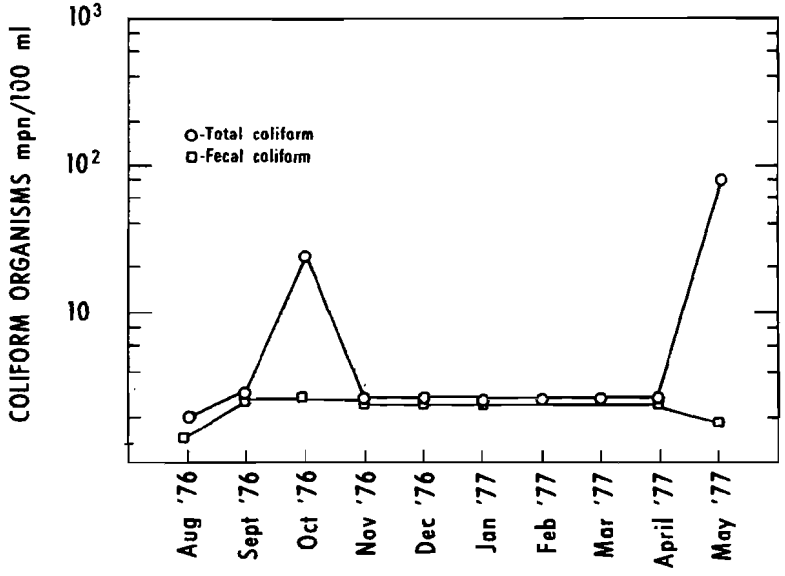

FIGURE 3–13 *Total and Fecal Coliform Counts (Per 100 Milliliters) Babylon Well.*

Table 3–22

COLIFORM AND VIRUS ISOLATION

Babylon Well

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
August 1976	2	<2	ni
September 1976	<3	<3	ni
October 1976	23	<3	ni
November 1976	<3	<3	3.6
December 1976	<3	<3	ni
January 1977	<3	<3	ni
February 1977	<3	nt	ni
March 1977	<3	nt	ni
April 1977	<3	<3	ni
May 1977	79	<2	ni

ni = No Isolates
nt = Not Tested

Table 3–23

VIRUS ISOLATE IDENTIFICATIONS

Babylon Well

Date	Identifications Include:
November 17, 1976	Coxsackievirus Type B-3 U*

U = Identity Unknown

4. Stormwater Recharge Basin

Viruses were recovered from groundwater beneath the North Massapequa stormwater recharge basin during the month of August (Table 3–24). At no time during the entire sampling period (July '76–May '77) were coliform counts higher than four per 100 milliliters (Figure 3–14). The pH values (Table 3–25) for water beneath the basin were among the lowest recorded of any of the areas studied. A contributing factor to the low pH may have been rainfall, which tends to be acidic in this region.

Table 3–24

COLIFORM AND VIRUS ISOLATION

North Massapequa Well

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
July 1976	4	<3	ni
August 1976	4	<3	4.0
September 1976	<3	<3	ni
October 1976	<3	<3	ni
November 1976	<3	<3	ni
December 1976	nt	nt	nt
January 1977	<3	<3	ni
February 1977	<3	nt	ni
March 1977	<3	nt	ni
April 1977	<3	<3	ni
May 1977	2	<2	ni

ni = No Isolates
nt = Not Tested

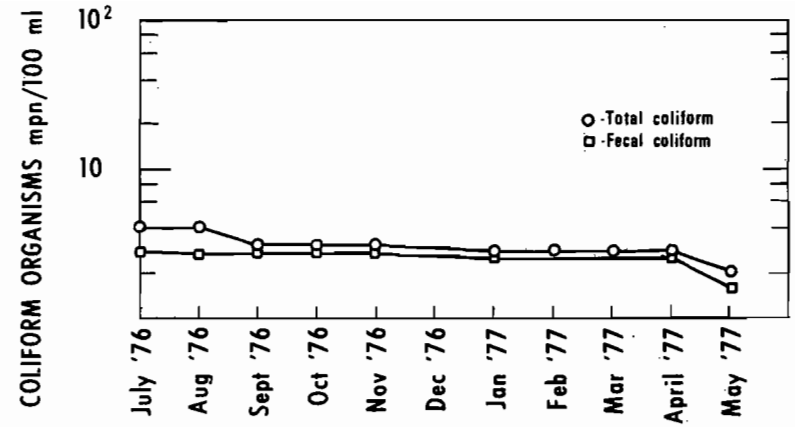

FIGURE 3–14 *Total and Fecal Coliform Counts (Per 100 Milliliters) North Massapequa Well.*

Table 3–25

AMBIENT pH VALUES OF WATER FROM VARIOUS SITES

Site	June 1976	July 1976	Aug 1976	Sept 1976	Oct 1976	Nov 1976	Dec 1976	Jan 1977	Feb 1977	Mar 1977	Apr 1977	May 1977	June 1977
	Month												
Meadowbrook STP	7.1	6.3	7.1	7.2	7.2	8.2	7.5	7.4	7.4	7.1	7.2	nt	6.8
Oyster Bay STP	6.8	7.4	7.1	6.2	7.1	7.1	7.0	7.2	nt	7.0	7.1	7.4	nt
Parkland STP	nt	7.7	7.2	8.1	7.2	7.2	6.8	7.3	7.3	7.3	7.1	nt	6.2
Stony Brook STP	6.9	7.5	6.5	7.2	6.8	6.6	6.8	6.9	7.3	7.3	nt	7.1	nt
Sunrise STP	nt	nt	7.0	7.4	7.3	7.2	7.0	7.8	7.2	7.2	7.5	7.0	nt
Meadowbrook Well	nt	nt	6.2	6.2	6.1	6.3	6.2	6.3	6.2	6.3	6.4	nt	nt
Parkland Well	nt	nt	7.0	7.0	7.0	7.6	6.7	7.0	6.9	7.0	7.0	nt	6.8
Stony Brook Well	nt	nt	nt	6.6	6.4	6.6	6.4	6.4	6.4	6.6	nt	6.4	nt
Sunrise Well	nt	nt	nt	6.7	6.6	7.0	nt	6.7	7.1	6.8	7.0	6.7	nt
Great South Bay *Closed* Shellfish H_2O	nt	8.0	8.6	8.1	nt	7.8	nt	nt	7.9	7.5	7.2	nt	7.5
Great South Bay *Open* Shellfish H_2O	nt	8.2	8.2	8.1	nt	7.8	nt	nt	8.0	7.8	7.3	nt	7.6
Oyster Bay *Closed* Shellfish H_2O	nt	7.7	7.4	7.5	nt	8.1	nt	nt	6.9	8.3	8.1	nt	7.4
Oyster Bay *Open* Shellfish H_2O	nt	7.9	7.9	7.6	nt	7.9	nt	nt	8.3	8.1	8.0	nt	7.9
Lake Ronkonkoma	nt	10.0	7.6	7.7	nt	7.2	nt	6.8	nt	6.7	nt	6.6	nt
Penataquit Creek	6.6	7.5	6.4	6.8	nt	7.1	7.1	7.0	6.6	6.6	6.6	6.7	nt
Bayport Well	6.0	6.2	8.8	8.9	6.6	7.1	7.4	6.8	6.9	7.2	6.7	6.8	nt
Oakdale Well	5.8	6.3	6.1	6.2	6.3	6.1	5.7	6.1	6.6	6.5	6.3	6.4	nt
North Massapequa Well	nt	6.0	5.7	5.6	5.5	5.3	nt	5.0	5.0	4.5	4.7	4.5	nt
Babylon Well	nt	nt	7.3	7.1	7.1	7.2	6.9	6.9	7.0	7.1	7.2	7.0	nt
SCHD Experimental Site	nt	7.0	6.1	6.2	6.5	6.0	6.0	6.2	6.2	6.3	6.0	5.7	nt

nt = Not Tested

Since little is known about the virological make-up of stormwater runoff, it would be presumptuous to identify this as the sole source of virus contamination. The diversity of viral species isolated (Table 3–26) suggests a recent human fecal source, lending some credibility to the theory of septic tank seepage from homes surrounding the basin. Further testing would have to be conducted before either or both possibilities could be dismissed.

5. Sewage Treatment Plants

(a) Discharge to Surface Waters—Oyster Bay. The secondarily treated, chlorinated effluent discharged from the Oyster Bay sewage treatment plant (STP) was found to contain significant numbers of viruses on four sampling occasions (Table 3–27). As is typical with sewage effluent, a wide variety of virus species was isolated (Table 3–28). There was little correlation between viral numbers isolated and corresponding coliform counts (Figure 3–15).

Table 3–26

VIRUS ISOLATE INDENTIFICATIONS

North Massapequa Well

Date	Identifications Include:
April 4, 1977	EC Ovirus Type 23 ECHOvirus Type 11 Coxsackievirus Type A-16

Table 3–27

COLIFORM AND VIRUS ISOLATION

Oyster Bay STP

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
June 1976*	4,300,000	390,000	nt
July 1976	2,300,000	430,000	227.0
August 1976	23	<3	ni
September 1976	430	43	67.2
October 1976	43	<3	ni
November 1976	9	<3	ni
December 1976	430	<3	ni
January 1977	39	<3	ni
February 1977	13	<2	ni
March 1977	150	nt	2636.4
April 1977	2,300	nt	216.4
May 1977	23	<3	ni

** Unchlorinated*
ni = No Isolates
nt = Not Tested

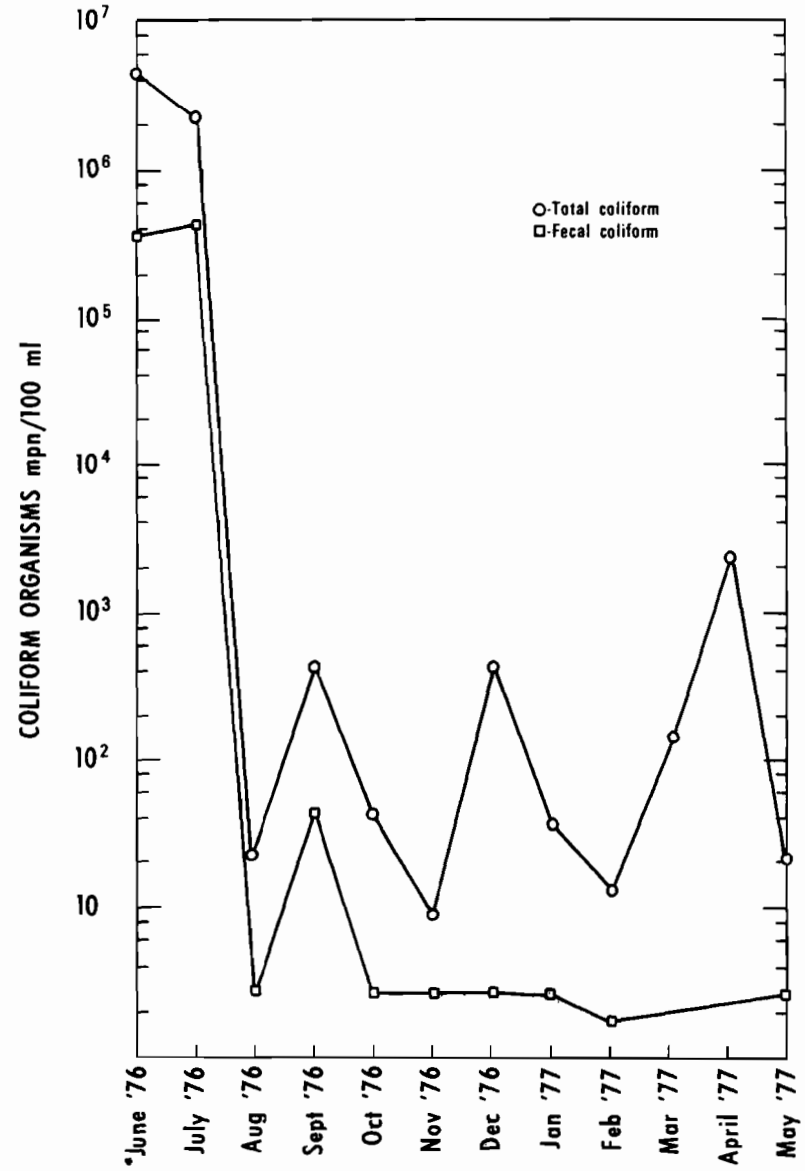

FIGURE 3–15 *Total and Fecal Coliform Counts (Per 100 Milliliters) Oyster Bay STP.*

Table 3–28

VIRUS ISOLATE IDENTIFICATIONS

Oyster Bay

STP

Date	Identifications Include:
July 12, 1976	ECHOvirus Type 25 ECHOvirus Type 14 Coxsackievirus Type A-16 Coxsackievirus Type B-3 ECHOvirus Type 17 ECHOvirus Type 27 Coxsackievirus Type B-6 ECHOvirus Type 11 ECHOvirus Type 13 Coxsackievirus Type A-7 Coxsackievirus Type B-4
September 21, 1976	ECHOvirus Type 5 ECHOvirus Type 25 Coxsackievirus Type B-2 ECHOvirus Type 17 ECHOvirus Type 11 Coxsackievirus Type B-5 ECHOvirus Type 6 Poliovirus Type 3 (Vaccine strain) ECHOvirus Type 12
March 8, 1977	Coxsackievirus Type B-3 ECHOvirus Type 11 Poliovirus Type 2 (Vaccine strain)
April 5, 1977	U* ECHOvirus Type 6 Coxsackievirus Type B-3 Coxsackievirus Type A-17

**U = Identity Unknown*

Viruses were isolated in summer, early fall, late winter and spring. Isolations were not made when residual chlorine levels were in excess of 1.0 parts per million (Table 3–29, Figure 3–16), but there is insufficient information to conclude that use of such residuals would consistently result in virus-free effluents. (*Note:* chlorine residual readings presented in all STP samples were taken on the day that virus sampling occurred. They should not be interpreted as being the levels that existed throughout the month.)

Beginning in March, effluent turbidity levels were monitored in order to investigate a previously proposed relationship between virus occurrence and high turbidities in STP effluents. Isolations were made in March and April when turbidity levels were 20 and 24 Nephelometric Turbidity Units respectively (Table 3–30). No isolations were recorded in May when the turbidity level was ten Nephelometric Turbidity Units. While these data do not contradict the theory of a virus-turbidity relationship, they do not of themselves represent a confirmation. This could only be established by more intensive sampling and comparison.

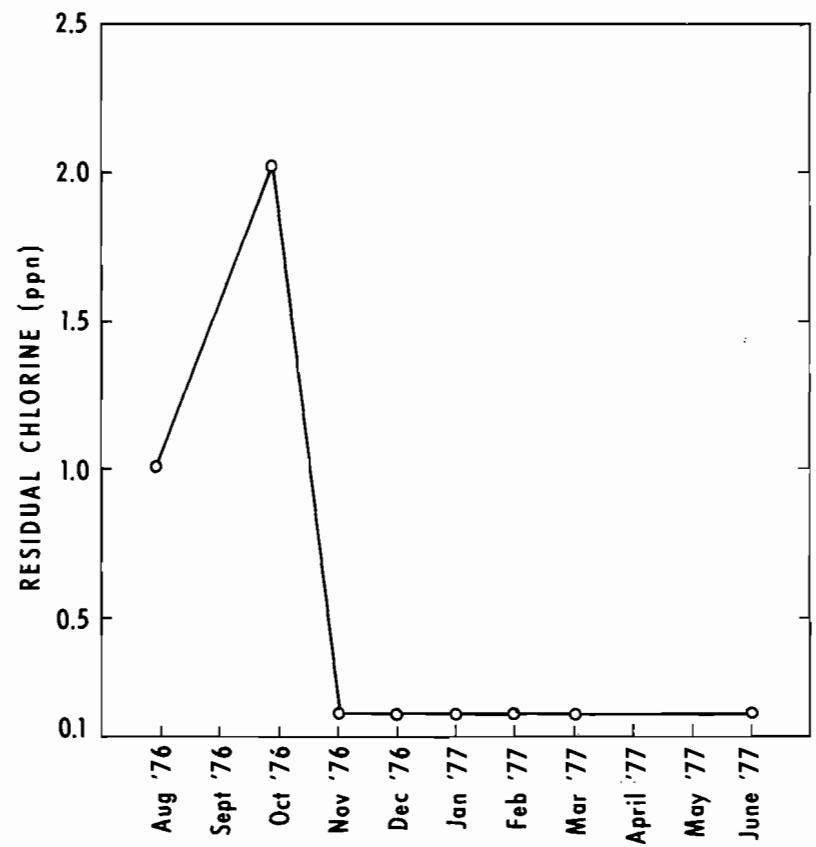

FIGURE 3–16 *Residual Chlorine (Parts Per Million) Oyster Bay STP.*

Table 3–29

RESIDUAL CHLORINE VALUES (ppm) FOR SEWAGE TREATMENT PLANT EFFLUENTS

Site	Month												
	June 1976	July 1976	Aug 1976	Sept 1976	Oct 1976	Nov 1976	Dec 1976	Jan 1977	Feb 1977	Mar 1977	Apr 1977	May 1977	June 1977
Meadowbrook STP	1.0	2.0	2.0	1.5	1.5	1.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	nt
Oyster Bay STP	nt	nt	1.0	nt	2.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	nt
Parkland STP	nt	1.5	2.0	2.0	2.0	<0.2	<0.2	<0.2	<0.2	<0.2	nt	nt	<0.2
Stony Brook STP	1.5	3.0	3.0	2.0	2.0	<0.2	<0.2	<0.2	<0.2	<0.2	nt	<0.2	nt
Sunrise STP	nt	nt	2.0	2.0	2.0	nt	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	nt

nt = Not Tested

Table 3–30

TURBIDITY VALUES (NTU) FOR SEWAGE TREATMENT PLANT EFFLUENTS

Site	Month			
	March 1977	April 1977	May 1977	June 1977
Meadowbrook STP	19	10	14	nt
Oyster Bay STP	20	24	10	nt
Parkland STP	37	9.5	nt	20
Stony Brook STP	10	nt	25	nt
Sunrise STP	25	6.8	19	nt

(b) Discharge to Leaching Fields–Sunrise Garden Apartments. With two exceptions, which cannot be accounted for, significant numbers of viruses were routinely isolated in chlorinated treated wastewater (Table 3–31). At the same time, extremely high coliform counts were also recorded (Figures 3–17 and 3–18). The high levels of virus and bacteria are indicative of grossly inadequate treatment procedures, which resulted in effluents of such poor quality that chlorine residuals as high as 2.0 parts per million (Figure 3–19) were unable to affect any appreciable disinfection. The net result was an effluent that often resembled (microbially) the product of a primary treatment plant. It was impossible to identify all isolates from each sample, and it is likely that many more virus species would have been identified than indicated in Table 3–32.

Table 3–31

COLIFORM AND VIRUS ISOLATION

Sunrise STP

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
August 1976	93,000	43,000	1440.0
September 1976	24,000,000	4,600,000	1900.0
October 1976	2,400,000	9,300	854.2
November 1976	4,600,000	43,000	ni
December 1976	2,400,000	23,000	1232.0
January 1977	230,000	4,300	10.8
February 1977	110,000,000	930,000	ni
March 1977	2,400,000	nt	990.0
April 1977	930,000	43,000	4000.0
May 1977	9,300,000	2,300,000	120.0

ni = No Isolates
nt = Not Tested

Despite the high virus numbers entering the leaching fields, only two samples from the groundwater observation well yielded positive results (Table 3–33). This unexpected finding indicated the extraordinary virus adsorbing capacity of the soil. It is probable that a majority of the viruses in the effluents were bound to small particles. The particles were then removed during horizontal passage through the soil by a sieving action. Reductions were also noted in coliform numbers (exceptions occurred in February and April). Precise determinations of virus and bacterial removal could not be made due to a lack of information concerning effluent residence time in the leaching fields, and the soil characteristics of the area.

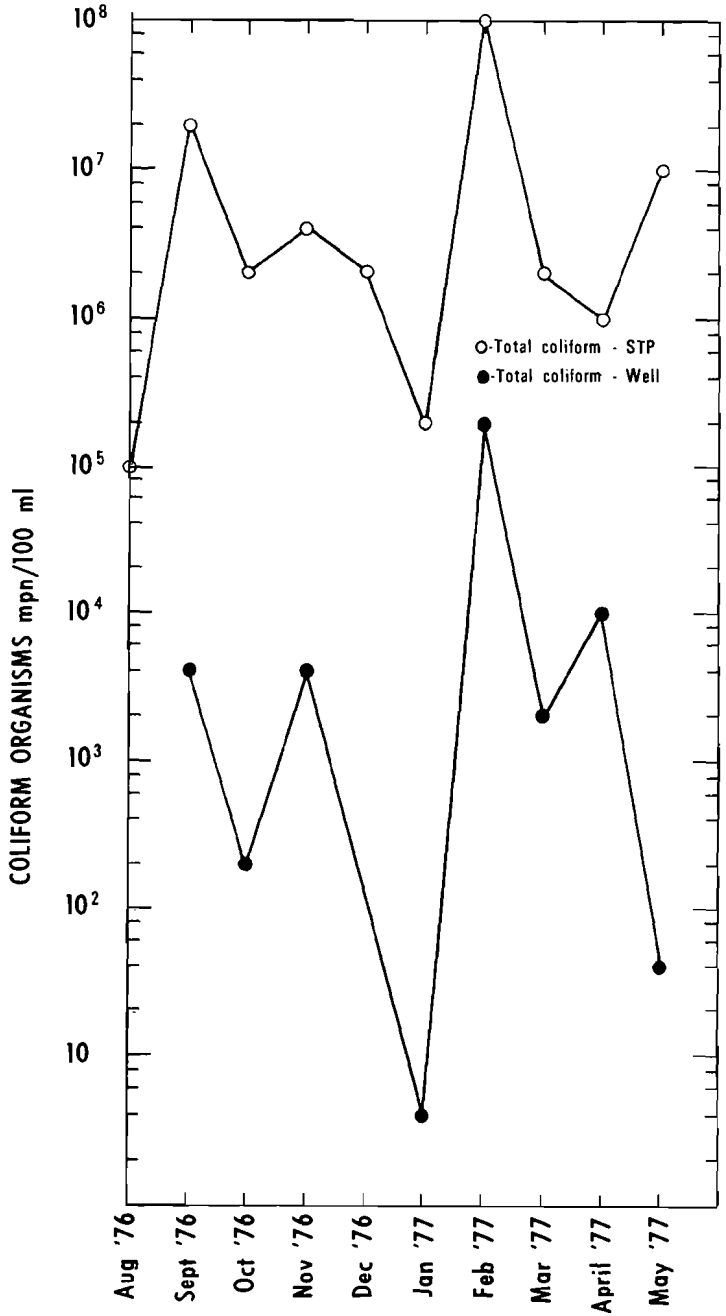

FIGURE 3–17 *Total Coliform Counts (Per 100 Milliliters) Sunrise STP and Sunrise Well.*

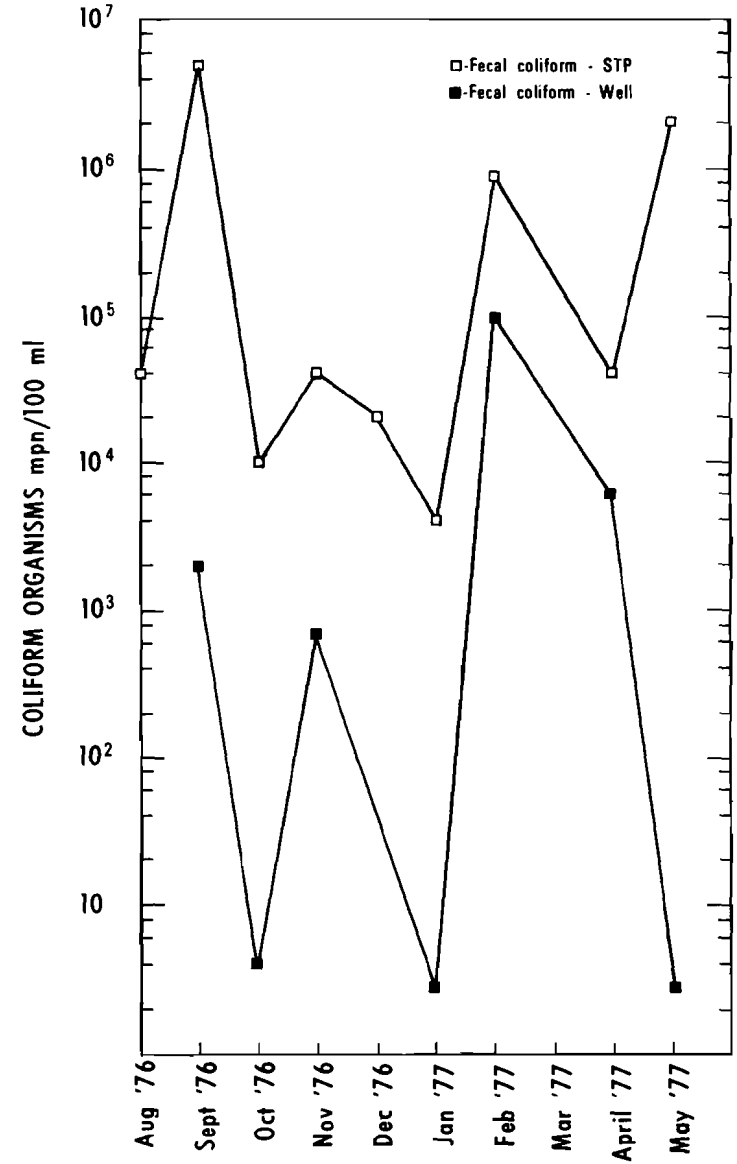

FIGURE 3–18 *Fecal Coliform Counts (Per 100 Milliliters) Sunrise STP and Sunrise Well.*

Table 3–32

VIRUS ISOLATE IDENTIFICATIONS

Sunrise

STP and Observation Well

Date	Sample Type	Identifications Include:
August 13, 1976	Effluent	Coxsackievirus Type B-3 ECHOvirus Type 6 ECHOvirus Type 7 ECHOvirus Type 21 Coxsackievirus Type B-4
September 22, 1976	Effluent	ECHOvirus Type 6 Coxsackievirus Type B-6 Poliovirus Type 2 (Vaccine strain) Coxsackievirus Type B-2 ECHOvirus Type 7
October 19, 1976	Effluent	Coxsackievirus Type A-16 ECHOvirus Type 15 U* ECHOvirus Type 31
December 15, 1976	Effluent	ECHOvirus Type 31 ECHOvirus Type 24 ECHOvirus Type 25 Coxsackievirus Type B-3
January 18, 1977	Effluent	Coxsackievirus Type B-3 ECHOvirus Type 24
January 18, 1977	Observation Well	U*
March 22, 1977	Effluent	Poliovirus Type 2 (Vaccine strain) Poliovirus Type 1 (Vaccine strain) ECHOvirus Type 6 Coxsackievirus Type B-4
April 20, 1977	Effluent	U* ECHOvirus Type 2 Coxsackievirus Type B-3 Poliovirus Type 3 (Vaccine strain)
May 16, 1977	Effluent	U*
May 16, 1977	Observation Well	U*

**U = Identity Unknown*

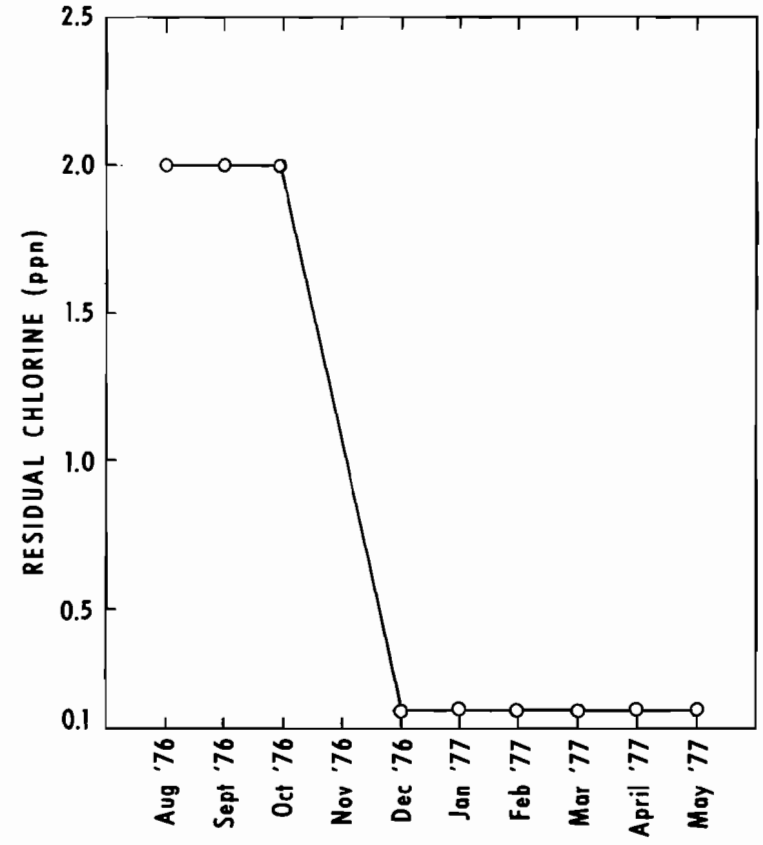

FIGURE 3–19 *Residual Chlorine (Parts Per Million) Sunrise STP.*

(c) Sewage Treatment Plants with Groundwater Recharge Basins

i. MEADOWBROOK STP. Viruses were isolated in chlorinated effluents on three occasions (Table 3–34). Of interest was the isolation of virus during periods when coliform counts were extremely low (September and February), and the absence of virus isolates during months when coliform counts were unusually high (Figures 3–20 and 3–21), the exception being the sample from June 1976. In all likelihood, human viruses were present during those periods of high coliform densities (August and January), but their adsorption to virus concentrating filters may have been inhibited. (Other workers have noted similar difficulties when using the virus concentrator in grossly contaminated waters. The process responsible has not as yet been determined.) Viruses were recovered from effluents with chlorine residuals as

Table 3–33

COLIFORM AND VIRUS ISOLATION

Sunrise Well

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
September 1976	4,300	2,300	ni
October 1976	230	4	ni
November 1976	4,300	750	ni
December 1976	nt	nt	ni
January 1977	4	<3	3.8
February 1977	230,000	93,000	ni
March 1977	2,300	nt	ni
April 1977	12,000	6,400	ni
May 1977	43	<3	5.7

ni = No Isolates
nt = Not Tested

Table 3–34

COLIFORM AND VIRUS ISOLATION

Meadowbrook STP

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
June 1976	430,000	23,000	80.0
July 1976	23,000	9,300	ni
August 1976	750,000	43,000	ni
September 1976	<3	<3	6.4
October 1976	230	<3	ni
November 1976	230	<3	ni
December 1976	2,300	43	ni
January 1977	11,000,000	2,400,000	ni
February 1977	49	11	100.0
March 1977	9,300	nt	ni
April 1977	9,300	nt	ni
May 1977	2,300	4	ni

ni = No Isolates
nt = Not Tested

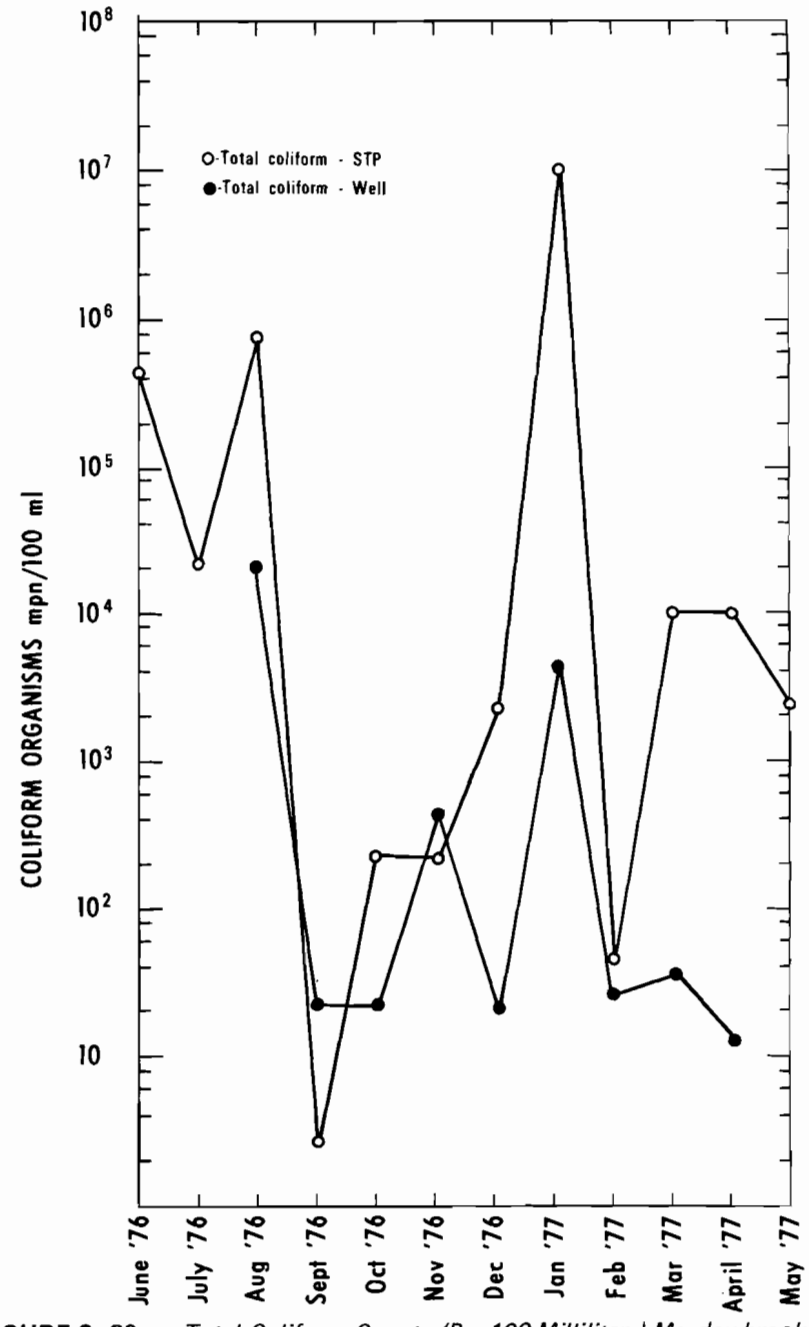

FIGURE 3–20 *Total Coliform Counts (Per 100 Milliliters) Meadowbrook STP and Meadowbrook Well.*

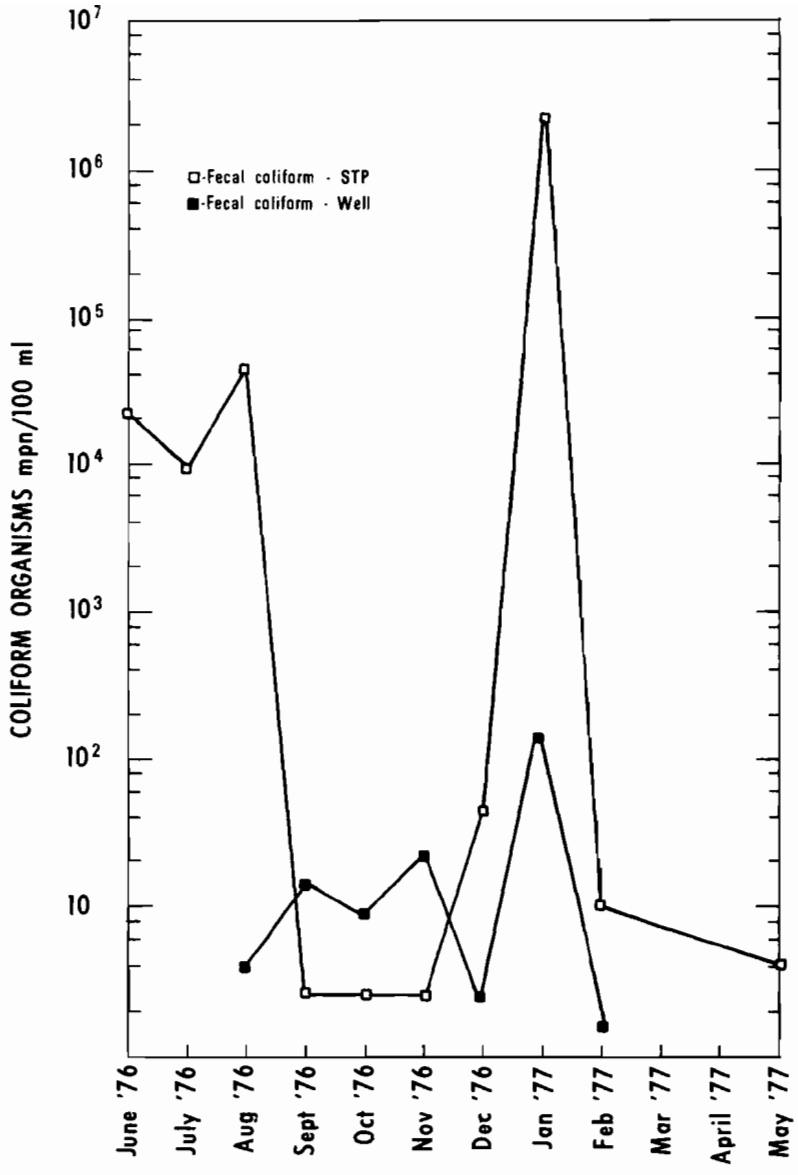

FIGURE 3–21 *Fecal Coliform Counts (Per 100 Milliliters) Meadowbrook STP and Meadowbrook Well.*

high as 1.5 parts per million (Table 3–29, Figure 3–22). Isolate correlation with turbidity levels could not be made (Table 3–30). Isolate identifications (Table 3–35) included a wide variety of enterovirus species. Among the isolates obtained from the September 1976 sample were Coxsackievirus types B-3 and B-4. The same virus species had been reported during that period as having been isolated from numerous patients suffering from a variety of clinical symptoms by Dr. Wayne Klein, Chief of Virology Service, Nassau County Medical Center (Meadowbrook Hospital).

Small numbers of virus were found on three occasions in the observation well (Table 3–36), indicating vertical movement of virus particles through the basin. The likelihood of horizontal movement of viruses cannot be commented upon due to the location of the observation well. The well had been sunk within eight feet of the bank of the basin. At such close proximity, it is likely that the well drew from the dome of recharged water that extended outward from beneath the basin. Well samples were therefore not representative of groundwater that had undergone any appreciable horizontal flow. Viral isolations showed little relationship to coliform counts in the well water samples.

Table 3–35

VIRUS ISOLATE IDENTIFICATIONS

Meadowbrook

STP and Observation Well

Date	Sample Type	Identifications Include:
June 22, 1976	Effluent	ECHOvirus Type 13 ECHOvirus Type 21 Coxsackievirus Type B-3
August 17, 1976	Observation Well	ECHOvirus Type 12 U*
September 13, 1976	Effluent	Coxsackievirus Type B-4 Coxsackievirus Type B-3 ECHOvirus Type 6 Poliovirus Type 1 (Vaccine strain)
September 13, 1976	Observation Well	U*
February 2, 1977	Effluent	Coxsackievirus Type B-4 ECHOvirus Type 30 U*
April 5, 1977	Observation Well	U*

**U = Identity Unknown*

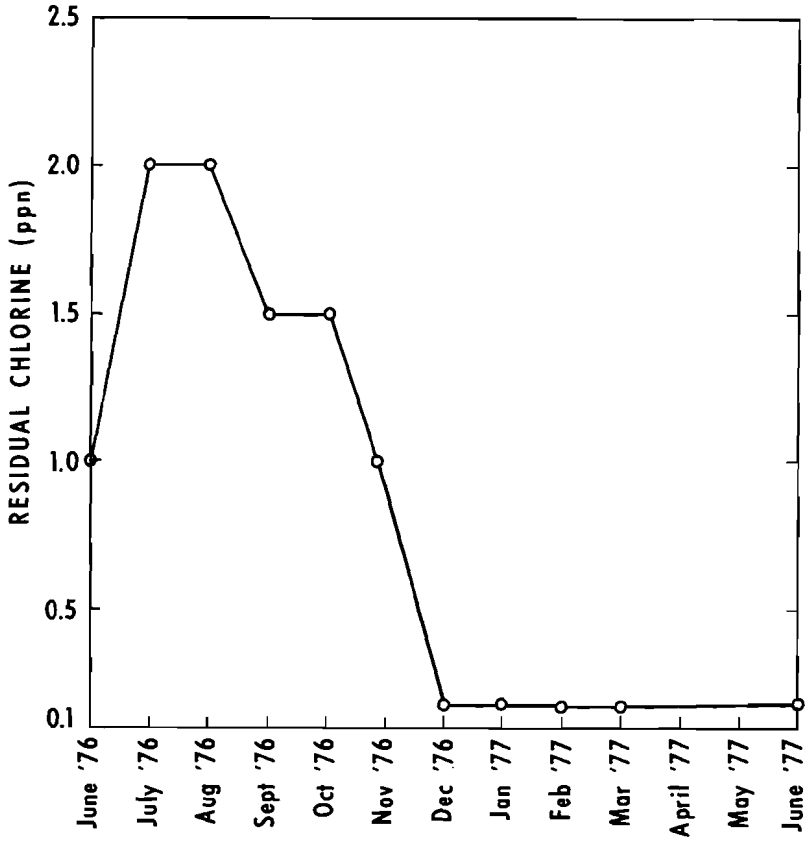

FIGURE 3–22 *Residual Chlorine (Parts Per Million) Meadowbrook STP.*

ii. STONY BROOK STP. Human viruses were isolated from chlorinated effluents during winter and spring months (Table 3–37). On three occasions there were correlations with unusually high coliform counts (Figures 3–23 and 3–24). Most of the isolations occurred when chlorine residuals were less than 0.2 parts per million (Table 3–29, Figure 3–25). The sporadic nature of the coliform and virus levels suggests a temporary breakdown in treatment or disinfection processes. Such breakdowns were known to occur at this and other plants studied.

Well samples yielded no virus isolations, indicating the inability of viruses to penetrate the 80 feet from basin bottom to groundwater aquifer (Table 3–38). Coliform counts were also substantially reduced during soil percolation (with the obvious exception of the December sample). The results for this month do not fit the trends observed over the year and cannot be readily explained.

Overall, the results were viewed as supporting the practice of the recharge of properly treated sewage effluents through basins located at reasonable distances (*e.g.,* 80 feet) above groundwater aquifers (Table 3–39).

Table 3–36

COLIFORM AND VIRUS ISOLATION

Meadowbrook Well

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
August 1976	23,000	4	1.3
September 1976	23	15	3.6
October 1976	23	9	ni
November 1976	430	23	ni
December 1976	23	<3	ni
January 1977	4,300	150	ni
February 1977	27	<2	ni
March 1977	39	nt	ni
April 1977	15	nt	2.4
May 1977	nt	nt	ni

ni = No Isolates
nt = Not Tested

Table 3–37

COLIFORM AND VIRUS ISOLATION

Stony Brook STP

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
June 1976	7,500	3,900	ni
July 1976	2,300	150	ni
August 1976	9	<3	ni
September 1976	9,300	<30	ni
October 1976	4	<3	ni
November 1976	11,000,000	nt	84.4
December 1976	2,400,000	430,000	369.6
January 1977	2,300	23	ni
February 1977	9,300	430	ni
March 1977	4,300	nt	32.4
April 1977	930,000	240,000	23.2
May 1977	240,000	240,000	ni

ni = No Isolates
nt = Not Tested

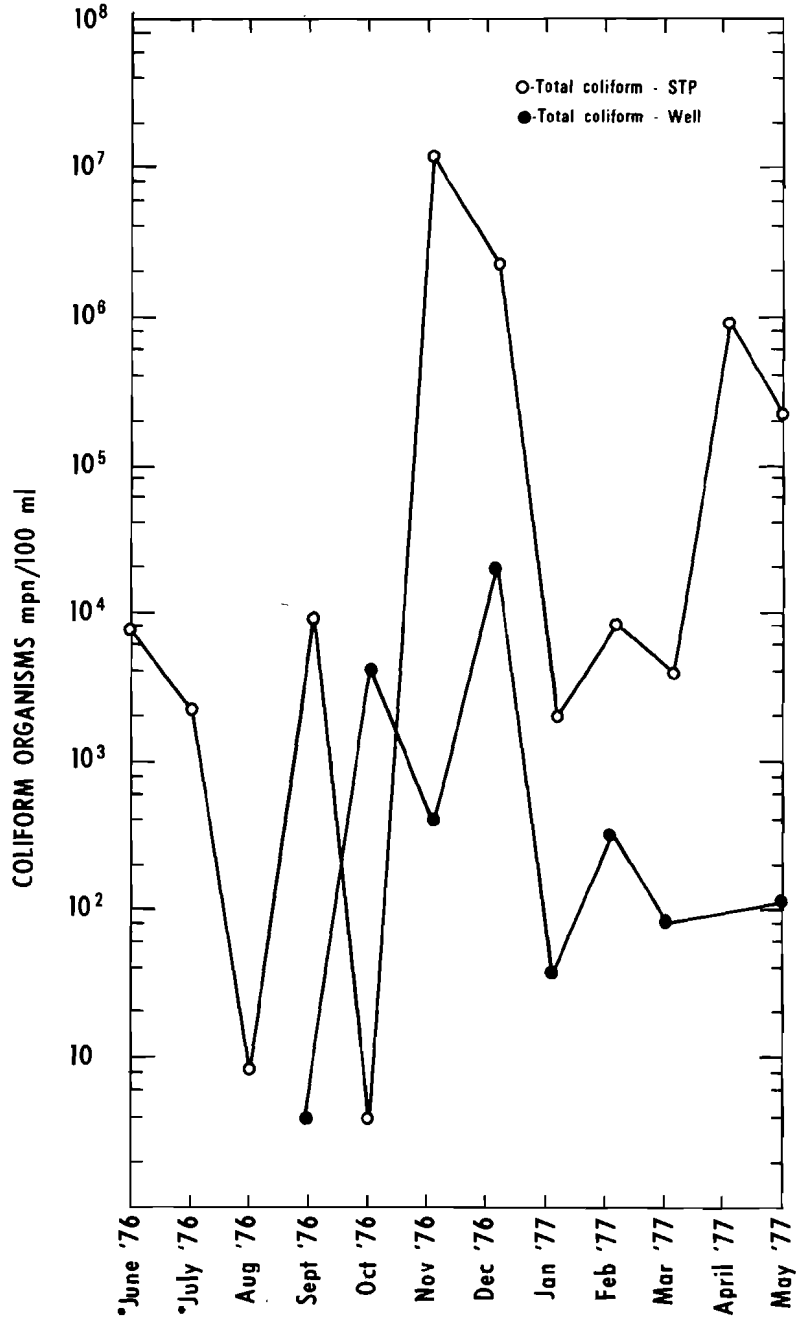

FIGURE 3–23 *Total Coliform Counts (Per 100 Milliliters) Stony Brook STP and Stony Brook Well.*

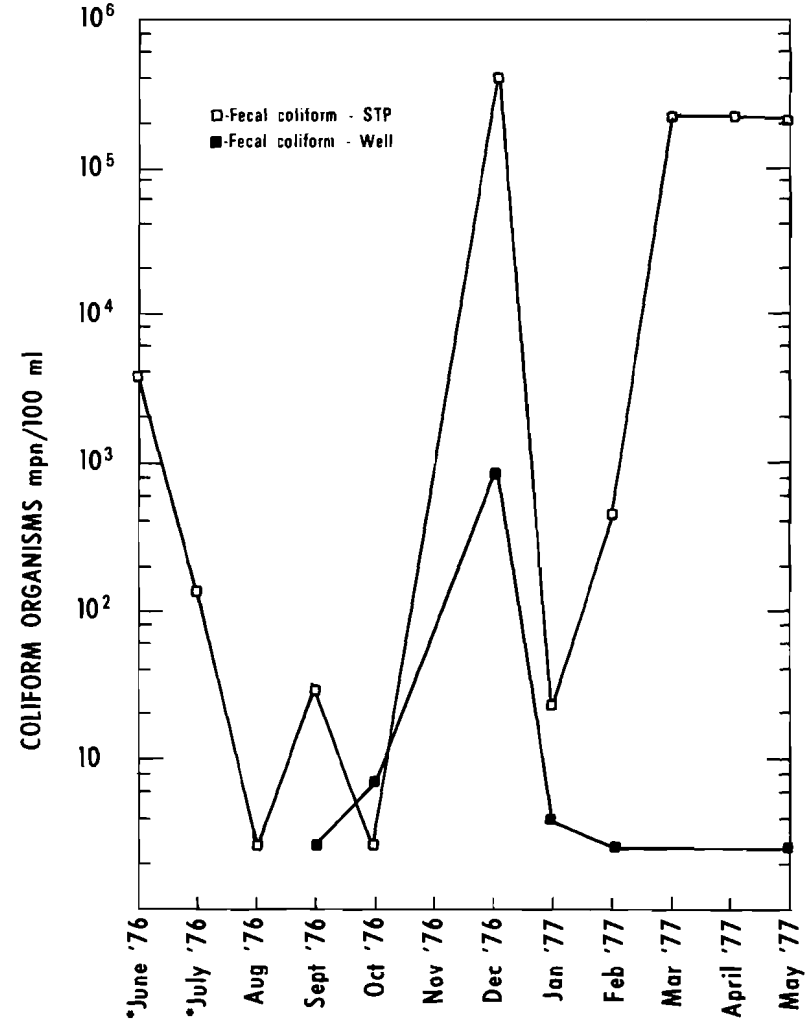

FIGURE 3–24 *Fecal Coliform Counts (Per 100 Milliliters) Stony Brook STP and Stony Brook Well.*

iii. PARKLAND III STP. The Parkland III plant, which was the only tertiary treatment system sampled during the study, experienced a number of operating problems during the study period. As a result, monthly coliform counts were quite high, and viruses were isolated on six different occasions (Table 3–40, Figures 3–26 and 3–27). Viral and bacterial numbers were lowest when chlorine residuals were above one part per million (Table 3–29, Figure 3–28). At residuals below 0.2 parts per

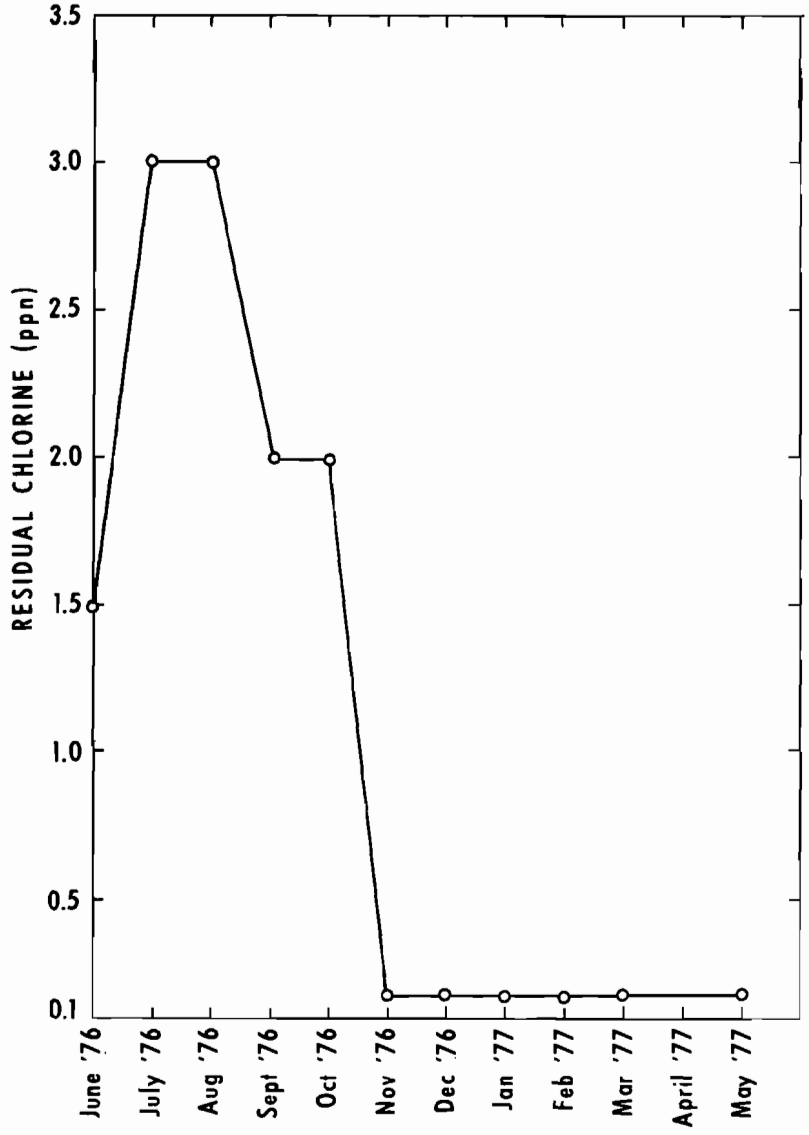

FIGURE 3–25 *Residual Chlorine (Parts Per Million) Stony Brook STP.*

million, the microbial quality of the effluent often resembled that of primary treated sewage. The highest virus count occurred in March when turbidity was at a high of 37 Nephelometric Turbidity Units (Table 3–36). As noted with a previously discussed STP effluent, the isolation of additional viruses during the months of December, January and April was probably inhibited by the presence of excessive numbers of coliform bacteria.

Table 3–38

COLIFORM AND VIRUS ISOLATION

Stony Brook Well

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
September 1976	4	<3	ni
October 1976	4,300	7	ni
November 1976	430	nt	ni
December 1976	23,000	930	ni
January 1977	43	4	ni
February 1977	390	<3	ni
March 1977	93	nt	ni
April 1977	nt	nt	ni
May 1977	150	<3	ni

ni = Not Isolated
nt = Not Tested

Table 3–39

VIRUS ISOLATE IDENTIFICATIONS

Stony Brook

STP

Date	Identifications Include:
November 9, 1976	ECHOvirus Type 2 ECHOvirus Type 21 U* Coxsackievirus Type A-16 Coxsackievirus Type B-3
December 13, 1976	Coxsackievirus Type B-3 Poliovirus Type 1 (Vaccine strain)
March 16, 1977	ECHOvirus Type 6
April 12, 1977	U*

**U = Identity Unknown*

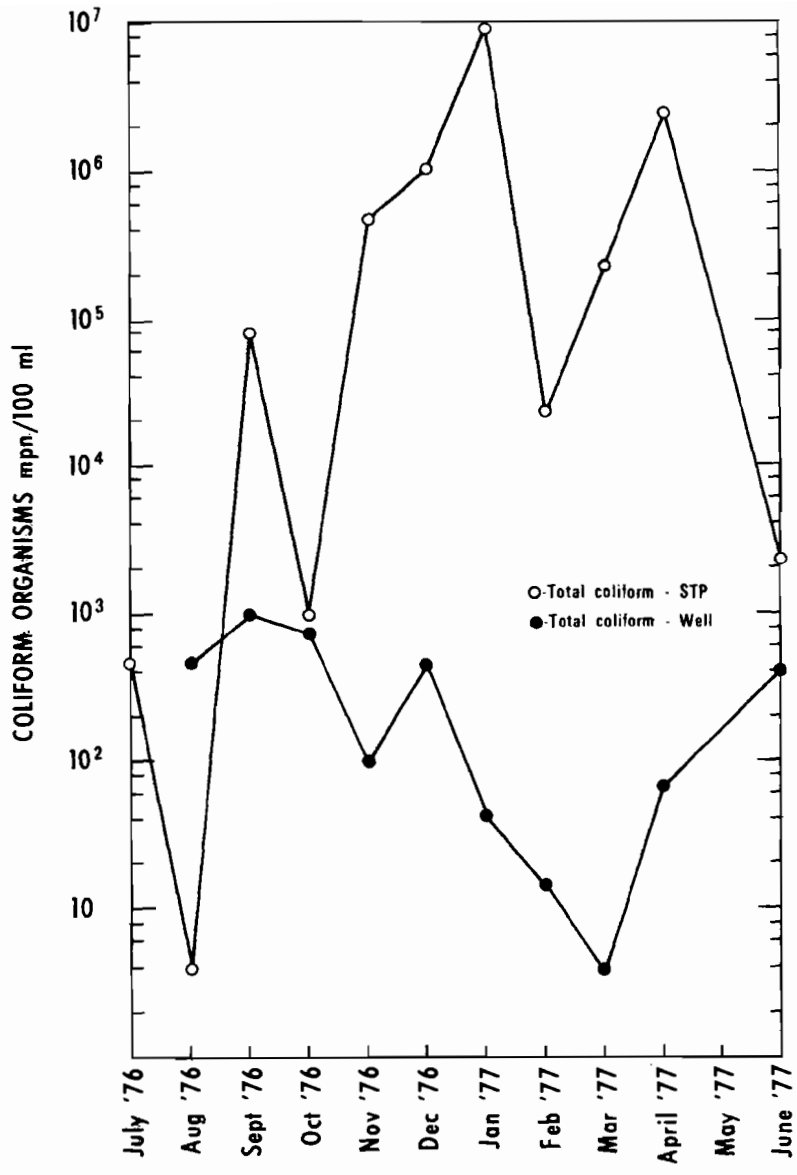

FIGURE 3–26 *Total Coliform Counts (Per 100 Milliliters) Parkland III STP and Parkland III Well.*

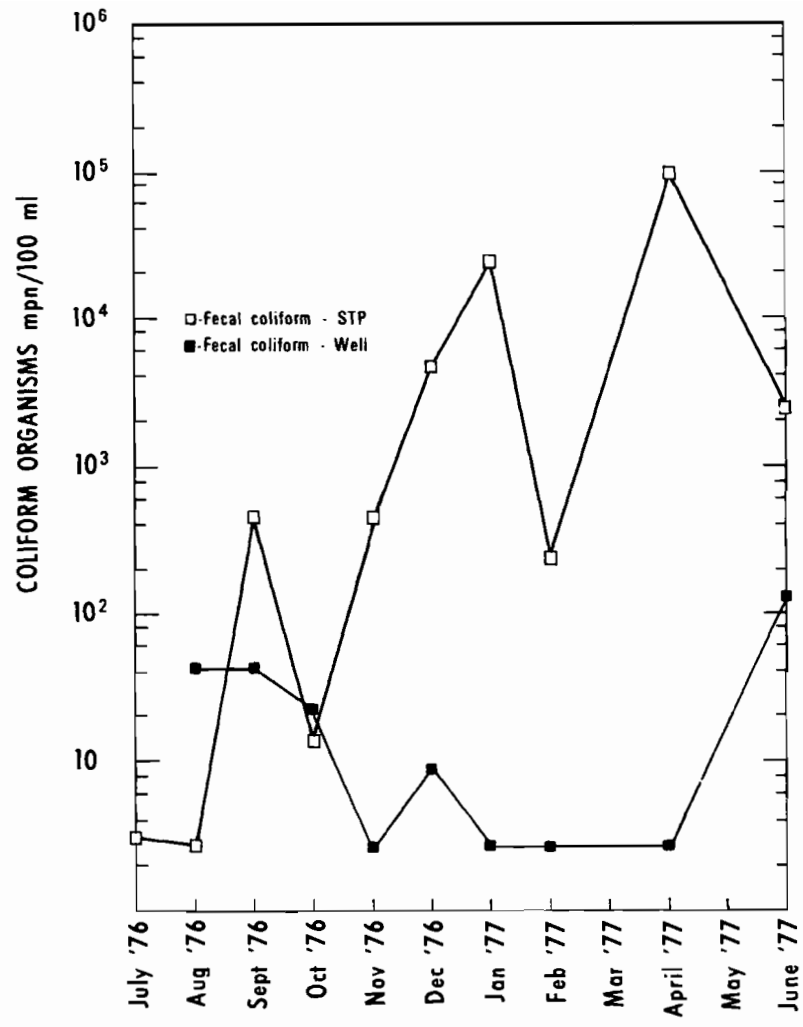

FIGURE 3–27 *Fecal Coliform Counts (Per 100 Milliliters) Parkland III STP and Parkland III Well.*

Isolate identifications included the broad range of enteric viruses commonly associated with municipal wastewater (Table 3–41). As of this writing, three Poliovirus isolates recovered from effluent samples during February, March and April have been tentatively identified as being wild type (non-vaccine) strains. Final confirmation of these isolations will be made with the assistance of the Center for Disease Control (C.D.C.) Atlanta, Georgia.

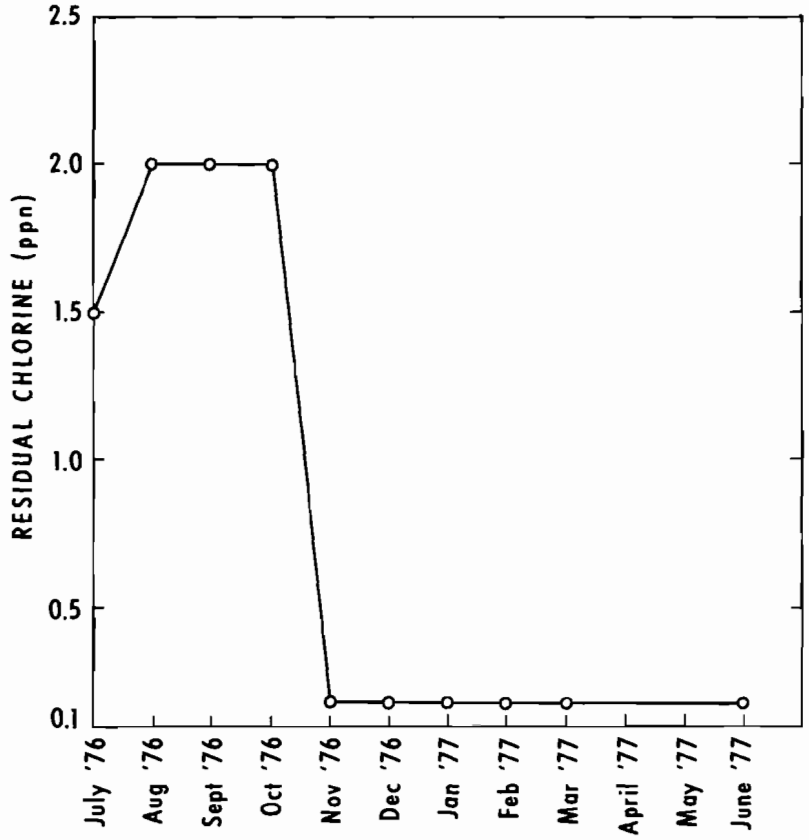

FIGURE 3–28 *Residual Chlorine (Parts Per Million) Parkland III STP.*

Comparatively low numbers of viruses were isolated from the observation well on three occasions (Table 3–42). The well was situated a sufficient distance from the basins to be representative of some horizontal flow. The high virus and coliform numbers occurring in improperly treated effluents represented a never-intended stress to the removal capacities of the recharge system. Despite the loading, the system appeared to have removed a significant number of organisms. It is not known how far the viruses could have moved through the aquifer, but they would likely have been subject to the same removal mechanisms that occur during vertical penetration through basins.

Table 3–40

COLIFORM AND VIRUS ISOLATION
Parkland III STP

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
July 1976	430	3	ni
August 1976	4	<3	ni
September 1976	75,000	430	6.8
October 1976	930	15	ni
November 1976	430,000	430	ni
December 1976	930,000	4,300	22.0
January 1977	11,000,000	23,000	94.7
February 1977	23,000	230	315.5
March 1977	230,000	nt	1070.7
April 1977	2,400,000	93,000	94.0
May 1977	nt	nt	nt
June 1977	2,400	2,400	ni

ni = No Isolates
nt = Not Tested

Because of the prevalence of low quality effluents, it was not possible to adequately assess the recharge system's ability to perform under normal plant operating conditions.

6. Experimental Septic System

The routine isolation of high concentrations of human viruses and coliform bacteria from raw septic tank influent was expected (Table 3–43). No unusual species were noted among the many isolates identified (Table 3–44).

Results from tests of the system's undisinfected effluents were nothing less than remarkable. Viruses were isolated on a single occasion in the very beginning of the study (Table 3–45). Effluent coliform counts were often similar to those found in drinking water (Figure 3–29). There was little evidence of any major system failure, and removal efficiency did not appear to be affected by seasonal change.

Simple adsorptive processes cannot account for the tremendous removal rates observed. Further elucidation of the mechanisms involved must await additional study.

Table 3–41

VIRUS ISOLATE IDENTIFICATIONS
Parkland III
STP and Observation Well

Date	Sample Type	Identifications Include:
August 17, 1976	Observation Well	ECHOvirus Type 6
September 6, 1976	Effluent	ECHOvirus Type 9
December 14, 1976	Effluent	U*
December 14, 1976	Observation Well	ECHOvirus Type 21 ECHOvirus Type 24
January 18, 1977	Effluent	Poliovirus Type 3 (Vaccine strain) U*
February 8, 1977	Effluent	Coxsackievirus Type B-3 Poliovirus Type 3 (Non-vaccine strain) Poliovirus Type 2 (Vaccine strain)
February 8, 1977	Observation Well	U* ECHOvirus Type 25 U*
March 15, 1977	Effluent	U* Poliovirus Type 2 (Non-vaccine strain) ECHOvirus Type 13 ECHOvirus Type 25 Poliovirus Type 3 (Vaccine strain) Coxsackievirus Type A-16
April 13, 1977	Effluent	U* Poliovirus Type 3 (Non-vaccine strain) ECHOvirus Type 32

**U = Identity Unknown*

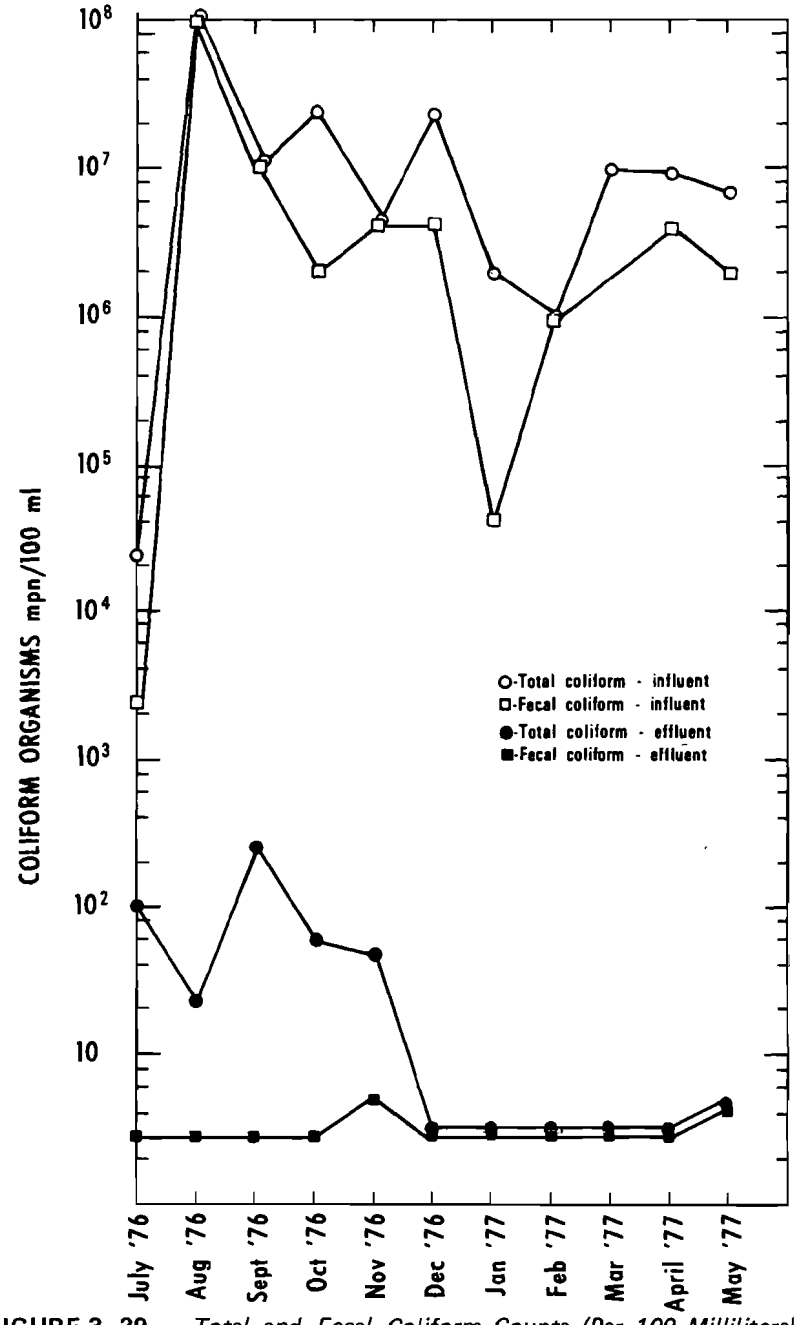

FIGURE 3–29 *Total and Fecal Coliform Counts (Per 100 Milliliters)—SCHD Experimental Septic System Influent and Effluent.*

Table 3–42

COLIFORM AND VIRUS ISOLATION

Parkland III Well

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
August 1976	430	43	3.7
September 1976	930	43	ni
October 1976	750	23	ni
November 1976	93	<3	ni
December 1976	430	9	1.6
January 1977	43	<3	ni
February 1977	15	<3	10.6
March 1977	4	nt	ni
April 1977	75	<3	ni
May 1977	nt	nt	nt
June 1977	460	150	ni

ni = No Isolates
nt = Not Tested

Table 3–43

COLIFORM AND VIRUS ISOLATION

SCHD Influent

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
July 1976	23,000	2,300	5,400.0
August 1976	110,000,000	110,000,000	600.0
September 1976	11,000,000	11,000,000	10,000.0
October 1976	24,000,000	2,400,000	2,730.0
November 1976	4,600,000	4,600,000	1,800.0
December 1976	24,000,000	4,600,000	8,880.0
January 1977	2,100,000	43,000	1,660.0
February 1977	930,000	930,000	ni
March 1977	11,000,000	nt	672.0
April 1977	11,000,000	4,600,000	ni
May 1977	7,500,000	2,300,000	ni

ni = No Isolates
nt = Not Tested

Table 3–44

VIRUS ISOLATE IDENTIFICATIONS

SCHD Septic System

Influent and Effluent

Date	Sample Type	Identifications Include:
July 8, 1976	Influent	U*
		ECHOvirus Type 21
		Poliovirus Type 2 (Vaccine strain)
		Coxsackievirus Type A-16
		ECHOvirus Type 25
		Poliovirus Type 3 (Vaccine strain)
July 8, 1976	Effluent	U*
August 2, 1976	Influent	ECHOvirus Type 23
		U*
		ECHOvirus Type 11
September 14, 1976	Influent	ECHOvirus Type 11
		Coxsackievirus Type B-3
		Coxsackievirus Type B-5
		ECHOvirus Type 2
		Coxsackievirus Type A-16
		ECHOvirus Type 23
		U*
October 5, 1976	Influent	Poliovirus Type 1 (Vaccine strain)
		ECHOvirus Type 21
		ECHOvirus Type 12
		ECHOvirus Type 24
		U*
November 2, 1976	Influent	Coxsackievirus Type A-16
		U*
December 7, 1976	Influent	Poliovirus Type 2 (Vaccine strain)
		ECHOvirus Type 2
		Coxsackievirus Type A-16
		U*
January 10, 1977	Influent	ECHOvirus Type 11
		Coxsackievirus Type B-3
		U*
March 14, 1977	Influent	Coxsackievirus Type B-3
		ECHOvirus Type 2
		ECHOvirus Type 25
		ECHOvirus Type 14
		U*

**U = Identity Unknown*

Table 3–45

COLIFORM AND VIRUS ISOLATION
SCHD Effluent

Month	Total Coliform/100 ml	Fecal Coliform/100 ml	Virus PFU/gal
July 1976	93	<3	10.0
August 1976	23	<3	ni
September 1976	230	<3	ni
October 1976	43	<3	ni
November 1976	28	4	ni
December 1976	<3	<3	ni
January 1977	<3	<3	ni
February 1977	<3	<3	ni
March 1977	<3	nt	ni
April 1977	<3	<3	ni
May 1977	4	4	ni

ni = No Isolates
nt = Not Tested

3.4 DISCUSSION

3.4.1 Introduction

There is as yet no established standard for viral pollution levels in aquatic systems. The reasons for this include the difficulty of sampling, the nonexistence of a single standard method for enumeration and identification, and the lack of concise epidemiological information concerning the waterborne transmission potentials of the virus groups involved. In isolating members of the Enterovirus group in Long Island aquatic systems, we do not stress their significance as disease causing agents, but rather as indices of recent contact with human fecal material.

The study described herein does not represent the "definitive" statement on pollution in the areas studied. Such a determination would be obviated by the low sample numbers, and the brief duration of the program. In addition, there was no information gathered on non-Enterovirus species, which may also be found in sewage polluted systems (*e.g.,* Adenovirus, Reovirus, Rotavirus [Reo-like], Norwalk-agents).

The conclusions presented on the following pages were developed with the above restrictions in mind, but based primarily upon the results obtained from the study. As this rationale exists throughout the report, the dangers of out-of-context interpretation by the reader cannot be underestimated.

3.4.2 Discussion of Results from Field Samples

1. Public Water Supplies

Reliable technology for the study of virus in drinking water has only been recently developed. Methods now exist which enable specialized laboratories to sample volumes of water ranging from 380 liters to 1900 liters (Sobsey *et al.*, 1973; Farrah *et al.*, 1976). The techniques have recently been approved and included in the 14th edition of *Standard Methods for Examination of Water and Waste Water* (1976).

Several studies have dealt with the sensitivities of the new methods. Hill *et al.* (1976) reported that three to five PFU per 380 liters could be recovered when 1900 liters of sample water were tested, with overall recovery efficiencies ranging from 28 to 42%, with an average of 35%. The methods have been successfully tested for a number of viruses including Polio, Coxsackie, ECHO, Reo and Adenovirus.

Few virus isolations would be expected in public water supplies due to a number of factors including the inability of human viruses to reproduce outside of their host; the natural physical, biological and chemical processes that inactivate virus in aquatic environments; and the efficiency of virus removal and inactivation by conventional drinking water treatment plants (Akin and Jakubowski, 1976). Evidence for the presence of virus in drinking water is sketchy and incomplete. A few reports have cited viral isolations from drinking water. After subsequent testing, the findings could not be confirmed and were judged to be the result of contamination. To avoid similar errors in the future, Akin and Jakubowski (1976) proposed a set of guidelines for sampling finished water:

–Personnel directly involved in sample collecting and handling should routinely have throat and rectal swabs collected. They should be processed if a virus-positive water sample is found.

–Aseptic technique in a closed system should be used for sample collecting and processing.

–When samples are to be stored prior to testing, they should be placed in ultralow temperature freezers that contain no other type of virus sample.

–Samples should be processed in isolation facilities where no other type of virus sample is handled.

–Multiple barriers to air contamination should exist, *i.e.*, separate isolation facility, laminar flow hoods, etc.

–All isolates must be confirmed as being viral in nature.

Few existing laboratories can meet all the above recommendations, particularly in regard to a separate isolation facility. The Brookhaven National Laboratory Virology facility was able to adopt a majority of the Environmental Protection Agency's recommendations for studying the drinking water samples from Bayport and Oakdale.

The study wells were specifically chosen because of their relatively shallow depths and vulnerability to contaminants because of their location.

The water quality met appropriate drinking water standards in all cases. Based upon our data, which showed no virus isolations from any drinking water samples, it may be concluded that virus and bacterial-free water should result from the adequate treatment of groundwater from public supply wells that have been located considerable distances from possible pollution sources, such as contaminated rivers or streams, or heavily developed (housing) areas where leaching from closely packed septic systems may adversely affect water quality in the surrounding area. In light of the above findings, it is tentatively recommended that such measures be taken whenever possible for public water supplies on Long Island. As the systems studied (Bayport, Oakdale) may not represent the "average" water supply well on Long Island, it is further recommended that additional virological studies be carried out on a variety of public water supply systems in order to lend support and further justify the above conclusions.

2. Surface Waters

(a) Lake Ronkonkoma. A review of the available literature reveals no previous report of isolation of human viruses in lake water in the United States. The major reason for this would appear to be the lack of virus studies actually carried out on this particular type of aquatic resource.

Isolation of human viruses in Lake Ronkonkoma samples on two out of seven occasions (28.5%) could theoretically be attributed entirely to the influence of bathers. The theory is easily applied to the occurrence of viruses at a bathing area in early September, a time when the area was still in use. Survival of human viruses in lake water would appear to be extensive (Hermann *et al.*, 1974), especially if they become trapped within the sediments. It is possible (but not proven) that such viruses could survive for periods of up to six months, which would explain the isolations in March of 1977. There were, however, an insufficient number of measurements taken between September and March to totally support or refute this theory.

It is impractical to ignore the possibility of other sources contributing to viral presence in the lake. As previously mentioned, the March isolations could reflect the passage of feces—contaminated liquid from domestic septic systems to the water of the lake. Information gathered at other sites concerning the likelihood of horizontal migration of virus particles through soils would suggest that septic systems would have to be located adjacent to the shores of the lake for this type of movement to occur with any predictable frequency. In order to adequately assess the likelihood of this particular type of source, it would be necessary to test the waters in those areas where septic systems are known to occur.

Standards now exist regarding the placement of septic systems near surface waters. It is recommended that further study be carried out to assess the adequacy of these standards in preventing the passage of viral contaminants into these waters.

(b) Penataquit Creek. Numerous studies have demonstrated the presence of human viruses in the tributary waters leading to embayments (Metcalf and Stiles, 1967; Vaughn and Metcalf, 1975). In most instances, pollutants have been traced to direct discharge of treated or untreated sewage into the rivers, creeks or streams under study. The likelihood of the passage of infectious virus through tributaries and into embayments of estuarine regions has been established. In the case of Penataquit Creek, the two positive samples out of a total of eleven taken (18.1%) could not be traced to a regular discharge of sewage effluent. While leakage from septic systems along the creek bank, run-off from streets, and the discharge from large boats located in the creek may be suspect, the periodicity of virus isolation (and that of bacteria) suggests a more intermittent source.

Penataquit Creek exerts an influence on the water quality of the nearby region of Great South Bay. An improvement in the quality of this and other creek waters would likely result in a corresponding improvement in the immediate area of the bay.

(c) Marine Embayments and their Shellfish. (Author's Note: Over the past several months much debate has been centered on the adequacy of the coliform index to accurately identify the potential hazards posed by sewage-borne pathogens to commercial shellfish beds. It is not the intent of the 208 virus study to pursue this question, and the present report contains insufficient information to properly address the problem. Caution is therefore advised regarding any correlation of viral and bacterial data which could not be supported by the authors or by Brookhaven Laboratory.)

Numerous investigators have described the isolation of human viruses from shellfish and shellfish growing waters (see Literature Review—Section II). In most of the cases described, the source of viral pollution was the discharges of primary or secondary sewage treatment plants.

Although a definite correlation between viral numbers in Penataquit Creek and those in Great South Bay could not be established, the creek obviously represents one of the sources of contamination to the bay. The transmission from creek to bay was probably in effect during the entire year (even though we were unable to isolate them from the creek at all times), with the actual virus concentrations fluctuating with season. Viruses were isolated from "closed" waters in 37.5% of the samples tested while being found in 28.5% of all "closed" clam samples. The "open" area yielded positive results in 37.5% of the water and shellfish samples. These results do not conflict with established survival patterns for marine waters that show extended survival in water, shellfish and sediments (Vaughn and Metcalf, 1975; Akin *et al.*, 1975b; DeFlora *et al.*, 1975).

The installation of septic systems along the immediate shoreline has been curtailed by state and county regulation, which should prevent further movement of viruses to near shore areas of the bay. The role of stormwater run-off as a source of human viruses has been suggested but not proven in the area studied. Additional studies would be necessary to define both the extent of the pollution contributed by run-off, and the likely measures for control.

The "open" and "closed" areas studied in Oyster Bay were probably influenced by separate sources of pollutants. Results showed that 12.5% of all

water and shellfish samples taken at the "open" site contained species of human viruses. Likely sources of viral contamination to this region include overland run-off, septic tank leaching and the nearby (one to two miles) discharge of treated sewage effluent from the Oyster Bay sewage treatment plant. While the major viral source could not be determined within the confines of this study; it should be noted that previous work by one of the authors (Vaughn and Metcalf, 1974; Metcalf, Vaughn and Stiles, 1972), conducted in a similar bay system receiving discharges from secondary treatment plants, indicated the presence of human viruses in shellfish beds that were located seven to eight miles from the nearest outfall.

The "closed" site was located several miles west of the "open" area discussed above. Microbial contamination at this site was probably influenced slightly by the sewage outfall, the more likely sources being from overland run-off and septic tank seepage from the numerous older homes surrounding the area. The results of sampling in this area yielded no virus isolates in the water column, yet 37.5% of the shellfish tested did contain viruses. The likely reason for this discrepancy, previously discussed in the Results section, was the heavy turbidity of the water. This finding raises some interesting questions concerning the accuracy of sole use of water samples to predict the viral quality of shellfish residing in especially turbid environments.

As the sources of viral pollution in these areas cannot be specifically identified without further study, it is impractical to offer concrete suggestions concerning their control.

3. Babylon Landfill

The banning of the open burning of trash, and the demise of the "town dump" have popularized the use of sanitary landfills for the disposal of trash items. Certain precautions should be taken to prevent the passage of viruses through the landfill and into the groundwater aquifer. Such precautions could include the use of impermeable membranes beneath the fill to prevent leaching, or the use of "filtering systems," such as artificial peat bogs, to polish the leachates before percolation to groundwater aquifers.

Investigators have previously isolated human viruses in solid wastes (Peterson,1974), but few have reported similar isolations in landfill leachates. To date no reports have described isolations in leachate-contaminated groundwater. Correlation of the results of our study with those of previous studies was complicated by the presence of scavenger waste pits on the Babylon landfill, a practice which is apparently not often used in other parts of the country. The presence of so obvious a source of human viruses tended to diminish the likelihood of other potential sources such as disposable diapers.

Virus isolations were made in 10% of the groundwater samples tested. Because neither the scavenger waste, nor the landfill leachate was tested, little can be concluded concerning the virus removing capacity of the landfill itself (significant removal could have actually occurred during movement through the groundwater aquifer between the landfill and the observation well).

While the greatest threat to groundwater pollution by landfill leachates is likely chemical rather than biological in nature, the possible movement of potentially harmful microbes through landfills (especially those which mix domestic sewage or sludge with fill) cannot be ignored. Studies to define procedures (*e.g.,* those precautions mentioned above) for the abatement of biological pollutants in leachates would be indicated.

4. Storm Water Recharge Basins

Little is known about the occurrence, transmission and survival of human viruses in storm water, and questions concerning their passage through storm water recharge basins are moot. The isolation of viruses from the groundwater beneath the North Massapequa recharge basin provides more questions than answers. Since the storm waters entering the basin were not tested, it is not certain that viruses were ever present within them. The only alternative virus source noted was possible leaking or overflow from septic systems located around the basin. Again, there is not sufficient information to make this conclusion.

Additional testing of groundwater and the storm water run-off entering the basin over a period of time would likely provide information regarding viral source, or at the very least provide additional data with which to determine the significance of the single isolation that was encountered.

Should storm water be identified as the virus source, it would be most interesting to determine the effect of the low pH of waters beneath the basin on the removal of viruses during percolation through the soil (as previously mentioned, pH levels between 3.0 and 5.5 tend to enhance virus adsorption to many surfaces).

5. Sewage Treatment Plants

Currently practiced sewage treatment methods cannot guarantee the removal of all human viruses. Isolation of viruses in treated effluents is therefore not surprising. The results of tests carried out on a number of sewage treatment plant effluents indicated that efforts could be made to minimize the number of virus in treated wastewater (*i.e.,* carrying out standard treatment practices in a properly designed plant). Three of the plants released significant virus numbers in less than 50% of their effluent samples tested (Stony Brook STP—36.3%, Oyster Bay STP—36.3%, Meadowbrook STP—25.0%). The Parkland III plant showed slightly higher frequency with 54.5% of samples taken yielding positive results. Least effective at removing viruses (and bacteria) was the Sunrise Garden Apartments plant which showed an 80% frequency of virus isolation.

The Oyster Bay facility was the only plant studied which was discharging treated effluents into surface waters. While the virus removing efficiency of this plant was among the highest of those studied, significant numbers of virus particles were periodically released into areas of the bay that are now closed. It can be calculated, given the survival capacities of viruses in such systems, that even infrequent discharges of viruses and other

microbial pollutants can eventually affect the water quality of the entire bay area. Such a risk should not be ignored and more effective virus-removing methods, or alternative means of effluent disposal should be considered.

The increasing demand for potable water to supply domestic and commercial needs has prompted a search for methods to supplement freshwater reserves. Among methods proposed are several dealing with the recharge of groundwater aquifers with renovated wastewater, including spray irrigation; land application; well injection; and percolation through recharge basins. Inherent in any scheme of wastewater reuse is the potential hazard posed by the pathogenic microorganisms commonly found in sewage. The success of many recharge methods may depend largely upon their ability to successfully remove these organisms. An important facet of the 208 virus study was the monitoring of several groundwater recharge sites in order to qualitatively assess their ability to remove human viruses (*Note:* quantitative assessment would require more elaborate programs than those conducted for 208). While being unable to define all the necessary conditions, it was hoped that the program of monthly viral analysis would be able to indicate the likelihood of returning virus-free waters to groundwater aquifers.

While not usually listed among recharge methods, the use of subsurface leaching fields associated with sewage treatment plants will eventually result in the return of water to the aquifer. It is recommended that effluents of similarly low quality to those found at the Sunrise plant not be used for such purposes. However, the information gathered at this site may be useful as an index of the efficiency of such recharge systems under "worst possible conditions." Viruses were isolated from 80% of the STP effluent samples taken, while only a 22.2% frequency was noted in the groundwater observation well. The data suggested that this type of disposal of low volume effluents in fairly isolated areas would be practical, providing the effluents were of adequate quality.

Among treatment plants discharging into recharge basins, the best results were obtained from the Stony Brook site where no viruses could be isolated from the eight samples tested. Parkland III yielded positive results in 20% of samples taken, and Meadowbrook showed an isolation frequency of 25.0%. Previously cited studies have demonstrated an inability of effluent-borne viruses to penetrate appreciable distances through soil columns depending on soil composition and effluent application rates. The apparent inability to recover significant numbers of virus at the Stony Brook site was likely a result of the soil depth from the bottom of the recharge basin to the aquifer, which measured some 80 feet.

The 34 foot soil layer from basin to aquifer at the Meadowbrook site seemed to be a less efficient virus remover. This conclusion does not account for differences in effluent qualities, and soil characteristics. Studies of the latter may have indicated the presence of small fissures which would have allowed rapid virus infiltration by channeling. Had the observation well been located further down-flow, rather than within the dome of recharged water, some estimate of virus removal during horizontal flow would have been possible. In the absence of this information, it can only be assumed that removal rates through the aquifer would be similar to those encountered during percolation through the recharge basin. Based upon this, it is calculated that viral penetration in the aquifer would not be significant after the first 100–200 feet of travel. Confirmation of this hypothesis would require an additional study of the site, which would include the installation of a second observation well 150 feet down groundwater flow from the recharge basin.

The microbial quality of effluents discharged from the Parkland III plant did not resemble those of a properly operated tertiary treatment system. In spite of this, encouraging removal rates were noted in observation well waters. Based upon these data, it is conceivable that the recharge of properly treated effluents would contribute no significant virus numbers to the aquifer. The premise could be confirmed with a study similar to that just completed.

On the basis of viral information derived from this and other ongoing and recently completed studies, the following general guidelines concerning the recharge of domestic sewage treatment plant effluents on Long Island are presented for consideration:

—The overall microbial quality of effluents to be recharged should, at the very least, conform to standards prescribed for secondary effluents, including a suggested fecal coliform count of no greater (and preferably less) than the EPA recommended 200 per 100 milliliters (geometric mean). Properly treated secondary effluents with chlorine residuals of 1.5–2.5 parts per million (15 minutes contact time) should contain reasonably low numbers of viruses that should be removed during percolation.

—Recharge basins should be located in areas where groundwater aquifers are at a significant depth. Because of differences in soil characteristics, an exact figure cannot be indicated. Depths to ground water of 60–100 feet would appear to be adequate for the removal of a majority of virus particles. Shallower recharge zones might be acceptable to a minimum of approximately 30 feet. Construction of recharge basins with distances to groundwater of less than 30 feet would have to be carefully scrutinized. Alternative treatment methods may modify the above considerations.

—Recharge basins should not be constructed in areas abutting lakes, rivers, creeks, streams or coastal waters where saturated soil conditions would facilitate the movement of viruses.

—Consideration should be given to the siting of recharge operations with respect to their proximity to public water supply wells.

—A series of additional monitoring wells should be constructed at each recharge site in order to routinely monitor the quality of the recharged water and its effect on aquifer quality.

6. Experimental Septic System

A major portion of Suffolk County is unsewered, and is likely to remain so for some time, necessitating the use of septic tanks. In an effort to find a more efficient septic system, the Suffolk County Health Department constructed an experimental subsurface system on the grounds of Brookhaven National Laboratory, which treated a portion of raw wastes originating from the Laboratory's apartment complex.

Results from the testing of this system, which was part of the 208 Virus Program, indicated it to be most promising for the treatment of small volumes of raw wastewater. In spite of the large number of viruses and bacteria entering the system, undisinfected effluents consistently revealed significant removals of both. The removal mechanisms involved could not be determined within the confines of the 208 program, but it is hoped that this research may be conducted in the future.

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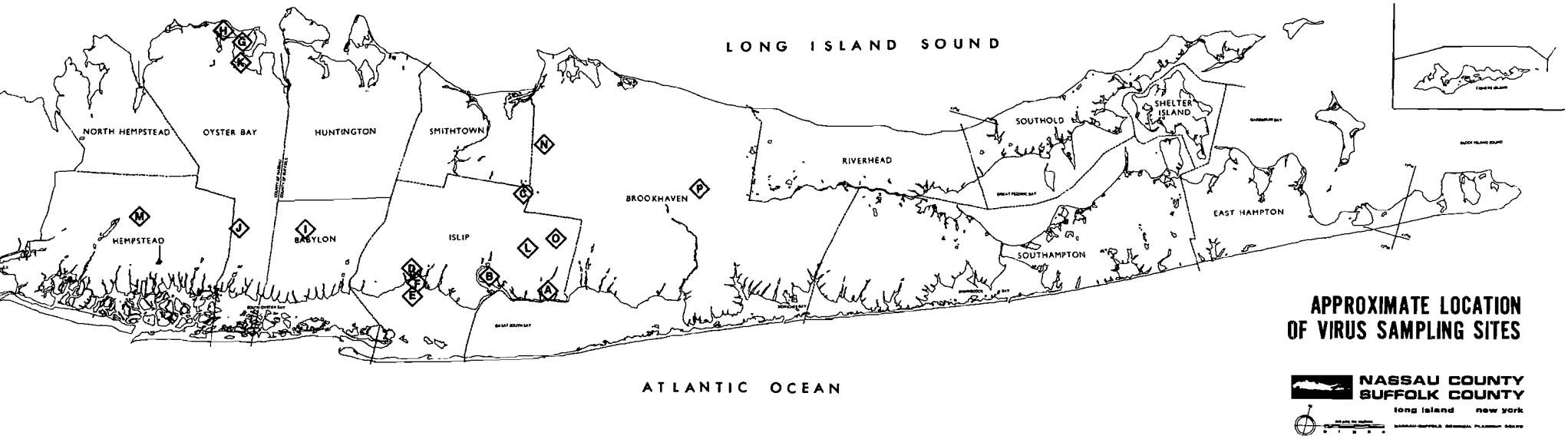

FIGURE 3–30 *Approximate Location of Virus Study Sampling Sites.*

Site	Map Designation
Bayport Well	A
Oakdale Well	B
Lake Ronkonkoma	C
Penataquit Creek	D
Great South Bay Open Waters	E
Great South Bay Closed Waters	F
Oyster Bay Open Waters	G
Oyster Bay Closed Waters	H
Bablyon Well	I
North Massapequa Well	J
Oyster Bay STP	K
Sunrise STP	L
Meadowbrook STP	M
Stony Brook STP	N
Parkland III STP	O
SCHD Experimental Septic System (Brookhaven National Laboratory)	P

Section 4 Organics

4.0 INTRODUCTION

This section presents the initial results of an investigation of the presence of organic chemicals in Long Island's ground and surface waters, and describes the data, sampling and analytical techniques, and the uncertainties associated with this study.

The information contained in this section is the result of a sampling and analysis program conducted to support the development of a 208 Areawide Waste Treatment Management Plan for Nassau and Suffolk Counties, New York. The organic chemicals study was conducted under severe time and budgetary constraints and must therefore be supplemented and expanded with additional field work and laboratory analyses.

The study demonstrated the presence of a number of organic chemicals in Long Island's ground and surface waters. The nature and extent of this demonstration, however, is subject to a number of uncertainties related to the statistical significance implied by the number of samples obtained and analyzed; the replication of analytical results obtained from multiple sampling for volatile compounds; the problems associated with sample collection, transportation, storage, and preparation; and the quality assurance problems inherent in a state-of-the-art laboratory procedure conducted at the parts per billion level.

Along with the problems associated with collection and analysis, there is significant uncertainty relating to probable risk, threshold exposure level, and other public health implications of the data.

Some of the major problems in the interpretation and evaluation of organic chemical data concern the identification of probable sources. Some of these chemicals seem to be pervasive in the environment, while others are found in a few instances and may not be found at all in replicate sampling. Many of these chemicals are related to industrial activities and processes, but they also have been found in places that have not seen any such activity. Identification of groundwater sources is especially difficult because of slow groundwater velocities, the varying rates of diffusion, and the essentially probabilistic nature of virtually all groundwater investigations.

4.1 REVIEW OF PRIOR STUDIES IN NASSAU AND SUFFOLK COUNTIES

Except for some widely publicized chemicals such as carbon tetrachloride and pesticides, the presence of organic contaminants in water has only recently attracted concern. Because of a lack of emphasis on organics monitoring in water surveys, and the relatively recent development of precise analytical techniques, organic chemicals data for the Long Island region are incomplete.

Baier (1976) reviews USGS data on pesticides in Long Island groundwater and concluded that pesticide contamination should not be considered a major pollution problem for Long Island's groundwater. Table 4—1 summarizes the results of samples from 197 test wells in Suffolk County. Few significant occurrences of pesticides are noted.

Slimak and Harris (1976) conducted a sampling program of various water media on Long Island, including stormwater runoff, effluent from secondary and tertiary domestic sewage treatment plants, and percolates of effluent. Qualitative analyses were performed by GC/MS. Various phthalates, stearates and paraffins were identified. Other organic contaminants found

Table 4–1

PESTICIDES IDENTIFIED IN USGS TEST WELLS LOCATED IN SUFFOLK COUNTY

Well No.	Pesticides and/or Herbicides (μg/l) identified in general screening process	Levels observed in subsequent resampling event (μg/l)
S43808	Dieldrin = .01	less than .01
S43815	PCB = trace	
S43819	Silvex = .01	less than .01
S45208	PCB = trace	
S46912	DDE = .01 DDT = .02 Dieldrin = .09	all less than .01
S46913	DDD = .04 DDE = .02 DDT = .08 Dieldrin = .11	all less than .01
S46914	Dieldrin = .02	less than .01
S46963	2, 4-D = trace	less than .01
S47222	Silvex = trace	less than .01
S47230	Silvex = trace	less than .01
S47235	DDD = trace DDE = trace	both less than .01
S47977	2, 4-D = .07	less than .01
S48425	2, 4-D = trace	less than .01
S48946	PCB = trace	
S51575	DDD = 8.1	DDD = 1.6
S51583	Diledrin = .01	less than .01

Source: Baier, 1976.

included benzene, toluene, xylene, chloroform, and several other hydrocarbons. Table 4–2 summarizes the results of the five samples taken. A large number of chemicals was observed.

The Nassau County Department of Health (1977a) and the Suffolk County Department of Health Services (1978) assembled results of sampling of Nassau and Suffolk County municipal water supplies, which was performed concurrently with the ERCO study. Significant (10μg/l) concentrations of volatile organics were found to contaminate water supply wells in some locales. For example, the most frequently observed contaminant, trichloroethylene, occurred in 25 of 303 samples in Nassau, and 46 of 125 samples in Suffolk. Chronological analysis of data seemed to show decreases in measured amounts over time. However, methods were not standardized, and different labs were used in a chronological sequence, so no firm conclusions could be drawn. Tables 4–3 and 4–4 summarize the results.

The Nassau and Suffolk County Health Departments and the Long Island Water Conference established interim guidelines for contaminants in Long Island water supply wells (Tables 4–5, 4–6 and 4–7) by endorsing the New York State Health Department guidelines for "restricted" and "reserve" wells.

In an attempt to identify the origins of organic chemicals in groundwater, the Nassau County Department of Health examined many common consumer products that contain potential organic contaminants, and surveyed the usage of some of these products within the County (see Tables 4–8 through 4–12). These NCDH studies served to demonstrate, on a preliminary basis, the diversity of potential sources for organic contaminants.

4.2 POTENTIAL HEALTH RISKS DUE TO ORGANIC COMPOUNDS IN WATER

Health risks from organic compounds include: (1) toxic effects; (2) carcinogenic effects from low levels in drinking water; (3) bio-accumulation in certain organs of shellfish, fish and other wildlife; and (4) tainting of shellfish and fish by hydrocarbons and other odor and taste inducing organics. Of these problems, the first and second are of major concern; the third was of concern in Long Island in the past when DDT and related pesticides were in common use (Porter *et al.*, 1977) and is now mainly of concern with respect to fish that spawn in areas such as the Hudson River, where substances such as PCBs occur (Beck *et al.*, 1978). The fourth has not been shown to be a problem on Long Island. The organic chemicals study was limited to the first and second types of effects.

> "The potential for existing concentrations of organic pesticides and other organic contaminants in drinking water to adversely affect health, cannot be answered with certainty at this time. The key issue is whether or not certain organic chemicals found in very low concentrations can cause or increase the rate of cancer development in man. Even though several of these chemicals have demonstrated carcinogenicity in laboratory animals, the extrapolation of such results to man remains difficult for a number of reasons.
>
> "Because the bioassays that have been used to establish carcinogenicity of certain organic chemicals are conducted at doses which are hundreds to thousands of times greater than the levels at which these chemicals occur in water, the risks at these low levels must be obtained by extrapolation from higher doses. There is no hard evidence that low level oral exposure to any of these chemicals produces cancer. An argument has been made that the dose levels used to establish carcinogenicity are so

Table 4–2

ORGANICS OBSERVED ON LONG ISLAND IN 1976

	Volatile Organics	Fractions From the Extraction Procedure				
		Neutral Fraction	Acidic Fraction	Acid Esterified Fraction	Basic Fraction	Particulate Extract
Untreated storm-water runoff	benzene toluene ethyl benzene p-xylene n-xylene	ethyl phthalate butyl phthalate isobutyl phthalate (T) ethyl hexyl phthalate dioctyl phthalate 2 additional phthalate compounds	methyl-18 methoxyabiatate 2-isopropyl-1, 3-dioxolane ethyl benzaldehyde (T) diethyl phthalate methyl palmitate butyl phthalate dioctyl phthalate	methyl nonanoate phenyl eicosane (T) methyl myristate methyl palmitate methyl stearate squalene (T)	diethyl phthalate dibutyl phthalate dioctyl phthalate	ethyl phthalate ethyl hexyl phthalate dioctyl phthalate 2 additional phthalate compounds
Groundwater percolate of untreated storm-water runoff	methylene chloride benzene toluene 3 additional aromatic BC's	ethyl phthalate ethyl hexyl phthalate phthalate compound dioctyl phthalate	diethyl phthalate butyl phthalate 2-isopropyl-1, 3-dioxolane dioctyl phthalate 1-decyne (T)	benzyl-2 (benzyl thio) propionate (T) methyl myristate (T) diethyl phthalate methyl palmitate methyl stearate butyl phthalate dioctyl phthalate squalene (T)	dioctyl phthalate	ethyl phthalate butyl phthalate ethyl hexyl phthalate dioctyl phthalate phthalate compound
Blank	methylene chloride (T)	butyl phthalate isobutyl phthalate butyl isobutyl phthalate	ND	ND	butyl phthalate octyl phthalate	ND
Medford effluent, tertiary treatment	ND	isobutyl phthalate butyl phthalate butyl isobutyl phthalate dibutoxyethane (T) iso-octyl phthalate	ND	ND	isobutyl phthalate	isobutyl phthalate butyl phthalate butyl isobutyl phthalate

Table 4–2 . . . cont'd.

	Volatile Organics	Fractions From the Extraction Procedure				
		Neutral Fraction	Acidic Fraction	Acid Esterified Fraction	Basic Fraction	Particulate Extract
Groundwater percolate of Medford effluent, tertiary treatment	chloroform	isobutyl phthalate butyl phthalate butyl isobutyl phthalate	methyl isoxanoate nor-octyl eicosane nor-decyl docosane b-butyl docosane 11-n decyl docosane n-pentyl beneicosane 10-n-10-n hexyleicosane n-octyl heptadecane methyl tricosane n-nonacosane n-datriaccotane n-octyl tetracosane	ND	ND	ND
Wantagh effluent, secondary treatment	perchloro-ethylene o-dichloro-benzene	ND	isobutyl phthalate butyl phthalate	butyl phthalate	butyl phthalate methyl undecane methyl decane	butyl phthalate isobutyl phthalate butyl isobutyl phthalate

Key: (T) = tentative identification.
ND = no compounds detected in sample.

Table 4—3

SUMMARY OF VOLATILE ORGANIC SAMPLING OF NASSAU COUNTY MUNICIPAL WATER SUPPLIES

Organic Compounds(1)(2)	number of samples observed at ≥10μg/l(3)	number of samples observed at ≥50μg/l(3)	number of samples observed at ≥100μg/l(3)
1, 1, 2 trichloroethylene	25	7	2
1, 1, 1 trichloroethane	16	7	4
chloroform	11	1	0
tetrachloroethylene	7	5	4
1, 2 dichloroethylene	6	0	0
benzene	3	1	0
toluene	2	0	0
bromodichloromethane	1	0	0
vinyl chloride	0	0	0
trifluorotrichloroethane	0	0	0
carbon tetrachloride	0	0	0
methylene chloride	0	0	0
ethyl ether	0	0	0

[1] *All samples were collected between June 1975 and May 1977.*

[2] *Samples were analyzed by various labs using a variety of analytical methods.*

[3] *The total number of samples is 303; not all compounds were analyzed for in all samples.*

Source: NCHD, 1977a.

high that they overwhelm normal detoxification or repair mechanisms or both, and produce cancer by some mechanism that does not operate under low dose conditions. Experimental animals subjected to such high doses could be considered a population different from those exposed to lower doses that do not produce pathological alterations and changes in pharmacokinetic parameters, or biochemistry.

"Extrapolating from laboratory animals to man would be more meaningful if comparative metabolic information between the different species was available. Some species do not metabolize a parent compound to its activated form so that use of these species in toxicological bioassays is inappropriate if the compound undergoes activation in man. The converse situation also is true. Differences may also occur with respect to other parameters such as rates of biotransformation, absorption, excretion, and biological half life.

Table 4—4

SUMMARY OF VOLATILE ORGANIC SAMPLING OF SUFFOLK COUNTY MUNICIPAL WATER SUPPLIES

Organic Compounds(1)(2)	No. of Samples Observed at ≥10μg/l(3)	No. of Samples Observed at ≥50μg/l(3)	No. of Samples Observed at ≥100μg/l(3)	Total No. of Samples Analyzed
1, 1, 2 trichloroethylene	46	29	19	125
1, 1, 1 trichloroethane	41	16	7	121
tetrachloroethylene	18	3	1	122
chlorofrom	8	2	1	123
carbon tetrachloride	4	0	0	105
1, 2 dichloroethylene	2	0	0	30
toluene	1	0	0	48
benzene	1	0	0	49
vinyl chloride	0	0	0	29
trichlorotrifloroethane	0	0	0	45
bromodichloromethane	0	0	0	62
dichloromethane	0	0	0	7
chlorodibromomethane	0	0	0	1

[1] Samples were collected between February 1976 and January 1978.

[2] Analyses were done by the following labs: NYSHD, Stony Brook; NYSHD, Albany; EPA, Ada, Okla.; New York Industrial Testing Lab; EPA, Edison, N. J.

Source: SCDHS, 1978.

"Risk assessments based on extrapolations which fail to consider species differences with respect to sensitivity, tissue susceptibility, kinetics, pathology or biotransformation pathways may be inappropriate. This kind of information is not presently available.

"In light of such uncertainties, a cautious approach must be adopted when dealing with potentially harmful chemicals. Even more uncertainty exists when one considers the possibility that some of these chemicals may also be mutagenic or teratogenic. The methodologies used to establish these effects are even less applicable to man than cancer bioassays.

"For many of the organic compounds identified in drinking water, virtually no toxicity data are available. Ideally, all of these agents (as well as any new ones) should be subjected to an exten-

Table 4–5

NEW YORK STATE INTERIM GUIDELINES
FOR ORGANIC CONTAMINANTS IN WATER SUPPLIES

Maximum Allowable Concentrations of Contaminants

Constituent	Allowable Concentration (μg/l)
Vinyl chloride	10
Other individual organics contaminants (listed below) measured for any one substance	50
Total of organics contaminants (listed below) measured for the sum of all individual concentration levels	100

These guidelines apply to the following organic chemicals:

Benzene
Carbon tetrachloride
Chloroform
1, 1, 2 trichloroethylene
Tetrachloroethylene
Bromodichloromethane
Toluene
1, 2 Dichloroethylene
Chloroethyl ethyl ether
Chloromethyl ethyl ether
Methyl chloride

Source: New York State Department of Health Interim Guidelines.

sive battery of toxicity tests including chronic bioassay. In practice, there is a need to determine those agents for which the generation of data is most pressing.

"...A number of assays using bacteria and yeast have shown promise in yielding high correlations between mutagenic activity and known carcinogenic activity for certain classes of materials. These may prove to be useful in establishing a first level screen for potential carcinogens."[1]

At present, the best approach for assessing health risks on Long Island, taking into account the above-mentioned uncertainties, is a balanced use of the NAS guidelines, the EPA and N. Y. State Health Department guidelines, and the use of best judgment for compounds not included in those guidelines and criteria.

Table 4–6

BASIS OF WELL CATEGORY ASSIGNMENTS

Category	Basis for Assignment*	Limitations on Use
"Presumptive Unacceptable"	(1) After having been in the Unrestricted Category, one analysis with one or more contaminants in excess of the allowable concentrations (Table 4–5).	To be decided on a case-by-case basis, with the understanding that the well not be used if at all possible. Blending of water with uncontaminated water from an adjacent well on the site is recognized as an acceptable procedure.
"Restricted"	(1) After having been in Presumptive Unacceptable Category, one or more consecutive analyses with one or more contaminants over the allowable concentrations (Table 4–5).	Well not to be used except in emergency, or on being granted approval of the Health Department. Blending of water with uncontaminated water from an adjacent well on the site is recognized as an acceptable procedure.
"Reserve"	(1) After having been in Restricted Category, a minimum of two consecutive analyses at least 24 hours apart, showing the contamination below the allowable concentrations, would be required. (2) After having been in the Presumptive Unacceptable Category, one analysis showing the contamination below the allowable concentrations would be required.	Unrestricted wells to be used first.
"Unrestricted"	(1) After having been in the Reserve Category, a minimum of two consecutive analyses at least 24 hours apart, showing the contamination below the allowable concentrations, would be required. (2) Not previously in the Restricted or Reserve Categories, and having no individual constituent and/or total organic concentration in excess of the allowable concentration.	None.

**As of 6/16/77.*

Note: All resampling must include all constituents that were analyzed for in previous samples.
Source: Holzmacher et al., 1977.

Table 4–7

SUMMARY OF "RESTRICTED" AND "RESERVE" WELLS IN NASSAU AND SUFFOLK COUNTIES

Summary of wells in each category by county as of March 15, 1977 (1) (2)

Category	County: Nassau	County: Suffolk
Restricted	2	5
Reserve	4	1

Summary of contaminant levels observed which resulted in restrictions (1) (2)

Contaminant	Observed Level: ≥10 µg/l	≥50 µg/l	≥100 µg/l
Carbon Tetrachloride	2	1	0
Chloroform	6	3	1
Trichloroethylene	21	14	8
Tetrachloroethylene	5	4	3
Trichloroethane	6	3	2

Summary of Nassau wells in each category as of March 16, 1978 (3) (4)

	Status: March 15, 1978	Status: Dec. 31, 1977	Status: June 1977
Presumptive Unacceptable	0	1	4
Restricted	24*	24*	17*
Reserved	2	2	2
Unrestricted but previously reserved, restricted, or unacceptable	9	7	4

**Includes 19 industrial source wells restricted to industrial use only.*

[1]Source: Holzmacher et al., 1977.

[2]All samples collected between 11/29/76 and 3/15/77.

[3]As of 3/30/77.

[4]Source: Myott, 1978.

Table 4–8

NASSAU COUNTY DEPARTMENT OF HEALTH CONSUMER PRODUCTS SURVEY (by Generic Category)

Product Category	Organic Chemical Ingredients Listed
Household Cleansers	Petroleum distillates, glycol ethers, xylenols, isopropanol
Drain Cleaners	1, 1, 1 Trichloroethane
Toilet Cleaners	Chlorinated phenols, xylene sulfonates
Laundry Soil and Stain Removers	Petroleum distillates, tetrachloroethylene
Spot Removers and Cleaning Fluids	Petroleum hydrocarbons, benzene, trichloroethylene, 1, 1, 1 trichloroethane
Hand Cleaners	Petroleum distillates, benzaldehyde
Metal Polishes	Petroleum distillates, petroleum naptha, isopropanol
Cesspool Cleaners	Tetrachloroethylene, methylene chloride, dichlorobenzene
Cleaning Solvents	Pure strength benzene, acetone, trichloroethylene
Paint and Lacquer Thinners	Benzene, toluene, acetone, butyl acetate, methyl ketones
Paint and Varnish Removers, Deglossers	Methylene chloride, toluene, acetone, xylene, ethanol, methanol
Paint Brush Cleaners	Aliphatic hydrocarbons, toluene, acetone, methyl ethyl ketones, methanol, glycol ethers
Degreasers for Engines and Metals	Chlorinated hydrocarbons, dichloroperchloroethylene, toluene, phenols
Degreasers for Driveways, Garages	Petroleum solvents, alcohols, glycol ether
Engine Flushes	Petroleum solvents, ketones, glycol ethers
Radiator Flushes	Petroleum distillates, butanol
Antifreeze	Ethylene glycol, methanol
Auto Transmission, Crankcase Additives	Petroleum distillates, xylene
Car Washes	Alkyl benzene sulfonates
Car Waxes, Polishes	Petroleum distillates, aliphatic hydrocarbons
Bug and Tar Removers	Petroleum distillates, xylene

Source: Dowling, 1977; Mackay, 1977.

Table 4—9

NASSAU COUNTY DEPARTMENT OF HEALTH
CONSUMER PRODUCTS SURVEY (by Brand Name)*

Brand Name	Product Usage	Compound
Carbona Spray Spot Remover	Spot Remover	Methylene chloride
Dax (Kocatah)	Scalp Conditioner	Tar oil
3-in-1 Plastic Wood	Wood Filler	Toluene
Flecto Varathane	Spray Paint	Toluene/Xylene
Saf-te Strip	Paint Remover	Methylene chloride
Bix (2 types)	Paint Remover	Toluene, Methylene chloride
Rock Miracle	Paint Remover	Methylene chloride
Formula A	Paint Remover	Methylene chloride
The Remover	Paint Remover	Methylene chloride
Amazon	Sealer	Creosote oil
Cabots	Tree Healer/Paint	Creosote oil
Nankes	Lacquer Thinner	Toluene
Harmel	Spray Enamel Primer	Methylene chloride
Harmel	Spray Enamel Black	Vinyl toluene soya alkdresin carbon black
Miniwax	Polyurethane Sealer	Toluene diisocyanante
Weldwood Woodlife	Wood Preservative	Pentachlorophenols
LS Liquid Sandpaper	Liquid Sanding	Xylene naphtha
Zip Strip	Paint Remover	Methylene chloride
Heddy	Graffiti Remover	Methylene chloride
Weldwood	Spray 'N' Glue	Methylene chloride
Afta	Solvent	Trichloroethylene
Shout	Stain Remover	Tetrachloroethylene
Fabspray Vinyl Colorspray	Paint	Toluene
Lacquer Thinner	Paint Thinner	Toluene
Woodlife	Wood Preservative	Pentachlorophenol
Lysol	Disinfectant	Xylenols
Warner DeGreaser	Auto Degreaser	Methylene chloride
Lan-o-Sheen	Engines	1, 1, 2 Trichloroethylene
Ortho	Pruning	Asphalt
Pratt Spray's	Insects	Xylene
Grumbacher	Retouch Varnish	Methylene chloride
Choke	Choke Cleaner	Methylene chloride
Drainz	Cesspool Cleaner	Petroleum distillate
Snap	Choke Cleaner	Xylene
Warner	Choke/PVC Cleaner	Toluene, Methylene chloride
Zing Semi-Paste	Paint Remover	Toluene, Methylene chloride
Red Devil	Brush Cleaner	Benzene
Red Devil	Paint/Varnish Remover	Benzene, Methylene chloride
Five Star	Lacquer-Thinner	Toluene
Bendite	Epoxy Primer	Halogenated Aromatic Hydrocarbon
Rust-Oleum	Spray Rust Preventative	Toluene, Xylene
Bernzomatic	Flat Tire Fixer	Toluene
Doublesealed	Lacquer Thinner	Toluene
Rich	Liquid Roof Coating	Asbestos fibre
Black Jack	Plastic Asbestos Cement	Asbestos fibre
Empire	Asbestos Cement	Asbestos fibre
Umbrella	Water Proofing	Aromatic Hydrocarbons
NYBCO Silver Touch	Silver Spray Enamel	Toluene
NYBCO Silver Touch	Wet Look Enamel	Toluene
KR2 Spot Lifter	Spot Remover	Chlorinated hydrocarbons
Baldwin	Lacquer Thinner	Toluene
Gumout	Choke Cleaner	Xylenes
STP	Carburetor Cleaner	Xylenes
RP Superfilter Coat	Odor & Dust Removing Air Filter Adhesive for Washable Filters	Hexachlorophene
Imperial Wonder Paste	Paint Remover	Methylene chloride

Table 4–9 . . . Cont'd.

Brand Name	Product Usage	Compound
TM-4	Paint and Finish Remover	Methylene chloride
Weldwood Multipurpose Floor Cement	Cement	Toluene
Weldwood Waterproof Cement	Cement	Toluene
Asphalt Asbestos Fibre Roof Plastic	Roof Coating	Asbestos
Empire Asbestos Cement	Cement	Asbestos
Asphalt Asbestos Roof Fix Roof Coating	Roof Coating	Asbestos
Digest	Sewage Grease and Waste Solvent	Trichlorobenzene
Bilco Creosote Oil Compound	Wood Sealer	Asbestos
3-in-1 Plastic Wood Solvent	Solvent	Toluene
Duro Liquid Solder	Metal Repair Cement	Toluene

**These products were identified in a one day survey of supermarkets and hardware stores by the Nassau County Department of Health.*

Source: Dowling, 1977; Mackay, 1977.

4.2.1 National Academy of Sciences Guidelines

The National Academy of Sciences has recently reviewed the existing literature on environmental pollutants, and has divided the organic contaminants of water supplies into four categories: (1) known or suspected carcinogens (Table 4–13), (2) noncarcinogenic toxins (Table 4–14), (3) compounds which have been insufficiently studied with respect to chronic toxicity (Table 4–15), and (4) compounds which have not been subjected to chronic toxicity tests (Table 4–16).

The NAS results are relevant to Long Island. Table 4–13 indicates health risks in terms of the probability of occurrence of cancer fatalities. In order to apply a set of standards, these risk numbers must be translated into allowable concentrations levels. This requires establishment of an acceptable risk level for cancer. Chloroform, carbon tetrachloride, and trichloroethylene occur on Long Island in all types of aquifer water samples. Therefore, the presence of these contaminants can reasonably be inferred to impose cancer risks according to *animal* carcinogenicity studies summarized in Table 4–13.

Phthalates were detected at concentrations equal to or greater than ten μg/l in a number of samples on Long Island (mainly from shallow aquifer wells), and in some cases were detected at concentrations greater than 50 μg/l. These levels were found by the NAS to constitute a toxicity risk, but not a cancer risk. The NAS (Table 4–14) reported that 38.5 μg/l is the threshold level for the safe consumption of di-n-butyl phthalate. Therefore, the observed concentration of di-n-butyl phthalate exceeds these levels in some Long Island shallow aquifer wells.

According to the NAS, many of the groundwater contaminants that are of concern on Long Island have not been sufficiently studied for their toxicity or carcinogenicity (see Tables 4–15 and 4–16), including tetrachloroethylene; 1, 2-dichloroethane; bromoform; bromodichloromethane; and propyl benzene. Others, such as 1, 1, 1-trichloroethane and dibromochloromethane, were not included in the NAS study. Thus, despite the existence of information enabling the assessment of health risks for a few of the organic chemicals of concern on Long Island, major uncertainties about the health risks of many others have not been resolved by the NAS.

4.2.2 EPA and New York State Guidelines

The EPA-proposed maximum contaminant levels (MCL's) for organics are limited to trihalomethanes, for which a 100 μg/l composite level is proposed. The New York State maximum allowable concentrations, which are presented in Table 4–5, were established in anticipation of the EPA proposal and are somewhat more comprehensive. Potential public health risks can be assessed by the frequency of violation of these standards, which were based on the same data used in the NAS report; however, many contaminants present in Long Island aquifers were not examined by the NAS (see Section 4.2.1).

In an attempt to limit public exposure to these chemicals, the USEPA is proposing the use of activated carbon in the treatment of all public water supplies serving more than 75,000 people.

4.2.3 Compounds of Unknown Health Risk

Compounds such as 1, 1, 1-trichloroethane, which occurred in 49 percent of the samples of this study, and tetrachlorethylene, which occurred in 33 percent of the samples, are not addressed in the toxicologic literature.

A literature search was performed for this study using the 1972–1977 DIALOG data base, which abstracts most of the published literature on health and environmental toxicology, and includes about 90 percent of the citations included in the TOXLINE search. Some 193 relevant citations were identified in a preliminary screen, of which 27 turned out to be applicable to Long Island. Dibutylphthalate (see Table 4–14), dioctyl-phthalate (not listed in the NAS report), and naphthalenes (also not listed) have been studied for a variety of toxic effects that are reported in the literature. Mutagenic screens or carcinogenicity tests for chemicals identified in Long

Table 4—10

CESSPOOL CLEANERS AND DRAIN OPENERS USED IN NASSAU COUNTY: SUMMARY OF KNOWN INGREDIENTS AND SALES INFORMATION

Brand Name	Manufacturer	Ingredients	Source of Information	Gallons Sold Yearly[1]
Action Degreaser	Action Chemicals, Inc. Brooklyn, N. Y.	Petroleum Distillates Orthodichlorobenzene	Product Label	2,210
Cess-Flo	Pequa Industries, Inc. Massapequa Park, N. Y.	Petroleum Distillates	Product Label	650
Drainz	Jan-Cyn Manufacturers 155 Oval Drive Central Islip, N. Y. 11722	Methylene Chloride—35% 1, 1, 1-Trichloroethane—31% Aliphatic/Aromatic Fractions—35%	Laboratory Analysis	27,155
Drainz Super Strength Concentrate	Jan-Cyn Manufacturers 155 Oval Drive Central Islip, N. Y. 11722	Similar to "Drainz"		4,100
Hercules Wham EPA Reg. No. 7687-2	Hercules Chemical Corp. New York, N. Y. 10011	Orthodichlorobenzene—80% Inert—20%	Product Label	2,500 (mfgrs. estimate)
The Unstuffers Liquid Cleaner for Septic Tanks & Cesspools	Coastal Industries, Inc. 190 Jony Drive Carlstadt, N. J. 07072	Solvent Blend	Per manufacturer's representative	2,330
Clog-Buster	Action Chemicals, Inc. Brooklyn, N. Y.	Petroleum Distillates	Product Label	210
Drano Aerosol Plunger	The Drackett Company 5020 Spring Grove Ave. Cincinnati, Ohio	Utilizes pressure to open drain		3,200
Glamorene Drain Power	Glamorene Product Corp. 175 Entin Road Clifton, N. J. 07014	Utilizes pressure to open drain 1, 1, 1,-Trichloroethane Chlorofluorocarbon propellant oil of pepper, perfume	Per manufacturer's representative	3,040
Kitchen Drano	The Drackett Company 5020 Spring Grove Ave. Cincinnati, Ohio 45232	1, 1, 1-Trichloroethane—75% Paraffinic Oil—25%	Per manufacturer's representative	2,210

[1] *Actual response of 60% of surveyed retail establishments.*

Source: NCDH, 1977b.

Table 4—11

ESTIMATES OF CESSPOOL CLEANER SALES IN NASSAU COUNTY
(by Chemical)

Chemical	Quantity (Gallons/Year)
Methylene Chloride	17,400
1, 1, 1-Trichloroethane	18,600
Orthodichlorobenzene	3,300
Other Aromatic and Halogenated Compounds	17,600
Total Suspected Carcinogenic or Other Harmful Organics	**56,900**
Petroleum Distillates	10,600
Grand Total	**67,500**

Source: NCDH, 1977b.

Island groundwater and not studied by the NAS (see Tables 4—13 and 4—14) were not found in the literature. Some EPA screening programs are known to be in progress, and these data are needed before further evaluations of health risks can be made.

Chemicals of unknown health risk are being identified in water supply and other groundwater samples. Since the few chlorinated volatile organics that have been studied present cancer risks, it is prudent to assume that the presence of any halogenated volatile organic chemical constitutes a potential health risk. However, the presence of a health risk does not necessarily mean that wells should be closed, or that treatment measures should be instituted. First, further toxicological screening studies, such as those under way by the EPA, must be examined. Second, acceptable levels of risk must be established, since a level of zero risk is unlikely to be achievable.

4.3 NASSAU-SUFFOLK 208 ORGANIC CHEMICALS SAMPLING STUDY METHODOLOGY

4.3.1 Sampling

The sampling plan for this study was devised by the Nassau-Suffolk 208 Technical Advisory Committee. All samples were collected by the Suffolk County Department of Health Services (SCDHS). A typical sampling event involved the collection of five samples for both volatile and methylene chloride (CH_2Cl_2) extraction analyses on a Tuesday, and the shipping of samples the following day.

Except for samples QA-1 to QA-24, all sample containers were prepared by ERCO. For volatile organics analyses (VOA's), new containers were used for all samples. The 250 milliliter glass containers were washed and baked at 250° C for three hours. Containers were then sealed with a teflon septum and closed with a screw cap. For samples QA-1 to QA-24, the SCDHS provided and prepared sample bottles. Samples were then collected by the SCDHS. Samples were filled to the top of the container and resealed with the teflon septa. Samples were immediately brought to 4° C and shipped to ERCO at that temperature. Samples were shipped by truck from Long Island to Cambridge. At the laboratory, VOA samples were stored at 4° C.

Samples for CH_2Cl_2 extraction were collected in five gallon bottles that were washed and CH_2Cl_2-rinsed by ERCO. The bottles were then sealed with foil-lined stoppers. The SCDHS rerinsed all bottles with CH_2Cl_2, and then with water from the medium to be sampled, prior to sampling. Two hundred milliliters of CH_2Cl_2 was added to each five gallon sample immediately after collection, and then the bottles were resealed with the foil-line stoppers.

4.3.2 Volatile Organics Analysis

Volatile Organics Analysis (VOA) is a technique which allows detection of that fraction of the organic components in water that vaporize (volatilize) at room temperature. During the past two years, considerable advances have been made in VOA techniques, Thus, the samples reported on in this report have been analyzed by an evolving technique. The final 24 samples (QA-1 to QA-24) were analyzed in a state-of-the-art system with excellent accuracy for identification of fourteen components, and with a precision of plus or minus twenty percent. The previous samples were analyzed with techniques giving somewhat lower precision and lower accuracy with respect to the resolution of some of the compounds.

The 118 samples were analyzed in four batches. Each succeeding batch was analyzed using more advanced techniques. The essential elements of the four techniques are given in Table 4—17.

The Electron Capture Detector (ECD) used for the first set of samples, JDW-1 to JDW-39, is not the ideal detector for the measurement of the suite of halogenated organics of concern in drinking water because it does not enjoy a linearity of response for most volatile components. Further, it has an uneven detection capability, *i.e.,* some volatile components are detected with great sensitivity, while others are detected with poor sensitivity.

The second set of samples, JDW-41 to PWG-28, were analyzed using a different gas chromatograph column and temperature program (see Table 4—17) and a detector that is superior to the electron capture detector in its stability, linearity of response over wide concentration ranges, and its reliability. However, sensitivity for nonhalogenated nonionized compounds is low. Significant problems were encountered in the use of the sample concentrator hardware. These problems resulted in the inability to resolve some of the chemically similar components. This showed up as apparently very high chloroform levels. Compounds which should have eluted just prior to and following chloroform appeared as one large "chloroform peak." Similar problems have been encountered by virtually all users of this hardware. How-

Table 4—12

INDUSTRIAL ORGANIC CHEMICAL USAGE IN NASSAU COUNTY: STATUS AS OF NOVEMBER 1977
(Gallons/Year)

Industry	No. Companies	Standard Industrial Classification No.	Priority I Total	Trichloroethylene	Benzene	Tetrachloroethylene	Toluene	Methylene Chloride	Priority II Total	1, 1, 2-Trichloroethane	Xylene	Priority III Total	1, 1, 1-Trichloroethane	Acetone	Freons	MEK	Miscellaneous
Printers	93	(271-279)	1,824		174		660	990	312	312		55,349	120	275		20	54,934
Electrical & Electronic Products	53	(361-365)	70,502	15,167	10	3,800	1,525	50,000	19,416	19,356	60	242,332	2,720	2,440	2,220	7,412	227,540
Mechanical & Engine Repair	50	(353-371-373)	3,482	2,245		625		612	135		135	22,375	102		360	26	21,807
Tool & Machine	88	(345, 346 356, 359)	24,882	14,804	8	5,400	3,430	1,160	7,100	5,000	2,100	70,857	2,600	85		5,530	62,642
Consumer Products	65	(386, 355, 395, 209, 229, 239, 284)	14,536		34	11,000	1,162	2,340	205	55	150	68,751	1,890	59			66,802
Chemical Products	15	(281-289)	409,560	5,400	170	3,080	166,000	234,910	21,600	19,000	2,600	297,770	4,910		4,500		288,360
Misc. Manufacturers	80	(399)	13,982	8,092	65	885	4,190	780	86,230	75,955	10,275	177,070	17,380	3,210	220	4,823	151,437
Aerospace	1	(3721-3761) (3728)	125,070	103,850			21,220		1,230		1,230	60,610	23,375		3,000	19,100	15,135
Dry Cleaners (Extrapolated)	400		350,000			350,000											
Totals	**845**		**1,013,838**	**149,638**	**461**	**374,760**	**198,187**	**290,792**	**136,228**	**119,678**	**16,415**	**995,114**	**53,177**	**6,069**	**10,300**	**36,911**	**888,657**

Source: NCDH, 1978.

Table 4–13

CATEGORIES OF KNOWN OR SUSPECTED ORGANIC CHEMICAL CARCINOGENS FOUND IN DRINKING WATER

Compound	Highest observed concentrations in finished water in U. S. (μg/l)	Upper 95% Confidence estimate of lifetime cancer risk per μg/liter
Human Carcinogen		
Vinyl Chloride	10	5.1×10^{-7}
Suspected Human Carcinogens		
Benzene	10	ID
Benzo (a) pyrene	D	ID
Animal Carcinogens		
Dieldrin	8	2.6×10^{-4}
Kepone	ND	4.4×10^{-4}
Heptachlor	D	4.2×10^{-5}
Chlordane	0.1	1.8×10^{-5}
DDT	D	1.2×10^{-5}
Lindane (γ-BHC)	0.01	9.3×10^{-6}
α-BHC	D	6.5×10^{-6}
β-BHC	D	4.2×10^{-6}
PCB (Aroclor 1260)	3	3.1×10^{-6}
ETU	ND[3]	2.2×10^{-6}
Chloroform	366	3.7×10^{-7}
Carbon tetrachloride	5	1.5×10^{-7}
PCNB	ND	1.4×10^{-7}
Trichloroethylene	0.5	1.3×10^{-7}
Diphenylhydrazine	1	ID
Aldrin	D	ID
Suspected Animal Carcinogens		
Bis (2-chloroethyl) ether	0.42	1.2×10^{-6}
Endrin	0.08	ID
Heptachlor epoxide	D	ID

ID = Insufficient data to permit a statistical extrapolation of risk.
ND = Not detected.
D = Detected but not quantified.
Source: NAS, 1977.

ever, these problems should not affect the validity of the data obtained for these 34 samples for other compounds eluting after chloroform.

The third set of samples, PWG-29 to PWG-55, were analyzed after operating modifications of the sample concentrator hardware were made. Gas flow rates were changed to improve peak resolution. However, even with these advances in analytical procedures, there was difficulty in resolving 1, 2 dichloroethane from chloroform and Cl_3—from CCl_4. These substances are very close in their relative retention indices. All other volatile compounds were resolved in this third set of samples.

The fourth and final set of samples, QA-1 to QA-24, were analyzed using a drastically modified (ERCO design) purge and trap unit and a Tracor 700 Hall detector with significantly altered operating conditions.[2] Modifications were also made in the gas chromatography technique. These two modifications resulted in a greatly increased ability to resolve the more volatile compounds. Temperature programming and gas flow changes were also instituted to optimize resolution. The completely modified system was tested with two EPA-supplied performance evaluation samples. Replicate analyses of these samples showed reproducible resolution of all peaks to within twenty percent.

4.3.3 Methylene Chloride Extractable Organics Analysis

The methylene chloride (CH_2Cl_2) extractable organics have an approximate boiling range of 80° C to 260° C, and correspond to the neutral and acid extractables in the EPA protocol for priority pollutants.

The screening for organic contamination was carried out by the extraction of the five-gallon water samples followed by gas chromatograph analysis. The 112 samples were analyzed in two batches. The procedures followed differed somewhat in the extraction stage for the two batches.

The first batch included samples JDW-1 to PWG-15. For these samples, extraction of the sample was carried out under neutral conditions. Some 600 ml of nanograde CH_2Cl_2 was added to the sample. After thorough mixing, the CH_2Cl_2 was siphoned through a teflon tube to a separating funnel to separate the extract from any water. The extract was then reduced to approximately 5cc in a Kuderna-Danish evaporator. The extracts were further concentrated under a stream of pre-purified nitrogen.

The second batch included samples PWG-16 to QA-24. For these samples, both neutral and acid extractions were performed. The two extracts were then combined, since sufficient analytical time was not available to generate two separate chromatograms for each sample. The procedure was as follows: first, 300 cc of nanograde CH_2Cl_2 was added to the sample; second, after thorough mixing and settling, the CH_2Cl_2 was siphoned through a teflon tube into a CH_2Cl_2-rinsed glass bottle; third, ten cc of sulphuric acid was added to the remaining water phase; fourth, 300 cc more of CH_2Cl_2 was added, mixed, and allowed to settle; fifth, the solvent layer was siphoned through a teflon tube into the bottle already containing the neutral extract;

Table 4—14

ORGANIC PESTICIDES AND OTHER ORGANIC CONTAMINANTS FOUND IN DRINKING WATER, WITH SUPPORTING DATA ON CHRONIC TOXICITY

Compound	Maximum Observed Concentrations in H_2O, µg/l	Maximum Dose Producing No Observed Adverse Effect mg/kg/day	Uncertainty Factor†	ADI†† mg/kg/day	Suggested No-Adverse Effect Level from H_2O, µg/l Assumptions* 1	2
2, 4-D	0.04	12.5	1,000	0.0125	87.5	4.4
2, 4, 5-T		10.0	100	0.1	700	35.0
TCDD		10^{-5}	100	10^{-7}	7×10^{-4}	3.5×10^{-5}
2, 4, 5-TP	detected**	0.75	1,000	0.00075	5.25	0.25
MCPA		1.25	1,000	0.00125	8.75	0.14
Amiben		250	1,000	0.25	1,750.0	87.5
Dicamba		1.25	1,000	0.001125	8.75	0.14
Alachlor	2.9	100	1,000	0.1	700.0	35.0
Butachlor	0.06	10	1,000	0.01	70.0	3.5
Propachlor		100	1,000	0.1	700.0	35.0
Propanil		20	1,000	0.02	140.0	7.0
Aldicarb		0.1	100	0.001	7.0	0.35
Bromacil		12.5	1,000	0.0125	87.5	4.4
Paraquat		8.5	1,000	0.0085	59.5	2.98
Trifluralin (also for Nitralin and Benefin)	detected**	10	100	0.1	700.0	35.0
Methoxychlor		10	100	0.1	700.0	35.4
Toxaphene		1.25	1,000	0.00125	8.75	0.44
Azinphosmethyl		0.125	10	0.0125	87.5	4.4
Diazinon		0.02	10	0.002	14.0	0.7
Phorate (also for Disulfoton)		0.01	100	0.0001	0.7	0.035
Carbaryl		8.2	100	0.082	574	28.7
Ziram (and Ferbam)		12.5	1,000	0.0125	87.5	
Captan		50	1,000	0.05	350	17.5
Folpet		160	1,000	0.16	1120	56.0
HCB	6.0	1	1,000	0.001	7	0.35
PDB	1.0	13.4	1,000	0.0134	93.8	4.7
Parathion (and Methyl parathion)		0.043	10	0.0043	30	1.5
Malathion		0.2	10	0.02	140	7.6
Maneb (and Zineb)		5.0	1,000	0.005	35	1.75
Thiram		5.0	1,000	0.005	35	1.75
Atrazine	5.0	21.5	1,000	0.0215	150	7.5
Propazine	detected**	46.4	1,000	0.0464	325	16.0
Simazine	detected**	215.0	1,000	0.215	1,505	75.25
di-n-butyl phthalate	5.0	110	1,000	0.11	770	38.5
di (2-ethyl hexyl) phthalate	30.0	60	100	0.6	4,200	210.8
hexachlorophene	0.01	1	1,000	0.001	7	0.35
methyl methacrylate	1.0	100	1,000	0.1	700	35.2
pentachlorophenol	1.4	3	1,000	0.003	21	1.25
styrene	1.0	133	1,000	0.133	931	46.5

† *Uncertainty factor—the factor of 10 was used where good chronic human exposure data was available and supported by chronic oral toxicity data in other species, the factor of 100 was used where good chronic oral toxicity data were available in some animal species, and the factor of 1000 was used with limited chronic toxicity data or when the only data available were from innalation studies.*

†† *Acceptable Daily Intake (ADI)—Maximum dose producing no observed adverse effect divided by the Uncertainty factor.*

* *Assumptions: Average weight of human adult = 70 kg. Average daily intake of water for man = 2 liters.*

1. *20% of total ADI assigned to water*
   30% from other sources
2. *1% of total ADI assigned to water*
   99% from other sources

** *Detected but not quantified.*

Source: NAS, 1977.

Table 4–15

ORGANIC PESTICIDES AND OTHER ORGANIC CONTAMINANTS FOUND IN DRINKING WATER, WITH INSUFFICIENT DATA ON CHRONIC TOXICITY

	Highest Concentration in Finished Water, μg/l
Acetaldehyde	0.1
Bromobenzene	detected
Bromoform	detected
Carbon disulfide	detected
Chloral	5.0
Chlorobenzene	5.6
Cyanogen chloride	0.1
1, 2-Dichloroethane	21.0
2, 4-Dichlorophenol	36.0
2, 4-Dimethylphenol	detected
e-Caprolactam	detected
Hexachloroethane	4.4
o-Methoxyphenol	detected
Methyl chloride	detected
Methylene chloride	7.0
Phenylacetic acid	4.0
Phthalic anhydride	detected
Propylbenzene	<5.0
t-Butyl alcohol	0.01
Tetrachloroethane	4.0
Tetrachloroethylene	<5.0
Toluene	11.0
Trichlorobenzene	1.0
1, 1, 2-Trichloroethane	detected
Nicotine	3.0
Cyanazine	detected
xylene	<5.0

detected = detected but not quantified
Source: NAS, 1977.

and sixth, the CH_2Cl_2 extract was passed through a separating funnel and reduced in volume, as was done with the first batch.

Each extract was then analyzed by gas chromatography using a Hewlett-Packard Model 5840 GC with a flame ionization detector (FID). The HP 5840 was equipped with an automatic integrator which computed the amounts of individually resolved compounds. The column used was a 6-foot SP-2100 prepared by Supelco, Inc. Gas chromatographic conditions were as follows:

T_{inj} = 260° C
T_{det} = 300° C
T_{oven} = 50° C for 4 minutes
50–250° C at 8°/minute
250° C isothermal for 20 minutes

Table 4–16

ORGANIC CONTAMINANTS FOUND IN DRINKING WATER, WITH INFORMATION ON CHRONIC TOXICITY LACKING

Compound	Highest Concentration in Finished Water, μg/l	Highest Concentration in Raw Water, μg/l
1, 2-Bis (chloroethoxy) ethane	0.03	
Bis (2-chloroisopropyl) ether	1.58	
Bromochlorobenzenes	detected	
Bromodichloromethane	116	11
Butyl bromide	detected	
Chloroethyl methyl ether	detected	
Chlorodibromomethane	100	1.4
Chlorohydroxybenzophenone	detected	
Chloromethyl ethyl ether	detected	
Chloropropene	detected	
Crotonaldehyde	5.0	
Dibromobenzene	detected	
Dibromodichloroethane	0.63	
1, 3-Dichlorobenzene	<3.0	
Dichlorodifluoroethane	detected	
Dichloroiodomethane	0.5	
1, 1-Dichloro-2-hexane	1.0	
1, 2-Dichloropropane	<1.0	
1, 3-Dichloropropene	<1.0	
1, 2-Dimethoxybenzene	detected	
4, 6-Dinitro-2-aminophenol	detected	
Dioctyladipate	20.0	
Hexachloro-1, 3-butadiene	0.07	
Isodecane	5.0	
Metachloronitrobenzene	detected	
Methylstearate	detected	
Nonane	4.0	
Octyl chloride	detected	
Pentachlorophenyl methyl ether	0.1	
1, 1, 3, 3-Tetrachloroacetone	1.0	1.0
2, 4, 6-Trichlorophenol	detected	
Trimethylbenzene	6.1	

Source: NAS, 1977.

Table 4—17

SUMMARY OF VOLATILE ORGANICS ANALYSIS (VOA) METHODS AND INSTRUMENTATION

	Sample Batch			
	JDW-1 to JDW-39	JDW-41 to PWG-28	PWG-29 to PWG-55	QA-1 to QA-24
Purge & Trap Instrument	Specially-fabricated Bellar & Lichtenberg apparatus[1]	Tekmar Liquid Sample Concentrator[2]	Tekmar Liquid Sample Concentrator	ERCO-designed purge trap
Gas Chromatograph	Perkin-Elmer 3920	Perkin-Elmer 3920	Perkin-Elmer 3920	Perkin-Elmer 3920
Column	6' Chromasorb 101	0.2% Carbowax 1500 on 60/80 Carbopac C	0.2% Carbowax 1500 on 60/80 Carbopac C	8' Chromasorb 101 1' precolumn 3% carbowax 1500 on 60/80 Carbopac C Chromasorb WAW
Detector	Perkin-Elmer ECD	Tracor 700 Hall[2]	Tracor 700 Hall	Tracor 700 Hall
Temperature Program	50°–200° C at 8°/min 2 min at 200° C	60°–160° C @ 8°/min 2 min at 160° C	60°–160° C @ 8°/min 4 min at 160° C	30°–160° C @ 8°/min 2 min at 160° C

[1] *Drs. Bellar and Lichtenberg were consulted in the construction of this unit. The work was done in connection with EPA Contract 68-01-2925 reported on in "Accumulation of Organic Pollutants by Solid Adsorbants," EPA Publication No. 560/7-77-002. See Bellar and Lichtenberg (1974).*

[2] *These two pieces of apparatus were recommended by EPA-Cincinnati which had made a similar instrumentation conversion at approximately the same time.*

Representative samples were subjected to analysis by combined gas chromatography/mass spectrometry (GC/MS) using the same analytical conditions as for the GC analysis. GC/MS was performed on an average of one sample in seven.

Concentrations of individual organic components were determined by integration of peak areas. A response factor, which relates area to amount of compound, was calculated daily by injections of two standard hydrocarbons, nC_{14} and nC_{28}. The response factor to all classes of organics was assumed to be the same.

Standards for several hydrocarbons were run daily to verify retention times and FID sensitivity. The nC_{14} and nC_{28} standards were run daily to verify calibration of the column and detector. Blanks were run daily, and after samples showing significant concentrations of contaminants.

4.3.4 Sample Storage

Samples for volatile organics analysis (VOA) were stored refrigerated in sealed glass containers filled to the brim. Samples for non-volatile organics analysis were stored at room temperature in glass containers sealed with foil-lined stoppers.

Storage times, between sample receipt and sample analysis, ranged from 20 days to over 6 months during the 208 organic chemicals study. Ideally, in a routine operating situation, storage times would be less than a week. However, VOA is not, as yet, a routine procedure, and storage was required in some cases. A previous study (Brass *et al.*, 1977) showed that extensive sample storage does not significantly affect analytic results. Thus, it is unlikely that sample storage significantly affected VOA sample results during the 208 Study.

4.3.5 Quality Control and Detection Parameters

Several quality control measures were followed to ensure the validity of the results. These included routine machine quality control procedures, analysis of control samples, and analysis of a series of EPA performance review samples.

For VOA, standard quality control included daily runs of a series of standards for each volatile compound screened, daily runs of blanks, and runs of blanks after each sample containing significant concentrations of contaminants.

For CH_2Cl_2 extracts, standard quality control included daily runs of

standards for nC_{14} and nC_{28} alkanes to verify calibration of the column and detector, daily runs of other standards to verify retention times and FID sensitivity, and the frequent use of blanks. Control samples included samples of distilled water and precipitation.

Several EPA performance review samples for VOA were run.[3] Two were run before and during analysis of samples PWG-29 to PWG-55. These samples showed some lack of resolution at the low end of the chromatogram. Results were very good for chromatograms above chloroform. Third and fourth samples run before analysis of samples QA-1 to QA-24 showed very good qualitative and quantitative results for all parts of the spectrum. The results suggested that samples run under those conditions, samples QA-1 to QA-24, were accurate to within about 20 percent.

The routine detection limit of the FID is 30 nanograms. This has been verified by ERCO for their instruments. A recent experimental program (ERCO, 1976) showed a recovery efficiency of approximately 70 percent for 20-liter samples. At that recovery efficiency, the detection of 30 nanograms of material translates to .3 parts per billion. Thus approximately .3 ppb is the minimum detectable organic contaminant concentration for the FID.

ERCO also participated in a quality assurance program along with New York State Department of Health labs in Albany and Stony Brook, and an EPA Laboratory at Ada, Oklahoma. The New York State labs have been used by Nassau and Suffolk County to analyze public drinking water supply samples for volatile organics. The EPA lab at Ada has been in the forefront of research in volatile organics sampling and analysis methodologies.

Samples QA-1 through QA-13, collected by Suffolk County Department of Health Services personnel, were utilized. Every attempt was made to ensure that each laboratory was given identical samples, and each lab was instructed to analyze the samples the morning after they were received. Each lab used its own analysis procedure; ERCO's technique is outlined in Section 4.3.2 (see Table 4–17).

The results of the program indicated that a wide range of values were obtained for many of the samples. This range was even greater than an order of magnitude in some cases. The cause of this appears to be the analytical technique used by each lab. The New York State labs showed very similar results using identical analytical procedures. EPA in Ada, Oklahoma, also produced results within tolerable limits (except for QA-10) of those produced by NYS. As a whole, the results from ERCO tended to be greater than the results produced by the other labs and, in some instances, substantially greater. It must be noted that the correct results are not known since these were naturally occurring waters and not laboratory prepared standards.

From the results obtained, it is apparent that great care must be taken when a regulatory agency uses organic test results to either open or close a public supply well. What is required is a standard method, as has been developed for other chemical constituents, in order to achieve reproducible results. Such a standard should be indicative of the danger posed by these compounds, and should be compatible with the state-of-the-art of the analytical procedure, as well as its confidence levels.

Ada Labs consistently was able to extract dichloromethane and 1, 2 dichloromethylene. In verbal conversations with ERCO, EPA indicated that dichloromethane was found, but not reported, since that chemical is used as a fixative for the non-volatile faction and would be present in the sampling vehicle as an air pollutant. No other labs identified these two organics. NYS Stony Brook detected 1, 1, 2 trifluorotrichloroethane, whereas no other lab detected this compound.

4.4 NASSAU-SUFFOLK 208 ORGANIC CHEMICALS SAMPLING STUDY RESULTS

4.4.1 Sampling Data

The organic chemicals detected in the 208 sampling program are presented in full in Tables 4–18 through 4–23. Each separate table presents results from a set of samples analyzed under one set of analytical conditions. In some cases, stations were not sampled for both volatiles and methylene chloride extractables. In some other cases, samples were collected, but one or the other of the sample fractions included a sample matrix which prevented analysis.

For the VOA, four different tables are given. Table 4–18 presents those samples analyzed using the ECD detector. The suite of compounds that can be detected using the ECD detector are not the same as those detected when using the Hall detector. Tables 4–19 through 4–21 give results for three sets of operating conditions using the Tekmar purger and Hall detector. The technique became more refined as each set was run. Thus, the set presented in Table 4–21 was run under conditions allowing the most accuracy and resolution. Samples included in Table 4–18 can only, at best, be interpreted with respect to the presence or absence of a contaminant. Samples included in Tables 4–19 through 4–21 can be interpreted with respect to levels observed as well as the presence or absence of contaminants. The quantitative accuracy of samples QA-1 to QA-24, in particular, is backed up by a highly rigorous quality control program (see Section 4.3.5).

For the methylene chloride extractables, the samples were analyzed in two batches, which are presented in Tables 4–22 and 4–23. The methodology used for analysis of each batch was slightly different, as discussed in Section 4.3.3. In the second batch, some of the identified substances were classified to a greater level of detail than in the first. As long as this difference in treatment of the two sets of data is taken into account, the two batches of samples are comparable for purposes of interpretation.

4.4.2 Interpretation of Summary Statistics

The 124 samples taken represent 102 different sample stations. In most cases, only one sample was collected at each station. Thus, there is little

Table 4—18

ANALYTICAL RESULTS FOR SAMPLES JDW-1 TO JDW-39
(in μg/l)

Volatile Organic Compounds in Order of Elution

SAMPLE*	MEDIUM OR AQUIFER**	Diethyl Ether	Chloro-form	Tri-chloro-ethane	Tri-chloro-ethylene	Tetra-chloro-ethylene
JDW-1	Water Distribution	ND	1	ND	<1	<1
JDW-2	Glacial	ND	1	ND	1	1
JDW-3	Glacial	1	2	ND	2	1
JDW-4	Glacial	4	2	ND	1	1
JDW-5	Glacial	ND	1	ND	1	<1
JDW-6	Glacial	ND	1	ND	1	1
JDW-7	Glacial	ND	<1	ND	<1	1
JDW-8	Glacial	ND	1	ND	1	1
JDW-9	Glacial	2	2	ND	2	1
JDW-10	Glacial	ND	1	ND	1	<1
JDW-11	Glacial	3	1	ND	2	2
JDW-13	Glacial	<1	1	ND	1	ND
JDW-14	Glacial	ND	1	ND	1	<1
JDW-15	Glacial	ND	1	ND	1	<1
JDW-16	Glacial	3	2	ND	2	1
JDW-17	Glacial	ND	1	ND	1	1
JDW-18	Glacial	ND	1	ND	1	1
JDW-19	Glacial (ws)	ND	1	ND	1	1
JDW-20	Glacial (ws)	1	1	ND	1	<1
JDW-21	Glacial (ws)	ND	<1	ND	ND	<1
JDW-22	Glacial (ws)	ND	2	ND	1	1
JDW-23	Glacial	ND	2	ND	1	<1
JDW-24	Glacial	ND	2	ND	1	<1
JDW-25	Magothy	<1	2	ND	1	<1
JDW-26	Glacial	ND	2	ND	1	<1
JDW-27	Glacial	<1	1	ND	1	<1
JDW-28	Glacial	<1	1	ND	1	1
JDW-29	Glacial	ND	2	ND	2	<1
JDW-30	Glacial	ND	1	ND	1	<1
JDW-31	Effluent	ND	1	ND	1	<1
JDW-32	Effluent	ND	2	ND	2	<1
JDW-33	Magothy (ws)	ND	<1	ND	<1	<1
JDW-34	Magothy (ws)	<1	1	ND	1	1
JDW-35	Magothy (ws)	<1	2	ND	1	<2
JDW-36	Glacial	ND	2	ND	1	<1
JDW-37	Magothy (ws)	<1	1	ND	<1	<1
JDW-38	Magothy (ws)	ND	<1	ND	<1	<1
JDW-39	Magothy (ws)	ND	1	ND	1	<1

**Samples were analyzed using a Bellar-Lichtenberg type purge and trap method on a Perkin-Elmer 3920 G. C., and a Perkin-Elmer Electron Capture Detector (ECD).*

***(ws) denotes water supply.*

statistical validity associated with looking at the contaminant levels at individual sites. For example, one should reject from the onset the notion that a given aquifer site or well is contaminated, or that a specific water supply well should be shut down. Such types of judgements would need to be based on averages of several measurements. Later in this section, the establishment of the minimum number of samples needed to calculate such averages, and hypotheses about patterns at individual well sites (that need to be checked by performing further sampling), are discussed.

Results obtained by sampling twenty-one sampling stations twice for methylene chloride extractable substances showed that considerable variation occurs. Similar comparisons for the volatiles from this program were not possible because of the methodology changes made. However, the same sort of comparisons for Nassau County Health Department data were made, and showed similar variations. These results point out clearly that values from one-time sampling events cannot be confidently assigned to individual wells.

The sampling results have been analyzed by media and chemical species in Tables 4—24 through 4—26.

4.4.2.1 Water Media Characteristics.

Glacial Aquifer. Over one-third of the sixty wells tested were significantly contaminated by volatiles, and over one-half by methylene chloride extractables (see Table 4—24). One-fifth of the wells contained organic contaminants at the 50 parts per billion level, the level currently in use as a cancer health risk threshold (see Section 4.2). The sample size was sufficiently large for there to be little doubt that organic contaminants reside in the Glacial aquifer at statistically significant levels.

Magothy Aquifer. Volatile organics appear to have penetrated to the Magothy aquifer to a statistically significant extent; CH_2Cl_2 extractables were not measured at significant ($\geq$ 10 μg/l) levels (See Table 4—24). However, the sample size of Magothy wells tested was marginally small. Hence, no firm conclusions were possible from these data.

Effluent. Volatile and CH_2Cl_2 extractable organics were present in the effluents that were sampled (see Table 4—24). Most of these were sewage treatment plant effluents, some of which were recharged. The halogenated volatile organics may have resulted from the chlorination of the effluents.

Lloyd Aquifer, Water Supplies, and Surface Waters. The number of samples collected was too small to allow statistical analyses (see Table 4—24).

4.4.2.2 Chemical Species Characteristics.

Trichloroethylene; Chloroform; 1, 1, 1 Trichloroethane; and Tetrachloroethylene. Three of these substances occurred in at least fifty percent of the stations tested (see Table 4—25). Incidence of 50 parts per billion observations was over four percent. Many of the occurrences noted in this study were in Glacial aquifer wells. However, sampling of Nassau County water wells (NCDH, 1977a) showed a statistically significant level of occurrence of these contaminants in water supply wells, many of which draw from the Magothy. As noted in Section 4.2, chloroform and trichloroethylene

Table 4—19
ANALYTICAL RESULTS FOR SAMPLES JDW-41 TO PWG-28
(in μg/l)

SAMPLE*	MEDIUM	Volatile Organic Compounds in Order of Elution							
		Unresolved compounds including chloroform, 1,1 dichloroethylene and 1,1 dichloroethane**	Carbon Tetrachloride	Bromodichloromethane	Trichloroethylene	Dibromochloromethane	Trichloroethane	Bromoform	Tetrachloroethylene
JDW-41	Magothy	>1	4	<1	89	8	28	8	3
JDW-42	Effluent	>1	<1	ND	3	ND	ND	ND	<1
JDW-43	Water Distribution	>1	1	ND	5	3	4	2	6
JDW-44	Water Distribution	>1	1	<1	6	ND	4	ND	4
JDW-45	Water Distribution	>1	2	ND	6	47	4	19	2
JDW-50	Effluent	ND	<1	ND	<1	ND	ND	ND	ND
PWG-1	Glacial	>1	3	<1	79	3	34	ND	2
PWG-2	Glacial	>1	3	3	62	2	10	ND	2
PWG-3	Glacial	>1	2	1	44	2	7	ND	1
PWG-4	Glacial	>1	1	ND	19	<1	4	ND	ND
PWG-5	Glacial	>1	1	<1	18	<1	2	ND	ND
PWG-6	Glacial	>1	1	<1	13	<1	1	ND	ND
PWG-7	Glacial	>1	2	<1	75	3	24	ND	<1
PWG-8	Glacial	>1	28	ND	6	<1	<1	ND	2
PWG-10	Glacial	>1	1	ND	13	ND	1	ND	ND
PWG-11	Glacial	>1	2	ND	63	ND	14	ND	ND
PWG-12	Glacial	>1	1	ND	22	3	3	ND	ND
PWG-13	Effluent	>1	<1	ND	16	3	60	ND	ND
PWG-14	Glacial	>1	1	ND	8	ND	1	ND	ND
PWG-15	Effluent	>1	3	<1	58	2	26	ND	<1
PWG-16	Glacial	>1	<1	ND	2	ND	1	ND	<1
PWG-17	Effluent	>1	2	ND	57	2	35	ND	<1
PWG-18 (19)	Glacial	>1	3	<1	11	2	1	ND	ND
PWG-19 (18)	Water Distribution	>1	1	<1	50	<1	22	ND	<1
PWG-20	Glacial	>1	2	<1	60	2	18	<1	<1
PWG-21	Control	>1	<1	ND	5	ND	1	ND	<1
PWG-22	Control	>1	1	ND	7	ND	1	ND	<1
PWG-23	Control	>1	1	ND	12	<1	2	ND	<1
PWG-25	Glacial	<1	<1	ND	<1	ND	ND	ND	ND
PWG-26	Glacial	>1	<1	ND	1	ND	<1	ND	<1
PWG-27	Effluent	>1	1	ND	12	1	21	ND	ND
PWG-28	Effluent	>1	2	ND	12	ND	1	ND	ND

Samples were analyzed using a Tekmar liquid sample concentrator or a Perkin-Elmer 3920 G. C. and a Tracor 700 Hall Electrolytic Conductivity Detector. This method did not resolve out compounds eluting before chloroform; hence, the first column of the table represents a group of compounds

***These results are not interpretable since quantification of mixed peaks is inaccurate, but are included for completeness.*

Table 4—20

ANALYTICAL RESULTS FOR SAMPLES PWG-29 TO PWG-55
(in μg/l)

SAMPLE NUMBER	MEDIUM *	Volatile Organic Compounds in Order of Elution												
		Tri-chloro-fluoro-methane	1,1 di-chloro-ethylene	1,1 di-chloro-ethane	Chloro-form	1,2 di-chloro-ethane	1,1,1 tri-chloro-ethane	Carbon tetra-chloride	Bromo di-chloro-methane	Tri-chloro-ethylene	Di-bromo-chloro-methane	Bromo-form	Tetra chloro-ethylene	1 chloro-propane
PWG 29	Magothy (ws)	ND	ND	ND	38	ND	4	ND	ND	13	ND	ND	ND	ND
PWG 30	Magothy (ws)	ND	ND	ND	12	ND	43	ND	ND	221	ND	5	6	ND
PWG 31	Glacial	UNRESOLVED COMPONENTS - NOT ANALYZABLE												
PWG 32	Glacial	ND	ND	ND	6	ND	19	ND	ND	14	ND	1	ND	ND
PWG 33	Glacial	ND	ND	ND	41	ND	4	ND	ND	13	ND	ND	ND	ND
PWG 34	Glacial	UNRESOLVED COMPONENTS - NOT ANALYZABLE												
PWG 35	Glacial	ND	ND	ND	48	ND	5	ND	ND	15	ND	ND	ND	ND
PWG 39	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 40	Effluent	ND	ND	ND	11	ND	21	ND	ND	4	ND	ND	ND	ND
PWG 41	Glacial	ND	ND	ND	3	ND	ND	ND	ND	<1	ND	ND	ND	ND
PWG 42	Glacial	ND	ND	ND	28	ND	3	ND	ND	11	ND	ND	ND	ND
PWG 43	Lake	ND	ND	ND	14	ND	2	ND	ND	6	ND	ND	ND	ND
PWG 44	Lagoon	ND	ND	ND	8	ND	112	ND	ND	7	ND	ND	31	ND
PWG 45	Effluent	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 46	Glacial	ND	ND	ND	10	ND	7	ND	ND	5	ND	ND	<1	ND
PWG 47	Lloyd	ND	ND	ND	24	ND	3	ND	ND	12	ND	ND	ND	ND
PWG 48	Magothy	ND	ND	ND	14	ND	2	ND	ND	7	ND	ND	ND	ND
PWG 49	Influent to Recharge Basin	ND	ND	ND	88	ND	20	ND	ND	3	ND	ND	21	ND
PWG 50	Glacial	ND	ND	ND	4	ND	2	ND	ND	4	ND	ND	84	ND
PWG 51	Glacial	ND	ND	ND	2	ND	8	ND	ND	1	ND	ND	24	27
PWG 52	Glacial	ND	ND	ND	50	ND	ND	ND	ND	1	ND	ND	ND	ND
PWG 53	Glacial	ND	ND	ND	17	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 55	Glacial	ND	ND	ND	40	ND	9	ND	ND	10	ND	ND	ND	ND

Samples were analyzed using a Tekmar liquid sample concentrator with modifications on a Perkin-Elmer 3920 G. C. and a Tracor 700 Hall Electrolytic Conductivity detector. Methodology was modified from that used for samples JDW-41 to PWG-28 allowing a better peak resolution.

(ws) denotes water supply.

Table 4—21

ANALYTICAL RESULTS FOR SAMPLES QA-1 TO QA-24
(in μg/l)

SAMPLE NUMBER	MEDIUM*	Volatile Organic Compounds in Order of Elution										
		Freon-11 Trichloro-fluoro-methane	1,1 Di-chloro-ethylene	1,1 Di-chloro-ethane	Chloro-form $CHCl_3$	1,2 Di-chloro-ethane	1,1,1 Tri-chloro-ethane	Carbon Tetra-chloride	Bromodi-chloro-methane	Tri-chloro-ethylene	Dibromo-chloro-methane	Tetra-chloro-ethylene
QA-1	Recharge Basin	ND	ND	ND	50	ND	19	ND	4	80	ND	3
QA-2	Glacial	2	3	30	10	ND	275	ND	1	275	ND	218
QA-3	Glacial	ND	2	14	ND	ND	104	ND	592	ND	ND	88
QA-4	Magothy (ws)	ND	ND	ND	14	2	4	1	ND	34	ND	ND
QA-5	Magothy (ws)	ND	ND	ND	ND	ND	40	ND	ND	ND	ND	ND
QA-6	Magothy (ws)	ND	ND	ND	145	ND	32	ND	17	122	ND	3
QA-7	Magothy (ws)	6	ND	ND	45	4	11	8	1	8	ND	12
QA-8	Recharge Basin	ND	ND	14	ND	ND	56	ND	ND	23	ND	10
QA-9	Glacial	ND	ND	5	1	ND	14	ND	ND	2	ND	150
QA-10	Magothy (Ws)	ND	2	ND	ND	1	7	ND	ND	109	ND	10
QA-11	Magothy (ws)	ND	ND	ND	ND	ND	ND	ND	ND	3	ND	ND
QA-12	Glacial	ND	ND	ND	1	ND	ND	ND	ND	1	ND	150
QA-13	Glacial	ND	ND	ND	2	ND	ND	ND	ND	400	ND	5
QA-14	Quench Water	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND
QA-15	Recharge Basin Influent	ND	ND	ND	1	ND	ND	ND	ND	1	ND	ND
QA-16	Leachate	NOT ANALYZABLE										
QA-17	Glacial (ws)	ND	ND	ND	22	ND	ND	ND	17	ND	7	ND
QA-19	Glacial (ws)	ND	2	5	40	ND	16	8	ND	285	ND	19
QA-20	Glacial	2	ND	ND	1	ND	3	ND	ND	1	ND	2
QA-21	Magothy	ND	ND	ND	25	ND	290	ND	ND	3	ND	5
QA-22	Magothy	1	ND	ND	2	ND	ND	ND	ND	ND	ND	ND
QA-23	Magothy (ws)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA-24	Magothy (ws)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA-25	Precipitation 11/7-8/77	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND

Samples were analyzed by the ERCO-Scott Purge and Trap method on a Perkin-Elmer Model 3920 G. C. and a Tracor 700 Hall Electrolytic Conductivity detector. This set of samples was run on a system which successfully ran an EPA-Edison, NJ performance sample with resolution of all peaks. Extra resolution of peaks was brought about by instrument and methodology (gas flow, etc.) modifications which allowed identification of a larger number of chlorinated species. All numbers are in parts per billion.

**(ws) denotes water supply.*

Table 4—22

METHYLENE CHLORIDE EXTRACTABLE ORGANIC FRACTION FOR SAMPLES JDW-1 TO PWG-15
(in μg/l)

SAMPLE	MEDIUM OR AQUIFER*	Naph-thalene	Methyl Naph-thalene	Dimethyl Naph-thalene	Ethyl Toluene	C_4 Benzene	Fluo-rene	Dibutyl Phthalate	Octyl phenols	Dioctyl Phthalate	Bromo form	Penta-chloro-propane	Dibutoxy-ethoxy Ethyl Methane	Plasticizer (composi-tion uni-dentified)
JDW-1	Water Distribution	<1	1	<1	ND	ND	ND	3	3	ND	ND	ND	ND	ND
JDW-2	Glacial	ND	2	1	ND	ND	1	2	11	ND	ND	ND	ND	ND
JDW-3	Glacial	ND	2	1	ND	ND	1	1	4	ND	ND	ND	ND	ND
JDW-4	Glacial	17	8	1	2	ND	1	12	11	ND	ND	ND	ND	3
JDW-5	Glacial	13	16	3	1	ND	1	15	8	ND	ND	ND	ND	3
JDW-6	Glacial	1	4	1	1	1	<1	6	2	ND	ND	ND	ND	ND
JDW-7	Glacial	8	6	8	1	4	1	95	3	ND	ND	ND	ND	ND
JDW-8	Glacial	2	6	4	1	2	1	67	1	ND	ND	ND	ND	ND
JDW-9	Glacial	1	4	4	<1	2	1	58	2	ND	ND	ND	ND	ND
JDW-10	Glacial	1	3	2	ND	<1	<1	37	1	ND	ND	ND	ND	ND
JDW-11	Glacial	1	2	2	ND	1	6	30	1	ND	ND	ND	ND	ND
JDW-13	Glacial	12	28	19	2	19	1	ND	30	ND	ND	ND	ND	5
JDW-14	Glacial	2	6	5	<1	4	1	92	109	ND	ND	ND	ND	ND
JDW-15	Glacial	7	18	16	4	4	3	171	4	ND	ND	ND	ND	3
JDW-16	Glacial	1	5	4	ND	1	1	80	1	ND	ND	ND	ND	ND
JDW-17	Glacial	1	5	4	<1	1	<1	73	1	ND	ND	ND	ND	ND
JDW-18	Glacial	3	3	2	ND	ND	ND	44	1	ND	ND	ND	ND	ND
JDW-19	Glacial (ws)	ND	ND	ND	ND	ND	<1	1	<1	ND	ND	ND	ND	ND
JDW-20	Glacial (ws)	ND	ND	ND	ND	ND	ND	<1	<1	ND	ND	ND	ND	ND
JDW-21	Glacial (ws)	ND	ND	ND	ND	ND	<1	1	1	ND	ND	ND	ND	ND
JDW-22	Glacial (ws)	ND	ND	ND	<1	ND	<1	1	<1	ND	ND	ND	ND	ND
JDW-23	Glacial	1	ND	1	ND	1	ND	ND	3	ND	ND	ND	ND	ND
JDW-24	Glacial	1	<1	1	ND	1	ND	ND	3	ND	ND	ND	ND	ND
JDW-25	Magothy	<1	ND	<1	ND	ND	ND	ND	1	ND	ND	ND	ND	ND
JDW-26	Glacial	1	<1	1	<1	1	ND	ND	3	ND	ND	ND	ND	ND
JDW-27	Glacial	1	<1	<1	ND	<1	ND	ND	3	ND	ND	ND	ND	ND
JDW-28	Glacial	ND	1	1	<1	1	<1	ND	1	ND	ND	ND	ND	ND
JDW-29	Glacial	ND	<1	1	ND	ND	ND	ND	1	ND	ND	ND	ND	ND
JDW-30	Glacial	2	2	1	ND	12	6	ND	9	ND	ND	ND	ND	ND

(ws) denotes water supply.

Table 4—22 . . . . Cont'd.

SAMPLE	MEDIUM OR AQUIFER*	Naph-thalene	Methyl Naph-thalene	Dimethyl Naph-thalene	Ethyl Toluene	C_4 Benzene	Fluo-rene	Dibutyl Phthalate	Octyl phenols	Dioctyl Phthalate	Bromo form	Penta-chloro-propane	Dibutoxy-ethoxy Ethyl Methane	Plasticizer (composi-tion uni-dentified)
JDW-31	Effluent	ND	3	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND
JDW-32	Effluent	ND	<1	ND	ND	ND	ND	<1	ND	2	ND	ND	ND	ND
JDW-33	Magothy (ws)	ND	1	ND	ND	ND	ND	<1	ND	2	ND	ND	ND	ND
JDW-34	Magothy (ws)	ND	1	ND	ND	ND	ND	<1	ND	4	ND	ND	ND	ND
JDW-35	Magothy (ws)	ND	1	ND	ND	ND	ND	<1	ND	6	ND	ND	ND	ND
JDW-36	Glacial	ND	1	ND	ND	ND	ND	<1	ND	9	ND	ND	ND	ND
JDW-37	Magothy (ws)	ND	1	ND	ND	ND	ND	<1	ND	4	ND	ND	ND	ND
JDW-38	Magothy (ws)	ND	1	ND	ND	ND	ND	2	ND	7	ND	ND	ND	ND
JDW-39	Magothy (ws)	ND	1	ND	ND	ND	ND	2	ND	8	ND	ND	ND	ND
JDW-40	Magothy (ws)	ND	ND	ND	ND	ND	ND	1	ND	2	ND	ND	ND	ND
JDW-41	Magothy (ws)	ND	1	ND	ND	ND	ND	1	ND	2	ND	ND	ND	ND
JDW-42	Effluent	ND	ND	ND	ND	ND	ND	3	ND	2	ND	ND	ND	ND
JDW-43	Water Distribution	ND	1	ND	ND	ND	ND	<1	ND	4	19	4	ND	ND
JDW-44	Water Distribution	ND	<1	ND	ND	ND	ND	<1	ND	2	12	2	ND	ND
JDW-45	Water Distribution	ND	ND	ND	ND	ND	ND	<1	ND	2	41	4	ND	ND
JDW-50	Effluent					NOT ANALYZABLE								
PWG-1	Glacial	ND	1	ND	ND	ND	ND	17	ND	4	ND	ND	18	11
PWG-2	Glacial	ND	1	ND	ND	ND	ND	22	ND	2	ND	ND	21	12
PWG-3	Glacial	ND	1	ND	ND	ND	ND		ND	2	ND	ND	10	6
PWG-4	Glacial	ND	1	ND	ND	ND	ND	10	ND	2	ND	ND	8	4
PWG-5	Glacial	ND	<1	ND	ND	ND	ND	8	ND	2	ND	ND	5	3
PWG-6	Glacial	ND	1	1	ND	ND	ND	19	ND	6	ND	ND	16	7
PWG-7	Glacial	ND	1	2	ND	ND	ND	36	ND	2	ND	ND	2	ND
PWG-8	Glacial	ND	2	4	ND	ND	ND	53	ND	1	ND	ND	3	ND
PWG-10	Glacial	ND	4	7	ND	ND	ND	34	ND	1	ND	ND	2	2
PWG-11	Glacial	ND	<1	1	ND	ND	ND	ND	ND	1	ND	ND	5	1
PWG-12	Glacial	ND	<1	1	ND	ND	ND	ND	ND	7	ND	ND	ND	3
PWG-13	Effluent	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	107	ND
PWG-14	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	2	ND	ND	1	2
PWG-15	Effluent	ND	ND	ND	ND	ND	ND	2	ND	3	ND	ND	1	5

*(ws) denotes water supply.

Table 4—23

METHYLENE CHLORIDE EXTRACTABLE ORGANIC FRACTION FOR SAMPLES PWG-16 TO QA-24
(in μg/l)

METHYLENE CHLORIDE EXTRACTABLE ORGANIC COMPOUNDS

SAMPLE NUMBER	MEDIUM*	ethyl benzene	o,m xylenes	p xylene	isopropyl benzene (cumene)	o-dichlorobenzene	diethyl benzene	DMN (dimethyl naphthalene)	methyl naphthalene	ethyl naphthalene	2,3 dimethyl naphthalene	acenaphthene	t-butyl phenol	C_{14} alkane	C_{15} alkane	fluorene	C_{16} alkane	diethyl phthalate	C_{17} alkane	C_{18} phytane	dibutyl phthalate	C_{19} alkane	di-tert butyl phthalate	C_{20} alkane	C_{21} alkane	C_{22} alkane	phthalate	phthalate compound	phthalate derivative	dioctyl phthalate	C_{23} alkane	C_{24} alkane	C_{25} alkane	C_{26} alkane	thymol	C_{28} alkane	tri-t-butyl orthoformate	cyclohexanone	trimethyl hexanoic acid	p-ethyl-cumene	tributyl phosphate	C_3 naphthalene	$C_{22}H_{16}$	$C_{23}H_{48}$	toluene	naphthalenes
PWG 16	Glacial	ND	ND	ND	ND	ND	ND	ND	3	ND	ND	12	ND	ND	ND	ND	ND	ND	ND	9	30	ND	ND	32	7	ND	9	ND	ND	8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8	ND	ND	ND	ND	ND
PWG 17	Effluent	ND	ND	ND	ND	ND	ND	2	3	ND	ND	ND	ND	ND	ND	ND	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	2
PWG 18	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	1	ND	ND	ND	ND	<1	ND	ND	ND	ND	4	ND	ND	ND	ND	16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 19	Water Distr.	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	<1	<1	ND	<1
PWG 20	Glacial	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND
PWG 21	Control	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 22	Control	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	14	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 23	Control	ND	ND	ND	ND	ND	ND	6	ND	ND	ND	ND	ND	ND	ND	8	ND	ND	ND	ND	ND	ND	15	ND	ND	ND	1	1	1	6	ND	ND	ND	2	ND	2	ND	12	20	ND	ND	ND	ND	ND	ND	ND
PWG 25	Glacial	ND	ND	<1	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 26	Glacial	ND	ND	ND	ND	ND	ND	<1	ND	ND	<1	ND	ND	<1	ND	ND	ND	ND	ND	<1	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 27	Effluent	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	4	ND	ND	7	ND	4	ND	ND	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 28	Effluent	ND	ND	ND	ND	ND	ND	ND	1	ND	3	2	2	ND	ND	2	ND	1	ND	1	2	ND	8	ND	ND	ND	ND	1	7	2	ND	ND	ND	ND	11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 29	Magothy (ws)	1	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 30	Magothy (ws)	ND	<1	ND	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 31	Glacial	ND	ND	5	ND	ND	ND	ND	ND	10	14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	8	4	3	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 32	Glacial	ND	ND	ND	ND	<1	ND	<1	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 33	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	<1	ND	<1	ND	ND	ND	ND	ND	ND	ND	1	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 34	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	1	1	2	1	1	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 35	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3	ND	1	ND	1	1	ND	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 36	Glacial	ND	ND	3	ND	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	4	ND	4	2	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 37	Effluent	ND	ND	ND	ND	ND	ND	1	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	<1	1	ND	1	ND	ND	2	ND	ND	ND	ND	3	ND	7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 38	Glacial	ND	ND	ND	ND	ND	46	ND	ND	ND	6	ND	ND	ND	ND	2	ND	ND	ND	2	ND	ND	3	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 39	Glacial	ND	ND	ND	ND	ND	ND	<1	1	<1	ND	1	1	ND	ND	ND	1	ND	ND	ND	1	ND	2	ND	ND	ND	4	ND	3	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 40	Effluent	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	1	ND	<1	ND	ND	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 41	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 42	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND
PWG 43	Lake	ND	ND	ND	ND	ND	ND	2	2	1	ND	1	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	1	ND	ND	ND	2	ND	1	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 45	Effluent	ND	ND	ND	ND	ND	ND	ND	2	1	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	2	ND	ND	ND	40	5	12	ND	ND	ND	ND	ND	ND	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 46	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 47	Lloyd	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	<1	<1	ND	ND	ND	ND	ND	<1	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

(ws) denotes water supply.

Table 4–23 . . . . Cont'd.

METHYLENE CHLORIDE EXTRACTABLE ORGANIC COMPOUNDS

SAMPLE NUMBER	MEDIUM*	ethyl benzene	o,m xylenes	p xylene	isopropyl benzene (cumene)	o-dichlorobenzene	diethyl benzene	DMN (dimethyl naphthalene)	methyl naphthalene	ethyl naphthalene	2,3 dimethyl naphthalene	acenaphthene	t-butyl phenol	C_{14} alkane	C_{15} alkane	fluorene	C_{16} alkane	diethyl phthalate	C_{17} alkane	C_{18} phytane	dibutyl phthalate	C_{19} alkane	di-tert butyl phthalate	C_{20} alkane	C_{21} alkane	C_{22} alkane	phthalate	phthalate compound	phthalate derivative	dioctyl phthalate	C_{23} alkane	C_{24} alkane	C_{25} alkane	C_{26} alkane	thymol	C_{28} alkane	tri-t-butyl orthoformate	cyclohexanone	trimethyl hexanoic acid	p-ethyl-cumene	tributyl phosphate	C_3 naphthalene	$C_{22}H_{16}$	$C_{23}H_{48}$	toluene	naphthalenes
PWG 48	Magothy	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2	ND	2	3	ND	2	ND	ND	ND	ND	22	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 49	Recharge Basin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	16	ND	ND	ND	ND	ND	2	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 50	Glacial	ND	ND	ND	ND	ND	ND	ND	2	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	80	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 51	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12	ND	ND	ND	2	ND	15	ND	ND	ND	3	ND	ND	<1	1	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 52	Glacial	ND	ND	ND	ND	ND	1	ND	1	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	58	ND	ND	ND	3	ND	2	1	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 53	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	<1	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 54	Glacial	ND	ND	ND	ND	ND	ND	ND	<1	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	<1	<1	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PWG 55	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	<1	<1	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 1	Recharge Basin	ND	ND	ND	<1	ND	<1	8	1	6	ND	ND	ND	ND	ND	1	1	ND	<1	<1	ND	ND	<1	1	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	1	ND	ND	ND	ND	ND	ND
QA 2	Glacial	ND	ND	<1	<1	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	<1	ND	ND	ND	ND	ND	ND	ND	<1	ND	<1	<1	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 3	Glacial	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	<1	ND	ND	<1	ND	<1	<1	ND	ND	ND	ND	ND	ND	ND	<1	1	<1	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 4	Magothy (ws)	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	3	ND	ND	<1	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 5	Magothy (ws)	ND	ND	<1	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 6	Magothy (ws)	ND	1	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	2	ND	ND	<1	ND	ND	ND	ND	ND	<1	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND
QA 14	Quench Water	ND	ND	<1	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	2	ND	1	ND	ND	1	ND	1	ND	ND	7	ND	ND	1	ND	ND	5	1	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 15	Recharge Basin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	2	1	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 17	Glacial (ws)	ND	110	10	290	ND	15	ND	28	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	400	ND	ND	ND	ND	ND	ND	ND	ND	710	ND	540	ND	ND	ND	ND	ND	ND	ND	ND
QA 18	Magothy	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	<1	ND	ND	<1	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 19	Glacial (ws)	ND	ND	ND	ND	ND	ND	ND	220	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 20	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	<1	ND	ND	ND	3	ND	ND	<1	ND	ND	ND	ND	ND	ND	26	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 21	Glacial	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	1	ND	ND	ND	7	ND	1	1	ND	ND	ND	ND	ND	ND	6	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 22	Glacial	ND	ND	1	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	<1	ND	ND	ND	<1	ND	<1	<1	ND	ND	ND	ND	ND	ND	<1	<1	ND	ND	ND	ND	ND	ND	ND	ND
QA 23	Magothy (ws)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	<1	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
QA 24	Magothy (ws)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND	<1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

*(ws) denotes water supply.

Table 4–24

SUMMARY STATISTICS–ORGANIC CONTAMINANTS IN WATER, NASSAU AND SUFFOLK COUNTIES

Medium	Volatiles*				Methylene Chloride Extractables			
	No. stations	No. stations w/at least 1 compound >10 μg/l	No. stations w/at least 1 compound >50 μg/l	No. stations w/at least 1 compound >100 μg/l	No. stations	No. stations w/at least 1 compound >10 μg/l	No. stations w/at least 1 compound >50 μg/l	No. stations w/at least 1 compound >100 μg/l
Effluent	12	7	4	0	14	5	1	1
Magothy	14	10	5	3	18	1	0	0
Glacial	37	30	13	6	68	32	12	3
Water Distribution	4	3	2	0	5	3	0	0
Lloyd	1	1	0	0	1	1	0	0
Surface Water	1	1	0	0	1	1	0	0

**Only includes samples JDW-41 to QA-25.*

Table 4–25

SUMMARY STATISTICS–VOLATILE ORGANIC COMPOUNDS

Compound	No. stations measured*	No. stations detected	No. stations occurring @ >10 μg/l	No. stations occurring @ >50 μg/l
trichloroethylene	78	62 (79%)	35 (44%)	15 (19%)
chloroform	44	34 (75%)	20 (45%)	4 (9%)
1, 1, 1 trichloroethane	78	57 (73%)	25 (32%)	6 (8%)
carbon tetrachloride	78	28 (36%)	1 (1%)	0
tetrachloroethylene	78	23 (29%)	10 (13%)	5 (6%)
dibromochloromethane	78	15 (19%)	0	0
1, 1 dichloroethane	44	5 (11%)	3 (7%)	0
bromodichloromethane	78	8 (10%)	3 (4%)	1 (1%)
freon-11	44	4 (9%)	0	0
1, 1 dichloroethylene	44	4 (9%)	0	0
1, 2 dichloroethane	44	3 (7%)	0	0
bromoform	78	5 (6%)	1 (1%)	0
1 chloropropane	44	1 (2%)	1 (2%)	0

**Only results from samples JDW 41 to QA 25 have been considered quantitatively reliable for purposes of this summary.*

appear on the National Academy of Sciences' list of known animal carcinogens. Thus, the presence of these chemicals in the Magothy aquifer may represent a potential health risk. Identification and control of the sources of these contaminants should be of high priority.

Carbon Tetrachloride and Dibromochloromethane. These contaminants were observed in well over fifteen percent of the samples (see Table 4–25). Although they were widely present, they were only found at low levels. Thus, although their wide distribution is of concern, they cannot at present be considered to impose significant potential health risks.

Other Volatile Organic Contaminants. Eight other volatile compounds were observed (see Table 4–25). They occurred in only a small number of wells at generally small concentrations. However, in the final set of samples (QA-1 to QA-24), which were analyzed under the best conditions, both 1, 1 dichloroethane and bromodichloromethane occurred at significant levels.

Phthalates. This general class of CH_2Cl_2 extractable organics occurred ubiquitously. Phthalate compounds were detected at very high levels in about eight percent of the samples (see Table 4–26). Phthalates occur as plasticizers. Thus the presence of phthalates may have been partially due to use of plastic tubing as part of the sampling devices. Nevertheless, since phthalates occur on the NAS list of chronic toxins, it is only prudent to consider the high observed phthalate levels as a possible potential health risk.

Methylene Chloride Extractable Organic Contaminants. A wide variety of compounds were observed in the samples. Some occurred at levels greater than 50 parts per billion (see Table 4–26). Eighteen substances occurred at levels greater than ten parts per billion. However, information on health risks imposed by these substances is scanty. Thus the risk levels cannot presently be assessed.

Table 4–26

SUMMARY STATISTICS–METHYLENE CHLORIDE EXTRACTABLE ORGANIC COMPOUNDS

Compounds detected at >10 μg/l for at least one station	Number of Stations >1 μg/l	Number of Stations >10 μg/l	Number of Stations >50 μg/l
methyl naphthalene	45	2	1
dimethyl naphthalene	37	3	0
dibutyl phthalate	34	20	8
octyl phenols	27	4	1
C_4 benzene	20	4	0
di-tert-butyl phthalate	20	6	2
phthalate (composition undetermined)	19	2	1
naphthalene	19	3	0
phthalate derivative (composition undetermined)	14	1	0
dibutoxy-ethoxy-ethyl methane	13	4	1
phthalate compound (composition undetermined)	8	1	0
acenaphthene	6	1	0
C_{16} alkane	6	2	0
C_{28} alkane	6	1	1
tri-t-butyl orthoformate	6	1	0
diethyl benzene	5	2	0
2, 3 dimethyl naphthalene	4	1	0
thymol	3	1	0
cyclohexane	3	2	1
o, m xylenes	2	1	1
isopropyl benzene	2	1	1
C_{20} alkane	2	1	0
trimethyl hexanoic acid	1	1	0

4.4.3 Patterns of Occurrence

The samples can be divided into several groups characterized by effluent types and overlying land use. A summary of the results tabulated according to these groups is given in Table 4–27. The results indicate that organics in the Upper Glacial aquifer are not necessarily restricted to locales underlying specific sources. Percent occurrences at $\geq$ 10 μg/l range from 100 to 43 percent. Organic contamination of greater than 10 μg/l is observed in 100 percent of the leachate and leachate plume samples, and samples collected under commercial/industrial and wooded areas.

An additional indication of patterns of contamination is given in Tables 4–28 and 4–29, which present the highest tenth percentile of observed organic chemical contamination ranked by highest contaminant level per sample and number of chemicals observed at concentrations $\geq$ 10 μg/l.

4.4.4 External Factors and Analytical Limits

The information obtained during this sampling program is limited by the analytical conditions and the sampling plan. Some of these limiting conditions are relevant in the interpretation of results presented here.

4.4.4.1 Limitations of the Sampling Plan. The sampling plan imposes the following limits on how the data should be used:

Data points were determined by existing well locations and depths. The existing wells are clumped in some areas of the Island, and leave other locales unrepresented. For example, many of the sampling wells are located along the Nassau-Suffolk border in a north-south line. Also, the majority of well samples were selected from the Glacial aquifer, leaving the Magothy and Lloyd under-represented. In addition, there is no simple method for extrapolating from the data collected to unsampled aquifers or sections of the Island.

Few water supply wells were included in the sampling plan. Hence, little direct information about the condition of water supplies was provided by the study.

Few deep wells were included. Hence, little information about the condition of deep groundwater was provided by the study.

No multiple-depth samples were taken at one site. Thus, no information about how organics are traveling through the groundwater column in zones of recharge was provided.

Few replicates were taken. Thus the variations of organic concentrations in the groundwater could not be well defined.

4.4.4.2 Limitations of the Analytical Method. While the analytical techniques used were capable of identifying a large number of organic compounds, these compounds form only a small fraction of the total organic content of a sample. Those classes of compounds which were *not* observed include the following:

Water-Soluble Organics. Highly water-soluble materials, in particular, very polar compounds, are not extracted from the water in appreciable amounts by lipophilic methylene chloride. Among these compounds are strong acids and bases, sugars, proteins, and some phenolic materials.

Non-Volatile Organics. Gas chromatography, as employed in this study, can only be used to analyze those materials that can be vaporized at 250° C and which will pass totally through the analytical column at a temperature of 250° C or less. This limits the analysis to molecules of size approximately C_{35} or less. It also eliminates from the analysis any compounds that are destroyed by the high injection-port temperatures.

Volatile Organics. The Bellar-Lichtenberg purge and trap volatile analysis methodology can only be used to analyze those materials which can be vaporized at room temperatures.

Non-Halogenated Non-Ionized Volatile Organics. The Hall detector generally is only useful for detection of halogenated ionized compounds.

While the project was in progress, EPA issued a protocol enabling the screening of organic components in water samples. It involved three

Table 4–27

EFFLUENT AND GLACIAL CONTAMINANT LEVELS RANKED BY FREQUENCY OF OCCURRENCE OF CONTAMINANTS AT ≥10 μg/l*

	# SAMPLES W/OBSERVATIONS ≥10 μg/l			# SAMPLES W/OBSERVATIONS ≥50 μg/l			# SAMPLES ANALYZED		
	Volatile Organics[2]	Methylene Chloride Extractable Organics	All Organics[1]	Volatile Organics[2]	Methylene Chloride Extractable Organics	All Organics[1]	Volatile Organics[2]	Methylene Chloride Extractable Organics	All Organics
EFFLUENT									
Effluent Type:									
Leachate	1	1	2 (100%)	1	1	2 (100%)	2	1	2
Domestic Chlorinated STP Effluent	4	2	5 (71%)	3	1	3 (43%)	4	7	7
Runoff Effluent	1	1	1 (50%)	1	0	1 (50%)	2	2	2
GLACIAL									
Overlying Land Use/ Aquifer Characteristics:									
Leachate Plumes	3	2	4 (100%)	3	0	3 (75%)	3	3	4
Commercial/Industrial Unsewered	2	2	3 (100%)	1	1	1 (33%)	2	3	3
Wooded	3	1	3 (100%)	1	0	1 (33%)	3	3	3
Agricultural	7	3	7 (87%)	3	0	3 (37%)	7	8	8
Runoff Recharge	6	3	6 (75%)	3	1	4 (50%)	8	8	8
Residential Sewered	1	7	8 (73%)	1	3	4 (50%)	1	10	11
Domestic STP Recharge	3	4	5 (63%)	0	0	0	7	8	8
Residential Unsewered	5	6	8 (50%)	4	5	7 (44%)	6	16	16
Mixed Unsewered	3	1	3 (43%)	1	1	2 (28%)	3	7	7

[1] *Percent of total number of samples analyzed (see Column 9).*

[2] *Only results from samples JSW-41 to QA-25 have been considered quantitatively reliable for the purpose of this summary.*

* *Samples were biased toward contaminated areas.*

extractions: base-neutral, acid, and pesticide. Volatiles were included as a fourth category. The extracts were all run on GC/MS to identify the most prevalent components at critical locations. Additional locations were looked at only for those components. This offered a better way to conduct such a program, but it was far more expensive. For example, a typical screening sample cost between $900 and $3000 in 1978, depending upon the laboratory selected. Verification samples were often half this price, depending upon the number of components to identify and quantify. While the expense

Table 4–28

HIGHEST 10th PERCENTILE OF OBSERVED CONTAMINANT LEVELS ORDERED BY HIGHEST CONTAMINANT LEVEL PER SAMPLE

Sample Type*	Sample No.	Highest Contaminant Level
Glacial-residential-unsewered	QA 3	592 μg/l bromodichloromethane
Glacial-mixed-unsewered (WS)	QA 17	400 μg/l phthalate compound "a"
Magothy (WS)	QA 13	500 μg/l trichloroethylene
Glacial-agricultural	QA 21	290 μg/l 1, 1, 1-trichloroethane
Glacial-residential-unsewered	QA 19	285 μg/l trichloroethylene
Glacial-residential-unsewered	QA 2	275 μg/l 1, 1, 1-trichloroethane
Magothy (WS)	PWG 30	221 μg/l trichloroethylene
Glacial-residential-unsewered	JDW 15	171 μg/l dibutyl phthalate
Glacial-leachate plume	QA 9	150 μg/l tetrachloroethylene
Glacial-mixed-unsewered (WS)	QA 12	150 μg/l tetrachloroethylene
Magothy (WS)	QA 6	145 μg/l chloroform
Scavenger waste lagoon	PWG 44	112 μg/l 1, 1, 1-trichloroethane
Glacial-residential-unsewered	JDW 14	109 μg/l octyl phenols
Magothy (WS)	QA 10	109 μg/l trichloroethylene

(WS) = water supply well.

Table 4–29

HIGHEST 10th PERCENTILE OF OBSERVED CONTAMINANT LEVELS ORDERED BY NUMBER OF CHEMICALS OBSERVED AT ≥10 μg/l PER SAMPLE

Sample	Sample No.	No. Organic Chemicals Observed at ≥10 μg/l
Glacial-mixed-unsewered (WS)	QA 17	8
Glacial-residential-unsewered	QA 19	5
Glacial-residential-unsewered	QA 2	5
Glacial-runoff recharge	PWG 1	5
Glacial-runoff recharge	PWG 2	5
Glacial-commerical/industrial-unsewered	JDW 13	5
Glacial-residential-unsewered	QA 3	4
Magothy (WS)	QA 6	4
Glacial-residential-sewered	QA 8	4
Control (passed through plastic tubing)	PWG 23	4
Runoff	PWG 49	4
Glacial-residential-unsewered	PWG 51	4

may have been great, the information retrieved was more useful in locating potential water quality problems.

While this project took place, rapid advances in the state-of-the-art of VOA methods were made. ERCO strived throughout to keep up with the technology to assure that results would be as accurate and valid as possible. This resulted in an inability to aggregate the entire VOA data set for interpretation.

Less desirable VOA methods, such as extraction or head space techniques, which are still used in many commercial labs, could have been used throughout this project. However, as EPA Cincinnati has recognized, there are serious problems associated with the use of such methods. Such an approach would have produced results with little validity.

The ERCO system used for samples QA-1 to QA-24 operated with ± 20 percent accuracy, provided good resolution of peaks, and allowed good recovery efficiency and reproducibility. The ERCO system is still under review by EPA.

4.5 CONCLUSIONS

From the results of this study, and using the results of prior studies, it can be concluded that high (> 50 ppb [μg/l]) levels of volatile organic compounds occur locally in the Long Island Upper Glacial and Magothy aquifers. Methylene chloride extractable compounds occur at high levels locally in the Upper Glacial aquifer. Employing the 1977 NAS study as a reference, it can be further concluded that these high levels of organic contaminants constitute a potential public health risk if the aquifer is used for public water supply. Some sources of the contaminants can be suggested, but no firm conclusions are possible.

4.5.1 Levels of Contamination: Volatiles

Trichloroethylene, chloroform, 1, 1, 1-trichloroethane, tetrachloroethylene, and bromodichloromethane have all been observed at > 50 μg/l. Thus, these compounds are of particular concern due to their high environmental levels.

Trichloroethylene, chloroform, and 1, 1, 1-trichloroethane have all been observed in 50 percent or more of the samples. Thus, those compounds are of particular concern due to their widespread occurrence.

Nine other volatile organics have been positively identified in several of the samples; some at high levels. Thus, there are a large number of contaminants with which control strategies must deal.

Total volatile organics contamination at levels greater than 50 μg/l has been noted locally in the Magothy aquifer. Occurrence of these contaminants at Magothy depths suggests that volatile organic contaminants may travel more rapidly through aquifers than non-volatiles. Magothy contamination by volatiles constitutes a potential local threat to the water supply.

4.5.2 Levels Of Contamination: Methylene Chloride Extractables

Several methylene chloride extractable organics have been observed at > 50 μg/l in the samples. Each of these ten compounds is of concern for its high environmental levels.

Phthalates, napthalenes, C_4 benzenes, and octyl phenols have been identified in a large number of samples. Thus, these compounds are of particular concern due to their widespread occurrence.

Methylene chloride extractable organics have not significantly penetrated the Magothy aquifer.

Methylene chloride extractable organics are especially troublesome because such a large number of compounds have been found in significant quantities. This makes monitoring efforts expensive and time consuming.

Sample PWG-23, a control sample run through 50 feet of plastic sampling hose, suggests that the sampling procedure may introduce the phthalate family of synthetics at levels up to 20 μg/l. However, one experimental sample provides little basis for conclusions.

4.5.3 Public Health Risks

Of the chemicals for which risk levels have been established—chloroform, carbon tetrachloride, trichloroethylene, phthalate compounds— all have been observed on Long Island at levels greater than 50 μg/l. Thus, present levels of those contaminants constitute a definite potential health risk. Samples from certain wells suggest that, if consumption of water in some specific locales is continued without treatment (or the provision of alternate sources), impact on public health may occur.

Chlorinated volatiles, other than the three mentioned above, occur in the groundwater. Although definitive dose response studies have not been performed, it is likely that these contaminants are harmful. Thus, present levels of these contaminants constitute a possible health risk.

The health risks due to presence of methylene chloride extractable organics, other than those in Tables 4—13 and 4—14, cannot be determined at this time.

Organic contaminants that are suspected carcinogens may present some level of risk even at very low levels. Since it is not feasible to reduce environmental levels to zero, cancer risk due to organic contaminants cannot diminish to zero and, thus, an acceptable level of risk must be established.

4.6 RECOMMENDED RESEARCH

The following research studies should be undertaken as a continuation of this study:

Inventory the sources of organic contaminants. A quantitative inventory is needed to identify the relative importance of non-point, wastewater treatment plant, and industrial point sources of the organic chemical compounds found at high levels in the groundwater. Some preliminary steps in this direction are currently being undertaken by the NCDH.

Utilize bacterial screens for dose-response assessment. The Ames screen, or a similar bacterial screen, should be used for those chemicals detected in Long Island groundwater that are not listed in Table 4—13. This involves determining bacterial mutation induced by the contaminants as an initial step in the identification of carcinogens, and in the intelligent establishment of health standards.

Determine the level of Magothy contamination. Additional analysis of existing NCDH and SCDHS data on supply wells should be combined with further sampling work to gain an overall picture of the quality of the Magothy aquifer.

Sample sources such as landfill leachates, chlorinated and unchlorinated wastewater treatment plant effluents, recharge basins, residential areas, and agricultural areas. A sampling effort is needed to fully characterize the transport of organic contaminants from surface sources. Detailed studies may be needed for specific major sources that may be identified by an inventory.

Study vertical transport. Sampling studies of gradients in vertical columns are needed to characterize the downward transport of organic contaminants. Such studies are only suitable in Magothy recharge zones.

Study variability at individual sites. Sampling studies involving replicates at particular sites are needed to establish the variance of each of the organic contaminants in each medium.

Utilize bioaccumulation screens. Fish and shellfish samples should be analyzed to screen for the occurrence of bioaccumulation of organic contaminants.

Test water distribution systems. All water distribution systems should be characterized as to organic contaminant levels as a first step in setting up a monitoring program, especially for the presence of precursor compounds which may become trihalomethanes upon chlorination.

Improve guidelines and standards. Current State and Federal guidelines are inadequate. Drinking water standards for Nassau and Suffolk Counties need to be researched and established. The use of bacterial screens is an important first step. Standards need to be established at a bi-county level to be fully responsive to the special contaminant problems occurring on Long Island.

Improve analytical procedures and quality control. An adequate interlab calibration program needs to be established to ensure the validity of all future analytical work that may be done relative to organic chemicals on Long Island. This should include the establishment of a quality control reference lab.

Investigate treatment methods for water supplies. In addition to granular activated carbon, treatment methods for water supplies should be investigated, with special emphasis on removal of lower molecular weight compounds such as the volatile organic compounds found in the bi-county area.

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NOTES

[1]National Academy of Sciences, 1977.

[2]These modifications were designed by Mark Scott, ERCO, in conjunction with EPA laboratories which had been working on the various methodology and hardware deficiencies during the duration of this sampling program. This ERCO purge and trap system has since been judged EPA-acceptable based upon accuracy of results for EPA Performance Evaluation Standards.

[3]The EPA has requested that the numerical results not be published since the performance sample sets are still being used to referee various labs.

LIST OF ABBREVIATIONS

CH_2Cl_2	methylene chloride
EPA	(U. S.) Environmental Protection Agency
ERCO	Energy Resources Company Inc.
FID	flame ionization detector
GC	gas chromatography
GC/MS	gas chromatography/mass spectrometry
LIWC	Long Island Water Conference
NCDH	Nassau County Department of Health
NYSHD	New York State Health Department
PCB	polychlorinated biphenyl
SCDHS	Suffolk County Department of Health Services
USGS	United States Geological Survey
μg/l	micrograms per liter (10^{-6} grams per liter)

GLOSSARY

Accuracy. The degree of conformity to some recognized standard value.

Ames Screen. A particular bacterial screening procedure developed by Bruce Ames of Stanford.

Aquifer. A water-bearing bed or stratum of permeable rock, sand, or gravel capable of yielding considerable quantities of water to wells or springs.

Bacterial Screen. Sets of procedures which involve inoculation of bacterial populations with different concentrations of a substance to determine the proportion of a bacterial population which mutate when exposed to the substance.

Bioassay. Exposure of biological individuals to a range of concentrations of a substance under controlled conditions to determine the effect of the exposure.

Blank Sample. Sample which does not contain the substance(s) to be tested for.

Carcinogenic Risk. The chance of mortality due to cancer incidence; usually expressed as a probability (a fraction of one).

Chlorinated Organic. Organic chemical with chloride ion(s) substituted for hydrogen(s).

Chronic Toxicity. The occurrence of mortality due to long-term low-level exposure to a substance or condition.

Column, G. C. Tube, usually stainless steel or glass, packed with a substance such as clay, silica gel, or alumina, by which means gases are separated.

Criteria Level. Threshold level of effect established (by the EPA) as a recommended level but not enforceable as would be a standard level.

Detection Limit. Concentration level below which a substance cannot be detected.

Detector, G. C. Device which monitors the passage of substances out of the end of a G. C. column.

DIALOG. A computerized abstracting service for health and environmentally related citations.

Dose-Response Relationship. A curve or other relationship showing the level of toxicity expected for each possible level of exposure.

Elute. To remove adsorbed material from an adsorbent by means of a solvent.

Gas Chromatography (G. C.). A process of separating gases in a mixture of solution by selective adsorption on clay, silica gel, or alumina as the mixture passes over the adsorbent media.

Gas Chromatography/Mass Spectrometry (G.C./M.S.). A process which couples gas chromatographic separation with mass spectrometric analysis of the compounds present.

Halogens. Any of the five elements fluorine, chlorine, bromine, iodine, and astatine.

Halogenated Organic. Organic chemical with halogen ion(s) substituted for hydrogen(s).

Kuderna-Danish. A special laboratoy device for the evaporation of solvent from a sample.

Linearity of Response. Consistent sensitivity of a laboratory instrument to a substance over a wide range of concentration levels.

Lipophilic. Promoting the solubilization or absorption of fats or other lipides.

Methylene Chloride (CH_2Cl_2) Extractable Organics. Those organic chemicals soluble in CH_2Cl_2 and which volatilize at 250° C or less.

Performance Review Sample, EPA. Spiked samples distributed to various labs to allow standardization and evaluation of quantitative and qualitative laboratory results.

Polar. Molecules with distinct negative and/or positive poles or charges in water or solvent.

Pyrolyze. Cause to react at elevated temperatures in the absence of oxygen.

Precision. The degree of refinement with which a measurement is performed.

Recovery Efficiency, G. C. The proportion of a substance which passes completely through the extraction and gas chromatographic procedure.

Reserve Wells. With reference to LIWC Guidelines (Holzmacher, 1977), wells which have been removed from the restricted list. No restrictions on use are imposed.

Resolution. The ability to separate a mixture into its component parts.

Restricted Wells. With reference to LIWC Guidelines (Holzmacher, 1977), wells not to be used for supply except in emergencies. These wells contain contaminants at levels exceeding standards.

Retention Index. A coefficient specifying the relative retention time of a gas in the chromatographic column.

Retention Time. The length of time a gas will be retained in the gas chromatographic column before elution.

Sensitivity. The concentration level to which a substance can be detected.

Spiked Samples. Samples containing known concentrations of various compounds used to test analytical resolution and recovery efficiency.

Standard Levels. Threshold level which has been established by an agency as an allowable level for an effluent stream or ambient body.

Standard Samples. A set of samples containing a compound of known concentrations used to test linearity of response and to calibrate a G. C. for quantification.

TOXLINE. A computerized abstracting service of toxicological citations.

Unresolved Compounds (G. C.). Components not separated into discrete peaks in a gas chromatograph.

Volatile Organics. Those organic compounds which vaporize at room temperature.

Section 5 Nitrates

5.0 INTRODUCTION

To what extent is nitrogen a potential or actual contaminant in Long Island's waters? This question presupposes two others: what are the major sources of nitrogen; and what is the fate of the nitrogen in the environment? Both questions are deceptively simple.

This section describes studies that have, in part, attempted to answer them. One of the aims of this section is to identify the more important uncertainties. This section presents methods and results that may be of value in managing nitrogen on Long Island.

The management of nitrogen appears to be essential to protect the region's drinking water supplies and the ecological balance of marine bays. Given current high levels of water consumption and use, the risks of degrading the water resources, whether it be the contamination of groundwater or the pollution of surface waters, are very high. Urban development and overuse of groundwater in Kings and Queens Counties have already caused contamination of the water supply on the western end of the Island.

The marine environs adjacent to the western end of Long Island have also been adversely affected, especially by sewage effluents and the dumping of sludge, provoking apprehension that the marine water resources of the whole of Long Island could decline in quality as Nassau and Suffolk also become further urbanized. Nitrogen is regarded as one of the key factors in that potential decline.

In this section, aspects of the nitrogen balance are briefly described; the development of the Island with respect to nitrogen is outlined; and the major sources and fate of nitrogen, as determined by recent studies, are discussed. The impact of nitrogen on the region's water resources is assessed. Finally, work undertaken at Cornell University, which is attempting to construct detailed nitrogen budgets for Nassau and Suffolk, is described and interpreted.

5.1 ASPECTS OF THE NITROGEN CYCLE

Since the early 1800's, man has known that nitrogen is a critical nutrient. Nitrogen is a component of all protoplasm, including, specifically, protein and nucleic acids. On the average, nitrogen constitutes more than fifteen percent of living organisms. Nitrogen is required by crops in amounts greater than any other nutrient. Requirements exceed 200 lbs/acre/year for some crops.

Nitrogen is also plentiful. In the atmosphere, it constitutes about 80 percent of the total volume. An even greater reservoir of nitrogen exists in primary rocks, where the quantity of nitrogen bound up is estimated to be 50 times greater than that in the atmosphere (Hutchinson, 1944). The nitrogen in rocks is held largely in a combined form, such as ammonium, and could, therefore, be utilized by living matter, were it accessible. Although the rate at which such nitrogen becomes biologically available is not known, it

is believed to have a relatively minor role in the nitrogen cycle, compared to atmospheric nitrogen.

Living matter depends primarily on the atmosphere as its source of nitrogen. However, dinitrogen, as the molecule N_2 is called, is inert because of the strength of the bond between the two nitrogen atoms. The conversion of dinitrogen into a nitrogenous form that is available for plants is performed by a specialized group of microbes. These include bacteria, many of which are symbiotic, and blue-green algae. In a process called fixation, the microbes are able to reduce N_2 to ammonium using a catalytic enzyme called nitrogenase. The ammoniacal nitrogen can then be incorporated into the principal biospheric reservoirs in various forms of nitrogen: nitrite, nitrate, urea, protein and nucleic acids.

Organisms that fix dinitrogen play a highly critical role in the nitrogen cycle. In fact, nitrogen fixation is one of the major factors limiting life on earth. Although estimates are speculative, it is believed that nitrogen fixation in terrestrial and aquatic environments varies broadly from about 150 mg/m^2 to over 1000 mg/m^2.

Nitrogen is also fixed naturally by electrical storms, which dissociate nitrogen and oxygen molecules that recombine to form an oxide of nitrogen. This reacts with water vapor to produce nitric acid, which is carried in precipitation to the ground, where it becomes available for living organisms.

Since the industrial revolution, man has increasingly been unable to rely on natural fixation to satisfy his need for nitrogen. Until the early 1900's, immediate sources of nitrogen were supplemented by inorganic nitrogen from mineral deposits (salt petre) and dried organic wastes of seabirds or bats.

Currently, about 95 percent of all the nitrogen applied as fertilizer in the U. S. is produced by artificial fixation. There are nearly 100 industrial complexes in the Nation capable of producing a total of about twenty million metric tons per year.

These figures demonstrate the potential augmentation of the amount of nitrogen entering the biosphere due to man's activities. It is estimated that approximately 80 million metric tons of nitrogen are fixed synthetically every year, which is more than one-third of that fixed naturally. Some of the environmental consequences of this augmentation are readily evident, the accelerated enrichment of surface waters and contamination of groundwater being major examples.

An important characteristic of nitrogen is that, once in the biosphere, most nitrogenous compounds are easily transformed. Organic forms are readily decomposed by biochemical processes. Inorganic nitrogen is either soluble or volatile. Hence nitrogen does not accumulate in the biosphere in large deposits, as do sulphur or carbon. Doubtless, there is some long term biochemical enrichment of the lithosphere as a result of the formation of sedimentary rocks, with a corresponding loss from the atmosphere. However, this loss is partly offset by the release of nitrogen from primary rocks.

There is no evidence that there is a significant loss of nitrogen from the atmosphere in the long term because the process of biological denitrification returns an amount of nitrogen to the atmosphere commensurate with that which is fixed. Denitrification is brought about by certain bacteria that are able to grow in either the presence or absence of oxygen. If oxygen is absent, then denitrifying bacteria are able to reduce nitrate (NO_3) to dinitrogen (N_2) or nitrous oxide (N_2O). These gaseous products eventually escape to the atmosphere and are temporarily lost to the biosphere.

The artifical augmentation of the flow of nitrogen in the environment has undoubtedly increased denitrification. Unfortunately, from the point of view of the nitrogen balance, denitrification is the most difficult component to quantify. Anaerobic conditions in the field may arise under diverse circumstances that may be transient; may occur at a multitude of micro sites; or may be general, and yet remain impractical to monitor. This difficulty has moved Cooke (1967) to assert that attempts to construct a balance sheet are bound to fail, at least with respect to crops. It is an anomaly of the nitrogen cycle that nitrification, the bacterial oxidation of ammonia to nitrate, requires oxygen, whereas the reduction of nitrate to gaseous nitrogen requires its absence. There is no doubt, however, that many regional nitrogen computations reveal a large loss that may be as much as 50 percent of the total budget (Porter, 1975). In the absence of evidence that nitrogen is being stored in the biosphere, it appears reasonable to attribute the unaccounted nitrogen loss primarily to denitrification.

In summary, the life sustaining components of the natural nitrogen cycle depend on microbial fixation and denitrification. Over recent decades, however, man has disrupted this natural cycle by means of artificial fixation.

Excessive augmentation of the nitrogen cycle places ground and surface water at risk. This is due to the natural interaction of the nitrogen and water cycles. Flowing water is a primary agent in the transport of nitrogen compounds. In its nitrate form, nitrogen can be leached from the soil by water. Other organic and inorganic forms of nitrogen may be removed by water flowing over land. Man also uses water to carry off his wastes. The surface or groundwaters that eventually receive this nitrogen may be undesirably affected if, as a result, a drinking water supply is contaminated or an ecosystem is substantially altered.

Degradation of groundwater quality and enrichment of surface waters by nitrogen has occurred to a marked degree on Long Island. An assessment of the causes of such changes is the subject of this section.

5.2 HISTORICAL BACKGROUND TO THE PROBLEM OF NITROGEN ON LONG ISLAND

In a recent study of nitrogen isotope ratios of nitrate in Nassau and Suffolk Counties, Kreitler *et al.* (1978) concluded that the source of nitrate in the Magothy "is from a dominant agricultural source plus animal wastes." If this conclusion is correct, it explains an apparent anomaly in levels of

nitrate in the groundwater in Nassau. For some time it has been apparent that older water in the Magothy aquifer had high levels of nitrogen which, in many areas, were higher than those found in the overlying Glacial aquifer. Since the water in the Magothy predated much of the urban development in the County, it was puzzling that newer water was of better quality, since the use of cesspools and septic tanks in the original developments were an obvious major source of nitrate-nitrogen.

An explanation of the anomaly could be that earlier agricultural activity had introduced significant amounts of nitrate to the groundwater. The history of farming on Long Island as a potential source of nitrogen is briefly discussed below.

Long Island has a history of intensive farming. The coincidence of fertile soils and a favorable climate with a ready market in New York City promoted a thriving agricultural industry on the Island. In the early nineteenth century, the enthusiasm of the farmers led to exhaustion of the soils. The land was rescued from premature retirement when it was discovered that fish made excellent fertilizers. The farmers organized fishing fleets to obtain sufficient quantities of fish. The fish were incorporated into the soil (*i.e.* one fish per hill of corn, a practice known to the Indians) or were broadcast on the surface (Talmage, 1977).

Extension of the Long Island Railroad throughout the Island also facilitated the use of organic fertilizers. The Railroad provided stable manure from New York City at 80 cents per wagon load, while at the same time, of course, making the city more accessible as a market. In the 1870's, according to Talmage, commercially prepared fertilizers became available and were widely used by the farmers.

The history of farming in the 20th century in Nassau and Suffolk may be noted from Table 5–1. According to the U.S. Census data almost half of the area in the two counties was in agricultural use at the beginning of the century. It may further be noted that the number of animals raised was significant. These livestock made their own contribution to the flow of nitrogen, in addition to that provided by imported manure.

Although it is accepted that the use of fertilizers has greatly increased during the last two decades, on Long Island the data suggest that fertilizers, both organic and inorganic, were generously applied earlier in this century.

For example, in 1915, extension personnel were quoted by the *Brooklyn Daily Eagle* as saying "that farmers in almost every section of the Island have been driven to the excessive use of commercial fertilizer as a substitute for the barnyard variety, but it is a poor substitute, as it lacks the water-holding properties of the natural fertilizer, and it does not keep the ground loosened up for the inhalation of air." The "barnyard variety" referred to was dairy manure, which was in increasingly short supply on the Island. This was due to the imposition of strict health regulations governing the handling of milk, and dairy farmers, rather than accept the regulations, discontinued production.

In 1929, a survey of Long Island potato farms was conducted by the Department of Agricultural Economics, Cornell University. The annual average rate of commercial fertilizer application applied by the growers to their potato crops was found to be 100 pounds of nitrogen per acre. In addition, 61 farmers out of the 112 included in the study applied an average 7.7 tons of manure per acre as an additional source of nitrogen (Underwood, 1933). Underwood also reported that the costs of applying fertilizers in 1912, and 1929, were 33 and 23 percent, respectively, of the total cost of production. This compares to an estimated sixteen percent in 1976 (Snyder, 1977). Farming methods have greatly changed over the past seventy years, so the above cost figures must be viewed with caution. For example, pesticides now constitute a major cost, which was not the case early in this century. This notwithstanding, the data indicate that fertilizers have been a major factor in farming production for a considerable period. It may therefore be concluded, as suggested by Kreitler *et al.* (1978), that previously farmed lands were a possible major source of nitrogen to groundwater.

The potential significance of previous land use was probably obscured as Nassau County developed in the 1930's and 1940's, and as malfunctioning cesspools and septic tanks subsequently became a conspicuous cause of groundwater contamination. In 1949, for example, detection of nitrate contamination in shallow public supply wells in the Levittown area produced an awareness that led eventually to abandonment of the Upper Glacial aquifer in the County as a source of water supply (Nassau Department of Health, 1971). Since that time, many reports have indicated the potential hazards of domestic disposal systems in heavily populated areas of Long Island (Smith and Baier, 1969; Cohen *et al.*, 1968; SCDEC, 1972; Perlmutter and Koch, 1972).

Apart from domestic wastewater, another potential source associated with urbanization that was identified by several reports is nitrogenous fertilizers applied to lawns (Holzmacher *et al.*, 1970; Miller *et al.*, 1974). It is now fully recognized that the cumulative effects of the many sources of nitrogen created by man must now be identified and controlled if the region's valuable water resources are to be preserved.

5.3 HUMAN WASTEWATER ON LONG ISLAND

5.3.1 Introduction

It is estimated that approximately 46 billion gallons of wastewater are produced annually in Nassau and Suffolk Counties. Of this flow, nearly 60 percent is treated by some type of on-site disposal system, such as septic tank systems. This percentage is comparatively high. In the entire United States, 29 percent of the population disposes of its waste through on-site disposal units. Nassau and Suffolk constitute two out of only four counties in the whole Nation with more than 100,000 domestic waste disposal systems (USEPA, 1977b). It follows that nitrogen from individual domestic disposal units is a main component in the region's nitrogen budget.

Table 5–1

AGRICULTURAL DATA FOR NASSAU AND SUFFOLK COUNTIES, 1900–1974

County	Total Acreage	Acreage in Farmland	Cropland Harvested (Acres)	Value of Land & Bldgs. Per Acre	Number of Livestock: Total Cattle	Horses	Poultry	Ducks (Other Poultry)	Hogs	Beef	Sheep	Goats
Nassau												
Year												
1900	–	88,452	–	–	–	–	–	–	–	–	–	–
1910	–	55,770	–	–	–	–	–	–	–	–	–	–
1920	175,360	59,353	–	765.79	2,442	3,065	76,815	5,836	2,340	240	387	22
1925	"	42,991	27,316	1,036.80	1,601	1,780	69,903	–	219	–	90	20
1930	"	23,477	19,066	1,522.22	1,119	648	76,402	1,703	215	191	97	2
1935	"	27,895	19,302	1,251.49	1,626	1,044	44,960	–	2,248	–	83	22
1940	192,000	26,543	15,988	1,390.93	1,277	671	31,414	288	145	–	246	115
1945	"	32,122	24,744	970.15	2,209	330	69,199	–	1,125	–	266	93
1950	"	27,000	14,580	–	1,400	400	36,400	–	200	–	400	–
1954	"	12,964	6,848	3,163.51	1,412	196	16,532	256	158	–	347	–
1959	"	7,406	4,268	8,570.13	343	122	6,814	–	29	–	129	–
1964	"	5,565	3,512	6,850.11	193	–	4,000	–	33	–	101	–
1969	"	2,437	–	7,262.00	–	–	–	–	–	–	–	–
1974	"	1,112	695	16,902.00	76	126	519	–	–	–	–	–
Suffolk												
Year												
1900	–	276,860	–	–	–	–	–	–	–	–	–	–
1910	–	178,063	–	–	–	–	–	–	–	–	–	–
1920	588,800	159,249	–	189.65	7,605	5,870	247,526	70,646	11,637	418	1,374	67
1925	"	111,762	67,446	351.98	5,732	4,609	322,945	–	3,305	–	435	26
1930	"	99,671	63,063	607.67	3,614	2,521	1,338,124	119,005	2,548	–	487	62
1935	"	123,251	64,556	410.28	5,335	3,178	297,159	–	3,405	48	491	35
1940	590,080	119,061	66,526	409.79	5,206	1,517	348,949	712,853	2,807	–	469	410
1945	"	120,837	74,893	450.44	4,808	618	361,786	–	4,234	–	484	570
1950	"	123,000	68,880	–	4,200	500	398,300	–	3,000	–	700	–
1954	"	99,752	64,967	837.37	4,218	194	286,757	4,800,822	1,661	–	428	–
1959	"	89,776	61,621	1,444.36	3,197	252	238,342	8,000,000	1,956	–	192	–
1964	"	74,308	53,215	1,867.00	2,443	–	165,000	–	2,895	–	154	–
1969	"	61,520	–	3,513.00	–	–	–	–	–	–	–	–
1974	"	55,397	41,007	4,840.00	959	321	56,774	4,200,000*	647	–	114	–

**CES estimate.*
Source: U.S. Bureau of the Census.

5.3.2 Domestic or On-Site Disposal Systems

On-lot systems conventionally rely on two phases of treatment. In the primary phase, sedimentation occurs with some digestion and liquefaction of solid materials. On Long Island, septic tanks or cesspools are generally used to provide this treatment. In the secondary phase, treatment is provided by the soil in the so-called absorption field to which the cesspools, or tile drains, discharge. Purification occurs through the agency of the soil and soil organisms, which filter, break down and absorb most of the pollutants contained in the sewage. These processes, however, do not function effectively if the disposal system is overloaded. The U.S. Environmental Protection Agency, in its recent comprehensive review (1977a), noted that numerous studies have shown soil to be an extremely efficient purifying medium under properly managed conditions. Removal rates of potential disease organisms and viruses may be very high as described by Vaughn and Landry (1977). Heavy metals and complex organic substances are also effectively removed from percolating wastewater by the soil (USEPA, 1977a). A critical exception is the highly soluble inorganic compound: nitrate.

In assessing the potential role of on-site disposal systems, this study sought answers to specific questions:

1. What is the average daily flow of wastewater generated per person?
2. What is an average concentration of organic and inorganic nitrogen in
   a. the influent to the disposal system?
   b. the effluent from the disposal system?
   c. the percolate in the leaching area, *i.e.*, what is the rate of attenuation in the concentration of nitrogen as it moves downward through the soil?
3. What are typical concentrations of nitrogen in groundwater immediately underlying the disposal systems?

A very large number of studies have considered wastewater flows and nitrogen loads to and from disposal systems, both on Long Island and elsewhere. There is substantial agreement between reported per capita flows, as can be seen from Table 5–2. The overall average is 44 gallons per person per day; the lowest value was reported in the *Long Island Groundwater Pollution Study* (NYSDH, 1969).

There is considerably more variability in reported nitrogen loadings. In addition, the strength of raw sewage is often not analyzed, or only inorganic nitrogen is measured. Such omissions render it almost impossible to assess the systems studied in terms of their effectiveness in treating nitrogen.

5.3.3 Holding Tanks

Concentrations of organic and inorganic nitrogen found in raw sewage prior to entry into disposal systems, and the corresponding strength of effluents, are shown in Tables 5–3 and 5–4, respectively. Although only three of the studies, (Hickey and Duncan, 1966; USEPA, 1977a; Andreoli, 1978) reported both influent and effluent concentrations, it appears that significant reductions in concentrations of nitrogen may occur in the septic tank or cesspool. The overall mean reduction for the three studies was sixteen percent (see Table 5–5). This reduction may be due in part to storage in the tank or gaseous losses. Early studies of the composition of gases produced by septic tanks indicated significant percentages of nitrogen (Fuller, 1912; Metcalf and Eddy, 1916). More recently, Hickey and Duncan (1966) obtained the results shown in Table 5–6.

Table 5–2

AVERAGE PER CAPITA FLOWS INTO DOMESTIC DISPOSAL SYSTEMS

Study cited		Average daily per capita flow (g/c/d)
Weibel *et al.*	(1949)	44
Watson *et al.*	(1967)	56
NYSDH	(1969)	40
Bouma	(1975)	42
Laak	(1972)	41
Bennett and Linstedt	(1975)	45
USEPA	(1977a)	43
Overall average		**44**

Table 5–3

LEVELS OF VARIOUS FORMS OF NITROGEN MEASURED IN RAW DOMESTIC SEWAGE (mg/l)

Form of Nitrogen	Source of data: Weibel et al. (1949)	Hickey & Duncan (1966)	Watson et al. (1967)	USEPA (1977a)	Andreoli (1978)
Organic	58	23	17	–	25
Ammonia	15	24	57	–	50
Total	**73**	**47**	**73**	**62**	**75**

5.3.4 Absorption Fields

Complex processes govern the movement of nitrogen in absorption fields. Organic nitrogen and ammonia are readily retained by the soil (Walker *et al.*, 1973; Andreoli *et al.*, 1977). However, organic nitrogen is subject to mineralization, and the ammonia consequently produced, along with that already present, can be oxidized to nitrite and nitrate. Thus, in the long run, all the nitrogen, regardless of its initial form, may be subject to leaching as nitrate.

Table 5–4

LEVELS OF VARIOUS FORMS OF NITROGEN IN EFFLUENT FROM SEPTIC TANKS
(mg/l)

Form of Nitrogen	Source of data: Salvato (1955)	Preul (1964)	Hickey & Duncan (1966)	Corey et al. (1967)	Popkin & Bendixen (1968)	Polta (1969)	Boyle & Polkowski (1970)	Walker et al. (1973)	Otis & Boyle (1976)	USEPA (1977a)	Andreoli (1978)
Organic	12	10	5	10	6	10	16	14	16	16	20
Ammonia	24	25	34	34	25	25	14	66	35	39	41
Total	**36**	**35**	**39**	**44**	**31**	**35**	**30**	**80**	**51**	**55**	**61**

Table 5–5

AVERAGE LEVELS OF NITROGEN AND PERCENT REMOVED BY SEPTIC TANKS
(mg/l)

Total Nitrogen	Source of data: Hickey & Duncan (1966)	USEPA (1977a)	Andreoli et al. (1977)	Average of the three	Overall average Tables 5–3 & 5–4
Influent	47	62	75	61	65
Effluent	39	55	61	52	45
% removed	17	11	19	15.7	31

Table 5–6

COMPOSITION OF GASES PRODUCED BY SEPTIC TANKS AT VARIOUS TEMPERATURES
(percentages)

Gas	Septic Tank Temperature: 59 °F	40 °F	33 °F
CO_2	2.2 ± 0.3	0.3 ± 0.01	0.27 ± 0.05
O_2	4.0 ± 1.1	8.9 ± 2.8	5.2 ± 2.2
N_2	90.7 ± 1.3	90.6 ± 2.9	95.1 ± 1.8
CH_4	2.1 ± 0.7	–	–

Walker *et al.* (1973) found that both organic and ammoniacal nitrogen were retained within centimeters of the crust formed in seepage beds, and that the levels of nitrate-nitrogen in the leachate were significantly less than the level of the total nitrogen originally entering the absorption field. Salvato (1955) found that the level of total nitrogen in a subsurface sand filter was 42 percent lower than that in the effluent from a septic tank. Finally, results from an experimental system reported by Andreoli *et al.* (1977) indicate that similar reductions of total nitrogen occurred in a field-scale experimental system on Long Island.

It should be noted that these results are not consistent with those obtained by the *Long Island Groundwater Pollution Study* (NYSDH, 1969), which investigated individual home installations. Great variability was observed, and in some cases very little reduction in nitrogen was found to occur.

Without detailed measurements, it is very difficult to interpret levels of nitrogen measured in groundwater underlying absorption fields. The dilution afforded by groundwater may produce an apparent attenuation in concentrations of nitrate-nitrogen that is misleading. For example, work reported by Viraraghawan and Warnock (1976) showed that levels of nitrate fell to background levels within 50 feet of the end of a tile field. This result is in contrast to those obtained by Walker *et al.* (1973), who demonstrated that concentrations of nitrate-nitrogen could exceed 10 mg/l at more than twice that distance.

In a study of eleven septic tank systems on sandy soils (Dudley and Stephenson, 1973), the average nitrate concentration in groundwater was about 15 mg/l. At none of the eleven sites were concentrations found to be greater than 10 mg/l at distances more than 50 feet downgradient from the absorption fields. These results are in agreement with those obtained by Preul (1966).

Such results indicate the difficulty of establishing the maximum number of disposal units that would not produce nitrate levels in excess of 10 mg/l over a broad area.

5.3.5 Discussion

For the purposes of this study, it was assumed that the daily average domestic wastewater flow was 40 gallons per person (Weston, 1976). As can be seen from Table 5–2, this flow rate is in close agreement with other studies.

Estimates of average levels of nitrogen in the influent to, and effluent from, on-site disposal systems are more difficult to achieve. Loadings of nitrogen per person are therefore not easily determined. Even greater uncertainties arise in assessing the fate of the nitrogen in the primary and secondary phases of on-site systems.

A summary of the levels of nitrogen and the percent removed by the primary treatment phase of the on-site systems is shown in Table 5–5. If the assumed average influent concentration is 61 mg/l of total nitrogen (based on the average of values from Hickey and Duncan, USEPA, and Andreoli, see Table 5–3), and the per capita flow is 40 gallons per day, then the corresponding annual load of nitrogen would be just over seven pounds. If Andreoli's estimate of 75 mg/l total nitrogen for influents is used, then the annual per capita load is equal to just over nine pounds.

Andreoli also took detailed measurements of the leachate in the absorption field. Over a twelve month period, the average concentration of total nitrogen at a four foot depth in the leaching field was 38.2 mg/l. This compared with the average influent concentration of 75 mg/l. Thus, an overall reduction of about 50 percent was observed. Although the data were less complete, measurements at a greater depth indicated that the levels of nitrogen continued to decrease and approached an overall reduction of 60 percent relative to the original strength of the sewage. This result is consistent with other studies, which have shown that average levels of nitrogen directly underlying on-site disposal systems that are functioning properly are rarely above 30 mg/l (Dudley and Stephenson, 1973).

Concentrations above 30 mg/l would appear to be atypical on Long Island even in high density residential areas that are unsewered (Perlmutter and Koch, 1972; Katz, 1978; USGS, 1976). Exceptions to this generalization might be expected where the disposal systems malfunction and the soil is heavily overloaded.

Exceptionally high concentrations of total nitrogen were observed during the *Long Island Groundwater Pollution Study* (NYSDH, 1969). At one of six sites studied, average concentrations of ammonia in the groundwater were as high as 75 mg/l. The disposal system on the site consisted of a septic tank and tile drains. Despite the 25 feet depth to groundwater, and the sand and gravel content of the soil, there was little nitrification or adsorption of ammonia.

The *Long Island Groundwater Pollution Study* did not include measurements of organic nitrogen, so it is not possible to determine what the total nitrogen loadings to the systems were. Also, measurements were taken of the septage in the tanks themselves, rather than of the influent or effluent, so the construction of a nitrogen balance from the data is impossible.

Despite the uncertainties regarding the data obtained from the *Long Island Groundwater Pollution Study,* it appears prudent to recognize that the levels of nitrogen measured were substantially higher than generally reported elsewhere. Therefore, for the purposes of this study, it was conservatively assumed that the average annual per capita nitrogen load in wastewater is ten pounds, which corresponds to an average nitrogen concentration of 82 mg/l in 40 gallons per day of raw sewage. It was further assumed, for initial calculations, that 50 percent of the nitrogen in the raw sewage will reach the groundwater.

Wastewater flows are also generated by institutional, commercial and industrial sources. The nitrogen in wastewater from these land uses can be estimated by using a standard sewage BOD to nitrogen ratio, and the sewage BOD loadings for various land use categories previously estimated by the NSRPB (1975).

In areas that are totally sewered, wastewater flows can be assumed to equal the sum of all the flows from all land uses. Where there is only partial sewering, sewage flow figures can be divided between sewers and septic tanks according to the fraction of sewered land.

Studies by the U. S. Geological Survey (Franke and McClymonds, 1972) have indicated that about ten percent of the wastewater (and, therefore, ten percent of the nitrogen) transported in sewers leaks out to groundwater. Of the remaining 90 percent of the nitrogen load conveyed by sewers, some is discharged to groundwater after treatment; the remainder is discharged in the ocean after treatment, and the nitrogen it contains is lost.

5.4 NITROGEN FROM FERTILIZERS

5.4.1 Introduction

In assessing the potential impact of nitrogenous fertilizers on ground or surface waters, it is necessary to have reliable estimates of the quantities of fertilizers used and the fate of the nitrogen following application.

Rykbost (1973) undertook a survey of thirty-five Long Island sites in order to assess the effects of various fertilizer rates on turf. In their report of 1970, Holzmacher *et al.,* estimated that householders applied an average of 3 lbs. N/1000 sq. ft./year to their lawns.

The Suffolk County Department of Environmental Control also undertook a study of the Twelve Pines area, Medford, in 1974 (SCDEC, 1974). A total of 161 householders were interviewed during the summer of 1974. As a result, the Department estimated that 9,600 pounds were applied to 21 acres of turf, corresponding to an annual application rate of 2.2 pounds of nitrogen per 1000 square feet.

5.4.2 208 Household Fertilizer Use Survey Methodology

During this study, extensive field surveys were carried out to quantify the use of fertilizers by major types of users: home owners, farmers, and insti-

tutions. Field work was also undertaken at representative sites throughout the Bi-county Region to monitor the movement and fate of nitrogen in the soil throughout the growing season.

A household survey was conducted using a questionnaire designed to elicit information regarding the quantity of nitrogenous fertilizers used, the extent of watering, the variety and quality of turf, and the method of disposing of grass clippings. A preliminary survey was made in Riverhead to test the questionnaire. Seven additional sites in Nassau and Suffolk were selected for the survey. In selecting the sites, particular attention was given to population density and to average household income.

The density of housing can affect the amount of fertilizer used, since density and the extent of impervious areas are directly related, and are inversely related to the area available for vegetation. Household income was considered because it was surmised that the degree of lawn care would be related to the level of income. Although there is doubtless some relation between income level and housing density, both should be considered, since some high density areas are occupied by high income households (*e.g.*, central western Nassau).

Some consideration was also given to the topography and the age of existing development at potential survey sites, since these factors may also affect the care given to lawns and gardens. The age of a development may also affect the number of trees and size of those trees, which in turn affects the size of the lawn and variety of grass it contains. The maturity of the lawn is also important since well established lawns could behave differently in relation to fertilizer uptake than recently seeded lawns.

Seven areas were selected on the basis of the above considerations. The locations of the areas are shown in Figure 5–1. Within each area, the individual households to be surveyed were randomly selected. A sample size of sixty households was chosen based on information obtained during a SCDEC survey in the Twelve Pines area of Medford. From the Medford study results, the mean fertilizer use and standard deviation were estimated:

Mean = 1.52 lbs N/1000 sq. feet; Standard deviation = 1.4

A desirable sample size was then calculated using the argument of Snedecor and Cochran (1956). Using a permitted error of up to 25 percent of the mean, at the 95 percent level of confidence, the sample size required was as follows:

$$n = 4 \frac{(\text{standard deviation})^2}{(0.25\ (\text{mean})^2)} = 54$$

Hence it was decided to administer 50 or more surveys per area. Two persons conducted the entire survey, and an effort was made to sustain uniformity in the way the questionnaires were administered. The Riverhead trial survey indicated that households at which responses could not be obtained on the initial visit should be replaced with alternate households. To avoid introducing a possible bias by making surveys only during working hours, the surveys were made from approximately 2:00 to 8:00 p.m.

In those cases where households used contract service for lawn and garden maintenance, the firm providing the service was questioned. Since the surveys were made during the summer, the results obtained had to be adjusted to provide estimates for the whole year. It is common practice to make

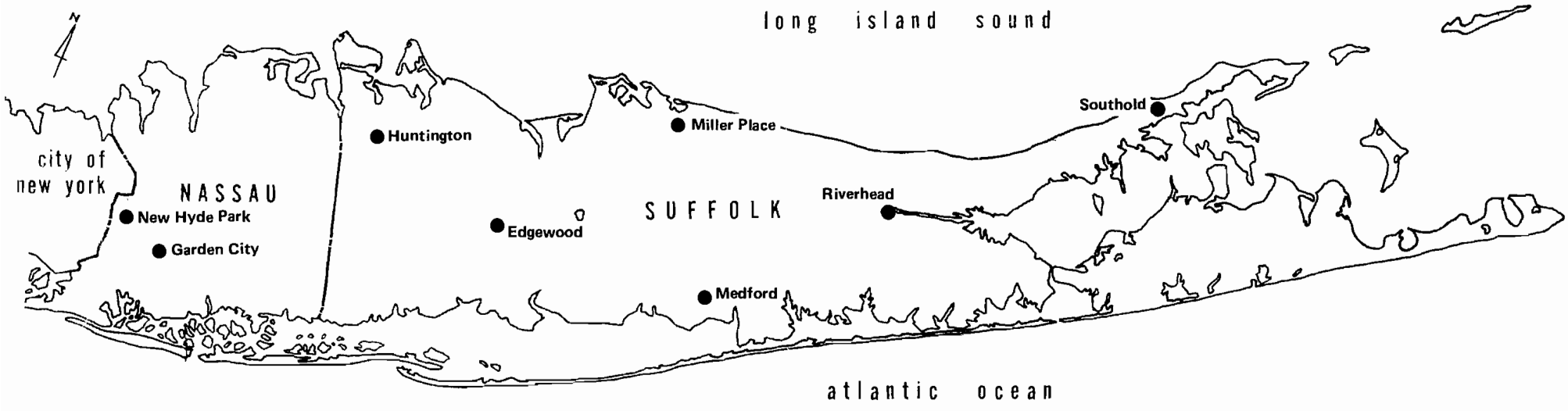


FIGURE 5–1 *208 Field Survey Areas: Household Fertilizer Use.*

one or more fertilizer applications to turf in the fall, and indeed such applications are recommended. (See the publication: *Cornell Recommendations for Turf.)* A further questionnaire was mailed to all the houses visited in order to obtain additional information with which to adjust the estimates. As happens with many surveys conducted by mail, the response was poor. However, it was possible to estimate that about 50 percent more fertilizer was applied in the fall by the householders who used fertilizers. This conclusion is consistent with recommendations for fertilizer use on turf.

5.4.3 208 Household Fertilizer Use Survey Results

Use of fertilizer was characterized by extremes, *i.e.,* was either nonexistent or exceeded recommended rates. There are a variety of reasons why homeowners do not fertilize at all, among them being lack of income; the presence of a large number of trees on the property, and therefore little grass to fertilize or a deeply shaded lawn; or the fact that the residence is temporary housing, either a rental or summer occupancy. The behavior of a majority of homeowners represented one of these two extremes; only a minority followed the application instructions on the package. For this reason, care should be exercised in interpreting nitrogen application rates for an area. If 4 lbs N/1,000 ft.^{2} is applied to one lot and none to another, the average input will be 2 lbs/1,000 ft.^{2}, which does not appear to be excessive. However, a large fraction of the fertilizer may leach through the soil on the first plot, while a much smaller amount would leach were two pounds applied to the entire area.

Some householders fertilize various parts of the yard differently. Sometimes the front lawn is fertilized and the back lawn is not. This gives validity to the idea that appearance and social value are important factors in maintaining a high quality lawn. Householders who kept their clippings often used them as a garden mulch or attempted to compost them along with other materials.

During the survey, an attempt was made to quantify the use of water for irrigating the lawns. Irrigation may induce higher rates of leaching of nitrogen than would otherwise occur. Initially, householders were requested to place a can on their lawns to catch the water, in an attempt to make crude estimates of the amount of water used. The results were erratic. Householders were then asked how frequently they watered. Although the information obtained does not permit good estimates to be made of the volumes of water applied, it does appear that some individuals apply water excessively.

The veracity of the responses to the questionnaire must also be considered. It was perceived that there was some unwillingness to respond to questions frankly, especially in the higher income areas of Nassau. Efforts were made to assure the respondents that responses would be kept confidential. Frequent explanations were made of the study being conducted and when requested, informative booklets were provided. However, quite a few homeowners appeared wary of the survey and some were very uncooperative. Where there was reserve in replying to questions, it appeared that respondents were inclined to give underestimates of their use of fertilizers. (A similar observation applies to pesticide use.)

Finally, time was the most limiting factor in this study. Although a large number of surveys were completed, the degree of confidence in extrapolating the results would have increased had more areas been surveyed. The Nassau-Suffolk Region is large and extremely diverse. Hence, the results of the survey must be accepted with caution. A summary of the results is given in Table 5–7.

Table 5–7

SUMMARY OF RESULTS FROM THE 208 HOUSEHOLD FERTILIZER USE SURVEY

Survey Area	Number of Questionnaires Completed	1969 Average Family Income[1] (Dollars)	Average Lot Size (square feet)	Fertilizer N Application lbs/1000 sq. ft. turf/year[2]	Fertilizer N Application Tons/acre turf/year
Edgewood	60	8,662	5,000	1.74	0.0379
Southold	63	10,376	27,000	1.73	0.0377
Miller Place	50	10,673	29,000	1.70	0.0370
Medford	109	13,000[3]	13,000	2.19	0.0477
Huntington	52	14,713	15,000	3.32	0.0723
New Hyde Park	65	15,008	5,000	3.00	0.0653
Garden City	61	21,805	7,000	3.75	0.0817

[1] *Calculated from 1969 income data as reported in the 1970 Census of Population.*

[2] *Based on CES Survey responses, multiplied by 1.5 to account fertilizer applied after survey was taken.*

[3] *CES estimate for area surveyed.*

As can be seen from Table 5–7, rates of fertilizer application by householders appear to be closely related to the level of household income. A graph showing the data and a line "fitted" to them by linear regression is depicted in Figure 5–2. The equation of the line accounts for about 85 percent of the variance.

FIGURE 5–2 *Relationship Between 1969 Family Income and 1976 Turf Fertilizer Use.*

The equation was used to estimate the total quantities of nitrogen applied in Nassau and Suffolk. The grid cells defined by the NSRPB were the units of computation used for the calculation. (See Section 5.6.2, Figure 5–12.) Unfortunately, income levels were not available for each cell. To make the estimation, grid cells were individually tabulated by listing the numbers of the 1970 census lying within their boundaries. The median family income for each tract for 1969 was obtained from the 1970 U.S. Census. An estimated average income level, for the households within each grid cell, was then estimated by computing the arithmetic mean of the median income levels of the tracts lying within the cell. (See Table 5–7.)

To complete the estimation for the entire region, it was necessary to calculate the total area of household lawns within each grid cell. During the survey, it was found to be impractical to use direct measurement in all areas in order to estimate the portion of the lots that were turfed. Direct measurements were made in a medium-density residential area. The average turfed area was found to comprise at least 40 percent of the entire lot. Table 5–8 presents estimates of turfed area based upon observations made during the survey, and the assumption that a specified fraction of the previous area of each lot is turfed.

Using the derived percentages of turfed areas, it is possible to calculate the total number of acres devoted to turf in each cell by multiplying the fractions corresponding to each category of residential area with the net acreage used for that category. Finally, by combining this result with an estimated rate of application related to income level, the total amount of nitrogenous fertilizer applied to residential lawns can be estimated. (See Section 5.7.1.)

Table 5–8

ESTIMATED IMPERVIOUS AND TURFED AREAS OF LOTS, BY RESIDENTIAL CATEGORY

NSRPB Residential Categories	% Impervious Area*	% of Area Turfed and Fertilized*
Low density	25	30
0–1 Dwelling units/acre	35	39
2–4 Dwelling units/acre	45	40
5–10 Dwelling units/acre	55	36
High density	65	28

**Percentage of gross acre.*

5.4.4 Use of Fertilizers on Turf Other Than Household Lawns

CES investigated the use of nitrogen on recreational and ornamental turf, such as golf courses, highways, playing fields and parks. A summary of the average annual rates of application is shown in Table 5–9.

Throughout 1976, extensive and intensive monitoring of nitrogen applied to turf was carried out. (See Figure 5–3 for monitoring locations.) A total of fourteen areas were sampled for soil nitrogen and soil water levels every two to three weeks. Samples were taken at several depths to determine profiles of nitrogen and water within and below the root zone. It was assumed that the greater part of the inorganic nitrogen detected below the root zone would eventually leach to groundwater. Some of the sites were subdivided and fertilized at different rates. Detailed measurements were made on a mature lawn at the Long Island Horticultural Research Station, where fertilizer and water were applied under controlled conditions. A listing of the basic data is available at the Suffolk County Cooperative Extension Service office in Riverhead.

Although sod farms were included in the survey, they more properly fall into the category of agricultural production, and were so regarded in this study. A key factor in normal turf culture is that it is not cropped in an agricultural sense. Although after cutting the grass the clippings may be re-

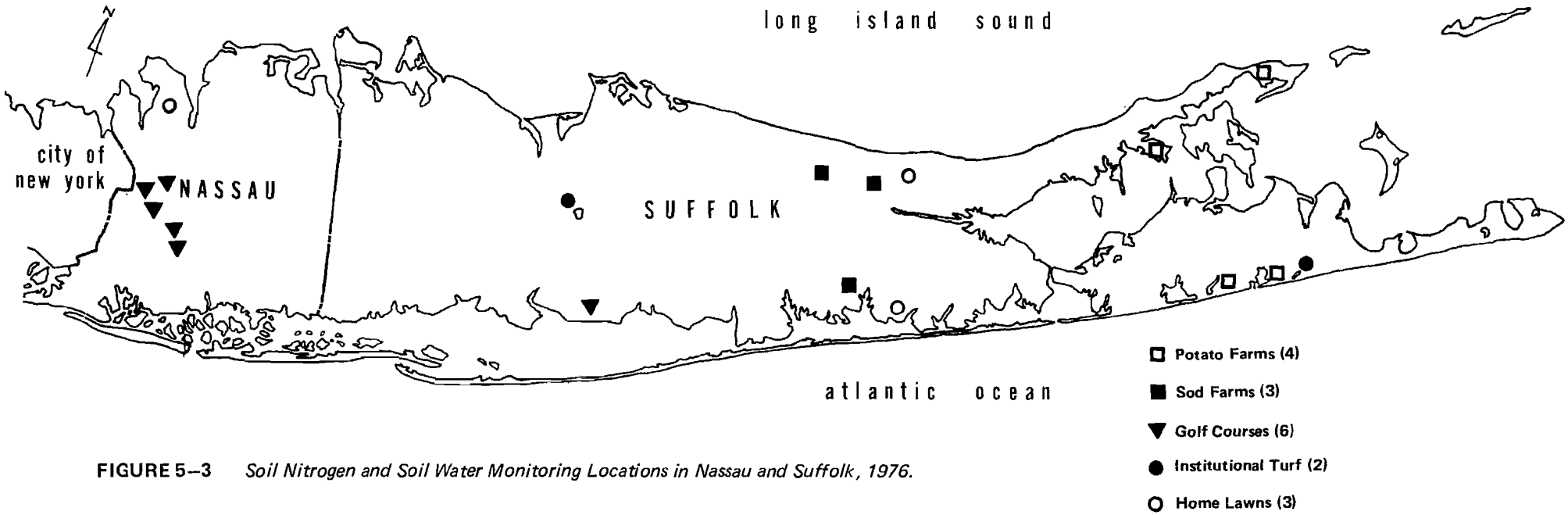


FIGURE 5–3 *Soil Nitrogen and Soil Water Monitoring Locations in Nassau and Suffolk, 1976.*

Table 5–9

ESTIMATED AVERAGE ANNUAL USE OF NITROGENOUS FERTILIZERS APPLIED TO RECREATIONAL AND ORNAMENTAL TURF

Use	Annual rate lbs N/1000 sq. ft.
Golf courses	
Greens	7
Tees	5
Fairways	3
Weighted average*	3.5
Playing fields	3
Parks**	2
Highways	0–1

**Weighted according to relative areas based on County of Nassau golf courses:*
Greens = 4.4%
Tees = 3.3%
Fairways = 92.3%

***As a rule only 10% of the turfed area in parks is fertilized.*

moved, the nitrogen is not deliberately removed entirely as is normally the case with an agricultural crop. This is a key factor in the nitrogen balance for turf. A simplified representation of the nitrogen balance for turf is shown in Figure 5–4. Evidence suggests that under mature grass, soil organic nitrogen is in equilibrium with the soil, *i.e.,* the curve representing organic nitrogen is asymptotic as shown in Figure 5–4. In this case, losses of nitrogen will approximately equal gains. Thus, on Long Island, if volatilization, denitrification and runoff are minimal, then virtually all the nitrogen in fertilizer supplied to mature grass will be leached. This may even be true if the grass is cropped and the clippings removed, because the clippings presumably remain in the area. There is, however, a possibility that there would be some volatilization of ammonia from the clippings, especially if they are composted, in which case the area may sustain an actual loss of nitrogen.

The interpretation of many field studies is not straightforward, as can be seen from Figure 5–4. If the grass were immature, and the soil initially poor in organic nitrogen, there could be a net accumulation for an indefinite period. In such a case, the quantity of organic nitrogen being mineralized (D) will be less than the inorganic nitrogen being utilized by plants (B) and hence losses of nitrogen (E) will be less than gains (A) in the short run.

An investigation was made to determine the levels of losses of nitrogen due to volatilization that may be expected in freshly cut clippings. Replicated samples of grass clippings were taken and treated four ways, as indicated in Table 5–10. The highest average loss, which was only 12.8 percent, occurred

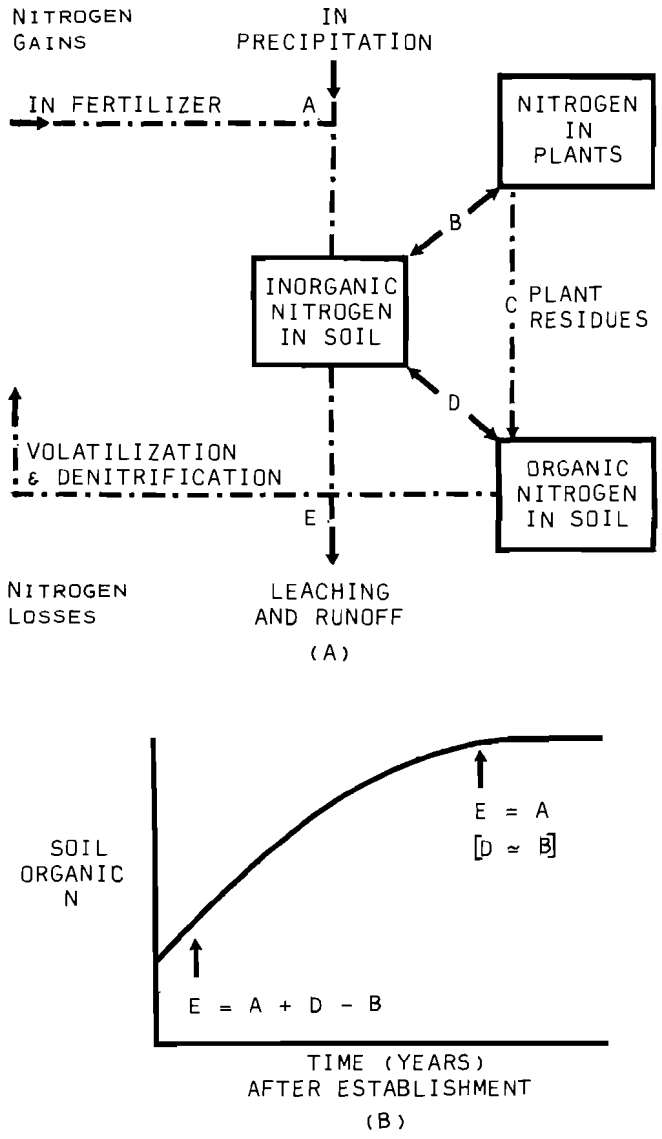


FIGURE 5–4 *Nitrogen Balance for Soil Under Turf.*

Table 5–10

LOSS OF NITROGEN FROM FRESHLY CUT GRASS CLIPPINGS

Treatment	% nitrogen in clippings after treatment	% reduction in nitrogen
Original clippings	4.68	–
Oven dried immediately	4.08	12.8
Air dried after three days	4.25	8.8

when freshly cut clippings were immediately dried in an oven. It does not, therefore, appear from these results that this gaseous loss of nitrogen from turf is likely to be significant.

As already indicated, the primary aim of the study was to measure the movement of inorganic nitrogen below the root zone. Such movement was found to occur on all plots, although to varying degrees. (See Figures 5–5 through 5–10.) As expected, the extent of downward movement of the nitrogen depended on soil conditions and the amount of nitrogen applied. The greatest losses occurred when nitrogen was applied immediately preceding irrigation or rainfall. For example, Figure 5–10 represents the measurements taken on mature turf at the Long Island Horticultural Research Station. The intent of the work was to determine the movement of nitrogen, after application, when the turf was irrigated following application.

The plots were ten feet by ten feet in area. Bulk densities, infiltration capacities, and field capacities were measured. In the first experiment, water was applied at the rate of one inch, twice a day for three days, following an application of 4 lbs. KNO_3 – N/1000 sq. ft. In the second experiment 2 lbs. of $NaNO_3$ –N/1000 sq. ft. was applied, and water was applied at the rate of one inch per day for seven days. As may be seen from the figure, the soil nitrogen profiles are very similar.

In addition to the intensive field experiments on turf already described, another experiment was conducted over a longer period of time. The intent of the experiment was to monitor the movement of inorganic nitrogen induced by rainfall and natural soil water percolation.

Eight plots, each measuring ten feet by ten feet, were marked out on good quality mature turf consisting of a mixture of bluegrass and fescue. Four treatments were applied to the plots: 0, 1, 2, and 3 lbs/1000 sq. ft. of ammonium nitrate-nitrogen. Two plots were utilized for each treatment.

Measurements for soil nitrogen were taken on October 4, 1976 at five equal depths, from zero to twenty inches. As can be seen from Figure 5–11, all the plots had similar initial background levels of inorganic nitrogen. Following the measurements, the fertilizer was applied. The data represent the averages of the results for each pair of replicates. A comparison of the

graphs clearly shows the direct relation between the amounts of nitrogen applied and the levels actually observed. Movement of inorganic nitrogen down through the soil may be seen from the graphs, especially in the cases of the treatments involving higher rates of application. Measurements were taken every few days up until mid-December; a further set of measurements was made in mid-March. By that time, virtually all signs of the added inorganic nitrogen had disappeared from the soil profile.

5.4.5 The Impact of Turf Fertilization

Traditionally, studies of turf fertilization have been directed towards achieving the highest quality of turf. Only recently has there been considerable interest in the possible environmental effects of turf fertilization (Ricke and Ellis, 1974). In the past five years, several studies have explicitly examined the movement of nitrogen in the soil. English *et al.* (1974) found that both ammonia and nitrate-nitrogen were leached from soil columns seeded with creeping bentgrass. Losses of nitrogen in the columns were found to occur in all treatments studied, although to varying degrees. This conclusion was supported by subsequent work of Waddington *et al.* (1976) in which it was found that all but one fertilizer application of turfgrass produced higher levels of nitrogen in the soil.

Ricke and Ellis (1974) studied several treatments of nitrogen applied to 'Merion' Kentucky bluegrass. The authors concluded that the leaching of nitrate-nitrogen is greatest when (a) high annual rates of nitrogen are applied, (b) infrequent and heavy applications of soluble inorganic nitrogen are made, (c) irrigation or rainfall is heavy and (d) the soil is light and sandy. As has been noted on Long Island, virtually no nitrate-nitrogen was left in the top twenty inches of soil after the winter months.

Finally, Brown *et al.* (1977) obtained results similar to those above, *i.e.*, losses of nitrogen and concentrations of nitrate in leachate were directly related to the amount of nitrogen and water applied. As in the case of the previous studies, the authors found that losses could be greatly reduced by irrigating at a rate commensurate with evapotranspiration, and by applying organic and slow release fertilizers. The authors concluded that, under careful management, losses of nitrogen from fertilized turf could be reduced to low levels.

There have also been several recent studies on Long Island. In 1973, Rykbost undertook a short term survey of thirty-five sites, including a variety of grass species, soil types and levels of fertilization. The sites included golf courses, institutions and household lawns in the Nassau-Suffolk Region. Each site was visited twice during the summer of 1973. Levels of inorganic nitrogen were determined from soil samples taken at three depths: 0–2, 2–9 and 9–16 inches. The results are summarized in Table 5–11. The table lists average levels of inorganic nitrogen measured in the top twenty inches of soil under turf at thirty-five sites. The turf at each site was fertilized at one of the four rates indicated in the table. Total nitrogen was not measured, so the

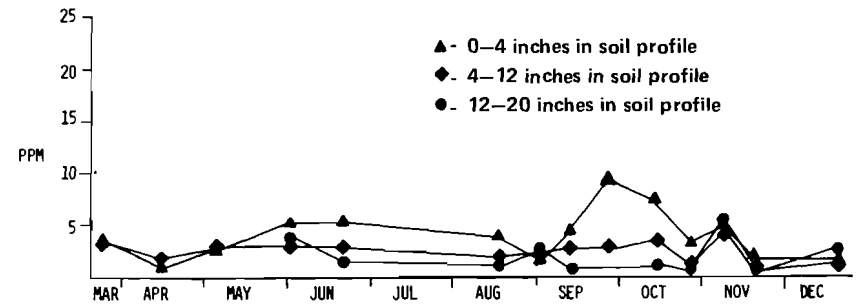


FIGURE 5–5 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under a Neglected Household Lawn, 1976.*

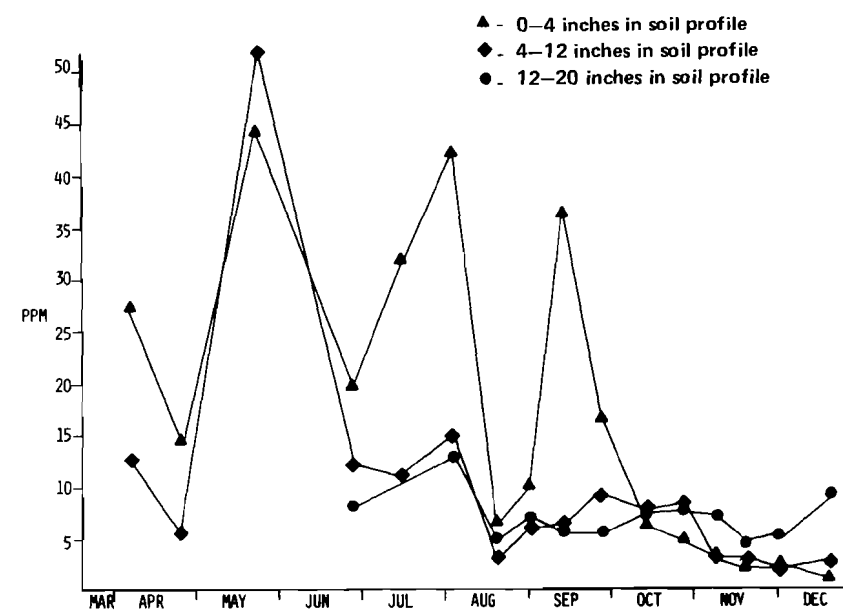


FIGURE 5–6 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under a Well-Kept Household Lawn, 1976.*

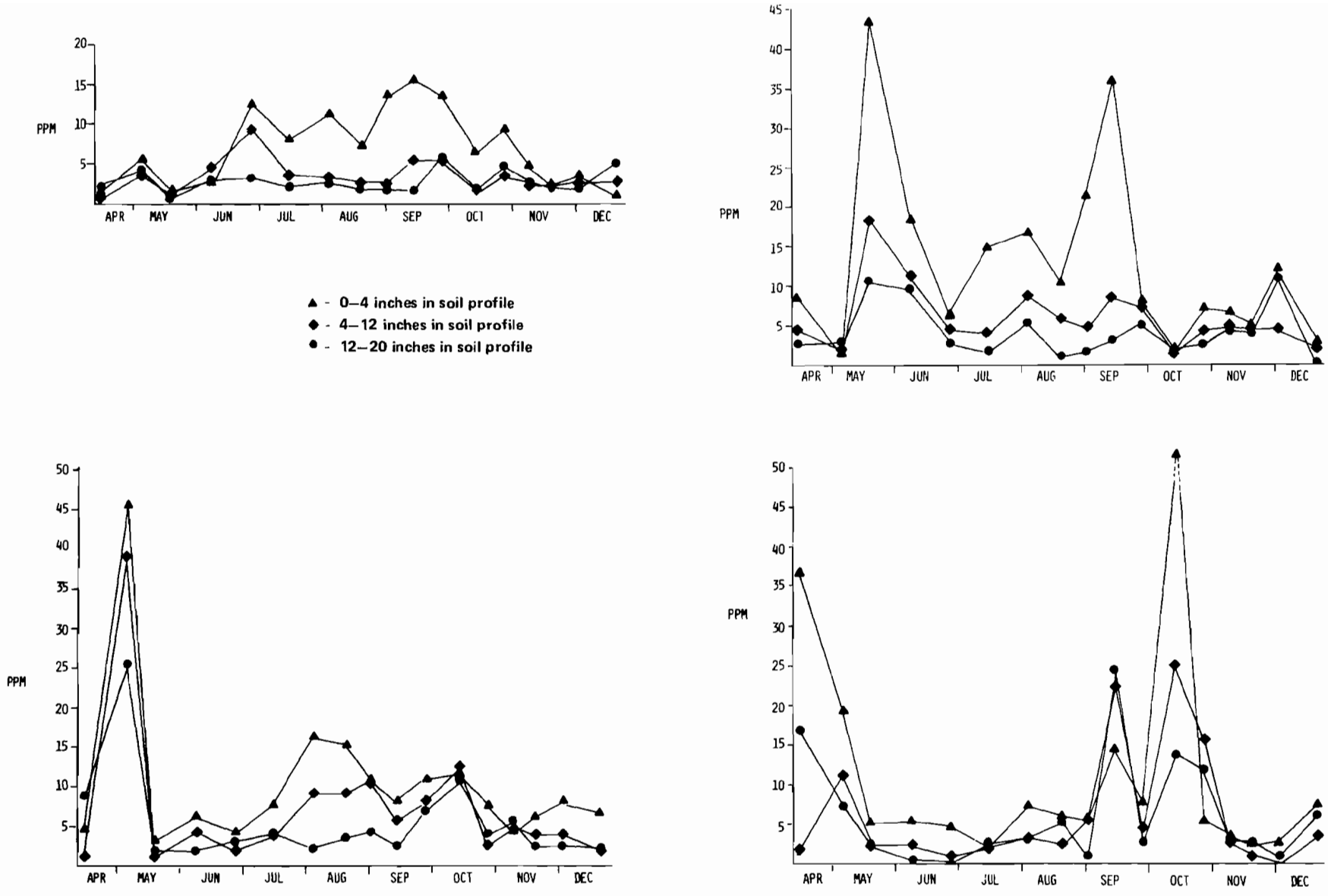


FIGURE 5–7 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under Golf Course Greens, 1976.*

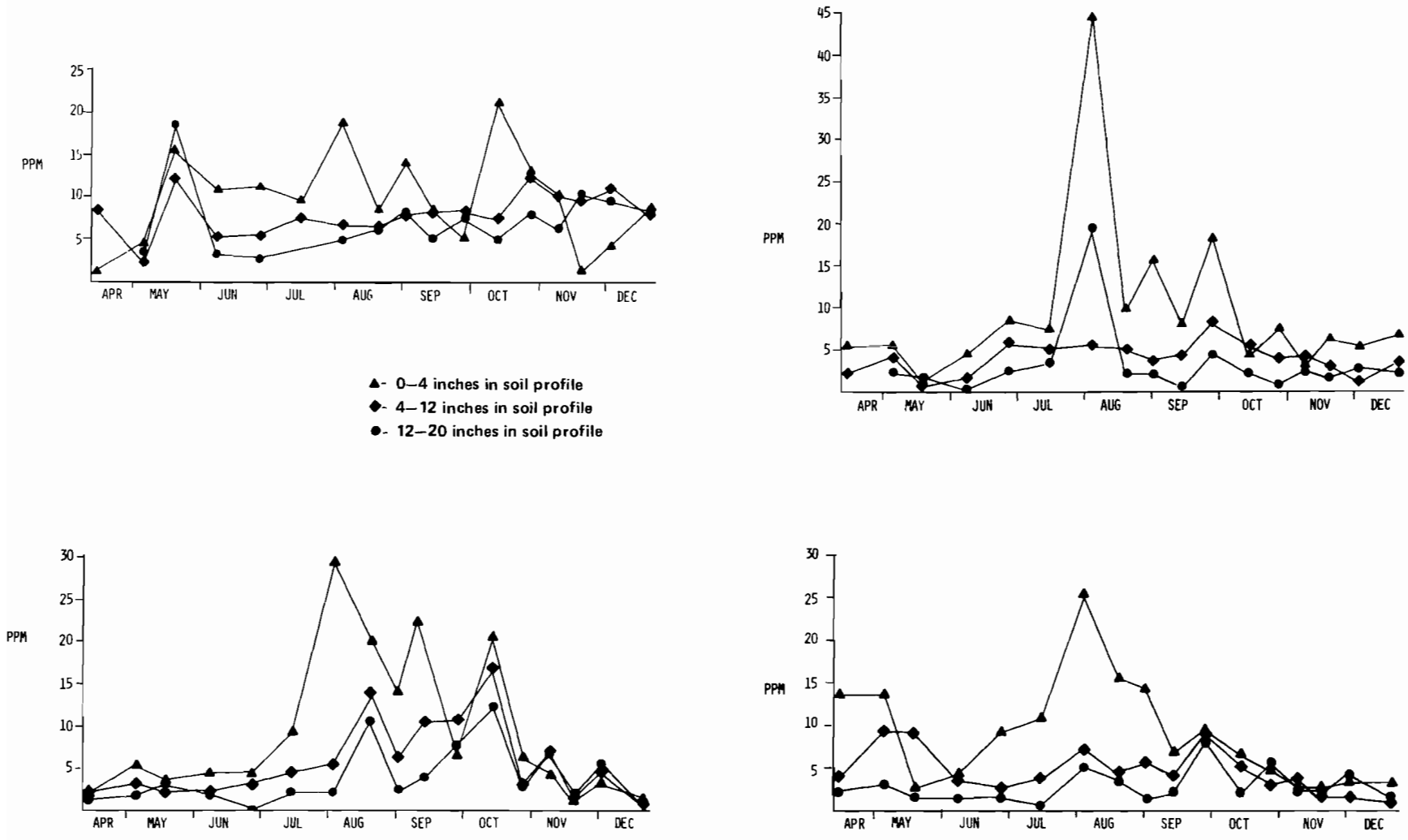


FIGURE 5–8 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under Golf Course Fairways, 1976.*

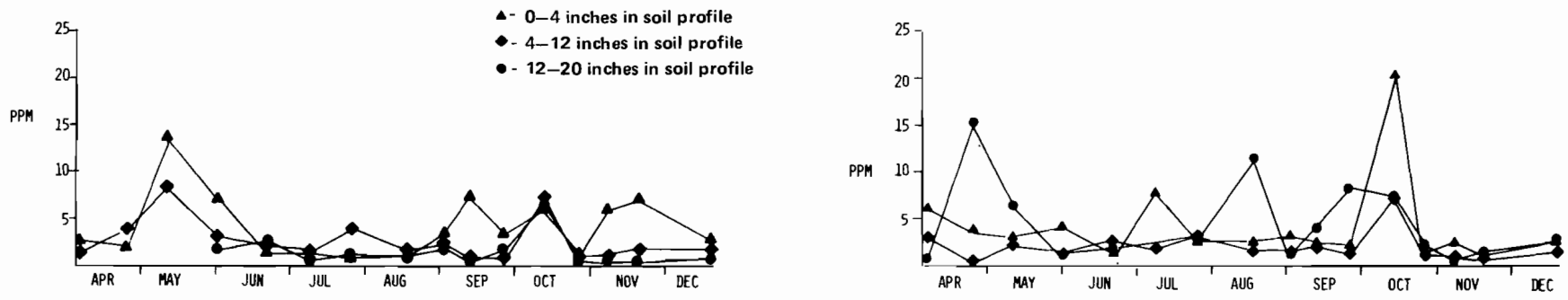


FIGURE 5–9 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under Sod Farms, 1976.*

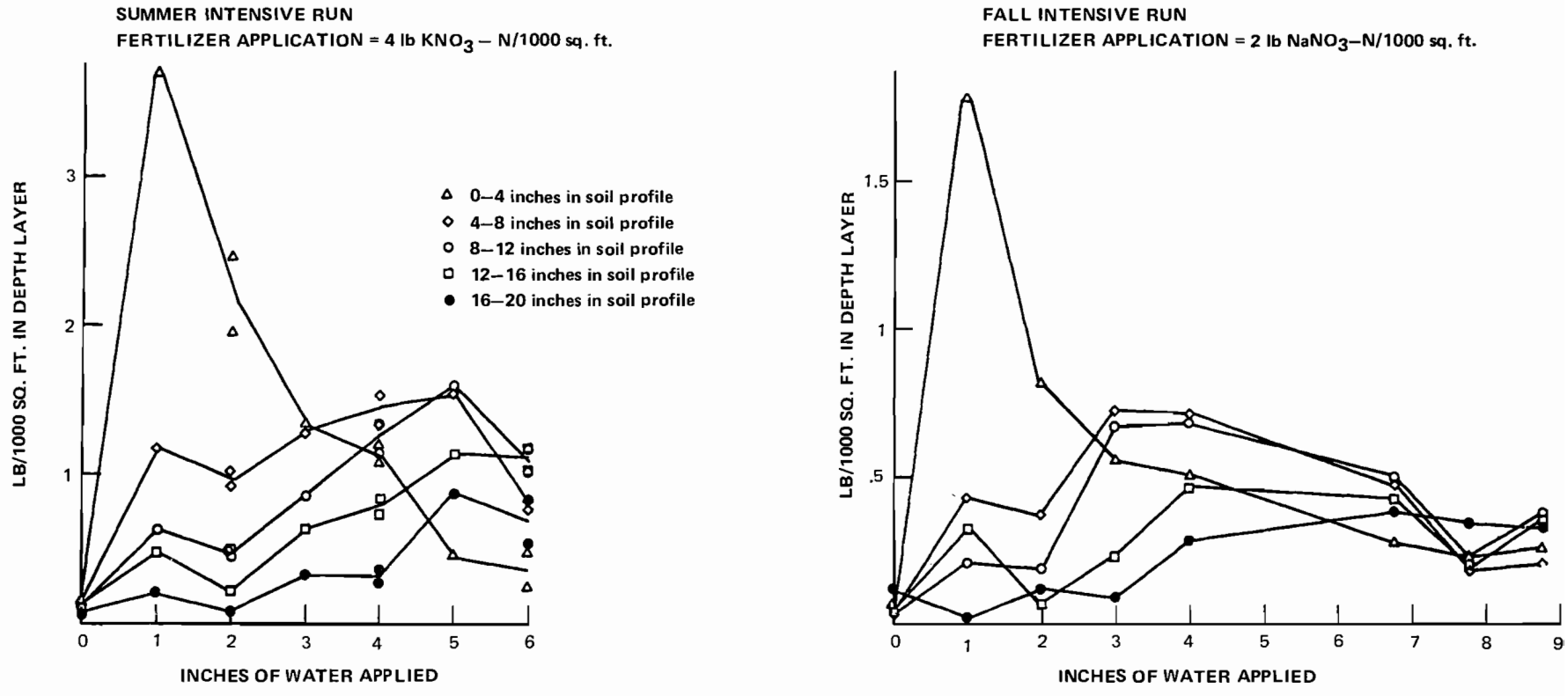


FIGURE 5–10 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under Mature Turf as a Function of the Amount of Water Applied.*

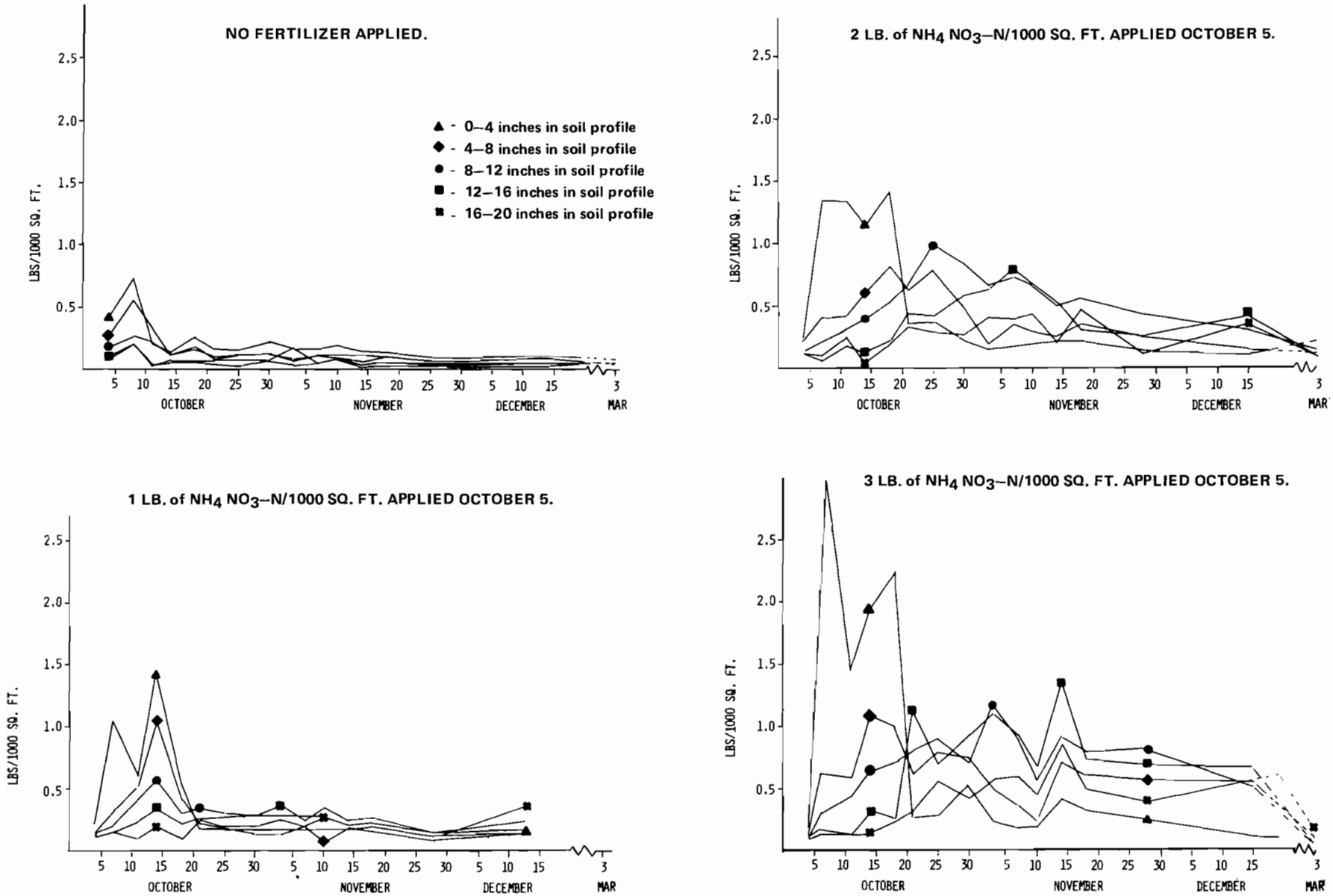


FIGURE 5–11 *Total Inorganic Nitrogen Measured in the Top 20 Inches of Soil Under Turf Plots as a Function of the Amount of Fertilizer Nitrogen Applied, October 4, 1976 to March 3, 1977.*

Table 5–11

AVERAGE INORGANIC NITROGEN CONTENT OF TURFED SOILS RANKED ACCORDING TO THE LEVEL OF NITROGEN APPLICATION*

Soil Depth	Zero	Level of N application** Low	Medium	High
0–2"	9.8	13.2	22.5	16.7
2–9"	3.9	4.6	9.5	7.7
9–16"	2.1	4.6	5.8	6.1

**ppm on a dry soil weight basis*
***Definition of levels:*
Zero = No regular fertilization
Low = About 2 lbs/1000 ft.
Medium = About 2.5–4.5 lbs/1000 ft.
High = More than 4.5 lbs/1000 ft.
Source: Rykbost, 1973.

concentrations of inorganic nitrogen only serve as rough guides to the potential leaching of nitrogen associated with various levels of fertilization. As can be seen from the table, higher levels of inorganic nitrogen tend to be associated with higher application rates. It follows, therefore, that the higher application rates are likely to be associated with greater rates of leaching. On Long Island, turf roots rarely extend beyond nine inches into the soil; hence, soil inorganic nitrogen below nine inches is subject to leaching to groundwater.

Snow (1976) studied the effects of different rates of fertilizer applications on Kentucky bluegrasses. In particular, Snow attempted to account for the nitrogen applied by measuring the nitrogen recovered in clippings and the turf biomass. As a result of this work, Snow concluded "that large quantities of N may be leached from turfgrass areas."

The Cooperative Extension Service has estimated that the total nitrogen load in fertilizer applied to all types of turf on Long Island is about 9,300 tons per year, of which approximately 5,600 tons per year may leach to groundwater. (See Section 5.7.1.)

5.4.6 Fertilizers Applied to Potatoes

About half the total cropland in Suffolk County is devoted to potato production. Thus, it was decided that this study should also be concerned with fertilizers applied to potatoes.

Potatoes require an ample supply of nutrients, and, traditionally, large amounts have been supplied. Recent work completed by Meisinger (1976a), however, indicated convincingly that yields of potatoes could be sustained with applications of nitrogenous fertilizers as low as 150 lbs/acre. Normal applications were generally higher than this, and it is known that in some cases double that amount was applied annually. Surveys conducted by Rykbost (1976) indicated that the average rates have now fallen, in part in response to the work done by Meisinger and the Cornell Horticultural Research Station. Rykbost concluded that average annual rates were about 220 pounds.

A detailed survey of eight representative farm operations was made for this study in cooperation with the Cornell University Cost Accounts Program. The average rate of application of nitrogen by the farmers, in 1976, was about 200 pounds, an estimate close to that obtained by Rykbost.

The staff of the Cornell Long Island Research Farm has been conducting research on the variations in yield obtained in response to different types of fertilizer, amounts of fertilizer, methods of fertilizer application, and timing of application. A major part of the recent work was funded by the Suffolk County Department of Environmental Control. Results indicated that equivalent yields could be obtained with less nitrogen fertilizer than the amounts used in current fertilizer programs (Meisinger, 1976a). It was found that split applications could provide fertilizer more effectively than a single application at the time of planting. Split applications decrease the total amount of fertilizer required, and also decrease the amount of fertilizer potentially available for leaching. In January 1975, the research farm commenced a project to test these results under commercial conditions.

Four commercial farmers agreed to participate in the study. On each of the farms, the field was divided in half; half to be fertilized according to the farmer's current management practices, and half according to an experimental management program. Skimming wells were installed in each half field to monitor the groundwater nitrate-nitrogen concentrations. Yields were measured for comparative productivity. In 1976, monitoring wells were installed upgradient of the fields to determine background nitrogen levels.

The objectives of this part of the study were to determine the potential losses and gains of nitrate-nitrogen and ammonium-nitrogen within the soil under the potato crop. Core samples were taken every two weeks from March 1976 through December 1976, when preplanting, post harvest, and cover crop establishment and growth took place. A one inch diameter soil probe was used to extract samples to a twenty inch depth. The samples were divided into units of 0–12 inches and 12–20 inches. An assumption was made that the root zone was completely contained within the uppermost twelve inches. Therefore, any nitrates or ammonium measured in the 12–20 inch unit were assumed to be available for leaching into the groundwater. Each sample was taken two inches to either side of the seed through the fertilizer band.

Three random samples were taken from each half of the field, composited, placed in airtight containers, and stored at 35° F until chemical analyses were made. Storage time varied from zero to two weeks. The effects of the storage time were considered negligible.

The chemical analyses consisted of two measurements: gravimetric measurement and a micro-Kjeldahl steam distillation determination for nitrate-nitrogen and ammonium-nitrogen. Gravimetric measurements were made of twenty (20) gram samples of sifted soil. (The sifting process elimin-

ated gravels which would affect the gravimetric measurement.) The twenty gram samples were oven dried at 100°F for no less than twelve hours. The dried samples were reweighed, and the soil water content determined. Micro-Kjeldahl steam distillation required a preparation of potassium chloride (KCl) saturated soil samples. The twenty gram soil samples were extracted with 100 ml KCl. Magnesium oxide (MgO) and Devardo's alloy were used as reducing agents.

Well water samples were taken every two weeks by the staff of the Long Island Horticultural Research Station. These were also analyzed by micro-Kjeldahl steam distillation. Only nitrate-nitrogen (NO_3–N) was measured, since the concentration of ammonium-nitrogen (NH_4–N) was insignificant. The depth of the static water level was determined when the wells were installed. The depth indicated the potential time interval between the application of fertilizer and possible leaching through the soil profile to the groundwater. It was important to determine this relationship in order to derive a complete correlation between fertilizer management and the groundwater concentrations of nitrate-nitrogen.

Soil characteristics were determined for each of the demonstration potato farm sites. Soils were generally slightly acid, sandy loams, with low organic matter content and poor water holding capacities (high infiltration and permeability rates).

The results of the study showed low NO_3–N and NH_4–N concentrations in the early spring, prior to planting, indicating that the background soil nitrogen levels are low. Observed levels of nitrogen at various depths indicated a downward movement of the NO_3–N. The immediate and obvious response to fertilization application at planting was an increase in soil NO_3–N and NH_4–N concentrations. Leaching was apparent from the concentrations measured in the twelve to twenty inch layer, where it is unavailable to plant uptake. Decreasing concentrations in the surface layer for the two samples taken after fertilization were primarily due to plant uptake and/or leaching.

Sidedressing applications increased nitrogen concentrations in the surface layer but did not tend to influence the subsurface layer. This suggests that the sidedress applications coincided with the times of high plant uptake requirements. Post harvest application of fertilizer for the winter cover crop of rye showed increased concentrations of NO_3–N in both the surface and subsurface layers. The observed presence of NH_4–N in subsurface soil layers indicated a tendency for the NH_4–N to leach.

The well water nitrate-nitrogen concentration data indicated several important points. During the first year, the well water samples from the experimental fertilizer management program fields registered higher NO_3–N concentrations than those from the current management program fields. This probably reflected antecedent management practices, and seemed to imply a considerable transit time between the surface and the groundwater. At each farm, current management program field well samples having greater NO_3–N concentrations than the experimental management program field well samples began to show up early in the second year (1976). This suggests that the experimental fertilizer management program may have been effective in reducing the NO_3–N concentrations leaching to the groundwater. (For further details see reports of the Cornell Horticultural Research Station, L.I.)

The experimental management program consistently used 160 lbs N/acre. The rate applied by the current management programs ranged between 190–270 lbs N/acre. The significance of this comparison is that the lower rates of fertilization were able to produce comparable yields. The premise of the experimental management program was that effective fertilizer applications must coincide with plant nutrient requirements. The peak of the nitrogen uptake occurs approximately six weeks after planting; therefore, the heaviest application should occur at this time. The experimental fertilization program applied 60 lbs N/acre at planting, and followed approximately six weeks later with a sidedress of 100 lbs N/acre.
six weeks

The current fertilizer management programs apply the bulk of the fertilizer at planting, with a light sidedressing later in the season. If heavy rainfall occurs in the interval, and on Eastern Long Island this is more than likely, then the bulk of the fertilizer will be leached out of the root zone. Thus in the experimental fertilization program, the fertilizer is made more available to the plants and less susceptible to leaching to the groundwater.

The soil sampling program monitored nitrogen fertilizer movement during the potato season. A comparison of the fertilizer management programs indicates that there is approximately 40 to 70 percent more nitrogen available for leaching under the current management practices. The Long Island Horticultural Research Station calculated that, with efficient fertilizer management, 175 lbs N/acre/year would yield 125 lbs N in tubers/acre/year, and approximately 50 lbs N/year would be available for leaching. This leached nitrogen would produce a groundwater nitrate-nitrogen concentration of 10 mg/l if the annual recharge rate from precipitation is assumed to be 550 millimeters. This concentration is presently the maximum acceptable level for drinking water set by the USEPA. Therefore, it may be concluded that the previous rates of fertilization resulted in groundwater recharge concentrations that exceeded desired levels. Reductions in the rate of fertilization, in combination with the practice of timed fertilizer applications, have the potential to reduce nitrogen losses, while maintaining yields.

5.5 DOMESTIC ANIMALS AS A SOURCE OF NITROGEN

5.5.1 Dogs and Cats

As part of the 208 Program, the Soil Conservation Service (SCS) conducted a survey of households in five selected areas and found that "between 33% and 40% of the homeowners interviewed in the study of the sampled areas reported dog ownership" (Soil Conservation Service, 1977). The results of the survey were extrapolated to the whole Bi-county Region to produce an estimated total of between 300,000 and 360,000 (or 425,000 if strays are

included). This range corresponds closely to the estimate of 385,000 dogs, based on license data of the New York State Bureau of Dog Licensing. In order to avoid overestimating the canine nitrogen contribution, the following analysis uses a more conservative population estimate of 350,000.

From the same field survey, the Soil Conservation Service concluded that there are two cats to every three dogs in the region, or 233,000 in all. Assuming a human population of 2.735 million persons in the region, it follows that there is one cat to every twelve persons and one dog to every eight persons. Estimates of the total nitrogen load per dog per day were not readily available. For the purposes of the study, it was assumed that the nitrogen/BOD_5 ratio for humans could be applied to the animals. Hence:

$$\text{Nitrogen load per dog} = 0.08 \text{ lb } BOD_5 \times 0.147 \text{ lb N/lb } BOD_5\text{/day} = 4.29 \text{ lb N/dog/year}$$

Similarly, for cats, Loehr (1974) states that the BOD_5 load per cat per day = 0.06 lb. Therefore:

$$\text{Nitrogen load per cat} = 0.06 \text{ lb } BOD_5 \times 0.147 \text{ lb N/lb } BOD_5\text{/day} = 3.22 \text{ lb N/cat/year}$$

It is thereby possible to estimate the annual load of nitrogen from the pets per person as follows:

$$\text{lb N from pets/person/year} = \frac{233{,}000 \text{ cats} \times 3.22 \text{ lb N/cat/year} + 350{,}000 \text{ dogs} \times 4.29 \text{ lb N/dog/year}}{2{,}736{,}000 \text{ persons}} = 0.82 \text{ lb N/person/year.}$$

A surprisingly large fraction of the nitrogen in freshly defecated matter is rapidly volatilized. In fact, data supports the hypothesis that approximately half the nitrogen in fresh animal waste is lost by volatilization as ammonia (Porter *et al.,* 1975). For the purposes of this study, it was accordingly assumed that 50 percent of the nitrogen in pet waste would be lost in a gaseous form. It was also assumed that the remainder is deposited onto the soil surface, where it is available for removal by runoff or subsurface percolation. Thus, the actual nitrogen load from pets that may ultimately pollute ground and surface waters is equal to about 0.41 lb N/person/year.

5.5.2 Horses

It has been estimated by the Soil Conservation Service (SCS, 1977) that "there may be 30,000 or more horses in the bi-county planning area". If it is assumed that the average nitrogen content in a horse's daily waste is 0.3 pounds (Loehr, 1974) then the daily nitrogen loading from this source would be equivalent to over 300,000 persons, or about ten percent of the population. The magnitude of this equine source is therefore potentially highly significant.

The estimate of 30,000 horses, which has had wide circulation, appears to have originated in a feature article, written by Barbara Delatiner, printed in the Brooklyn, Queens and Long Island section of the *New York Times,* Sunday, July 28, 1974. In the article, the president of the Nassau-Suffolk Horseman's Association claimed that despite the decline of Long Island as a horse center, "it is estimated that some 30,000 horses still remain on the Island". The president did not indicate what fraction of this number applied to Nassau and Suffolk County, nor does other data apparently support the estimate.

In 1973, a SCS Survey of veterinarians identified 4,000 horses located in concentrations of ten or more animals. Since most horses are stabled in groups, this figure may account for a major portion of the horses, exclusive of race horses, in the Nassau-Suffolk Region.

It may be noted that in the 1974 Census of Agriculture, 34 farms were listed for Suffolk County as containing 321 horses. Even prior to the universal adoption of motor tractors on and off the farm, less than 15,000 farm and domestic horses and mules were reported for both Nassau and Suffolk Counties (1920 census).

It may further be noted that a significant part of the feed for the region's horses may be provided by the region itself, especially those animals which are pastured. Thus, the net addition to the region's nitrogen economy would be correspondingly reduced. To pasture the 4,000 horses enumerated by the Soil Conservation Service would take about 1,000 acres. It is not known how much land is devoted to pasture in the Bi-county Region, although that on farms is negligible.

Finally, according to the SCS (1977), about 2,000 race horses may be housed in the region during the racing season. However, since the waste they produce is shipped daily to mushroom farms in Pennsylvania, these animals may be virtually ignored in the region's nitrogen budget.

In summary, two conclusions are apparent. The total number of horses, and their distribution in the region are unknown, and their net contribution to the region's nitrogen budget cannot be quantified. However, it would appear there are probably substantially fewer animals then the 30,000 that have been estimated. With existing data, it appears that the 5,000 non-racehorses is a reasonable estimate, and that these regionally would not represent a significant input to the nitrogen budget.

5.6 ASSESSMENT OF NITROGEN SOURCE EFFECTS ON GROUNDWATER QUALITY

5.6.1 Introduction

Several recent studies have examined groundwater data from Long Island in an attempt to gain a greater understanding of the main causes of contamination. Sulam and Ku (1977) examined long term records of groundwater quality in an unsewered area of southeast Nassau County, and concluded that the maximum concentration of contaminants had occurred during the most recent period, "when the effluents from thousands of cesspools and septic tanks were being discharged". The authors also concluded that

fertilizers used before and during urbanization may have contributed large quantities of contaminants to the groundwater.

Katz (1978) made a very comprehensive study of data obtained from the southern half of Nassau County over the last twenty-five years, which showed that an improvement in the quality of groundwater with respect to nitrogen had occurred in the sewered part of the study area; improvement had also occurred in the unsewered area, but to a lesser degree. In another study of water samples from shallow wells, Katz (1978) examined short term variations in quality, and concluded that the fluctuation in quality appeared to be related to variations in non-point source pollution inputs. A preliminary analysis of trends in data from individual wells in Nassau County was made in an attempt to correlate urbanization and the extension of sewer service with groundwater quality. Unfortunately, the analysis failed to reveal a clear trend (see below).

Groundwater quality depends upon many factors, some of which may be markedly intermittent. For example, variations in the levels of inorganic nitrogen reaching groundwater may be governed by seasonal or meteorological factors, as suggested by Katz. Therefore, to adequately estimate an average concentration for a given year, a representative set of observations must be made. One observation per month appears to be a minimum number required.

Analyses for annual trends will be misleading if good estimates of annual mean concentrations are lacking. Furthermore, a period of several years must be covered by the observations. When such factors as long term cyclical patterns in the weather are taken into account, a minimum period of at least ten years is needed. Since no wells in Nassau County have a sufficient number of observations within each year, or a continuous observation record lasting at least a decade, the trend analyses undertaken by Katz and others were inconclusive.

5.6.2 Soil Conservation Service Analysis

The SCS was able to overcome some of the problems discussed in the previous section by grouping observations from different wells located in the same vicinity and aquifer. An example of such a grouping is shown in Tables 5–12 and 5–13. Wells screened in the Upper Glacial aquifer in Nassau County were grouped according to the NSRPB land use grid cells. (See Figure 5–12.)

The median concentrations of wells in each cell, as estimated by the USGS, were averaged over the period 1972 to 1976. All grid cells that were entirely sewered, or those that were without sewers, and for which observations were available, are listed in Table 5–12 and 5–13, respectively. The corresponding estimated population densities which were derived by dividing the estimated 1975 population in each grid cell by the number of acres of land (usually 1,440) in each grid cell, are also shown. As can be seen, there appear to be significantly lower nitrate-nitrogen concentrations in the sewered areas. The overall unweighted average population density in the sewered area is 12.7 persons per acre, with a corresponding average nitrate-nitrogen concentration of 4.5 mg/l. This compares with a lower overall population density of 5.8 persons per acre in the unsewered area, and a higher average median concentration of 5.8 mg/l. It should be noted that this comparison must be accepted with caution, since the histories of the areas within the two sets of grid cells differ.

After examination, the estimated average of the medians for two of the grid cells in Table 5–13, grid cells 81 and 123, were considered to be unreliable. Grid cell 81 is located in Bayville, on the North Shore of Nassau County. Measurements were available from only one well, which was screened

Table 5–12

POPULATION DENSITIES AND THE AVERAGE OF THE MEDIAN NITRATE-NITROGEN CONCENTRATIONS IN WATER FROM WELLS SCREENED IN THE UPPER GLACIAL AQUIFER IN AREAS THAT ARE ENTIRELY SEWERED

Grid Cell No.	Persons/Gross Acre	Average Median* (Mg/l)
18	6.4	5.6
19	12.2	5.9
29	9.1	4.4
30	13.7	1.4
31	11.8	7.2
33	14.1	3.9
34	12.2	5.8
43	10.2	6.8
44	11.0	4.2
46	13.0	4.8
48	14.5	2.6
59	10.7	3.6
60	16.8	2.7
61	9.6	2.0
63	12.4	1.6
75	27.2	7.0
76	12.5	6.7
93	16.5	3.2
94	13.2	1.4
143	9.0	4.9
159	11.2	9.4
Overall Average	**12.7**	**4.5**

**Medians based on observations made during 1972–76 from 49 wells.*

Source: USGS Open-file report 76–845

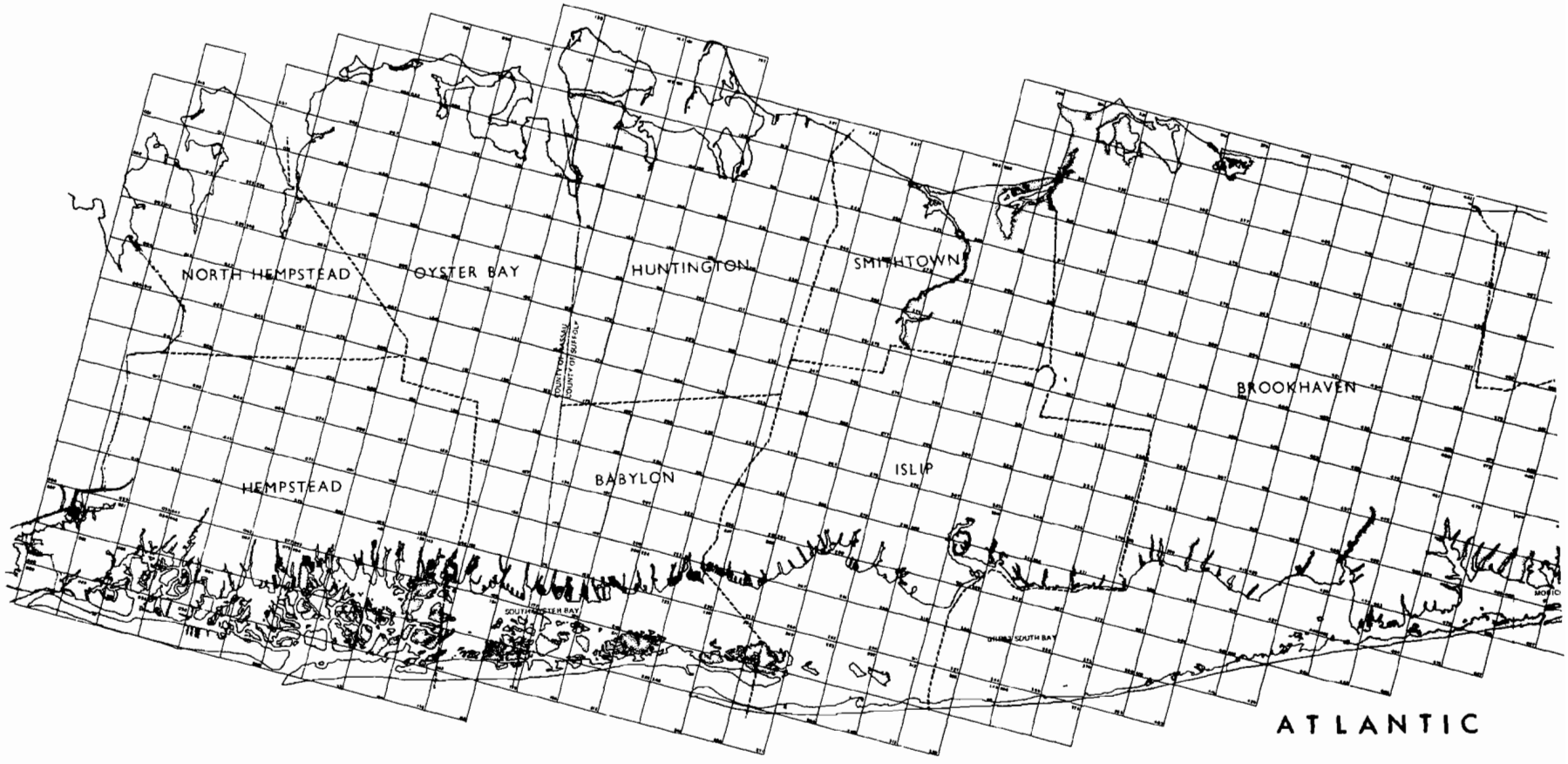


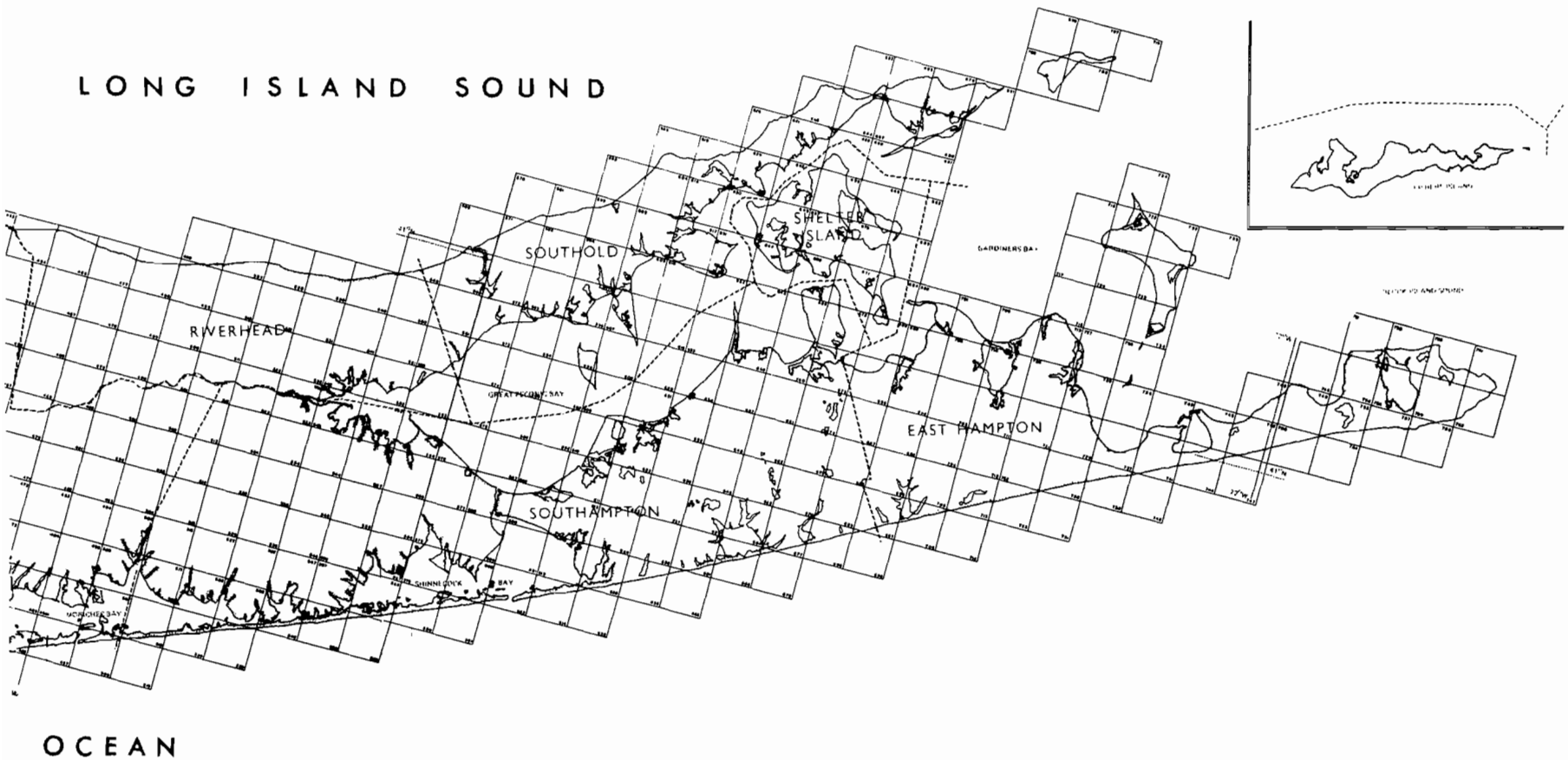
FIGURE 5—12 *NSRPB Land Use Grid Cells.*

at about 160 feet. Therefore, data from grid cell 81 were omitted from further analyses. Grid cell 123, which is in Levittown, had the largest number of wells and observations. Land use within grid cell 123 is primarily residential, with a population density of 10.5 persons per gross acre. Despite the uniformity of land use, concentrations of nitrate-nitrogen varied from less than 1 mg/l to about 16 mg/l (see Table 5—14), and the range is even larger if the individual observations, rather than the averages, are considered.

Table 5—14 shows that long term averages can be misleading, since, after 1965, samples were no longer collected from the two wells with the highest average concentrations. Abandoning wells producing poor quality water and replacing them with new wells is a common procedure. As a result, aggregate long term averages of well data may be biased in that they tend to understate pollutant concentrations.

A linear regression analysis was made relating population densities to the average of the median concentrations in the other grid cells. The result is shown in Figure 5—13. The relation obtained was based on observations over the period 1972—1976 for all wells, with the two exceptions noted, located in the Upper Glacial aquifer in unsewered areas (see Table 5—13).

Another analysis was performed independently using observations from wells that were carefully selected according to location and depth (Weston, 1977). Although this analysis mainly considered southeast Nassau County, the results obtained were very similar.



5.6.3 Groundwater Quality, Population Density, and the Drinking Water Standard for Nitrate

The variability of nitrate-nitrogen concentrations measured at public water supply wells makes it difficult to interpret these data in relation to the drinking water standard of 10 mg NO_3–N/l (applicable to water at the tap). An average (mean) value of 10 mg/l at the wellhead implies that the measured nitrate-nitrogen concentrations will exceed this level an unspecified percentage of the time. In order to assess the health implications of wellhead nitrate-nitrogen concentrations, the relationship between mean nitrate values and the percentage of measurements violating the 10 mg/l standard must be determined. An evaluation of this relationship for Nassau County wells was made by Porter (1977).

Porter's statistical analysis required the calculation of 90th, 80th, 70th, 60th, and 50th percentile values (the nitrogen concentration values below which the various percentages of measured concentrations occurred). Wells were grouped according to NSRPB land use grid cells so that the calculation of 90th percentile values, which requires at least 30 well measurements, could be made. A total of seventeen Nassau County grid cells, with a combined total of 865 observations from 54 wells, were utilized by Porter (see Table 5–15). Linear regression analyses were made for each set of percentile values and associated means in each grid cell (see Figure 5–14).

Figure 5–14 indicates the relationship between the average (mean) con-

Table 5–13

POPULATION DENSITIES AND THE AVERAGE OF THE MEDIAN NITRATE-NITROGEN CONCENTRATIONS IN WATER FROM WELLS SCREENED IN THE UPPER GLACIAL AQUIFER IN AREAS WITHOUT SEWERS

Grid Cell No.	Persons/Gross Acre	Average Median* (Mg/l)
2	1.5	2.5
55	3.3	6.6
66	0.9	1.9
71	1.5	1.5
81	9.5	19.0
82	4.2	3.1
84	0.7	1.5
104	4.4	2.3
105	10.9	9.6
119	1.6	5.0
120	6.3	9.8
123	11.9	2.3**
133	1.3	1.2
140	12.8	13.0
154	2.1	3.2
157	16.6	8.4
174	8.5	7.5
Overall Average	**5.8**	**5.8**

**Medians based on observations made during 1972–76 from 27 wells.*
***This estimate appears to be highly biased. See text for discussion.*
Source: USGS Open file report 76–845.

centration of nitrate-nitrogen measured at a particular well and the percentage of the measurements for that well that will be less than a specified concentration (in particular, the 10mg NO_3–N/l concentration used as the standard for drinking water). For example, if the average value of nitrate measurements for a well is 6mg/l, then 90% of the measurements from that well will be less than 10 mg/l (or conversely, 10% of the measurements will be greater than 10 mg/l). Similarly, if the average value of nitrate measurements is 7.1 mg/l, then only 80% of the measurements will be less than 10 mg/l (see Table 5–16).

Figure 5–14 can also be used to determine the average (mean) concentration of nitrate-nitrogen measured at a well that would correspond to a specified percentage of compliance with the 10 mg/l drinking water standard (or some other standard). For example, if it is desired that 90% of the samples from a well have concentrations below 10 mg/l (*i.e.*, meet the drink-

Table 5–14

NITRATE-NITROGEN CONCENTRATIONS IN WELLS IN GRID CELL 123 (Levittown)

Well No.	Depth (ft.)	No. of Observ.	Mean (Mg/l)	Standard Deviation	Last Year of Observation
2581	55–81	12	15.62	11.74	1965
2403	59–84	12	15.02	3.95	1965
7702	25–28	8	0.99	1.23	1968
2402	164–206	20	7.33	3.23	1968
7703	–	6	3.32	3.49	1970
7698	23–26	13	0.60	0.93	1972
7699	27–30	14	0.89	1.80	1972
7696	28–31	14	5.64	1.67	1972
7701	–	8	1.24	1.02	1972
7700	–	9	2.17	1.28	1972
7687	26–29	14	1.75	.91	1972
		130	**5.02**	**5.25**	

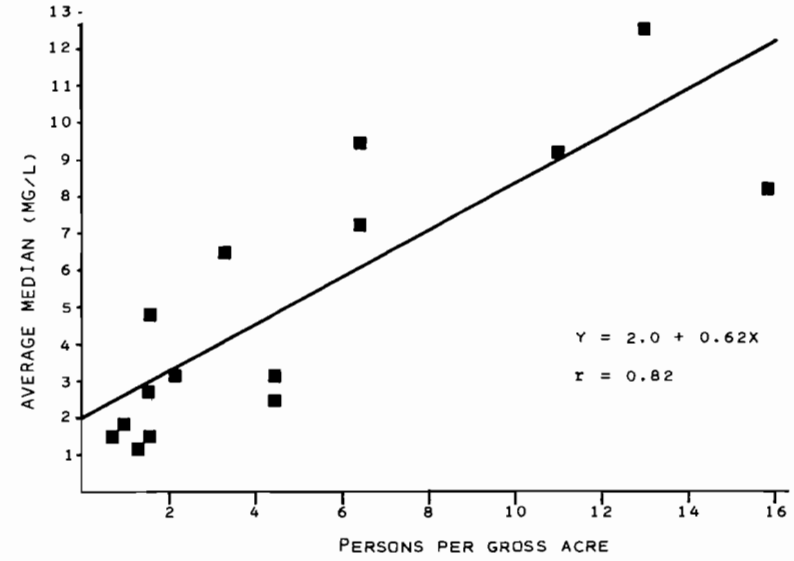


FIGURE 5–13 *Population Density and Related Nitrate-Nitrogen Concentrations in Underlying Groundwater.*

ing water standard 90% of the time), then the average (mean) concentration for water from the well would have to be less than or equal to 6 mg/l. Similarly, if compliance with the 10 mg/l standard is desired for only 50% of the samples (*i.e.*, 50% of the time), then the average concentration in the well water could be as high as 10.3 mg/l (see Table 5–16).

The relationships between population density and groundwater nitrate-nitrogen concentrations (see Figure 5–13), and between groundwater nitrate-nitrogen concentrations and the percentage of violations of the drinking

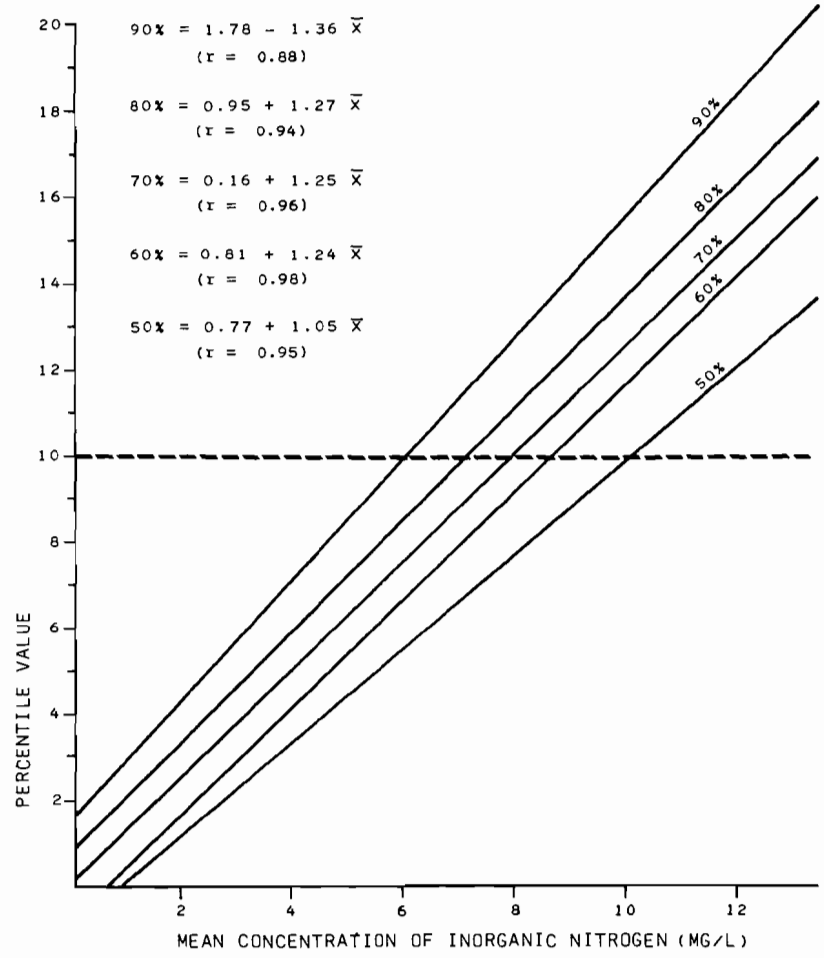


FIGURE 5–14 *Relationship Between Mean Groundwater Nitrogen Concentrations and Percentile Values.*

water standard (see Figure 5–14) can be compared to relate population density to percent violations (see Table 5–16). The statistical analysis relating population densities to variation in groundwater concentrations, as specified by percentage violation of the standard, is justified as a planning tool in the absence of reasonably convenient alternatives. The following three reservations should be noted:

1. The analysis is more empirical than statistical.
2. It would be an error to interpret the analysis as demonstrating a relation between population density *per se* and groundwater quality. Population density, as a statistical variable, is correlated with many other variables, including highways, animals and lawns (Weston, 1977). Cross correlations between such variables have been discussed by Haith (1975).
3. The groundwater data used for the analysis itself may be misleading. On purely theoretical grounds, the concentrations of nitrate-nitrogen appear too low. When all the sources of nitrogen associated with human settlements are considered, it appears remarkable that a population of ten persons per acre, with all the associated sources of nitrogen, would correspond to an average concentration of about 8 mg/l of nitrogen in the underlying groundwater. At normally assumed values of recharge (about twenty inches per year) a concentration of 8 mg/l would result from a per capita loading of about four pounds of nitrogen per year. Such a value is remarkably low, since the quantity of original nitrogen associated with an individual is close to four times that value.

That the observed groundwater concentrations are frequently unexpectedly low has been remarked by others. This may also be seen when the gross estimates of the nitrogen loads originating from the major sources are tabulated (see Section 5.7).

From a management standpoint, it is important to recognize the limitations in relying exclusively on existing groundwater data to guide management decisions. Since sources of groundwater contamination are subject to management, rather than the groundwater itself, it appears prudent, when deriving management policies, to quantify the actual sources themselves.

5.7 NITROGEN BUDGET FOR NASSAU AND SUFFOLK COUNTIES

5.7.1 Nitrogen Budget Formulation

In order to construct a comprehensive nitrogen budget for Nassau and Suffolk Counties, a computer program was developed at Cornell University that considers the relationships shown schematically in Figure 5–15. Computations were made for areas defined by the NSRPB land use grid cells (see Figure 5–12). The hydrological computations required for the program were based on the Bi-county Regional Water Budget Model described by Baskin (1977). By using the water budget model in combination with the nitrogen balance calculated for each grid cell, it was possible to estimate nitrogen loads in surface runoff to marine waters, and the loads and corresponding concentrations of inorganic nitrogen that leach to groundwater.

Table 5—15

SUMMARY OF WELL DATA USED TO DERIVE MEAN PERCENTILE RELATIONSHIPS

Grid Cell No.	Number Wells	Number Observ.	Median	Average	Standard Deviat.	Percentiles 90%	80%	70%	60%	50%
18	1	39	12.4	12.3	2.0	14.3	14.0	13.6	13.0	12.4
19	2	39	7.6	6.4	2.9	9.8	9.1	8.5	7.9	7.6
25	2	48	3.0	2.9	0.9	4.1	3.7	3.5	3.3	3.0
26	3	63	0.8	1.9	2.0	5.1	4.0	3.5	1.0	0.8
29	2	45	6.2	7.3	3.4	13.0	10.2	7.8	6.9	6.2
30	2	47	7.1	7.2	4.7	13.5	11.3	10.8	9.6	7.1
31	2	32	7.8	7.6	1.9	9.7	9.0	8.8	8.5	7.8
52	2	36	4.8	4.4	1.0	5.5	5.3	5.1	5.0	4.7
61	3	54	1.6	2.3	2.7	5.9	5.1	3.4	2.6	1.5
75	5	55	9.7	9.7	3.0	13.0	12.0	11.0	11.0	9.7
76	3	55	6.7	6.9	1.6	8.9	8.4	7.6	7.2	6.7
77	4	37	4.4	4.8	2.0	8.7	6.2	5.5	4.7	4.4
82	2	53	4.5	8.3	6.5	16.9	15.2	13.3	8.9	4.5
100	4	63	1.8	1.7	0.5	2.4	2.1	1.9	1.8	1.8
123	11	130	2.7	5.0	5.3	13.9	9.7	7.3	4.8	2.7
141	3	38	15.0	13.7	7.1	23.1	20.0	19.0	18.0	14.5
142	3	31	8.7	8.1	4.7	14.2	11.0	10.0	9.0	8.7

Table 5—16

RELATIONSHIP BETWEEN PERCENT VIOLATIONS OF THE 10 mg/l STANDARD FOR DRINKING WATER, MEAN GROUNDWATER NITRATE CONCENTRATIONS AND POPULATION DENSITIES

Percent violations	mean concentrations mg/l	population densities persons/gross acre
10%	6.0	6.7
20%	7.1	8.6
30%	7.9	9.8
40%	8.7	11.2
50%	10.3	13.7

Figure 5—16 shows the computed range of average inorganic nitrogen concentrations in percolating water in unsaturated soil for Nassau and Suffolk Counties. Table 5—17 lists the estimates of gross nitrogen loadings to the marine bays. For comparison, the estimates made by Tetra Tech (NSRPB, 1978) are included. Agreement between the two sets of results is reasonable for the North Shore bays and Peconic River, but less so for the South Shore bays. It should be noted that the methods of estimation used are different. Tetra Tech's estimates were largely based on the field measurements made during the 208 Program. The Cornell estimates are derived from water and nitrogen budgets.

A nitrogen budget for the region is presented in Table 5—18. As shown in the table, the estimated annual load of nitrogen carried down to groundwater by regional recharge is over 16,000 tons. This nitrogen is primarily in the nitrate form, and about 30 percent of it originates from human wastes discharged to the ground. The 16,000 tons that appears in the groundwater is only about 50 percent of the original load. Runoff accounts for very little of

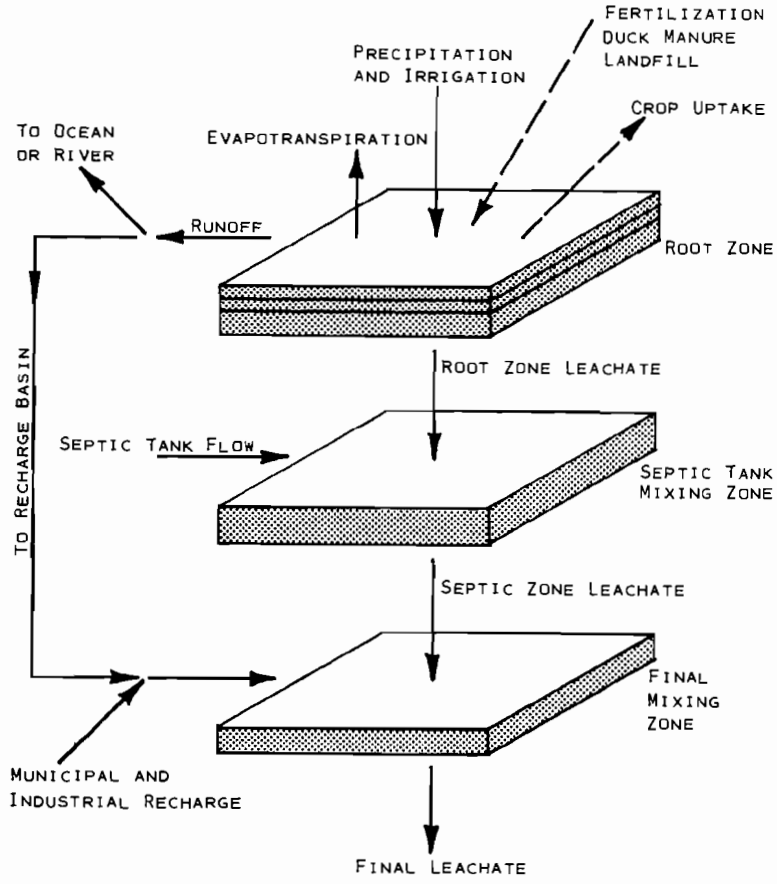


FIGURE 5–15 *Macromodel of Nitrogen Leaching.*

the difference, and it is believed that denitrification in the soil is a major factor. A very large portion of the nitrogen input to the Long Island system is believed to escape to the atmosphere in the gaseous form.

The figures given in Table 5–18 represent gross averages for the entire Bi-county Region. It must be recognized that a great deal of variability will be encountered under specific conditions. Also, the relative average magnitudes of the various components will change from locality to locality within the region. Table 5–19 shows gross estimates of nitrogen produced in a residential area with medium density housing (three houses per acre). A comparison

Table 5–17

COMPARISON OF ESTIMATES OF RUNOFF TO NASSAU-SUFFOLK MARINE BAYS

Marine Bay	Method of deriving estimates: Stormwater sampling[1] (lbs. N/yr.)	Water and nitrogen budgets[2] (lbs. N/yr.)
Manhasset Bay	62,050	86,000
Hempstead Harbor	80,300	110,000
Oyster Bay	105,850	101,000
Huntington Bay	135,050	129,500
Port Jefferson Harbor	73,000	70,400
Flanders Bay	10,950	10,600
Peconic River	20,000	23,800
Mecox Bay	21,900	8,820
Shinnecock Bay	21,900	38,000
Moriches Bay	69,350	76,420
Great South Bay	405,150	581,200
South Oyster Bay	98,550	154,400
Nassau Bays[3]	233,600	327,000
Totals	**1,337,650**	**1,717,140**

[1] Estimated by Tetra Tech (NSRPB, 1978)
[2] Estimated by CES
[3] East, Middle and Hempstead Bays

with the estimates in Table 5–18 shows that the relative magnitudes of the loads from the various sources for medium density residential land use differ from those for the region as a whole. The original total load of nitrogen for the acre would produce a concentration of inorganic nitrogen of about 30 mg/l, if it all leached. On the basis of work done during the 208 program, it has been estimated that ' uctions in nitrogen levels during, or prior to, leaching to groundwater, ɔuld produce an actual concentration closer to 15 mg/l. This compares with 10 mg/l that would be predicted by empirical relations based on groundwater data presented in Section 5.6.

The variability in the relative magnitudes of major nitrogen sources—domestic waste (population), fertilizers, precipitation, domestic pets—as a function of population density, is shown in Figure 5–17. The estimates depicted in the figure were derived from the nitrogen budget applied to unsewered areas (the grid cells listed in Table 5–13) with various land use mixes and household income levels (see Sections 5.4 and 5.6). Clearly, the variation in potential nitrogen loads from area to area is an important consideration when developing wastewater management policies for specific areas.

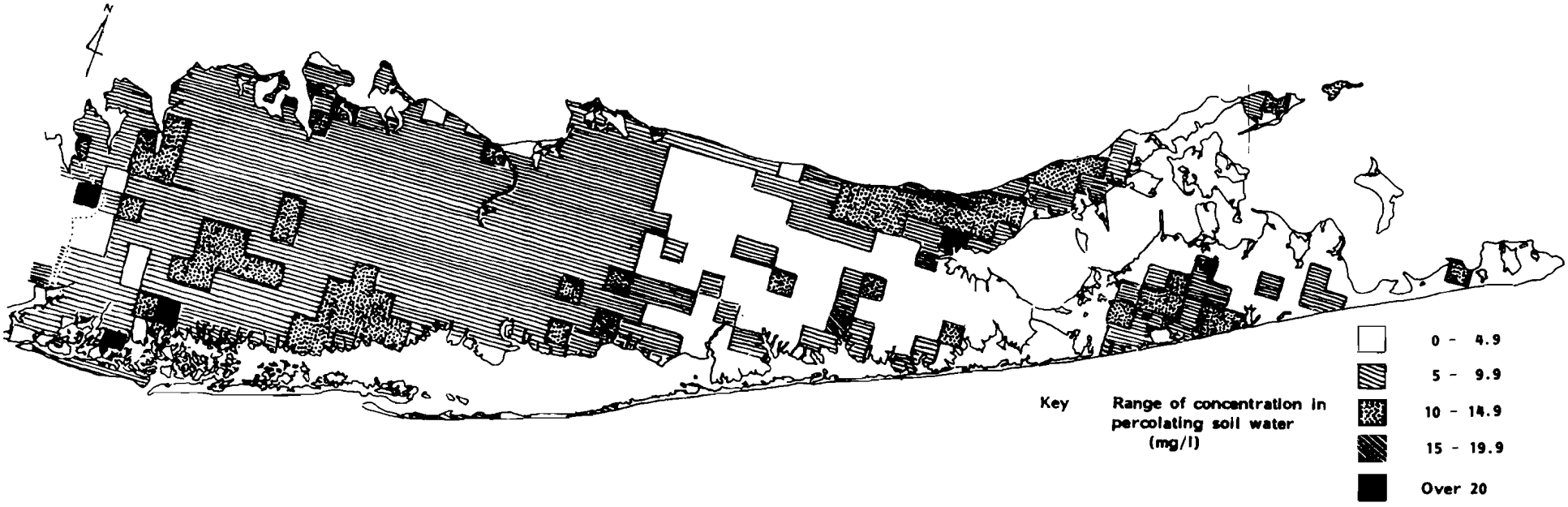


FIGURE 5–16 *Computed Range of Average Inorganic Nitrogen Concentrations in Percolating Water in Unsaturated Soil: Nassau and Suffolk Counties.*

5.7.2 Summary and Conclusions

The amount of nitrogen released into the Long Island environment by major sources of nitrogen was estimated. The estimation was made utilizing field data for fertilizer obtained during the period of the study, and a review of the literature on other sources.

Extensive and intensive monitoring of nitrogen was also performed to determine the downward movement of nitrogen from fertilizer through the upper soil profiles under different conditions. This, combined with other data obtained during the recent 208 Study, provided a comprehensive means of estimating the transport of nitrogen, from its sources, down to groundwater and overland to surface waters.

A computer program was constructed to provide a convenient means of identifying water and nitrogen budgets for each of the grid cells defined by the Nassau-Suffolk Regional Planning Board. Components in the budgets were related to land use characteristics.

The following conclusions were reached:

1. The major sources of nitrogen are human waste and fertilizers, which annually contribute approximately 14,000 and 13,000 tons, respectively.

2. Available data indicates that there are large (*e.g.,* 50%) reductions of nitrogen in on-site disposal systems, although variations in removal capability may vary significantly.

3. Available data indicates that most of the nitrogen applied to turf is lost to ground and surface waters, except in those cases where clippings are removed and taken to landfills.

4. It is estimated that about 75 percent of nitrogen applied to agricultural crops such as potatoes is removed by the crop.

Table 5–18

SUMMARY OF GROSS ESTIMATES OF SOURCES AND FATE OF NITROGEN IN THE BI-COUNTY REGION
(based on 1975 and 1976 data)

Source	Initial Nitrogen Load (tons/yr)	Load to Groundwater (tons/yr)	Comment on Sink
Wastewater			
On-site systems	8,500	4,300	(Denitrification, etc.)
Sewers & sewage treatment Sewer leakage	500	200	(Denitrification, etc.)
Effluent discharge to ground	200	100	(Denitrification, etc.)
Effluent discharge to marine bays	4,200	—	(Discharge to sea)
Sub-total	**13,400**	**4,600**	
Fertilizers and Animals			
Farm (Incl. sod farms)	4,000	1,000	(Crop removal)
Turf (Incl. households, golf courses, etc.)	9,300	5,600	(Volatilization & Denit.)
Animals (primarily dogs & cats)	1,600	800	(Volatilization & Denit.)
Ducks	600	300	(Volatilization & Denit.)
Sub-total	**15,500**	**7,700**	
Precipitation	4,000	3,700	(By difference from totals)
Total	**32,900**	**16,000***	**(Totals estimated by water/nitrogen model)**

**Assuming an annual recharge of about 500 billion gallons, the resulting concentrations in the leachate equals about 6.8 mg/l.*

Table 5–19

ESTIMATED ANNUAL LOADS ORIGINATING ON AN ACRE OF RESIDENTIAL LAND WITH THREE HOUSES

Source	Lbs. of Nitrogen Initial Load	Lbs. of Nitrogen Approx. load to Groundwater	Assumption
10 Persons	100	50	(10 lbs. N/person)
15,000 sq. ft. of turf	45	25	(average household income $16,000)
Pets	10	5	(0.82 lbs/person approx.)
Precipitation	10	6	(1 mg/l)

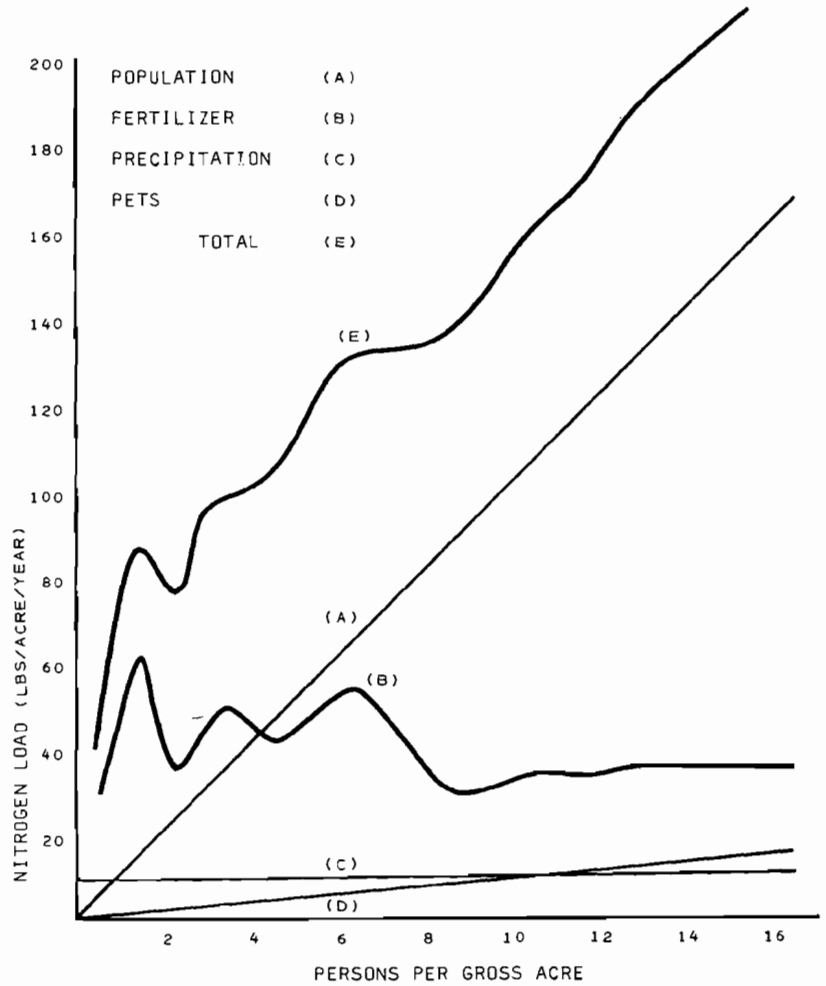


FIGURE 5–17 *Relationships Between Population Density and Nitrogen Loadings to Groundwater from Major Pollution Sources.*

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Section 6 Animal Waste

6.0 INTRODUCTION

Two water quality objectives defined by Public Law 92–500 are the elimination of the discharge of pollutants into navigable waters by 1985, and achievement, by 1983, of interim goals, which provide for the protection and propagation of fish, shellfish, and wildlife and provide for recreation in and on the water. Achieving these goals requires meeting the criteria for "fishable and swimmable water." The New York State Environmental Conservation Law calls for the promulgation of rules and regulations setting limits for total and fecal coliform bacteria, dissolved oxygen, copper, zinc, total dissolved solids and other parameters.

Other goals not specifically defined under the law but also of great importance are the reduction of sediment, the control of nitrogen and phosphorus, and the prevention of salt water intrusion into surface and groundwaters.

Inasmuch as animal wastes appear to contribute to the pollution of the Nassau-Suffolk surface and groundwaters, they must be considered in water quality management planning.

The purpose of this section is to define and identify the non-point sources of pollution that are caused by animal wastes in the bi-county area and to recommend appropriate actions.

Animal population, waste characteristics, waste impact and control are discussed in detail. General recommendations and specific recommendations for waste control are included.

Nassau and Suffolk are suburban counties, with a 1977 population of approximately 2.8 million. Although Suffolk leads all counties in the State in dollar income from farming, it has few farm animals other than commercial market ducks. However, the bi-county area has many pets, recreation horses, and wild animals. Except for market ducks, animal populations are generally widely scattered and dispersed, with few concentrations.

Estimates of manure production per animal or per 1,000 pounds of live weight vary widely as do the estimates for each component of manure. These factors vary as a function of animal species, breed, age, sex, type of feed, climate, and measurement methods. Table 6–1, which is based on average values, indicates the relative importance of different animal wastes in the bi-county region. Table 6–2 shows the daily production and composition of livestock manure (feces and urine).

The values in Table 6–1 represent only the solids portion of animal manure. The liquid portion, although not represented, also contains BOD, nitrogen and other components. The daily per animal values for BOD shown in Table 6–1 were calculated from pounds of BOD per day per 1,000 pounds of live weight, using average weights of 125 pounds for humans, 1,000 pounds for horses, four pounds for ducks, 1,350 pounds for cattle, 4.5 pounds for poultry, and 150 pounds for swine. The daily per animal value for dogs was derived from Table 6–5 and other sources. Wild ducks (not included

Table 6–1

SUGGESTED HUMAN AND ANIMAL WASTE PRODUCTION VALUES FOR BIOCHEMICAL OXYGEN DEMAND (BOD) AND BACTERIOLOGICAL CONTENT

	Daily Solid Waste Prod				Solid Waste Only			Solid Waste Bacteria Content (Million MPN/g)			
Biotype	Nassau-Suffolk Population (Numbers)	Single Animal (Grams)	Total Population (Pounds)	BOD per Animal Per Day (Pounds)	Human BOD Equiv.	Daily Total Human BOD Equivalent	Total Animal BOD Load (% Human)	Coliform Total	Coliform Fecal	Fecal Strepto-Cocci	FC/FS*
Human	2,735,637	150	903,000	0.17	1.00	2,735,637	100.0	NA	13.30	3.0	4.43
Dog	425,000	227	212,500	0.13	0.76	323,000	11.81	18.0	18.00	7,300.	0.002
Horse	30,000	16,100	1,063,875	1.40	8.24	247,200	9.04	NA	NA	NA	NA
Duck	750,000	336	400,000**	0.02	0.12	90,000	3.29	NA	32.70	53.6	0.61
Cattle	1,825	26,300	105,721	1.89	11.12	20,294	0.74	NA	0.23	1.3	0.18
Chicken	121,200	182	48,587	0.02	0.12	14,544	0.53	NA	1.30	3.4	0.38
Swine	635	2,700	3,776	0.34	0.20	1,270	0.05	NA	3.30	84.0	0.04

**Fecal Coliform-Fecal Streptococci ratio*

***Total volume of waste from market ducks adjusted for probable age distribution and does not include wild or semi-wild population.*

Sources: American Public Works Association; Water Pollution Aspects of Urban Runoff; USDI; Federal Water Pollution Control Administration; Washington, D.C.; January 1969. Anvik, J.O., E.A. Hyne, and A. Rahaman; "A Method of Estimating Urban Dog Populations and Its Application to the Assessment of Canine Fecal Pollution and Endoparasitism in Saskatchewan," Canadian Veterinary Journal; Vol. 15; No. 8; August 1974. Moore, J.A.; "Animal Waste Management to Minimize Pollution;" ibid. United States Department of Agriculture, Soil Conservation Service; Agricultural Waste Management Field Manual; Washington, D.C.; August 1975. United States Department of Commerce, Bureau of Census; 1974 Census of Agriculture Preliminary Report, Nassau County, New York; Washington, D.C.; June 1976. Wadleigh, C.H.; Wastes in Relation to Agriculture and Forestry; USDA, Misc. Publication 1065, Washington, D.C.; March 1968.

in this table), are about one pound lighter than market ducks. Information regarding cats, turkeys, wild geese and other animals was not available. However, geese can be roughly estimated at 4.5 times the duck figures (H.W. Oneth, November 30, 1976).

Coliform bacteria are a major component of urban and rural stormwater runoff and have been a factor responsible for the closure of portions of Great South Bay to shellfishing. Table 6–3 shows the total coliform and fecal coliform counts in stormwater runoff from four typical Long Island areas. Stormwater samples were collected by the Soil Conservation Service (SCS) staff during the spring, summer and fall of 1976 and analyzed by New York State Department of Environmental Conservation.

The values in Table 6–3 indicate that the suburban and agricultural areas contribute similar amounts of total coliform bacteria. High total coliform counts are expected from agricultural areas, since normal soil coliform bacteria, *Aerobacter aerogens,* are included as part of the total coliform count. They also indicate that agricultural watersheds contribute markedly fewer fecal coliform bacteria. Since the urban areas studied have sanitary sewers, it is logical to assume the probable source of their high fecal coliform counts is animal. Dogs were inventoried in approximately 35 percent of the households. The Baldwin site watershed drains directly into Baldwin Bay.

Table 6–2

DAILY PRODUCTION AND COMPOSITION OF LIVESTOCK MANURE (FECES AND URINE)
(Upper Figure is average; lower figures represent the range given in literature)
(Dashes indicate date not available or entry not appropriate)

	Dairy Cattle	Beef Cattle	Feeder Swine	Breeder Swine	Poultry	Ducks 1/	Sheep	Horses	Catfish	People
	lb/day/1,000 lb live weight									
Manure	85 72–90	62 41–88	69 50–90	50	53 32–67	–	36 30–40	50 40–60	–	31.2
Total Solids	9.3 6.8–13.5	8.9 6.0–11.1	7.2 6.0–9.0	4.3	13.9 9.0–17.4	2/ 24 2/ 13–31	9.5 8.4–10.7	17.5	3.1 2.8–3.5	3.4 2.4–4.4
Volatile Solids	6.9 5.7–7.9	6.9 4.8–8.2	5.7 4.0–7.0	3.2	10.8 8.0–12.9	2/ 14.5 2 8.7–17.5	8.0 6.0–9.1	–	–	2.0 1.1–2.6
BOD_5	1.4 0.8–1.8	1.5 1.0–1.8	2.3 2.0–2.8	1.3	3.4 1.6–5.5	5.1 4.1–7.6	0.8 0.7–0.9	1.4	2.3 1.1–4.9	1.36 0.6–2.10
COD	8.4 4.2–13.3	7.9 6.6–9.0	5.9 4.7–7.1	5.2	12.5 9.5–15.8	–	10.0 7.5–12.0	–	–	3.12 1.0–3.5
Total Nitrogen as N	0.37 0.29–0.51	0.43 0.30–0.58	0.45 0.20–0.70	–	0.86 0.45–1.50	1.42 1.17–1.62	0.40 0.34–0.45	0.30	1.6 0.7–2.5	0.20 0.14–0.26
Total Phosphorus as P	0.069 0.026–0.100	0.090 0.023–0.170	0.17 0.09–0.27	–	0.40 0.20–0.75	0.62 0.4–0.9	0.075 0.040–0.120	0.12	0.25 0.24–0.26	0.024
Total potassium as K	0.20 0.08–0.35	0.23 0.11–0.38	0.25 0.10–0.60	–	0.35 0.12–0.50	0.9 0.6–1.2	0.32 0.24–0.40	0.25	1.5 0.7–2.4	0.064

Although there are built up areas on Long Island that do not shed storm runoff to any surface waters, the densest population centers are located in watersheds that discharge directly to the marine edge and to inland lakes and ponds. These watersheds share similar topography and soil characteristics. Highways and local roads are mostly depressed below the ground level and serve as the principal drainage channels for runoff water. Hempstead, Babylon, Islip, and portions of Brookhaven and Southampton towns all drain into Great South Bay and its tributaries.

The residents in the Great South Bay watersheds use garden sprays and fertilizers, and pet populations are apparent. Some residents were observed dumping dog waste and oil into storm sewer inlets. When questioned, most people demonstrated little awareness of the environmental impact of these

practices.

In the past thirty years the introduction of the recharge basin, a form of large excavated pit vertical drain, has provided for storm water discharges from most new subdivisions in Suffolk County and many in Nassau. An evaluation of the impact of waste carried into these recharge basins and its possible effect on groundwaters is not included as a part of this report.

Dogs and semi-wild ducks were found to be major sources of non-point pollution in the bi-county area. Market, ducks, horses, cattle, wild ducks and geese may be major sources of pollution locally, but vary widely in both volume and characteristics of the waste material.

Other sources of non-point pollution such as deer, seagulls, and miscellaneous wildlife were not considered because adequate waste information was not available.

6.1 ANIMAL POPULATIONS

Agricultural animals in the bi-county region are generally found in small groups and in widely scattered locations. There are an estimated 500 dairy cows and 1,300 other cattle and calves; 121,000 chickens; 26,000 turkeys; and up to 750,000 market ducks. Sheep number 120; swine, 635; and horses on agricultural units, 550 (U.S. Department of Commerce, 1976). The recreational horse population is estimated at 30,000 and the dog population, at 425,000.

6.1.1 Cats

Cats outnumber all domestic animals except dogs. In the course of homeowner interviews in selected study areas in the two counties, it was found that there were about 2/3 as many cats as dogs. If this ratio is valid, the bi-county area contains an estimated 285,000 cats. Neither the existing literature nor the SCS interviews gave any indication that cat fecal waste poses a surface water pollution problem.

6.1.2 Dogs

Dogs are generally found in high concentrations in suburban and vacation-recreation areas. Nassau and Suffolk Counties follow this pattern, encountering problems of overpopulation and limited dog controls. The actual number of dogs in Nassau-Suffolk can only be estimated, because a reliable census count has not been compiled.

The following paragraphs discuss some of the common estimating methods and the results obtained when they are applied to the bi-county area.

The New York State Department of Agriculture and Markets licensed 135,143 dogs in Nassau in 1975 and 121,795 dogs in Suffolk. The two counties alone account for almost 25 percent of the total New York State dog registration. The number of dogs licensed in the bi-county area can be

Table 6–3

STORMWATER RUNOFF: TOTAL COLIFORM AND FECAL COLIFORM CONTENTS

Drainage Area	Land Use	Total Coliform (MPN/100ml)		Fecal Coliform (MPN/100ml)	
		Range	Median	Range	Median
Baldwin	Medium Density Residential	43,000–11,000,000	230,000	4,300–430,000	43,000
Lake Success	Low Density Residential	43,000–11,000,000	430,000	2,400–2,400,000	43,000
Sagaponack	Non-Irrigated Agricultural	2,400–24,000,000	230,000	3.0–230,000	4,025
Wildwood	Irrigated Agricultural	74,000–24,000,000	830,000	23.0–93,000	1,470

assumed to be considerably short of the actual total number of dogs for several reasons: first, only dogs over six months of age are licensed; second, owners caught with unlicensed dogs are usually required to obtain a dog license without penalty (newer dog owners questioned perceived not licensing their dog as a reasonable gamble); third, the present basis for dog licensing, *i.e.,* the dog census, taken by local municipalities to identify those homes having dogs, is conducted in a way that does not best serve the purpose of dog licensing controls. Dog owners may not be at home or they may not report their dogs completely. The per dog fee paid to enumerators for taking the census is too small to generate a vigorous search for even a majority of the dog owners. A total of 287,951 dogs were enumerated in the bi-county area in 1976.

According to New York State Bureau of Dog Licensing, less than two thirds of all dogs are actually licensed (Kehrer, 1976). Applying this ratio to the license figures results in an estimate of 385,000 dogs. If the same ratio is applied to the 1976 enumeration figures, the estimate is 462,000.

The dog population can also be estimated using interview material from the detailed study of watershed areas. Between 33 and 40 percent of the homeowners interviewed in the study of five sampled areas reported dog ownership. Among dog owners, one in five, or 20 percent reported more than

one animal. If it is assumed that ownership patterns in the sampled areas are representative of those in the Island as a whole, and that the Nassau-Suffolk Regional Planning Board estimate of a total of 750,000 households is correct, then the bi-county dog population comprises between 300,000 and 360,000 animals.

Still another method of estimating dog populations was used by Beck (A. Beck, 1973). He suggests that human population numbers can be used as a basis for predicting number of dogs. A ratio of 7:1 for urban and 5:1 for suburban areas should be used. On the basis of Beck's ratios, the estimated 2,736,000 bi-county residents could be expected to own between 400,000 and 470,000 dogs. Dr. R.W. Johnson (1975) estimated that in 1975, in Nassau County alone, there were approximately 350,000 dogs.

The canine population is increasing rapidly. In fact, the dog population on Long Island and in the nation is expanding more rapidly than the human population. Anvik (1974) estimates that the nationwide rate is 4.5 percent per year. Djerassi, *et al* (1973), estimated that 2,000 to 3,000 dogs and cats are born hourly in the United States. Others have suggested that hourly birth rates may be as high as 10,000.

The number of stray dogs in an area has a strong effect on the growth rate of the canine population. Strays are defined as any dogs running loose, whether licensed or not. Dogs released temporarily by their owners are technically stray dogs.

This impact of strays is discussed further, and in detail in *The Ecology of Stray Dogs: A Study of Free Running Urban Animals* by A. Beck (1973). Hummer (1975) reports that a single fertile stray female dog can generate more than 400 additional female dogs in five years under ideal conditions. Strays are more common in the more densely populated suburban areas, probably due to a greater availability of food.

Table 6–4 provides recent dog license and enumeration figures, which may be used to estimate dog populations in Long Island municipal subdivisions.

In summary, the dog population of the bi-county area is between 300,000 and 500,000. For purposes of this report, 425,000 has been selected as the most likely number. Canine numbers are increasing at an estimated rate of over four percent per year. Stray dogs play a major role in these increases.

6.1.3 Wildfowl

Certain wildfowl population figures are available from the New York State Department of Environmental Conservation Mid-winter Aerial Wildfowl Census. For the Long Island area in January 1975, diving ducks numbered 56,200; other ducks, 17,100; geese, 4,800; Brant, 24,000; swans, 700; and Mergansers, 6,700. In 1976 total counts declined slightly, while in 1977, the numbers of wildfowl enumerated returned to 1975 levels.

Table 6–4

DOGS ENUMERATED AND LICENSED: NASSAU AND SUFFOLK TOWNS, CITIES, AND SELECTED VILLAGES

Municipality	Enumerated 1976	Licensed 1976	Village	Enumerated 1976	Licensed 1976
Town					
Hempstead	59,995	50,682	Atlantic Beach	482	222
North Hempstead	21,957	22,573	Bayville	613	613
Oyster Bay	30,525	29,048	Bellerose	128	130
			Cedarhurst	553	535
Cities			Centre Island	113	117
			Floral Park	1,629	1,522
Glen Cove	2,418	2,064	Laurel Hollow	320	325
Long Beach	1,953	1,874	Freeport	3,916	3,336
			Garden City	2,002	2,332
Town			Hempstead	3,250	2,593
			Hewlett Bay Park	84	79
Babylon	27,515	21,564	Hewlett Neck	71	64
Brookhaven	35,324	26,372	Lynbrook	2,258	1,926
East Hampton	1,683	2,302	Malverne	1,021	1,005
Huntington	18,175	24,687	Massapequa Park	3,075	2,727
Islip	39,811	23,206	Mill Neck	291	269
Riverhead	2,674	2,824	Old Brookville	336	300
Shelter Island	378	1,597	Oyster Bay Cove	436	439
Smithtown	12,633	11,894	Rockville Centre	2,124	2,238
Southold	2,747	3,066	Sea Cliff	896	807
Southampton	6,500	4,283			

THE FOLLOWING WERE ENUMERATED IN 1974 AND LICENSED IN 1975:

Village			Village		
East Rockaway	1,535	1,153	Lawrence	798	693
Farmingdale	640	621	S. Floral Park	131	140
Hewlett Harbor	208	197	Stewart Manor	267	309
Island Park	526	524	Valley Stream	3,763	3,598
			Woodsburgh	105	88

Total Enumerations 287,951 **Total Licensed 256,938**

The Federation of New York State Bird Clubs (1976) reports about 6,500 wintering Canada and snow geese. If it is assumed that a typical goose (Oneth, 1976) is four to five times the weight of a duck and has similar waste characteristics, it can be estimated that 100 geese produce 330 pounds of manure in a 24-hour period. This means that the total average wintering goose population produces 21,450 pounds of manure daily. Much of this is discharged directly into surface waters or adjacent to them.

Canada geese located on ponds along Merrick Road and the Sunrise Highway in Nassau County are changing their migration habits and are becoming year round residents, according to Dr. R.W. Johnson (1975). This change, which may be the result of feeding by man, sharply increases the waste loading from geese on these ponds. The greenskeeper at the Lake Success Golf Course reports fairway grass heavily damaged by the droppings of Canada geese living on and near the lake. Crop farmers in the Mecox Bay area report that certain farm fields are heavily manured by geese in fall and winter. Geese are attracted to the fields by the winter cover crops. Some of these fields shed storm runoff to Mecox Bay.

6.1.4 Semi-wild Ducks

White Pekin ducks that have been released, abandoned, or have escaped, and their descendants that are produced from interbreeding between the White Pekins and wild ducks are sometimes called "Indian Runners". These semi-wild ducks also include crosses between Indian Runners and wild ducks. The first and second generation cross breeds are too heavy bodied, 4.3 pounds and up, to sustain prolonged flight. They usually have a light tan appearance, pinto coloration, and large white patches on the neck, breast and tail. The male Indian Runner-Mallard cross usually has a black head; the female cross is without the distinctive black mask on the beak.

An accurate count of the semi-wild ducks on Long Island's inland ponds is not available. White Pekin ducks have been observed in the bi-county area on many ponds including Hook Pond in East Hampton, Westhampton Sanctuary, Barry Road Pond, Wading River Pond, Blydenburgh Park Pond, Argyle Lake, Stony Brook Mill Pond, Setauket Mill Pond, Cowen's Lake and the Peconic River. (See map at the end of this section).

The origin of the semi-wild duck population is largely related to the practice of giving baby ducklings to children at Easter. Park employees interviewed reported noticeable increases in the white duck populations within two months after Easter. An inventory of semi-wild duck populations on fresh surface waters in Nassau is currently being conducted by the Nassau Health Department (Natural Resources Defense Council, Inc., 1975). Inventory data was not available at this writing. John Renkavinsky, Fish and Wildlife Division, New York State Department of Environmental Conservation, estimated the inland pond wild duck population for Nassau-Suffolk at 18,000 (Renkavinsky, 1976).

A count of the semi-wild duck population is essential to help educate the public as to the need for the control of pet duck sales and the release of pet ducks. The Federation of New York Bird Clubs and/or other organizations might include such a count when they make their next annual bird count effort.

6.1.5 Horses

The Nassau-Suffolk Horsemen's Association, Inc. estimates that there are approximately 30,000 horses in the bi-county area. However, the Association officials, concerned about regulations, have been reluctant to locate or identify horse concentrations. Prior to 1973, the Cooperative Extension Service office at Riverhead attempted to locate horseowners in order to control an outbreak of equine encephalitis.

Response was limited and counts have since been lost. In 1973 the Riverhead staff of the SCS, in attempting to locate concentrations of horses of ten or more animals, contacted most of the large animal veterinarians within the bi-county area. Good cooperation was received. Only 4,000 horses were located in concentrations of ten or more animals.

The 1974 *United States Census of Agriculture* (1976), lists 60 farms having nearly 600 horses and the telephone book lists 25 commercial riding stables in Nassau County and about 50 in Suffolk. Two racetracks, Belmont and Roosevelt Raceway, house about 2,000 horses in season and half that number when the racing season is closed. Veterinarians report local areas in both counties—Muttontown, Brookville, East Patchogue, Oakdale, and Sayville among them—where the number of horse owning residents is well above the Nassau-Suffolk average. Horseback riding is a popular family activity in the bi-county area. The presence of more than 75 commercial riding stables and of many private clubs and horse farms indicates a prominent future for the Long Island riding horse.

In summary, there may be 30,000 or more horses in the bi-county planning area, of which probably less than 5,000 are housed in concentrations of ten or more. Approximately 25,000 horses are owned and housed in singles, pairs or small numbers, as a widely dispersed population of large animals. The dispersion of the horse population suggests that there may be many small non-point equine waste pollution sources affecting Long Island surface waters.

6.2 ANIMAL WASTE CHARACTERISTICS

Waste composition varies with animal age, breed, sex, and feed (Moore, 1970). For example, ducks produce about twice the daily volume of waste of humans, but more than five times the fecal coliform bacteria and more than 36 times the fecal streptococci. Tables 6—1 and 6—2 provide additional details regarding this variability. The following paragraphs describe the waste characteristics of dogs, semi-wild ducks and horses:

6.2.1 Dog Waste

The volume or weight of waste generated by a dog population can vary according to size, age, diet, and level of activity. Johnson (1975), concludes that an average Nassau County dog will produce a half-pound of feces and 3/4 quart of urine daily. Kramer (1971), estimates that 500,000 New York City dogs produce 110,000 pounds of waste on a dry basis each day. The half-pound of waste per dog per day value is regarded as conservative by veterinarians (Oneth, 1976).

A study in Saskatoon, Saskatchewan Canada (Anvik, Hyne and Rahaman, 1974), estimated that the city's 13,200 dogs produced 7,260 pounds of solid waste per day. It also estimated that 29,300 pounds of dog solid waste were on the streets of Saskatoon on March 30, 1973. A detailed study of a sample area of twenty of the city's 1,400 blocks provided the basis for these figures. Beck has reported that a large dog will produce 50 percent more waste than the average sized dog under similar conditions (Beck, 1973). Using 425,000 as the most probable number of dogs for the bi-county area, the SCS estimates that the total daily yield of dog waste amounts to about 106 tons of feces and 80,000 gallons of urine. This would amount to approximately 38,700 tons and 29 million gallons annually.

More documentation of the composition of dog waste is needed in view of its impact on Long Island surface waters. Generally dog wastes are high in nitrogen and are a source of coliform bacteria. The results of laboratory analyses of three collections in the Chicago area are shown in Table 6–5.

Table 6–5

ANALYSIS OF DOG DROPPINGS

Item	1	2	3
Water Soluble, mg/100 ml	16.5	20.2	178.3
Volatile Water Soluble, mg/100 ml	10.3	15.9	145.8
BOD_5, mg/g	78	377.3	300
COD*	200.7	552	720
Coliform, MPN/g	16,090	16,090	1,400,000

**Source does not provide dimension, assumed to be mg/g.*
Source: American Public Works Association; Water Pollution Aspects of Urban Runoff; USDI; Federal Water Pollution Control Administration; Washington, D.C.; January 1969.

6.2.2 Duck Waste

Certain specific kinds of ducks, other than commercial ducks and wild ducks cause pollution of surface waters on Long Island. They are the semi-wild White Pekin ducks and their descendants that do not migrate.

The amount and characteristics of waste produced by semi-wild ducks is similar to that produced by White Pekin ducks. Variations are due to differences in feeding, activity and age (Moore, 1970). Domestic farm reared ducks are known to be heavy feeders. During the first seven weeks of their lives they can consume 21 pounds of concentrated feed. Young semi-wild ducks can be expected to consume even larger volumes of food, since the food they eat is not concentrated.

Best estimates indicate that 100 semi-wild ducks on a typical park pond can produce 74 pounds of duck manure per day or 13.5 tons per year (Geldreich, 1969 and Wadleigh, 1968). A group of 100 semi-wild ducks would contribute about 207 pounds of nitrogen, 90 pounds of phosphorus, and 130 pounds of potash to such a pond each year. Each duck adds eleven billion fecal coliform bacteria to its watery environment each day.

Table 6–6, which shows the average amounts of the major nutrients contained in the daily waste per 1000 pounds live weight of humans, ducks, and chickens, facilitates comparison of the nutrient loadings attributable to each of these sources.

Table 6–6

AVERAGE COMPOSITION OF DAILY WASTE PER 1,000 LBS. LIVE WEIGHT

Nutrient (lbs.)	Man	Ducks	Chickens
Total Nitrogen as N	0.20	1.42	0.86
Total Phosphorus	0.024	0.62	0.40
Total K	0.064	0.9	0.35

Source: United States Department of Agriculture, Soil Conservation Service; Agricultural Waste Management Field Manual; Washington, D.C.; August 1975.

Duck waste is a concentrated pollutant. Table 6–7 confirms that bacteria and nutrient levels of White Pekin duck waste are especially high in coliform and nitrogen and exceed those of humans and chickens.

6.2.3 Horse Waste

An average horse produces eight to eleven tons of feces and urine per year (SCS), or, stated somewhat differently, a 1,000 pound horse will average 0.9 cubic feet of waste per day of which 65 percent will be water (Parr, 1974). Given the estimated 30,000 horses kept in the Nassau-Suffolk area, the expected daily waste production would be between 660 and 900 tons. Yearly horse waste figures probably total 300,000 tons, exclusive of bedding straw, chips or hay. By comparison, a human population of 2,700,000 people produces an estimated human waste total of 1,725,000 tons yearly.

Table 6–7

ESTIMATED PER CAPITA CONTRIBUTION OF INDICATOR MICROORGANISMS

Animal	Daily Production Fecal Coliform, (Million)	Fecal Strep., (Million)	Ratio FC/FS
Man	2,000	450	4.4
Ducks	11,000	18,000	0.6
Chickens	240	620	0.4

As indicated in Table 6–8, horse waste is relatively low in five day biochemical oxygen demand (BOD_5) and higher in phosphorus than most other animal wastes.

Table 6–8

AVERAGE COMPOSITION OF ANIMAL MANURES
lbs/day/1,000 lbs. of live weight

	Horses	Ducks	Poultry	Cows	People
BOD_5	1.4	5.1	3.4	1.4	1.36
N-Nitrogen	0.30	1.42	0.86	0.37	0.20
P-Phosphorus	0.12	0.62	0.40	0.069	0.024
K-Potassium	0.25	0.9	0.35	0.20	0.064

Source: United States Department of Agriculture, Soil Conservation Service; Agricultural Waste Management Field Manual; Washington, D.C.; August 1975.

Horse feces generally contain a higher percent of undigested nutrients than that present in human wastes. The waste from a single horse contains eleven times the BOD of an average human. The 30,000 horses in the bi-county area produce waste having the equivalent BOD_5 of 330,000 people.

6.3 ANIMAL WASTE IMPACT

In any animal waste management planning and control program, careful attention must be paid to the extreme variability in both volume and characteristics of the animal waste in question. The following paragraphs discuss actual and potential impact of wastes from dogs, ducks, and horses in the bi-county area.

Burge (1974), in his consideration of health hazards associated with animal waste, concludes that the incorporation of manures into farm fields lowers the impact of animal wastes on the environment and provides a sound and reasonable disposition of animal waste. Feces deposited on grassy soil areas are reduced by sunlight and air, and are less likely to be washed away by storm water. Soluble pollutants and bacteria are more likely to be washed into the topsoil layer where pollutants are consumed, impounded and recycled.

Recent studies indicate that if proper management is followed, manures can be applied to land on a year-round basis to achieve a lowered environmental impact. Young and Mutchler (1976), report that less than three percent of the total nitrogen and four percent of orthophosphate in manure ran off of manured, sloping land during the winter when it was fall plowed preceding the application. This contrasted with sixteen to twenty percent of total nitrogen and orthophosphate in the runoff from similarly treated grassland. It is concluded that level, or nearly level, fall plowed cropland can effectively retain animal manures that are applied to frozen ground if such procedure is necessary to control or reduce pollution from animal waste accumulations over winter. At other times spreading and plowdown or soil injection of animal waste slurry is appropriate for land application of animal wastes.

6.3.1 Dog Waste Impact

Dr. P. M. Schantz (1976), of the Center for Disease Control, Atlanta, Georgia, has stated that there is "a potentially important public health problem as a result of the increasing numbers of stray dogs in urban areas..." Marron *et al.* (1974), found that at least thirteen diseases are transmitted to man by parasites in dog feces, including salmonelloses, tuberculosis, toxoplasmosis and visceral larval migrans.

Beck and others (Beck, 1973; Burge, 1974; and Johnson, 1975) have commented extensively on the problem of dog feces in public areas as it relates to pollution and health. Dogs assimilate only 30 to 50 percent of their food, providing food for rats in their excrement. Dogs are attracted to beaches and parks by the food scraps.

Dog urine causes cankers and other damage to trees and thus increases landscape maintenance or replacement costs (Hummer, 1975).

In 1973, James Redman (1973), Aquatic Biologist for New York State Department of Environmental Conservation (NYSDEC) at Stony Brook, reported that, "Storm water runoff has been directly responsible for most of the recent closures of shellfish growing areas. Results of these (urban land runoff) sample examinations demonstrated conclusively that this (runoff) material transports large numbers of organisms. Methods should be developed for diverting urban runoff from estuarine waters."

Redman analyzed a number of street runoff water samples for fecal coliform and fecal streptococci. Microbiologists generally agree that the fecal coliform content of human waste will be more than two times the fecal streptococci content. In animal waste, it is usually the reverse. A majority of Redman's samples showed the fecal strep to be more numerous, supporting the contention that animals are the major source of the fecal coli in storm runoff.

The example of a single southeastern Nassau village lends further credence to Redman's findings. Residents of Massapequa Park have 2,727 licensed dogs. Application of the previously described estimation techniques indicates that the total dog population comprises 4,090 animals producing some 373 tons of solid animal waste annually. This village sheds or diverts most of its storm drainage water to South Oyster Bay. Using the Saskatoon, Canada figures cited above (Anvik, Hyne and Rahaman, 1974), an estimated 9,000 pounds of solid dog waste is present at any particular time on the streets of such a village. Much of this will be flushed into the Bay by the next major rainstorm.

6.3.2 Duck Waste Impact

The duck waste impact includes pollution from domestic duck farm operations, from the White Pekin duck that has been released or abandoned, and from the wild duck population.

6.3.2.1 Duck Farm Operations. Major changes in duck farm operations are now taking place. Discharges of treated wastewater have decreased from more than 6,000,000 gallons per day in 1972 to less than one-third of that amount in 1976. Storm runoff which formerly flowed through the farms is now largely contained or will be by mid-year. A few farms have already eliminated wastewater discharges completely. Solid waste consists of sludge from treatment lagoons, scrapings from pens, and straw and manure cleaned from buildings. Building manure is taken or given to gardeners or spread on cropfields. The sandy pen scrapings are frequently used as fill within the closed system. Some farmers cover rather than scrape. Lagoon sludge is removed and trucked away by cesspool cleanout firms. The SCS believes that this sludge should be applied to agricultural land as a valuable soil amendment. However, specialized manure handling equipment is needed.

In the United States as a whole, land application of duck wastes, including partially treated duck process waste water, has been considered the generally appropriate and available method for waste disposal for the duck industry. However, on Long Island fewer than five farms have sufficient land for such a procedure. Only about half the duck farms are so located that nearby vacant land, which could be combined with owned land to provide sufficient acreage for irrigation of the waste water, is available for sale or lease.

If correct management is followed, animal waste can be disposed of by applications on a year-round basis without adverse impact on ground or surface waters. (Graber, 1974; Moore, 1970; Parr, 1974; SCS, 1975; Wadleigh, 1968; Young and Mutchler, 1976; and Burge, 1974). Because of variations in soil, slope and waste characteristics, adjacent land use, and other factors, each application site requires planning on an individual basis. Conservation plans, as prepared for farm operators by the SCS working through the Suffolk County Soil and Water Conservation District, can include such planning.

The SCS classifies soils by "hydrologic groups". Knowledge of these groupings can provide guidance for proper management of irrigation waste water. Soils in Group "A" are moderately rapidly permeable sands, have limited internal surface area, limited absorption capacity and base exchange capacity. Soils in Group "B" have 30 to 80 percent fines, are moderately slowly permeable and have greater runoff potential than the "A" soils. Soils in groups "C" and "D" are not common and are of little significance on Long Island. Although "B" group soils are present in the bi-county area, they are not usually found on or near existing duck farms, an important factor in planning waste application rates.

A combination of waste water management measures is probably the best approach to the achievement of zero discharge that is available to duck farmers today. These measures should include the treatment and recycling of wastewater in periods of no precipitation, and irrigation of wastewater on managed hayfields after storms. To accomplish this, water use flows must be cut to the minimum during and after periods of rainfall. Adequate storm water holding ponds or holding areas should be developed. Continued operation of present treatment systems would be necessary, but without discharges to receiving waters. In most cases irrigation equipment and land would have to be added.

Another option for waste waster disposal involves the use of the marsh-pond waste treatment system, pioneered by Maxwell Small of Brookhaven Laboratory and the Town of Brookhaven. Approximately sixteen of the present duck farms do have sufficient land for such a facility. Marsh-pond treatment is designed to produce a high quality effluent appropriate for high rate land application.

An additional and as yet unattractive alternative for duck farmers is duck production without waste water. So far, this has been tried without economic success, making this option uncompetitive and unsuitable at the present time. The nationally renowned Duck Research Laboratory at Eastport would be the logical institution to undertake further research on the question.

Relocation of duck farms to interior areas of Long Island has been suggested. However, studies to determine the impacts of such a relocation on the movement of nitrogen and other pollutants through the soil are needed before relocation can be endorsed.

If the completely dry operation concept were to become fully and economically feasible, relocation, if it were still necessary, would then become more realistic. Such an operation requires continuous housing, which has been particularly unsuccessful with the "breeder" ducks that produce the eggs for starting new ducklings every seven weeks.

6.3.2.2 Semi-wild Ducks. The White Pekin pet duck that has been released or abandoned onto a public pond is dependent on feeding by humans for survival. It is common to see parents bring their children to feed these ducks at local ponds. Unable to fly in search of food, the semi-wild duck

becomes an aggressive beggar, making the act of feeding more rewarding for children. Such feeding sustains high duck populations, promotes growth, and indirectly, pollutes the pond. The Nature Conservancy recognizes that the feeding of wildlife creates this kind of problem and prohibits feeding at its sites on Long Island. Artifical feeding also alters the eating and migrating habits of wild ducks that visit the pond.

Ducks have an aquatic orientation and their waste is deposited directly into or near surface waters. Ponds, especially in residential areas, are under particular stress. Extraneous inflows such as those from urban storm runoff are often rich in nutrients that stress the ecosystem. Any unnecessary duck waste can further upset a pond's nutrient balance and can be responsible for production of excessive algae and weeds and the presence of high coliform counts.

Numerous diseases are communicated to animals and man via waters contaminated with duck wastes. These duck related diseases include the following: Salmonella, Psittacosis or Ornithosis, Type A Influenza, Yoba I Virus, Eastern Equine Encephalitis (E.E.E.), Schisosomiasis (Swimmer's Itch) and New Castle Disease. All but Eastern Equine Encephalitis can be passed to humans through waste contaminated water (Burger and Maher, 1977).

Swimming at Hempstead Harbor beaches was recently jeopardized because of high levels of coliform (8,000–10,000 MPN/100ml) at the outfall of Rosyln Park Pond. The large duck population, over 500 birds on the pond, was deemed responsible for the high coliform counts. In addition to chlorinating the pond outflow, the town officials transplanted ducks from this pond to other town ponds. The population of "Indian Runners", sustained in large measure by hand feeding, had grown so rapidly that, in effect, a pollution problem was transplanted along with the ducks. The present resident duck population at Roslyn Park Pond is now estimated to include over 100 White Pekins.

6.3.2.3 Wild Ducks. The wild duck populations of Long Island are a cherished part of our wildlife heritage. Much of the general public is unsympathetic toward the duck hunter, insisting on strong enforcement of federal and state laws that limit duck hunting. These same protective attitudes toward ducks reinforce the concept of feeding semi-wild ducks on inland ponds.

To a degree, wild ducks pollute bays and ponds. Brandvold, *et al.* (1976), in their study of the influence of wild ducks and waterfowl on surface waters, concluded that large migrating populations increase the available nitrogen and phosphorus compound and cause increased oxygen demand.

6.3.3 Horse Impact

Although it is comparatively easy to prove that there are a large number of horses producing vast quantities of waste that constitute a serious threat to Long Island surface waters, it is not possible to criticize the average horse owner for waste mismanagement. The relatively few known concentrations of waste are managed relatively well, with most stable waste stored away from storm runoff wash, and most accumulations faithfully picked up by gardeners, farmers or trash collectors.

At Belmont and Roosevelt Raceways, stables are cleaned daily and a large amount of straw is used to absorb waste liquids. The waste is stored in bins, one for every 26 horses, and these are emptied twice each week. The manure is loaded on trucks and shipped daily to mushroom farms in Pennsylvania.

Commercial riding stables usually stockpile manure out of sight behind buildings and provide some rainfall runoff protection. Some owners lime the manure or use a fly repellent. The waste is given to gardeners, nurserymen or farmers. The demand seems to exist the year round. No large piles were observed at the stables visited.

There have been isolated instances of complaints about commercial stables and stable owners expressed concern over their neighbors' past complaints to the local health department. Such complaints had been followed by a visit from the health inspector, who provided guidelines for cleaning up the nuisance.

Most local governments issue a general business license to commercial stables. The license evidently has no connection with waste management or complaints. However, some riding stable owners expressed concern that the license might be used to limit their activities in the future.

During this study, horses were observed in a variety of locations—in garages, backyards, woodlands, near ponds in residential settings. In isolated cases runoff from small paved surfaces having horse waste was seen draining into surface waters. The field staff only occasionally observed situations where storm runoff washed horse waste onto the drainage ways of neighboring properties.

Manure applied to nearly level to gently rolling grasslands at the rate of ten to 30 tons of dry waste per acre per year presents little or no hazard from nitrate runoff or leaching. Applications in excess of 30 tons per year can result in potentially harmful nitrate leaching (Parr, 1974).

6.4 ANIMAL WASTE CONTROLS

The Federal Water Pollution Control Act, 1972 Amendments, (PL 92-500) and subsequent EPA guidelines and standards as published specify those animal feeding operations that are subject to permit regulations:

> "Only an animal feeding operation defined as concentrated animal feeding operations is subject to the permit requirements. Such an operation occurs where: (1) more than 1,000 animal units are confined and there is a discharge of pollutants more frequently than that resulting from a 25-year, 24-hour storm event; (2) more than 300 and less than 1,000 animal units are confined and there is a discharge of pollutants into navigable waters more frequently than that resulting from a 25-year, 24-hour storm event through a man-made device or directly into

navigable water flowing through a feedlot; (3) there are 300 animal units or less confined and the Director of the State Program, after an on-site inspection, determines that pollutants are discharged into navigable waters through a man-made device or directly into navigable waters flowing through a feedlot." (Final NPDES regulations from the March 18, 1976 Federal Register on concentrated animal feeding operations.)

The New York State Sanitary Code classifies animal wastes as both offensive material and sewage when the animal wastes are water borne. Section 17-0105, Article 17, of the State Environmental Conservation Law, defines sewage as the "water-carried human or animal wastes from residences, buildings, industrial establishments or other places together with such ground water infiltration and surface water as may be present...." This section of the law together with related health rules and regulations provides a limited basis for the control of animal waste pollution by designated state and local agencies. However, the definition of "sewage" does not specify a lower limit of animal waste concentrations. Street runoff carrying dog waste components may be "sewage" under the law.

California, Iowa, Maine, Nebraska and Ohio, states with substantial animal husbandry, have passed laws or rules and regulations controlling disposal of farm animal wastes and have developed guidelines for land disposal and/or irrigation of liquid manures. However, no state laws were found to deal with wastes from dispersed animal populations.

The California State Water Resources Control Board has issued guidelines for the disposal of animal wastes to protect water quality and prevent other problems. Storm water management devices must be designed to accommodate the flow from a 10-year frequency, 24-hour storm. Storm runoff must not flow through manure storage areas on farms or other animal enterprises.

Iowa considers land application of animal wastes the primary means of disposal. The Water Quality Commission has formulated a policy giving recommended application rates and time of application. It includes a procedure to be used on land near watercourses that are subject to ten year frequency flooding.

Maine has developed guidelines for animal waste disposal, which, although they do not have the effect of law, are cited as references in municipal ordinances. Conformance with the guidelines is required as a condition of approval for large farm development. The guidelines specify time and rates of application of waste and of waste spreading with regard to water courses or water supply sources. Soils and slopes receive special attention. Conditions for manure piling and lagoon liquid manure disposal by irrigation are covered. Commercial fertilizer relationships are suggested.

Nebraska has rules and regulations primarily addressing animal waste disposal from point sources with no consideration for waste from pastures or rangeland. Rule No. 20 of "Rules and Regulations Pertaining to Livestock Waste Control" focuses on proper storage and disposal concentrations of animal waste to prevent water and land pollution. It includes a prohibition of manure spreading on frozen ground, and, therefore, represents a degree of animal waste control that reduces non-point source pollution.

Ohio's sediment and animal waste control law provides for implementation of non-point source control through soil and water conservation districts and locally prepared conservation plans (Unger, 1976). A Livestock Waste Management Guide has been prepared to assist an owner in the selection of a waste handling system. It deals primarily with cattle and swine, but some mention is made of horses. Specific mention is made of rainfall runoff. The value of manure as a source of plant nutrients, *i.e.,* as fertilizer, is stressed.

Present New York State and local health regulations that permit the control of offensive material provide that upon receipt of a complaint, a health department representative may investigate and cause a hearing to be held relative to a "nuisance", and may subsequently require the abatement of such nuisance.

Except for the 28 duck farms, Suffolk and Nassau counties have fewer than twenty commercial livestock or animal husbandry farm operations. Very few abut surface waters. Accumulated animal wastes are managed in accordance with present controls. These controls appear to be sufficient to prevent serious or repeated animal waste pollution from livestock farm operations in the bi-county area. The following paragraphs describe existing and proposed controls affecting dogs, ducks and horses.

6.4.1 Dog Controls

The first New York State Dog Control Law was enacted in 1917. This law, which superseded local laws that were considered ineffective, was a licensing law intended to protect domestic animals from dogs and to create a fund to compensate the animal owners for damages caused by dogs (Kehrer, 1975 and Renkavinsky, 1976). The 1929 revision to the New York State Dog Control Law included authority to impose restrictions on the keeping and running of dogs at large. Dogs are the only animals required to have a license in New York State.

In 1973, the New York State Department of Agriculture and Markets proposed a revision of the 1929 dog licensing law to achieve more effective dog population control. Many of the suggested changes were strongly opposed by dog owners during a series of emotion-filled public hearings. Notwithstanding their apparent unpopularity, the same law change proposals have merit today. The 1973 proposed law included the following provisions, none of which were enacted (Kehrer, 1975):

1. Substantial increases in fees for fertile dogs, with moderate fees for sterilized dogs.
2. Ear tattoos for identification (as now used with cattle).
3. Electronic data processing for licenses and enumeration, to be sup-

plemented by the existing animal control officers, who would also register new dogs.

4. Provision to allow witholding of dog control funds from any municipality failing to adequately control and enumerate their dogs.

The shortcomings of the present law are revealed in part, by the above proposals for change. Local units of government are supposed to hire dog enumerators to canvas an area and to list all dogs. Dog census takers are paid 50 cents per dog counted. Dog owners may not be contacted, or may not acknowledge all their dogs, or the census taker may lose interest when not enough dogs are found per hour of work.

The Dog Control Laws enacted recently on Long Island deal primarily with the nuisance of dog waste on streets and lawns, and usually require dog waste clean up. Dog waste related complaints are common. Nassau County Health Department reported 550 animal waste related complaints during 1975, and an expenditure of $32,000.00 in salaries to service them (Cooperative Extension Service of Suffolk County, 1975).

Local leash laws are designed to prevent dogs from running loose, causing damage or a nuisance, or threatening the public. All towns and villages in Nassau and Suffolk counties except the Town of East Hampton reported having a leash law. East Hampton and Southampton Towns ban dogs from beaches and Hempstead Village, Valley Stream, and Roslyn exclude dogs from parks.

Dog curb laws may have a negative effect on the environment. East Hills and Rockville Centre have dog curbing laws requiring that owners walking dogs allow their pets to defecate only at or near the street curb. In theory, the waste will then be swept up by street cleaning operations. In fact, animal waste in or near the road is easily flushed into the storm drainage system by rainstorm runoff. The drainage system empties into bays and estuaries, recharge basins, etc.

Dog cleanup laws, discussed subsequently, are one alternative to simple curbing ordinances. Other alternatives found in literature searched included dog toilets, or grassed areas near apartment buildings (probably would become offensive); punitive license fees, including a WCBS editorial suggestion of $1.00 per pound of body weight; waste areas at parks, authority for dog wardens to shoot free roaming dogs on sight; authority to require neutering of captured dogs before being returned to a claiming owner; etc. It was concluded that none of the above had sufficient merit and/or appeal to receive popular support.

Residents of Eastern Suffolk County are concerned about summer vacationers who often acquire dogs and then leave them behind upon their return "to the city". It was frequently suggested that dogs belonging to temporary residents be required to have an ear tattoo and be registered.

Dog controls are a highly emotional subject, as evidenced at numerous public hearings on dog laws. Strong leadership at the county and regional level may be necessary to bring about significant improvements in dog waste management.

6.4.2 Duck Controls

Duck farm animal waste disposal is regulated by Federal and State laws. Under those laws, duck farms are required to achieve zero discharge of wastewater to any receiving surface waters by 1983. A majority of the present Long Island duck farmers now plan to meet this requirement.

Wild duck population numbers are affected to a degree by Federal and State regulation of hunting. The Federal law sets hunting seasons, bag limits and areas where lead shot may not be used. State and local laws may further specify areas where hunting is prohibited or limit hunting in other ways. The overall effect is to protect and stabilize migratory waterfowl populations. Long Island tidal wetlands have been classified as "The most important coastal waterfowl area in the North Atlantic States" (Natural Resources Defense Council, Inc., 1975).

Semi-wild ducks are not specifically controlled or protected by law. The State law, authorizing towns and municipalities to establish dog catchers as peace officers with certain police powers, is not clear as to whether such persons can enter properties to capture and remove semi-wild ducks. Property owners can, under this law, have the town or municipality receive and impound the ducks which an owner removes from his property.

The Soil Conservation Service has found no law or section of a law that can be construed to support the contention that semi-wild ducks are a public nuisance. However, Article 26, Section 354 and Article 25B, Section 35 of the Agriculture and Markets Law do address aspects of the problem. The first, which attempts to discourage the sale of baby ducks for pets, states that, "No person shall sell, offer for sale, barter or give away live baby chicks, ducklings or other fowl under two (2) months of age in any quantity less than six" (Berman, 1970). In attempting to solve the problem of domestic ducks polluting local ponds, these laws may have complicated the issue by encouraging larger purchases. The second, which applies to dogs and other animals as well as ducks, states that: "The owner . . . of an animal, who abandons such animal . . . is guilty of a misdemeanor, punishable by imprisonment of not more than one year or by a fine of not more than $500 or both."

6.4.3 Horse Controls

The present primary document for statewide control of horse waste is the New York State Public Health Law, which cites animal wastes as sewage when they are water borne, whether carried by storm runoff or baseflow seepage, and as a public nuisance when the waste is offensive to neighboring property owners. Upon complaint, a health department representative may investigate, cause a hearing to be held relative to the nuisance, and require the abatement of the problem.

Zoning ordinances are often used to control the keeping of horses and, indirectly, the related problems. In the more densely populated areas in western Nassau County, such ordinances frequently prohibit the stabling of horses or limit such activities to a few selected locations.

Babylon Village and others require a special permit. In Smithtown,

where larger lots are more common, one horse may be kept on half an acre and up to three horses on one acre of land. Southold and Brookhaven allow no more than two horses on one acre of land. The Islip Town Board recently passed an ordinance prohibiting keeping a horse on less than half an acre of ground or more than two horses on each additional half an acre. Horse owners must provide stables with no less than 50 square feet of space, covered containers for manure, rodent-proof feed storage places and at least 400 square feet of outside corral space "enclosed by a suitable fence" ten feet from the property line. A $5.00 two-year license for each horse is required.

Methods for handling waste disposal are specified in Smithtown, Brookhaven and Islip ordinances. Closed waterproof containers away from property lines are required for manure storage. Huntington requires tertiary treatment of wastewater at dairies and commercial stables, unless served by the municipal sewage system; but has no regulation for horse manure disposal from private residences.

Outside the New York area, the Ogden, Utah and Greenwich, Connecticut codes prohibit the housing of horses or other large farm type animals or their waste, within 75 feet of a public street, drain or body of water.

6.4.4 General Recommendations

Recommendation I: Require that each landowner having concentrations of animals that exceed those stated in the table below, have a soil and water conservation plan.

Table 6—9

MAXIMUM ANIMALS PER ACRE OF OPEN LAND WITHOUT A CONSERVATION PLAN

Equine Livestock	2	Hogs	14
Beef Cattle	3	Ducks	400
Dairy Cows	2	Sheep	24
Turkeys	160	Dogs	20
Chickens	500		

or any combination of animals exceeding 2,000 lbs. of body weight.

Source: Federation of New York State Bird Clubs, New York State Waterfowl Count; rough work sheets; January 1976.

Under present State law, almost every agricultural producer must obtain a soil and water conservation plan by January 1, 1980. An amendment to the Soil and Water Conservation Districts Law, Chapter 441, of the Laws of New York 1975, directed the New York State Soil and Water Conservation Committee to define the lower limits of animal concentrations for concentrated agricultural operations. Table 6—9 above, quotes the figures that were adopted for all animals except dogs. This item has been added in response to local needs. The above recommendation will extend coverage to non-agricultural animals whose owners maintain high concentrations of animals per acre.

Chapter 441 describes a soil and water conservation plan as a "document containing proposals for the conservation of soil and water resources, and which provides an orderly method for landowners and occupiers to follow in limiting soil erosion and reducing the amount of pollutants entering into the waters or on the lands of the State of New York".

Soil and Water Conservation Plans are prepared for any requesting landowner or operator, by the local Soil and Water Conservation District. There is no charge for the services, which are subject to the limits of staff availability. Districts will determine priorities. Plans must meet USDA, SCS Conservation Planning Standards. Plans may be prepared by others as long as they are reviewed and approved by the District.

Conservation Districts historically give high priority to plan requests that result from animal waste problems. Health officers investigating an animal waste problem can refer property owners directly to the local Conservation District for such a plan. Implementation and installation of planned pollution control practices are the responsibility of the landowner or operator.

The amendment to the Soil and Water Conservation Districts Law cited above makes no provision for plan implementation and enforcement. Enforcement of provisions of the Conservation Plan should be by those local agencies now charged with regulating animal waste nuisance abatement. These agencies include the State DEC, the county health departments, environmental control agencies and town conservation agencies.

Recommendation II: Request the USDA Agricultural Research Service and/or others to conduct research to establish safe and effective methods and rates for land application of duck waste water on Long Island soils.

Research needs to include the following:

1. Investigation of the efficiency of marsh-pond duck waste water treatment in obtaining a high quality effluent for land application.
2. Monitoring of nitrogen movement and denitrification near duck pens.
3. Investigation of methods to enhance the economic feasibility of continuous housing of breeder ducks.

6.4.5 Dog Recommendations

Recommendation I: Repeal ordinances that require the curbing of dogs in order to reduce dog waste pollution.

Curb your dog ordinances, specifying that the curb area of a street is the proper place for dogs to defecate, have a negative effect on the environment in most watersheds. These laws encourage dog defecation and urination on or near impervious street surfaces. Part or all or such curbed dog animal waste is usually flushed into the storm water collection system to pollute nearby receiving surface waters.

Albert C. Jensen, of the Division of Marine and Coastal Resources, New York State Department of Environmental Conservation, writes: "We believe that a major source of the coliform bacteria in street runoff is the feces of dogs and other animals. An informal survey of the Great South Bay watershed indicated a population of 80,000 to 100,000 dogs . . . approximately ten tons of dog feces per day impacting the ecosystem of the bay." (Jensen, 1973).

Dog curbing laws may not withstand court appeal. For example, an Essex County, New Jersey court decided that a local dog curb law is "unreasonable, arbitrary, and dangerous" (Knapp, 1972). The Essex (N. J.) County Court held, in October 1971, that,

> "a New Jersey ordinance requiring a dog owner to remove excrement and dispose of it in a sanitary manner constitutes proper exercise of police power, but portion of the ordinance requiring the dog owner to curb the dog in the street is invalid, since it exposes the owner and dogs unnecessarily to the dangers of vehicular traffic."

The decision reads, in part:

> "There was a time when dog owners loved their animals as pets, but today we find that such large dogs are being employed extensively for security purposes as well, because of the alarming increase in crimes of violence. The tons of solid waste and urine that are daily deposited by dogs have undeniably fouled our streets, our walks and parks to the extent that it has become well-nigh intolerable, threatening the health and safety of our citizens."
>
> "Persons stepping into dog feces on sidewalks or in street while crossing, or when entering or alighting from automobiles, can easily carry it on their shoes, and thence into their homes. Infants crawling about a rug or floor upon which such animal feces have been deposited may ingest them, since young children, especially babies, are known to be constantly placing their fingers into their mouths. Following a heavy rainfall, dog feces are known to find their way into sewers, along with other litter and debris."

The laws governing municipalities for N. J. hold that,

> "The right to the possession of dogs in a municipal corporation is subject to the limitation that such possession must not interfere with the health, security, and comfort of the other inhabitants of the corporation."

The use of the street-curb area for the deposit of dog waste can be further evaluated by comparing the rainfall runoff coefficients for lawns with those for pavement. Solid wastes are not easily flushed from sod areas by storm flows. During a three and one-half inch rainfall (two-year frequency, 24 hours storm) typical Long Island lawns shed only one-seventh (1/7) the runoff water as paved areas of equal size.

Recommendation II: Prepare a dog cleanup model ordinance *for inclusion in the 208 Plan recommendations and urge the adoption of this ordinance by municipalities having an average density in excess of 100 residences per square mile (or other appropriate ratio).*

Such a model ordinance should contain clauses that would accomplish the following:

1. Prohibit owners from permitting dogs to defecate on roads, sidewalks, parking lots, play areas, parks or other places where people congregate, unless there is prompt cleanup and removal of feces.
2. Prohibit the free roaming of dogs, with or without license and collar, except as expressly permitted by the landowner involved.
3. Call for the sanitary disposal of feces collected during cleanup.

The model ordinance should provide penalties for failure to comply, but make it clear that the dog owner's property is exempt from the cleanup requirement. It must provide some guidance for disposal of the cleaned material, such as public or commercial trash collection or shallow pit composting. However, the emphasis of the ordinance should be on dog control and the cleanup of solid waste from impervious surfaces that shed storm runoff to a public storm drainage system.

The primary objective of such an ordinance is the development of constructive public attitudes toward the control of dog waste in public places. If serious attempts at enforcement are to be considered, then such an ordinance will benefit from a "presumptive evidence" clause, wherein the person walking a dog shall be presumed to have no intention of cleaning up after the dog if he or she fails to carry appropriate clean up equipment.

The Soil Conservation Service feels that the clauses outlined above can adequately meet the needs of a community for managing dog waste in public places. However, local residents may desire additional clauses in the law to control dog damage to residential lawns and other property.

Several villages on Long Island have passed dog waste clean up laws. Malverne was the first, followed by Freeport, Great Neck, Hempstead, Valley Stream, Westbury, the Town of Smithtown, Rockville Centre, Great Neck Estates and Ocean Beach. Stewart Manor also has a cat ordinance. In Malverne in the last five years, between 175 and 200 summonses have been

issued, bringing fines as high as $25. The ordinance permits fines up to $250. Valley Stream passed its dog waste pickup ordinance a year ago, hired a part-time person to enforce it, and has issued summonses. Complaints have diminished since enforcement began.

Probably two-thirds of dog owners "put the dog out" to defecate at least part of the time. Data gathered in the five study areas for this report showed that only 40 percent of the owners said they leashed and walked their dogs.

Recommendation III: Revise dog licensing procedures under the NYS Agriculture and Markets Law, as follows:

1. Provide that first and second dog-related offenses may be handled administratively, without court proceedings.

2. Provide that local units of government be allowed to increase dog licensing fees: (a) to cover their dog-related expense and (b) to discourage fertile dog ownership.

3. Provide a record of dog-related offenses.

Administrative rather than judicial proceedings are needed to handle summonses related to dog control. Court calendars are crowded, especially in larger jurisdictions. Dog defecation cases are usually given low priority. Some law enforcement officers interviewed reasoned that dog-related offenses were not of much importance, since they were seldom given court hearing time. If an unlicensed dog is picked up, but returned upon purchase of the standard dog license, there may be no incentive to relicense the dog the following year. Under an administrative procedure, a set fine for failure to license dogs could be imposed. Automated, computerized dog licensing is needed to keep track of dog owner offenses effectively, thereby making it possible to increase penalties for repeat offenders. Such a record is a key element in dog control law enforcement and a major factor in dog waste management.

In 1971 the Town of Islip licensed 22,135 dogs and obtained $42,276 in license fees. Townwide dog control expense that year came to $296,000. For Babylon, the figures were 20,185 dogs licensed, $39,186 in fee income, and $75,000 in dog control costs.

An increase in fee differentials between sterilized and fertile dogs of either sex can help to reduce the number of unwanted dogs. Present fees, set in 1929, are $2.35 for a male or spayed female and $5.35 for an unspayed female. In 1929, spaying a bitch cost little more than the license fee differential, and that difference was sufficient to provide a large incentive for spaying. Today, dog neutering costs range from $30 to $80.

Recommendation IV: Fund a continuing public information program through the appropriate county environmental control agency to make dog owners more aware of their responsibilities.

Dog owners need frequent reminders that dog waste in streets pollutes; pet abandonment is a crime; their dog's waste in public places is their responsibility; failure to license a dog is wrong; and clean up is the law in some communities. The proposed public information program should extend to schools and other organizations.

Interviews of dog owners, conducted in the five study watersheds generally indicated that few if any dog owners had any idea that dog waste is a substantial source of storm runoff water pollution. More than 50 percent of the owners interviewed admitted they routinely released their pets; that they were not aware that a released dog was technically a stray dog; and that their action was, therefore, illegal in municipalities with leash laws.

Recommendation V: Provide partial funding for dog neutering programs in critical watershed areas; use increased license fees for fertile dogs to help defray costs. (The latter part of this recommendation would depend on the adoption of Recommendation III).

Anvik (Anvik, Hyne and Rahaman, 1974) reports dog and cat populations are expanding more rapidly than the human population, due largely to the numbers of stray animals. The Town of Brookhaven has already proposed the funding of a neutering program in their capital budget. The Town of Islip is preparing to set up a subsidized program of pet sterilization. Nassau County is also considering proposals for pet sterilization. "Critical Watershed Areas" are those municipalities with high density land areas (*e.g.,* more than 100 homes per square mile) shedding storm runoff to shellfish or recreation-use waters.

The probable dog population of the bi-county area is 425,000 animals. A sizable percentage of these dogs are not sterilized. It is probably too costly to subsidize an area-wide dog sterilization service. Therefore, a base map should be developed showing major land areas that contain critical watersheds. Dog owner residents of these critical watersheds should have first priority on available funding.

Whether or not to fund the sterilization of male dogs can be debated. It is doubtful that reducing by one-half the number of fertile males in an area would actually reduce dog pregnancies. The probability would always exist that a small but effective number of fertile males would be attracted to the female in heat. However, the public educational value of both male and female dog sterilization is recognized. Public support for controlling dog numbers is thought to be needed for any effective dog waste management program. Islip Town representatives, knowledgeable about their own neutering program, and leaders from other communities with dog neutering programs strongly support sterilization of both sexes, primarily for the educational value.

During our interviews with local officials, we learned that veterinarians have objected to continuous employment at dog sterilization clinics, preferring to work at more mixed activities. The cost of establishing these clinics was also considered objectionable.

Suggestions were received from interviewees urging the financing of dog neutering clinics through a local tax on pet food. It was also proposed

that animal shelters be required to offer only sterilized pets for adoption and that a limit be set on the number of unsterilized dogs per household. This section neither supports nor opposes these ideas.

6.4.6 Duck Recommendations

Recommendation I: Eliminate White Pekin ducks and their derivatives from inland ponds that are not part of a farm operation.

Alternatives for implementing this recommendation are as follows:

1. Generate legislation at the county and/or municipality level authorizing and directing dog wardens, park employees and law enforcement officers to remove White Pekin ducks and their derivatives from publicly controlled reaches of inland bodies of water.

2. Provide a bounty for the delivery to local animal pounds of White Pekin ducks and their derivatives that have been removed from non-farm inland freshwaters.

In support of this recommendation, it should be recognized that the introduced White Pekin duck stimulates artificial feeding, attracts wild ducks, is non-migratory, is a heavy coliform and nitrogen polluter, spreads avian diseases, and may destroy shoreline vegetation, causing shore erosion.

The Soil Conservation Service concludes that if the White Pekin duck and its descendants are effectively eliminated from public inland water bodies, the feeding of wild ducks, while not desirable, is not sufficiently harmful to surface water quality to warrant prohibition of such feeding.

Recommendation II: Prohibit the sale of White Pekin ducks as pets within the bi-county area.

Generate a penalty law against retail sales of ducks for pet keeping purposes.

In view of the nature of the proposed measures, it may be necessary to conduct a public information program to avoid adverse public attitudes toward White Pekin duck elimination.

6.4.7 Horse Recommendations

Recommendation I: Prepare a model ordinance for local use providing a limitation on the number of horses per acre on residential land and specifying the management of and disposal of certain horse wastes.

The following clauses should be included in order to insure adequate waste management:

1. Not less than one-half acre of open unpaved land shall be provided for a single horse or other equine livestock; not less than one-fourth acre of open unpaved land shall be provided for each additional horse.

2. Each premises having less than one-half acre of open, unpaved land per horse shall have and meet the provisions of an animal waste management plan, approved by (agency to be specified) or be in violation.

3. Animal waste, including manure and soiled bedding shall be kept in weatherproof containers at least 50 feet from adjoining property lines.

4. Paved or otherwise unvegetated or bare soil areas used as horse yards, paddocks, pastures, or similar shall be graded or controlled so that no storm runoff water from one-year frequency rainstorms falling on such areas, shall flow from the horse owner's property to other public or private lands.

Recommendation II: Where Horse Recommendation I is not implemented, authorize the county health departments to require the preparation and implementation of a conservation plan covering animal waste management whenever necessary to abate a horse waste related nuisance.

The plan should be prepared by a professional conservationist or the equal and reviewed by the SWCD for each horse waste related complaint involving (1) animal waste sewage flowing off the property, or (2) failure to properly store horse waste.

6.5 CONCLUSION

Nassau and Suffolk Counties are suburban residential counties having a 1977 population of approximately 2.8 million persons. The densest population centers are generally located in watersheds that discharge directly onto the marine edge and to inland lakes and ponds. Highways and local roads are usually depressed below the natural ground level and serve as principal drainage channels for runoff water. Recharge basins provide storage for storm water discharges for most new subdivisions in Suffolk County and many in Nassau.

Dogs and semi-wild White Pekin ducks were found to be unregulated sources of non-point animal waste pollution. Urban runoff containing dog waste and other animal waste is responsible for most of the recent closures of shellfish growing areas. An information program and new laws are recommended to control dog waste disposal. Semi-wild White Pekin ducks and their descendants are also serious sources of pollution in many ponds and lakes. Diseases are communicated to animals and man via waters contaminated by duck wastes. New laws and public awareness concerning the problem are needed to control these wastes.

Market duck waste has been a pollution hazard in the past and is now regulated by Federal and State laws. Under these laws duck farmers are required to achieve very limited discharges of wastewater by July 1, 1977, and zero discharge to any receiving surface waters by 1983.

Zoning ordinances in some municipalities are used to control horses and, indirectly, the waste related problems. However, there are many small non-point horse waste pollution sources affecting surface waters. These may require control.

Under present state law agriculture producers must develop a plan to reduce sediment and related animal waste pollution by January 1, 1980. This plan is developed with the assistance of the Nassau and Suffolk County Soil and Water Conservation Districts. It is recommended that the present law be amended to require non-agricultural animal owners, who have high concentrations of animals per acre, to develop a plan, with Soil Conservation District assistance, for the control of animal waste.

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Section 7 Modeling Studies

7.0 INTRODUCTION

The waste treatment planning process requires a knowledge of: the quantity and quality of the ground and surface fresh waters; the quality of the marine surface waters; the movements of ground and surface waters; the inter-relationships of ground and surface fresh waters with the marine waters—in terms of movement and quality; the contaminants that enter and impact each and all of these waters; and the structural and non-structural abatement alternatives most suited to cope with each set of problems in order to achieve the protection and/or rehabilitation of drinking and swimming waters to safe levels of water quality.

This requires an in-depth knowledge of existing conditions and an ability to predict future conditions under a variety of impacts. The study of existing conditions can be made by direct investigation. Water samples can be taken and analyzed, and controlled experiments can be conducted. This in fact has been done. However, in a region of more than 1200 square miles and as complex and dynamic as the Nassau-Suffolk Region it is prohibitive in terms of time and cost to totally rely on field studies. Furthermore, the only way that field studies can be used for predictive answers is to actually build a facility or to add contaminants and then measure the results. Fortunately a more effective and efficient set of tools is available to complement the field examinations; namely, the use of models.

One of the significant components of the Long Island 208 study centers on the development and use of appropriate mathematical models. The wastewater management plan for this area ultimately depends on the ability to quantify a preference for one set of structural and non-structural alternatives over another. In the process of doing so it is necessary to understand what the impact of these alternatives may be on ground and surface waters in terms of changes in movement and quality which result from the options used. The modeling efforts provide flexible tools to evaluate and predict such impacts without engaging in prohibitive tests on the actual water bodies themselves. That is, modeling is a surrogate for reality in which certain basic inter-relationships in the real world are expressed by mathematical statements. By manipulating these proxy statements one simulates, as it were, the events which actually take place. The models are therefore a method for organizing the complex interactions which occur between the water bodies and the stresses placed on them. This is a simplification of nature in that all interactions are excluded other than those which are of relevance to the study.

The use of mathematical statements to imitate reality has a long tradition in water management and other planning studies. Models enable researchers to carry out "what if" experiments on nature. For example, one can replace the actual waste loads which enter Long Island bays with esti-

mated loads which result from potential abatement options and then see what effect this has on subsequent bay conditions. Thus these changes can be simulated without having to physically build treatment facilities. That is, one can look into the future by tracking present conditions to determine what eventual effects they produce on water movement and quality. Finally one can play out enough such alterations in initial and boundary conditions to find the 'best' future scenario.

Section 7.1 of the report provides a straightforward but intuitive discussion of hydrodynamics. Fortunately, just a few basic facts concerning the relation between water elevation (or 'head') and flow velocity suffice to derive all the fundamental equations used in the modeling of movement of ground and surface waters. As a result there is an essential conceptual unity between the apparently different modeling efforts used in the 208 study. The various models also use a common and simple idea, that of mass balance, in calculations of water quality and "water budget" considerations.

Section 7.2 contains a review of the surface water (including river) models, with some discussion of their limitations and uses. These models characterize the changes which occur over time (in a water body) to constituents such as salinity, nitrogen and dissolved oxygen. There is also a discussion of the models developed for achieving ecological balances under various conditions of constituent loadings.

Groundwater models are reviewed in Section 7.3. Two were developed; an analog and a digital one. In addition, water budget studies are explained.

Section 7.4 attempts to tie together the entire 208 modeling effort with a discussion of the results actually obtained and how they will be used in the development of a wastewater management plan.

The reader who does not wish to linger over some of the technical arguments can simply read the last section to get a perspective of how the models relate to the 208 study. We caution the reader, however, that this report cannot be a substitute for the detailed documentation provided by the respective consultants. The aim of this report is to explain the ideas which are necessary to an understanding of the structure of the models, their limitations, and integration into the overall 208 study. Explicit details concerning computational schemes, data sources, and eventual model validation are only hinted at, and the technically interested reader must consult the original sources on these questions. (See Bibliography.) Also excluded is a description of model outputs for different sites on the Island since these are also fully documented in reports issued by the consultants.

Every attempt was made to explain these models in understandable prose form. Differential equations—the language of models—were eliminated from the discussion. In those instances where technical jargon was deemed inescapable it was followed by a common language definition. A glossary listing is included at the end of the report.

7.1 HYDRODYNAMIC BACKGROUND

7.1.1 Introduction

The groundwater and surface water models used in the 208 study are based on the same hydrodynamic principles. It will be convenient, therefore, to review these basic ideas before they are applied to the models themselves. The discussion is somewhat simplified in order to provide a broad understanding of this material.

The derivations therefore will generally be intuitive to avoid technical complications or the overuse of mathematical formulae that add little or nothing to an overall appreciation of the essential ideas. Those readers not familiar with mathematical notation can safely omit the occasional allusion to equations. These are given as footnotes and hopefully do not intrude in too distracting a way.

7.1.2 Fluid Flow

Imagine a water body as being represented by a rectangular tank of elevation H and a fixed surface area A_S connected to the outside by an inlet pipe or channel (see Figure 7–1). The tank volume is therefore $A_S H$. Water flows into or out of the tank through the channel with a velocity u. If the tube has a cross sectional area A_C then the net flow of water is designated by Q. Using meters as a unit of length, u can be expressed as meters per second. Therefore flow is given as cubic meters per second and the relation between the two is

$$Q = A_C u \tag{7.1}$$

It is apparent that if there is no mass flow into or out of the tank then the rate of change over time of the volume of water which it stores must be zero. This is simply a statement of *conservation of mass.* However if the net mass flow Q is non-zero then the volumetric change per second must equal Q itself. This is one of the two fundamental facts used in the models. Note that H (also known as the 'head') varies up and down as Q increases or decreases.[1]

Suppose now that the channel is connected to another water column and that the storage tanks are labeled as 1, 2. If the elevation of water in

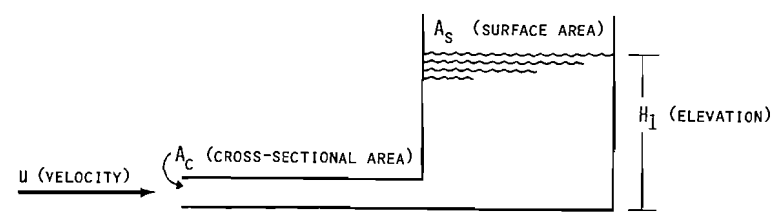

FIGURE 7–1 *Flow Into a Water Tank.*

each of these is different then the resulting pressure differences at the two ends of the channel cause water to flow (See Figure 7–2). The rate at which this flow changes is in fact proportional to the difference in head. In particular if $H_1 = H_2$ then there is no flow. In actuality there is another force which acts to impede flow in the conduit. This is frictional resistance, a quantity which we denote by R, caused by roughness of the channel walls. If we ignore this resistance, what we have is essentially a statement that water flows from a higher to a lower level and that the rate of flow is proportional to the difference in level. This is our second fundamental fact. In effect, it expresses Newton's contention that every body has inertia and that the only way it moves is in response to some external force. When that force is zero, there is no motion.[2]

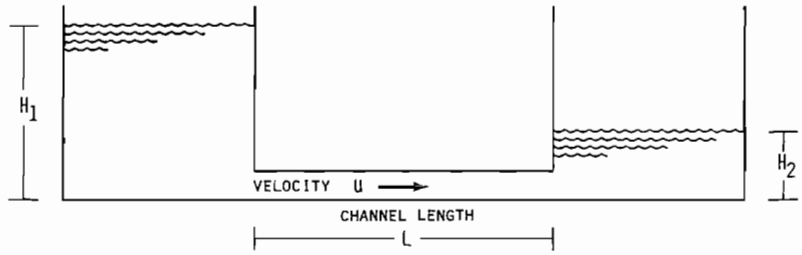

FIGURE 7–2 *Flow Between Water Tanks of Different Elevations.*

To adequately describe flow in the aquifers in the groundwater system it is necessary only to introduce a minor addition to the discussion above. In essence, the soil occupies some of the space which would normally contain water. It is as if we examined the tank in Figure 7–1 and, to represent soils, threw into the tank a number of balls to represent a porous medium. In such a case, the flow of water into the tank causes greater increases in the head since some of the space is already taken up. Similarly, in Figure 7–2 we should fill both tanks and, more importantly, the channel with balls. It is then evident that these will considerably restrict the flow of water from one tank to another (see Figure 7–3). In surface waters, where the flow is relatively free, water movement from one place to another in the system takes place over periods of hours which corresponds to a tidal cycle. However, in the groundwater system the flow is so restricted that it requires a much longer time. It should be kept in mind in reading later sections that this discrepancy in the time required for differences in head to be equalized is one of the most significant differences between surface and groundwater models.

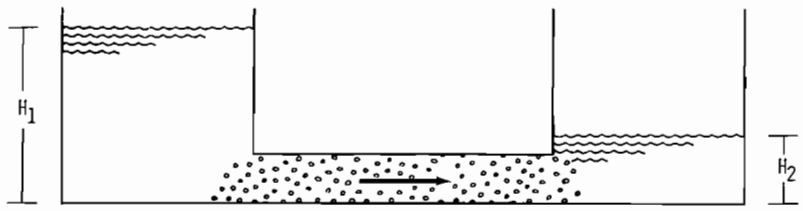

FIGURE 7–3 *Flow in a Porous Medium. For a Given Volume of Water, Both H_1 and H_2 Are Greater Than in Open Water Since the Medium Occupies Some of the Bulk of the Tanks.*

Let us try to make the discussion more precise. The flow of fluid in a porous saturated medium is dominated by two features not present in the open surface case. First, there is *porosity.* This represents the fraction of bulk volume in a tank which consists of open pores accessible to fluid storage. Porosity can be defined by the number ϵ, where

$$\epsilon = \frac{\text{volume of pores}}{\text{bulk volume}} \tag{7.2}$$

It is apparent that ϵ is less than one. Although in open waters H is volume divided by surface area A_s, in porous medium H equals the volume divided by ϵA_s and therefore is larger. Second, the interconnected pores act as thin capillary tubes. This creates a condition known as viscosity. *Viscosity,* which we denote by μ, describes the fluid resistance toward flow past a boundary. *Permeability,* indicated by k, describes the restriction upon flow imposed by the porous medium itself. These fluid and medium properties can be combined to describe the overall *hydraulic conductivity,* or ability of water to flow in the groundwater system.[3]

Two very similar pairs of relations are now derived; one for open water flow and the other for flow in a porous medium. The first set will be used in surface modeling and the other in groundwater modeling. Each pair of relations expresses the temporal change in hydraulic head of a water body in terms of velocity of flow into that body, as well as the temporal change in velocity between two parts of a water body in terms of the differences in head and the resistance of the medium. Thus the essential output of the hydrodynamic equations are a knowledge of how H and u vary over time in relation to each other.

The only major difference between the arguments used in the derivations above and those which would be used in a more exact mathematical approach is that the macroscopic view of tanks and conduits is replaced by a study of the instantaneous changes of infinitesmal slices of volume. This leads to what is known as partial differential equations of motion for H and u which are valid at any point of the water body rather than to an entire water column as above. Such equations are not used in this report.

Let the symbol Δ refer to an incremental increase or decrease of some quantity. In the discussion of rates of change of H and u over some time let ΔT denote the interval of time in which things happen and let ΔH and Δu refer to the corresponding jump in the value of H and u. If ΔT is the increment from some previous time to the present, then our two basic relations relate ΔH to the previous value of u and Δu to the previous value of

the head difference $H_1 - H_2$. This is an important observation because it says that one can compute present values of H and u from previous values since ΔH and Δu, the incremental change, is now known. Following this argument back to some initial time we see that if head H and velocity u are both specified initially, all future values are predictable. Note also that in the process of obtaining these future values, H and u are both dependent on each other. Taken together they tell us about the movement of a water body over successive intervals of time. In essence this is the core of what is called *hydrodynamics.*

In order to illustrate what can happen over successive intervals of time (where ΔT represents a few hours, for example) let us consider the exchange of water between two tanks as shown in Figure 7–4. This could represent "snapshots" of water elevation in two parts of a bay due to oscillations which result from tidal flow. Once set in motion, the water's momentum causes it to move back and forth. If the external influences of the open sea were suddenly to cease then the oscillations would eventually damp down (due to frictional resistance) and the system would come to rest. The second fundamental

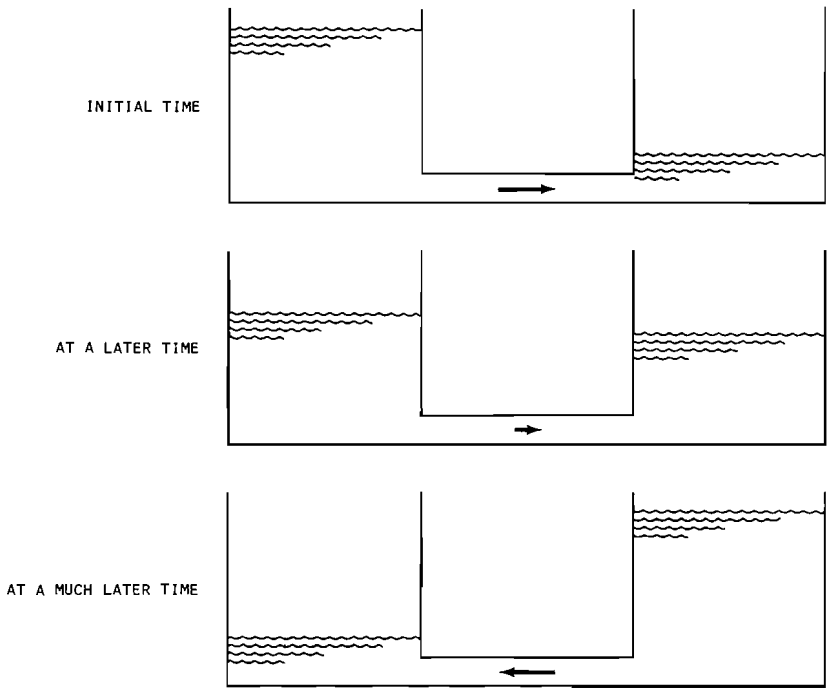

FIGURE 7–4 *Flow Between Water Tanks in Successive Instants of Time.*

relation is but a restatement of this fact. Except for the external forces which intrude, this is exactly what would happen in practice.

In the discussion of surface and groundwater models later in this report the simple ideas expressed above will prove to be the key ingredients to understanding how the models work. There is also another idea which we need to treat here since it forms the basis for water quality modeling and for the *water budget* model. This is an extension of conservation of mass, as used above for water, to include all substances which enter into the water due to natural and man-made discharges. If these substances, such as nitrogen and phosphorus, do not decay over time then in the absence of any external influences which may add or subtract from the total amount, the total mass remains unchanged over time. This statement is completely analagous to the observation made earlier about the water in a bathtub and the way it is used is to remark that the only changes which can take place in a water body, other than external "sources" or "sinks," is that the water constituent shifts in concentration from one place to another with the total amount remaining constant. Therefore if one adds up all decreases in the concentrations in different parts of a bay, these must equal the sum of increases in the remaining parts of the bay. This fact forms the basis of an accounting procedure known as "mass balances." The concept of "water budget" is also very similar, as will be shown.

There is one last remark to be made in this connection. If a substance is inserted into a water body it will move about due to two forces. The first, called *advection,* is the displacement of the constituent from one place to another because the water in which it finds itself happens to be moving. If a dye is put into a bathtub and a wave is generated, then the dye will tend to migrate in the direction of the wave movement. The other force, called *diffusion,* is the propensity for a substance to move from a region of high concentration to a lower one at a rate proportional to the difference in concentration between two points (this is similar to water itself wanting to move from a high point to a lower one at a rate proportional to the difference in head[4]). This results in a spreading out in all directions of the original mass until it reaches a state of total dispersion. Again, if you place a dye in a tub, even in a perfectly motionless tub, it will move away and thin out from where it was put in. One of the main goals of the surface and groundwater models is to capture the effects of advection and diffusion to describe water quality in a water body. To do this, hydrodynamic considerations are important since water movement determines advection.

To summarize: essentially two basic facts were reviewed which dominate the structure of all the models in the 208 project. Each states the premise that in the absence of any external forces a water body (or of a conservative substance within it) reaches a state of equilibrium in which total mass remains unchanged and in which velocity of flow is zero. When this is not true, the lack of equilibrium is proportional to the sum of the forces which act on the body or on the substances within it.

7.2 SURFACE WATER MODELS

7.2.1 Water Quality

7.2.1.1 Hydrodynamics in an Estuary. The Long Island waters are contoured by a number of bays and estuaries. Pollutants which enter these waters are largely dispersed through the flushing action of the tides. The purpose of the Tetra Tech modeling effort is to determine the concentrations of the various constituents which enter the waters both spatially, and over time, as a result of this tidal action. In order to understand how this can be done, it will be convenient to first describe the unsteady flows of the coastal waters and then to relate this to the procedures used in computing water quality. The first part therefore is based on the discussion of hydrodynamic relations which were developed in 7.1.

A number of plausible assumptions are made in the formulation of the model in order to make the analysis more tractable. To begin with there is the problem of spatial dimensionality. If one assumes the water body being studied is completely mixed in the vertical direction (no differences in salinity, for example) then it is possible to consider the body as a two dimensional expanse of water in which all changes take place in the planar directions. For bays and estuaries in which water depth is shallow compared to the planar width this assumption is reasonable. However, even the two dimensional description is generally too complicated. Therefore we further reduce this problem into a set of much simpler one-dimensional descriptions. How this is done will be shown in a moment. It is worth noting immediately that what makes this reduction from a single hard problem into many simpler ones useful is that it is typically more efficient to code a computer to carry out a large number of straightforward computations than to have it perform a single complex problem.

The model divides the water body in question into a set of "nodes" which are joined together in a network by a series of interconnecting "links." Each node represents a completely mixed "tank" of water having a specified surface area A_S, an elevation H (relative to some arbitrarily chosen datum) and a volume $A_S H$. The nodes are where water is stored in the bay (from now on "bay" refers to any coastal water body and may in fact be an estuary) and the links represent channels through which water is conveyed from node to adjacent node. Each channel preserves information about flow Q and velocity u of water movement as well as the coefficients of resistance to that flow; it also has a specified length L and a cross sectional area A_C which varies along its longitudinal dimension, as well as a specified width. Figure 7–5 exhibits a grid network of nodes and links overlayed on a typical bay while Figure 7–6 displays one possible representation of a node and of a channel. When there are N nodes in the network then it is useful to label them in some order.

Since flow is along the longitudinal direction of each channel the characteristics of motion in a channel are one-dimensional. The price paid for this reduction in dimensions is that there are now a large number of channels to

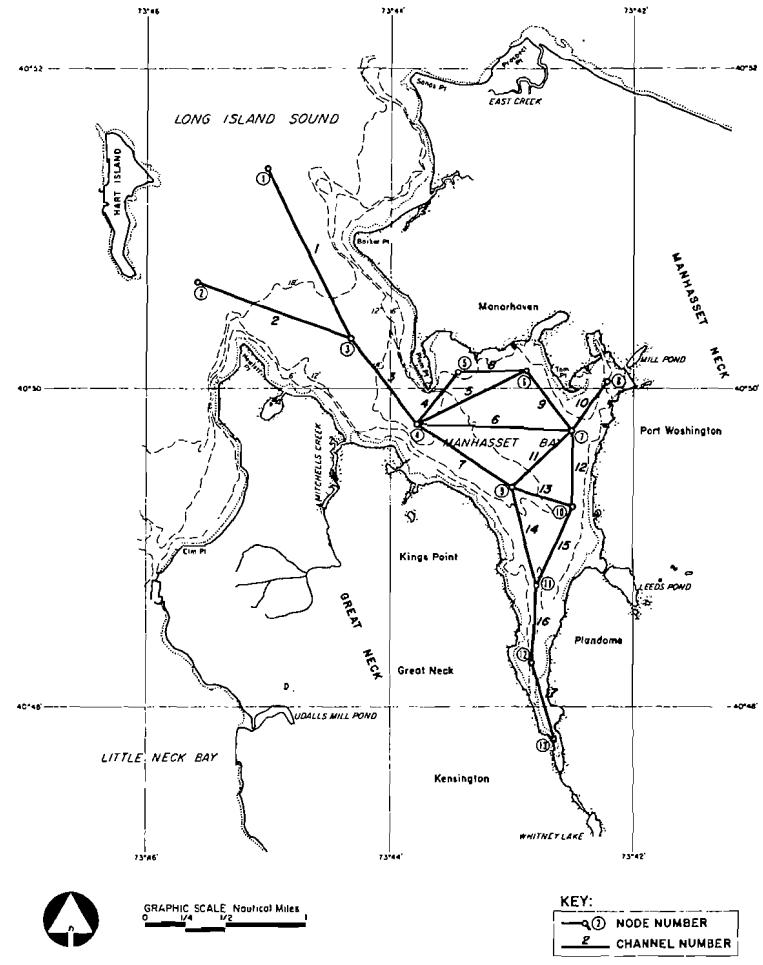

FIGURE 7–5 *Node and Channel Layout for the Manhasset Bay System.*

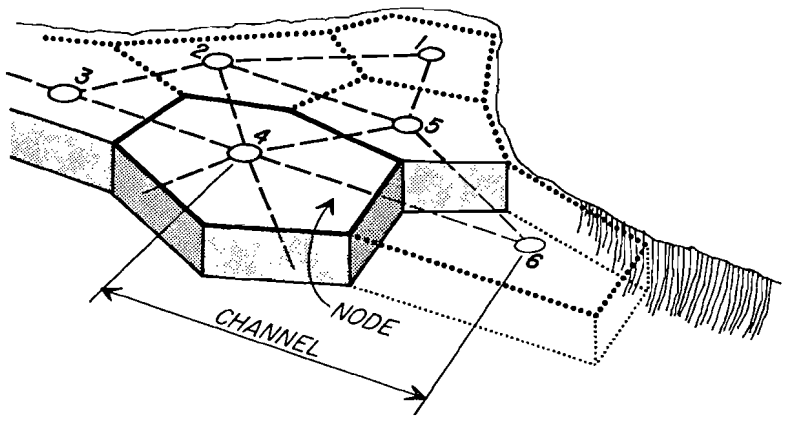

FIGURE 7–6 *Typical Section of an Estuarial Node-Link Network.*

consider simultaneously but, as said earlier, this is preferable from a computational point of view. Collectively, this network of one-dimensional flows constitutes a proxy for the original problem. It is apparent that in bays of irregular shoreline geometry, some care must be taken to account for changes in flow patterns caused by these irregularities by choosing a suitable placement of junctures for the links. If there are natural channels of flow then links of appropriate length and width are inserted to represent this. The grid is not uniform, being densely laid out where water quality or hydrodynamic conditions change rapidly and being more sparse in those portions of the bay where it is likely that there will be less action. The nodes themselves will vary in size (that is, in surface area) depending on the accuracy desired. Since a node represents a completely mixed water column, the extent to which the constituents of the water are actually homogeneously distributed is a determining factor in how big or small such nodes should be. Therefore careful judgement must be made in the preparation of a grid configuration prior to any computations. This is one of the places where the skill of the model maker is revealed.

Before continuing it must be noted that the channels are considered to extend from the center of one node to the center of the adjacent one. The nodes or water tanks are all contiguous and together cover the bay. Hence all exchanges of constituents within a node resulting from the flows into and out of the tank are assumed to occur at its center.

Let us now consider a typical node, having some fixed surface area. Over time the only thing that varies within it is the elevation or head of the water. Then as known from section 1 the rate of change of H, denoted by ΔH during the interval ΔT is proportional to the velocity u.

Suppose there are m channels connected to the given node which is labeled as node s as shown in Figure 7–7. The channels link to other nodes which we can arbitrarily index by j where j runs between 1 and the number m. At any given time the average flow in each channel is written as Q_j (away from or towards node s). In addition at node s there may be some *additional sources or sinks* (that is, additions or losses) of flow which we write as Q_s^{in} and Q_s^{out}. For example if node s is near the shoreline then Q_s^{in} could represent tributary inflows or sources of waste discharges from a treatment plant or some measure of runoff along the embankment while Q_s^{out} could denote water diversions and evaporation. Groundwater inflows and even rainfall can also be accounted for at each node. This allows us to extend our basic relation about head to say that at each node s, ΔH is proportional to the velocity in addition to the net flow $Q_s^{in} - Q_s^{out}$.[5] The second fundamental relation of section 1 does not require modification except to make the dependence on the node arrangement more explicit (see Figure 7–7).[6]

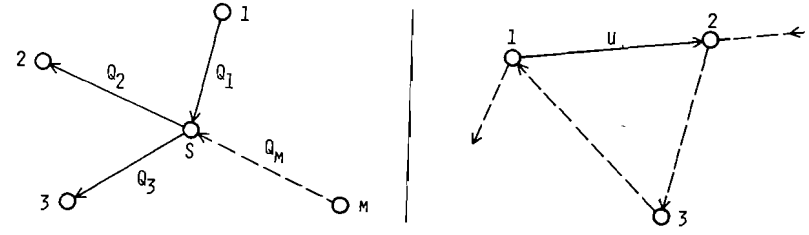

FIGURE 7–7 *Typical Flows as Seen in Part of an Estuary Node-Channel Layout.*

7.2.1.2 Solution Procedure. The detailed numerical procedure employed to obtain solutions to the basic hydrodynamic equations is described in "Documentation Report for the Estuary Water Quality Models" (*Tetra Tech,* May, 1977). Herein, it is only important to summarize the elements required in order to carry out these computations. To begin with the grid network must first be specified. This means that the geometic layout must be given, and also the values of surface area A_s for each node and the length L and widths of each channel.

In addition boundary and initial conditions must be specified. The solution of the equations begins at some initial time and proceeds over a set of incremental steps whose duration ΔT is usually of the order of an hour or more. All those nodes having a known inflow Q^{in} and outflow Q^{out} must have these values given at each time step for the entire computational horizon which is being considered for running of the model (the question of time span will be reconsidered in more detail later). These values may of course be constant in some problems. Generally speaking, the nodes so specified are located along the boundary of the bay. Also those nodes which interface with the

open sea (Long Island Sound and the Ocean) will need to have the elevations H given corresponding to the actual tidal oscillations which prevail there. These are similarly given at discrete time intervals over an entire tidal cycle.

The knowledge of head H_j at the boundary nodes is used to derive the elevations at all other nodes. In order to carry out the numerical procedure it is necessary to also specify in addition to the boundary conditions described above, a set of initial values for the velocities in each channel and a tidal elevation of other than seaward nodes (these may be taken initally to be zero). As the computations proceed these values repeatedly adjust and after running through several tidal cycles one begins to notice that successive values of velocity u and head H over two consecutive cycles no longer differ significantly. At this point equilibrium has been achieved in the model and the numerical procedure terminates. A typical plot of elevations at two nodes in an estuary would be as shown in Figure 7–8 where a shift in phase and a difference in amplitude can be seen. This is largely due to the drag induced by the channel resistance R, especially during ebb tide when the estuary is shallow.

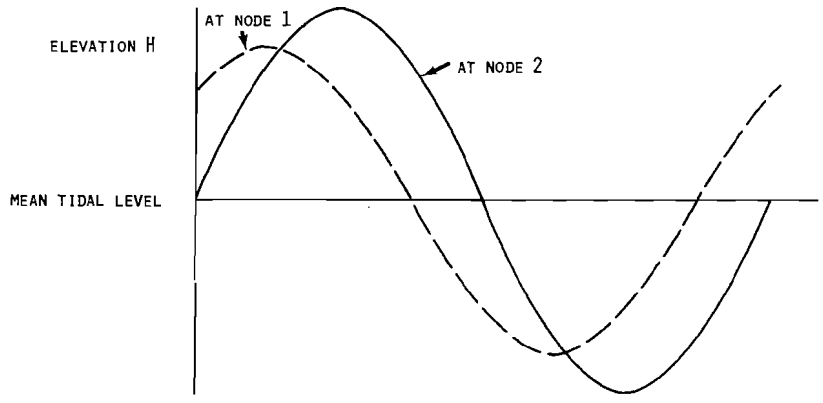

FIGURE 7–8 *Phase Shift of Tidal Oscillation in an Estuary.*

After equilibrium has been achieved in the computations one may wish to compare model results with actual field data obtained at monitoring stations in the bay. Tide gauges, for example, will give elevations which occur at various locations and these can be used for comparison. If the model results differ substantially from this data then the modeler engages in *model calibration.* The values of the resistance R along each channel are used for this purpose. By adjusting these values for each channel and re-running the model computations a greater or lesser degree of compliance to field results can be achieved although there is a reasonable limit to the amount of adjustments which are possible. Experienced modelers can usually do this without too many trials. If, however, compliance is still not satisfactory it may mean that the original grid of nodes and links does not supply enough detail. By enlarging the grid geometry by the inclusion of more nodes, it is possible to improve overall accuracy. However, there is a purely technical snag here which should be pointed out. For the computations to remain stable it is necessary to require that the time step ΔT be smaller than some factor of the smallest channel length in the network. Therefore as grid size is made more dense in portions of the bay the computation work is increased because of the extra nodes and links, and the number of time steps of size ΔT also decreases. There is therefore a practical limit to the amount of detail that can be expected from the network configuration itself.

After calibration it is usual to further check the model against a new set of field data (assuming these are available). This process is known as model *verification,* although in practice it is often difficult to distinguish the exercise of verification from that of calibration. If the model results fit the new data set reasonably well then this lends confidence in the use of the model as a predictive tool.

At this point one can use the hydrodynamic information so far obtained to derive an understanding of water quality. This is discussed in the next section.

7.2.1.3 Water Quality in An Estuary. When pollutants enter a bay, they are dispersed, largely as a result of the action of the tides. Some fraction is carried out to sea and the remainder is spread throughout the water body through mixing. In addition some of the constituents of the bay will decay over time. The relationship between the concentration of a constituent and the forces of tidal flushing and decay follows.

The model formulation assumes the same node/channel configuration of the bay as in the hydrodynamic equations. Several assumptions are made in addition to that of complete vertical mixing in each node. These will be described as we proceed. Vertical mixing is somewhat problematic for those nodes in the vicinity of an outfall or at the head of a fresh water tributary. Here the concentration of an effluent or, in the case of a tributary stream, of the salinity is non-uniformly dispersed and forms a plume. As a result there is some stratification of constituents in the water column. However these will be considered to be negligible effects in the model.

As a result of tidal oscillations, the concentrations which spread out from the boundaries of the bay are folded back and forth on each other. This dispersion is caused by two separate forces as seen in 7.1. The first, called *advection,* is the result of material being transported through the displacement of the water itself. The second, called *diffusion,* is the natural process by which any concentrated material tends to distribute itself uniformly throughout the water body.

Two kinds of constituents are handled by the Tetra Tech model—

conservative and *nonconservative.* The first group are the conservative components of salinity, total nitrogen, and total phosphorous. 'Conservative' refers to the fact that they do not decay in the water over time. The nonconservative components (that is, those which decay due to bacterial decomposition or which are otherwise removed due to chemical reaction and sedimentation) are total and fecal coliforms, nitrogenous and carbonaceous biochemical oxygen demanding materials (or simply *BOD* for short), and dissolved oxygen (or *DO*). Temperature in the water can also be modeled as a decaying substance but is not considered here. The nonconservative substances are assumed to decay at a rate which at any instant is proportional to their concentration at that time.

Let a constituent be measured by concentration c (kg. per cubic meter). Then its total mass in a node of volume V is simply V times c. Since the principle of conservation of mass says that the rate of change of a nondecaying substance c in the bay is zero (total mass is conserved), therefore, if one observes changes in mass from node to node it must be due either to advection or diffusion or decay or to other special sources or sinks. That is

$$\text{Rate of change of c in a node} = \text{Advection} + \text{Diffusion} - \text{Decay} + \text{Other Sources} - \text{Other Sinks} \quad (7.3)$$

Relation 7.3 is called a *mass balance relation* because it says that in order to know the total change of a constituent in a node during an interval of time ΔT one must add up all amounts coming in and subtract all amounts which leave. If these two amounts balance each other then the total mass of the constituent remains unchanged and, conversely, if no change in mass takes place then losses must balance the gains (principle of mass conservation). Of course there are N such relations to satisfy for each constituent if there are N nodes in the bay.

The advection terms in equation 7.3 reflect simply mass transport of the constituent from one node to another during tidal flushing. The concentration in the nodes shown in Figure 7–2 will depend upon volume of water in the tanks (here again a simplified view of the water body as a system of tanks with connecting conduits is adopted). The diffusion terms in equation 7.3 reflect the tendency of the difference in concentrations between the two tanks in Figure 7–9 to equalize. When c_2 is greater than c_1, there is a pollutant dispersion in the direction shown. This is similar to the spread of dye dropped into a bathtub as discussed in Section 7.1. The rate of diffusion is dependent on the level of concentrations between tanks. Where substantial differences in concentration are found, rapid diffusion is present. The overall rate of change of concentration is governed by an empirically determined diffusion constant which is labeled k_D. This constant is discussed further below.

For a nonconservative substance the decay rate is proportional to the quantity of the substance which may be present.[7] When the decay is zero it signals that the substance is conservative.

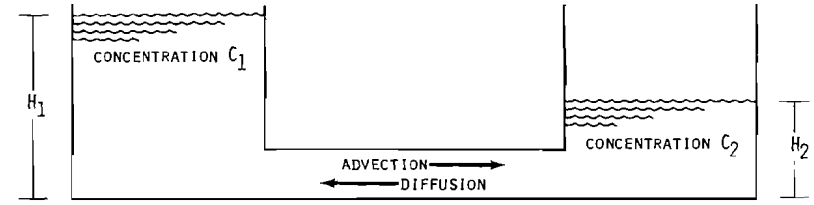

FIGURE 7–9 *Suppose C_2 is Greater Than C_1, but H_1 is Greater Than H_2. Then Advective and Diffusive Flows Are in the Directions Shown.*

Sources include waste discharge outfalls, storm runoff, groundwater inflow, rainfall, etc. Sinks refer to losses such as benthic uptake, water pumping, and so forth. Although it is not explicitly shown here equation 7.3 can be further extended to include other terms of constituent loss or accretion when these are applicable. In particular the equation for dissolved oxygen would include first order relations for *re-aeration* and *photosynthesis* (positive accretion terms) and for *respiration* (negative loss terms).[8] Both photosynthesis and respiration depend on the concentration of algae. One can also add terms for loss of constituent if there is benthic uptake since this acts as a sink.

It is important to note that since constituents such as nitrogen and phosphorous are nutrients for the various microorganisms and other marine life (especially phytoplankton) which inhabit the bay, one could usefully include in the balance equation an accounting of how nutrients are used up and later returned to the estuary by this marine life. In the process oxygen levels will vary considerably over a diurnal cycle (that is, over a 24 hour period) since photosynthesis depends on the amount of sunlight which penetrates the water body. The phytoplankton are prey for the various zooplankton and the populations of both fluctuate over time. Therefore the terms used above in which photosynthesis and algal concentrations are assumed constant must be considered as rough approximations. Benthic uptake is also assumed constant. *Benthic* uptake represents chemical and biological oxygen losses to the bay bottom. An extension of the water quality model to include these additional marine interactions constitutes what is known as an ecological model. This will be briefly discussed at the end of this chapter.

In order to solve equation 7.3 one must know, in addition to decay constants, diffusion constants, and the like (all empirically determined) the values of the volume of each node and the flows which determine advection. Moreover these must be known for each successive interval of time. But of course the flows and volumes (which are given in terms of head)

are already known from the solution of the hydrodynamic relations. One can therefore appreciate now why the Tetra Tech modeling process is necessarily a two step procedure: water quality mass balance equations require hydrodynamic inputs.

7.2.1.4 Calibration Procedure. When the model is to be calibrated one has available the various constants used in equation 7.3. Perhaps the most significant is that of k_D, the diffusion constant. It is worth taking a closer look at it. Mixing in a bay or estuary is subject to location. At or near the ocean outlet most mixing is due to velocity differences which advect the constituents in the water in varying directions and at varying rates. This induces a kind of turbulence which causes the constituents to disperse. At the same time the back and forth flow caused by tidal oscillations also results in mixing. However as one moves further into the bay these forces tend to lessen especially in estuaries where tidal flow from the ocean interfaces stream flow. At the interface we have a mix of salt and fresh waters and dispersion occurs mainly as a result of the increased salinity gradients, by which is meant that the stratification of the estuary into layers, due to differences in water density, causes mixing to occur between water at different depths. Finally as the fresh water zone is neared all of the above effects abate and non-advective dispersion will be minimal. Although density differences are supposedly ignored in the assumption of vertically mixed water columns, the constant k_D can capture this effect indirectly. Tetra Tech proposes therefore that k_D be computed as

$$k_D = k_{D1} + k_{D2}\,\Delta s$$

where Δs is the salinity differences between two nodes divided by channel length. k_{D1} and k_{D2} are chosen so that where tidally induced and advective mixing predominates k_{D1} is larger than k_{D2} but the contrary be true where salinity effects begin to predominate. This is illustrated in figure 7–10. By suitable adjustment of k_D one may adequately account for the actual dispersive effects in the water body. Again this is a question of judgement and skill on the part of the modeler.

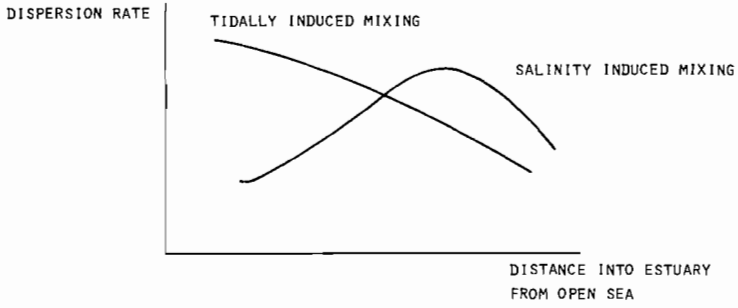

FIGURE 7–10 *Dispersion Rates Versus Distance.*

There is one more observation to make about the solution of the balance equation. It may happen that relations which apply to one constituent require information about another one. In this case one has a coupled system and it matters which set of equations is solved before the others. This is especially true in the case of BOD/DO interactions since the amount of DO depends on the amount of BOD there is. The solution to the equation for DO therefore requires that the solution to that for BOD be obtained first.

7.2.1.5 Dynamic Versus Steady State. The above model formulation can be run in a computer in several different modes, each of which has its own virtues and limitations. These are steady state, quasi-dynamic and dynamic. Tetra Tech refers to these as Aqual and Dyqual. The most complex and detailed is the *dynamic, or time varying, model* in which changes at each node are followed at each time step of duration ΔT over an entire tidal cycle or indeed longer. The time step can be as small as one wishes depending on the level of detail that is desired but of course computational expense usually limits ΔT to be of the order of one or several hours. If no essential changes take place in a bay over repeated tidal cycles then it suffices to run the model for one or two such periods. However the major utility of the model is to account for short term and rapidly changing boundary conditions which may induce variations in water quality over a longer period of time. For example, stormwater inputs or intermittent and unsteady effluent discharges will require source flows and concentrations to be altered over a sequence of time steps at the boundary nodes. The resulting concentrations of the several constituents in the water may fluctuate considerably for a long stretch of time and over a period of several days or weeks may never actually settle down to equilibrium values. In addition the values of temperature (which affects the decay constant k) and photosynthesis and respiration rates (which vary over a diurnal cycle) may also be varied over the time steps allowing for a better accounting of nutrient interactions with marine life. Of course this is still only a proxy for a more comprehensive ecological model but in many cases it may suffice for an adequate prediction of water quality changes.

However dynamic models are expensive to run, as we said, and so one may on occasion more usefully employ a simpler version known as the tidally-averaged, or *quasi-dynamic,* model. This consists of computing average water quality conditions over an entire tidal cycle and then monitoring subsequent changes from cycle to cycle. This approach is especially apt when one wishes to follow changes which may occur in the bay over a long term period, from several weeks to several months. The results of the hydrodynamic model are first calculated as in the dynamic version. Then instead of using the resulting flows and elevations at each time step, the computed values are averaged over all the increments used in the tidal cycle. At the same time any inflows and outflows of constituents, which vary over time are also averaged over each successive cycle, and the concentrations which result from the mass balance equations then represent average water quality conditions over consecutive time periods, where the duration of each

period is a cycle. If one wishes, in fact, the averaging can even be done on a daily basis. Although this would lead to less accurate portrayals it does permit one to more economically track the changes in pollutant levels over longer time horizons. This model is dynamic in the sense that it does allow for gross temporal changes although it does sacrifice the detail of the more truly dynamic version discussed above. An even simpler approach is the *steady state* model. This too is tidally-averaged but it further assumes that no significant changes occur from cycle to cycle. In essence this assumption implies that the bay has come to equilibrium with respect to the pollutants and other constituents which enter the water and that all transient effects due to past disturbances have died out. This kind of situation would prevail in the long run if ideally the initial influences on the bay (in terms of inflow, outflow, algae concentrations and the like) had dissipated and no further changes took place. Obviously this is a considerable simplification but it does allow one to make some rough comparisons between alternative wastewater abatement schemes or to estimate the approximate effect of the water body of different boundary conditions. Of course this approach would be inadmissible if one were to track a series of storm events.

Since time no longer plays a role in steady state modeling both the hydrodynamic and mass balance equations become considerably simpler to handle. This is because the left sides of the equations can now be made to vanish since the rates of change over time must be zero. Needless to say, if the water body is in fact subject only to slow changes in pollutant levels, and if it is relatively undisturbed as in some less populated coastal areas, the steady state modeling may be the appropriate and only sensible tool to use.

One should also note that after a sufficiently long time period has been simulated with dynamic or quasi-dynamic models, all changes that occur in successive time periods may become increasingly negligible. In this case the dynamic models eventually reach a condition of steady state. What the steady state model does is to regard the future as now.

A technical note should be interjected concerning steady state and quasi-dynamic models. Since both are tidally averaged, the dispersion of pollutants due to advective forces is less significant than in the dynamic model since only average values are used and the larger velocity changes at extremes of the tidal cycle remain underrepresented. In order to compensate for this, it is expedient to increase the value of the dispersion coefficient k_D in order to better approximate the actual mixing which occurs in a cycle. This procedure is followed by Tetra Tech.

One can summarize the discussion of the Tetra Tech modeling effort by noting that the water quality component is a set of equations which are simply adjoined to the equations for hydrodynamics. The latter describe how water flows into and out of the bay while the water quality model tells how something which is injected into that water will disperse because of the back and forth motion. The relation between the two is graphically illustrated by Figure 7–11 which is adopted from the Tetra Tech user's guide.

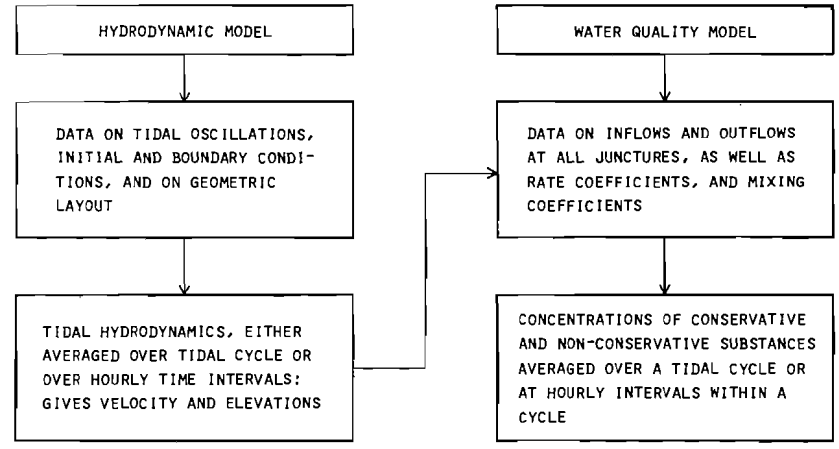

FIGURE 7–11 *Tetra Tech Modeling Efforts.*

7.2.2 Limitations and Uses of Estuary Model

The discussion has attempted to underscore the most significant assumptions made in model development. Each such assumption is a shortcut to reality, and it reflects an implicit belief that in spite of such simplifications all essential relationships which occur in nature will be preserved by the model. Depending on the context this may or may not be true. Credibility in a model rests on the extent to which the user is willing to accept such assumptions as plausible and the extent to which model calibration and verification demonstrates the ability of the model to portray actual conditions in the water body considered.

Some of the simplifications made are explicitly stated by modelers, but often there are others which appear only implicitly. For example, although complete vertical mixing is clearly part of model formulation for surface water quality, much less explicit is the fact that the equation ignores the effect of velocity differences over the length of the channel. Fortunately, this is not a very significant omission.

Many assumptions have been made beginning with the choice of a particular geometric configuration for the grid layout, the size of nodes, the choice of time step, the use of first order reaction terms for decay and photosynthesis of material (among others), the setting of dispersion k_D as a linear function of salinity differences and so on. Also, although some of the parameters used as constants in the models are better known than others, all are but approximations to actual values which may vary both spatially and over time. Similarly, boundary conditions on distributive inflow sources, dis-

charge rates of treatment plants, and tidal depths at the sea are only known approximately. Therefore the models cannot be expected to reproduce exactly the behavior of the water body. However, experience with the models has demonstrated that they can be usefully employed to obtain acceptable measures of actual water quality conditions and, therefore, to predict future conditions under a variety of changes.

Calibration and of course the eventual verification of a model does depend on having available a data source on actual water quality and hydrodynamic conditions over time at a variety of sampling stations. These are used to adjust or "tune" the model and then to compare model outputs to actuality. Such data is, however, hard to come by and is sometimes incomplete or of poor quality. For this reason adequate validation remains a difficult and time consuming task, although in the 208 project this does not appear to be a serious problem.

It may be argued that by increasing model detail, accuracy and confidence can both be improved. The most cogent reason for limiting such detail is however to achieve a level of complexity which is compatible with the available computational capabilities. Also, complexity for its own sake is illusory since the information needed to closely model certain interactions is often not known well enough. In the Long Island 208 the Tetra Tech modelers have avoided this pitfall.

In the context of the 208 project the Tetra Tech models are used to provide information on water quality as part of the general assessment of environmental conditions and structural alternatives. They play a crucial role in quantifying the impact of sewage and runoff on the coastal water. What is more, the models can compare alternative tactics for abating this impact through sewage treatment, recharge, and shifts in land use.

The basic input to the models is information generally provided on discharges into the rivers and bays in terms of flows from various sources (streams, point discharges, runoff, and so on) and in terms of the pollutant loads carried by these flows. As the reader now appreciates, this information constitutes much of the boundary data for the models.

The models can be run in three modes, as discussed earlier. The dynamic, or time varying mode, is especially useful in studying the short term transient effects of storm runoff and in computing the diurnal variations in dissolved oxygen which result from changes in algal activity. The information is provided over small time steps but this of course precludes model runs which exceed more than a few tidal cycles. For longer stretches of time, a more flexible mode is quasi-dynamic or tidally-averaged dynamic. Here one can follow slow changes in pollutant levels as boundary conditions gradually change over a period of weeks and months. Changes which occur over a tidal cycle are averaged out so that the fine detail of a more fully dynamic model is now lost. Finally, in the event that discharges to the water body are reasonably constant over a long period, or when one can assume that the water body has come to equilibrium with respect to the flows and loads which enter it, a steady state model is more appropriate. Here not only is information averaged over a tidal cycle, but it also no longer varies from cycle to cycle. Tetra Tech has found all the above modes useful in its work with some modes being more appropriate than others in certain bays. In all bays, however, steady state runs were provided in addition to some dynamic runs in select areas.

The actual use of a model depends not only on the time scale and level of detail required but also on whether it is to be used as a descriptive or predictive tool. As a descriptive tool, one uses the model to explain existing conditions in the water bodies. For example, to understand the extent to which tidal fluxes will account for larger concentrations of some constituent in one part of a bay over another. This kind of information is generally part of the process of model verification. Another use is as a predictive tool. Here one wishes to know what future changes will occur in the water body as a result of present conditions. For instance, what are the nitrogen concentrations in a bay tomorrow as a result of a storm surge today? Here one predicts future changes in a way that clearly is impossible by observation of the bay itself until after the storm surge has occurred. The value of a well designed model as an oracle largely accounts for the fascination such quantitative tools possess. Finally, the models can be used for purposes of optimization. Not only do we wish to predict future conditions but one would like to shape that future by manipulating the present. Thus, for example, by varying the outfall location, size, and level of treatment of a plant, one gets different eventual concentrations of BOD in portions of the bay. Of these many options on the treatment plant, one of them will clearly result in a lowest BOD level at some future time. If one disregards cost and other factors which may actually inhibit the selection of this option, one now has an optimal way of influencing the future of the bay. In the 208 study all the above model uses are present but in terms of developing a final waste management plan it is the predictive and optimization modes which will dominate as a tool.

7.2.3 River Models

Tetra Tech has developed appropriate hydrodynamic and water quality models for the Carlls and Peconic Rivers. This section is much shorter than preceding ones since the essential ideas are really special cases of what has gone before, and the equations used are very much simpler.

Once again one employs a node/channel schematization with the same assumption of complete vertical mixing. However, now each node is linked to only two adjacent nodes (as shown in Figure 7—12) in a simple linkage which follows the course of the river. Each channel links only two nodes which are labeled $j = 1, \ldots, N$ starting at the river source. The channels are similarly labeled. The model structure will allow two upstream channels to converge at one node. Likewise the downstream flow from one node can diverge into two channels. These features will allow one to model river tributaries, rivers with branching structures, and two flow channel systems.

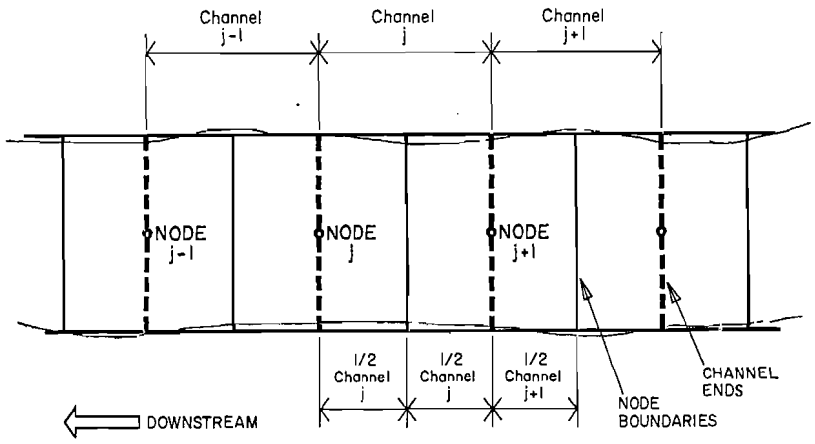

FIGURE 7–12 *Model Representation of a River.*

All flow is now unidirectional beginning at the river source and moving to the mouth. No tidal motion is involved. This means that elevation differences play a different role than before in that flow into node j + 1 is simply the flow out of node j plus inflows from tributaries which empty into the river at that node, as well as plant discharges and groundwater inflows along the river's boundary (Figure 7–13). Hence, if these boundary inflows are known, the total flow out of the node is determined from flow into the node. If we carry this argument back to the source, one need only know the upstream flow at the first node, plus boundary inflows, in order to determine the rest.

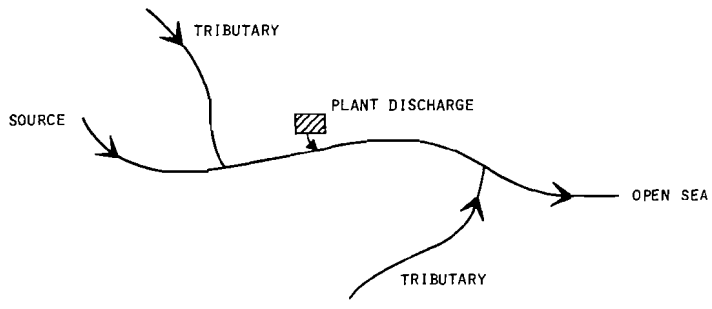

FIGURE 7–13 *Schematic of a River.*

Once flows are known at each node, one refers to empirically determined *stage-flow relationships* (that is, observed values of river depth at different river locations for varying flow rates) to obtain estimates of river depth in a channel. The depth in the node is the average of the channel depths at each end of the node. River width is determined from the channel cross section. Width of a river node is the average of the channel widths. The channel cross sectional area is calculated as a trapezoid. The velocity u in a channel is then simply flow divided by area A_c, as in the previously discussed estuary model.

The channel/node scheme should roughly correspond to changes along the river. Each stretch of river from one tributary juncture to the next should certainly include at least one node. Also, major changes in the river's configuration (such as bends) may suggest additional node detail.

Using this hydrodynamic information, the water quality component of the model computes concentrations of various constituents exactly as before except that now the question of dispersion by diffusion is far less significant than the result of the advective unidirectional flow. Of course, decay of nonconservative substances, benthic uptake and the like, all have their effect and are taken into account in balance equations which resemble those of the estuary models. It is not necessary to repeat this description here because it is but a slight variant of the previously derived equations. It does appear, however, that Tetra Tech does incorporate the effect of heat losses and gains in the river across the air/water interface in a more pronounced way than in the bay models. Temperature, together with re-aeration, photosynthesis and respiration of algae, and BOD loading, are all factors which contribute to the dissolved oxygen deficit of the river. Each of the balance computations involve the volume of a node, but these are easily computed from the depth, width, and channel length.

If inflows and outflows along the river vary with time then the hydrodynamic computations would be carried out over a set of successive time increments of duration appropriate to the rate at which significant changes occur (hourly, daily, or even longer time spans). When all flows and loads are constant over time and when there is no change in constituent concentrations, one obtains the steady state modeling situation referred to in the discussion of surface models. However, in the event that one wishes to track variations over a diurnal cycle, it is possible to do so by choosing suitable small time steps in the water quality mass balance equations. This is referred to as the dynamic water quality model by Tetra Tech.

7.2.4 Phytoplankton Model

Some consideration is being given to an ecological assessment of how structural and nonstructural abatement alternatives impact on the bays. This work essentially extends the water quality considerations which were treated earlier. In the estuary model it was noted that dissolved oxygen is dependent

on concentrations of algae in the water, since these microorganisms both produce and utilize oxygen through the process of photosynthesis and respiration. This concentration is assumed to be a known quantity which is given as one of the model inputs. What this explicitly ignores, however, is that the algae concentration is itself dependent on other factors which include not only the level of nutrients in the water, such as the various nitrogen and phosphorous compounds which form part of the waste loads discharged into the bays, but also on the level of oxygen itself. In effect, one has a coupled system of mutually interacting influences which are accounted for in the Tetra Tech models only in an implicit way.

An *ecological model* attempts to capture some of the interactions which take place over time between nutrients and organisms in the water in order to give a better grasp of the diurnal fluctuations which do occur, and in order to predict the conditions which can lead to *eutrophication.* The process of eutrophication is characterized by an excessive growth of algae ("blooms"), an accumulation of organic debris, as well as low oxygen levels.

The model uses a set of mathematical relations which describe how *phytoplankton* (a class of microorganisms which include algae) are consumed by herbivorous animals (the *zooplankton*) and how the detritus of dead matter and excreta is recycled through bacterial decomposition to provide a new supply of nutrients for the phytoplankton. These relations are conceptually similar to the ones used in the water quality model in that each of them give the rate of change of one constituent over a time interval ΔT in terms of the values of other constituents. For example, the rate of growth of zooplankton is proportional to the population level of phytoplankton, with a growth rate which measures the efficiency of feeding (zooplankton graze more than they actually consume). In this way one in effect writes down a set of equations which simply extends and complements the ones given in the earlier model. Figure 7–14 below displays a schematic of the various interrelations which are dealt with in an ecological model. Note that oxygen is used in the process of bacterial decay of waste loads generated either by man induced wastes or through the natural processes of organic decay in the waters. The nutrients on which the phytoplankton feed are provided either through these same man-induced loads which enter the bays as sewage and runoff or through the natural recycling process which transforms decomposed material into a new supply of nutrients. Therefore, one deals here with a nearly closed system except for such external factors as waste discharges or temperature and sunlight (each of the last two affect both the rates of photosynthesis which generates oxygen) and of respiration (which absorbs oxygen). Incidentally, large temperature increases can also occur from man-made heat discharged from power plants.

The complete loop is generally self limiting in the sense that under "normal" conditions all interactions balance each other and therefore no single constituent can grow in an unlimited fashion. An unbalanced situation, triggered perhaps by a large input of organic wastes during a storm surge, can

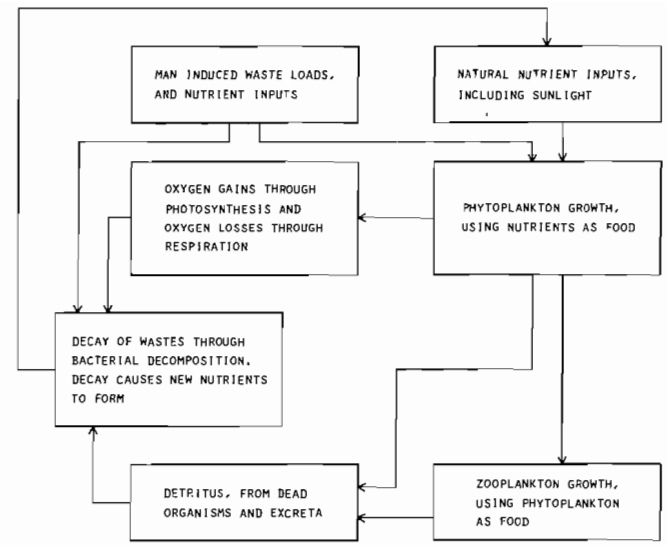

FIGURE 7–14 *The Ecological Cycle in Estuaries.*

cause excessive algae growth, and a mathematical model allows one to roughly predict what the extreme conditions must be to cause such behavior. In this way another tool is added to the arsenal which is available to manage water quality in surface waters. One should caution that, as with all modeling, it is clearly impossible to capture all of the interactions which actually take place and that the equations can at best approximate reality. Moreover, many of the parameters of the model (such as grazing rates, growth rates as a function of sunlight penetrations, and so on) are imperfectly known. Nonetheless, with proper interpretation of the results useful insights can be obtained. The environmental consultant intends to utilize these ideas as part of the overall environmental assessment in combination with other techniques and approaches. The model, in fact, is essentially a modification of the classical mathematical relations which describe interactions between predator and prey. In this case the predators are zooplankton, and prey are phytoplankton which feed on a nutrient source. In the absence of predators the growth of the prey is limited by the population carrying capacity, denoted by a value k_A, which varies with the level of nutrients in the water. The predators grow at a rate which is proportional to AB, where A is the concentration of prey and B is the concentration of the predators themselves. (The units of A, B are biomass per unit volume). However, these organisms also have a carrying capacity which limits their productivity and in the model an additional curtailment on growth is imposed which is based on the idea that predators reach a level of satiation in their feeding. The various feeding rates and the satiation constants are determined empirically.

7.3 GROUNDWATER MODELING

7.3.1 Introduction

The groundwater modeling studies carried out for the 208 project by Princeton University and the United State Geologic Survey are oriented toward an understanding of groundwater flows and pollutant dispersion in the aquifers which underlie Long Island, as shown in Figure 7–15. Model development is similar to that described in Section 7.2 for surface waters but with two important distinctions. The geometry and physical characteristics of the soils which constitute the aquifers act to impede and redirect the fluid flow. Consequently, it becomes necessary to accurately represent the interaction between the water and the medium through which it flows. In addition, whereas vertical mixing in surface waters permits reduction to planar flow, here three-dimensional water movement is considered. In reality, the vertical flows are considerably smaller than horizontal and a simplified picture may be constructed in which an aquifer is represented as a series of horizontal planes, or layers, which are then linked together in the vertical direction. As in the case of surface waters, the hydrodynamics of water flow is first modeled and pollutant dispersion, or water quality modeling, is then based upon the hydrodynamic solution. The general character of both hydrodynamics and pollutant dispersion follows the discussion in chapter 1 of this report, though the analogy of the use of tanks interconnected by pipes is replaced with a more specific description of how the groundwater system is represented for model development.

In this description of groundwater flow, it is assumed that the aquifer, or medium, is saturated with water. The medium gives rise to several important features of fluid flow not present in the earlier discussion of surface waters.

Since the material of the medium takes up some of the space in a given total volume, the remaining open pores available for the storage of water are characterized by a porosity ϵ. In addition, empirical studies show that water flows through the medium as if it were moving through long capillary tubes. This creates a condition in which the medium is partially restrictive of the water flow, and this is described by permeability k. Within the thin capillaries, viscosity μ of the fluid establishes resistive forces which dominate the flow. The porous structure of aquifers is also highly *anisotropic*. That is, under specified pressure differences the velocity of groundwater flow will vary widely with direction, often by more than an order of magnitude. Flow velocities are greatest along more or less horizontal planes in the aquifers and least in the vertical direction. Finally, these primary physical parameters which govern groundwater hydrodynamics—porosity, permeability, viscosity, anisotropy—are all dependent upon the specific aquifer (since these have different soil types) and upon spatial distribution within an aquifer both horizontally and vertically. Consequently, while the model equations will have the same form from place to place within an aquifer, the values of the governing parameters will need to be specified in great detail.

Two fundamental relationships are required to describe groundwater flow which are analogous to the hydrodynamic equations for surface waters. First, the velocity of flow is driven by differences in pressure, or head, from one point to another in the aquifers. Second, hydrostatic head changes with time as the flow velocity transports fluid from one place to another in the aquifers.

Therefore, two equations are required to determine the two variables of head (pressure) and velocity. The basic form of the equations was discussed in Section 7.1 and, here, they are made specific to groundwaters.

For convenience in model formulation and computation, consider an aquifer divided into layers of square nodes of finite volume interconnected by channels. For the present, the vertical coupling between layers is ignored, to be added as a source term later. In the simplified illustration of nodes coupled together in Figure 7–16, a change in head (water elevation or pressure) at node 1 results from the net flow of fluid into the node. Since the node surface area A_S remains constant, the volume change is due to change in head. Compared to surface waters, the porosity ϵ (which is less than or equal to one) implies larger head changes for the same net inflow into the node. In addition to flow of water from one node to another due to differences in head, there may be various natural and/or man-made mechanisms for flow into or out of the node. Consider for example the aquifer layer which represents the water table, or top of the groundwater system. This layer is subject to distributed recharge from natural sources as well as direct wastewater recharge at specific locations. Recharge flow Q^{in} (cubic meters per second) at each node must be specified and these contribute to increasing head. Similarly, there are natural and induced sinks or losses. Wells utilized for public water supply and other withdrawal purposes act to decrease head at each node they impact. In addition, there are groundwater seepages and discharge to streams and underflow to bays. The pumping wells and natural discharges are introduced at each node by terms Q^{out} (cubic meters per second).[9] Finally, there is the coupling from one layer in the model to another. Since such flows are driven by vertical pressure differences in the aquifers, they are characterized by terms analogous to the horizontal velocity. It should be emphasized that such terms reflect the anisotropic flow and the vertical velocity will tend to be small in relation to the horizontal flow velocity. It proves convenient to define a *specific storage* S as $\epsilon A_S/A_C L$, where L is the channel length between nodes, which is roughly the node horizontal surface area divided by node volume. Specific storage S is therefore approximately the height of the aquifer layer.[10] The change in velocity with time is limited by hydraulic conductivity K, a team which combines fluid viscosity with the permeability of the medium. This constant reflects the role of viscous forces upon fluid flow in porous soils.

This discussion of groundwater equations may be summarized by noting that the starting point for both Princeton and USGS models is in the

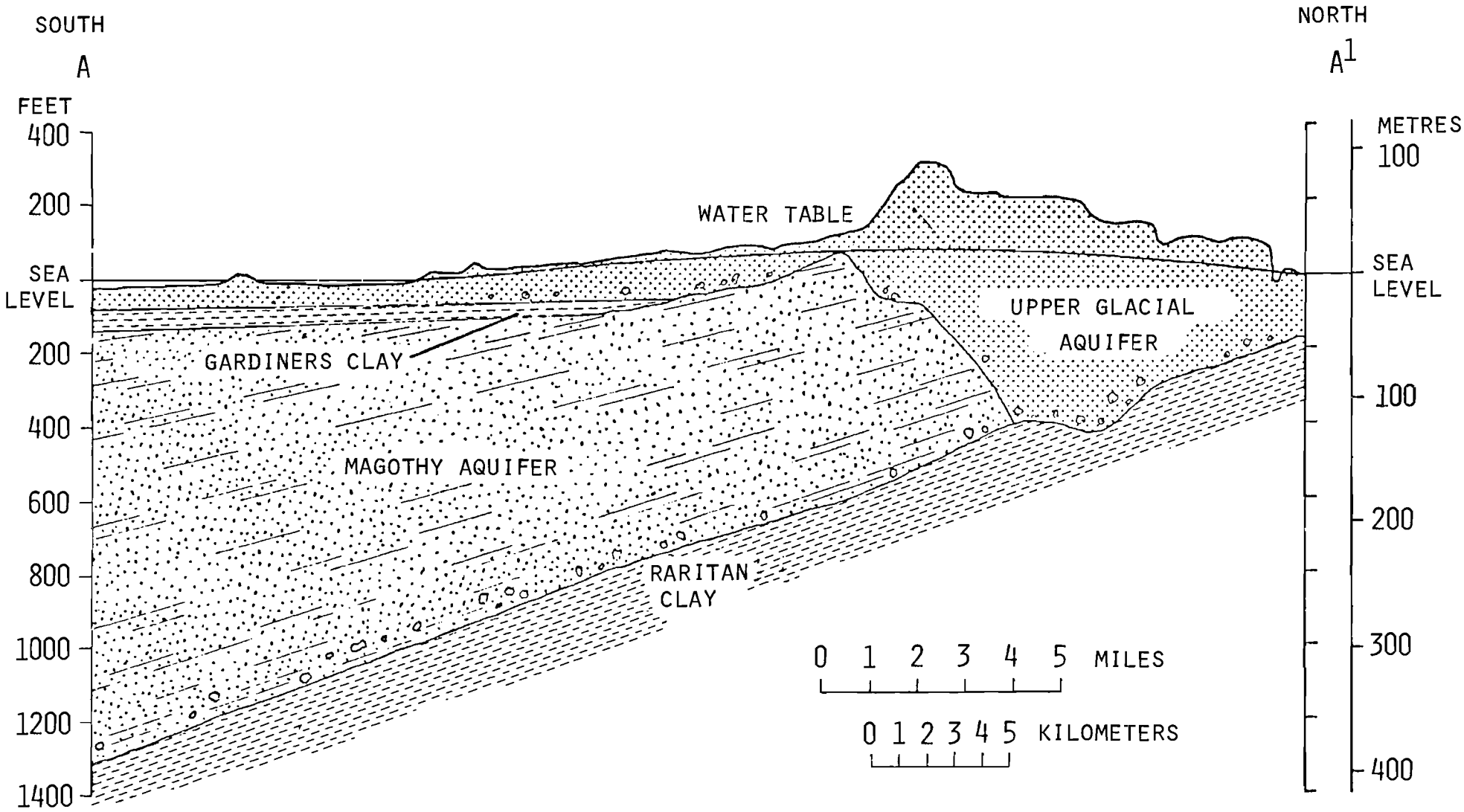

FIGURE 7–15 *Crossection of Long Island Groundwaters.*

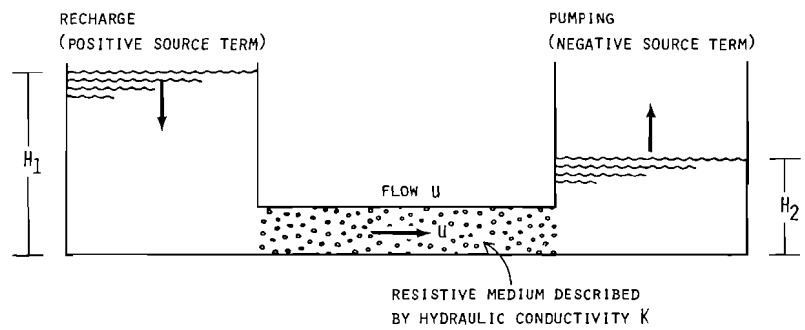

FIGURE 7–16 *Simple Schematic to Illustrate Flow in a Porous Medium.*

hydrodynamic equations of motion for head and velocity. There are then two basic choices in an approach to construction of a model of groundwater movement. One can adopt a strategy of taking the basic hydrodynamic equations and develop a direct computer solution. Such computer solutions have the advantage that information in the model may be adapted from one area to another so that the model is relatively transferable. This is how the Princeton group approached it. An alternative is to build some type of physical structure which behaves in the same way as the groundwater system. This is the approach taken by the USGS. It should also be emphasized that a computer oriented approach facilitates the inclusion of pollutant dispersion, which will be discussed in connection with the Princeton University modeling effort, whereas analog models generally do not.

Before we proceed to detailed discussion of the Pinder finite element method and USGS analog model structures, it will be helpful to get some idea of the magnitude and relation between head H and velocity u and the parameters of specific storage S and hydraulic conductivity K. It can be shown that the solution to the velocity equation has the form shown in Figure 7–17. In physical terms, the velocity responds to a pressure difference by increasing to a maximum steady state velocity u_o which is known as the *Darcy Velocity* (first measured in experiments by Darcy in the late 1800's).[11] Using hydraulic conductivity typical of Long Island Upper aquifers, and a hydrostatic head difference of 2 meters between nodes of spacing about 2000 meters apart (as in the USGS model), the steady state velocity u_o is about .01 meters per day and flow rate is therefore quite small. Note that the time t_o required for velocity to respond to pressure difference is about K/g from Figure 7–17. Using the hydraulic conductivity above and gravitational acceleration 9.8 m/sec$_2$, the equilibrium time becomes 9 microseconds. As we see below, this represents very rapid achievement of the steady state Darcy velocity compared to the time over which hydrostatic head differences are compensated.

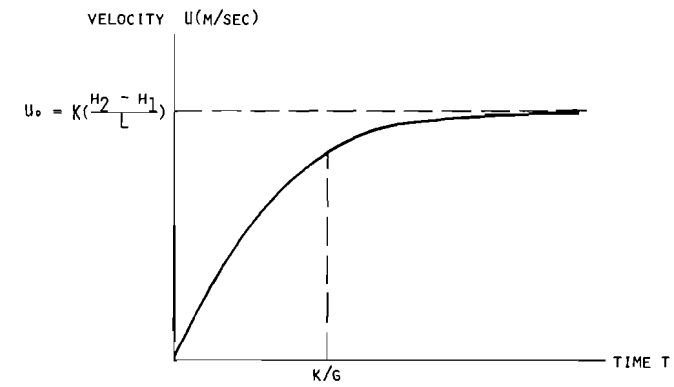

FIGURE 7–17 *The Darcy Velocity in a Porous Medium.*

Using the steady state velocity, the equation for hydrostatic head has a solution shown in Figure 7–18. The heads approach a steady state condition $H_2 = H_1$ in which there is no pressure difference and consequently no remaining flow. As noted earlier, the specific storage is approximately an aquifer thickness of about 50 meters. Then using hydraulic conductivity (10m/day) and node spacing (2000 m) from above, the time required for the pressure to go to equilibrium in Figure 7–18 is about 30 years. Hydrostatic head equilibrium is achieved slowly because viscous flow in the porous medium limits hydraulic conductivity, and hence limits velocity to .01 m/day. This brief description of the general character of groundwater flows is sufficient to proceed to specific model formulations.

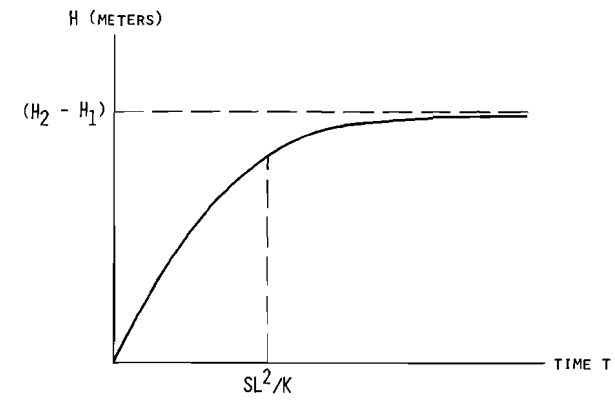

FIGURE 7–18 *Head Change in a Porous Medium.*

7.3.2 Analog Model

The USGS model of Long Island groundwater is formulated by using an analogy between the hydrodynamic equations for steady flow and the voltage-current relationships in electrical circuits. In Figure 7–19, it is seen that water flow into a node, or tank, in the groundwater system leads to an increase in head. Analagously the flow of current into a capacitor leads to increase in voltage across a capacitor. Indeed, the two equations for these physical phenomena have exactly the same form. Consequently, to construct a physical representation of the groundwater system requires that a capacitor be chosen of the right size to represent storage at each node of the model. It might be noted that capacitors are devices which are each about the size of a U.S. twenty-five cent coin. Continuing with the development of the analogy, Figure 7–20 shows that the flow of water from one point to another in the groundwater system is driven by a difference in head. Analagously, the current through a resistor is driven by the difference in voltage between the two ends of the resistor. Consequently, for each channel which connects nodes together, one resistor which is a device about the size of a small piece of chalk is introduced. Overall, the model may be constructed as a set of capacitors which represent specific storage within each node and a set of resistors which represent hydraulic conductivity associated with a flow between the nodes, as shown in Figure 7–21.[12]

The model includes a description of recharge and discharge at each node in the system. Recharge to the aquifers is represented by current generators which pump current directly into the capacitor which represents a node, much as is shown in Figure 7–19. Similarly, discharge or seepage to streams and bay waters, pumping and other sources of loss from a node, are presented by a current drain away from the node.

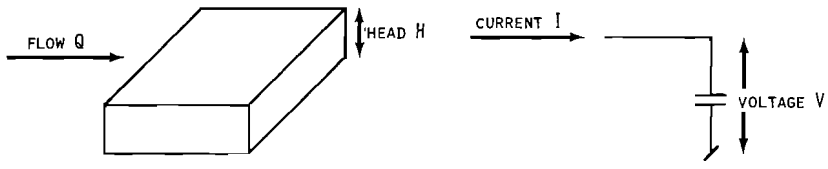

FIGURE 7–19 *Analogy Between Water Flow and Electrical Current in USGS Model.*

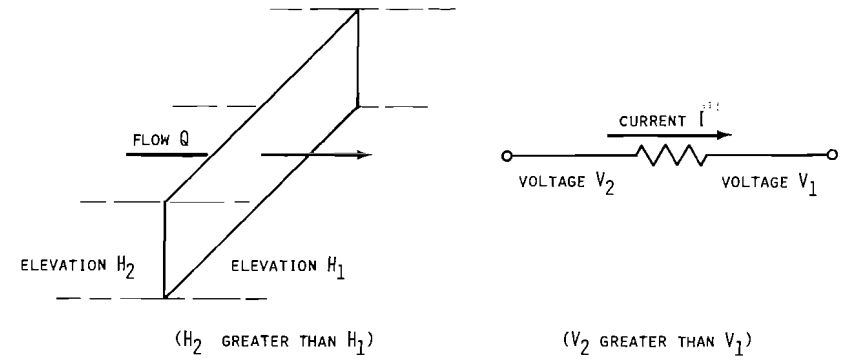

FIGURE 7–20 *Analogy Between Water Flow and Electrical Current in USGS Model.*

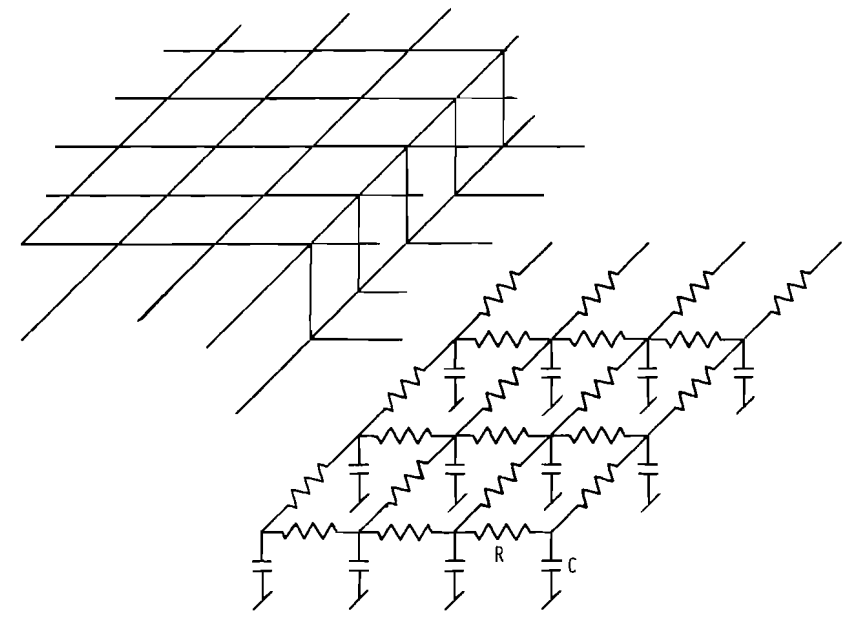

FIGURE 7–21 *Analogy Between Water Flow and Electrical Current in USGS Model.*

The USGS analog model represents the upper glacial, Jameco and Magothy aquifers in a five layer structure. As seen in Figure 7–22, the grid system specifying the nodes extends into the New York City portions of the Long Island groundwater system. Groundwater conditions in the North Fork and South Fork are not included in the model. The horizontal node spacing is 1829 m, while the vertical depth of nodes ranges from zero to about 120 m. The five layer structure is required to accurately represent vertical change in hydraulic conductivity K and specific storage S which are the governing parameters in the hydrodynamic equations. More importantly, these two parameters vary widely in the horizontal plane. Therefore, it is necessary to specify K and S for each grid element in Figure 7–22 and to calculate a value for the resistor R and capacitor C which represent these parameters in the analog model. In practice, the specific storage is poorly known but appears relatively constant over reasonable areas, and this simplifies determination of capacitors. Conversely, hydraulic conductivity varies widely.

There are some 2000 horizontal grid elements in Figure 7–22 which are represented in the model, and there are five such layers. Consequently, there are about 10,000 nodes or capacitors. At each node, there may be a connection to as many as six other nodes using resistors. In addition, recharge, pumping wells, discharge to streams, and the like are all entered at specific nodes primarily in the upper layers, from which we see that the construction of a physical analog model can be quite laborious.

Given the types of data available on specific storage and hydraulic conductivity throughout the aquifers, the USGS model makes several plausible assumptions. Specific storage is taken as constant within a particular model layer; capacitors are uniform. The primary variation in hydraulic conductivity is its anisotropy. They assume a roughly 10:1 ratio between horizontal and vertical conductivity. Therefore, at each point in the system an average horizontal conductivity is established from field data and the vertical values are then scaled accordingly.

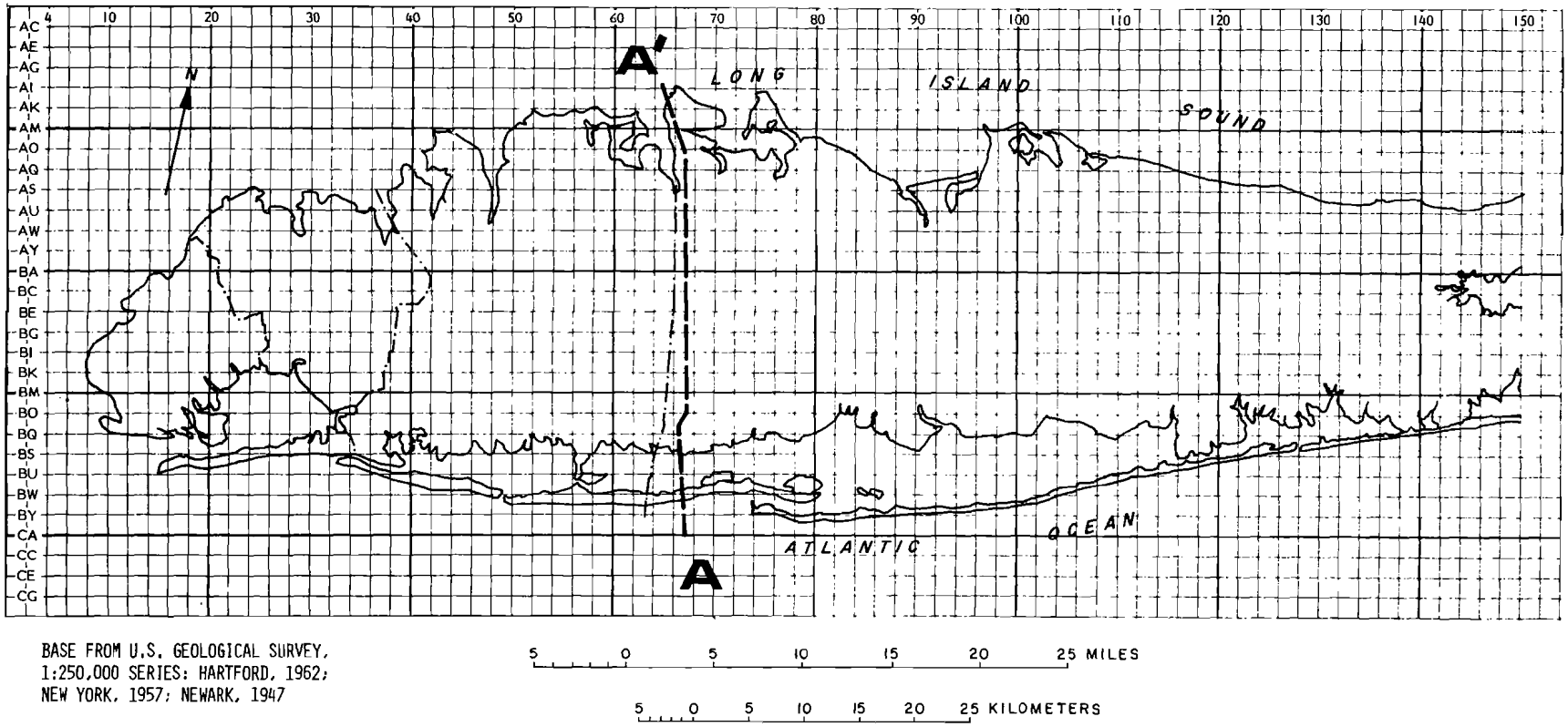

FIGURE 7–22 *Grid Layout For USGS Model.*

The effects of recharge and discharge are thought of as "stresses" upon the groundwater system. The model is assumed calibrated and verified if it replicates past variations in head when the historical pattern of stresses is used to drive the model. Where discrepancies arise between predicted and observed head, the vertical hydraulic conductivity is a primary calibration parameter because it is the least certain of the data inputs (remember this requires physical change in the values of resistors). Following such calibration, the model is assumed valid for future prediction of response to new stresses upon the system.

7.3.3 Finite Element Model

The Princeton University group (Pinder for hydrology models, Cleary for the groundwater quality model) has prepared groundwater models which have been utilized in hydrology studies on the South Fork and main portions of the Island and in examination of water quality surrounding the Babylon landfill site. It should be noted immediately that the hydrodynamic equations for the USGS analog model and the Pinder computer-based models are the same; only the solution technique differs.[13] However, within the analog model it is virtually impossible to introduce pollutant dispersion, whereas the computer formulation lends itself to an extension into groundwater quality modeling.

The use of the hydrodynamic models, and pollutant dispersion models within the overall framework of the 208 project will be quite different. For area-wide studies of the impact of pumping and recharge upon water table, the USGS analog and Pinder computer-based models provide comparable information. On the other hand, it was noted earlier that groundwater flows are quite slow and it requires decades for water to move over distances of a mile or so. As a result, the dispersion of pollutants within the groundwater system is quite localized. The Cleary groundwater quality model best serves to define the details of contamination around localized sources, such as the Babylon landfill.

The Princeton University group has prepared four specific models for analysis of groundwater conditions on Long Island, as noted in Table 7–1. The two South Fork models are of course specific to this particular area of the Island where water availability and quality have become major concerns. The regional South Fork model describes head, or water table, throughout the area and includes explicit representation of the saltwater-freshwater interface as it shifts due to withdrawals for water supply and irrigation needs. The local well South Fork model specifically considers saltwater intrusion into a major pumping well where the regional model results indicate that such problems might arise. The Long Island groundwater model is identical to the USGS analog model (with the exception of mathematical solution technique as noted earlier). Both models essentially describe change in head or water table for various stresses such as pumping, recharge, changing stream flow, and the like upon the groundwater system. Because these Long Island models

Table 7–1

Computer Based Groundwater Models

Title	Purpose
South Fork-Regional (Pinder)	Spatial distribution of height of water table. Movement of saltwater-freshwater interface.
South Fork-Local Well (Pinder)	Saltwater intrusion into a pumping well.
Long Island-Regional (Pinder)	Spatial distribution of height of water table (equivalent to USGS but different mathematical formulation).
Groundwater Quality (Cleary)	Contaminant plume (pollutant concentration from a landfill or other source).

are designed for large-scale analyses, they do not include any detailed characterization of saltwater/freshwater interface for the main island and, as a result, are not appropriate for saltwater intrusion studies. Finally, the Cleary groundwater model is a very localized hydrodynamic model somewhat similar to the South Fork local well model, augmented by pollutant dispersion which will be described briefly below. Cleary takes an approach which involves direct solution of the coupled hydrodynamic-pollutant concentration equations so that certain non-linear interactions between groundwater flow velocities and contaminant diffusion are fully represented in the model and permits study of a very wide range of contamination problems.

In the description of pollutant dispersion, there is one important distinction between the surface water system and groundwater. Nonconservation pollutants are those which tend to decay or change over time. This includes, for example, fecal coliforms, biological oxygen demanding substances (BOD), and the like. Such contaminants have rates of decay which are typically hours or days. In consideration of tidal flows, the movement of water takes place over periods of hours as does pollutant decay, and it is important to track both the movement and the decay of such pollutants. However, in the groundwater system, the residence time before there is any substantial movement of water is decades. Consequently, nonconservative pollutants introduced into the groundwater system undergo effective decay at the point of entry, and they will not be found at any substantial distance from the source. As a result, the pollutant dispersion mechanism need be considered only for conservative pollutants. With this distinction, the description of pollutant dispersion is otherwise quite similar to that in surface waters.[14]

The general character of pollutant dispersion in the groundwater system is shown in Figure 7–23. The change in concentration of a contaminant introduced into the groundwater at, say, a recharge well, occurs because of two general forces. First, advection describes the overall flow of water from one point to another in the aquifers. If the motion were entirely uniform, a "slug" of contaminant would remain intact. In reality, we have noted earlier that flow is anisotropic. The small downward components of flow lead to some vertical spreading of the pollutant and, hence, reduction in level of concentration. Superimposed upon this advection is diffusion, the tendency of any concentrated pollutant to spread out and fill the entire volume in which it is situated, as illustrated in Figure 7–23. In the absence of any groundwater flow (no advection) diffusion itself will lead to lower concentration of pollutant. For example, a drop of dye placed in a bathtub gradually diffuses to fill the entire tub with a low uniform level of dye, as pointed out earlier. As noted in Figure 7–23, the superposition of advection and diffusion leads to development of a containment *plume* in the aquifer. Such a plume extends several miles south of the Babylon landfill site on Long Island. Remember that groundwater flow is quite slow and that it takes decades for such plumes to form.

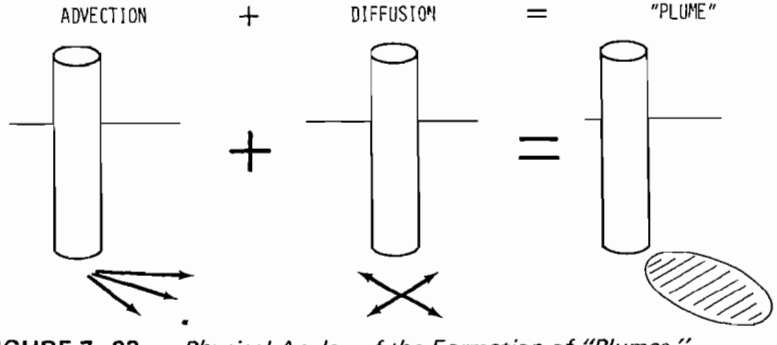

FIGURE 7–23 *Physical Analog of the Formation of "Plumes."*

7.3.4 Uses and Limitations of the Groundwater Models

Five distinct models have been described: USGS and the four Princeton ones. Each of these has been utilized in the study of selected problems. Some have been mentioned earlier and need only brief mention here. In some ways, the models have much in common. They are all dynamic models and depend upon the same basic aquifer parameters. They tend to differ in their detailed descriptions of specific phenomena such as saltwater intrusion which are primarily localized phenomena.

All of the models assume that an adequate data base exists for specific storage (porosity of the soils in the aquifer) and hydraulic conductivity (permeability of the soil in conjunction with viscosity) which govern the hydrodynamics. However, these parameters vary widely depending upon spatial location in the Long Island region and upon depth and type of aquifer. These may be adjusted during calibration to achieve an adequate match between head predicted by the model and actual field data, but other factors such as stream flows might also be factors. Thus, one cannot always be certain that the right parameters have been set during calibration. Once again this largely depends on the experience of the modeler and in the Long Island 208 this is not a real concern.

The USGS analog model and Princeton Long Island models serve the same purpose. They each compute the height of the water table or head at roughly 1 mile spatial increments everywhere between the New York City line and Riverhead in the Bi-County region. In addition to specific storage and hydraulic conductivity parameters, the models require groundwater seepage to streams, natural recharge and other stresses including pumping well locations and volumes, injection wells for recharge and the like. The information needs for such regional models, involving up to 10,000 nodes, are extensive. Fortunately, such a set of data has been prepared for the Long Island region. The models may be run in a dynamic mode using time steps of a year since decades are required for large differences in head to appear. The analog model requires considerable effort to establish electrical circuit arrangements for stresses and/or physical parameters and this places some limits on its ability to compute a wide range of alternatives for wastewater management. The Princeton model provides a computational advantage over the analog model simply because it is computer based. In the Princeton version it is easier to change the values used in the model and even the geometry of the grid system itself. The model is therefore more flexible in that the time required for modifications is short. This means that it is more readily transferable from one place to another since it does not entail the re-wiring of a physical analog.

The South Fork model is a parallel to the Long Island hydrology models. Because of the geology of the South Fork and the potential of saltwater intrusion problems, the model is structured as a two-layer aquifer system (rather than five for the Island) and includes a detailed description of the saltwater-freshwater interface. It is utilized to assess overall impacts of pumping in much the same way as the models above and is subject to the same limitations. Again, the model provides a dynamic history and/or future of head changes and how the saltwater/freshwater interface shifts in response to pumping stresses.

The Local Well model is essentially a small piece of the regional model in which a fine grid configuration may be used to follow saltwater intrusion into a well. In this case, it relies upon an accurate knowledge of the physical constants of the aquifers as well as some detailed history of saltwater and freshwater movement in the local area of the well considered. Such measurements are often difficult to assemble. Consequently, these highly localized models are often calibrated and verified for the specific well under study, for which an extensive data base may exist, but the model and its results may not be easily transferable to other situations.

The Cleary groundwater quality model is another highly localized

model which is an adaptation of a small section of the hydrology models with additional relations to describe dispersion of pollutants within an aquifer. As such it is a water quality model. In addition to data limitations associated with the groundwater hydrology, the model requires sufficient local data to establish a pollutant diffusion coefficient in order to track the spread of the contaminants.

Overall, the groundwater models fall into two categories. The hydrology models are designed to supply information of the spatial distribution of the water table and its change in the future. The localized well and water quality models are useful in the specific sites for which they are prepared and are not directly applicable on a more extensive basis.

7.3.5 Water Budget Model

The water budget model prepared by the Cooperative Extension Service (CES) for the 208 project has two primary purposes: first, to estimate recharge of precipitation and/or irrigation to the groundwater and, second, to provide a transport model for nitrogen loadings to both ground and surface water, in the Long Island area. In this section, the transport mechanisms contributing to the overall water cycle and the extension of this transport model to consider nitrogen loads is described.

We wish to draw attention immediately to the fact that this work does not constitute a groundwater model in the sense of the USGS and Princeton efforts. Recharge here is to the upper aquifers where the soil is relatively unsaturated and does not deal with movements of water in the deeper aquifer layers. The basic premise of the water budget model is that most of the predominant processes involving uptake of water and/or nitrogen occur within the root zone for vegetation on the Island. One consequence of this observation is the fact that whereas lateral movement of groundwater is more significant than vertical flow in the models of sections 7–1 and 7–2, in the present discussion it is the vertical infiltration of the unsaturated subsurface medium which is important. Lateral flows are, as we will see, considered insignificant.

A schematic of water flows is shown in Figure 7–24. The root zone itself is some one to three feet deep depending upon vegetation type. The whole of the Long Island Bi-County region is divided into such cells with surface areas of 2.25 miles, coincident with the planning maps for demographic and land use development. Twelve types of land use development may be introduced on the surface of any cell. The model states simply that recharge is the net of precipitation and/or irrigation inflow over runoff, evapotranspiration uptake by plants, and other outflows from the cell.

In each cell a *mass balance* relation is employed which asserts that total water into a cell must equal total amount leaving it. This assertion is conceptually no different from the mass balance relations utilized in the water quality models discussed earlier. For a given cell one has the following relation which defines 'water budget':

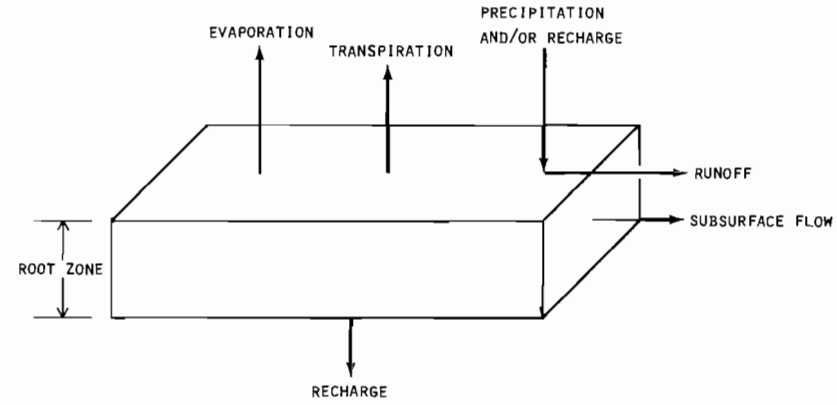

FIGURE 7–24 *Representation of the Recharge Model of CES. Subsurface Flow is Generally Assumed to be Zero in this Model.*

$$\text{Recharge} = \text{Precipitation} + \text{Irrigation} - \text{Runoff} - \text{Evapotranspiration} \qquad (7.4)$$

One should also add to this equation a term for net horizontal flow of water into or out of neighboring cells, but this is considered negligible in relation to vertical flow since the soils are generally considered to be loose, sandy and unsaturated. The term *evapotranspiration* in relation (7.4) refers to evaporation plus transpiration of water through the root zone of plants.

The generation of recharge to the groundwater system may be viewed as a two step process. First, precipitation and/or irrigation cause the entry of water into the system, as illustrated in Figure 7–25. Secondly, vegetation takes up some water for respiration. These evapotranspiration losses are also shown in Figure 7–25.

At the surface, water either infiltrates the ground or creates runoff. The split between these two is characterized by a runoff coefficient determined for various types of soils and surfaces. Impervious surfaces associated with land use development are assumed to block all infiltration. There is an effective "active storage capacity," which describes its overall ability of the soil to capture and retain water. This storage capacity is the product of depth of the root zone and an available moisture capacity.

In general, the moisture content of the soil varies from a "field capacity" in which all available pore space in the soil has been occupied by water down to a minimum in which the little remaining water is locked into the soil structure (see Figure 3.12). When soil moisture drops, evapotranspiration by plants becomes limited by available moisture. At the minimum level, called the "wilting point," the little remaining water is unavailable to plants. Conversely, near the field capacity, soils are near saturation and excess water is generally present over and above that required to support plant respiration at its maximum. As the moisture content drops below the satu-

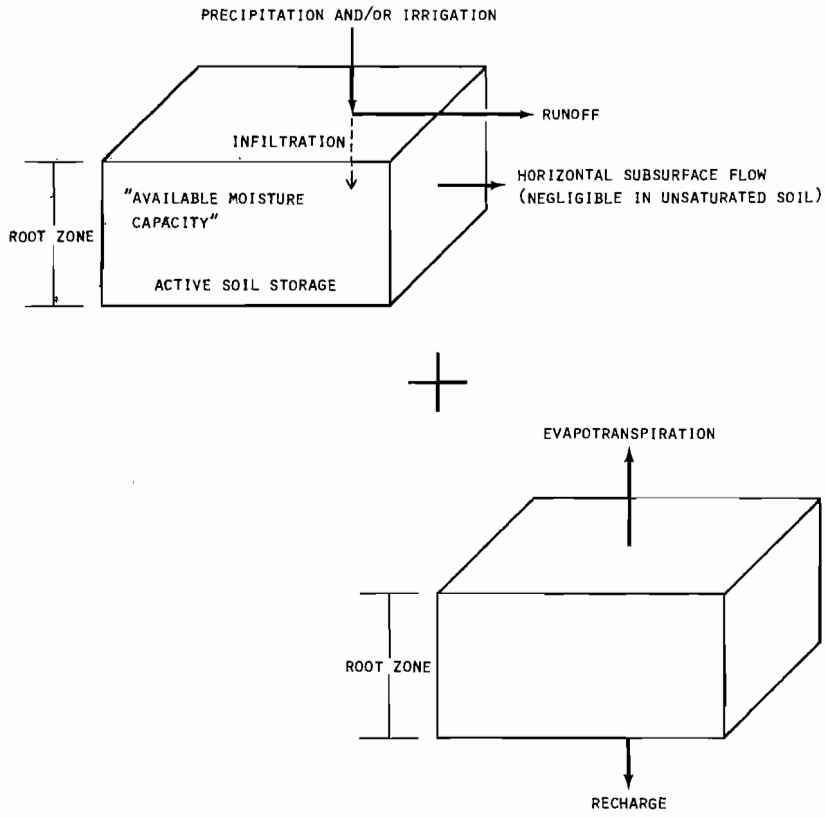

FIGURE 7–25 *Recharge as a Two-Step Process.*

rated condition, plants still have a plentiful supply. However, at a level denoted as critical moisture, plant respiration requires larger amounts of water than available from the soil. Moisture content of the soils becomes the limiting factor in plant respiration. The wilting point is that where no free moisture remains and plant life ceases.

Within the model it is necessary to characterize four major parameters noted above:

precipitation/irrigation—these are the primary water inputs to the system.

runoff coefficient/impervious area—the coefficient describes runoff in areas of vegetation, whereas impervious area gives 100% runoff. However, because of the wide distribution of recharge basins, both natural and man-made, runoff is assumed to occur only in those grid cells adjacent to a water body, e.g. only within about 2 miles of shorelines or streams.

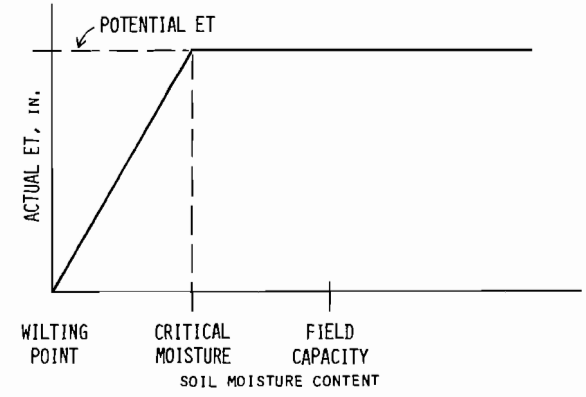

FIGURE 7–26 *Relation Between Evapotranspiration (ET) and Soil Moisture Levels.*

active soil storage (root zone depth multiplied by the available moisture capacity)—this parameter describes the ability of the root zone area to store water.

critical moisture—this parameter characterizes the limiting moisture content for evapotranspiration.

To establish values for these parameters, the CES group relied upon an extensive review of existing data and literature supplemented by field testing, particularly in the area of evapotranspiration effects. The model is calibrated for iteration over steps of one month to obtain annual water cycles. Since precipitation rates, and hence soil moisture content, vary widely within any month, it is important to test the accuracy with which one month averages describe actual recharge. In general, errors in using monthly rather than daily water balances are less than five to ten percent. In addition, following calibration of the parameters above, estimates of recharge and runoff from the model are in good agreement with past direct measurements in selected areas on the Long Island region.

The model is oriented toward the immediate impact of land use development upon recharge to the groundwater system. In its present form it provides a picture of the way in which continuing and alternative land use development limit eventual recharge.

The model above may be supplemented by the addition of nitrogen loadings. Primarily, nitrogen loads reflect the use of fertilizers in residential and commercial areas for lawn maintenance as well as in agricultural areas. It becomes necessary in this case to augment the evapotranspiration relationships with a description of nitrogen uptake in the plant life. With this addition, the model tracks the infiltration and/or runoff of nitrogen, its uptake in the root zone, and the balance which flows on through the system as recharge.

7.4 INTEGRATED USE OF MODELS

The Long Island area is one of wide variety in terms of marine and hydrogeologic water systems. The study area shown in Figure 7–27 has some 1000 miles of shoreline, wetland areas, barrier beaches, shallow bays, and a number of other important elements of the coastal environment. The groundwater system is equally complex, consisting of shallow and deep aquifers, intervening clay layers, underflow to bays, seepage to lakes and streams, and is subject to the problem of salt water intrusion near shorelines. Surface features which contribute recharge to groundwater and runoff to estuaries range from built up urban environments to natural meadowlands. Within this kind of framework the use of models plays an important role in addressing the difficult question of regional strategy for wastewater management, particularly in our ability to quantify the impacts of different land use schemes and wastewater alternatives. Data gathering and assessment for model development, as well as the models themselves, also prove valuable in clarifying the present condition of surface and groundwaters in the area and thus serve to provide a backdrop against which the future may be judged.

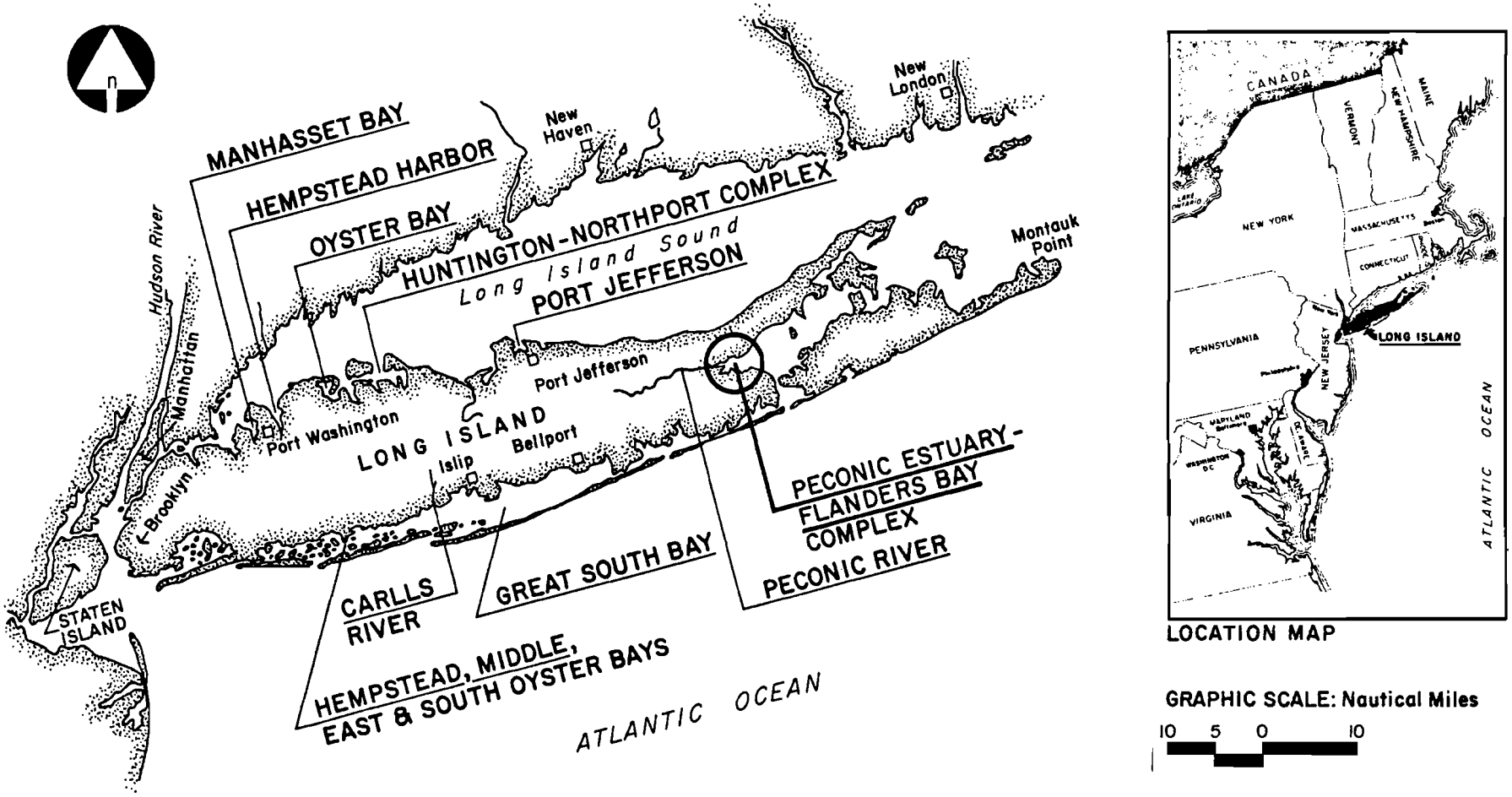

FIGURE 7–27 *Location of Study Areas.*

The way in which results from the different modeling efforts are used in the evaluation of various alternatives for the wastewater management is a complex process. Moreover, it is important to distinguish the use of the models in their role as evaluators of alternatives from that of guiding the selection of alternatives which are appropriate to specific areas. As observed above, much of the data used in model development and calibration serves as a backdrop for the selection of alternatives. In addition, some of the estimates of future wastewater loads may be used in conjunction with the models to define the general character of the region's wastewater future. The model computations, in this case, serve as a backdrop of future conditions, within which to choose viable management strategies. While it is appropriate to discuss such overall regional strategies, specific alternatives will most often concern selected study areas. Consequently, we provide here a short discussion of the models and the ways in which information from these is integrated. It should be pointed out that this integration generally takes place in the context of meetings of groups of individuals, rather than through any type of formal or computer link between the models themselves. The illustrative case study is the Riverhead/Peconic Bay (Figure 7–28). Similar considerations of course apply elsewhere.

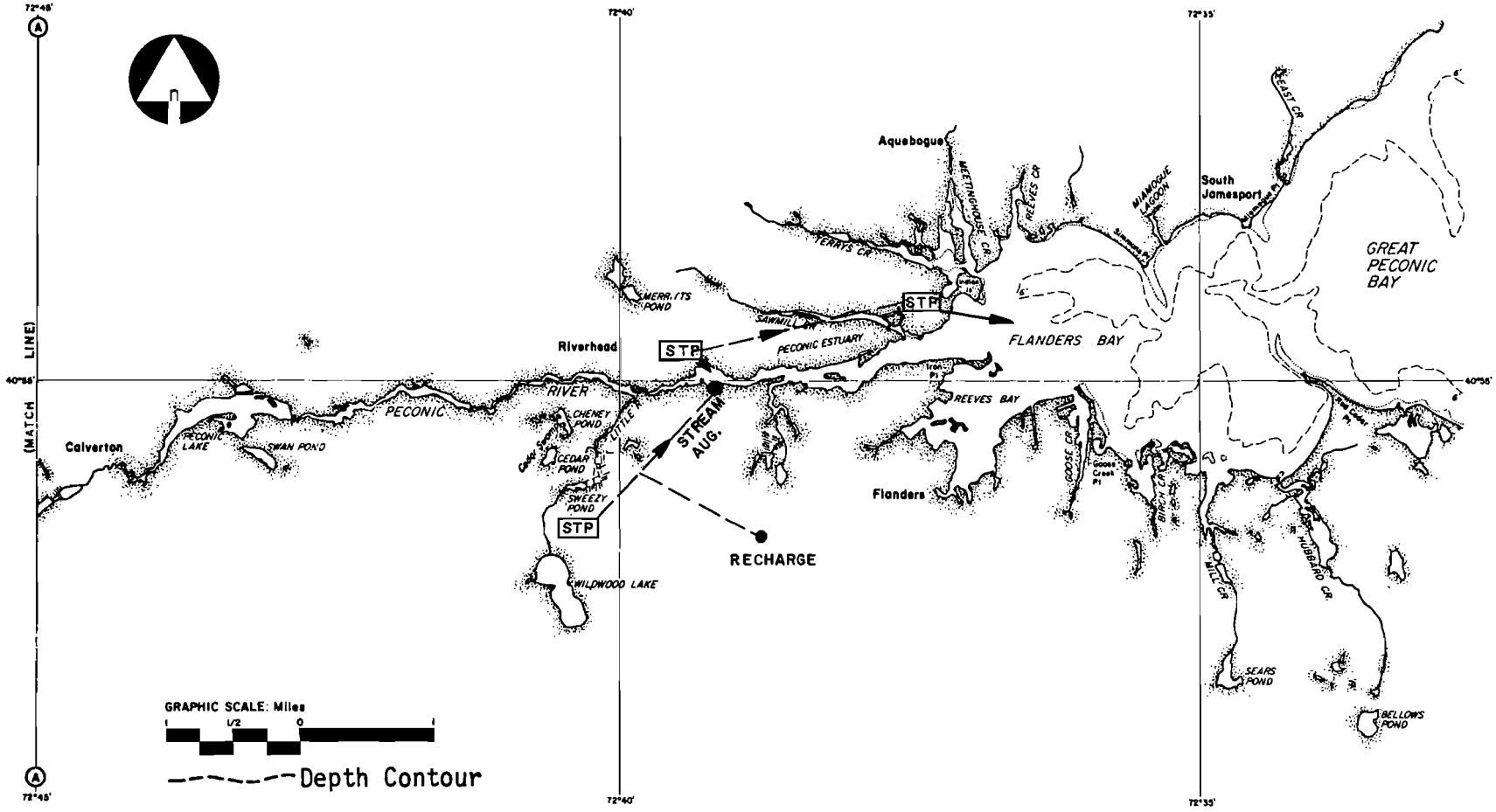

FIGURE 7–28 *Peconic River, Peconic Estuary, Flanders Bay with Waste-Water Management Structural Alternatives.*

The engineering consultants have recommended a number of alternatives which include the use of regional, sub-regional, and local sewage treatment plants or diversions to the Riverhead sewage treatment plant, which may require-expansion of that plant. There have also been expressed concerns with Peconic River stream flow conditions so that it might be appropriate to consider stream augmentation and/or recharge options which assist in maintaining stream flows, the water table, or water quality, respectively. To test the various alternatives, including location of outfall pipes, stream augmentation, recharge, and the like, requires the use of different models for different water bodies. The impacts of discharge to rivers can have secondary effects upon the bay systems, for example through increased effluent loading to the bays. Likewise, in the Riverhead/Peconic area, recharge options may reduce nutrient and organic loading to streams which could have adverse effects upon flora, fauna, and stream water quality. In the face of these complex interactions, it often becomes necessary to combine the information from the several models to properly evaluate these types of wastewater management alternatives.

Figure 7–28 illustrates some of the possible structural options in the Riverhead/Peconic region.[15] The water budget model (Cornell Extension Service) is utilized to establish an accounting of precipitation, evapotranspiration recharge, and runoff components in the total water cycle as shown in Figure 7–29 for the Riverhead area. Of course, paved surface, recharge basins, and other characteristics of the future land use lead to changes in runoff, while removal of vegetation decreases evapotranspiration water loss. The model is so constructed that it can describe the impact of land use development upon runoff, which is a component which enters into estuary and stream models, and recharge, the flow of water which enters the groundwater system. Since it has been estimated that runoff nutrient levels can be a substantial part of the total load to surface waters in areas such as Riverhead, the water budget model can be used to estimate runoff itself as a contaminant to bays, and for recharge to the water table. It should be noted, however, that this model describes only aggregate water flow over large areas and is able to only include conservative contaminants as part of the water cycle, primarily nitrogen and phosphorous. Some of the information which the model does not address is made available through estimates provided by the engineering consultants.

With regard to sewage treatment plants, some method of disposal of effluent is required either to surface waters or groundwater. In the event of discharge to estuarine waters, the Tetra Tech models prove useful in the assessment of the impact upon water quality in such bays. Outfall discharges may add to the water flow and contaminant load. For example, if one considers a specific outfall site in the bay, the Tetra Tech model provides profiles of constituent loading at various locations (as shown by the nodes along the bay channel in Figure 7–30, such as for total nitrogen N and phosphorous P. This is shown in Figure 7–31. The curves correspond to total concentrations

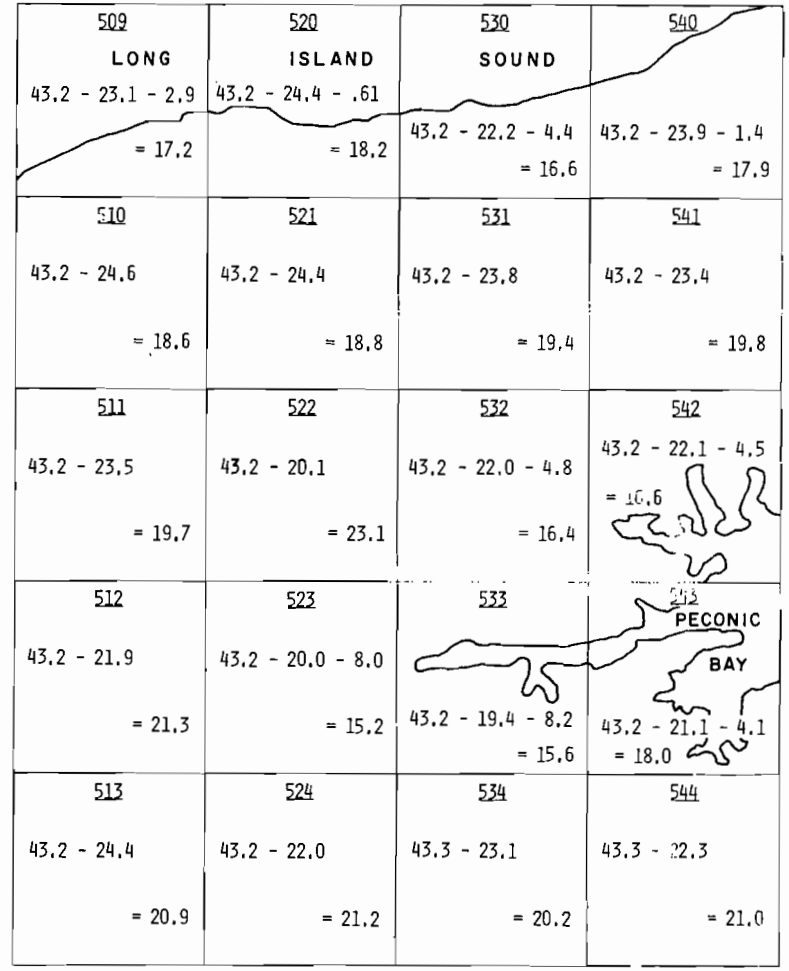

FIGURE 7–29 *Example of CES Computations in Peconic Bay: Precipitation–Evapotranspiration–Runoff=Recharge.*

in milligrams per liter for a typical model run. An alternative strategy might be to consider the diversion of wastewater flows to existing or new plants as suggested in Figure 7–28. The options for wastewater discharge from such plants may include stream augmentation. In this case, the Tetra Tech river models are utilized to describe water quality along the length of a river as well as the impact of the discharge upon the water flow itself.

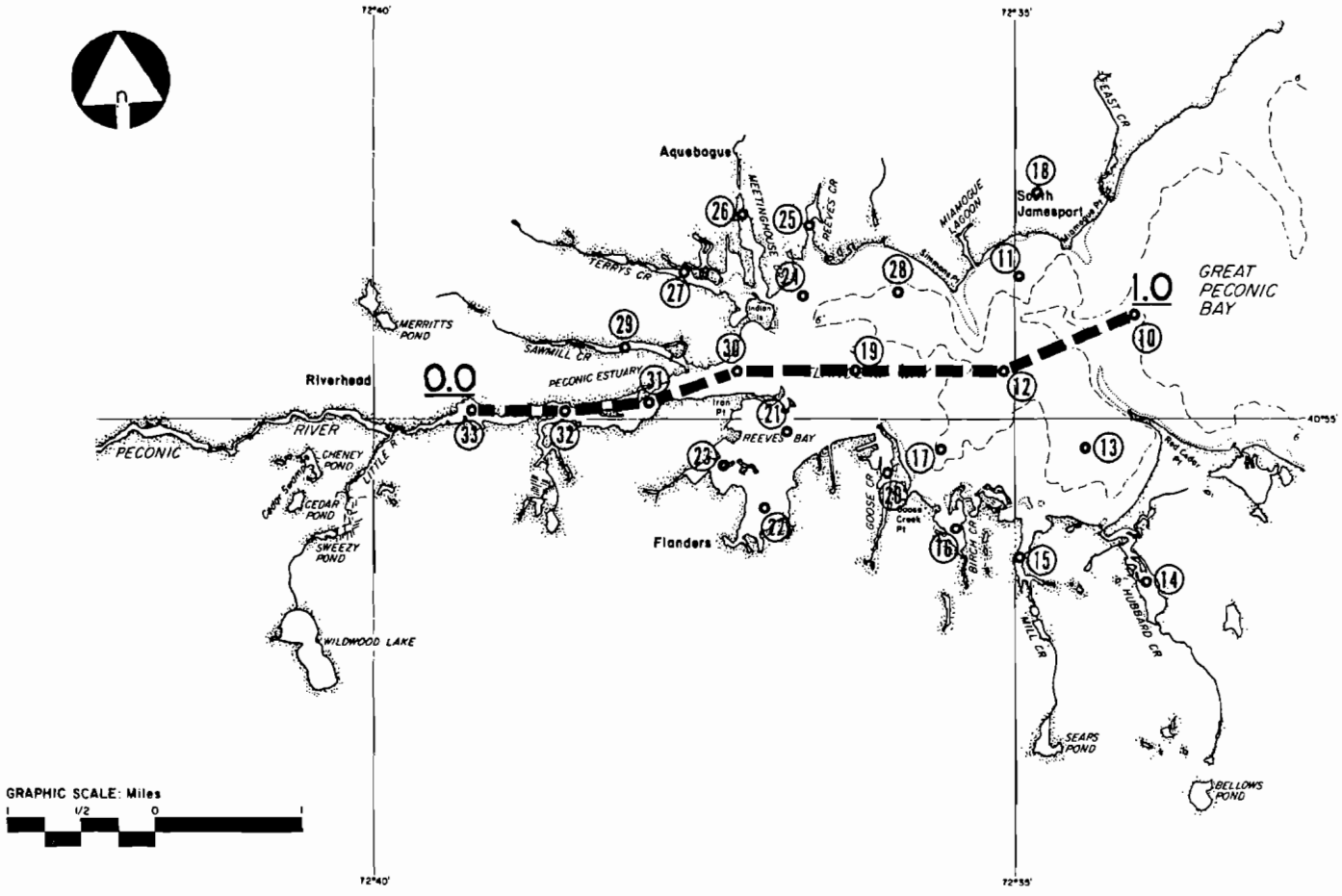

FIGURE 7–30 *Transect Specified for Calibration, Verification and Sensitivity Profile Plots.*

Discharge to the groundwater system has two effects. First, there are local increases in the water table elevation and in addition, the local groundwater quality may be either improved or degraded depending upon prior water quality. Where only a description of impact upon water table and water flow from one point to another in the aquifers is necessay, the USGS and Princeton University models may be applied. For example the Pinder model for North Haven would typify groundwater "hills" such as those shown in Figure 7–32 which would surround an injection well at the point of recharge. In the evaluation of alternatives involving recharge, it might also prove useful to utilize the Cleary groundwater quality model for assessing the flow of contaminants away from the injection well though data sufficient to effectively utilize the model is not readily available for all areas of the Island.

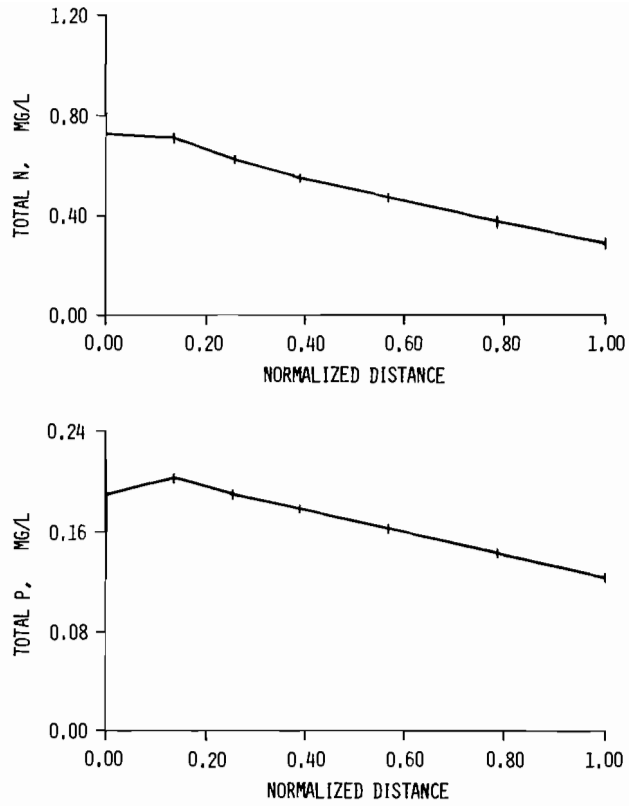

FIGURE 7–31 *Typical Plots of Total Nitrogen and Total Phosphorous Along Transect of Peconic Bay, for Seven Locations Shown in Figure 7–30.*

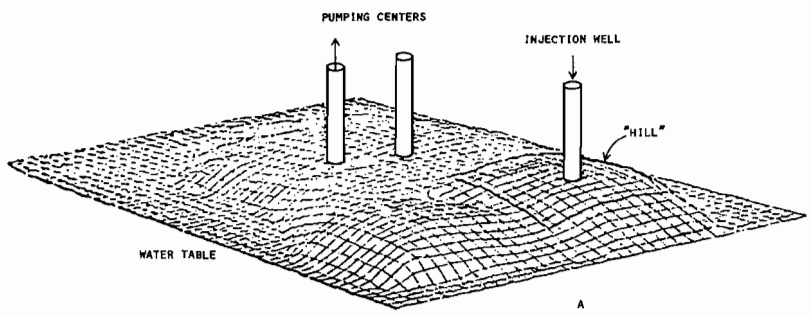

FIGURE 7–32 *Illustration of Water Table "Hill" Due to Recharge.*

The flow of data and information for the evaluation of wastewater management alternatives is exhibited in a different form in Figure 7–33. Here we indicate the possible role of land use development as a basic driving force for the region.

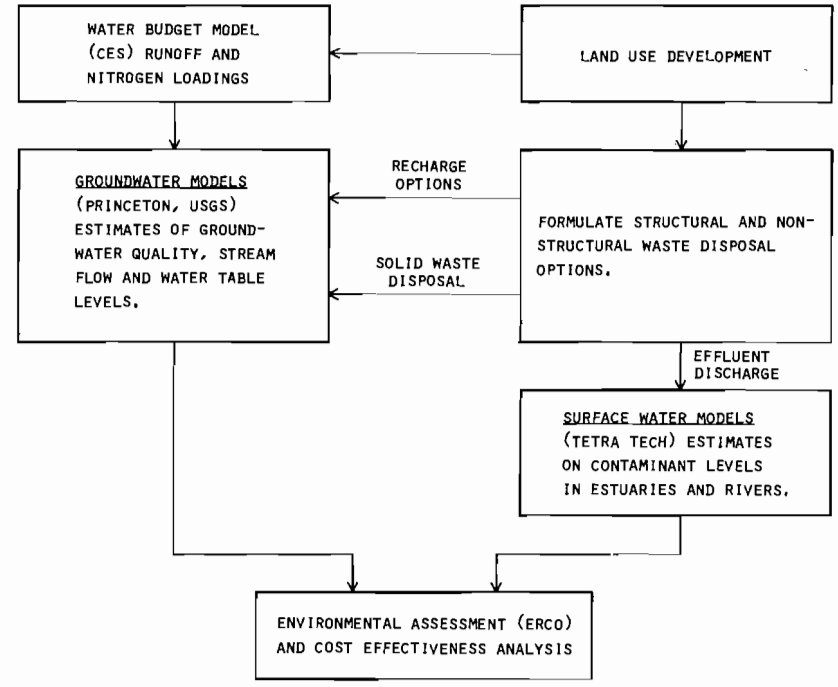

FIGURE 7–33 *Evaluation of Management Alternatives.*

It should be noted that the solid lines indicated in Figure 7–33 denote flow of information within the 208 project itself and not formal links between the various computer models. Ideally, one would like to tie together the models into an overall comprehensive assessment. However, there would be a number of difficulties in carrying this out. The models were all developed by separate organizations using different programmers, programs, computer languages and computer systems. Consequently, it would be a formidable task to pull these together into a comprehensive whole. In a practical sense, however, it is not really necessary to pull all the models into one package. In the assessment of various alternatives, such as a sewage

treatment plant option, its impact upon the water system in the area is assessed using only the specific models which apply. For example, if only a bay outfall is to be considered as the discharge option, the Tetra Tech estuary model alone would be used to assess this. There are, in addition, a wide range of qualitative and quantitative considerations which are drawn into the evaluation of wastewater management alternatives at this point, but which lie outside the scope or abilities of the models. Outfalls to open surface waters could have impacts on stream flows. The groundwater models are not constructed to deal effectively with such effects in individual streams. Moreover, the river model itself does not accurately describe the impact of outfalls on upstream water levels. Environmental impacts upon shorelines, drainage structures, flooding, and ecology of bay and river systems also fall outside the range of the models. However, the models do provide the quantitative background of water quantity and quality required to address these questions. Where impacts of alternatives are considered undesirable, one may cycle back by reconsidering the option, introduce some changes in the character of the alternative, and then run the new option back through the models to assess whether its impacts might now be considered more favorable.

After having surveyed in this report the several modeling components of the 208 it is useful to give a brief summary of what each model does in terms of output, where that output is directed in terms of Long Island waste management, and the inputs required to make the model operational. This is shown in a series of flow diagrams, given in Figures 7–34, 7–35 and 7–36. This introductory view of the 208 models may hopefully encourage the serious reader to consult some of the more technical documents provided by the consultants.

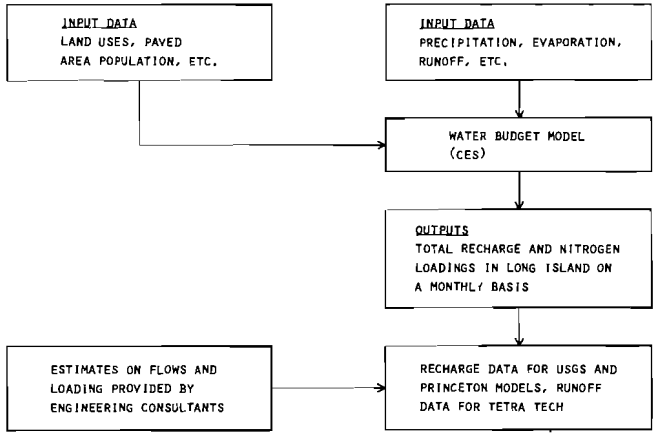

FIGURE 7–34 *Water Budget Modeling.*

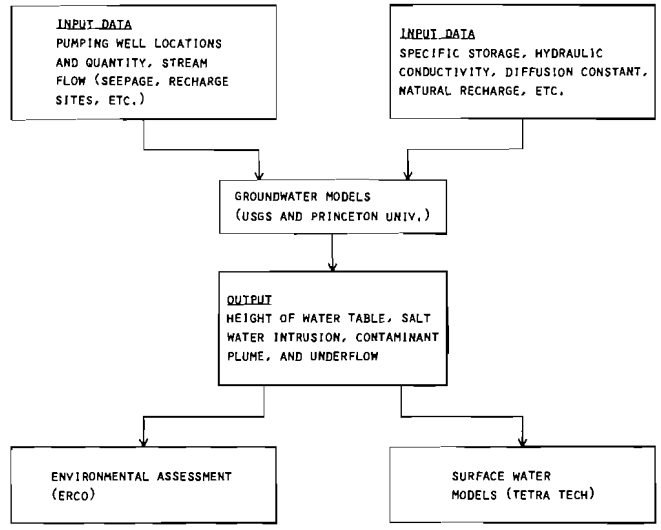

FIGURE 7–35 *Groundwater Modeling.*

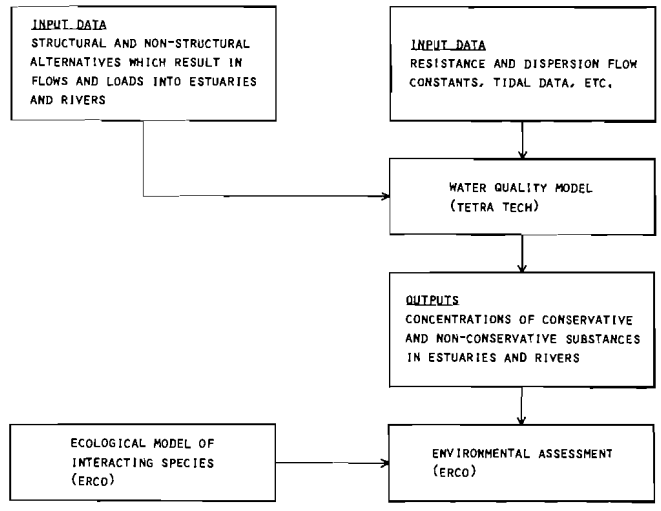

FIGURE 7–36 *Surface Water Modeling.*

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NOTES

[1] Let ΔH denote the incremental change of H during a time interval of duration ΔT seconds. Then the volumetric change during ΔT is given by $\Delta H A_s$ and the principle of mass conservation then says that

$$\Delta H A_s = Q \Delta T \tag{1}$$

where $Q\Delta T$ is the net flow during ΔT. Using (1) equation (2) is often written as

$$\frac{\Delta H}{\Delta T} = \frac{A_c}{A_s} u \tag{2}$$

As we will see later a simple variant of (2) also holds for groundwater flows.

[2] Let ρ denote the water density (kg per cubic meter) so that $\rho A_c L$ is the total mass in kilograms of the water in the tube. The momentum of the moving fluid is the product of mass and velocity and is given by $\rho A_c L u$. Newton's second law of motion says that the rate of change of momentum over time must equal the sum of the forces which act on the moving body. In the absence of any external forces on the fluid, the rate of change of momentum is zero, which is the principle of *conservation of momentum*. One such force, as we already noted, must be due to the pressure difference exerted at the two ends of the channel. If we add to this the resistive force due to friction caused by the roughness of the channel then, since u is the only quantity which can vary in the expression for momentum, the rate of change may be stated as

$$\rho A_c L \frac{\Delta u}{\Delta T} = \text{Pressure Force} + \text{Resistive Force} \tag{3}$$

in which Δu is the incremental change in velocity during an interval of duration ΔT.

It can be shown that the *pressure force* is given by

$$\rho g A_c (H_1 - H_2)$$

where g is a number known as the gravitational constant (9.8 meters per second squared). Note that if H_1 is greater than H_2 then the force is positive and it acts so as to give a flow from tank 1 toward tank 2. When H_2 is greater than H_1 the opposite is true and the flow is reversed. When $H_1 = H_2$ the the net force is zero and there is no exchange of water between tanks.

Resistive force is found from an empirically derived relationship which states that resistance is proportional to the square of the velocity. That is

$$\text{Resistive Force} = -\rho A_c R L u |u|$$

where R is a constant which measures the roughness of the channel walls. As the ratio of the area A_c to the perimeter of the cross section of the channel increases the resistance R decreases. The particular form of the above expression was chosen so that the force will always operate in a direction opposite to the direction of flow (if we had written u^2 instead of $u|u|$ this would no longer be true.)

By combining the above remarks together into relation (3) and by eliminating ρA_c from both sides of the equation one obtains

$$\frac{\Delta u}{\Delta T} = g\left(\frac{H_1 - H_2}{L}\right) - Ru|u| \tag{4}$$

[3] Hydraulic conductivity is defined by a number K which equals $\mu\rho g/k$. Once again g is the gravitational constant. As K increases, resistance decreases.

In view of the above discussion the basic relations 2 and 4 need to be modified slightly. Consider 2 first. Since ϵ is now the fraction of volume which may store water, then $\Delta\epsilon A_s H$ is the effective change in volume of the water in the tank due to a change H in head. Otherwise the same conservation of mass principle still applies as before and so equation 2 becomes

$$\frac{\Delta H}{\Delta T} = \frac{A_c}{\epsilon A_s} u \tag{5}$$

When $\epsilon = 1$ (as in open water) this relation of course reduces to the previous one. Note also that when ϵ is smaller than 1 then, since there is now less volume in which to store water, the change ΔH is larger than for open waters. Relation 4 for open water is similarly modified in the case of a porous medium. Once again A_c is replaced by ϵA_c as the effective cross-sectional area which is acted on by the pressure force. Also the resistive force is now due to the viscosity of the water in the permeable medium as we discussed above and is empirically found to be proportional to the velocity u. Specifically one can show that

$$\text{Resistive Force} = -\rho g \epsilon A_c L \frac{u}{k}$$

This allows us to write an analog of relation (4) as

$$\frac{\Delta u}{\Delta T} = g\left(\frac{H_1 - H_2}{L}\right) - g\frac{u}{k} \tag{6}$$

Note that although in open water resistance to flow is proportional to the square of the velocity, in the porous medium it is simply proportional to the velocity itself.

[4] The analogy can be carried further. Heat flows from a point of high temperature to a lower, also at a rate proportional to the temperature difference. Finally, in an analogy that will be referred to again in the section on groundwater models, current flows in a circuit at a rate proportional to voltage difference between two points. The difference in concentrations relative to the distance between two points of water levels, or temperature, or voltage, describe what are called "gradients." When these gradients or differences are zero there is no further exchange between the two points in the body and the system is said to be in *equilibrium*. One more point: all the flows described here are also subject to the level of conductivity (or permeability, or what have you) in the channel which connects the points. The smaller the "conductivity," the greater is the resistance to flow.

[5] Referring to equation 2 this can be stated mathematically for each node s,

$$\frac{\Delta H_s}{\Delta T} = \sum_{j=1}^{m} \frac{A_c}{A_s} u_j + Q_s^{in} - Q_s^{out} \qquad (7)$$

where all flow conditions on the right side of (7) are determined at some previous time and ΔH_s is the net incremental change in H during a time step ΔT which takes us to the present moment. The symbol Σ is of course the usual shorthand for taking a sum of terms from j = 1 through j = m.

[6] Equation 4 must now be interpreted in terms of a head difference between two specified nodes labeled as j_1 and j_2 and u then flows between these two nodes.

[7] Consider BOD, for example. Suppose k_B is a constant which denotes the rate at which BOD decays over time. If c is the quantity of BOD in a given volume V, at some earlier instant, then $k_B c \Delta T$ is the amount of BOD lost to decay during the next time interval of duration ΔT. If we subtract this from the previous value of c we obtain the current value of BOD. That is

$$V \Delta c = - k_B c \Delta T$$

The reason for subtracting is that the new value of BOD will always be less than its previous value. Of course this argument assumes that all other factors which may affect BOD are absent during the time interval. That is, no sources or sinks and no advection or diffusion. The relation for BOD is simply a special case of equation 7.3. In general the full relation for BOD will include all these other terms in addition to the one given here for decay.

[8] *Re-aeration* refers to oxygen gains which occur at the surface of the water due to contact with air, while *photosynthesis* is the process whereby microorganisms in the water release oxygen as a result of the manufacture of carbohydrates from water and carbon dioxide. Finally *respiration* is the opposite of photosynthesis and refers to the biological activity in which organic carbon is oxidized. As a result oxygen is consumed.

[9] This leads to the equation

$$\epsilon A_s \frac{\Delta H}{\Delta T} = u A_c + Q^{in} - Q^{out} \qquad (8)$$

where u is velocity in the channel of the area A_c. This extends the equation to include source and sink terms and is analagous to equation (7) for surface models.

[10] Consequently, using the expression (8) above we see that

$$S \frac{\Delta H}{\Delta T} \approx \frac{u}{L} + \frac{Q^{in}}{\epsilon A_s L} - \frac{Q^{out}}{\epsilon A_s L}$$

where the left side is approximately the percentage change in head which is driven by the velocity and the various recharge, pumping and seepage flows for the node. Note that since $\epsilon A_s L$ is the node volume for water storage, $Q/\epsilon A_s L$ is a percentage volumetric flow. The overall change in head is a result of all incoming flows from other nodes within the layer considered, or to the layers above and below, and contributions from recharge or discharge at the node.

The expression for change in velocity (or momentum) with time requires no modification. As shown in Figure 7–15, the velocity is driven by the difference in head, or water elevation between two adjacent nodes. However, the soil acts to restrict flow of groundwater and the rate of change of velocity is

$$\frac{\Delta u}{\Delta T} = g\left(\frac{H_2 - H_1}{L}\right) - g\frac{1}{k} u \qquad (9)$$

for the two coupled nodes. If we generalize to a multi-layer aquifer system, three separate equations of type (9) must be written for velocities u_x, u_y, and u_z along x, y, and z axis, respectively. However, this will not be critical to our discussion of the model below.

[11] given by $u_o = K(H_2 - H_1)/L$

[12] The choice of resistor and capacitor values is important. For convenience, capacitors should be small enough that the currents required to drive the physical model are appropriate for small operational amplifiers and small signal equipment. Similar conditions hold for resistors in order that impedance match to external sources not be a problem. Also, the time required to resolve pressure differences in the real groundwater system is something like thirty years, as we know, and in the model this is characterized by the time constant for resistor/capacitor circuits. However, we prefer this not be the thirty year equilibrium for the aquifer, but some convenient laboratory time. The USGS model is formulated so that two years real time is about 1/1000 sec. in model time.

[13] The Princeton models are finite element models as opposed to finite differences represented in the USGS model. Finite difference refers to sectioning the aquifer layer into nodes (points) and channels (lines) so that one has a set of difference equations involving head at each node. Finite element refers, roughly, to sectioning the aquifer layer into finite-sized cells (of any shape). The head is described by a mathematical function having spatial dependence and the particular value for water elevation at each finite element is found simply by numerical evaluation of the function.

[14] The above numbers, although generally true, overlook the fact that the distribution of pollutants observed in groundwater systems is due to several mechanisms, of which physical dispersion is only one. A pollutant which may behave conservatively (not decay with time or react with the permeable media) in one aquifer may behave non-conservatively in another. For example a pollutant which absorbs strongly in silt and clays would be attenuated in shorter distances than in a system which is mainly sand and gravel. Moreover, the ability of groundwater systems to assimilate certain pollutants may be limited upon the rate at which pollutants are introduced (e.g., simple wastewater soil treatment systems clog with excessively high organic loads.)

[15] Those shown in the figure are somewhat hypothetical and do not conform with the options being prepared by the engineering consultants.

GLOSSARY

Because this report is largely intended for the general reader certain unfamiliar technical terms have been defined in the text at the place at which they first occur. These are listed below together with the page location where the definition can be found. Certain more commonly used expressions are not included.

Term:	Page
Advection	246, 249
Anisotropy	256
Analog Model	259
Benthic	250
BOD	250
Calibration	249
Conservative Substance	250
Conservation of Mass	244
Darcy Velocity	258
DO (dissolved oxygen)	250
Diffusion	246, 249
Dynamic Model	251
Ecological Model	255
Evapotranspiration	263
Eutrophication	255
Finite Element	261
Hydrodynamics	246
Hydraulic Conductivity	245
Mass Balance	250
Non-conservative Substance	250
Permeability	245
Phytoplankton	255
Photosynthesis	250
Porosity	245
Plume	262
Quasi-Dynamic Model	251
Re-aeration	250
Respiration	250
Sink	248
Specific Storage	258
Steady State Model	252
Stage-Flow Relationships	254
Verification	249
Viscosity	245
Water Budget	246
Zooplankton	255

Section 8 Management Alternatives

8.0 INTRODUCTION

Performing the 208 areawide study for Long Island involved a variety of investigations that were necessary for the development of sufficient data upon which future planning will be based. These fact finding studies were undertaken by a number of government personnel and private consultants specializing in various aspects of environmental management.

One of the key objectives of the study is the development of a planning process that will lead to the implementation of controls and abatements from nonpoint and point sources of pollution. This interim report covers in general terms the structural and non-structural options that can be employed on Long Island for these purposes. The principal sources of information reported are past studies and those included in the present 208 undertaking. An attempt has been made to incorporate only that material which is most useful to the development of the final plan. As such, the interim report provides an overview for planning purposes. This report is not meant to be inclusive, but rather to identify the major classes of techniques and technology for the interested reader. The actual selection of specific equipment and facilities is beyond the scale of the 208 program. No preferences are stated or implied. Normative judgements are made in the *Plan Summary*. This section is presented in two parts.

The first section addresses nonpoint pollution sources and predominately stresses non-structural solutions applicable under three major headings, *i.e.,* stormwater runoff control, conservation and watershed management, and land use controls. Legal, administrative and design criteria are not mentioned. They are covered in the *Plan Summary* and in Section Six.

The second section addresses point source pollution control and here the emphasis is on structural solutions. Conventional treatment technology is generally covered, and includes primary, secondary and tertiary treatment. A limited discussion of advanced removal techniques for phosphorus, nitrogen and dissolved inorganics is included. The balance of the section mentions alternatives to conventional technology, ranging from sprinkler irrigation and meadow/marsh/pond systems to onsite facilities, such as waterless composting toilets, aerobic biological units and subsurface denitrification septic systems.

8.1 NONSTRUCTURAL APPROACHES

8.1.1 Introduction

Nonpoint source pollutants cause many of the most common and familiar pollution problems, including polluted well water; polluted and clogged rivers and streams; an overgrowth of weeds and algae, bacterial contamination of shellfish, plus sediment in lakes and ponds; and loss of wildlife. A description of these problems will demonstrate why attention must be given to a control program that limits discharges from nonpoint sources.

8.1.1.1 Pollution of Ground and Surface Waters. When the groundwater that supplies municipal and private wells becomes polluted, the water can no longer be used for drinking without costly treatment — treatment that may be impractical in the case of private wells. Groundwater becomes polluted when bacteria, chemicals or salts find their way into aquifers, the water-bearing underground rock formations.

A primary source of pollution of groundwater can be from cesspools

and septic tanks. They were often placed where the soil cannot do its proper filtering job because it is either too impervious (like clay) or too wet. Similarly, leaks that develop in sewer pipes — and they often do — will contribute to groundwater pollution.

Improperly located, designed and managed landfills, chemical or petroleum storage facilities and mining operations also may contribute to both chemical ground and surface water pollution. The concentration of pollutants works its way through soil and reaches the aquifer. And especially in coastal areas, freshwater wells may turn brackish as the water that is removed is replaced by the ocean's salt water.

Pollution of streams and the accumulation of silt or other sediment is a problem in some areas. When organic matter is washed into streams, there is an increased demand for oxygen (biochemical oxygen demand or BOD), which reduces the oxygen available for fish and other aquatic life, sometimes to a point where the water can no longer support life. It also may make the water unfit for swimming or other recreational uses. A stream that is filled with sediment can no longer support aquatic life, supply reliable amounts of water or offer boating and other recreational opportunities.

While much stream and groundwater pollution comes from inadequately treated point source waste discharges, a substantial amount comes from the following nonpoint sources: urban storm runoff, agricultural runoff, construction sites, hydrographic modification and solid waste sites.

Urban storm runoff carries with it debris; concentrations of chemicals and fertilizers that have accumulated on the earth's surface during dry weather; leaves, twigs and other organic matter; grease and spilled petroleum products from roads, parking lots and gas stations; animal droppings; and during winter thaws, salt used to melt ice on streets and sidewalks. The extent of pollution from urban runoff is partly due to the large areas of impervious surface which increase runoff water and do not allow contaminants to be absorbed into the soil where they can be filtered.

Agricultural runoff from croplands and pastures carries sediment, fertilizer, pesticides, herbicides and animal waste into the water.

Construction sites, where the land has been stripped of soil-holding vegetation, unless developed according to an approved erosion control plan will erode and contribute locally heavy sediment.

Hydrographic modification, *i.e.,* changing the character of the stream itself by such measures as channelizing, may lead to increased flooding in unprotected downstream areas or modifying of fish and wildlife habitats.

Solid waste sites, including landfills and dumps, petroleum storage areas or mining operations, if poorly designed and operated, may contaminate both surface and underground water supplies with toxic chemicals and/or bacteria.

8.1.1.2 Pollution of Marine Waters. Weeds and algae have a number of unpleasant effects. Besides disrupting the ecological balance of the water body and reducing fish production, excessive weed and algae growth interferes with swimming and boating, and is generally unpleasant to look at. Algae smells as it decays. Excessive sediment can significantly reduce the depth of lakes and streams, eventually filling them in. Adding too many organic nutrients to the water accelerates the eutrophication or aging process; the growth and decay of weeds and algae is speeded up, using up the oxygen supply and killing off fish and other water life.

The nonpoint sources that contribute to this problem are similar to those contributing to stream and groundwater pollution: urban and agricultural runoff which include fertilizer and animal wastes, semi-wild duck populations on inland ponds and individual cesspools and septic systems.

Added to this problem has been the loss of some of the Island's wetlands. Wetlands are like nature's treatment plants. They act as retention basins and filtering systems, removing and storing many of the nutrients in agricultural and urban runoff before they reach open waters. By interfering with the efficient natural system, we have had to create new, expensive and often less successful systems to replace what nature provided free. Fortunately, the remaining wetlands in Nassau and Suffolk Counties are now protected by the provisions of the Tidal and Freshwater Wetlands Acts of 1973 and 1975.

One of the major concerns that must be addressed satisfactorily in waste treatment planning is that of nonpoint source pollution. In drafting the 1972 Amendments to the Water Pollution Act, Congress recognized that structural controls over sources of nonpoint pollution are often undesirable and inappropriate. Structural controls are limited in coping with sediment, pesticide, micro-organisms and nutrient runoffs.

Proponents of land use planning and control strategies claim that the structural approach has been inadequate on four counts. First, control technologies have not been able, at the current level of funding, to keep pace with the growth in waste loads. Second, control technologies are not available for all sources. For instance, sediments, nitrates and phosphates resulting from land runoff are not practically susceptible to treatment at this time. Third, even the most effective technologies seldom achieve 100 percent removal, which may be necessary for sustaining environmentally sound growth in some urban/industrial centers. (At this time, even 90 percent removal effectiveness is still an outstanding achievement.) Fourth, the exponentially increasing costs associated with higher removal rates may impose economic burdens upon governments and private firms which are beyond their current financial capacity.

The most practical and economic approach to such pollution is preventive rather than remedial, *i.e.,* preventing erosion and runoff by improvements in land use management and agricultural practices.

In general, nonpoint source pollution control relies on "best management practices" (BMP). For example, good agricultural conservation practices can reduce sediment yields from 50 to 90 percent.[1] Preventive measures can

[1] Mark Pisano, "Nonpoint pollution! an EPA view of areawide water quality management," *Journal of Soil and Water Conservation,* May, June 1976, p. 98.

include limits, prohibition, substitution and changes in the method of use of various contaminants to achieve control over the magnitude of specific sources. Figure 8–1 depicts the relationships between source and type of water pollution.

TYPE \ SOURCE	Domestic Waste	Industrial Waste	Agricultural Drainage	Construction Runoff	Urban Storm Water Runoff	Mine Drainage
Organic Waste	●	□	●	□	●	
Nutrients	●	□	●		□	
Sediment			□	●		□
Thermal Waste		□				
Toxicants		□	□		□	□
Other Types*		□				

● Major or primary factor
□ Possible major factor — varies with conditions
* Includes bacteria, oils, scums, etc.

FIGURE 8–1 *Relations Between Source and Type of Water Pollution.*

8.1.1.3 Land Use Practices. Most of these problems are caused by relatively few practices, most of which have to do with the way we use the land. The choice is to use land wisely by either limiting the production of pollutants or to keep pollutants from entering the waters and affecting its quality. Or land can be used poorly, and lead to serious and expensive consequences.

A list of poor land use practices, those that lead to lowered ground and surface water quality, includes the following:

Using unnecessarily large areas of pavement which increases urban runoff.

Cleaning streets infrequently, with the possible result that the "first flush" after a storm in an urban area carries large quantities of chemcals, debris and organic materials.

Overusing lawn fertilizer or road salt, or piling leaves in the gutters of urban streets.

Overusing agricultural fertilizers, allowing animals direct access to streams, and other agricultural practices.

Failing to take measures to reduce soil erosion during construction, or during agricultural and forestry operations.

Failure to take measures to reduce or prevent sand mine leachates and petroleum and chemical spills from reaching ground and surface waters.

Locating housing with septic systems on unsuitable soils.

Filling and using wetlands for urban development.
Locating and designing waste disposal sites so that they leach (filter down) into water sources.

Location of industrial facilities in prime recharge areas.

Dog curbing laws, sales of ducks as Easter pets, and encouraging semi-wild duck populations on inland ponds by artificial feeding.

Efforts to clean up and prevent water pollution from nonpoint sources are aimed at halting or remedying these kinds of practices. The solutions involve regulation, monitoring, improved maintenance practices, voluntary citizen compliance, structural improvement, improved construction practices and improved land use planning implementation. By and large, nonpoint sources that can best be controlled by regulatory and administrative means and by public education, *e.g.*, industrial and animal wastes, landfills, agricultural chemicals, etc., are not stressed in this report. These issues are covered in Section Six, the Plan Summary and Section J of the Areawide Waste Treatment Management Plan. The balance of the non-point portion of this report discusses three broad approaches to nonpoint control — stormwater runoff, water conservation and watershed management, and land use strategies.

8.1.2 Stormwater Runoff

Every parcel of land is part of a larger watershed. Ideally, a stormwater runoff management solution for any development project should be based on, and support, a plan for its entire drainage basin. This is not a revolutionary idea, but only recently have data collection and data handling technology made this economically possible in a meaningful way. Even in the absence of such basin-wide plans, new approaches to residential land planning, which have been evolving since about 1955, have made it possible to apply more creative approaches to stormwater management within a project. With their application, the new effects of incremental urbanization can avoid most

negative impacts and may produce benefits, enhancing opportunities for future implementation of an overall basin-wide drainage plan. See Figures 8–2 and 8–3.

The major residential boom in the post 1945 era relied on the total subdivision of land into individual lots, often with the complete stripping of natural site features and their replacement by an "efficient" design. However, some proposed residential developments clustered dwellings and created common open space, seeking to preserve and enhance natural site attributes. These various innovative concepts of land planning, which have now become grouped under the common title Planned Unit Development, present opportunities for stormwater management consistent with the emerging new philosophy advocated by this report. Traditional subdivision design practices will also benefit from the new stormwater management approaches, but not always to the same degree.

8.1.2.1 The Basic Concepts. The water falling on a given site should, in an ideal design solution, be absorbed or retained onsite such that development

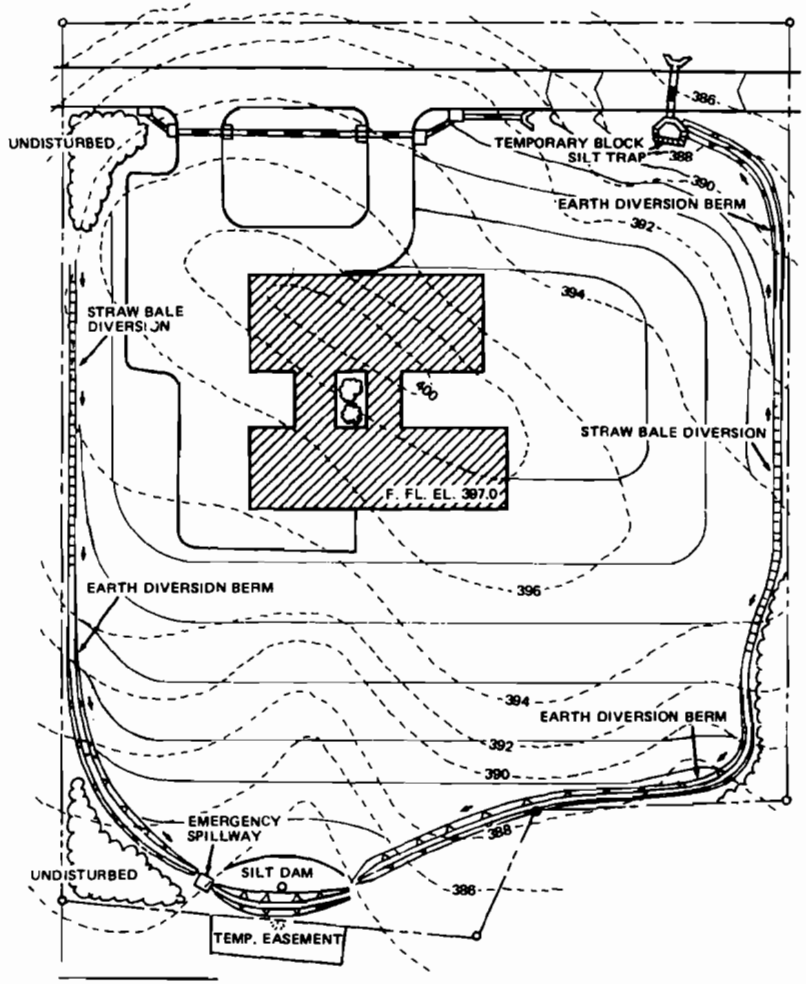
Mechanical Measures

1. **Land Grading:** Grade only those areas necessary for immediate construction. Minimize cut and fill; avoid heavy grading.
2. **Bench Terraces:** Constructed across the slope of the land to break long slopes and slow the flow of runoff.
3. **Subsurface Drains:** Sometimes required at base of fill slopes to remove excess ground water.
4. **Diversions:** Ridges and channels used to divert runoff away from erodable slopes; particularly useful along highway embankments.
5. **Dikes:** Useful around large parking lots to collect runoff for gradual release through grassed outlets or subsurface drains.
6. **Sediment Basins:** A permanent or temporary dam to detain runoff and trap sediment.
7. **Filter Berms:** Gravel or straw bale dikes used to filter stormwater runoff prior to discharge.
8. **Vertical Drainage:** Techniques to infiltrate excess runoff water to rapidly permeable subsoil to reduce excess runoff water.

Vegetative Measures

1. **Vegetative Protection:** Conserve maximum amount of ground cover particularly along stream corridors.
2. **Temporary and Permanent Seeding:** Seeding will add stability to soils which are not needed either permanently or temporarily for construction. Grasses, legumes, trees, shrubs, vines and ground covers can be used.
3. **Mulch:** Straw mulch can be used to protect constructed slopes and other areas regraded at an unfavorable time for seeding.
4. **Stream Channel Stabilization:** Eroding or erosion-prone channels and stream banks can be stabilized by use of vegetation, rip-rap and mechanical measures.

FIGURE 8–2 *Partial List of Erosion and Sediment Control Measures for Construction Sites.*



Source: *Erosion-Siltation Control Handbook* (Draft), Fairfax County, Virginia.

FIGURE 8–3 *Sample Erosion and Sedimentation Control Plan.*

would not significantly alter the quantity and peak rate of runoff leaving the site from that produced from undeveloped sites.

Just as the importance of water quality is being increasingly recognized, a major new emphasis needs to be placed on the identification and application of "natural" engineering techniques to preserve and enhance the natural features of a site, and to maximize economic-environmental benefit. "Natural" engineering techniques are those which capitalize on, and are consistent with, natural resources and processes. Engineering design can be used to improve the effectiveness of natural systems, rather than negate, replace or ignore them.

Among the new trends in basic philosophy that should be pursued are:

(a) Concurrent recognition of the convenience drainage and overflow or flood conveyance elements of existing and proposed drainage systems, the use of on-site detention storage to reduce downstream peak flows, the use of land treatment systems to manage stormwater, and a recognition that temporary ponding at various points in the system, including on the individual lot, is a potential design solution rather than a problem in many situations.

(b) A continuing recognition that there is a balance of responsibilities and obligations for collection, storage and treatment of stormwater to be shared by individual property owners and the community as a whole.

(c) A new recognition that stormwater is a component of the total water resources of an area which should not be casually discarded but rather should be used to replenish that resource. Stormwater problems signal either misuse of a resource or unwise land occupancy.

(d) A growing emphasis on the recognition that every site or situation presents a unique array of physical resources, occupancy requirements, land use conditions and environmental values. Variations of such factors within a community generally will require variations in design standards for the optimal achievement of runoff management objectives.

The above key concerns, while not all-inclusive, embody a basic philosophy that should receive consideration. Although this portion focuses primarily on residential design practices, these concepts should be considered and applied to entire drainage basins in which any development may proceed. The responsible solution for individual developments will be more difficult to achieve in the absence of basin-wide plans, particularly where current practices are based on traditional drainage concepts. For example, if current practices allow an upstream development to use traditional drainage approaches that increase runoff, a development relying on new concepts might be unable to accomodate the amount of excess runoff thereby generated without additional significant costs. The approaches suggested herein should allow development to proceed on individual projects in the absence of a basin-wide plan, since the strategy for the retention and attenuation of peak runoff and total runoff to values not significantly different from predevelopment levels would normally be compatible with any future plan that might evolve for a watershed.

8.1.2.2 A Definition of "Stormwater Runoff System." The term "stormwater runoff system" used herein is, first of all, composed of both natural and man-made elements. In the past, designers have often failed to capitalize upon natural elements and have at times ignored them when a constructed element was installed. These components include not only those which contain and convey stormwater, but also those which absorb, store and otherwise use stormwater rather than dispose of it.

Within a single system, there are components that are designed primarily to obtain convenience at the smallest scale of the system, *e.g.,* the individual site of intersection, during minor or frequent storms. During an infrequent or major storm, the capacities of many of the convenience-oriented components will be exceeded and flow capacity must be provided by other components designed to provide safety and minimize damage throughout the system, from the individual site to the discharge point of the drainage basin to downstream areas. It must be recognized and emphasized that a total stormwater runoff system cannot be expected to prevent inconvenience and minor property damage during a major storm event. A design that would eliminate all such stress would be fundamentally unreasonable and economically infeasible. Expected damages from a major runoff event would include minor erosion and scour, damage to lawns and vegetation, and damage to unwisely located structures, but flooding or undermining of buildings or essential facilities should not occur.

Thus a stormwater runoff system should be considered as a single system having three purposes: (1) the control of stormwater runoff to minimize damage to property and prevent physical injury and loss of life which may result from major storm events having a frequency of occurrence of less than once in 50 years; (2) the control of stormwater runoff to minimize inconvenience and disruption of activity from more frequent storm events (greater probability of occurrence than once in 50 years); and (3) maximizing the infiltration of stormwater.

There are a wide range of analysis techniques available for guiding the design of stormwater runoff systems. The choice of technique must be suited to the size and complexity of the area, the degree of safety and convenience sought and the cost factors involved. Regardless of the techniques selected to guide the design, the following factors must be considered:

1. Rainfall
   a. historic
   b. predictable future
   c. bases for design
2. Drainage Area Characteristics
   a. at the site
   b. downstream,
   c. upstream
   d. basin-wide
3. Land Use Characteristics
   a. present

b. future-short term
c. full development

4. Design Options
   a. on site detention/storage
   b. overland flow
   c. channel capacity; volume/storage
   d. storage, detention, routing
   e. natural drainage system
5. Risk Analysis
   a. to life
   b. to property
      i. on the site
      ii. downstream
      iii. upstream
6. Costs
   a. initial
   b. amortization
   c. operation
   d. maintenance
   e. replacement
   f. inconvenience
   g. flood damage

8.1.2.3 Storage Considerations and Criteria. One of the primary factors to consider in stormwater runoff management is storage. The availability or absence of facilities for temporary or permanent runoff storage is an important element in design. Storage should not, however, be considered a cure-all for stormwater runoff management. In many instances, the storage capacity required to assure both maximum safety and convenience will not be economically feasible, but may still be desirable.

Providing stormwater storage can reduce peak runoff rates; aids the recharge to groundwater; provides attenuation mechanism if stormwater is to be treated; and reduces potential of downstream flooding, stream erosion and sedimentation.

Storage occurs naturally to some degree in most Long Island watersheds. Natural storage is provided by surface depressions and interception by vegetation. Greater storage is possible where the depressions and swales in the drainage area have highly pervious recharge areas. Much natural storage is usually lost through development. This volume can be replaced using swales, recharge techniques, vegetal practices, and by utilizing special inlets that meter the outflow from planned ponding areas. Where detention storage is used, overland conveyance must be designed with sufficient capacity to assure no downstream damage from major storm events. Large scale temporary retention storage should be used to replace storage loss due to the increase of impervious surfaces associated with development.

Rooftop and parking lot ponding are two methods of stormwater retention. In addition, recharge facilities and dry ponds may be utilized to control large amounts of stormwater runoff.

8.1.2.4 Degrees of Storage. Different degrees of storage should be considered in residential design. The lowest degree is the natural storage provided by surface depressions and by foliage and ground cover interception of rainfall. To take advantage of this storage, natural ground cover should be maintained. Small volumes of temporary storage can be provided for in the design of swales, pipes and channels. Outlets from temporary storage can be designed to attenuate peak outflow, and safely discharge stormwater runoff thus assuring protection of adjacent and downstream properties from flooding, erosion or sedimentation damage. Temporary storage facilities include rooftop and parking lot ponding, recharge sedimentation basins and normally dry ponds.

The comparative amounts of storage that may be achieved using different combinations of facilities will vary. The designer of storage should determine that the cost of storage provisions will not exceed benefits accrued and that the designs will be economical to maintain. The residential storage system should be coordinated with watershed and regional storage plans for flood control, water supply and recreation.

8.1.2.5 Other Storage Considerations. In creating ponds or lakes, the following considerations are worthy of mention.

1. Access to shorelines may be effectively limited to desired locations by planting thorny decorative shrubs.
2. Lake bottoms within ten feet of the shore should be so graded that water depth normally will not exceed eighteen inches, to simplify immediate rescue of small children.
3. Extensive areas of shallow water, especially in upper reaches of the lake, should be avoided to prevent undesirable weed growth.
4. Dense plantings of shrubs that will act as barriers to automobiles are appropriate where vehicles might otherwise run into the lake, especially at night.
5. Paved walkways roughly paralleling the shoreline, low-level night lighting, fixed benches, floored rain shelters and sensitive landscaping can add considerably to the charm of a lake or pond setting, and to the desirability of the surrounding neighborhood. Massive plantings of seasonally colorful shrubs, such as azaleas, redbud, dogwood or Japanese maple, can help publicize an area and create particular pride of ownership throughout the neighborhood.

8.1.2.6 Streets and Curbs. The primary purpose of residential streets is to provide vehicular access to homes and community facilities. Vehicles using the streets will vary from routine automobile traffic to larger delivery and service trucks and emergency police and fire vehicles. Streets also have several secondary functions. One is to provide routes for pedestrian and bicycle traffic; another, more relevant, is to collect and convey stormwater runoff.

Planning a drainage system should be done simultaneously with street layout and gradient planning, and careful consideration should be given to the following:

1. The functions of streets as parts of the stormwater management system.

2. Street slopes in relation to stormwater capacity and flow velocity in gutters and/or street swales.

3. The location and sizing of street culverts. Culverts may be sized to create temporary upstream storage if there is proper consideration of earth bank stability and potential overflow effects during major flood conditions.

4. Location of streets in relation to natural streams, storage ponds and open channel components of the system.

5. Location and capacity of inlet points to pipes in relation to gutter slopes, the spread of water across streets and the flow of water across intersections.

6. Coordination of street grades with lot drainage. Positive slope away from all sides of the house must be accomplished. Lot drainage becomes difficult when there is less than one and one-half to two percent (usually fourteen to 24 inches) fall from the earth grade at the center rear of the house to the street curb at the lowest front corner of the lot.

7. Use gutters, downspouts and dry wells on all newly constructed houses to reduce volume of runoff water in roads.

8.1.3 Water Conservation Practices

Water conservation is a means for reducing the necessary capacity of facilities needed to collect, convey and treat both domestic and industrial waste; for reducing per capita usage of water; and for the proper return of water to the aquifer.

The domestic use of various devices available to curtail water use include faucet aerators, flow control shower heads, automatic flush valve toilets, shallow trap water closets and the English dual cycle water closet. Figure 8–4 lists water saving devices ranked by cost-effectiveness.

Industrial, commercial and agricultural reuse of water is another option. For instance, in-plant recirculation of water would reduce total water requirements and also decrease waste discharges.

Planners of wastewater systems should be cognizant of possibilities for reuse of effluent, generally after some type of treatment, and alert both local governments and water users to such possibilities. Treated sewage effluent, for instance, can be utilized for irrigation purposes. However, special attention should be paid to land use impacts by such reuse practices (*i.e.,* heavy metal residues in food, reduction in soil permeability, etc.).

Water conservation practices could be encouraged by incorporating them within building codes, state and local regulations, and the initiation of pricing policies that encourage less wastage of potable waters — particularly when used for non-drinking purposes.

Hardware Device	Water Savings GPCD (1)	Estimated Installation Costs Matl. $	Labor $	Total $	Water-Savings Cost-Effectiveness Total $ / GPCD (1)
1. Aerator for Lavatory and Kitchen Sink	0.5	2	0	2	4
2. Dual Cycle Water Closet	17.5	100	30	130	7.4
3. Limiting Flow Valves for Shower	6	35	15	50	8.3
4. Batch-type Flush Valves (2) for Water Closet	15.5	120	38	158	10.2
5. Vacuum Flush Toilet (for 100 homes)	22.5	—	—	295	13.1
6. Recycle Toilets	24.7	300	25	325	13.2
7. Batch-type Flush Valve (1) for Water Closet	7.5	75	30	105	14
8. Shallow Trap Water Closet	7.5	80	30	110	14.7
9. Urinal with Batch-type Flush Valve	7	150	25	175	25
10. Washing Machine with Lever Control	1.2	35	0	35	29.2
11. Vacuum Flush Toilet (for Single Homes)	22.5	—	—	1520	67
12. Limiting Flow Valves for Lavatory	0.5	45	23	68	136

(1) GPCD, gallons per capita per day * *Source: Wenk (1976)*

FIGURE 8–4 *Water Conservation — Plumbing Devices Ranked by Water Saving Cost Effectiveness.*

8.1.4 Watershed Management

A properly implemented watershed management program is essentially a preventive and conservation approach primarily meant to prevent deterioration of groundwater supplies in undeveloped areas. It is a useful adjunct to other waste management options in the following ways:

1. It makes possible a broader range of community development patterns in non-watershed areas.

2. It helps minimize erosion and associated runoff problems.

3. It assures the availability of potable waters.

4. It can provide the locations for eventual recharge.

5. It is an important land use alternative in the attainment of Suffolk County's long standing open space protection program.

6. It may provide a significant cost-effective benefit over sewering approaches.

8.1.5 Land Use Practices

Land use strategies loom as a promising complement to treatment technology. The way the use of land is managed is pivotal to the entire pollution problem. Without environmentally sensitive land use planning and control, investments in wastewater treatment facilities can easily be squandered. Well conceived and administered land use controls will allow reasonable levels of growth with minimal resource degradation and with a more favorable cost-effectiveness rate.

8.1.5.1 The Land Use Planning Process. Land use planning is a decision process as to how land should best be allocated and used based on current conditions and anticipated future events, *i.e.,* as expansion, abandonment and renewal proceed through time. In simpler terms, it is an effort to anticipate future events and desires so that better decisions can be made today. The planning process has traditionally been oriented toward improving the man-made physical environment (*i.e.,* the location, character and quality of housing, commercial and industrial activities, transportation, utilities and community factilities).

The interrelationships of land use and water quality are numerous and quite complex. Figure 8–5 is a schematic diagram of these relationship. Summarily stated, population and economic growth, private market forces, land use regulations, public services and facilities, and the natural features result in a particular land use pattern and land consumption rate. This pattern, with its underlying determinants, can cause water quality problems:

Damaging, and perhaps poorly distributed, point source waste discharges (*i.e.,* domestic, industrial and power plant discharges).

Damaging non-point loads generated by urban and rural land uses as well as construction activities.

8.1.5.2 Overview of Land Use Strategies and Techniques. In developing land use strategies for water quality management programs, there are several goals toward which such efforts should be aimed (See Figure 8–6):

Reduce and balance point discharges with the water quality standards and established wasteload allocations for receiving waters. The planner should seek to distribute waste-generating development in a manner which does not overburden the receiving water body at points of waste discharge.

Reduce and balance harmful non-point discharges. The planner should set forth plans and programs which minimize both the production of non-point pollution and the entry of such wastes into water bodies.

Conserve the natural features and natural systems which protect water quality and quantity. The planner should plan and control

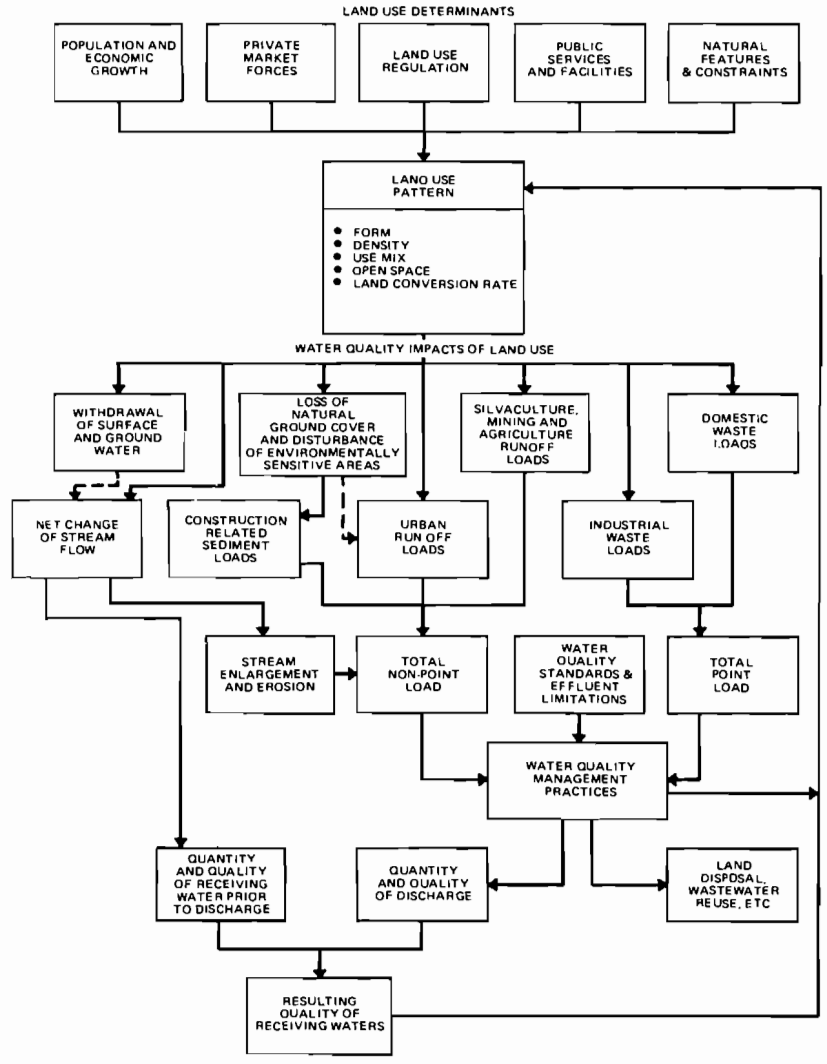


FIGURE 8–5 *Schematic Diagram of the Land Use/Water Quality Relationship.*

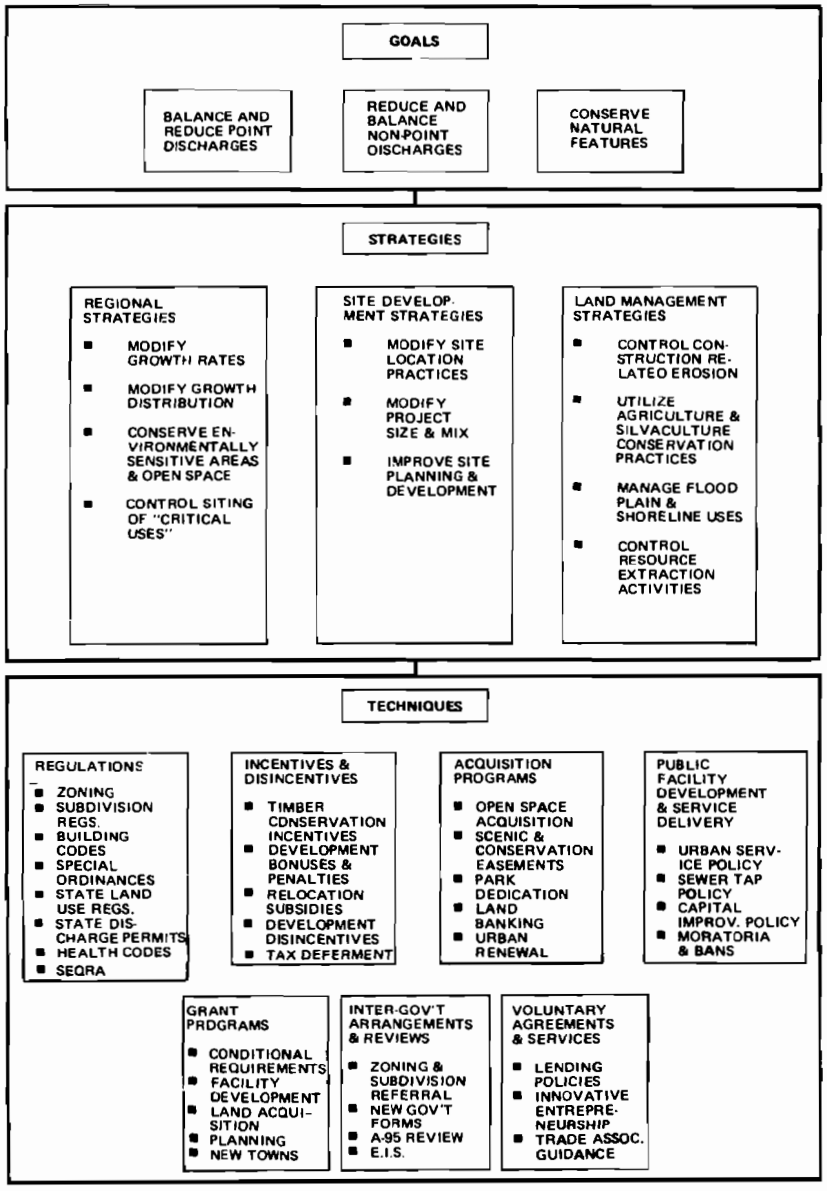


FIGURE 8–6 *The Role of Land Use Planning and Control in Water Quality Management.*

land use in ways which allow the natural terrain and ground cover to perform its runoff control, groundwater recharge and waste absorption functions.

Planning strategies oriented toward these general goals fall within three general categories which range in scope from areawide to site specific:

8.1.5.3 Regional Strategies. On the regional level, water quality management planners have responsibility for considering a wide range of options in meeting water quality standards and effluent limits. The achievement of this objective requires the sensitive consideration of growth objectives, alternative arrangements of the area's physical structures, composition of settlement areas and the location and character of open space and rural land uses. Four land use strategies which have potential for improving water quality at the regional level are:

a. Modify growth rates.
b. Modify growth distribution.
c. Conserve environmentally sensitive areas and open space.
d. Control the siting of critical uses. See Figure 8–7.

8.1.5.4 Land Management Strategies. Not all land/use water quality problems can be dealt with at the planning or planning-administration levels. Many water quality problems stem from poor land management in both rural and urban areas. The management of land is of great significance to the control of non-point pollution. The strategies which relate to land management include:

a. Control construction-related erosion.
b. Utilize agricultural best management practices to reduce storm runoff and control erosion.
c. Manage flood plain and shoreline uses.
d. Control resource extraction activities.

8.1.5.5 Site Development Strategies. Careful attention to the water quality impacts of individual projects can have important results, if not individually, at least cumulatively. At the site planning level, three strategies may prove fruitful, depending upon local conditions and institutional factors:

a. Modify site location practices.
b. Modify project size and/or mix.
c. Improve site planning and development.
d. Institute development site erosion control plan.

Techniques for implementing these strategies are diverse. In addition to traditional, well tested regulatory procedures, innovative policymakers and planners are devising an increasing array of controls in an attempt to weld environmental considerations to land planning and development endeavors. These implementation techniques include:

Regulations
Incentives and disincentives

CRITICAL USE	POTENTIAL HAZARDS TO WATER QUALITY	STRATEGY TO CONTROL IMPACT ON WATER QUALITY	PARAMOUNT LOCATIONAL CONSIDERATIONS
Sewage treatment plants	• Nutrients • Bacteria • BOD	• Separate from incompatible development • Utilize high level treatment • Separate from beneficial downstream uses	• Surrounding development • Projected need for expansion • Water quality at point of discharge • Downstream uses
Sanitary lendfill	• Leaching of minerals or other pollutants into ground or surface water • Erosion	• Separate from ground and surface water • Regulate management practices	• Location of ground water table and surface water • Existing and projected development in area • Final reuse of site
Industrial plants with independent discharges	• Toxic substances • Heat • Organic wastes	• Make location compatible with waste load limitations • In-plant treatment • Permit issuance • Fines for violations	• Existing water quality and water quality standards • Projected kind and amount of effluent • Treatment plant capacity
Water processing plants	• Decrease in surface water flow	• Balance with competing uses	• Water quality at intake point • Projected development in water shed • Location of competing water uses
Power generating plants	• Heat • Residual wastes	• Prohibit in environmentally sensitive areas • Dispersion of sites • On-site cooling techniques	• Location of competing or compatible uses • Tolerance of existing biotic communities
Highways	• Sedimentation • Stream channel modification	• Avoidance of watercourse crossings, hillside locations, & channel modification • Control construction-related erosion	• Locations of water channels • Soil characteristics • Engineering design • Construction practices
Intensive cattle feedlot	• Animal waste washoff • Groundwater contamination • Sedimentation	• Stream vegetation buffers • Regulation of management practices • Sediment basins • Prohibit in environmentally sensitive areas	• Level terrain • Soil & geologic characteristics • Water quality conditions

FIGURE 8–7 *Planning Considerations for Major Critical Uses.*

Acquisition programs
Public facility development and service delivery
Grant programs
Intergovernmental arrangements and reviews
Voluntary agreements and advisory services
Public informational programs.

These goals, strategies and implementation techniques are depicted graphically in Figure 8–8.

The land use strategies outlined here are not brand new, visionary ideas. They are being considered and frequently implemented in various places throughout the country. The mechanisms to implement these strategies are even more familiar. It is more universal acceptance and adoption of these strategies that is now needed. Localities pursuing strategies to modify growth distribution, control location of critical uses, minimize erosion and sedimentation, and all the other strategies will reap benefits of improved water quality and, collaterally, preservation of other natural and human values.

In the matrix shown in Figure 8–9, the strategies for land use are evaluated as to long and short-range potential for reducing water pollution and as to ease of implementation. Each cell was rated from one to five, with the number assigned by assessment of the strategy in terms of (a) potential effectiveness under ideal conditions, and (b) realistic feasibility for implementation, given existing and anticipated political and economic constraints. The short-term payoffs of the strategies, it will be noted, have lower scores than the long-term payoffs. Lead time involved in implementing strategies, both legally and fiscally, generally means that full scale implementation seldom comes about in the short range. More importantly, since land use strategies seldom begin with a pure water base, impact of existing point and non-point sources will be felt for years to come, as tomorrow's treatment labors to catch up with yesterday's mistake. However, adoption of appropriate land use strategies will not only minimize water quality degradation from new development, but water quality could be expected to improve as poor land use patterns and practices are phased out.

In the short term, it is concluded that the greatest likelihood of water quality improvement would be obtained by pursuing control of critical use siting, erosion control and improved site planning and development. In the more distant future, additional benefits will be possible through more sophisticated planning for growth distribution and through protection of environmentally sensitive areas, including flood plains, shorelines and watershed conservation areas. See Figure 8–10.

The payoff index also indicates that the most effective strategies are those which can be implemented most easily. For example, modifying the growth rate has a low hypothetical payoff, not because the strategy is not valid, but because widespread public acceptance and implementation are difficult to achieve. The matrix also summarizes tools for implementing the land use strategies. The tools were also evaluated as to political and economic feasibility as well as technical efficacy. Public controls such as zoning requirements, permits and other regulations can generally be enacted with little strain on the local budget or little widespread objection. Review and advisory services are not as effective simply because compliance cannot be enforced. The matrix also illustrates that all tools cannot be used for every strategy, but that there are several means available to implement each land use strategy to improve water quality.

8.2 STRUCTURAL APPROACHES

8.2.1 Water Pollution Control

The Alternative Systems Diagram for Water Pollution Control, Figure 8–11, comprises: a network of significant wastewater sources (*e.g.*, domestic wastewater); significant waste parameters (*e.g.*, biochemical oxygen demand, or BOD); wastewater treatment alternatives (*e.g.*, activated sludge); and effluent disposal alternatives (*e.g.*, groundwater recharge). Alternatives for disposal for the concentrated wastewater solids are also included.

It should be noted that the diagram is not all-inclusive of every wastewater source, discharge parameter or treatment process. For example, there are other constituents of wastewater besides BOD, nitrogen, phosphorus and dissolved solids. However, these are considered the most significant with respect to the selection of a suitable treatment system and mode of effluent disposal.

The impact of water pollution control systems upon coastal environments may be considered to be made up of three separately identifiable aspects. First and foremost, the impact of the effluent and the residual contaminants it carries must be considered. Secondly, the construction and

FIGURE 8–8 *Regional Strategies and Techniques.*

Strategy	Implementation Techniques	Examples
Modify Growth Rate	• Policy Recommendations and Decisions by Governmental Leaders • Zoning • Public Service Policy • Building Moratoria	• State and Local Studies in Virginia, Michigan, Fairfax County, Virginia, and Florida • Population Ceiling Imposed in Lake Tahoe, Proposed in Boca Raton, Florida
Modify Growth Distribution and Density	• New Town Assistance Programs • Locational Decisions for Major Public Facilities such as Sewage Lines and Treatment Plants and Location of Major Highways • Zoning • Local Moratoria on Sewage Taps or Extensions • Regional Planning and Adoption of Policy and Controls by Member Jurisdictions • A-95 Review and Environmental Impact Statements • Tax Abatement for Open Space • PUD, Large Lot Zoning • Negotiate Densities Proposed in Impact Areas	• New Towns – Columbia, Md., Reston, Va., Jonathan, Minn. • Special New Town Incentives or Assistance: Texas, Arizona, California, Ohio • Extensive Agricultural, Low Density Zoning, State or Local Level, Hawaii; New Jersey Communities – Ramapo, N. Y. Growth Plan • Nassau-Suffolk Regional Development Plan • Plan for Year 2000, D. C. Area • Sewer Moratoria in Florida & Washington, D. C. • Prince Georges Co. Staging Policy
Preserve Environmentally Sensitive Areas and Open Space	• Aquisition Special Zones Requiring Use Permits • Zoning • Private or Public Compacts • Tax Incentives and Disincentives	• National Parks and Forests, Local or State Parks • Acquisition and Easement Programs: Boulder, Colo., New Jersey, Florida, Ohio • Maine Site Location Law • Suffolk County Farmlands Acquisition Program • San Francisco Bay Conservation & Development Commission • Shoreline or Flood Plain Zones – Wisconsin, Minnesota, College Township, Pa., Buffalo County, Wisc., Delaware • Suffolk County Greenbelts • Favorable Taxes on Undeveloped Land: Va., Cal., Fla., Conn. • Proposed Abolition of Tax Benefits That Now Encourage Development in Certain Resort Areas
Control Location of Critical Uses	• Collaborative Regional Planning & Funding • Zoning • A-95 Review; Environmental Impact Statements • Federal or State Regulation of Certain Uses	• Special Exception or Permit Required – State or Local Level. Maine Site Location Act, Local Zoning Ordinances, New York State Environmental Quality Review Act • Proposed: Power Plant Siting Act, Sediment Control Act, Toxic Waste Disposal Control Act

PLANNING STRATEGY	POTENTIAL REDUCTION OF WATER POLLUTION		EASE OF IMPLEMENTATION		NET IMPACT		IMPLEMENTATION TECHNIQUES												
	SHORT TERM (1)	LONG TERM (2)	SHORT TERM (3)	LONG TERM (4)	SHORT TERM (1×3)	LONG TERM (2×4)	ZONING	SUB. REGS.	BLDG. CODES	PERMIT SYSTEMS	DISCHARGE STATUTES	SPEC. ORDINANCES, USE REGS.	STATE LAND PROGRAMS	INCENTIVE PROGRAMS	ACQUISITION PROGRAMS	DEVEL. & PUB. FAC. SERVICE	GRANT PROGRAM	GOV'T REVIEWS	PRIVATE AGREEMENTS
■ Modify Growth Rates	2	5	1	2	2	10	●					□	□				●		
■ Modify Growth Distribution	3	5	2	4	6	20	●				●		●			□	●	□	
■ Preserve Environmentally Sensitive Areas and Open Space	3	4	2	4	6	16	●	□			□		●	●		●		●	●	□
■ Control Siting of Critical Uses	3	4	3	5	9	20	●				●		●	□			□		●	
■ Control Construction-Related Erosion	3	3	3	4	9	12		●		□	●	●	□							□
■ Utilize Agriculture & Silvaculture Conservation Practices	2	4	1	3	2	12						●		□						□
■ Manage Flood Plain and Shoreline Use	3	4	2	4	6	16	●	□		□	□		●	□		□				
■ Control Resource Extraction Activities	1	2	2	3	2	6	□				□	●	□							□
■ Improve Site Planning & Development	3	4	3	5	9	20	●	●		□		□	□	□					●	□

Note: 1. Values are based upon authors' judgement and experience
2. Values range from one to five indicating minimal to maximal degrees of effectiveness or feasibility
3. Implementation tools are identified as follows:
● Primary Implementation Techniques
□ Secondary Implementation Techniques

FIGURE 8–9 *Assessment of Payoffs and Implementation Requirements.*

operation of the physical plant itself will impact the environment, and must be accounted for. Last is the impact, although secondary and indirect, of the final disposition of the wastewater solids which were concentrated and removed from the wastewater stream. The Alternative Systems Diagram delineates the possible alternatives and combinations of alternatives for treating the wastewater and disposing of the effluent, as well as the residual solids.

8.2.2 Conventional Treatment Technology

The current accepted method of wastewater treatment is that illustrated in Figure 8–12. This system is referred to by a variety of titles such as: conventional treatment, biological treatment and primary plus secondary treatment. This treatment has been specifically developed to remove suspended solids, biodegradable organics and microorganisms from wastewater.

TYPE	DESCRIPTION	MAXIMUM USE DESIRABLE	MEANS OF CONTROL
Shorelines	Land bordering bodies of surface water--lakes, ocean. For planning purposes, strip extending 1000' from water edge.	Only uses inseparable from water fronts: ports, harbors, recreation, water and sewage treatment plants	• Zoning • Acquisition • Special use permits • Tax incentives • Tree protection laws • Setback and bulkhead regulation
Wetlands	Water and flood water storage areas (marshes, swamps, and bogs)	Non-disruptive agriculture; isolated urban development	• Zoning • Acquisition • Special use permits • Tax incentives
Flood plains	Land bordering watercourses. For planning purposes generally defined as land with a flooding probability of from 50 years upward, or land within 300' of a navigable stream, whichever is greater.	Natural vegetative cover; uses which will not be damaged by flooding (recreation areas, parks), or are inseparable from flood plain use	• Zoning • Acquisition • Subdivision regulations • Building codes • Special use permits • Tree protection laws • Setback and bulkhead regulation
Steep slopes	Slopes of over 12%. Depending upon circumstances, a higher percentage may be chosen	Forestry (with conservation measures to prevent erosion): recreation; low density residential.	• Zoning • Erosion control regulations • Subdivision regulations • Tree protection ordinances
Forests and woodlands	Natural vegetative cover with tree canopy	Recreation; timber production; low density development	• Zoning • Acquisition • Tax abatement
Headwater regions	Upland tributaries where stream flows are low and seasonally incapable of assimilating increased waste loads	Low density development with export of domestic discharges	• Zoning • Acquisition • Erosion control regulations
Aquifer recharge areas	Points of interchange between aquifers and surface waters.	No polluting uses; minimal impervious surface	• Zoning • Impoundment of clean streams transecting aquifers • Acquisition

FIGURE 8–10 *Environmentally Sensitive Areas.*

Suspended solids produce sludge banks in rivers, biodegradable organics lower the oxygen resources of lakes and rivers and microorganisms are the source of most water-borne disease. In the past, it was only thought necessary to substantially remove these three classes of pollutants from wastewater prior to discharge to avoid adverse environmental effects. This is no longer generally true because of the newer awareness of other serious contaminants—the danger of which was not previously realized.

Although in many locations the conventional system no longer is sufficient of itself, it is the base upon which some newer, more effective treatment systems are constructed. Therefore, a short description of this system and the degree of treatment which it can provide is given.

Wastewater is first passed through preliminary treatment of screening and grit removal. Preliminary treatment is utilized to protect pumps and pipes downstream from being harmed by large articles and abrasives which are often found in sewage. Next, primary sedimentation is provided to remove relatively large organic solids. The following step is biological oxidation in which a large quantity of microorganisms is contacted with the sewage in an aerobic environment. In this step, the microbes convert the soluble and colloidal organics producing settleable masses of microbes plus carbon dioxide and water. Two systems which are used for biological oxidation are the trickling filter and activated sludge. The microbes which are active in biological oxidation settle by gravity from the flow in the secondary sedimentation tank since they cannot be discharged with the effluent. Some are recycled to the entrance of the biological oxidation process in order to maintain an adequate population in this unit, the remainder are sent to the sludge handling section. After passage through the secondary sedimentation tank the flow is disinfected, usually by the application of chlorine, and discharged. No attempt is made to sterilize the effluent since all that is required is destruction of pathogens (disease producing bacteria). Most pathogens are more susceptible to the effects of chemical disinfectants than the non-pathogens. It is important to note that the microbes which function in the biological oxidation process are non-pathogens.

When considering the cost and effectiveness of waste treatment technology, sludge disposal is often overlooked. This is unfortunate as up to half the cost of the conventional treatment train can be charged to sludge handling and disposal. Sludge is a thick suspension of organic solids which is drawn from the bottom of the primary and secondary sedimentation tanks. Disposal usually involves two steps, the first of which is dewatering. Dewatering is generally necessary because the cost of the second step "ultimate disposal" is proportional to the volume of the sludge. Unfortuantely, sludge is usually difficult to dewater unless chemicals are added and/or it is subjected to anaerobic biological treatment. The liquid removed during the dewatering step is referred to as supernatant and is usually recycled to the initial portion of the treatment plant, *i.e.*, path from 6 to 1–2 in Figure 8–12.

Among the methods employed for ultimate disposal are landfill, land spreading, incineration, wet oxidation and processing for recovery of useful byproducts. At present, research in ultimate disposal is aimed at reduction of costs of environmentally acceptable ultimate disposal methods.

Table 8–1 illustrates the performance which can be expected of a typical well-operated conventional treatment plant. The results have been presented both as percent removal and typical effluent characteristics. This type of plant cannot provide significant removal of phosphorus, nitrogen or salts. Suspended solids, organic removal and microorganism removal are significant.

8.2.3 Biological-Physical Treatment

The inability of gravity sedimentation in the final clarifiers to remove small, light particles places a limit on the capability of conventional treatment

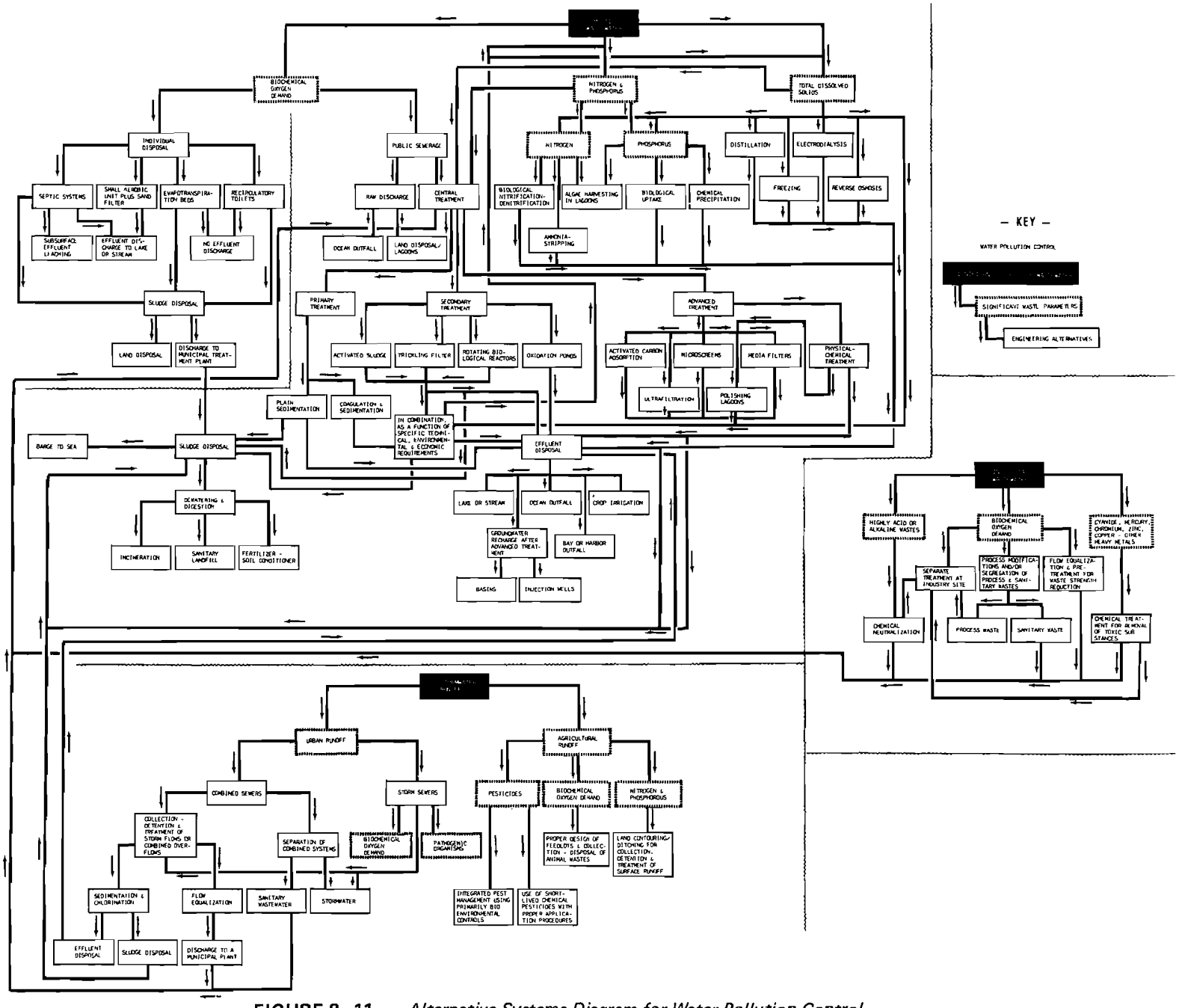


FIGURE 8–11 *Alternative Systems Diagram for Water Pollution Control.*

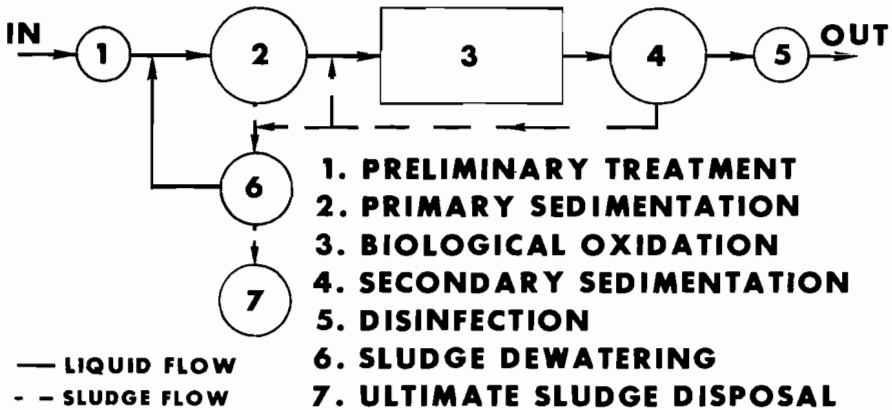


FIGURE 8–12 *Biological Treatment System—Primary and Secondary.*

to reduce suspended solids and BOD in the treatment of wastewater. The usual range of this limit is indicated by the figures presented for typical effluent characteristics in Table 8–1. Integration of a better liquid-solid separation device into the treatment scheme is thus one method of up-grading conventional treatment. Figure 8–13 illustrates the simplest type of advanced waste treatment, the biological-physical treatment system. This system is identical to the conventional treatment system with the exception of the provision of an additional solids removal step after secondary sedimentation. Three types of systems have been widely used to upgrade the performance of conventional systems; microstrainers, deep bed filtration and chemical treatment.

8.2.3.1 Microstrainers. The simplest system is the microstrainer, illustrated in Figure 8–14. Microstrainers are rotating drums on which woven filter fabrics, usually of stainless steel, are mounted. Incoming wastewater

Table 8–1

TYPICAL PERFORMANCE – CONVENTIONAL TREATMENT

Pollutant	Effluent mg/l	% Removal
Suspended Solids	20–30	80–90
BOD	15–25	80–90
COD (Chemical Oxygen Demand)	30–60	70–80
Ammonia-N	15–25	0–10
Phosphorus	6–10	0–40
Coliform	1 per ml	99.999

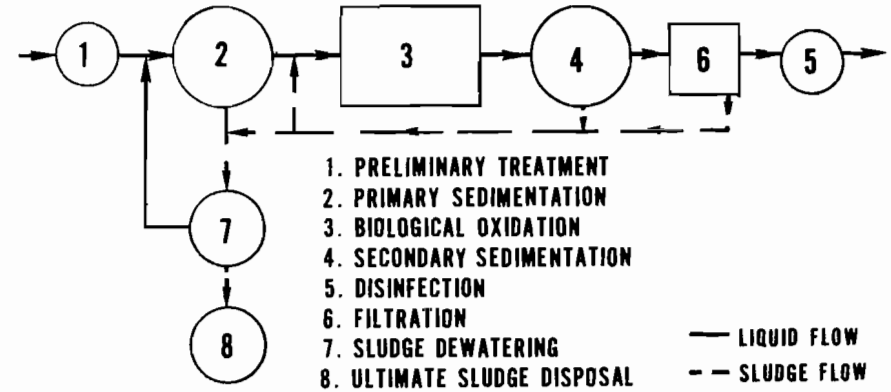


FIGURE 8–13 *Biological-Physical Treatment System.*

flows into the drums along the axis and then passes through the filter cloth which forms the drum surface. Filter rates are six to ten gallons per minute per square foot with head differential at about six inches of water. Control of headloss is obtained by washing the solids from the screen as that portion of the screen rotates to the top of the device. The backflow liquid discharges to a trough in the interior of the drum from which it is recycled to the sedimentation basin. Ultraviolet light mounted above the screen is used to prevent biological growth from blinding the screen.

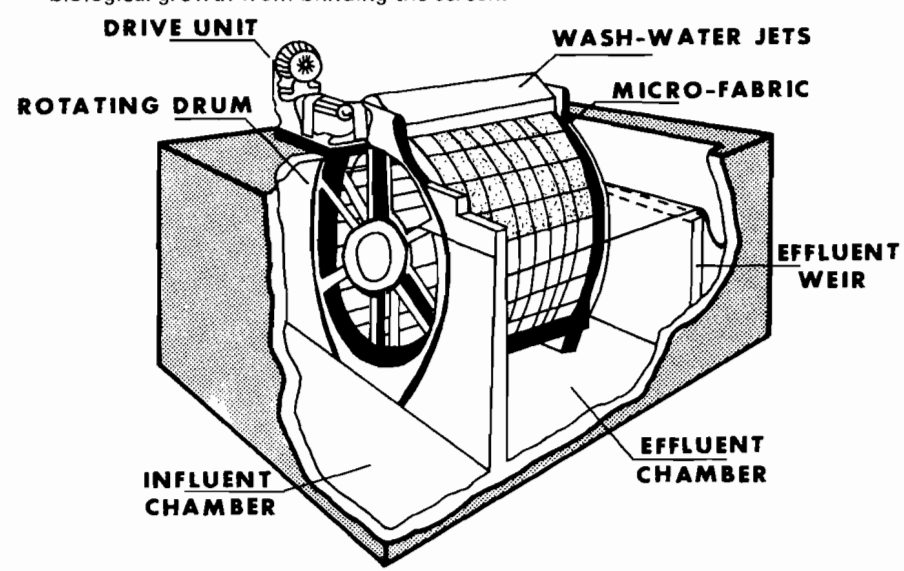


FIGURE 8–14 *Typical Microstrainer Unit.*

Microstraining is fundamentally a screening process, thus the performance is a function of screen size. Table 8–2 illustrates this effect. It can be seen that substantial improvement in effluent characteristics can be obtained by this technique. BOD removal closely parallels suspended solids removal as most of the BOD exerted by a conventional plant effluent is due to biological floc which escaped removal in the secondary tank. An extensive study of microstrainers was conducted in Chicago; based on this study a fifteen million gallons per day plant was designed and is now being installed.

Table 8–2

MICROSTRAINER PERFORMANCE ON SECONDARY EFFLUENT

Location	Screen Size Microns	Suspended Solids % Removal	BOD % Removal
Luton, Eng.	35	55	30
Bracknell, Eng.	35	66	32
Chicago, Ill.	23	71	74
Brampton, Ont.	23	57	54

8.2.3.2 Deep Bed Filtration. A somewhat more costly but more reliable upgrading technique is the use of deep bed filtration. A typical deep-bed filter installation is shown in Figure 8–15. In this technique, the wastewater is run at two to ten gallons per minute per square foot through several feet of a granular material wherein the suspended solids are deposited. Most of the removal takes place on the surfaces of the grains rather than in the bed pores. The accumulation of solids in the bed eventually produces an excessive pressure drop. At this point, the filtration run is terminated, and the bed is cleaned. Cleaning always involves an upward flow of water at a rate sufficient to expand the media, thus allowing for removal of the entrapped floc. In addition, an air scour and/or a water jet surface wash may be employed to remove solids which adhere to the grains. The nature of wastewater floc is such that it is almost mandatory for air scour or surface wash to supplement normal water backwash in order to achieve adequate cleaning.

Filter media ranges in size from ten mesh to 80 mesh and until recently only a single type of media has been employed. After backwash, however, a single medium filter is graded with the smallest size particles at the surface. This restricts filtration to the top layers of the bed. To counteract this effect, dual-media or multi-media filter beds are now coming into use. These employ granular materials of such sizes and specific gravities that after backwash the coarser material is always at the top of the filter. Typical combinations are coarse coal and fine sand or coarse coal, medium sand and fine garnet. These new combinations allow much longer filter runs at higher flow rates than single medium systems.

Typical performance of deep-bed filter systems for treatment of secondary effluent is given in Table 8–3. Removals of pollutants are only slightly better than with microstrainers, but deep-bed filters react well to shock loads.

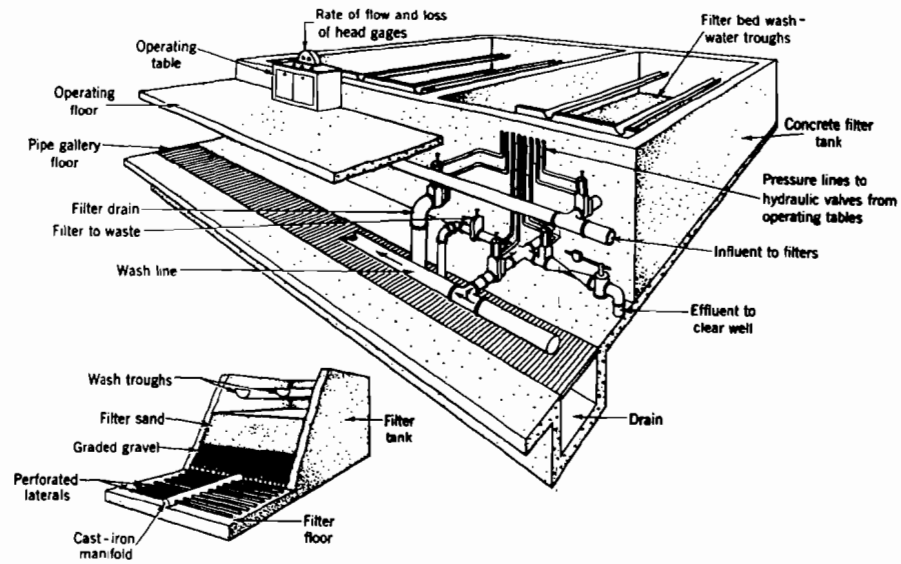


FIGURE 8–15 *Typical Rapid Sand Filter.*

Table 8–3

DEEP BED FILTRATION – SECONDARY EFFLUENT

	Flow Rate gal/min/sq. ft.	Suspended Solids % Removal	BOD % Removal
Luton, Eng.	1.5–4	72–91	52–70
Chicago, Illinois	2–6	70	80
Los Angeles, California	–	46	57
Tudor, England	–	85	–

8.2.3.3 Chemical Treatment. Suspended solids and BOD removal across a microstrainer or deep-bed filter will rarely exceed 80 percent because these processes cannot remove colloidal matter from wastewater. Chemical coagulation is the only feasible method for removal of colloids. In this process, chemicals added to the wastewater entrap the colloids into a floc which can then be removed by sedimentation or filtration. A large variety of chemical agents have been found useful as coagulants, these include salts of iron, salts of aluminum, lime and organic polymers. In addition to removing colloids, chemical treatment will coagulate the suspended solids in sewage forming large, dense flocs which are amenable to removal by sedimentation.

Chemical treatment itself only tends to entrap or coagulate colloids and suspended solids. Removal of these coagulated impurities requires liquid-

solid separation techniques. Consequently, a system which employs chemical treatment for upgrading can be quite simple or quite complex depending on the degree of removal and reliability desired.

The simplest system would have chemical addition and flocculation between the biological oxidation unit and the secondary tank. A more comprehensive system would employ the system above with a deep-bed filter following secondary sedimentation. The most complex system, which is illustrated in Figure 8–16, provides chemical addition, flocculation, sedimentation and deep-bed filtration after the secondary sedimentation step. It will be noted that a microstrainer is not included in any of these flow schemes because it does not perform well with a chemical floc.

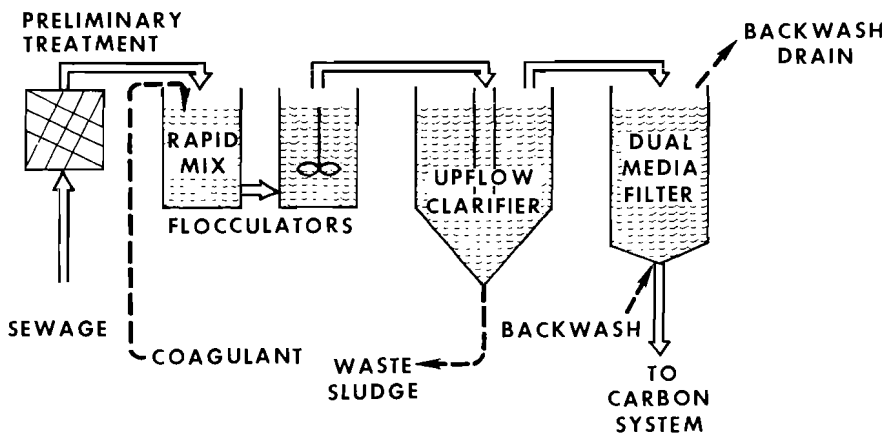


FIGURE 8–16 *Typical Flow Diagram of Clarification System.*

8.2.4 Tertiary Treatment

The term tertiary treatment causes some confusion in that it has a variety of meanings. In the general sense, it represents any stage of treatment or any treatment step applied after secondary treatment. This definition encompasses most of the unit operations and processes discussed in this chapter. In a more restricted sense, it represents a specific combination of treatment procedures applied after secondary treatment. In this restricted sense, tertiary treatment is the combination of chemical coagulation, flocculation, sedimentation, deep-bed filtration and activated carbon adsorption. Nitrogen removal procedures are optional in this treatment train. Figure 8–17 illustrates primary, secondary and tertiary treatment (restricted sense) combined together into a system which provides biological, physical and chemical treatment.

The ultimate goal of the combination of all these treatment procedures is to produce renovated wastewater, *i.e.,* wastewater which can be reused.

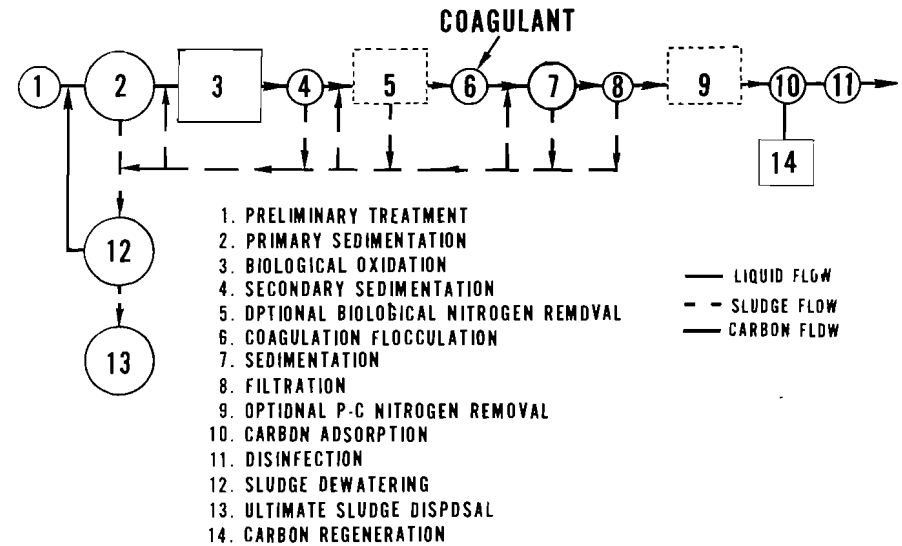


FIGURE 8–17 *Biological-Chemical-Physical Treatment System—Primary, Secondary and Tertiary.*

8.2.5 Phosphorus Removal

The key role of phosphorus in the process of eutrophication (aging of lakes and impoundments) has been known for many years. However, until recently, eutrophication of the Island's waterways was not a significant problem. Consequently, control of the phosphorus level in streams and lakes was not considered an important pollution control problem. Since the end of World War II, however, the rate of eutrophication has increased to the point where it is a major water quality problem. Although other nutrients play a role in eutrophication, recent articles have indicated that much of the recent increase in eutrophication rate is linked to significant increases in phosphorus discharges to rivers and lakes. Virtually all of the increase in phosphorus discharge is due to the activities of man and can be termed cultural eutrophication.

The major sources of phosphorus contributing to eutrophication are domestic sewage and agricultural runoff. Domestic sewage is the primary source in critical areas. Phosphorus gains entrance to sewage from human body wastes (primarily urine) and through the use of condensed inorganic phosphate compounds from detergents. Each of these sources accounts for about half of the phosphorus in domestic sewage. Treatment of domestic sewage to remove a significant portion of the phosphorus contributed by human wastes and detergents would have a significant effect on eutrophication rate.

8.2.5.1 Phosphorus Removal in Conventional Treatment. Removal of any pollutant from wastewater requires that it be converted to either an insoluble gas or an insoluble solid. Because none of the chemically stable forms of phosphorus is a gas at normal temperature and pressure, removal from wastewater is dependent on formation on an insoluble solid. Less than ten percent of the phosphorus discharged to municipal sewerage systems is insoluble and none of the conventional treatment techniques is particularly effective in insolubilizing this nutrient. Thus, phosphorus removal in conventional treatment systems is relatively poor. Primary treatment can remove only the ten percent of the phosphorus which is initially insoluble. During secondary treatment, phosphorus removal is achieved by synthesis into the biomass followed by sedimentation and sludge wasting. However, municipal sewage contains a considerable excess of phosphorus over that required for biomass synthesis during complete utilization of the organic carbon present; thus, removals are generally limited to twenty to forty percent. Studies indicate that biological systems have the capacity for much higher removals through the mechanism of "luxury uptake." However, attempts to implement this phenomenon in actual plants have not been successful.

8.2.5.2 Phosphorus Removal by Chemical Precipitation. Fortunately, phosphorus forms essentially completely insoluble precipitates with a number of substances, thus high levels of removal can be obtained when appropriate doses of the proper chemicals are applied. A large variety of chemicals can be utilized for this purpose but economic factors dictate the use of salts of iron, salts of aluminum or lime. In selecting the chemical for use at any particular site, the factors listed in Table 8–4 should be taken into account.

Table 8–4

FACTORS AFFECTING CHOICE OF CHEMICAL FOR PHOSPHORUS REMOVAL

Influent Phosphorus Level
Wastewater Suspended Solids and Alkalinity
Chemical Cost Including Transportation
Reliability of Chemical Supply
Sludge Handling Facilities
Ultimate Disposal Methods
Campatibility with Other Treatment Processes in Plant
Potential Adverse Environmental Effects

Phosphorus removal is achieved by precipitation followed by liquid solids separation. For the most part, the usual liguid-solids separation equipment in a treatment plant can be utilized for phosphorus removal. This results in a considerable savings in capital as well as integration of phosphorus removal into conventional treatment plant operation. In addition, it has been found that the use of chemical precipitants in conventional treatment can markedly upgrade performance of a treatment plant. This results from coagulation of organic suspended and colloidal solids by the chemicals added to precipitate phosphorus.

Figure 8–18 illustrates a conventional treatment plant with the three general sections in which phosphorus removal can be carried out. Chemicals can be added either just before the primary tank with removal taking place in the primary; in the secondary (biological) section of the plant with removal in the secondary sedimentation tank; or in a tertiary stage as was discussed in the section on suspended solids removal.

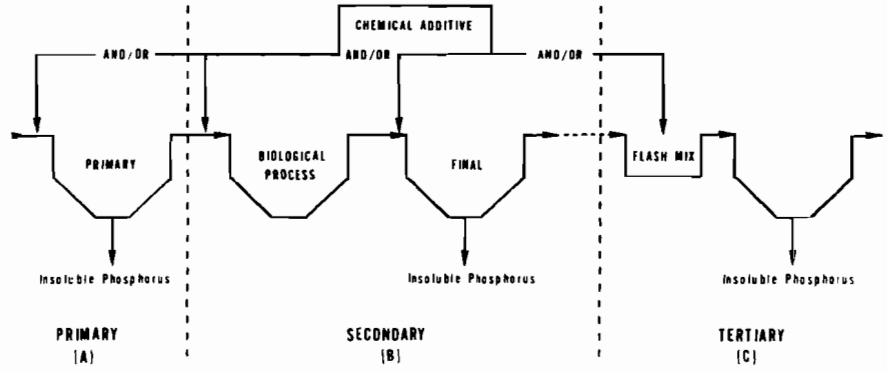


FIGURE 8–18 *Locations for Chemical Control of Phosphorus.*

Table 8–5 illustrates typical results obtained with phosphorus removal in the primary, secondary or tertiary. As can be seen, good removals are obtained in all sections; however, the lowest levels of phosphorus remaining are achieved in the tertiary addition. One reason for this is that a filter is usually included in the tertiary plant, thus better removal of fine precipitates is achieved. In addition, when the flow reaches this section of the plant all the complex phosphorus forms which are more difficult to precipitate have been hydrolyzed to orthophosphate which is the easiest to precipitate.

In plants where removal in the primary phase was practiced, a major effect to note is the significant increase in BOD and suspended solids removal achieved over the removal usually obtained in the primary tank. This may be important in helping to meet water quality standards for BOD and suspended solids if the treatment plant is overloaded.

In plants where the chemical is added in the secondary section, it has been observed that much more stable operation of the activated sludge is obtained than before chemical addition. The effect of the chemical is to weigh the sludge down, preventing its loss when a filamentous or dispersed growth predominates. Even in plants which have historically exhibited excellent performance chemical addition has improved performance by

helping maintain a higher concentration of activated sludge in the aeration tank. It has been found best to add the chemical between the biological reactor and the final sedimentation tank rather than at the head end of the secondary tank.

Table 8–5

PHOSPHORUS REMOVAL EXPERIENCE

Place	Chemical	P % Removal	P Effluent	BOD % Removal	S.S. % Removal
PRIMARY					
Grayling, Michigan	$FeCl_2$	72	4.4	78	58
Washington, D.C.	Lime	95	0.45	82	88
Mentor, Ohio	Pickle Liquor	83.5	–	59	74
SECONDARY					
Pomona, California	Alum	80–93			
Manassas, Virginia	Alum		1.0		
Richardson, Texas			0.5–0.75		
TERTIARY					
Nassau County, N.Y.	Alum		0.08		
Lake Tahoe, Calif.	Lime		0.14		
Lebanon, Ohio	Lime		0.1–0.5		

8.2.6 Nitrogen Control

Nitrogen can exist in the aquatic environment in any one of four forms: organic-N, ammonia-N, nitrite-N and nitrate-N. In sewage it is found primarily in the first two forms. In nature, biologically mediated reactions convert organic-N to ammonia-N which in turn is biologically oxidized to nitrite-N and nitrate-N.

Two major water quality objectives of nitrogen control are to prevent excessive build-up of nitrates in drinking water and depletion of the dissolved oxygen resources of streams by the biological oxidation of ammonia-N to nitrate-N. Table 8–6 shows the significance of the nitrogen oxygen demand (NOD) of a wastewater by comparison of the oxygen demand of raw wastewater to a well-treated secondary effluent. These data illustrate that 90 percent removal of organic oxygen demand (BOD) only results in a 74 percent removal of the total biological oxygen demand (TBOD). Nitrogen control is also important because ammonia-N exerts a chlorine demand which reduces disinfection efficiency, is toxic to fish and other aquatic life and stimulates corrosion of copper plumbing.

The least expensive method of preventing these adverse actions is to carry out the biological oxidation to nitrate under controlled conditions in the treatment plant. Control of ammonia-N is possible by altering the

Table 8–6

ULTIMATE OXYGEN DEMAND
IN RAW AND SECONDARY TREATED DOMESTIC SEWAGE

Component	Raw mg/l	Treated mg/l	% Removal
Organic Matter	250	25	90
Organic Oxygen Demand (BOD)	375	37	90
Ammonia-N	25	20	20
Nitrogen Oxygen Demand	112	90	21
Total BOD	487	127	74

operation of conventional activated sludge to provide for a significant degree of nitrification. The modifications involve increases in aeration rate, contact time and sludge age, and maintenance of the pH at 8.0–8.4. The latter is quite important in view of the tendency of the nitrification reaction to lower the pH. These reactions are quite temperature sensitive showing significant rate decreases as the temperature drops below 18° Centrigrade. As the temperature decreases, contact time and sludge age must be increased to compensate for the reduced reaction rates. Of all the factors listed above, sludge age is the most significant as it can be used to control the population of nitrifiers maintained in the system.

At low temperatures and when a significant diurnal flow variation exists, its has been found difficult to maintain both organic carbon oxidation and nitrification in a single reactor. In such situations, a two-stage system employing organic carbon oxidation in the first stage followed by a nitrification stage has shown significant superiority of performance. Separate sedimentation and sludge recycle is employed with each stage. This system exhibits much greater stability of performance because conditions in each stage can be established to favor the specific types of organisms desired in that stage.

Nitrification of sewage may not be sufficient for nitrogen control in some instances because an excess of nitrate in water will disqualify it from use as a potable water supply and because nitrogen in any form can serve as an algal nutrient. Phosphorus usually is the controlling nutrient in fresh waters whereas nitrogen appears to control within some estuarine environments. Areas where nitrogen is the controlling nutrient include San Francisco Bay, Lake Tahoe, the Potomac Estuary and Long Island. Removal of various forms of nitrogen from wastewater can be achieved by both biological and physical-chemical means.

8.2.6.1 Biological Denitrification. Under anaerobic conditions facultative heterotrophs will utilize nitrate ion as a hydrogen acceptor for the degradation of organic matter.

The end product of the nitrogen reduction is nitrogen gas which is essentially insoluble in water. Thus, a combination of nitrification followed by denitrification can achieve nitrogen removal from wastewater.

A three-stage biological system has been developed to provide nitrogen removal. The first stage is a high rate short aeration time (approximately two hours) biological reactor for organic carbon oxidation, and hydrolysis of organic nitrogen to ammonia. The second stage provides approximately three hours of detention and achieves essentially complete nitrification. The third stage is for denitrification of nitrate to nitrogen gas. An organic source must be added to the third stage to force the denitrification reaction to take place. A variety of substances has been evaluated for this use and methanol has been found to be far superior to all others. It is relatively inexpensive, reacts rapidly and provides only a minimum of energy for growth of new organisms. A diagram illustrating this system is given in Figure 8–19. Three alternate contactors are illustrated in the denitrification stage. Contactor I is a suspended growth contactor similar to that used in the first two stages. Solids control is somewhat difficult in this system, and it is often followed by a deep-bed filter. The other two systems supply a contact medium on which a heavy biological growth can develop. These latter systems require significantly less contact time than the three hours required in the suspended growth reactor, and they can accept higher hydraulic rates of application without fear of a washout of organisms. The coarse medium (one to two inches gravel) upflow system, requires a contact time of one to two hours and may require a supplemental filter. The fine medium downflow system utilizes particles as small as three millimeters in beds ten to twenty feet deep. Flow rate is that of a high-rate filter seven gallons per square foot with a bed contact of ten to twenty minutes. Backwash of the fine medium units is required once or twice per day to relieve clogging. In all of the denitrification systems discussed, essentially complete denitrification has been obtained in pilot-scale experiments.

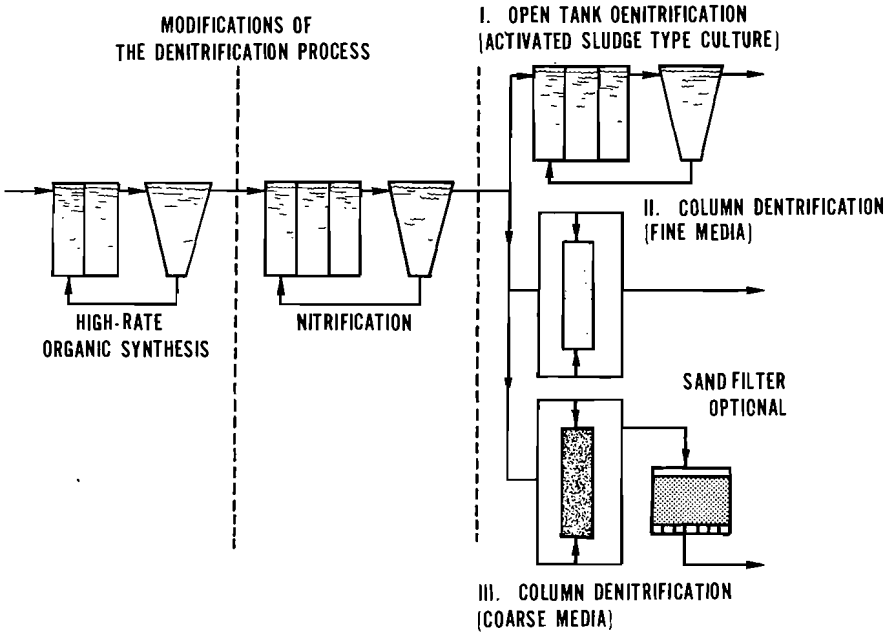


FIGURE 8–19 *Biological Denitrification—Three Stage System.*

Most experience has been with the three-sludge suspended growth system. In Suffolk County, the most used system for small treatment plants has been extended aeration and gravity sand filter. Results from a 100,000 gallons per day pilot plant in Washington, D.C. are presented in Table 8–7. This table includes data on phosphorus removal, as addition of alum to the first stage was practiced both to maintain solids control and achieve phosphorus removal.

8.2.7 Breakpoint Chlorination

Chlorine reacts with ammonia-N to yield a variety of amines and inorganic compounds by a variety of pathways. The reaction requires a theoretical dose of 7.6 grams chlorine per gram of ammonia-N. The reaction occurs in a stepwise fashion; various chloramines initially form which in turn rapidly react with additional chlorine to yield nitrogen gas.

8.2.8 Ammonia Removal by Air Stripping

Soluble ammonia can be air stripped from wastewater by converting the ammonium ion to the unionized form which is the soluble gas NH_3. This is accomplished by lime treatment to precipitate phosphorus and raise the pH of the wastewater to about eleven. Wastewater is brought to the top of a cooling tower and distributed over the column packing. Forced air is drawn through the packing media to extract the gaseous ammonia from the wastewater droplets. Problems with cold weather operation due to low air temperatures and scale formation on the tower packing media have yet to be overcome. However, ammonia stripping can be an attractive method of nitrogen removal because of its relative low cost, especially when chemical cost to raise the pH is also applied for phosphorus removal.

8.2.9 Organic Carbon Removal

Organic substances are removed by most of the processes discussed in the previous sections of this paper. However, some of the organics cannot be removed by coagulation and sedimentation, nor are they amenable to biological oxidation. These have been termed refractory organics. Activities in the advanced waste treatment program were aimed at removal of refractory organics, and two methods with economic feasibility were developed: activated carbon adsorption and ozonation.

Recent studies have illustrated that these processes are just as applicable to all types of organics present in wastewater; consequently, they will be employed in the future as general purpose procedures for removal of organics in wastewater.

Table 8–7

PERFORMANCE SUMMARY FOR THREE-STAGE BIOLOGICAL TREATMENT UTILIZING MINERAL ADDITION AND A SUSPENDED GROWTH REACTOR

Constituent	Raw Wastewater mg/l	Primary Effluent mg/l	High-Rate Effluent mg/l	Nitrified Effluent mg/l	Denitrified Effluent mg/l	Denitrified Effluent (filtered) mg/l
COD	320	218	64	43	44	38
Organic-N	10.3	5.9	0.8	0.4	0.4	0.2
Ammonia-N	11.3	13.7	7.7	0.6	0.3	0.4
Nitrite-N	–	–	1.1	0.3	0.3	0.4
Nitrate-N	–	–	4.3	11.5	0.9	0.9
Total Phosphorus	12.6	11.9	2.8	2.6	1.5	1.1
S.S.	157	90	8.8	7.1	7.1	1.7
pH (mode)	7.2	7.3	7.5	7.5	7.7	7.7

All values are averages except pH and are based on 40 determinations.

8.2.9.1 Activated Carbon Adsorption. The ability of activated carbon to remove soluble organics from wastewater is a result of the similarity of the surface chemistry of the activated carbon to that of the organic molecules. The ability of substances to adsorb organics is widespread; the characteristic of activated carbon which makes it unique is that it has a much higher adsorption capacity than other materials. The high capacity is the result of an extensive internal microporous structure formed during the activation process.

A generalized activated carbon treatment process is illustrated in Figure 8–20. The carbon and wastewater are contacted for a sufficient period of time for adsorption to take place, then they are separated. Eventually, the capacity of the activated carbon is exhausted, and it is removed from the contact vessel to a regeneration step. During regeneration some of the carbon is lost or consumed so make-up must be added.

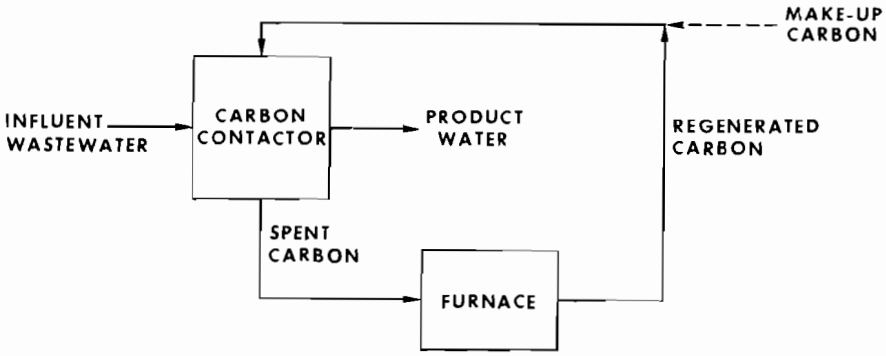


FIGURE 8–20 *Regeneration and Reuse of Activated Carbon.*

Commercial grades of activated carbon are either granular (sizes eight by 30 mesh, or twelve by 40 mesh) or powdered (greater than 300 mesh). Both forms have been found essentially equivalent in their ability to remove organics, but each type requires a different method of contacting and regeneration.

Granular carbon is contacted with sewage in columns through which the sewage flows. The columns may be either pressure vessels or gravity contactors; the former provide better operational flexibility, the latter are more economical. Flow may be upward through an expanded bed, upward through a packed bed, or downward through a packed bed. Packed bed operation provides filtration as well as adsorption but requires frequent backwash. Upflow systems allow for periodic removal of a portion of the carbon at the base, thereby providing countercurrent contact in a single vessel. However, good flow distribution is more difficult to achieve upflow than downflow. Columns can be connected in series as with the clinoptilolite system to achieve countercurrent contact. Alternately, a parallel flow arrangement can be used to achieve countercurrent contact. With the parallel flow arrangement, the starting time in service is staggered so that at any time one column is near exhaustion, one or more other columns are relatively fresh and all others are at some in-between stage. The flow from each column is blended to produce the final effluent.

Regardless of the contacting details, the fundamental system design parameter is contact time. The specific contact time to be used is a function of the effluent quality desired and the wastewater characteristics. In general, it has been found that as contact time increases, the rate at which organic removal takes place decreases. A point of essentially zero removal generally is located between 30 minutes and 60 minutes contact time. Contact time is always rated on an empty bed basis.

Regeneration of granular carbon is conducted in a multiple hearth furnace, a device which has had a long history of successful use for incineration of sewage sludge. Figure 8–21 illustrates a typical granular carbon regeneration scheme. Spent carbon is removed from the contactor by eduction, stored, partically dewatered, and then fed to the furnace. As the carbon moves from hearth to hearth it is dried, baked and finally reactivated. During the reactivation stage, the temperature is in the range of 1500° to 1700° Farenheit. After regeneration, the carbon is quenched and returned to a contactor. The furnace is rated at 80 pounds to 110 pounds carbon per square foot per day. Air pollution control equipment, such as an after burner and wet scrubber or cyclone, are usually required to purify the exhaust. Experience with this regeneration system at essentially full scale indicates carbon regeneration loss of five percent to ten percent per regeneration cycle. The losses are due to physical attrition in the regeneration loop and burnoff in the furnace.

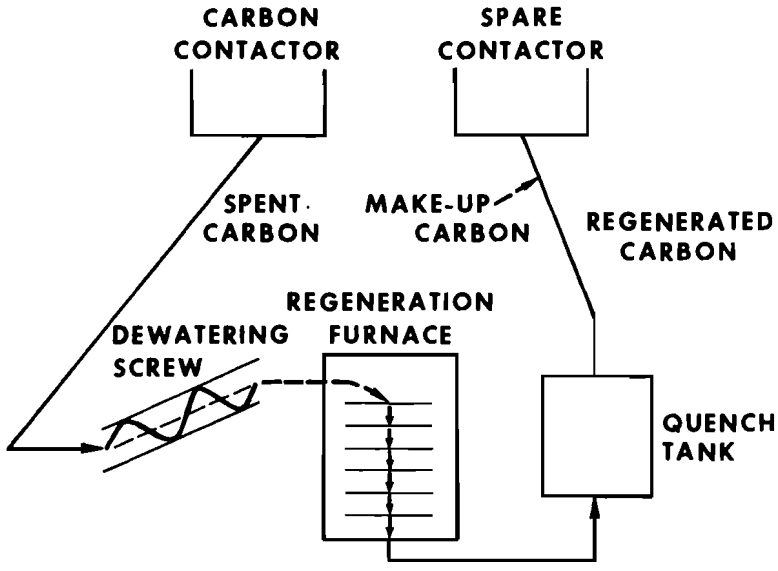


FIGURE 8–21 *Activated Carbon Regeneration System.*

In systems utilizing powdered carbon, contact is brought about by mixing of the carbon and the wastewater in a reactor-clarifier contactor. This apparatus is illustrated in Figure 8–22. The carbon and wastewater are flash mixed and flocculated in the center well of the apparatus. The mixture then flows into the outer section where gravity separation of the carbon and wastewater takes place. A pool of carbon in a thick slurry form is maintained at the bottom of this contractor.

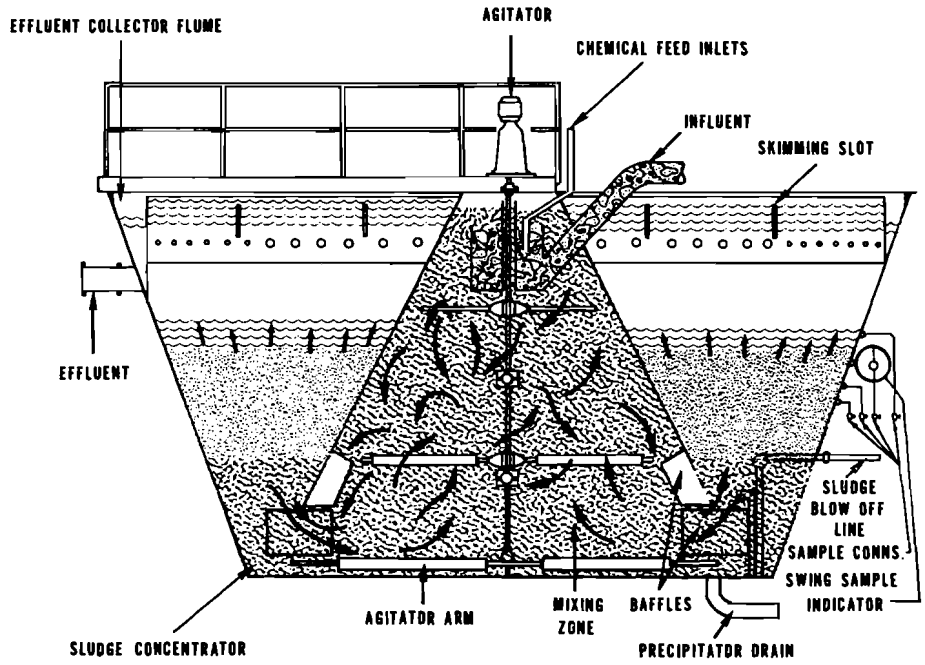


FIGURE 8–22 *Solids Contact Clarifier with Sludge Blanket Filtration.*

In this type of contactor the carbon comes to equilibrium with the organic concentration in the effluent wastewater, whereas it comes to equilibrium with the organic concentration in the incoming liquid in a granular contactor. The organic adsorption capacity of activated carbon is proportional to the concentration of organics with which it comes to equilbrium, thus it is more imperative that countercurrent contact be achieved in powdered carbon systems than in granular systems. Figure 8–23 illustrates schematically a two-stage counter flow contacting system which is utilized with powdered carbon treatment. The carbon is thickened (not shown) between stages to reduce pumping and the effluent is filtered to remove residual carbon fines. Figure 8–24 illustrates the most advanced system for powdered carbon regeneration. The slurry containing spent carbon is thickened, dewatered in a centrifuge or on a vacuum filter and injected into a fluidized bed furnace. The regenerated carbon is reslurried and pumped back into the system. In the furnace the temperature is maintained at the same level as in the multiple hearth furnace. Contact time of a carbon particle in the furnace averages several seconds. Shorter time results in only partial regeneration, long time results in particle incineration. Thus, tight control must be exercised with this regeneration scheme. To date small pilot studies have indicated the

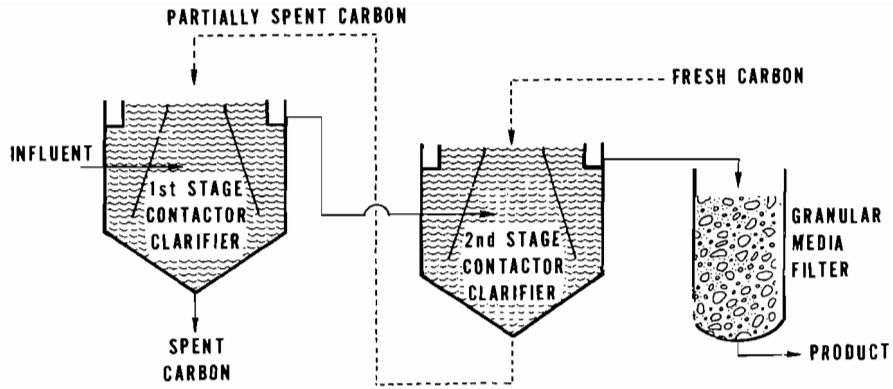


FIGURE 8–23 *Flow Diagram Two-Stage Countercurrent Powdered Activated Carbon System.*

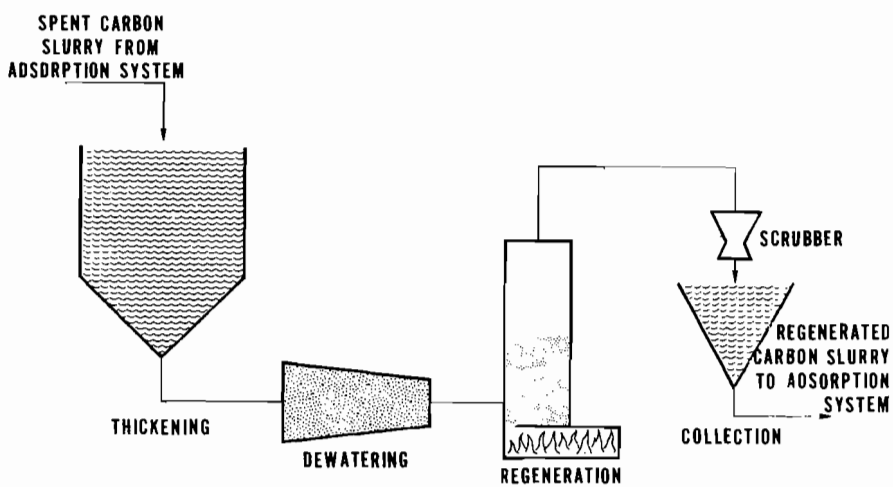


FIGURE 8–24 *Thermal Regeneration Powdered Carbon Flow Diagram.*

feasibility of this regeneration scheme with losses averaging fifteen percent. A larger version of this furnace is now being evaluated at Salt Lake City.

Both granular carbon and powdered carbon contact are excellent processes for organics removal from wastewater. Powdered carbon processes have advantages over granular carbon in that powdered carbon is cheaper than granular carbon (ten cents *vs.* 30 cents per pound); powdered carbon plants require a much smaller carbon inventory and can be dosed to meet the demand. However, granular carbon exhibits higher practical adsorption capacity, does not require complex dewatering procedures prior to regeneration and most important has been successfully regenerated at full scale. Economics demand that regeneration be incorporated into all but the smallest scale carbon adsorption plants. Thus, an engineer designing a treatment plant using carbon adsorption would most likely choose granular carbon.

Extensive processing experience has been obtained with the use of activated carbon for treatment of wastewater after biological treatment (tertiary application). Data from a number of facilities are summarized in Table 8–8. It can be seen that organic removal in the range of 70 percent to 80 percent was obtained. This is typical of the capability of activated carbon for organic removal from sewage. Data on adsorption capacity indicates a considerable spread, 0.25 to 0.87 pounds COD per pound activated carbon. This considerable spread occurs because carbon capacity is a function of desired effluent quality and influent organic concentration. Most significant, however, is that in all cases the capacity was significantly higher than that projected by an adsorption isotherm test. Biological activity on the carbon is the primary explanation of the significantly higher capacity obtained. It is theorized that partial regeneration in situ is accomplished by biological action. Naturally, this has had a favorable impact on the economics of carbon adsorption.

Table 8–8

ACTIVATED CARBON TREATMENT OF WASTEWATER TERTIARY APPLICATION

Location	Carbon	Organics, mg/l In	Organics, mg/l Out	% Removal	Organics Measurement
Pomona	Granular	43	10	77	COD
Colorado Springs	Granular	43	13	70	TOC
S. Lake Tahoe	Granular	12	3	75	TOC
Lebanon	Powdered	20	4	80	TOC
Tucson	Powdered	27	7.5	72.5	COD

The process design for carbon treatment has had to be adjusted to take account of biological action. For example, only a normal upflow backwash was provided in early granular carbon contactor design. This was found to be inadequate to insure cleaning of the carbon column so air scour and surface wash are frequently added. In addition, more frequent backwash (at least once per day) must be planned for in design. Under heavy load, carbon columns become septic and hydrogen sulfide is produced. Aeration of the feed may be required or extra-chlorination to oxidize the effluent sulfide may be needed. Under heavy load, expanded bed operation becomes superior to packed beds because clogging is less of a problem and aeration is easier to accomplish.

Powdered carbon contact design has also been affected by the realization that biological action may occur. It has recently been illustrated that when extensive biological action is encouraged, only one carbon contacting stage is required rather than two to achieve high adsorption capacity.

8.2.9.2 Physical-Chemical Treatment. Physical-chemical treatment of raw wastewater or more accurately chemical clarification—carbon adsorption was first evaluated as a treatment technique over three decades ago. It was found to produce a good quality effluent but at a cost greater than conventional processing. The recent up-grading of water quality standards has brought this treatment scheme closer to economic viability because it can produce an effluent superior to conventional processing. In addition, the developments discussed above in carbon adsorption techniques have tended to lower the cost of physical-chemical treatment. Finally, removals achieved by chemical clarification have been higher than anticipated which has also had a favorable effect on physical-chemical treatment costs.

Figure 8–25 is a general diagram of the clarification carbon treatment system. Following the standard type of preliminary treatment, the waste is dosed with chemical sufficient to achieve the desired level of suspended solids and/or organics and/or phosphorus removal required. The same chemicals are used as for phosphorus removal in the primary. Significant removals of

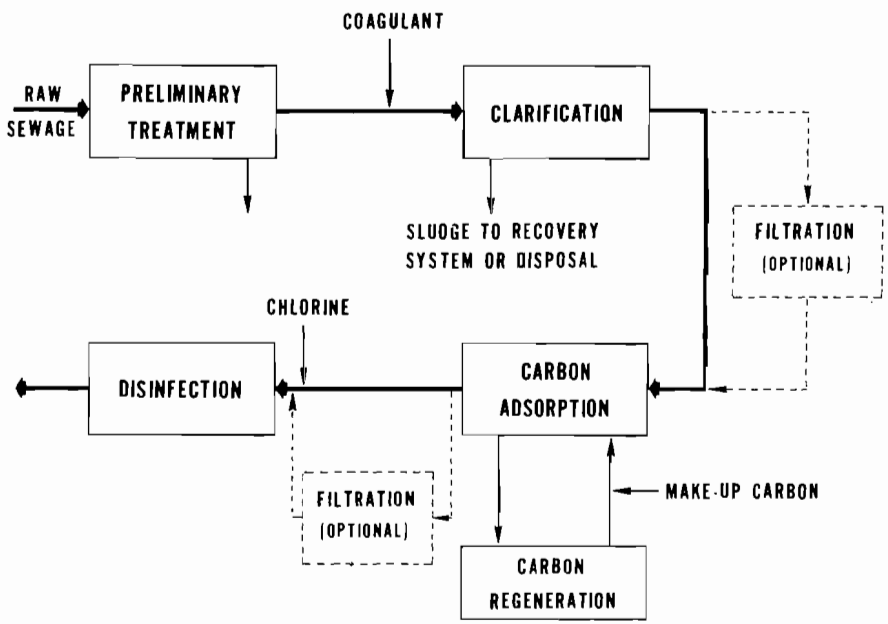


FIGURE 8–25 *Flow Diagram of a Physical-Chemical Treatment System.*

organics, suspended solids and phosphorus are obtained by chemical clarification as illustrated in Table 8–9. Especially significant is the organic removal which is higher than would be expected from complete removal of suspended solids. This extra removal is due to coagulation and possible chemical adsorption of colloidal and soluble organics. Up to 50 percent of the "soluble" organics in sewage may be removable by chemical coagulation.

Table 8–9

ACHIEVEMENTS OF CHEMICAL CLARIFICATION

Plant	Chemical	Organic Removal %	S.S. Removal %	P Removal %
Ewing-Lawrence	170 mg/l $FeCl_3$	80	95	90
New Rochelle (ZM)	Lime pH 11.5	80	98	98
Westgate, Virginia	125 mg/l $FeCl_3$	70	–	–
Salt Lake City	80–100 mg/l $FeCl_3$	75	–	80
Blue Plains	Lime pH 11.5	80	90	95

After clarification is complete, the wastewater is passed to the carbon adsorption step for completion of the removal of soluble organics. Table 8–10 gives data from a number of plants which indicate that very good quality effluents can be obtained as well as high carbon adsorption capacity. As indicated previously, this is the result of biological action on the carbon. In physical-chemical treatment systems, the carbon is subjected to a heavier load than in tertiary plants, thus extra care in design must be taken to insure that the disadvantageous features of biological action on carbon can be mitigated.

Table 8–10

ACTIVATED CARBON PERFORMANCE IN PHYSICAL-CHEMICAL TREATMENT PLANT

Plant	Effluent Organics mg/l	Carbon lbs. TOC lb. A.C.	Capacity lbs. COD lb. A.C.
Blue Plains (G)	TOC = 6	0.15	0.41
Lebanon (G)	TOC = 6	0.22	0.50
Ewing-Lawrence (G)	TOC = 3–5	0.3	–
New Rochelle (G)	COD = 8	–	0.6
Owosso (G)	COD = 25	–	0.65
Salt Lake City (P)	COD = 22	–	0.36

(G) - Granular Carbon
(P) - Powdered Carbon

Filtration is presented as an optional step in Figure 8–25, but it would be wise to include it in the treatment scheme. Filtration acts as the safety factor in the solids removal step; therefore, its use can bring a high degree of reliability to the treatment scheme. In addition, it can be used to prevent an

overload of solids on the carbon which could foster excessive biological action. The positioning of the filter prior to or after the carbon contact is dictated by the method of carbon contact. Expanded bed and powdered carbon systems usually require filtration after the carbon step. Packed bed systems will benefit from filtration before the carbon.

Tables 8–11, 8–12 and Figure 8–26 provide information on the performance of three physical-chemical treatment pilot plants. These data illustrate removals at various stages of treatment for a variety of pollutants. The Blue Plains data include nitrogen removal by clinoptilolite.

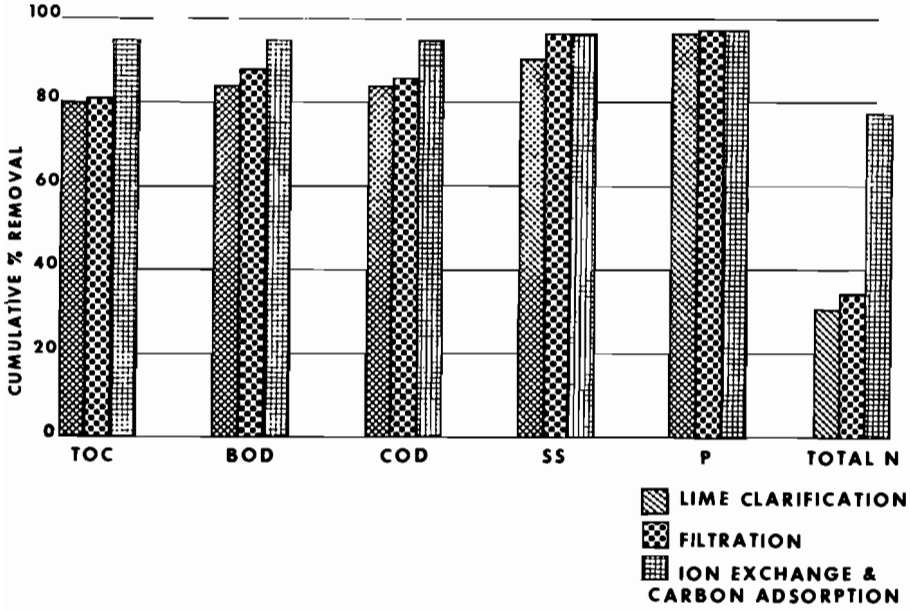


FIGURE 8–26 *Removal Efficiencies of Physical-Chemical Treatment—Blue Plains Pilot.*

Table 8–11

POWDERED CARBON PILOT PLANT OPERATING CONDITIONS

Flow Rate 50 gal/min
Chemical 425 mg/l Lime to pH 10.8
Carbon 150 mg/l + 0.4 mg/l polymer

Results

	COD	BOD	SS	P
Raw Sewage	222	144	200	7.3
Clarified Effluent	65	47	28	1.4
Final Effluent	35	13	7	0.4

Table 8–12

ROCKY RIVER WASTE TREATMENT PLANT CLARIFICATION-CARBON PROCESS

	Raw	Polymer Clarification	Carbon Contact Time, minutes			% Removed
			14	23.4	32.6	
Suspended Solids, mg/l	107	65	13	15	7	93.3
BOD, mg/l	118	57	21	11	8	93.3
COD, mg/l	235	177	67	50	44	81.3

Table 8–13 lists the features which physical-chemical treatment has with respect to conventional treatment systems. Because of these features and a favorable cost comparison a number of communities are planning physical-chemical treatment systems.

Table 8–13

ADVANTAGES OF PHYSICAL-CHEMICAL TREATMENT vs. CONVENTIONAL PRIMARY + SECONDARY

1. Less Area Requirement—½ to ¼
2. Lower Sensitivity to Diurnal Variation
3. Not Affected By Toxic Substances
4. Potential For Significant Heavy Metal Removal
5. Superior Removal of P Compounds
6. Greater Flexibility In Design And Operation
7. Superior Organic Removal

8.2.9.3 Ozone Oxidation. In addition to carbon adsorption, another physical-chemical method of organics removal, ozonation, has been evaluated and found worthy of development. However, this procedure is several years behind activated carbon in development because so much required information has not yet been obtained.

Ozone is a powerful oxidant which is generated by passing a properly conditioned air stream between electrodes, one of which produces a corona discharge. It must be generated on site and used immediately. Ozone is only poorly soluble in water so that special contacting techniques must be used to insure optimum utilization.

8.2.9.4 Pure Oxygen Activated Sludge. The last improvement in procedures for removing organics from wastewater is the application of pure oxygen in the activated sludge process. The use of pure oxygen does not permit activated sludge to go beyond its inherent capability but allows a closer approach to this limit within an acceptable economic framework.

Early work in the biological treatment field pointed out the advantages of pure oxygen over air as the source of oxygen in activated sludge. However, the cost of the pure oxygen was quite high and a feasible system to achieve high degreees of utilization was not available, so the concept lay dormant. Over the last decade, the cost of pure oxygen has decreased and a system was devised which could achieve high utilization efficiency. Figure 8–27 illustrates the UNOX system developed by Union Carbide. The key features of this system are the use of covered reactors to prevent loss of oxygen; a baffled reactor to prevent short-circuiting and recompression and recycle of gas in each chamber. In all other respects, the system is virtually identical to a conventional activated sludge.

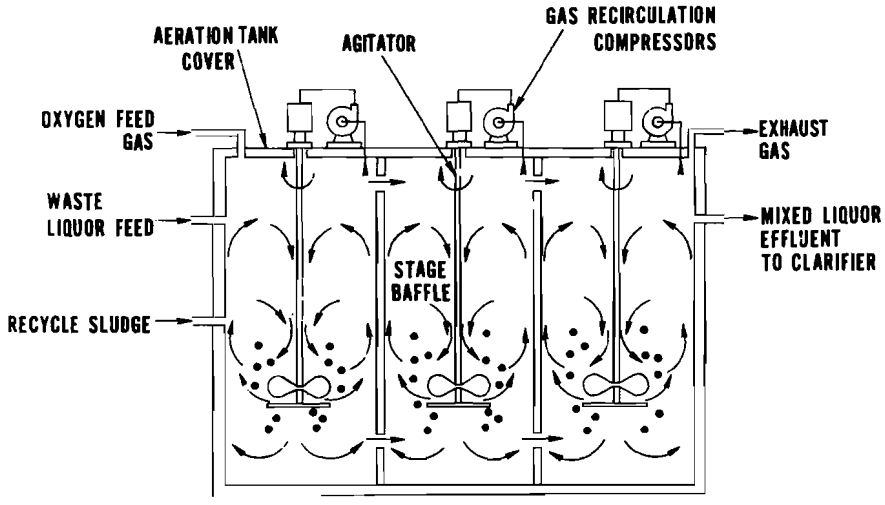


FIGURE 8–27 *Schematic Diagram of Multi-Stage Oxygenation System.*

8.2.10 Dissolved Inorganics Removal

In the process of its domestic or industrial use an increment of dissolved mineral matter is added to water. The magnitude varies from 100 milligrams per liter to 500 milligrams per liter per use depending generally on local conditions. Extensive reuse of wastewater even for industrial use will require at least partial demineralization of wastewater. Electrodialysis, ion exchange and reverse osmosis seem promising.

8.2.10.1 Electrodialysis. In sewage application, electrodialysis suffers severe limitations. The anion plates foul quite easily, drastically reducing treatment performance unless the feed has received extensive pretreatment. In addition, as the sewage is demineralized its electrical resistance increases. This limits the degree of economically feasible demineralization which can be obtained. It is difficult to reduce the TDS of water much below 300 to 400 milligrams per liter with electrodialysis. For these reasons electrodialysis is no longer considered a leading candidate process.

8.2.10.2 Ion Exchange. At present, ion exchange shows much promise f for removal of dissolved inorganics. Cost of operation is lowest, especially at the salt levels anticipated in wastewater and the technology of ion exchange at full scale is proven.

Ion exchange systems require regeneration with solutions much higher in TDS than the original feed yielding a difficult problem of brine disposal.

8.2.10.3 Reverse Osmosis. At present, reverse osmosis is the most expensive of the three processes discussed for demineralization. However, its potential is considerably superior to that of the other two. This process is indeed in its infancy as the first working membranes were developed only fifteen years ago. In addition, membranes which will desalt water will remove virtually every other pollutant from wastewater. Thus reverse osmosis may become an all purpose pollution contol system.

In this process water is forced to flow through a semi-permeable membrane (permeable to water but not to salts) by application of high pressure. Pressures of several hundred pounds per square inch are required to achieve fluxes of the order of ten gallons per square foot per day. The degree of demineralization can approach 99+ percent and increases with the pressure applied.

The heart of this process is the membrane. At present, the best membranes are cast from a mix of cellulose acetate, acetone, formamide and magnesium perchlorate. Special techniques form a membrane with a thin (one micron) skin which provides the desalting surface and a thick (100 microns) porous sublayer which supplies a structural backing. This membrane is compresssible, hydrolyzes at low and high pH and is easily damaged. Work is being conducted to develop new, tougher membrane materials.

Even if new membrane materials are found, the engineering problems of this process will remain unchanged. These problems are a structural support system to absorb the several hundred pounds per square inch pressure drop across the membrane and control of fouling on membrane surfaces. The support system must not only support the membrane but should provide high membrane area per unit volume.

Three configurations are in use, tubular, spiral-wound and hollow fine fiber. The tubular system has the membrane positioned along the inner wall of a porous one-half inch diameter tube. The spiral-wound module uses a stack of flat membranes separated by spacers and rolled into a jelly-roll form. The hollow fiber uses microscopic fibers of the membrane which are in essence thick-walled microcylinders. Here, pressure is applied outside the fiber and water permeates into the hollow core. As a rough guide, membrane area per unit volume is twenty square feet per cubic foot for tubular systems, 250 square feet per cubic foot for spiral wound systems and 2000 to 5000 square feet per cubic foot for hollow fine fibers. The systems are in reverse order on the basis of fouling resistance. In general, the tubular system is

preferred for dirty water application and the other two for clean water application.

Control of fouling can be achieved by pretreatment, establishment of turbulence at the membrane surface and chemical cleaning techniques. Application of these techniques is easiest in the tubular system. In addition, tubular systems afford the only opportunity for in-situ membrane replacement. At present none of the systems possess a marked advantage over the others.

The economics of wastewater demineralization are quite imprecise as life times of membranes and resins is not known, nor is degree of fouling and degree of demineralization required.

8.2.11 Summary

A review of many of the newest developments in wastewater treatment technology have been presented. In the interest of brevity, some areas such as microorganism removal and ultimate disposal have not been covered, and the coverage of others has been less than complete. It should be clear, however, that the wastewater treatment planner now has a whole range of treatment procedures. It is well within the realm of practicability to conceive of taking any wastewater and purifying it to any degree desired. All that is necessary is to hook together the various unit operations and processes required. A number of combinations which have already found some utility are summarized in the figures and tables below.

8.2.11.1 Biological-Physical Treatment. This system employs a filter to upgrade the performance of conventional treatment. It is illustrated in Figure 8–13 on page 299.

8.2.11.2 Biological-Chemical Treatment. In this system, illustrated in Figure 8–28, chemical coagulants can be added at various points for phosphorus removal and improved solids removal.

8.2.11.3 Physical-Chemical Treatment. In this system, illustrated in Figure 8–29, chemical clarification and activated carbon are combined to achieve wastewater purification.

8.2.11.4 Biological-Physical-Chemical Treatment. This system illustrated in Figure 8–27 combines a large number of processes to achieve a high degree of purification for a large variety of pollutants. Table 8–14 summarizes the performance to be expected from these treatment schemes.

8.2.12 Sprinkler Irrigation

Sprinkler irrigation of domestic, industrial and agricultural liquid wastes is appropriate when the disposal systems are adequately designed and conscientiously operated. The principles involved in adequately handling these liquid wastes can be discussed by use of a renovation-conservation cycle.

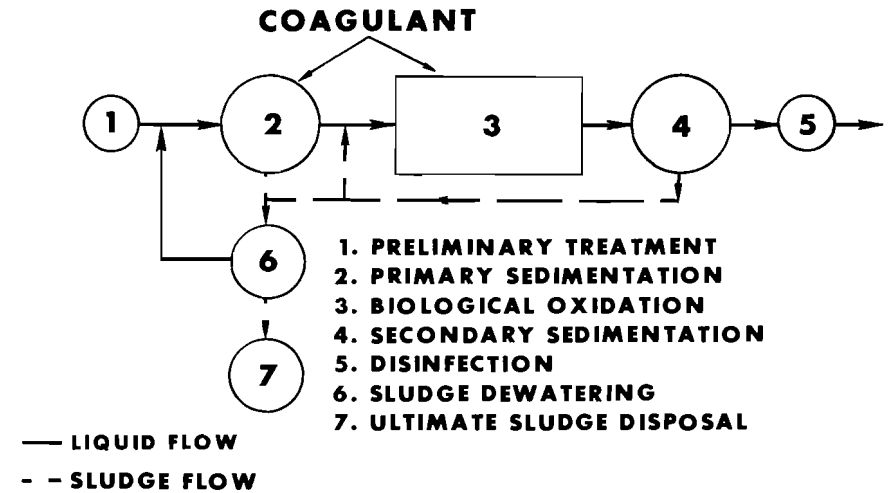


FIGURE 8–28 *Biological-Chemical Treatment System.*

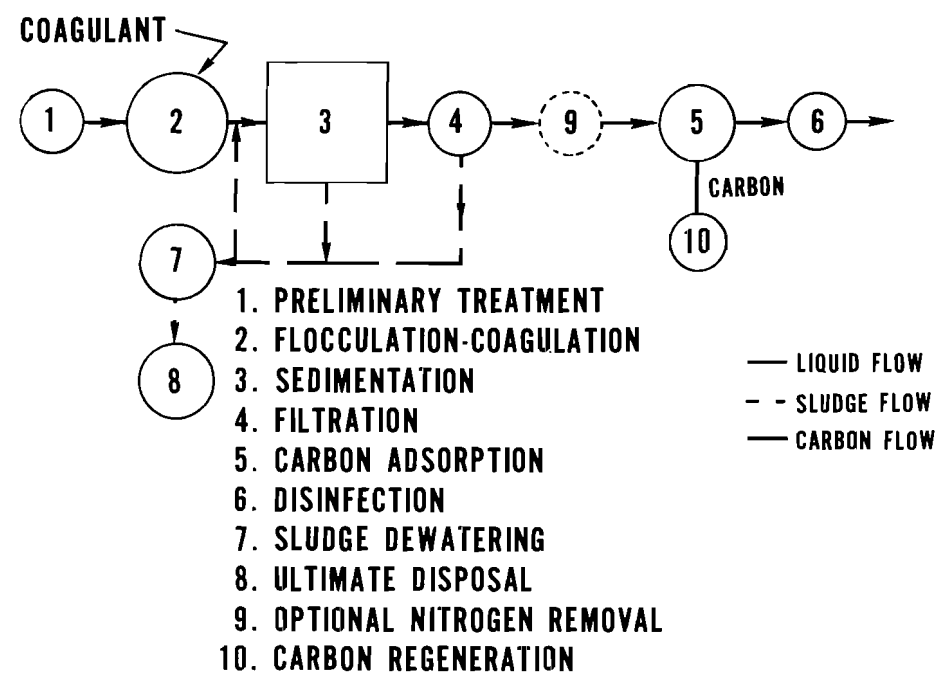


FIGURE 8–29 *Physical-Chemical Treatment.*

Table 8–14

TREATMENT PERFORMANCE SELECTED WASTEWATER TREATMENT SYSTEMS
Percent Removal

System Parameter	Conventional	Biological Physical	Biological Chemical	Physical Chemical	Biological Physical Chemical
Organics	80–90	85–95	90–95	95–99	99+
Suspended Solids	85–95	90–95	95–99	95–99	99+
Phosphorus	0–40	0–50	90–95	95–99	99+

8.2.12.1 4-R Wastewater-Renovation Conservation-Concept. One way of explaining the concept of liquid waste renovation and conservation is by considering it as a 4-R cycle, as depicted in Figure 8–30. The four R's being: Return, Renovation, Recharge and Reuse. *Return* of liquid wastes to the land is through an irrigation system. Surface soil layers *Renovate* this wastewater. The renovated water is *Recharged* into the ground water supply. Both the nutrients and the renovated water are available for *Reuse*. Each of these R's will be discussed briefly.

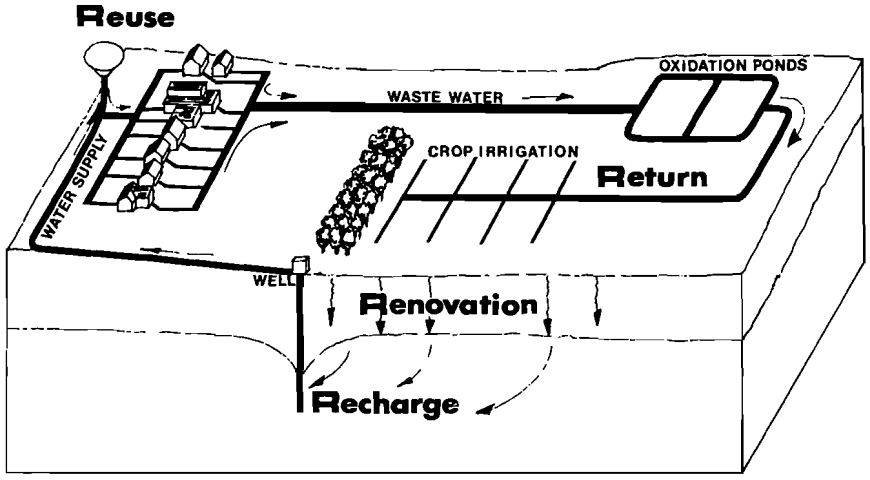


FIGURE 8–30 *Sprinkler Irrigation Disposal System.*

8.2.12.2 Return. Domestic wastewater ordinarily is returned to the land only after it has received a secondary level of treatment and chlorination. Industrial and cannery liquid wastes usually need to be chlorinated only if they also contain domestic wastes. Agricultural liquid manures frequently are irrigated in the form they are produced, as long as they are fluid enough to be pumped.

Three additional factors concerning the return phase of the cycle are important to effective operation. The liquid wastes must be distributed uniformly over the area. The rate of application must be sufficiently low so that all the water infiltrates through the soil surface. (It must move through the soil so that it can adequately be renovated.) The amount that is actually applied per week or the amount per year must be compatible with the soil type so that renovation can be assured.

8.2.12.3 Renovation. Under renovation, one usually considers mechanical, biological and chemical cleanup. Some industries are interested primarily in mechanical removal of organic material from the liquid wastes, followed by biological degradation. Municipal liquid waste disposal usually involves chemical renovation. That is, nutrients are removed from a solution through chemical reaction or transfer. This process is similar to that involved in agricultural, golf course or lawn fertilization.

In lawn fertilization, the fertilizer is placed on the surface of the soil and then irrigated or leached by rain. The fertilizer is taken into solution in the water. There is essentially no difference between this water and municipal sewage effluent. Each has nutrients in solution and as the water moves through the soil profile, these nutrients are chemically fixed in the soil or attached to the soil chemical complex where they stay until they are needed by the crop. Nutrients, such as nitrates, may be used directly by the crops or by soil microbes.

Farmers have been familiar with and have used this type of nutrient cycle for years. The nutrients are picked up by the crop and removed from the field with the crop. The same procedure is true when applying the various liquid wastes. Here, however, the nutrients are first applied to the soil and then a crop is grown in order to remove these nutrients. Harvesting of a crop makes room for the removal of the nutrients from the next application of wastewater.

8.2.12.4 Recharge. Before water is recharged, it must be adequately treated. Systems must be designed for each specific purpose and use intended for the irrigated liquid wastes.

8.2.12.5 Reuse. Potential reusers include agricultural, industrial and domestic. Agricultural reuse for crops is obvious. Distribution of wastewater over industrial and domestic water supply areas could frequently help alleviate waste disposal, as well as water supply problems.

8.2.13 Waterless Composting Toilet (Clivus Multrum)

Originally developed in Sweden, the composting toilet (or clivus multrum) is very similar in operation to the backyard "privy." Both toilet and solid, organic kitchen wastes are discharged to and then composted in a specially designed bin in the home. Shower and sink wastewater are disposed of by different mechanisms such as a cesspool or septic tank system.

In the clivus multrum system, the bin is nine feet long, four feet high and five feet wide. The bin holds the organic wastes of a family for several

years. During that time, microbial decomposition takes place to digest the waste and the end product (after two to four years) is a humus that can be used in a garden. Gasses and other volatile material that are produced are vented through a stack. The temperature of the chamber is sufficient to create a positive ventilation pattern with air entering through two tubes and leaving by way of the vent stack. See Figure 8–31.

Since the clivus multrum type of system does not use water, it results in a significant water savings (as much as 40 percent in a typical household). It requires little maintenance. Bacterial populations in the final humus product were shown to be consistent with typical soil bacteria types and levels. In addition, fecal coliform bacteria have not been shown to be present in the mulch.

Manufacturers claim that 90 to 95 percent of the original volume of waste has been converted to waste gas which is vented to the atmosphere. Typical end-product generation rates are three to ten gallons of humus per person per year after the two to four year digestion period.

8.2.14 Individual Home, Aerobic Biological Treatment Units

Traditional on-lot wastewater disposal systems for individual homes include cesspools or septic tank/tile field systems. In each, waste materials are decomposed by bacteria which do not require oxygen for their life systems. Hence, the processes are anaerobic or septic; *i.e.,* devoid of oxygen.

In recent years, equipment has been developed to provide for the aeration of home sewage in individual on-lot systems, thus achieving aerobic decomposition. Waste treatment utilizing aerobic microorganisms is more biologically efficient because the free oxygen dissolved in the wastewater allows the organisms to rapidly feed on and degrade both the suspended and dissolved organic matter. In a few hours, up to 90 percent of the organic matter is destroyed and a similar amount of suspended solids are removed.

A typical household aerobic treatment unit is depicted in Figure 8–32. It consists of two chambers, one for aeration and one for settling. Raw sewage (or septic tank effluent) enters the first chamber and is quickly mixed with the aerobic microorganisms by the air flow from the blower. The mixing brings the microbes into intimate contact with both the dissolved and undissolved waste matter. The nutrient material is rapidly absorbed by the organisms which utilize it for energy and cell growth, thus converting the majority of the organics in the waste to carbon dioxide, water and settleable sludge solids. In the second chamber, the sludge which contains the microorganisms settles out by gravity and is returned to the aeration chamber to continue the treatment process. The clarified effluent leaves the unit low in organic matter and suspended solids with partially reduced levels of fecal coliform bacteria. The aerobic home treatment units, however, do not remove nitrates from the wastewater.

While these units can produce a higher quality of effluent without odors, they require electrical energy, regular maintenance and servicing.

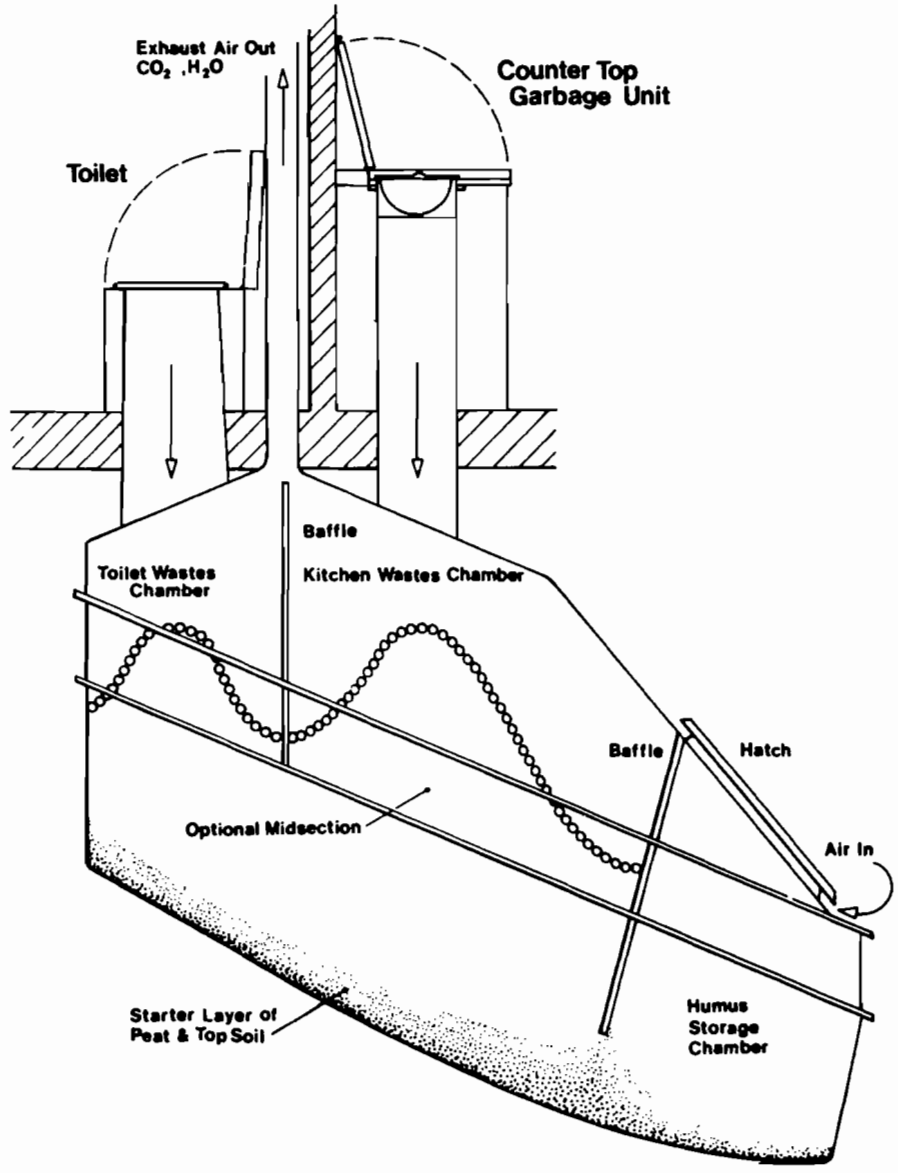


FIGURE 8–31 *Clivus Multrum Toilet.*

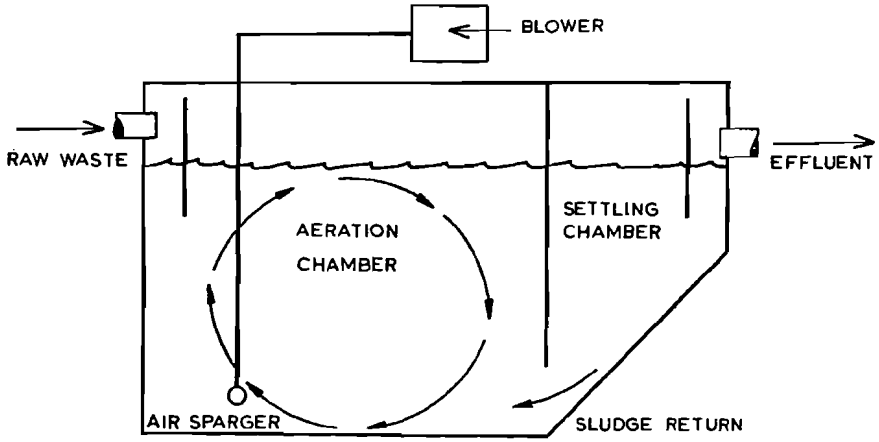


FIGURE 8–32 *Aerobic Biological Treatment System.*

Because they may reduce the amount of solids carried over to the tile field, manufacturers claim a longer life of the tile field in tight soils. However, the treatment process is easily upset thus causing high discharges of solids to the disposal field.

Household aerobic treatment units are considerably more expensive to install and operate than a septic tank/tile field system. They require constant maintenance whereas a septic tank system requires essentially no maintenance. The aerobic system appears to offer advantages in areas of tight, impermeable soils or where other leaching problems may occur.

8.2.15 Meadow/Marsh/Pond (M/M/P) System or Marsh/Pond (M/P) System

A meadow/marsh/pond system is an attempt to utilize aesthetically pleasing, natural systems for wastewater treatment. The approach depends upon long detention times for the slow, but effective, removal of suspended and disssolved pollutants. It utilizes physical removal of pollutants as well as biological reduction.

The process usually begins by screening the sewage to remove bulky objects. It may then pass through a degritter to remove sand and other non-degradable, coarse materials. The solid materials are then comminuted (shredded and chopped) to reduce degradables to fine, small particles. The waste stream then flows to basins where it is aerated and wherein biological decomposition begins.

Following aeration, the blend is normally pumped to a distribution box feeding two lined, sloped meadows. Only one meadow need be in operation at a given time while the other meadow is being dried out for harvesting of the crop. Meadows are alternated — the time intervals being determined by the sewage strength, the application rate, the condition of the crop and the season of the year. Meadowgrasses and crops are planted which assist in the removal of dissolved pollutants materials.

Gravity flow through the sloped meadow terminates in a lined marsh which merges with the meadow. The choice of plantings in the marsh depends on the geographic area and nature of the waste and generally will include harvestable crops which will flourish in the local climate.

In turn, the marsh terminates in a lined stabilization pond stocked with harvestable aquatic species which are indigenous to the area. A constant level is maintained in the marsh and pond by a fixed-invert overflow structure through which the treated waste can be recharged or disposed of in a different manner. Again, the biota of the pond are selected based upon the wastewater to be treated and the geographic area of the County.

Effluent levels of suspended solids, BOD and nutrients have been shown to be within regulatory agnecy standards. With high summer temperatures, bacteria populations may be higher than acceptable and a disinfection step would be necessary.

Since the entire M/M/P system has an underlying, impervious membrane liner there is no loss of contaminants to the groundwater environment. The entire process is thus controled prior to discharge.

The marsh/pond design is the same as the meadow/marsh/pond—without the meadows. The system requires less land and produces about the same quality effluent. It handles shock loadings fairly well but, like the full M/M/P system, has not been tested extensively in non-controlled conditions.

The M/M/P or M/P systems significantly reduce pollutants, including nitrates, if a system of cropping is instituted. Nitrogen in the wastewater is uptaken by the plants and becomes part of the biostructure. Unless that structure is removed, it will eventually die, decompose and release the nutrients back to the aquatic environment. See Figure 8–33.

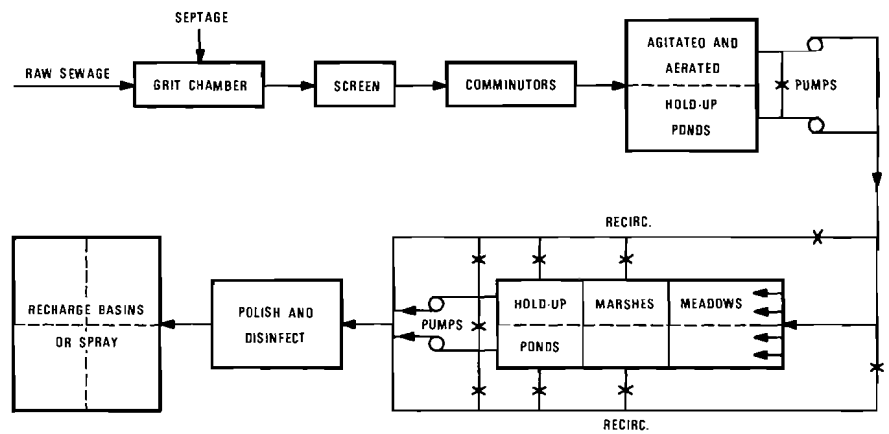


FIGURE 8–33 *Marsh/Pond System.*

8.2.16 Subsurface Denitrification of Septic Tank Effluents

In a granular type of soil, cesspool and septic tank systems, working in conjunction with the soil, are ideal for removal of organics and suspended solids. However, nitrates cannot be effectively removed without substantial modification.

The Suffolk County Department of Health Services is conducting a research project to demonstrate the feasibility of removing nitrogen in modified residential subsurface sewage disposal systems. An experimental disposal system has been constructed, consisting of a septic tank, leaching tile field system and denitrification system (see Figure 8–34). The disposal system is being fed with controled quantities of sewage from an apartment complex. The wastewater first enters a conventional septic tank and tile field. An impermeable membrane deflector is located six feet below the bottom of the tile field and is sloped as to intercept and deflect the waste-waster to a large impermeable pan.

Nitrogen compounds in the wastewater are first nitrified (converted from ammonia to nitrate) in the aerobic layer of native soil immediately below the tile field and above the membrane deflector. Once in the nitrate state, denitrification by certain types of bacteria (denitrifiers) will occur when anaerobic (devoid of oxygen) conditions are achieved in the pan. Methanol must be fed as a food source for the bacteria. This method of denitrification is commonly used in conventional waste treatment plants.

The denitrification process converts the nitrogen which is in the form of nitrate (NO_3) to a gaseous state (N_2). A venting mechanism for releasing the nitrogen gas to the atmosphere is provided.

Investigation is currently underway to eliminate the necessity of feeding methanol, which has drawbacks when applied to individual sanitary disposal systems. The most promising alternate method would be the diversion of part of the septic tank effluent to the anaerobic zone.

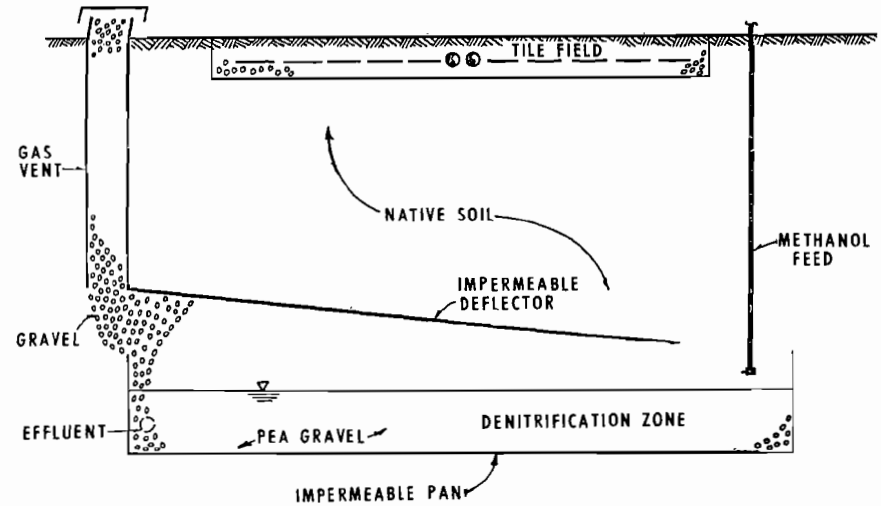


FIGURE 8–34 *Denitrification of Septic Tank Effluents.*

Section 9 Population Projections 1975-1995

9.0 INTRODUCTION

Population Estimates and Projections, 1975–1995 contains estimates of the present (1975) population and of the population at zoned capacity for each of the 108 municipalities, the 126 school districts and the 30 drainage basins in Nassau and Suffolk counties. It also contains the Nassau-Suffolk Regional Planning Board's projection of the population of those same geographic areas for the years 1980, 1985, 1990 and 1995, together with an explanation of the methodology used to develop the projections. There is a brief discussion of the major changes in town and school district population indicated by the projections, and of the relation of the projected totals to the "saturation population"; that is, the population of the projection areas at zoned capacity. This is followed by a consideration of gross residential densities. A brief discussion of the changes in zoned capacity and of the differences between the Nassau-Suffolk 1966 and 1975 projections conclude the body of the text. A comparison of the Nassau-Suffolk projections with those of other agencies is included in the Appendix.

The intended use of the projection influenced the selection of the geographic areas for which projections were developed. The 208 Study requires the production of "baseline" or trend projections in order to determine the magnitude of future needs and to evaluate the effects of various wastewater management alternatives on future population. Since large-scale wastewater management planning generally deals with drainage basins or sizable sub-basins it was necessary to provide the engineers, hydrologists, soil scientists and other technical personnel with population projections for drainage basins. However, a number of considerations—among them the Board's dependence upon readily available data, the potentially limited usefulness of projections for what were often extremely large, irregularly shaped drainage areas and the probable need for a subsequent breakdown of basin totals for sub-basins or other smaller areas for "208" or "201" (facilities planning) purposes, the desire for flexibility without loss of consistency, and the great number of requests for municipal and school district projections for general planning purposes—led the Planning Board to undertake the development of projections for the thirteen towns, the school districts or the portions thereof contained in each town, and the cities and villages or portions thereof in each town and school district. The availability of demographic and housing data and of zoning information for municipalities and school districts proved a most persuasive argument for the selection of these areas. The relative ease with which school districts or portions of school districts could be aggregated to drainage basins was an important consideration. The enhanced usefulness for general planning purposes and the simplicity of periodic revision, as necessary to reflect significant changes, were further reasons for the tabulation of data and the projection of data and the projection of population by municipality and school district.

9.1 CURRENT POPULATION ESTIMATES

The Nassau-Suffolk Regional Planning Board considers the Long Island Lighting Company's population estimates for January 1, 1975 as the most accurate available for the Bi-County area and has adopted them as the base year numbers for its population projections.

The LILCO figures are part of a continuing series of estimates, produced on an annual basis. They are essentially an up-date of the latest decennial census and of special censuses, where available, adjusted to reflect changes in the population as indicated by increases or decreases in the

number of occupied housing units. The changes in the number of housing units are obtained from company records of active meters, new connections and discontinuances of service. The meter count for each area is multiplied by a factor for household size to produce an estimate of the area's population. The household size multipliers are generally derived from the decennial census data and may be somewhat outdated and inaccurate by the latter half of the intercensal period. Nassau-Suffolk suspects that there may be areas in Nassau and in western Suffolk where the LILCO household size factors fail to reflect the full magnitude of recent changes in family size; however, such inaccuracies, if they do exist, are of little significance. The LILCO estimates for January 1,1975 have been used as the base year figures for projection purposes. The relatively small increase in population that has been projected for the period 1975–1980 is expected to compensate for any possible overstatement of the 1975 population.

Table 9–1 indicates the estimated population of the Nassau-Suffolk 208 Planning Region, the two counties, and the fifteen major municipalities as of 1975. Comparable estimates for school districts, villages and drainage basins are shown in Appendix Table A-1.

Table 9–1

ESTIMATED POPULATION OF THE NASSAU-SUFFOLK 208 PLANNING AREA

County and Region	Municipality	Population 1/1/75
	Glen Cove City	26,880
	Hempstead	814,050
	Long Beach City	34,766
	North Hempstead	238,559
	Oyster Bay	341,692
Nassau County		**1,455,947**
	Babylon	217,923
	Brookhaven	317,489
	East Hampton	13,053
	Huntington	213,643
	Islip	312,010
	Riverhead	21,184
	Shelter Island	1,918
	Smithtown	122,498
	Southampton	41,239
	Southold	18,733
Suffolk County		**1,279,690**
Nassau-Suffolk S.M.S.A.		**2,735,637**

9.2 SATURATION POPULATION

The methodology used by Nassau-Suffolk to develop the area-wide and sub-area projections combines the concept of land capacity; that is, holding capacity under existing zoning, with trend analysis on a small area basis. The following paragraphs describe the step by step procedure that was followed.

Step 1. *Identification and tabulation of all vacant land zoned for residential uses, including land in large estates.* Aerial photographs, tax maps and assessment records were used to identify vacant acreage, zoning exempt lots (filed subdivisions) and scattered parcels in built-up areas. Zoning maps were consulted to determine the zoning category of vacant acreage and scattered lots in developed areas. Field reconnaisance was employed when necessary to supplement aerials and office records. The number of acres of vacant land in each zoning category, in each municipality or school district was recorded for use in calculating the total number of potential building sites. The number of zoning exempt lots, if any, was also noted.

Step 2. *Calculation of existing vacant and potential building sites.* The number of already subdivided vacant parcels, including zoning exempt lots was tabulated. (The category "Zoning Exempt Lots," which is found most frequently in the eastern portion of Suffolk County, refers to lots on old filed maps that pre-date most of the local zoning ordinances. In areas characterized by considerable numbers of zoning exempt lots, the present zoning ordinance offers few clues as to the course of future development. For example, in some parts of the East End, the current zoning ordinance requires a minimum plot size of one acre or more; however, many parcels of 1/4 acre or less may constitute legal building sites because they were legal lots when the land was originally subdivided and have remained in single and separate ownership from that date to the present time. Wherever necessary an analysis of the tax map was undertaken in order to determine the magnitude of single and separate ownership and to permit evaluation of its impact on the ultimate utilization of the land. In built-up areas, any vacant parcels that appeared to be larger than necessary to conform to existing zoning were reviewed to determine whether they might yield more than a single building site. The computation of the potential yield of as yet unplatted acreage was accomplished through the application of a yield per acre factor for each zoning category to the total number of acres in that category. The yield per acre factors used are listed in Table 9–2. They represent average values based upon recent Nassau-Suffolk experience with conventionally designed subdivision plats.

The saturation estimate is based on existing zoning, so that if land were to be zoned for a higher or lower density, from or to non-residential use,

Table 9–2

ESTIMATED NUMBER OF DWELLING UNITS BASED ON EXISTING ZONING

Zoning Lot Size	Lots Per Acre	Zoning Lot Size	Lots Per Acre
4,000	6.8	16,000	1.9
5,000	5.4	16,500	1.8
6,000	4.5	18,000	1.7
6,500	4.1	18,500	1.6
7,000	3.8	20,000	1.6
7,500	3.6	20,500	1.5
8,000	3.4	21,780	1.5
8,500	3.3	22,000	1.4
9,000	3.1	25,000	1.3
10,000	2.7	30,000	1.0
11,390	2.6	40,000	0.8
12,000	2.5	43,560	0.7
12,500	2.4	60,000	0.6
13,000	2.3	2 Acres	0.4
14,000	2.1	3 Acres	0.27
14,500	2.0	4 Acres	0.20
15,000	2.0	5 Acres	0.16

or acquired for public purposes such as recreation or farm preservation, the saturation figure would have to be adjusted. Recent observations suggest that the pattern of zoning on Long Island has become relatively stable. Changes to higher density are often offset by other changes to a lower density or by a land acquisition, thus minimizing the impact of any change in the ultimate saturation calculation.

Step 3. *Identification and tabulation of housing units by occupancy status.* The 1970 Census housing counts for all units and for vacant, seasonal and occupied units were listed for each municipality and school district. Building permit data for the years 1970 through 1974 were employed to estimate the increase in the housing stock between 1970 and 1975. Where multi-family units constituted a sizeable percentage of the new housing, the number of single-family and multi-family units were noted separately. Long Island Lighting Company meter records were used in combination with 1970 census and 1970–74 building permit data to estimate the total number of dwellings and the number of occupied units in 1975.

Inasmuch as housing data in general and building permit data in particular are rarely tabulated for areas whose boundaries coincide with or even approximate those of school districts, it was necessary to employ allocation procedures utilizing aerial photographs, office records, and field verification in order to assign both pre-1970 and post 1970 housing to the appropriate school districts.

Step 4. *Calculation of the total number of housing units permitted under existing zoning.* The total number of housing units now in place and the total number of existing and potential building sites, each of which could be used to accomodate an additional unit, were summed to obtain an estimate of the number of potential housing units and households.

The saturation figure reflects the assumption that all existing housing units that are currently not occupied will be utilized and that seasonal and vacant year-round units will continue to exist in the five eastern towns of Suffolk County until after year 2000. Few seasonal and second homes are anticipated elsewhere on the island.

Step 5. *Estimation of household size at saturation.* Census counts of total population in households and occupied housing units were used to calculate the 1970 household size for each municipality and school district. Population and occupied housing unit estimates for 1975 were employed to calculate the significant changes, if any, that had occurred between the two dates. Following a review of the 1970 and 1975 figures and consideration of such relevant factors as the sharp decline in births, the age composition of the community, income, ethnicity, and of the increasing proportions of multi-family dwellings in a few localities, a probable average household size at saturation was selected for each of the projection areas. Appendix Tables A-2 through A-14 indicate the type of background information available for each of the towns and the format used for tabulations.

Increases have been projected for some communities presently characterized by a relatively small household size but having considerable potential for growth. Decreases have been projected for others now characterized by large households, little remaining land and declining school enrollments. Where the potential for apartment or condominium construction is greater than that for single family home construction, family size is expected to decrease. It is also expected to decrease in some Eastern Suffolk areas since these areas tend to attract small, elderly households despite the overwhelming predominance of single family homes.

The Nassau-Suffolk staff has made several assumptions that directly affect the selection of the household size factor for school districts and municipalities. It has been assumed that the overall trend towards smaller households that has been observed for more than a decade in much of Nassau and Suffolk will continue as both the national and local birth rate decline and as more and more young adults and the elderly choose to maintain their own households.

It is expected that an aging population will further reduce the number of births in many communities in Nassau and western Suffolk. As older households leave the area, the high cost of their former dwellings generally

precludes purchase by young families in the primary child-bearing age groups. The head of the household of the new family is likely to be between 35 and 49 years of age with a spouse of similar age and children in the 10 to 19 year age group. Some growth is expected to occur even in the absence of net natural increase. Although the new or in-migrant family may be somewhat smaller than that of the original occupants of the dwelling, it may be larger than the original family minus the grown children that have left to establish their own households. In communities where this type of change is occuring, a period of gradually decreasing household size is followed by a period of increasing household size that results in population gains.

Step 6. *Estimation of population at zoned capacity.* The number of existing and potential housing units, calculated in Step 2 was multiplied by the appropriate household size, selected in Step 5, to obtain the saturation population for each school district and municipality. The final line in Appendix Tables A-2 through A-14 indicates the estimated population at zoned capacity for each of the projection areas.

9.3 POPULATION PROJECTIONS

The twenty year projections are, in the first instance, town-wide projections. Figures for the school districts, cities, and villages were derived from the town projections by means of a step-down apportionment technique that permitted the allocation of anticipated growth to sub-areas. The following paragraphs summarize the procedures followed and describe some of the considerations that influenced the selection of growth rates and the assignment of shares.

As the initial step in the projection process, the growth patterns of the towns and sub-areas for the years 1970–1975 were subjected to detailed scrutiny and analysis. After in-depth study of the annual changes in population as estimated by Long Island Lighting Company, of building permit data, and of school enrollment figures, average annual growth rates were selected for each of the thirteen towns for the 1975–1980, 1980–1985, 1985–1990, and 1990–1995 projection periods.

The 1975–1980 rates were applied to the base year estimates to obtain figures for projected growth for the first five year period. Projected population increments and base year estimates for each town were summed to produce the 1980 projections. The rates for each of the three subsequent five year periods were applied to the projected population at the beginning of each period to obtain figures for anticipated growth and to permit calculation of the total population at the end of the respective five year projection period. Table 9–3 shows the base year estimates and the projected population for the thirteen towns, two cities, the counties and the Nassau-Suffolk Region.

Table 9–3

NASSAU AND SUFFOLK TOWNS AND CITIES
FIVE YEAR POPULATION PROJECTIONS: 1975–1995

	1975	1980	1985	1990	1995
Glen Cove	26,880	27,878	28,339	28,699	28,981
Hempstead T.	814,050	817,353	819,568	821,390	823,268
Long Beach	34,766	35,716	36,491	37,241	37,941
North Hempstead T.	238,559	240,706	242,994	245,424	246,650
Oyster Bay T.	341,692	346,136	348,302	349,067	349,725
Nassau County	**1,455,947**	**1,467,789**	**1,475,694**	**1,481,821**	**1,486,565**
Babylon T.	217,923	230,175	239,530	243,144	244,362
Brookhaven T.	317,489	378,654	438,904	494,346	546,198
East Hampton T.	13,053	15,549	18,992	22,066	25,637
Huntington T.	213,643	225,546	234,761	241,089	244,759
Islip T.	312,010	339,044	367,156	388,290	399,895
Riverhead T.	21,184	23,412	26,529	30,363	34,752
Shelter Island T.	1,918	2,228	2,790	3,324	3,960
Smithtown T.	122,498	128,913	134,810	141,534	147,381
Southampton T.	41,239	47,200	54,837	64,352	75,518
Southold T.	18,733	21,016	23,814	26,716	29,972
Suffolk County	**1,279,690**	**1,411,737**	**1,542,123**	**1,655,224**	**1,752,434**
Nassau-Suffolk S.M.S.A.	**2,735,637**	**2,879,536**	**3,017,817**	**3,137,045**	**3,238,999**

The apportionment of town growth to sub-areas was accomplished by the assignment of a share or percentage of the total growth to each school district or municipality or portion thereof located within the town. The prediction of long term change in small areas is difficult at best, and it was frequently necessary to develop not only a preliminary set but one or more revised sets of percentages before achieving an acceptable formula for the distribution of town growth. The shares, which varied considerably by area and projection period, were determined on the basis of staff assessment of relevant factors. The factors considered included, among others, the general development trends; the growth of the sub-area as compared with other sub-areas and the town as a whole; the availability of land; the desirability of sub-area, including accessibility; the type and cost of housing; and the presence or absence of impediments to development.

In some areas that are presently experiencing or are expected to experience population losses, the shares are characterized by negative values. The school districts or municipalities with negative shares were generally those in the older developed portions of the Region where the present population is close to or even exceeds the projected saturation population or where the losses resulting from a sharp decrease in household size are expected to more than offset the gains resulting from new development.

A comparison of the population estimates for 1975 and the figures for

the saturation population at zoned capacity indicates that many school districts and municipalities in Nassau County have already reached or exceeded the saturation figures. Several facts can be cited to explain this apparent contradiction. In most sub-areas the projected household size is smaller than the present household size and therefore the same, or possibly, even a slightly greater number of households can be expected to produce a smaller population at saturation than in 1975. In a few areas there are significant numbers of existing and potential illegal two or more family dwellings in single-family zones; however, in the absence of precise information as to their present number and as to local enforcement intentions, these had to be excluded from the saturation calculations. In every area having a sizeable institutional population, that population, or the population that could be accomodated at the one or more institutional facilities located in the school district or municipality was also excluded from the saturation calculation. The institutional population residing in such places as the state psychiatric centers, the Northport Veterans Hospital, and several universities was projected separately and then added to the household population to produce a combined total for both household and institutional population.

Appendix Tables A-15 through A-26 present the base year population, the five year change in the number of persons, and the total projected population for school districts and municipalities for the years 1980, 1985, 1990 and 1995.

Appendix Table A-27 summarizes the same data for the 21 school districts and 7 villages that include land in more than one town. Projections for drainage basins may be found in Appendix Table A-28. Appendix Tables A-30 through A-42 list the saturation population at zoned capacity and indicate the percent of saturation represented by the projected population for the school districts, the municipalities, and the districts and municipalities with land in more than one town.

A review of the school district and municipality projections reveals that in many of the areas already at or above saturation the population is expected to decrease somewhat but to remain above or near saturation throughout the twenty year period. It is anticipated that by 1995 the population of many other areas, particularly those in eastern Nassau and western Suffolk, will be at or near saturation. It appears unlikely that saturation at zoned capacity will be reached in most parts of central and eastern Suffolk until some time after the year 2000.

The reader should be aware that it is often even more difficult to project the precise timing of growth than it is to project its magnitude; and that consequently, the projection dates should be regarded as nothing more than the best possible approximations, given present uncertainties. For example, areas where lots in existing built-up neighborhoods or on mapped rapid change as large scale, well-financed developers proceed to convert estates, nurseries, clubs and preserves, and farmland to new communities.

Recent efforts to preserve farmland, shorefronts, wetlands and other areas of great environmental or recreational value have been taken into account in the projections and it has been assumed that should these efforts succeed, the growth rate in the affected areas will be slower than might otherwise be anticipated. It has also been assumed that as the population of a school district or municipality approaches saturation, the rate of growth will decline since the most desirable, moderately priced, easy to develop land will already have been utilized. The land that remains is frequently characterized by physical or legal impediments that deter its use for housing or, in other instances, is the subject of belated community efforts to preserve the last remaining local open space.

9.3.1 Projected Twenty Year Changes in Town and School District Populations.

According to the current series of projections, 93.1% of the Region's twenty year growth of approximately one half million persons will occur in streets constitute a large proportion of the vacant land can be expected to experience relatively slow, steady growth through most or all of the projection period; however, areas where large tracts of presently unsubdivided land constitute most of the vacant acreage can be expected to experience sudden, Suffolk County. Two towns, Brookhaven and Islip, each with a present population in excess of 300,000 persons, are expected to accommodate more than five-eighths of the additional residents. Table 9—4 indicates the number of persons and the share of the total Bi-County growth projected for the two counties and each of the fifteen major municipalities.

As might be expected, the population projections generally indicate little change in the number of residents in the Nassau County school districts; moderate change in the western Suffolk school districts; great change in the central Suffolk school districts; and little to moderate change, in the eastern Suffolk school districts.

Only four districts totally within Nassau County—Long Beach, Hempstead, Glen Cove, and Oyster Bay-East Norwich—and two Suffolk districts that include portions of Nassau—Cold Spring Harbor and Amityville—are projected to gain more than 2000 persons during the twenty year period. Another seven are projected to gain from 1000 to 2000 persons, while the remainder are projected to add fewer than 1000 persons or to lose population.

In contrast, four districts in Suffolk County—Connetquot in the Town of Islip, Sachem in the towns of Islip, Brookhaven and Smithtown, and Middle Island and William Floyd in the Town of Brookhaven—are expected to

add more than 20,000 new residents. Seven other districts—Smithtown in western Suffolk; Middle Country, Patchogue, Miller Place, Rocky Point and Shoreham-Wading River in central Suffolk; and Riverhead in eastern Suffolk—are expected to add between 10,000 and 20,000 new residents. Twenty districts are expected to add from 5000 to 10,000 persons. Three of these districts are in the Town of Huntington; two, in the Town of Babylon. One is in the Town of Smithtown; eight are in the Town of Islip; four, in the Town of Brookhaven; and two, in the Town of Southampton. Twenty-four districts, nine of them in the towns of Huntington and Babylon, are expected to add between 2000 and 5000 persons while the remaining sixteen districts—all but one of them located in eastern Suffolk—are expected to add fewer than 2000 persons.

Table 9—4

THE COUNTIES AND MAJOR MUNICIPALITIES:
AMOUNT AND DISTRIBUTION OF PROJECTED TWENTY YEAR GROWTH

	Projected Growth 1975—1995 (No. of Persons)	Share of Regional Growth (%)
Glen Cove	2,101	0.4
Hempstead T.	9,218	1.8
Long Beach	3,175	0.6
North Hempstead T.	8,091	1.6
Oyster Bay T.	8,033	1.6
Nassau County	**30,618**	**6.1**
Babylon T.	26,439	5.3
Brookhaven T.	228,709	45.4
East Hampton T.	12,584	2.5
Huntington T.	31,116	6.2
Islip T.	87,885	17.5
Riverhead T.	13,568	2.7
Shelter Island T.	2,042	0.4
Smithtown T.	24,883	4.9
Southampton T.	34,279	6.8
Southold T.	11,239	2.2
Suffolk County	**472,744**	**93.9**
Nassau-Suffolk S.M.S.A.	**503,362**	**100.0**

9.3.2 Gross Residential Density

Gross residential density; that is, the average number of persons per acre provides a crude indicator of probable need for the design and construction of local or area-wide wastewater collection and treatment facilities. Appendix Table A-30, which was originally prepared at the request of the 208 Study's consulting engineers, indicates gross densities for each of the thirteen towns and 126 school districts. Portions of school districts comprising land in more than one town are listed under their respective towns. Gross residential densities for the total area of the split districts can be obtained by dividing the sum of the population of the component sections by the sum of the acreage of those sections.

Table 9—5

SUMMARY OF EXISTING AND PROJECTED GROSS RESIDENTIAL DENSITIES IN PERSONS PER ACRE FOR NASSAU AND SUFFOLK TOWNS AND SCHOOL DISTRICTS, 1975 and 1995

Town	Town Average		School Districts Maximum		School Districts Minimum	
	1975	1995	1975	1995	1975	1995
Hempstead	11.82	11.99	21.04	21.11	7.37	7.39
N. Hempstead	6.99	7.17	20.07	20.10	0.42	0.83
Oyster Bay	5.26	5.40	13.33	13.17	0.85	0.90
Babylon	6.82	7.64	13.47	15.30	1.13	1.43
Brookhaven	1.92	3.27	5.29	6.73	0.05	0.19
East Hampton	0.29	0.56	1.56	2.11	0.08	0.18
Huntington	3.56	4.08	5.96	6.84	0.88	1.29
Islip	4.72	6.05	8.35	8.85	0.08	0.11
Riverhead	0.49	0.80	0.51	1.23	0.30	0.76
Shelter Island	0.26	0.54	0.26	0.54	0.26	0.54
Smithtown	3.57	4.29	5.98	8.20	0.59	1.30
Southampton	0.46	0.84	1.72	2.90	0.21	0.36
Southold	0.55	0.88	0.72	1.39	0.15	0.23

It is important to note the potentially critical limitations of a measure such as gross residential density. Its usefulness varies directly with the homogenity of development patterns and inversely with the proportion of the total acreage in non-residential uses in any particular area. As an average, it tends to mask extreme values and therefore fails to signal the presence of small sectors where existing or anticipated densities may be sufficient to warrant the provision of services not justified for the area as a whole. The presence of relatively large parcels devoted to industry, parks, airports or other public facilities often distorts the gross residential density calculation, making the area as a whole appear far less intensively utilized than is actually the case. In addition, for areas subject to seasonal variations in population, the figure for gross density, which is based on the number of year-round-residents, will be unduly low; for areas characterized by large numbers of persons in hospitals or other group quarters, it will probably be somewhat high.

9.3.3 Changes in Projected Population at Zoned Capacity

Table 9—6 facilitates comparison of the most recent figures for population at zoned capacity, or saturation population, and those figures that were

Table 9–6

NASSAU-SUFFOLK SATURATION PROJECTIONS

	Saturation Population		Changes in
Nassau County	**Current Series**	**1966 Series**	**Number of Persons**
Glen Cove City	31,140	29,900	1,240
Hempstead Town	834,272	816,123	18,149
Long Beach City	41,707	43,137	– 1,430
North Hempstead Town	261,896	249,167	12,729
Oyster Bay Town	353,015	365,912	– 12,897
County Total	**1,522,030**	**1,504,239**	**17,791**
Suffolk County			
Babylon Town	246,194	276,920	– 30,726
Brookhaven Town	820,709	887,380	– 66,671
East Hampton Town	92,366	164,640	– 72,274
Huntington Town	251,192	308,140	– 56,948
Islip Town	410,633	375,790	34,843
Riverhead Town	207,203	313,870	– 106,667
Shelter Island Town	16,983	18,370	– 1,387
Smithtown Town	153,529	169,500	– 15,971
Southampton Town	202,510	264,050	– 61,540
Southold Town	72,921	245,080	– 172,159
County Total	**2,474,240**	**3,023,740**	**– 549,500**
Nassau-Suffolk S.M.S.A.	**3,996,270**	**4,527,979**	**– 531,709**

developed a decade ago as part of the resource information for the Nassau-Suffolk Comprehensive Plan.

The new saturation population statistics for Nassau County show a potential increase of just under 15,000 persons, while those for Suffolk County show a decrease of over one half million. The small increase in Nassau is a result of a more accurate determination of available lots, rezonings to increase density, additional conversions to two family use and redevelopment of underutilized land. The reduction in the City of Long Beach is attributable to a density limit on major apartment buildings.

The significant decrease in Suffolk County has occurred largely as a result of municipal action by the eastern towns to implement plan recommendations calling for reductions in overall density in order to limit the demand for costly services, while maintaining the basically recreational-agricultural environment. The Town of Southold figures are a good example and show the result of a rezoning from lot sizes generally of 1/4 acre to lot sizes of one acre or more in most of the undeveloped parts of the Town. In contrast, the statistics for the Town of Islip reflect the acceptance and construction of higher density housing throughout the Town since the date of the earlier survey.

Table 9–7

NASSAU-SUFFOLK POPULATION PROJECTIONS FOR THE YEAR 1985

	1985 Population		
	Current Series	**1966 Series**	**Difference**
Glen Cove City	28,339	31,000	– 2,661
Hempstead Town	819,568	885,000	– 65,432
Long Beach City	36,491	37,000	– 509
North Hempstead Town	242,994	260,000	– 17,006
Oyster Bay Town	348,302	356,000	– 7,698
Nassau County	**1,475,694**	**1,569,000**	**– 93,306**
Babylon	239,530	267,000	– 27,470
Brookhaven Town	438,904	515,000	– 76,096
East Hampton Town	18,992	22,000	– 3,008
Huntington Town	234,761	260,000	– 25,239
Islip Town	367,156	374,000	– 6,844
Riverhead Town	26,529	44,000	– 17,471
Shelter Island Town	2,790	2,600	190
Smithtown Town	134,810	165,000	– 30,190
Southampton Town	54,837	67,000	– 12,163
Southold Town	23,814	28,000	– 4,186
Suffolk County	**1,542,123**	**1,744,600**	**– 202,477**
Nassau-Suffolk S.M.S.A.	**3,017,817**	**3,313,600**	**– 295,783**

9.3.4 Comparison of Present and Earlier Series of Small Area Projections

The latest population projections reflect a slower growth rate than that anticipated in the projections developed in the previous decade. Table 9–7 lists the 1985 projections of both series and indicates the magnitude of the difference between them. It should be noted that 1985 represents the mid-point of the current projection period, only ten years removed from the present; whereas it represented the final date, some twenty years from the present when the earlier series was developed a decade ago.

The Bi-County area is expected to have just over three million people in 1985 or 300,000 fewer people than were projected earlier. The new projections are approximately 200,000 lower in Suffolk and 100,000 lower in Nassau County. The 1985 Suffolk County projected totals, contained in the earlier report, may very well be reached in the period between 1995 and 2000, while the earlier 1985 Nassau projected totals should not be reached in the foreseeable future. The high cost of new housing, which prices younger or poorer families out of the housing market, and an overall slowdown in the economy appear to be the major reasons for the slowed growth in Suffolk, where land is still available for extensive housing developments. The Nassau decrease is related to the same factors; however, less land is available and new housing on this land is very costly. The reduction in projected family size and revised plans drastically limiting housing at Mitchel Field also help to explain the markedly slower growth now projected for Nassau County.

Appendix A

A-1 Population of School Districts, Villages, and Drainage Basins, 1975

	Population 1/1/75
TOWN OF HEMPSTEAD	
School Districts	
Hempstead 1	32,382
Uniondale 2	35,388
East Meadow 3	59,832
North Bellmore 4	29,645
Levittown 5	59,456
Seaford 6	19,165
Bellmore 7	15,216
Roosevelt 8	16,331
Freeport 9	37,536
Baldwin 10	35,318
Oceanside 11	41,786
Malverne 12	16,470
Valley Stream 13	30,283
Woodmere-Hewlett 14	24,183
Lawrence-Cedarhurst 15	35,530
Elmont 16	45,115
Franklin Square 17	28,724
Garden City 18	25,836
East Rockaway 19	12,121
Lynbrook 20	20,716
Rockville Centre 21	24,682
Floral Park 22 (pt)	20,285
Wantagh 23	20,887
Valley Stream 24	15,065
Merrick 25	21,836
Island Trees 26	19,189
West Hempstead 27	18,520
Long Beach 28	40,938
North Merrick 29	15,850
Valley Stream 30	18,414
Island Park 31	9,514
Westbury 1 (pt)	5
New Hyde Park 5 (pt)	2,598
Town of Hempstead & City of Long Beach Total	**848,816**
Municipalities	
Atlantic Beach Village	1,675
Bellerose Village	1,128
Cedarhurst Village	6,900
East Rockaway Village	11,906
Floral Park Village (pt)	16,685
Freeport Village	40,589
Garden City Village	25,401
Hempstead Village	40,881
Hewlett Bay Park Village	607
Hewlett Harbor Village	1,522
Hewlett Neck Village	541
Island Park Village	5,501
Lawrence Village	6,888
Lynbrook Village	23,470
Malverne Village	10,151
Mineola Village (pt)	101
New Hyde Park Village (pt)	4,333
Rockville Centre Village	28,396
South Floral Park Village	1,081
Stewart Manor Village	2,210
Valley Stream Village	40,929
Woodsburgh Village	829
Unincorporated Area	**542,326**
Town Total	**814,050**
City of Long Beach	**34,766**
TOWN OF NORTH HEMPSTEAD	
School Districts	
Westbury 1 (pt)	20,593
East Williston 2	9,478
Roslyn 3 (pt)	19,198
Port Washington 4	32,843
New Hyde Park 5 (pt)	22,445
Manhasset 6	15,989
Great Neck 7	48,763
Herricks 9	24,893
Mineola 10	28,205
Carle Place 11	12,250
North Shore 1 (pt)	685
Jericho 15 (pt)	187
Floral Park 22 (pt)	3,030
Town Total	**238,559**
Municipalities	
Baxter Estates Village	1,047
East Hills Village (pt)	8,717
East Williston Village	2,846
Floral Park Village (pt)	1,968
Flower Hill Village	4,528
Great Neck Village	11,207
Great Neck Estates Village	3,182
Great Neck Plaza Village	6,078
Kensington Village	1,597
Kings Point Village	5,747
Lake Success Village	3,260
Manorhaven Village	5,789
Mineola Village (pt)	22,288
Munsey Park Village	2,995
New Hyde Park Village (pt)	5,965
North Hills Village	263
Old Westbury Village (pt)	2,260
Plandome Village	1,607
Plandome Heights Village	1,050
Plandome Manor Village	830
Port Washington N. Village	3,084
Roslyn Village	2,549
Roslyn Estates Village	1,445
Roslyn Harbor Village	868
Russell Gardens Village	1,136
Saddle Rock Village	895
Sands Point Village	3,000
Thomaston Village	2,761
Westbury Village	15,805
Williston Park Village	9,252
Unincorporated Area	**104,540**
Town Total	**238,559**
TOWN OF OYSTER BAY	
School Districts	
NorthShore 1 (pt)	16,386
Syosset-Woodbury 2	34,057
Locust Valley-Bayville 3	15,970
Plainview-Old Bethpage 4	36,494
Glen Cove 5	26,880
Oyster Bay-East Norwich 6	14,590
Nassau County Sanitorium 7	0
Jericho 15 (pt)	15,468
Hicksville 17	47,713
Plainedge 18	24,469
Bethpage 21	22,342
Farmingdale 22 (pt)	45,402
Massapequa 23	61,011
Cold Spring Harbor 2 (pt)	1,508
Roslyn 3 (pt)	125
Amityville 6 (pt)	6,157
Town and City Total	**368,572**

A-1 Population of School Districts, Villages, and Drainage Basins, 1975 (cont'd)

	Population 1/1/75
Municipalities	
Bayville Village	6,706
Brookville Village	3,096
Centre Island Village	374
Cove Neck Village	348
East Hills Village (pt)	19
Farmingdale Village	9,442
Lattingtown Village	1,814
Laurel Hollow Village	1,459
Massapequa Park Village	22,468
Matinecock Village	867
Mill Neck Village	1,008
Muttontown Village	2,491
Old Brookville Village	1,878
Old Westbury Village (pt)	501
Oyster Bay Cove Village	1,590
Roslyn Harbor Village (pt)	384
Sea Cliff Village	6,087
Upper Brookville Village	1,216
Unincorporated Area	**279,944**
Town Total	**341,692**
City of Glen Cove	**26,880**

	Population 1/1/75
TOWN OF BABYLON	
School Districts	
Babylon 1	11,602
West Babylon 2	27,629
North Babylon 3	33,421
Lindenhurst 4	46,742
Copiague 5	26,220
Amityville 6 (pt)	18,527
Deer Park 7	27,385
Wyandanch 9	14,340
Half Hollow Hills 5 (pt)	8,970
Farmingdale 22 (pt)	3,087
Town Total	**217,923**
Municipalities	
Amityville Village	10,722
Babylon Village	13,563
Lindenhurst Village	30,082
Unincorporated Area	**163,556**
Town Total	**217,923**

	Population 1/1/75
TOWN OF BROOKHAVEN	
School Districts	
Three Village 1 (pt)	39,481
Comsewogue 3	19,183
South Country 4	16,343
Sachem 5 (pt)	42,569
Port Jefferson 6	6,387
Mt. Sinai 7	4,803
Miller Place 8	8,947
Rocky Point 9	10,345
Middle Country 11	52,912
Middle Island 12	29,878
South Manor 21	2,054
Patchogue-Medford 24	41,746
South Haven 30	569
West Manor 31	188
William Floyd 32	26,629
Center Moriches 33	4,805
East Moriches 34	3,059
Shoreham-Wading River 1 (pt)	4,511
Riverhead 2 (pt)	933
Bayport-Bluepoint 5 (pt)	4,351
Eastport-East Manor 11 (pt)	841
Fire Island 14 (pt)	143
Town Total	**320,677**
Municipalities	
Belle Terre Village	794
Bellport Village	2,856
Lake Grove Village	9,359
Old Field Village	824
Patchogue Village	11,283
Poquott Village	516
Port Jefferson Village	5,800
Shoreham Village	556
Unincorporated Area	**288,689**
Town Total	**320,677**
TOWN OF EAST HAMPTON	
School Districts	
East Hampton 1	5,576
Wainscott 2	376
Amagansett 3	1,360
Springs 4	2,731
Sag Harbor 5 (pt)	890
Montauk 6	2,120
Town Total	**13,053**

	Population 1/1/75
Municipalities	
East Hampton Village	1,955
Sag Harbor Village (pt)	890
Unincorporated Area	**10,208**
Town Total	**13,053**
TOWN OF HUNTINGTON	
School Districts	
Elwood 1	14,044
Cold Spring Harbor 2 (pt)	7,131
Huntington 3	36,701
Northport 4	40,700
Half Hollow Hills 5 (pt)	33,917
Harborfields 6	21,912
Commack 10 (pt)	20,607
South Huntington 13	38,631
Town Total	**213,643**
Municipalities	
Asharoken Village	613
Huntington Bay Village	1,866
Lloyd Harbor Village	3,605
Northport Village	8,031
Unincorporated Area	**199,528**
Town Total	**213,643**
TOWN OF ISLIP	
School Districts	
Bay Shore 1	31,953
Islip 2	16,617
East Islip 3	26,743
Sayville 4	19,341
Bayport-Bluepoint 5 (pt)	8,360
Hauppauge 6 (pt)	8,953
Connetquot 7	39,474
West Islip 9	33,061
Brentwood 12	77,086
Central Islip 13	33,138
Fire Island 14 (pt)	158
Sachem 5 (pt)	17,126
Town Total	**312,010**
Municipalities	
Brightwaters Village	3,881
Ocean Beach Village	93
Saltaire Village	35
Unincorporated Area	**308,001**
Town Total	**312,010**

A-1 Population of School Districts, Villages, and Drainage Basins, 1975 (cont'd)

	Population 1/1/75
TOWN OF RIVERHEAD	
School Districts	
Shoreham-Wading River 1 (pt)	1,818
Riverhead 2 (pt)	19,145
Laurel 11 (pt)	221
Town Total	**21,184**
Municipalities	
Unincorporated Area	**21,184**
Town Total	**21,184**
TOWN OF SHELTER ISLAND	
School District	
Shelter Island 1	1,918
Municipalities	
Dering Harbor Village	24
Unincorporated Area	**1,894**
Town Total	**1,918**
TOWN OF SMITHTOWN	
School Districts	
Smithtown 1	51,886
Kings Park 5	25,941
Three Village 1 (pt)	276
Sachem 5 (pt)	3,169
Hauppauge 6 (pt)	14,016
Commack 10 (pt)	27,210
Town Total	**122,498**
Municipalities	
Head of the Harbor Village	1,046
Nissequogue Village	1,412
Village of the Branch Village	1,679
Unincorporated Area	**118,361**
Town Total	**122,498**
TOWN OF SOUTHAMPTON	
School Districts	
Remsenburg 1	1,516
Westhampton 2	4,823
Quogue 3	1,047
Hampton Bays 5	7,219
Southampton 6	9,252
Bridgehampton 9	1,749
Sagaponack 10	678
Eastport-East Manor 11 (pt)	1,257
Tuckahoe 13	1,504
East Quogue 17	2,535
Riverhead 1 (pt)	5,304
Sag Harbor 5 (pt)	4,355
Town Total	**41,239**

	Population 1/1/75
Municipalities	
North Haven Village	798
Quogue Village	959
Sag Harbor Village (pt)	1,748
Southampton Village	5,101
Westhampton Beach Village	;2,142
Unincorporated Area	**30,491**
Town Total	**41,239**
TOWN OF SOUTHOLD	
School Districts	
Oyster Ponds 2	1,618
Fishers Island 4	395
Southold 5	5,002
Mattituck-Cutchogue 9	5,954
Greenport 10	4,289
Laurel 11 (pt)	898
New Suffolk 15	577
Town Total	**18,733**
Municipalities	
Greenport Village	2,518
Unincorporated Area	**16,215**
Town Total	**18,733**
SCHOOL DISTRICTS IN 2 OR MORE TOWNS	
Nassau County	
Farmingdale 22	48,489
Floral Park 22	23,315
Jericho 15	15,655
New Hyde Park 5	25,043
North Shore 1	17,071
Roslyn 3	19,323
Westbury 1	20,598
Suffolk County	
Amityville 6	24,684
Bayport-Bluepoint 5	12,711
Cold Spring Harbor 2	8,639
Commack 10	47,817
Eastport-East Manor 11	2,098
Fire Island 14	301
Half Hollow Hills 5	42,887
Hauppauge 6	22,969
Laurel 11	1,119
Riverhead 2	25,382
Sachem 5	62,864
Sag Harbor 5	5,245
Shoreham-Wading River 1	6,329
Three Village 1	39,757

	Population 1/1/75
MUNICIPALITIES IN 2 OR MORE TOWNS	
Nassau County	
East Hills Village	8,736
Floral Park Village	18,653
Mineola Village	22,389
New Hyde Park Village	10,298
Old Westbury Village	2,761
Roslyn Harbor Village	1,252
Suffolk County	
Sag Harbor Village	2,638
Drainage Basins	
Nassau 1	690,299
2	585,930
3	58,712
4	50,671
5	41,078
6	29,258
Suffolk 1	443,299
2	315,787
3A	145,672
3B	31,509
4	40,549
5	24,867
6	25,609
7	99,812
8	27,742
9	16,149
10	11,318
11A	957
11B	30,403
12A	505
12B	7,607
12C	9,240
13A	2,203
13B	15,956
14	1,918
15A	12,338
15B	16,927
16A	1,590
16B	530
17	395
Total	**2,738,830**

A-2 Town of Hempstead & City of Long Beach—Information for Land Capacity Analysis—School Districts & Municipalities.

SCHOOL DISTRICTS

	Hempstead 1	Uniondale 2	East Meadow 3	North Bellmore 4	Levittown 5	Seaford 6	Bellmore 7	Roosevelt 8	Freeport 9	Baldwin 10	Oceanside 11
1970 Data											
Population	31,272	34,796	59,454	28,906	59,286	18,702	14,634	16,296	37,345	34,877	40,953
Household Size	3.03	3.62*	3.90**	3.74	4.04	3.88	3.78	3.84	3.18	3.55	3.52
Occupied Units	10,333	8,942	15,046	7,726	14,682	4,821	3,876	4,242	11,739	9,829	11,623
Vac. Year Round Units	244	120	91	36	62	48	37	89	241	75	100
Seasonal Units	2	1	1	1	2	42	19	2	12	14	3
1975 Estimates											
Jan. 1,1975 Population	32,382	35,393	59,832	29,645	59,456	19,165	15,216	16,331	37,536	35,318	41,786
Vac. Land Lot Yield	211	123	129	112	11	253	95	118	252	163	159
Units from Vacant Land Zoned for Apts.	0	0	0	5	0	0	35	0	97	0	0
Estate Land Lot Yield	0	0	0	0	0	0	0	0	0	0	0
Total Available Units & Lots	211	123	129	117	11	253	130	118	349	163	159
Vac. Year Round Units	244	120	91	36	62	48	37	89	241	75	100
Seasonal Units	2	1	1	1	2	42	19	2	12	14	3
Occupied Units	11,456	9,141	15,181	7,987	14,742	4,985	4,082	4,262	12,036	9,990	11,865
Total Existing Units	11,702	9,262	15,273	8,024	14,806	5,075	4,138	4,353	12,289	10,079	11,968
Total Existing & Potential Units	11,913	9,385	15,402	8,141	14,817	5,328	4,268	4,471	12,638	10,242	12,127
Projected Average Household Size	3.01	3.50*	3.65**	3.60	3.90	3.80	3.70	3.88	3.32	3.41	3.34
Saturation Population	35,821	35,245	56,987	29,308	57,786	20,246	15,792	17,346	41,956	34,913	40,523

	Malverne 12	Valley Stream 13	Woodmere-Hewlett 14	Lawrence Cedarhurst 15	Elmont 16	Franklin Square 17	Garden City 18	East Rockaway 19	Lynbrook 20	Rockville Centre 21	Floral Park 22 (pt)
1970 Data											
Population	16,366	29,876	23,711	35,178	44,429	28,059	25,725	12,231	20,242	23,996	19,753
Household Size	3.53	3.47	3.43	3.37	3.51	3.46	3.33***	3.21	3.13	3.31	3.26
Occupied Units	4,635	8,612	6,917	10,445	12,659	8,099	7,481	3,805	6,471	7,240	6,060
Vac. Year Round Units	55	45	96	220	79	53	65	62	132	76	54
Seasonal Units	2	1	3	518	4	2	2	28	0	5	0
1975 Estimates											
Jan. 1,1975 Population	16,470	30,283	24,183	35,530	45,115	28,724	25,836	12,121	20,716	24,682	20,285
Vac. Land Lot Yield	67	76	235	592	81	28	49	42	59	99	31
Units from Vacant Land Zoned for Apts.	0	0	8	0	0	0	29	0	0	0	0
Estate Land Lot Yield	0	0	0	0	0	0	0	0	0	0	0
Total Available Units & Lots	67	76	243	592	81	28	78	42	59	99	31
Vac. Year Round Units	55	45	96	220	79	53	65	62	132	76	54
Seasonal Units	2	1	3	518	4	2	2	28	0	5	0
Occupied Units	4,674	8,737	7,071	10,616	12,890	8,333	7,520	3,819	6,704	7,477	6,195
Total Existing Units	4,731	8,783	7,170	11,354	12,973	8,388	7,587	3,909	6,836	7,558	6,249
Total Existing & Potential Units	4,798	8,859	7,413	11,946	13,054	8,416	7,665	3,951	6,895	7,657	6,280
Projected Average Household Size	3.57	3.48	3.42	3.39	3.51	3.50	3.27***	3.27	3.25	3.32	3.38
Saturation Population	17,139	30,801	25,387	40,471	45,878	29,456	26,061	12,913	22,402	25,448	21,202

*Excludes Hofstra University & A. Holly Patterson Home
**Excludes Nassau County Jail & Medical Center
***Excludes Adelphi University
****Excludes all of the above

A-2 Town of Hempstead & City of Long Beach—Information for Land Capacity Analysis—School Districts & Municipalities. (cont'd.)

SCHOOL DISTRICTS

	Wantagh 23	Valley Stream 24	Merrick 25	Island Trees 26	West Hempstead 27	Long Beach 28	North Merrick 29	Valley Stream 30	Island Park 31	Westbury 1 (pt)	New Hyde Park 5 (pt)	Town & City Total
1970 Data												
Population	20,513	14,953	21,561	19,144	18,015	38,864	15,672	18,198	9,130	4	2,578	834,719
Household Size	3.79	3.34	3.81	4.16	3.49	2.79	3.75	3.43	3.53	4.0	3.50	3.50****
Occupied Units	5,417	4,473	5,653	4,600	5,157	13,941	4,179	5,299	2,586	1	737	237,326
Vac. Year Round Units	46	43	69	22	43	1,557	25	47	84	0	6	4,022
Seasonal Units	2	0	0	1	1	1,800	1	0	25	0	0	2,494
1975 Estimates												
Jan. 1, 1975 Population	20,887	15,065	21,836	19,189	18,520	40,938	15,850	18,414	9,514	0	2,598	848,816
Vac. Land Lot Yield	29	14	168	3	23	1,005	78	33	143	0	7	4,488
Units from Vacant Land Zoned for Apts.	20	0	4	0	0	408	0	0	0	0	0	606
Estate Land Lot Yield	0	0	0	0	0	0	0	0	0	0	0	0
Total Available Units & Lots	49	14	172	3	23	1,413	78	33	143	0	7	5,094
Vac. Year Round Units	46	43	69	22	43	1,016	25	47	84	0	6	3,481
Seasonal Units	2	0	0	1	1	1,150	1	0	25	0	0	1,844
Occupied Units	5,550	4,663	5,751	4,616	5,336	15,210	4,243	5,359	2,687	0	744	243,922
Total Existing Units	5,598	4,706	5,820	4,639	5,380	17,376	4,269	5,406	2,796	0	750	249,247
Total Existing & Potential Units	5,647	4,720	5,992	4,642	5,403	18,789	4,347	5,439	2,939	0	757	254,341
Projected Average Household Size	3.60	3.30	3.60	4.00	3.50	2.75	3.60	3.26	3.56	0	3.3	3.43****
Saturation Population	20,329	15,587	21,571	18,568	18,911	51,600	15,649	17,718	10,467	0	2,498	875,979

MUNICIPALITIES

	Atlantic Beach Village	Bellerose Village	Cedarhurst Village	East Rockaway Village	Floral Park Village (pt)	Freeport Village	Garden City Village	Hempstead Village	Hewlett Bay Park Village	Hewlett Harbor Village	Hewlett Neck Village
1970 Data											
Population	1,640	1,136	6,941	11,795	16,527	40,374	25,373	39,411	586	1,512	529
Household Size	3.27	2.28	3.04	3.72	3.25	3.21	3.33***	3.06	3.45	3.67	3.65
Occupied Units	502	498	2,280	3,170	5,086	12,562	7,385	12,871	170	412	145
Vac. Year Round Units	22	1	39	52	49	248	66	288	1	12	2
Seasonal Units	432	0	2	0	0	12	2	3	1	1	0
1975 Estimates											
Jan. 1, 1975 Population	1,675	1,128	6,900	11,906	16,685	40,589	25,401	40,881	607	1,522	541
Vac. Land Lot Yield	49	2	22	32	16	251	49	257	4	19	4
Units from Vacant Land Zoned for Apts.	0	0	0	0	0	97	29	0	0	0	0
Estate Land Lot Yield	0	0	0	0	0	0	0	0	0	0	0
Total Available Units & Lots	49	2	22	32	16	348	78	257	4	19	4
Vac. Year Round Units	22	1	39	52	49	248	66	288	1	12	2
Seasonal Units	432	0	2	0	0	12	2	3	1	1	0
Occupied Units	504	498	2,280	3,202	5,086	12,879	7,443	14,094	174	413	149
Total Existing Units	958	499	2,321	3,254	5,135	13,139	7,511	14,385	176	426	151
Total Existing & Potential Units	1,007	501	2,343	3,286	5,151	13,487	7,589	14,642	180	445	155
Projected Average Household Size	3.40	2.60	3.00	3.50	3.40	3.33	3.23***	3.04	3.60	3.60	3.60
Saturation Population	3,424	1,303	7,029	11,501	17,513	44,867	25,510	44,538	648	1,602	558

*Excludes Hofstra University & A. Holly Patterson Home
**Excludes Nassau County Jail & Medical Center
***Excludes Adelphi University
****Excludes all of the above

A-2 Town of Hempstead & City of Long Beach—Information for Land Capacity Analysis—School Districts & Municipalities. (cont'd.)

MUNICIPALITIES

	Island Park Village	Lawrence Village	Lynbrook Village	Malverne Village	Mineola Village (pt)	New Hyde Park Village (pt)	Rockville Centre Village
1970 Data							
Population	5,396	6,566	23,151	10,036	101	4,304	27,444
Household Size	3.36	3.26	3.06	3.31	n.a.	3.46	3.20
Occupied Units	1,607	2,012	7,564	3,032	n.a.	1,243	8,575
Vac. Year Round Units	57	91	149	22	n.a.	13	112
Seasonal Units	25	3	2	2	n.a.	0	5
1975 Estimates							
Jan. 1, 1975 Population	5,501	6,888	23,470	10,151	101	4,333	28,396
Vac. Land Lot Yield	40	58	38	43	n.a.	7	70
Units from Vacant Land Zoned for Apartments	0	0	0	0	n.a.	0	0
Estate Land Lot Yield	0	0	0	0	n.a.	0	0
Total Available Units & Lots	40	58	38	43	n.a.	7	70
Vac. Year Round Units	57	91	149	22	n.a.	13	112
Seasonal Units	25	3	2	2	n.a.	0	5
Occupied Units	1,629	2,168	7,798	3,065	n.a.	1,250	8,826
Total Existing Units	1,711	2,262	7,949	3,089	n.a.	1,263	8,943
Total Existing & Potential Units	1,751	2,320	7,987	3,132	n.a.	1,270	9,013
Projected Average Household Size	3.40	3.20	3.24	3.30	n.a.	3.38	3.19
Saturation Population	5,953	7,424	25,852	10,336	101	4,294	28,770

	South Floral Park Village	Stewart Manor Village	Valley Stream Village	Woodsburgh Village	Unincorporated Area	Town Total	City of Long Beach
1970 Data							
Population	1,032	2,183	40,413	817	534,325	801,592	33,127
Household Size	3.79	3.56	3.41	3.40	3.72* **	3.54****	2.74
Occupied Units	272	614	11,868	240	143,113	225,221	12,105
Vac. Year Round Units	5	5	107	7	1,275	2,623	1,399
Seasonal Units	0	0	0	0	484	974	1,520
1975 Estimates							
Jan. 1, 1975 Population	1,081	2,210	40,929	829	542,326	814,050	34,766
Vac. Land Lot Yield	16	1	74	6	2,585	3,643	845
Units from Vacant Land Zoned for Apts.	0	0	0	0	450	576	30
Estate Land Lot Yield	0	0	0	0	0	0	0
Total Available Units & Lots	16	1	74	6	3,035	4,219	875
Vac. Year Round Units	5	5	107	7	1,196	2,544	937
Seasonal Units	0	0	0	0	344	834	1,010
Occupied Units	288	621	12,037	243	146,056	230,703	13,219
Total Existing Units	293	626	12,144	250	147,596	234,081	15,166
Total Existing & Potential Units	309	627	12,218	256	150,631	238,300	16,041
Projected Average Household Size	3.70	3.50	3.34	3.60	3.64	3.50	2.60
Saturation Population	1,143	2,195	40,814	922	547,975	834,272	41,707

*Excludes Hofstra Universtiy & A. Holly Patterson Home
**Excludes Nassau County Jail & Medical Center
***Excludes Adelphi University
****Excludes all of the above

A-3 Town of North Hempstead—Information for Land Capacity Analysis—School Districts & Municipalities.

SCHOOL DISTRICTS

	Westbury 1 (pt)	East Williston 2	Roslyn 3 (pt)	Port Washington 4	New Hyde Park 5 (pt)	Manhasset 6	Great Neck 7
1970 Data							
Population	20,046	9,357	19,086	32,135	22,247	15,860	47,901
Household Size	3.69	3.45	3.45	3.26	3.38	3.45	3.07*
Occupied Units	5,444	2,716	5,525	9,862	6,581	4,602	15,360
Vacant Year Round Units	99	45	130	154	42	64	248
Seasonal Units	3	1	1	22	1	14	55
1975 Estimates							
Jan. 1, 1975 Population	20,593	9,478	19,198	32,843	22,445	15,989	48,763
Vac. Land Lot Yield	157	102	84	1,284	46	136	238
Units from Vacant Land Zoned for Apts.	65	0	122	0	0	1,703	326
Estate Land Lot Yield	0	0	0	0	0	0	0
Total Available Units and Lots	222	102	206	1,284	46	1,839	564
Vac. Year Round Units	99	45	130	154	42	64	248
Seasonal Units	3	1	1	22	1	14	55
Occupied Units	5,679	2,766	5,598	10,222	6,771	4,861	15,550
Total Existing Units	5,781	2,812	5,729	10,398	6,814	4,939	15,853
Total Existing & Potential Units	6,003	2,914	5,935	11,682	6,860	6,778	16,417
Projected Average Household Size	3.63	3.47	3.41	3.40	3.40	3.24	3.05
Saturation Population	21,766	10,117	20,240	39,770	23,324	21,990	50,006

	Herricks 9	Mineola 10	Carle Place 11	North Shore 1 (pt)	Jericho 15 (pt)	Floral Park 22 (pt)	Town Total
1970 Data							
Population	24,766	27,727	12,015	676	186	3,005	235,007
Household Size	3.70	3.17	3.40	3.86	3.80	3.29	3.34*
Occupied Size	6,691	8,756	3,529	175	49	914	70,204
Vacant Year Round Units	31	114	31	4	1	4	967
Seasonal Units	0	3	0	0	0	0	100
1975 Estimates							
Jan. 1,1975 Population	24,893	28,205	12,250	685	187	3,030	238,559
Vac. Land Lot Yield	120	170	56	6	32	0	2,431
Units from Vacant Land Zoned for Apts.	1,319	0	0	0	0	0	3,535
Estate Land Lot Yield	0	0	0	0	118	0	118
Total Available Units and Lots	1,439	170	56	6	150	0	6,084
Vac. Year Round Units	31	114	31	4	1	4	967
Seasonal Units	0	3	0	0	0	0	100
Occupied Units	6,721	8,776	3,594	190	95	914	71,737
Total Existing Units	6,752	8,893	3,625	194	96	918	72,804
Total Existing & Potential Units	8,191	9,063	3,681	200	246	918	78,888
Projected Average Household Size	3.49	3.19	3.37	3.60	3.80	3.43	3.32
Saturation Population	28,613	28,876	12,392	720	935	3,147	261,896

*Does not include U.S. Merchant Marine Academy

A-3 Town of North Hempstead—Information for Land Capacity Analysis—School Districts & Municipalities. (cont'd.)

MUNICIPALITIES

	Baxter Estates Village	East Hills Village (pt)	East Williston Village	Floral Park Village (pt)	Flower Hill Village	Great Neck Village	Great Neck Estates Village	Great Neck Plaza Village
1970 Data								
Population	1,026	8,605	2,808	1,939	4,486	10,731	3,131	5,921
Household Size	2.94	3.75	3.43	3.31	3.59	3.15	3.37	2.05
Occupied Units	349	2,296	818	586	1,251	3,410	928	2,888
Year Round Units	10	17	12	2	5	56	8	76
Seasonal Units	0	0	0	0	1	4	13	16
1975 Estimates								
Jan. 1, 1975 Population	1,047	8,717	2,846	1,968	4,528	11,207	3,182	6,078
Vac. Land Lot Yield	7	13	15	0	66	79	18	4
Units for Vacant Land Zoned for Apts.	0	0	0	0	0	22	0	0
Estate Land Lot Yield	0	0	0	0	0	0	0	0
Total Available Units and Lots	7	13	15	0	66	101	18	4
Vac. Year Round Units	10	17	12	2	5	56	8	76
Seasonal Units	0	0	0	0	1	4	13	16
Occupied Units	359	2,323	826	586	1,279	3,472	945	2,923
Total Existing Units	369	2,340	838	588	1,285	3,532	966	3,015
Total Existing & Potential Units	376	2,353	853	588	1,351	3,633	984	3,019
Projected Average Household Size	3.00	3.80	3.40	3.50	3.60	3.10	3.40	2.00
Saturation Population	1,128	8,942	2,900	2,058	4,864	11,262	3,346	6,038

	Kensington Village	Kings Point Village	Lake Success Village	Manorhaven Village	Mineola Village (pt)	Munsey Park Village	New Hyde Park Village (pt)	North Hills Village
1970 Data								
Population	1,582	5,614	3,254	5,488	21,744	2,980	5,812	295
Household Size	3.26	3.75*	3.72	3.11	3.08	3.67	3.44	3.88
Occupied Units	486	1,297	875	1,763	7,056	812	1,691	76
Year Round Units	11	33	7	35	100	5	14	2
Seasonal Units	11	0	4	6	0	0	0	2
1975 Estimates								
Jan. 1,1975 Population	1,597	5,747	3,260	5,789	22,288	2,995	5,965	263
Vac. Land Lot Yield	9	68	7	21	98	25	21	0
Units for Vacant Land Zoned for Apts.	0	0	0	0	0	0	0	3,442
Estate Land Lot Yield	0	0	0	0	0	0	0	0
Total Available Units and Lots	9	68	7	21	98	25	21	3,442
Vac. Year Round Units	11	33	7	35	100	5	14	2
Seasonal Units	11	0	4	6	0	0	0	2
Occupied Units	487	1,320	878	1,861	7,086	919	1,736	76
Total Existing Units	509	1,353	889	1,902	7,186	924	1,750	80
Total Existing & Potential Units	518	1,421	896	1,923	7,284	949	1,771	3,522
Projected Average Household Size	3.30	3.80	3.70	3.10	3.10	3.60	3.40	2.73
Saturation Population	1,709	6,300	3,315	5,961	22,580	3,416	6,021	9,606

*Does not include U.S. Merchant Marine Academy

A-3 Town of North Hempstead—Information for Land Capacity Analysis—School Districts & Municipalities. (cont'd.)

MUNICIPALITIES

	Old Westbury Village (pt)	Plandome Village	Plandome Heights Village	Plandome Manor Village	Port Washington North Village	Roslyn Village	Roslyn Estates Village	Roslyn Harbor Village (pt)
1970 Data								
Population	2,186	1,593	1,032	835	2,883	2,607	1,420	830
Household Size	3.77	3.66	3.38	3.73	3.08	2.73	3.68	3.74
Occupied Units	580	435	305	224	937	956	386	222
Year Round Units	29	5	5	2	4	85	5	4
Seasonal Units	3	1	1	1	0	0	0	1
1975 Estimates								
Jan. 1, 1975 Population	2,260	1,607	1,050	830	3,084	2,549	1,445	868
Vac. Land Lot Yield	114	37	12	4	15	18	12	6
Units for Vacant Land Zoned for Apts.	0	0	0	0	0	0	0	0
Estate Land Lot Yield	118	0	0	0	0	0	0	0
Total Available Units and Lots	232	37	12	4	15	18	12	6
Vac. Year Round Units	29	5	5	2	4	85	5	4
Seasonal Units	3	1	1	1	0	0	0	1
Occupied Units	672	452	307	224	994	960	397	246
Total Existing Units	704	458	313	227	998	1,045	402	251
Total Existing & Potential Units	936	495	325	231	1,013	1,063	414	257
Projected Average Household Size	3.80	3.60	3.40	3.60	3.20	2.70	3.50	3.60
Saturation Population	3,557	1,782	1,105	831	3,242	2,870	1,449	926

	Russell Gardens Village	Saddle Rock Village	Sands Point Village	Thomaston Village	Westbury Village	Williston Park Village	Unincorporated Area	Town Total
1970 Data								
Population	1,174	895	2,916	2,486	15,362	9,154	104,218	235,007
Household Size	3.03	3.43	3.60	3.25	3.49	3.34	3.45	3.34*
Occupied Units	3.88	261	811	764	4,406	2,744	30,203	70,204
Year Round Units	6	2	22	12	62	20	311	967
Seasonal Units	4	0	12	0	0	3	17	100
1975 Estimates								
Jan. 1,1975 Population	1,136	895	3,000	2,761	15,805	9,252	104,540	238,559
Vac. Land Lot Yield	2	0	86	9	133	5	1,527	2,431
Units for Vacant Land Zoned for Apts.	0	0	0	0	65	0	6	3,535
Estate Land Lot Yield	0	0	0	0	0	0	0	118
Total Available Units and Lots	2	0	86	9	198	5	1,533	6,084
Vac. Year Round Units	6	2	22	12	62	20	311	967
Seasonal Units	4	0	12	0	0	3	17	100
Occupied Units	388	262	854	812	4,600	2,744	30,749	71,737
Total Existing Units	398	264	888	824	4,662	2,767	31,077	72,804
Total Existing & Potential Units	400	264	974	833	4,860	2,772	32,610	78,888
Projected Average Household Size	3.00	3.40	3.60	3.20	3.40	3.28	3.46	3.32
Saturation Population	1,200	898	3,506	2,666	16,524	9,099	112,795	261,896

*Does not include U.S. Merchant Marine Academy

A-4 Town of Oyster Bay & City of Glen Cove—Information for Land Capacity Analysis—School Districts & Municipalities.

SCHOOL DISTRICTS

	North Shore 1 (pt)	Syosset-Woodbury 2	Locust-Valley Bayville 3	Plainview-Old Bethpage 4	Glen Cove 5	Oyster Bay-East Norwich 6	Nassau County Sanatorium 7	Jericho 15 (pt)
1970 Data								
Population	15,806	31,784	15,174	35,671	25,770	13,544	125	14,961
Household Size	3.23	3.94	3.44	4.15	3.45	3.47	—	3.76*
Occupied Units	4,892	8,061	4,405	8,601	7,466	3,904	—	3,574
Vac. Year Round Units	91	59	227	31	196	188	—	73
Seasonal Units	12	7	186	0	5	29	—	2
1975 Estimates								
Jan. 1, 1975 Population	16,386	34,057	15,970	36,494	26,880	14,590	—	15,468
Vac. Land Lot Yield	336	617	557	52	224	429	—	223
Units from Vacant Land Zoned for Apts.	40	300	0	0	0	356	—	0
Estate Land Lot Yield	130	498	354	0	0	718	—	353
Total Available Units and Lots	506	1,415	911	52	224	1,503	—	576
Vac. Year Round Units	91	59	227	31	196	188	—	73
Seasonal Units	12	2	180	0	5	42	—	2
Occupied Units	5,019	8,535	4,560	8,834	8,225	4,270	—	3,770
Total Existing Units	5,122	8,596	4,967	8,865	8,426	4,500	—	3,845
Total Existing & Potential Units	5,628	10,011	5,878	8,917	8,650	6,003	—	4,421
Projected Average Household Size	3.25	3.80	3.46	3.85	3.60	3.53	—	3.68*
Saturation Population	18,270	38,017	20,314	34,330	31,140	21,191	—	17,683

	Hicksville 17	Plainedge 18	Bethpage 21	Farmingdale 22 (pt)	Massapequa 23	Cold Spring Harbor 2 (pt)	Roslyn 3 (pt)	Amityville 6 (pt)	Town & City Total
1970 Data									
Population	47,488	24,320	21,794	45,033	60,032	1,435	125	6,050	359,112
Household Size	3.84	4.02	3.99	3.84	3.99	3.72	3.29	3.85	3.82*
Occupied Units	12,374	6,050	5,456	11,718	15,048	386	38	1,573	93,546
Vac. Year Round Units	68	28	32	94	112	16	0	24	1,239
Seasonal Units	1	2	0	3	37	17	0	11	312
1975 Estimates									
Jan. 1,1975 Population	47,713	24,469	22,342	45,402	61,011	1,508	125	6,157	368,572
Vac. Land Lot Yield	87	18	27	84	131	133	0	33	2,951
Units from Vacant Land Zoned for Apts.	0	0	0	28	0	0	0	0	724
Estate Land Lot Yield	0	0	0	0	0	61	0	0	2,114
Total Available Units and Lots	87	18	27	112	131	194	0	33	5,789
Vac. Year Round Units	68	28	32	94	112	16	0	24	1,239
Seasonal Units	1	2	0	3	37	15	0	11	312
Occupied Units	12,444	6,072	5,574	11,792	15,217	403	30	1,820	96,565
Total Existing Units	12,513	6,102	5,606	11,889	15,366	434	30	1,855	98,116
Total Existing & Potential Units	12,600	6,120	5,633	12,001	15,497	628	30	1,888	103,905
Projected Average Household Size	3.70	3.75	3.75	3.63	3.83	3.70	3.80	3.80	3.68
Saturation Population	46,620	22,950	21,124	43,582	59,323	2,323	114	7,174	384,155

*Excludes C.W. Post College

A-4 Town of Oyster Bay & City of Glen Cove—Information for Land Capacity Analysis—School Districts & Municipalities. (cont'd.)

MUNICIPALITIES

	Bayville Village	Brookville Village	Centre Island Village	Cove Neck Village	East Hills Village (pt)	Farmingdale Village	Lattingtown Village	Laurel Hollow Village	Massapequa Park Village	Matinecock Village
1970 Data										
Population	6,147	3,212	374	344	19	9,297	1,773	1,401	22,112	841
Household Size	3.35	3.53*	3.14	3.25	3.80	3.00	3.62	3.68	4.16	3.46
Occupied Units	1,834	476	119	106	5	3,095	490	381	5,316	243
Vac. Year-round Units	136	9	30	14	1	55	15	3	27	13
Seasonal Units	163	1	16	22	0	0	9	7	0	4
1975 Estimates										
Jan. 1, 1975 Population	6,706	3,096	374	348	19	9,442	1,814	1,459	22,468	867
Vac. Land Lot Yield	250	63	34	28	0	47	52	112	38	19
Units from Vac. Land Zoned for Apts.	0	0	0	0	0	28	0	0	0	0
Estate Land Lot Yield	0	175	56	43	0	0	104	61	0	44
Total Available Units & Lots	250	238	90	71	0	75	156	173	38	63
Vac. Year-round Units	136	9	30	14	1	55	15	3	27	13
Seasonal Units	163	1	16	22	0	0	9	7	0	4
Occupied Units	1,954	496	125	108	5	3,137	502	398	5,393	246
Total Existing Units	2,253	506	171	144	6	3,192	526	408	5,420	263
Total Existing & Potential Units	2,503	744	261	215	6	3,267	682	581	5,458	326
Projected Average Household Size	3.40	3.50*	3.30	3.30	3.17	3.00	3.50	3.70	4.00	3.40
Saturation Population	8,510	4,018	861	710	19	9,801	2,387	2,150	21,894	1,108

	Mill Neck Village	Muttontown Village	Old Brookville Village	Old Westbury Village (pt)	Oyster Bay Cove Village	Roslyn Harbor Village (pt)	Sea Cliff Village	Upper Brookville Village	Unincorporated Area	Town Total	City of Glen Cove
1970 Data											
Population	982	2,081	1,785	481	1,320	295	5,890	1,182	273,806	333,342	25,770
Household Size	3.36	3.99	3.67	3.85	3.59	3.47	3.00	3.97	3.92	3.85*	3.45
Occupied Units	292	521	486	125	368	85	1,965	298	69,875	86,080	7,466
Vac. Year-round Units	14	11	15	4	17	0	51	17	611	1,043	196
Seasonal Units	4	2	0	1	8	0	11	0	59	307	5
1975 Estimates											
Jan. 1, 1975 Population	1,008	2,491	1,878	501	1,590	384	6,087	1,216	279,944	341,692	26,880
Vac. Land Lot Yield	47	344	293	0	266	7	28	184	915	2,727	224
Units from Vac. Land Zoned for Apts.	0	0	0	0	66	0	0	0	630	724	0
Estate Land Lot Yield	115	652	130	128	334	0	0	123	249	2,114	0
Total Available Units & Lots	162	996	423	128	666	7	28	307	1,794	5,565	224
Vac. Year-round Units	14	11	15	4	17	0	51	17	611	1,043	196
Seasonal Units	4	2	0	1	8	0	11	0	59	307	5
Occupied Units	307	626	537	125	447	85	2,003	306	71,540	88,340	8,225
Total Existing Units	325	639	552	130	472	85	2,065	323	72,200	89,680	8,426
Total Existing & Potential Units	487	1,635	975	258	1,138	92	2,093	630	73,904	95,255	8,650
Projected Average Household Size	3.40	3.80	3.60	3.70	3.70	3.63	3.00	3.80	3.73	3.69*	3.60
Saturation Population	1,655	6,213	3,513	955	4,210	334	6,279	2,394	276,004	353,015	31,140

*Excludes C.W. Post College

A-5 Town of Babylon—Information for Land Capacity Analysis—School Districts & Municipalities.

SCHOOL DISTRICTS

	Babylon 1	West Babylon 2	North Babylon 3	Lindenhurst 4	Copiage 5	Amityville 6 (pt)	Deer Park 7	Wyandanch 9	Half Hollow Hills 5 (pt)
1970 Data									
Population	10,965	26,151	31,456	43,705	23,775	16,871	26,801	12,693	8,216
Household Size	3.39	3.66	4.01	3.76	3.65	3.36	4.16*	4.21	4.01
Occupied Units	3,236	7,142	7,848	11,630	6,516	5,025	6,065	3,017	2,048
Vac. Year Round Units	71	146	109	197	145	102	60	81	37
Seasonal Units	254	9	17	249	50	25	13	18	6
1975 Estimates									
Jan. 1, 1975 Population	11,602	27,629	33,421	46,742	26,220	18,527	27,385	14,340	8,970
Vacant Acreage	21	58	59	—	68	50	94	27	73
Lot Yield of Vac. Acreage	138	156	161	—	196	156	544	97	177
Lots on Filed Maps	—	—	—	—	—	—	—	—	—
Scattered Vac. Lots	128	242	315	1,029	695	343	321	880	96
Total Available Lots	266	398	476	1,029	891	499	865	977	273
Vac. Year Round Units	71	146	109	197	145	102	60	81	37
Seasonal Units	254	9	17	249	50	25	13	18	6
Occupied Units	3,479	7,656	8,472	12,658	7,369	5,652	6,233	3,515	2,287
Total Existing Units	3,804	7,811	8,598	13,104	7,564	5,779	6,306	3,614	2,330
Total Existing & Potential Units	4,070	8,209	9,074	14,133	8,455	6,278	7,171	4,591	2,603
Projected Average Household Size	3.28	3.67	3.80	3.81	3.80	3.41	3.90	4.10	3.90
Saturation Population	13,365	30,117	34,466	53,889	32,129	21,421	27,967	18,823	10,152

	SCHOOL DISTRICTS		MUNICIPALITIES				
	Farmingdale 22 (pt)	Town Total	Amityville Village	Babylon Village	Lindenhurst Village	Unincorporated Area	Town Total
1970 Data							
Population	2,937	203,570	9,794	12,897	28,359	152,520	203,570
Household Size	3.70	3.79*	3.11	3.35	3.70	3.90*	3.79*
Occupied Units	794	53,321	3,149	3,845	7,665	38,662	53,321
Vac. Year Round Units	10	958	66	91	131	670	958
Seasonal Units	2	643	25	43	127	448	643
1975 Estimates							
Jan. 1,1975 Population	3,087	217,923	10,722	13,563	30,082	163,556	217,923
Vacant Acreage	10	—	21	12	—	427	—
Lot Yield of Vac. Map	31	—	79	32	—	1,545	—
Lots on Filed Map	—	—	—	—	—	—	—
Scattered Vac. Lots	128	4,177	106	129	822	3,120	4,177
Total Available Lots	159	5,833	185	161	822	4,665	5,833
Vac. Year Round Units	10	958	66	91	131	670	958
Seasonal Units	2	643	25	43	127	448	643
Occupied Units	846	58,167	3,415	4,098	8,051	42,603	58,167
Total Existing Units	858	59,768	3,506	4,232	8,309	43,721	59,768
Total Existing & Potential Units	1,017	65,601	3,691	4,393	9,131	48,386	65,601
Projected Average Household Size	3.80	3.75	3.00	3.24	3.77	3.85*	3.75*
Saturation Population	3,865	246,194	11,073	14,236	34,381	186,504	246,194

*Excludes Edgewood State Hospital

A-6 Town of Brookhaven—Information for Land Capacity Analysis—School Districts & Municipalities.

SCHOOL DISTRICTS

	Three Village 1 (pt)	Comsewogue 3	South Country 4	Sachem 5 (pt)	Port Jefferson 6	Mt. Sinai 7	Miller Place 8	Rocky Point 9
1970 Data								
Population	34,201	17,911	15,007	34,102	6,349	1,948	5,717	8,255
Household Size	3.59*	3.94	3.67	3.77	3.39	3.76	3.34	3.31
Occupied Units	8,183	4,549	4,089	9,048	1,873	518	1,710	2,493
Vac. Year Round Units	380	172	324	572	92	30	134	439
Seasonal Units	91	50	45	514	37	46	736	1,088
1975 Estimates								
Special Census 4/26/75	39,481	19,183	16,343	42,569	6,387	4,803	8,947	10,345
Vacant Acreage	3,075	1,180	3,470	1,877	316	2,260	1,950	4,100
Lot Yield of Vac. Acreage	3,883	2,330	7,867	4,143	401	3,130	2,560	3,890
Lots on Filed Maps	—	—	—	—	—	—	—	—
Scattered Vac. Lots	508	172	290	1,149	339	30	160	210
Total Available Lots	4,391	2,502	8,157	5,292	740	3,160	2,720	4,100
Vac. Year Round Units	380	172	324	572	92	30	134	439
Seasonal Units	91	50	45	514	37	46	736	1,088
Occupied Units	9,446	4,872	4,453	11,294	1,909	1,277	2,677	3,124
Total Existing Units	9,917	5,094	4,822	12,380	2,038	1,353	3,547	4,651
Total Existing & Potential Units	14,308	7,596	12,979	17,672	2,778	4,513	6,267	8,751
Projected Average Household Size	3.59*	3.88	3.91	3.76	3.18	3.80	3.80	3.60
Saturation Population	61,380	29,443	50,729	66,423	8,836	17,149	23,815	31,504

	Middle Country 11	Middle Island 12	South Manor 21	Patchogue-Medford 24	South Haven 30	West Manor 31	William Floyd 32	Center Moriches 33
1970 Data								
Population	40,861	13,803	1,499	35,528	643	118	14,525	4,745
Household Size	4.17	3.85	3.42	3.40	3.61	3.37	3.16	3.18
Occupied Units	9,792	3,589	438	10,445	178	35	4,594	1,492
Vac. Year Round Units	467	406	46	395	20	4	1,213	103
Seasonal Units	262	418	57	229	11	5	401	161
1975 Estimates								
Special Census 4/26/75	52,912	29,878	2,054	41,746	569	188	26,629	4,805
Vacant Acreage	1,924	—	3,820	3,232	810	940	2,080	1,320
Lot Yield of Vac. Acreage	4,691	25,442	6,220	6,480	1,620	1,870	5,035	2,640
Lots on Filed Maps	—	—	—	—	—	—	—	—
Scattered Vac. Lots	707	9,663	250	668	0	0	2,125	150
Total Available Lots	5,398	35,105	6,470	7,148	1,620	1,870	7,160	2,790
Vac. Year Round Units	467	406	46	395	20	4	1,213	103
Seasonal Units	262	418	57	229	11	5	401	161
Occupied Units	12,682	7,764	600	12,274	178	56	8,424	1,511
Total Existing Units	13,411	8,588	703	12,898	209	65	10,038	1,775
Total Existing & Potential Units	18,809	43,693	7,173	20,046	1,829	1,935	17,198	4,565
Projected Average Household Size	3.94	3.40	3.70	3.72	3.60	3.70	3.70	3.70
Saturation Population	74,046	148,556	26,540	74,578	6,584	7,160	63,633	16,891

*Excludes State University at Stony Brook

A-6 Town of Brookhaven—Information for Land Capacity Analysis—School Districts & Municipalities. (cont'd.)

SCHOOL DISTRICTS

	East Moriches 34	Shoreham-Wading River 1 (pt)	Riverhead 2 (pt)	Bayport-Blue Point 5 (pt)	Eastport East Manor 11 (pt)	Fire Island 14 (pt)	Town Total
1970 Data							
Population	2,161	2,419	344	4,376	706	42	245,260
Household Size	3.22	3.54	3.41	3.43	3.27	3.00	3.64*
Occupied Units	672	684	101	1,276	216	14	65,989
Vac. Year Round Units	54	189	11	98	20	6	5,175
Seasonal Units	69	281	14	3	26	2,599	7,143
1975 Estimates							
Special Census 4/26/75	3,059	4,511	933	4,351	841	143	320,677
Vacant Acreage	2,920	2,330	1,600	270	8,120	—	—
Lot Yield of Vac. Acreage	5,370	2,870	2,485	500	11,365	—	—
Lots on Filed Maps	—	—	—	—	—	—	—
Scattered Vac. Lots	330	90	55	130	25	858	—
Total Available Lots	5,700	2,960	2,540	630	11,390	858	122,701
Vac. Year Round Units	54	189	11	98	20	6	5,175
Seasonal Units	69	281	14	3	26	2,599	7,143
Occupied Units	951	1,385	274	1,276	273	48	86,748
Total Existing Units	1,074	1,855	299	1,377	319	2,653	99,066
Total Existing & Potential Units	6,774	4,815	2,839	2,007	11,709	3,511	221,767
Projected Average Household Size	3.70	3.72	3.70	3.30	3.66	3.00	3.66*
Saturation Population	25,064	17,895	10,504	6,623	42,823	10,533	820,709

MUNICIPALITIES

	Belle Terre Village	Bellport Village	Lake Grove Village	Old Field Village	Patchogue Village	Poquott Village	Port Jefferson Village	Shoreham Village	Unincorporated Area	Town Total
1970 Data										
Population	678	3,046	8,133	812	11,582	427	5,515	524	214,543	245,260
Household Size	3.53	3.27	3.68	3.55	2.97	2.99	3.23	4.19	3.71*	3.64*
Occupied Units	192	931	2,210	229	3,894	143	1,706	125	56,559	65,989
Vac. Year Round Units	21	50	239	26	134	41	81	29	4,554	5,175
Seasonal Units	2	11	115	6	94	38	22	2	6,853	7,143
1975 Estimates										
Special Census 4/26/75	794	2,856	9,359	824	11,283	516	5,800	556	288,689	320,677
Vacant Acreage	0	—	373	211	52	112	206	0	—	—
Lot Yield of Vac. Acreage	0	—	386	84	140	112	206	0	—	—
Lots on Filed Maps	—	—	—	—	—	—	—	—	—	—
Scattered Vac. Lots	49	277	128	83	248	18	317	30	—	—
Total Available Lots	49	277	514	167	388	130	523	30	120,623	122,701
Vac. Year Round Units	21	50	239	26	134	41	81	29	4,554	5,175
Seasonal Units	2	11	115	6	94	38	22	2	6,853	7,143
Occupied Units	226	981	2,446	253	4,529	178	1,786	138	76,211	86,748
Total Existing Units	249	1,042	2,800	285	4,757	257	1,889	169	87,618	99,066
Total Existing & Potential Units	298	1,319	3,314	452	5,145	387	2,412	199	208,241	221,767
Projected Average Household Size	3.60	3.10	3.50	3.60	3.20	3.40	3.10	4.10	3.68*	3.66*
Saturation Population	1,073	4,089	11,599	1,627	16,464	1,316	7,477	816	776,248	820,709

*Excludes State University at Stony Brook

A-7 Town of East Hampton—Information for Land Capacity Analysis—School Districts & Municipalities.

SCHOOL DISTRICTS

	East Hampton 1	Wainscott 2	Amagansett 3	Springs 4	Sag Harbor 5 (pt)	Montauk 6	Town Total
1970 Data							
1970 Population	4,799	320	1,126	2,172	835	1,728	10,980
Household Size	2.70	3.17	2.86	2.81	3.14	3.30	2.86
Occupied Units	1,779	101	394	773	255	524	3,837
Vacant Year-Round Units	307	54	641	743	328	321	2,394
Seasonal Units	740	87	177	160	11	539	1,714
1975 Estimates							
January 1, 1975 Population	5,576	376	1,360	2,731	890	2,120	13,053
Vacant Acreage	5,337	1,851	3,355	5,241	174	2,203	18,161
Lot Yield of Vac. Acreage	3,429	1,352	2,383	2,784	278	2,266	12,492
Zoning Exempt Lots	2,748	239	283	3,044	–	2,323	8,637
Scattered Vacant Lots	82	2	5	19	476	48	632
Total Available Lots	6,257	1,593	2,671	5,847	754	4,637	21,761
Vacant Year Round Units	494	129	790	855	364	508	3,140
Seasonal Units	740	87	177	160	11	539	1,714
Occupied Units	2,074	118	475	982	283	647	4,579
Total Existing Units	3,308	334	1,442	1,997	658	1,694	9,433
Total Existing & Potential Units	9,567	1,927	4,113	7,844	1,412	6,331	31,194
Projected Average Household Size	2.70	3.30	2.80	3.00	3.00	3.30	2.96
Saturation Population	25,831	6,359	11,516	23,532	4,236	20,892	92,366

MUNICIPALITIES

	East Hampton Village	Sag Harbor Village (pt)	Unincorporated Area	Town Total
1970 Data				
1970 Population	1,753	835	8,392	10,980
Household Size	2.96	2.96	2.91	2.86
Occupied Size	670	282	2,885	3,837
Vacant Year-Round Units	101	303	1,990	2,394
Seasonal Units	523	8	1,183	1,714
1975 Estimates				
January 1,1975 Population	1,955	890	10,208	13,053
Vacant Acreage	637	174	17,350	18,161
Lot Yield of Vac. Acreage	404	278	11,810	12,492
Zoning Exempt Lots	48	–	8,589	8,637
Scattered Vacant Lots	50	476	106	632
Total Available Lots	502	754	20,505	21,761
Vacant Year Round Units	135	303	2,702	3,140
Seasonal Units	523	8	1,183	1,714
Occupied Units	747	300	3,532	4,579
Total Existing Units	1,405	611	7,417	9,433
Total Existing & Potential Units	1,907	1,365	27,922	31,194
Projected Average Household Size	2.62	3.00	2.98	2.96
Saturation Population	4,994	4,085	83,287	92,366

A-8 Town of Huntington—Information for Land Capacity Analysis—School Districts & Municipalities.

SCHOOL DISTRICTS

	Elwood 1	Cold Spring Harbor 2 (pt)	Huntington 3	Northport 4	Half Hollow Hills 5 (pt)	Harbor-fields 6	Commack 10 (pt)	South Huntington 13	Town Total
1970 Data									
Population	13,586	6,173	33,862	38,137	31,769	19,551	19,000	38,094	200,172
Household Size	4.46	3.49	3.19	3.46*	4.42**	3.54	4.45	3.78	3.74
Occupied Units	3,045	1,771	10,616	10,492	6,557	5,523	4,270	10,077	52,351
Vac. Year Round Units	32	92	277	263	188	108	53	136	1,149
Seasonal Units	6	36	110	216	12	63	5	10	458
1975 Estimates									
Jan. 1, 1975 Population	14,044	7,131	36,701	40,700	33,917	21,912	20,607	38,631	213,643
Vacant Acreage	360	905	424	1,308	2,776	498	72	495	6,838
Lot Yield of Vac. Acreage	299	603	1,254	1,125	2,228	745	92	788	7,134
Lots on Filed Maps	—	—	—	71	—	N.A.	250	N.A.	321
Scattered Vac. Lots	286	324	224	443	149	N.A.	13	N.A.	1,439
Total Available Lots	585	927	1,478	1,639	2,378	745	355	788	8,895
Vac. Year Round Units	32	92	277	263	188	108	53	136	1,149
Seasonal Units	6	36	110	216	12	63	5	10	458
Occupied Units	3,144	2,035	11,473	11,499	7,029	6,165	4,618	10,214	56,177
Total Existing Units	3,182	2,163	11,860	11,978	7,229	6,336	4,676	10,360	57,784
Total Existing & Potential Units	3,767	3,090	13,338	13,617	9,607	7,081	5,031	11,148	66,679
Projected Average Household Size	4.00	3.95	3.32	3.45*	4.10**	3.70	4.00	3.80	3.70
Saturation Population	15,068	12,193	44,319	48,037	42,889	26,200	20,124	42,362	251,192

MUNICIPALITIES

	Asharoken Village	Huntington Bay Village	Lloyd Harbor Village	Northport Village	Unincorporated Area	Town Total
1970 Data						
Population	540	1,789	3,371	7,494	186,978	200,172
Household Size	3.23	3.74	4.13	3.23	3.75	3.74
Occupied Units	167	478	816	2,319	48,571	52,351
Vac. Year Round Units	23	20	65	75	966	1,149
Seasonal Units	56	16	21	19	346	458
1975 Estimates						
Jan. 1, 1975 Population	613	1,866	3,605	8,031	199,528	213,643
Vacant Acreage	575	30	480	90	5,663	6,838
Lot Yield of Vac. Acreage	251	24	192	226	6,441	7,134
Lots on Filed Maps	—	—	—	—	321	321
Scattered Vac. Lots	46	46	124	111	1,112	1,439
Total Available Lots	297	70	316	337	7,875	8,895
Vac. Year Round Units	23	20	65	75	966	1,149
Seasonal Units	56	16	21	19	346	458
Occupied Units	185	500	864	2,533	52,095	56,177
Total Existing Units	264	536	950	2,627	53,407	57,784
Total Existing & Potential Units	561	606	1,266	2,964	61,282	66,679
Projected Average Household Size	3.87	3.80	4.30	3.22	3.71	3.70
Saturation Population	2,171	2,303	5,444	9,544	231,730	251,192

*Excludes Northport Veterans Hospital
**Excludes Suffolk State School and State University at Farmingdale

A-9 Town of Islip—Information for Land Capacity Analysis—School Districts & Municipalities.

SCHOOL DISTRICTS

	Bay Shore 1	Islip 2	East Islip 3	Sayville 4	Bayport-Blue Point 5 (pt)	Hauppauge 6 (pt)	Connetquot 7	West Islip 9	Brentwood 12	Central Islip 13
1970 Data										
Population	30,254	15,236	24,545	17,668	7,063	7,971	29,219	31,478	73,352	32,149
Household Size	3.52	3.52	3.90	3.60	3.72	3.81	3.70	3.99	4.30*	3.89**
Occupied Units	8,604	4,326	6,289	4,909	1,901	2,090	7,900	7,897	15,153	6,586
Vac. Year Round Units	182	112	98	96	94	39	375	83	284	154
Seasonal Units	43	17	25	30	11	1	161	30	29	2
1975 Estimates										
Jan. 1, 1975 Population	31,953	16,617	26,743	19,341	8,360	8,953	39,474	33,061	77,086	33,138
Total Available Lots	1,832	1,589	1,106	1,397	812	818	3,943	736	2,268	2,391
Total Existing Units	9,357	4,889	7,102	5,560	2,414	2,439	11,652	8,507	16,639	7,053
Total Existing & Potential Units	11,189	6,478	8,208	6,957	3,226	3,257	15,595	9,243	18,907	9,444
Projected Average Household Size	3.59	3.70	3.90	3.80	3.80	3.90	3.90	3.80	4.20*	4.10**
Saturation Population	40,166	23,969	32,011	26,437	12,259	12,702	60,821	35,123	84,409	39,720

	SCHOOL DISTRICTS			MUNICIPALITIES				
	Fire Island 14 (pt)	Sachem 5 (pt)	Town Total	Brightwaters Village	Ocean Beach Village	Saltaire Village	Unincorporated Area	Town Total
1970 Data								
Population	182	9,763	278,880	3,808	109	37	274,926	278,880
Household Size	2.64	3.69	3.86***	3.54	2.73	2.64	3.87***	3.86***
Occupied Units	69	2,646	68,370	1,076	40	14	67,240	68,370
Vac. Year Round Units	14	210	1,741	15	1	—	1,725	1,741
Seasonal Units	1,712	10	2,071	3	463	248	1,357	2,071
1975 Estimates								
Jan. 1, 1975 Population	158	17,126	312,010	3,881	93	35	308,001	312,010
Total Available Lots	1,096	4,205	22,193	36	35	498	21,624	22,193
Total Existing Units	1,851	5,176	82,639	1,111	526	296	80,706	82,639
Total Existing & Potential Units	2,947	9,381	104,832	1,147	561	794	102,330	104,832
Projected Average Household Size	2.50	3.80	3.86***	3.50	2.50	2.50	3.84***	3.86***
Saturation Population	7,368	35,648	410,633	4,015	1,403	1,985	403,230	410,633

*Excludes Pilgrim Psychiatric Center
**Excludes Central Islip Psychiatric Center
***Excludes all of the above

A-10 Town of Riverhead—Information for Land Capacity Analysis—School Districts & Municipalities.

	SCHOOL DISTRICTS				MUNICIPALITIES	
	Shoreham-Wading River 1 (pt)	Riverhead 2 (pt)	Laurel 11 (pt)	Town Total	Unincorporated Area	Town Total
1970 Data						
Population	1,441	17,277	191	18,909	18,909	18,909
Household Size	3.1	3.1	3.0	3.1	3.1	3.1
Occupied Units	469	5,551	64	6,084	6,084	6,084
Vacant Year-Round Units	26	371	2	399	399	399
Seasonal Units	197	1,214	39	1,450	1,450	1,450
1975 Estimates						
January 1, 1975 Population	1,818	19,145	221	21,184	21,184	21,184
Vacant Acreage	417	27,122	531	28,070	28,070	28,070
Lot Yield of Vacant Acreage	625	N.A.	862	56,216	56,216	56,216
Lots on Filed Maps & Scattered Vacant Lots	90	N.A.	7	—	—	—
Total Available Lots	715	54,632	869	56,216	56,216	56,216
Vacant Year-Round Units	26	239	2	267	267	267
Seasonal Units	197	1,214	39	1,450	1,450	1,450
Occupied Units	569	6,177	72	6,818	6,818	6,818
Total Existing Units	792	7,630	113	8,535	8,535	8,535
Total Existing & Potential Units	1,507	62,262	982	64,751	64,751	64,751
Projected Average Household Size	3.2	3.2	3.2	3.2	3.2	3.2
Saturation Population	4,822	199,239	3,142	207,203	207,203	207,203

A-11 Town of Shelter Island—Information for Land Capacity Analysis—School Districts & Municipalities.

	SCHOOL DISTRICTS	MUNICIPALITIES		
	Shelter Island 1	Dering Harbor Village	Unincorporated Area	Town Total
1970 Data				
1970 Population	1,644	24	620	1,644
Household Size	2.5	3.4	2.5	2.5
Occupied Units	646	7	639	646
Vacant Year-Round Units	494	26	468	494
Seasonal Units	343	2	341	343
1975 Estimates				
January 1,1975 Population	1,918	24	1,894	1,918
Vacant Acreage	3,796	151	3,645	3,796
Lot Yield of Vac. Acreage	1,634	33	1,601	1,634
Lots on Filed Maps & Scattered Vacant Lots	3,503	3	3,500	3,503
Total Available Lots	5,137	36	5,101	5,137
Vacant Year-Round Units	557	26	531	557
Seasonal Units	343	2	341	343
Occupied Units	748	7	741	748
Total Existing Units	1,648	35	1,613	1,648
Total Existing & Potential Units	6,793	71	6,722	6,793
Projected Average Household Size	2.5	2.5	2.5	2.5
Saturation Population	16,983	178	16,805	16,983

A-12 Town of Smithtown—Information for Land Capacity Analysis—School Districts & Municipalities.

SCHOOL DISTRICTS

	Smithtown 1	Kings Park 5	Three Village 1 (pt)	Sachem 5 (pt)	Hauppauge 6 (pt)	Commack 10 (pt)	Town Total
1970 Data							
Population	46,459	25,106	276	2,380	13,616	26,820	114,657
Household Size	3.94	3.78*	5.52	3.66	4.10	4.27	4.00*
Occupied Units	11,778	4,958	50	650	3,319	6,282	27,037
Vacant Year-Round Units	264	116	2	31	43	50	506
Seasonal Units	110	88	1	16	9	4	228
1975 Estimates							
January 1, 1975 Population	51,886	25,941	276	3,169	14,016	27,210	122,498
Vacant Acreage	–	859	249	68	–	499	–
Lot Yield of Vacant Acreage	–	864	99	184	–	734	–
Lots on Filed Maps	–	300	–	–	–	382	–
Scattered Vacant Lots	–	580	21	60	–	12	–
Total Available Lots	4,717	1,744	120	244	1,006	1,128	8,959
Vacant Year-Round Units	264	116	2	31	43	50	506
Seasonal Units	99	79	1	14	8	4	205
Occupied Units	13,267	5,188	50	868	3,418	6,373	29,164
Total Existing Units	13,630	5,383	53	913	3,469	6,427	29,875
Total Existing & Potential Units	18,347	7,127	173	1,157	4,475	7,555	38,834
Projected Average Household Size	3.82	3.80*	4.00	3.80	3.80	4.00	3.85*
Saturation Population	70,132	31,083	692	4,397	17,005	30,220	153,529

MUNICIPALITIES

	Head of the Harbor Village	Nissequogue Village	The Branch Village	Unincorporated Area	Town Total
1970 Data					
Population	943	1,120	1,675	110,919	114,657
Household Size	3.85	4.01	4.17	4.00*	4.00*
Occupied Units	245	279	402	26,111	27,037
Vacant Year-Round Units	8	12	7	479	506
Seasonal Units	2	6	0	220	228
1975 Estimates					
January 1,1975 Population	1,046	1,412	1,679	118,361	122,498
Vacant Acreage	809	1,350	167	–	–
Lot Yield of Vac. Acreage	407	540	234	–	–
Lots on Filed Maps	–	–	–	–	–
Scattered Vacant Lots	21	–	5	–	–
Total Available Lots	428	540	239	7,752	8,959
Vacant Year-Round Units	8	12	7	479	506
Seasonal Units	2	5	0	198	205
Occupied Units	263	329	409	28,163	29,164
Total Existing Units	273	346	416	28,840	29,875
Total Existing & Potential Units	701	886	655	36,592	38,834
Projected Average Household Size	4.00	4.00	4.00	3.84*	3.85*
Saturation Population	2,804	3,544	2,620	144,561	153,529

*Excludes Kings Park State Psychiatric Center

A-13 Town of Southampton—Information for Land Capacity Analysis—School Districts & Municipalities.

SCHOOL DISTRICTS

	Remsen-burg 1	West-hampton 2	Quogue 3	Hampton Bays 5	South-hampton 6	Bridge-hampton 9	Sagapo-nack 10	Eastport-East Manor 11 (pt)	Tucka-hoe 13	East Quogue 17
1970 Data										
Population	1,316	4,213	953	6,041	8,472	1,520	578	1,085	1,435	2,147
Household Size	2.90	2.88	2.75	3.03	2.91	2.71	3.23	3.04	4.00	2.78
Occupied Units	454	1,464	346	1,992	2,907	561	179	357	359	773
Vacant Year-Round Units	163	257	101	341	547	126	33	20	56	52
Seasonal Units	265	1,017	462	1,287	1,360	158	54	16	405	599
1975 Estimates										
January 1, 1975 Population	1,516	4,823	1,047	7,219	9,252	1,749	678	1,257	1,504	2,535
Vacant Acreage	2,027	3,806	2,848	1,912	11,785	5,100	2,261	464	2,111	2,734
Lot Yield of Vacant Acreage	1,425	2,106	2,191	1,949	8,952	6,127	1,442	436	1,573	2,102
Zoning Exempt Lots	0	0	0	0	299	0	0	0	309	0
Scattered Vacant Lots	161	129	188	960	176	39	0	52	0	223
Total Available Lots	1,586	2,235	2,379	2,909	9,427	6,166	1,442	488	1,882	2,325
Vacant Year-Round Units	214	334	140	418	699	152	58	20	183	103
Seasonal Units	265	1,017	462	1,287	1,360	158	54	16	405	599
Occupied Units	523	1,674	380	2,386	3,176	646	209	412	414	912
Total Existing Units	1,002	3,025	982	4,091	5,235	956	321	448	1,002	1,614
Total Existing & Potential Units	2,588	5,260	3,361	7,000	14,662	7,122	1,763	936	2,884	3,939
Projected Average Household Size	3.00	3.00	2.75	3.28	3.00	3.60	3.20	3.20	3.60	3.05
Saturation Population	7,764	15,780	9,243	22,960	43,986	25,639	5,642	2,995	10,382	12,014

	SCHOOL DISTRICTS			MUNICIPALITIES						
	Riverhead 2 (pt)	Sag Harbor 5 (pt)	Town Total	North Haven Village	Quogue Village	Sag Harbor Village (pt)	South-ampton Village	Westhampton Beach Village	Unincorporated Area	Town Total
1970 Data										
Population	4,603	3,791	36,154	694	865	1,528	4,904	1,926	26,237	36,154
Household Size	3.35	2.79	2.98	3.08	2.86	2.60	2.95	2.89	3.02	2.98
Occupied Units	1,374	1,357	12,123	225	302	587	1,664	666	8,679	12,123
Vacant Year-Round Units	123	523	2,342	125	58	192	347	50	1,570	2,342
Seasonal Units	431	615	6,669	0	415	42	387	629	5,196	6,669
1975 Estimates										
January 1, 1975 Population	5,304	4,355	41,239	798	959	1,748	5,101	2,142	30,491	41,239
Vacant Acreage	6,122	2,393	43,563	929	2,131	184	1,859	540	37,920	43,563
Lot Yield of Vacant Acreage	6,090	1,885	36,278	398	1,644	294	2,121	646	31,175	36,278
Zoning Exempt Lots	0	524	1,132	171	0	0	0	89	872	1,132
Scattered Vacant Lots	400	155	2,483	183	162	65	176	158	1,739	2,483
Total Available Lots	6,490	2,564	39,893	752	1,806	359	2,297	893	33,786	39,893
Vacant Year-Round Units	200	624	3,145	145	95	192	402	35	2,276	3,145
Seasonal Units	431	615	6,669	0	415	42	387	614	5,211	6,669
Occupied Units	1,638	1,558	13,928	257	336	666	1,731	741	10,197	13,928
Total Existing Units	2,269	2,797	23,742	402	846	900	2,520	1,390	17,684	23,742
Total Existing & Potential Units	8,759	5,361	63,635	1,154	2,652	1,259	4,817	2,283	51,470	63,635
Projected Average Household Size	3.55	2.80	3.18	3.10	2.80	2.60	3.00	2.85	3.25	3.18
Saturation Population	31,094	15,011	202,510	3,577	7,426	3,273	14,451	6,506	167,277	202,510

A-14 Town of Southhold—Information for Land Capacity Analysis—School Districts & Municipalities.

SCHOOL DISTRICTS

	Oyster Ponds 2	Fishers Island 4	Southold 5	Mattituck-Cutchogue 9	Greenport 10	Laurel 11 (pt)
1970 Data						
Population	1,350	462	4,381	5,240	4,053	770
Household Size	2.65	2.66	2.69	3.01	2.82	4.70
Occupied Units	510	174	1,629	1,738	1,438	164
Vacant Year Round Units	143	—	173	611	254	114
Seasonal Units	219	184	631	300	163	8
1975 Estimates						
January 1, 1975 Population	1,618	395	5,002	5,954	4,289	898
Vacant Acreage	2,683	997	4,227	7,075	866	777
Lot Yield of Vac. Acreage	1,878	698	2,960	4,953	605	544
Zoning Exempt Lots	118	—	433	246	189	96
Scattered Vacant Lots	192	125	358	421	177	47
Total Available Lots	2,188	823	3,751	5,620	971	687
Vacant Year Round Units	189	0	229	807	336	151
Seasonal Units	219	184	631	300	163	8
Occupied Units	605	149	1,870	1,991	1,517	208
Total Existing Units	1,013	333	2,730	3,098	2,016	367
Total Existing & Potential Units	3,201	1,156	6,481	8,718	2,983	1,054
Projected Average Household Size	3.00	3.00	3.00	3.00	3.00	3.00
Saturation Population	9,603	3,468	19,443	26,154	8,949	3,162

	SCHOOL DISTRICTS		MUNICIPALITIES		
	New Suffolk 15	Town Total	Greenport Village	Unincorporated Area	Town Total
1970 Data					
Population	548	16,804	2,481	14,323	16,804
Household Size	3.11	2.88	2.77	2.90	2.88
Occupied Units	176	5,829	897	4,932	5,829
Vacant Year Round Units	7	1,302	118	1,184	1,302
Seasonal Units	104	1,609	2	1,607	1,609
1975 Estimates					
January 1, 1975 Population	577	18,733	2,518	16,215	18,733
Vacant Acreage	554	17,179	—	17,179	17,179
Lot Yield of Vac. Acreage	388	12,026	—	12,026	12,026
Zoning Exempt Lots	—	1,082	—	1,082	1,082
Scattered Vacant Lots	27	1,347	37	1,310	1,347
Total Available Lots	415	14,455	37	14,418	14,455
Vacant Year Round Units	9	1,721	109	1,612	1,721
Seasonal Units	104	1,609	2	1,607	1,609
Occupied Units	186	6,526	910	5,616	6,526
Total Existing Units	299	9,856	1,021	8,835	9,856
Total Existing & Potential Units	714	24,307	1,058	23,249	24,307
Projected Average Household Size	3.00	3.00	3.00	3.00	3.00
Saturation Population	2,142	72,921	3,174	69,747	72,921

A-15 Town of Hempstead & City of Long Beach: Population Projections & Percent Growth for School Districts by Five Year Periods, 1975–1995.

	Population 1/1/75	75–80 Projected Increase or Decrease No. Persons	75–80 Projected Increase or Decrease Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	80–85 Projected Increase or Decrease Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	85–90 Projected Increase or Decrease Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	90–95 Projected Increase or Decrease Percent	Projected Population 1995
School Districts													
Hempstead 1	32,382	595	1.8	32,977	507	1.5	33,484	514	1.5	33,998	516	1.5	34,514
Uniondale 2	35,388	179	0.5	35,567	120	0.3	35,687	116	0.3	35,803	52	0.1	35,855
East Meadow 3	59,832	85	0.1	59,917	–30	–0.1	59,887	–51	–0.1	59,836	–90	–0.2	59,746
North Bellmore 4	29,645	85	0.3	29,730	0	0.0	29,730	13	0.0	29,743	13	0.0	29,756
Levittown 5	59,456	60	0.1	59,516	15	0.0	59,531	26	0.0	59,557	26	0.0	59,583
Seaford 6	19,165	170	0.9	19,335	150	0.8	19,485	103	0.5	19,588	77	0.4	19,665
Bellmore 7	15,216	162	1.1	15,378	90	0.6	15,468	–13	–0.1	15,455	13	0.1	15,468
Roosevelt 8	16,331	21	0.1	16,352	224	1.4	16,576	206	1.2	16,782	206	1.2	16,988
Freeport 9	37,536	128	0.3	37,664	299	0.8	37,963	283	0.7	38,246	361	0.9	38,607
Baldwin 10	35,318	191	0.5	35,509	60	0.2	35,569	26	0.1	35,595	13	0.0	35,608
Oceanside 11	41,786	170	0.4	41,956	15	0.0	41,971	13	0.0	41,984	–13	–0.0	41,971
Malverne 12	16,470	25	0.2	16,495	30	0.2	16,525	0	0.0	16,525	26	0.2	16,551
Valley Stream 13	30,283	64	0.2	30,347	–30	–0.1	30,317	39	0.1	30,356	26	0.1	30,382
Woodmere-Hewlett 14	24,183	64	0.3	24,247	60	0.2	24,307	51	0.2	24,358	77	0.3	24,435
Lawrence-Cedarhurst 15	35,530	149	0.4	35,679	120	0.3	35,799	103	0.3	35,902	129	0.4	36,031
Elmont 16	45,115	111	0.2	45,226	75	0.2	45,301	77	0.2	45,378	77	0.2	45,455
Franklin Square 17	28,724	55	0.2	28,779	30	0.1	28,809	39	0.1	28,848	64	0.2	28,912
Garden City 18	25,836	38	0.1	25,874	15	0.1	25,889	0	0.0	25,889	13	0.1	25,902
East Rockaway 19	12,121	30	0.2	12,151	60	0.5	12,211	51	0.4	12,262	77	0.6	12,339
Lynbrook 20	20,716	94	0.5	20,810	150	0.7	20,960	102	0.5	21,062	103	0.5	21,165
Rockville Centre 21	24,682	132	0.5	24,814	45	0.2	24,859	13	0.1	24,872	13	0.1	24,885
Floral Park 22 (pt)	20,285	21	0.1	20,306	15	0.1	20,321	13	0.1	20,334	13	0.1	20,347
Wantagh 23	20,887	85	0.4	20,972	0	0.0	20,972	–26	–0.1	20,946	–52	–0.2	20,894
Valley Stream 24	15,065	42	0.3	15,107	0	0.0	15,107	26	0.2	15,133	77	0.5	15,210
Merrick 25	21,836	64	0.3	21,900	–15	–0.1	21,885	–26	–0.1	21,859	–26	–0.1	21,833
Island Trees 26	19,189	42	0.2	19,231	–15	–0.1	19,216	–13	–0.1	19,203	–39	–0.2	19,164
West Hempstead 27	18,520	9	0.0	18,529	6	0.0	18,535	13	0.1	18,548	26	0.1	18,574
Long Beach 28	40,938	1,170	2.9	42,108	925	2.2	43,033	836	1.9	43,869	723	1.6	44,592
North Merrick 29	15,850	55	0.3	15,905	15	0.1	15,920	–26	–0.2	15,894	–13	–0.1	15,881
Valley Stream 30	18,414	13	0.1	18,427	0	0.0	18,427	26	0.1	18,453	0	0.0	18,453
Island Park 31	9,514	140	1.5	9,654	105	1.1	9,759	77	0.8	9,836	90	0.9	9,926
Westbury 1 (pt)	5	–5	–100.0	0	0	0.0	0	0	0.0	0	0	0.0	0
New Hyde Park 5 (pt)	2,598	9	0.3	2,607	–51	–2.0	2,556	–39	–1.5	2,517	0	0.0	2,517
Town of Hempstead & City of Long Beach Total	**848,816**	**4,253**	**0.5**	**853,069**	**2,990**	**0.4**	**856,059**	**2,572**	**0.3**	**858,631**	**2,578**	**0.3**	**861,209**

A-15 Town of Hempstead & City of Long Beach: Population Projections & Percent Growth for Municipalities by Five Year Periods, 1975–1995.

	Population 1/1/75	75–80 Projected Increase or Decrease No. Persons	Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	Percent	Projected Population 1995
Municipalities													
Atlantic Beach Village	1,675	60	3.6	1,735	44	2.5	1,779	60	3.4	1,839	70	3.8	1,909
Bellerose Village	1,128	12	1.1	1,140	10	0.9	1,150	3	0.3	1,153	3	0.3	1,156
Cedarhurst Village	6,900	10	0.1	6,910	6	0.1	6,916	6	0.1	6,922	0	0.0	6,922
East Rockaway Village	11,906	0	0.0	11,906	–10	–0.1	11,896	10	0.1	11,906	10	0.1	11,916
Floral Park Village (pt)	16,685	5	0.0	16,690	5	0.0	16,695	10	0.1	16,705	8	0.0	16,713
Freeport Village	40,589	126	0.3	40,715	300	0.7	41,015	286	0.7	41,301	364	0.9	41,665
Garden City Village	25,401	124	0.5	25,525	65	0.3	25,590	0	0.0	25,590	63	0.2	25,653
Hempstead Village	40,881	640	1.6	41,521	590	1.4	42,111	544	1.3	42,655	541	1.3	43,196
Hewlett Bay Park Village	607	3	0.5	610	6	1.0	616	10	1.6	626	12	1.9	638
Hewlett Harbor Village	1,522	14	0.9	1,536	22	1.4	1,558	11	0.7	1,569	6	0.4	1,575
Hewlett Neck Village	541	4	0.7	545	4	0.7	549	3	0.5	552	0	0.0	552
Island Park Village	5,501	45	0.8	5,546	35	0.6	5,581	35	0.6	5,616	45	0.8	5,661
Lawrence Village	6,888	40	0.6	6,928	30	0.4	6,958	25	0.4	6,983	20	0.3	7,003
Lynbrook Village	23,470	100	0.4	23,570	164	0.7	23,734	135	0.6	23,869	165	0.7	24,034
Malverne Village	10,151	5	0.0	10,156	3	0.0	10,159	15	0.1	10,174	10	0.1	10,184
Mineola Village (pt)	101	0	0.0	101	0	0.0	101	0	0.0	101	0	0.0	101
New Hyde Park Village (pt)	4,333	12	0.3	4,345	–36	–0.8	4,309	–34	–0.8	4,275	0	0.0	4,275
Rockville Centre Village	28,396	120	0.4	28,516	30	0.1	28,546	13	0.0	28,559	13	0.0	28,572
South Floral Park Village	1,081	40	3.7	1,121	16	1.4	1,137	4	0.4	1,141	3	0.3	1,144
Stewart Manor Village	2,210	0	0.0	2,210	0	0.0	2,210	0	0.0	2,210	0	0.0	2,210
Valley Stream Village	40,929	124	0.3	41,053	–42	–0.1	41,011	13	0.0	41,024	25	0.1	41,049
Woodsburgh Village	829	0	0.0	829	6	0.7	835	9	1.1	844	12	1.4	856
Unincorporated Area	**542,326**	**1,819**	**0.3**	**544,145**	**967**	**0.2**	**545,112**	**664**	**0.1**	**545,776**	**508**	**0.1**	**546,284**
Town Total	**814,050**	**3,303**	**0.4**	**817,353**	**2,215**	**0.3**	**819,568**	**1,822**	**0.2**	**821,390**	**1,878**	**0.2**	**823,268**
City of Long Beach	**34,766**	**950**	**2.7**	**35,716**	**775**	**2.2**	**36,491**	**750**	**2.1**	**37,241**	**700**	**1.9**	**37,941**

A-16 Town of North Hempstead: Population Projections & Percent Growth for School Districts and Municipalities by Five Year Periods, 1975–1995.

	Population 1/1/75	75–80 Projected Increase or Decrease No. Persons	Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	Percent	Projected Population 1995
School Districts													
Westbury 1 (pt)	20,593	322	1.6	20,915	172	0.8	21,087	73	0.3	21,160	24	0.1	21,184
East Williston 2	9,478	86	0.9	9,564	57	0.6	9,621	61	0.6	9,682	43	0.4	9,725
Roslyn 3 (pt)	19,198	54	0.3	19,252	126	0.7	19,378	195	1.0	19,573	123	0.6	19,696
Port Washington 4	32,843	203	0.6	33,046	343	1.0	33,389	620	1.9	34,009	288	0.8	34,297
New Hyde Park 5 (pt)	22,445	43	0.2	22,488	34	0.2	22,522	24	0.1	22,546	6	0.0	22,552
Manhasset 6	15,989	301	1.9	16,290	606	3.7	16,896	644	3.8	17,540	362	2.1	17,902
Great Neck 7	48,763	258	0.5	49,021	320	0.7	49,341	182	0.4	49,523	68	0.1	49,591
Herricks 9	24,893	644	2.3	25,537	526	2.1	26,063	450	1.7	26,513	270	1.0	26,783
Mineola 10	28,205	150	0.5	28,355	92	0.3	28,447	97	0.3	28,544	18	0.1	28,562
Carle Place 11	12,250	22	0.2	12,272	–11	–0.1	12,261	12	0.1	12,273	–4	–0.0	12,269
North Shore 1 (pt)	685	0	0.0	685	–12	–1.8	673	7	1.0	680	2	0.3	682
Jericho 15 (pt)	187	64	34.2	251	46	18.3	297	53	17.8	350	22	6.3	372
Floral Park 22 (pt)	3,030	0	0.0	3,030	–11	–0.4	3,019	12	0.4	3,031	4	0.1	3,035
Town Total	**238,559**	**2,147**	**0.9**	**240,706**	**2,288**	**1.0**	**242,994**	**2,430**	**1.0**	**245,424**	**1,226**	**0.5**	**246,650**
Municipalities													
Baxter Estates Village	1,047	17	1.6	1,064	4	0.4	1,068	12	1.1	1,080	13	1.2	1,093
East Hills Village (pt)	8,717	22	0.3	8,739	15	0.2	8,754	12	0.1	8,766	2	0.0	8,768
East Williston Village	2,846	0	0.0	2,846	–4	–0.1	2,842	5	0.2	2,847	0	0.0	2,847
Floral Park Village (pt)	1,968	5	0.3	1,973	0	0.0	1,973	7	0.4	1,980	0	0.0	1,980
Flower Hill Village	4,528	33	0.7	4,561	46	1.0	4,607	49	1.1	4,656	14	0.3	4,670
Great Neck Village	11,207	43	0.4	11,250	23	0.2	11,273	0	0.0	11,273	–2	–0.0	11,271
Great Neck Estates Village	3,182	4	0.1	3,186	4	0.1	3,190	5	0.2	3,195	6	0.2	3,201
Great Neck Plaza Village	6,078	0	0.0	6,078	12	0.2	6,090	0	0.0	6,090	–18	–0.3	6,072
Kensington Village	1,597	4	0.3	1,601	4	0.2	1,605	12	0.7	1,617	7	0.4	1,624
Kings Point Village	5,747	70	1.2	5,817	59	1.0	5,876	52	0.9	5,928	11	0.2	5,939
Lake Success Village	3,260	0	0.0	3,260	0	0.0	3,260	5	0.2	3,265	–6	–0.2	3,259
Manorhaven Village	5,789	22	0.4	5,811	23	0.4	5,834	20	0.3	5,854	5	0.1	5,859
Mineola Village (pt)	22,288	120	0.5	22,408	73	0.3	22,481	17	0.1	22,498	6	0.0	22,504
Munsey Park Village	2,995	4	0.1	2,999	12	0.4	3,011	22	0.7	3,033	27	0.9	3,060
New Hyde Park Village (pt)	5,965	0	0.0	5,965	11	0.2	5,976	12	0.2	5,988	–6	–0.1	5,982
North Hills Village	263	1,010	384.0	1,273	1,281	0.6	2,554	1,202	47.1	3,756	730	19.4	4,486
Old Westbury Village (pt)	2,260	128	5.7	2,388	130	5.4	2,518	111	4.4	2,629	53	2.0	2,682
Plandome Village	1,607	11	0.7	1,618	23	1.4	1,641	29	1.8	1,670	15	0.9	1,685
Plandome Heights Village	1,050	0	0.0	1,050	4	0.4	1,054	7	0.7	1,061	0	0.0	1,061
Plandome Manor Village	830	–18	–2.2	812	–4	–0.5	808	12	1.5	820	–10	–1.2	810
Port Washington North Village	3,084	43	1.4	3,127	91	2.9	3,218	73	2.3	3,291	25	0.8	3,316
Roslyn Village	2,549	43	1.7	2,592	23	0.9	2,615	24	0.9	2,639	25	0.9	2,664
Roslyn Estates Village	1,445	0	0.0	1,445	–11	–0.8	1,434	0	0.0	1,434	–6	–0.4	1,428
Roslyn Harbor Village	868	0	0.0	868	–4	–0.5	864	12	1.4	876	4	0.5	880
Russell Gardens Village	1,136	–10	–0.9	1,126	23	2.0	1,149	5	0.4	1,154	0	0.0	1,154
Saddle Rock Village	895	0	0.0	895	–11	–1.2	884	7	0.8	891	–6	–0.7	885
Sands Point Village	3,000	86	2.9	3,086	69	2.2	3,155	36	1.1	3,191	18	0.6	3,209
Thomaston Village	2,761	–2	–0.1	2,759	9	0.3	2,768	0	0.0	2,768	–6	–0.2	2,762
Westbury Village	15,805	226	1.4	16,031	81	0.5	16,112	27	0.2	16,139	6	0.0	16,145
Williston Park Village	9,252	32	0.3	9,284	0	0.0	9,282	2	0.0	9,286	–21	–0.2	9,265
Unincorporated Area	**104,540**	**281**	**0.3**	**104,821**	**327**	**0.3**	**105,148**	**678**	**0.6**	**105,826**	**340**	**0.3**	**106,166**
Town Total	**238,559**	**2,174**	**0.9**	**240,733**	**2,313**	**1.0**	**243,046**	**2,455**	**1.0**	**245,501**	**1,226**	**0.5**	**246,727**

A-17 Town of Oyster Bay & City of Glen Cove: Population Projections & Percent Growth for School Districts and Municipalities by Five Year Periods, 1975–1995.

	Population 1/1/75	75–80 Projected Increase or Decrease No. Persons	75–80 Projected Increase or Decrease Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	80–85 Projected Increase or Decrease Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	85–90 Projected Increase or Decrease Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	90–95 Projected Increase or Decrease Percent	Projected Population 1995
School Districts													
North Shore 1 (pt)	16,386	264	1.6	16,650	121	0.7	16,771	124	0.7	16,895	38	0.2	16,933
Syosset-Woodbury 2	34,057	1,112	3.3	35,169	286	0.8	35,455	293	0.8	35,748	282	0.8	36,030
Locust Valley-Bayville 3	15,970	817	5.1	16,787	449	2.7	17,236	326	1.9	17,562	244	1.4	17,806
Plainview-Old Bethpage 4	36,494	0	0.0	36,494	–73	–0.2	36,421	–135	–0.4	36,286	–150	–0.4	36,136
Glen Cove 5	26,880	998	3.7	27,878	461	1.7	28,339	360	1.3	28,699	282	1.0	28,981
Oyster Bay-East Norwich 6	14,590	1,050	7.2	15,640	607	3.9	16,247	225	1.4	16,472	357	2.2	16,829
Nassau County Sanitorium 7	0	0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0
Jericho 15 (pt)	15,468	686	4.3	16,154	563	3.5	16,717	90	0.5	16,807	132	0.8	16,939
Hicksville 17	47,713	129	0.3	47,842	36	0.1	47,878	–56	–0.1	47,822	–47	–0.1	47,775
Plainedge 18	24,469	–16	–0.1	24,453	–32	–0.1	24,421	–101	–0.4	24,320	–141	–0.6	24,179
Bethpage 21	22,342	5	0.0	22,347	–7	0.0	22,340	–79	–0.4	22,261	–132	–0.6	22,129
Farmingdale 22 (pt)	45,402	93	0.2	45,495	32	0.1	45,527	–62	–0.1	45,465	–47	–0.1	45,418
Massapequa 23	61,011	103	0.2	61,114	7	0.0	61,121	–56	–0.1	61,065	–47	–0.1	61,018
Cold Spring Harbor 2 (pt)	1,508	93	6.2	1,601	85	5.3	1,686	67	4.0	1,753	75	4.3	1,828
Roslyn 3 (pt)	125	0	0.0	125	–5	–4.0	120	–6	–5.0	114	0	0.0	114
Amityville 6 (pt)	6,157	108	1.8	6,265	97	1.5	6,362	135	2.1	6,497	94	1.4	6,591
Town and City Total	**368,572**	**5,442**	**1.5**	**374,014**	**2,627**	**0.7**	**376,641**	**1,125**	**0.3**	**377,766**	**940**	**0.2**	**378,706**
Municipalities													
Bayville Village	6,706	362	5.4	7,068	165	2.3	7,233	67	0.9	7,300	56	0.8	7,356
Brookville Village	3,096	348	11.2	3,444	335	9.7	3,779	145	3.8	3,924	266	6.8	4,190
Centre Island Village	374	21	5.6	395	15	3.8	410	11	2.7	421	9	2.1	430
Cove Neck Village	348	21	6.0	369	17	4.6	386	11	2.8	397	9	2.3	406
East Hills Village (pt)	19	0	0.0	19	0	0.0	19	0	0.0	19	0	0.0	19
Farmingdale Village	9,442	93	1.0	9,535	49	0.5	9,584	11	0.1	9,595	0	0.0	9,595
Lattingtown Village	1,814	57	3.1	1,871	51	2.7	1,922	34	1.8	1,956	47	2.4	2,003
Laurel Hollow Village	1,459	67	4.6	1,526	56	3.7	1,582	33	2.1	1,615	47	2.9	1,662
Massapequa Park Village	22,468	51	0.2	22,519	–3	–0.0	22,516	–95	–0.4	22,421	–85	–0.4	22,336
Matinecock Village	867	41	4.7	908	34	3.7	942	34	3.6	976	38	3.9	1,014
Mill Neck Village	1,008	57	5.7	1,065	70	6.6	1,135	90	7.9	1,225	56	4.6	1,281
Muttontown Village	2,491	610	24.5	3,101	386	12.4	3,487	118	3.4	3,605	244	6.8	3,849
Old Brookville Village	1,878	109	5.8	1,987	97	4.9	2,084	113	5.4	2,197	38	1.7	2,235
Old Westbury Village (pt)	501	52	10.4	553	121	21.9	674	45	6.7	719	94	13.1	813
Oyster Bay Cove Village	1,590	362	22.8	1,952	218	11.2	2,170	271	12.5	2,441	197	8.1	2,638
Roslyn Harbor Village (pt)	384	0	0.0	384	–7	–1.8	377	–6	–1.6	371	–5	–1.3	366
Sea Cliff Village	6,087	103	1.7	6,190	2	0.0	6,192	0	0.0	6,192	5	0.1	6,197
Upper Brookville Village	1,216	165	13.6	1,381	156	11.3	1,537	113	7.4	1,650	132	8.0	1,782
Unincorporated Area	**279,944**	**1,925**	**0.3**	**281,869**	**404**	**0.1**	**282,273**	**–230**	**–0.1**	**282,043**	**–490**	**–0.2**	**281,553**
Town Total	**341,692**	**4,444**	**0.1**	**346,136**	**2,166**	**0.6**	**348,302**	**765**	**0.2**	**349,067**	**658**	**0.2**	**349,725**
City of Glen Cove	**26,880**	**998**	**3.7**	**27,878**	**461**	**1.7**	**28,339**	**360**	**1.3**	**28,699**	**282**	**1.0**	**28,981**

A-18 Town of Babylon: Population Projections & Percent Growth for School Districts and Municipalities by Five Year Periods, 1975–1995.

	Population 1/1/75	75–80 Projected Increase or Decrease No. Persons	75–80 Projected Increase or Decrease Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	80–85 Projected Increase or Decrease Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	85–90 Projected Increase or Decrease Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	90–95 Projected Increase or Decrease Percent	Projected Population 1995
School Districts													
Babylon 1	11,602	613	5.3	12,215	842	6.9	13,057	542	4.2	13,599	12	0.1	13,611
West Babylon 2	27,629	1,103	4.0	28,732	468	1.6	29,200	578	2.0	29,778	244	0.8	30,022
North Babylon 3	33,421	735	2.2	34,156	94	0.3	34,250	36	0.1	34,286	12	0.0	34,298
Lindenhurst 4	46,742	2,573	5.5	49,315	2,151	4.4	51,466	904	1.8	52,370	732	1.4	53,102
Copiague 5	26,220	2,450	9.3	28,670	2,151	7.5	30,821	398	1.3	31,219	134	0.4	31,353
Amityville 6 (pt)	18,527	1,347	7.3	19,874	1,029	5.2	20,903	687	3.3	21,590	12	0.1	21,602
Deer Park 7	27,385	368	1.3	27,753	47	0.2	27,800	108	0.4	27,908	12	0.0	27,920
Wyandanch 9	14,340	1,960	13.7	16,300	1,918	11.8	18,218	289	1.6	18,507	12	0.1	18,519
Half Hollow Hills 5 (pt)	8,970	613	6.8	9,583	374	3.9	9,957	36	0.4	9,993	36	0.4	10,029
Farmingdale 22 (pt)	3,087	490	15.9	3,577	281	7.9	3,858	36	0.9	3,894	12	0.3	3,906
Town Total	**217,923**	**12,252**	**5.6**	**230,175**	**9,355**	**4.1**	**239,530**	**3,614**	**1.5**	**243,144**	**1,218**	**0.5**	**244,362**
Municipalities													
Amityville Village	10,722	123	1.1	10,845	94	0.9	10,939	253	2.3	11,192	0	0.0	11,192
Babylon Village	13,563	282	2.1	13,845	271	2.0	14,116	217	1.5	14,333	49	0.3	14,382
Lindenhurst Village	30,082	1,470	4.9	31,552	1,590	5.0	33,142	470	1.4	33,612	487	1.4	34,099
Unincorporated Area	**163,556**	**10,377**	**6.3**	**173,933**	**7,400**	**4.3**	**181,333**	**2,674**	**1.5**	**184,007**	**682**	**0.4**	**184,689**
Town Total	**217,923**	**12,252**	**5.6**	**230,175**	**9,355**	**4.1**	**239,530**	**3,614**	**1.5**	**243,144**	**1,218**	**0.5**	**244,362**

A-19 Town of Brookhaven: Population Projections & Percent Growth for School Districts by Five Year Periods, 1975–1995.

	Population 4/26/75	75–80 Projected Increase or Decrease No. Persons	75–80 Projected Increase or Decrease Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	80–85 Projected Increase or Decrease Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	85–90 Projected Increase or Decrease Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	90–95 Projected Increase or Decrease Percent	Projected Population 1995
School Districts													
Three Village 1 (pt)	39,481	3,659	9.3	43,140	3,359	7.8	46,499	2,550	5.5	49,049	2,622	5.3	51,671
Comsewogue 3	19,183	1,028	5.4	20,211	1,067	5.3	21,278	923	4.3	22,201	1,112	5.0	23,313
South Country 4	16,343	1,142	7.0	17,485	2,370	13.6	19,855	2,172	10.9	22,027	3,791	17.2	25,818
Sachem 5 (pt)	42,569	5,712	13.4	48,281	4,148	8.6	52,429	2,172	4.1	54,601	1,011	1.9	55,612
Port Jefferson 6	6,387	171	2.7	6,558	119	1.8	6,677	163	2.4	6,840	568	8.3	7,408
Mt. Sinai 7	4,803	2,856	59.5	7,659	2,963	38.7	10,622	2,715	25.6	13,337	1,200	9.0	14,537
Miller Place 8	8,947	2,684	30.0	11,631	2,844	24.5	14,475	2,715	18.8	17,190	2,275	13.2	19,465
Rocky Point 9	10,345	1,714	16.6	12,059	1,896	15.7	13,955	3,258	23.3	17,213	4,044	23.5	21,257
Middle Country 11	52,912	6,283	11.9	59,195	4,445	7.5	63,640	2,172	3.4	65,812	1,516	2.3	67,328
Middle Island 12	29,878	13,138	44.0	43,016	14,519	33.8	57,535	14,119	24.5	71,654	15,163	21.2	86,817
South Manor 21	2,054	457	22.2	2,511	770	30.7	3,281	1,412	43.0	4,693	2,881	61.4	7,574
Patchogue-Medford 24	41,746	5,597	13.4	47,343	5,926	12.5	53,269	4,344	8.2	57,613	2,022	3.5	59,635
South Haven 30	569	57	10.0	626	119	19.0	745	217	29.1	962	859	89.3	1,821
West Manor 31	188	114	60.6	302	296	98.0	598	543	90.8	1,141	1,061	93.0	2,202
William Floyd 32	26,629	9,710	36.5	36,339	10,963	30.2	47,302	10,046	21.2	57,348	1,516	2.6	58,864
Center Moriches 33	4,805	114	2.4	4,919	178	3.6	5,097	978	19.2	6,075	1,769	29.1	7,844
East Moriches 34	3,059	685	22.4	3,744	770	20.6	4,514	1,195	26.5	5,709	1,921	33.6	7,630
Shoreham-Wading River 1 (pt)	4,511	1,885	41.8	6,396	2,015	31.5	8,411	1,738	20.7	10,149	1,921	18.9	12,070
Riverhead 2 (pt)	933	514	55.1	1,447	593	41.0	2,040	598	29.3	2,638	708	26.8	3,346
Bayport-Bluepoint 5 (pt)	4,351	57	1.3	4,408	119	2.7	4,527	163	3.6	4,690	303	6.5	4,993
Eastport-East Manor 11 (pt)	841	343	40.8	1,184	712	60.1	1,896	1,249	65.9	3,145	3,589	114.1	6,734
Fire Island 14 (pt)	143	57	39.9	200	59	29.5	259	0	0.0	259	0	0.0	259
Town Total	**320,677**	**57,977**	**18.1**	**378,654**	**60,250**	**15.9**	**438,904**	**55,442**	**12.6**	**494,346**	**51,852**	**10.5**	**546,198**

A-19 Town of Brookhaven: Population Projections & Percent Growth for Municipalities by Five Year Periods, 1975–1995.

	Population 4/26/75	75–80 Projected Increase or Decrease No. Persons	Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	Percent	Projected Population 1995
Municipalities													
Belle Terre Village	794	114	14.4	908	59	6.5	967	11	1.1	978	25	2.6	1,003
Bellport Village	2,856	–57	–2.0	2,799	59	2.1	2,858	109	3.8	2,967	127	4.3	3,094
Lake Grove Village	9,359	914	9.8	10,273	475	4.6	10,748	326	3.0	11,074	354	3.2	11,428
Old Field Village	824	57	6.9	881	59	6.7	940	71	7.6	1,011	101	10.0	1,112
Patchogue Village	11,283	–171	–1.5	11,112	237	2.1	11,349	434	3.8	11,783	404	3.4	12,187
Poquott Village	516	57	11.0	573	89	15.5	662	81	12.2	743	101	13.6	844
Port Jefferson Village	5,800	171	2.9	5,971	89	1.5	6,060	163	2.7	6,223	202	3.2	6,425
Shoreham Village	556	57	10.3	613	59	9.6	672	54	8.0	726	51	7.0	777
Unincorporated Area	**288,689**	**56,835**	**19.7**	**345,524**	**59,124**	**17.1**	**404,648**	**54,193**	**13.4**	**458,841**	**50,487**	**11.0**	**509,328**
Town Total	**320,677**	**57,977**	**18.1**	**378,654**	**60,250**	**15.9**	**438,904**	**55,442**	**12.6**	**494,346**	**51,852**	**10.5**	**546,198**

A-20 Town of East Hampton: Population Projections & Percent Growth for School Districts and Municipalities by Five Year Periods, 1975–1995.

	Population 1/1/75	75–80 Projected Increase or Decrease No. Persons	Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	Percent	Projected Population 1995
School Districts													
East Hampton 1	5,576	811	14.5	6,387	1,119	17.5	7,506	922	12.3	8,428	1,071	12.7	9,499
Wainscott 2	376	60	16.0	436	93	21.3	529	138	26.1	667	161	24.1	828
Amagansett 3	1,360	310	22.8	1,670	413	24.7	2,083	369	17.7	2,452	429	17.5	2,881
Springs 4	2,731	739	27.1	3,470	1,033	29.8	4,503	922	20.5	5,425	1,071	19.7	6,496
Sag Harbor 5 (pt)	890	57	6.4	947	90	9.5	1,037	77	7.4	1,114	89	8.0	1,203
Montauk 6	2,120	519	24.5	2,639	695	26.3	3,334	646	19.4	3,980	750	18.8	4,730
Town Total	**13,053**	**2,496**	**19.1**	**15,549**	**3,443**	**22.1**	**18,992**	**3,074**	**16.2**	**22,066**	**3,571**	**16.2**	**25,637**
Municipalities													
East Hampton Village	1,955	170	8.7	2,125	227	10.7	2,352	184	7.8	2,536	214	8.4	2,750
Sag Harbor Village (pt)	890	57	6.4	947	90	9.5	1,037	77	7.4	1,114	89	8.0	1,203
Unincorporated Area	**10,208**	**2,269**	**22.2**	**12,477**	**3,126**	**25.1**	**15,603**	**2,813**	**18.0**	**18,416**	**3,268**	**17.7**	**21,684**
Town Total	**13,053**	**2,496**	**19.1**	**15,549**	**3,443**	**22.1**	**18,992**	**3,074**	**16.2**	**22,066**	**3,571**	**16.2**	**25,637**

A-21 Town of Huntington: Population Projections & Percent Growth for School Districts and Municipalities by Five Year Periods, 1975–1995.

	Population 1/1/75	75–80 Projected Increase or Decrease No. Persons	Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	Percent	Projected Population 1995
School Districts													
Elwood 1	14,044	354	2.5	14,398	361	2.5	14,759	175	1.2	14,934	18	0.1	14,952
Cold Spring Harbor 2 (pt)	7,131	1,004	14.1	8,135	992	12.2	9,127	758	8.3	9,885	535	5.4	10,420
Huntington 3	36,701	2,125	5.8	38,826	1,803	4.6	40,629	1,340	3.3	41,969	857	2.0	42,826
Northport 4	40,700	2,928	7.2	43,628	2,083	4.8	45,711	1,324	2.9	47,035	600	1.3	47,635
Half Hollow Hills 5 (pt)	33,917	2,069	6.1	35,986	2,083	5.8	38,069	1,915	5.0	39,984	964	2.4	40,948
Harborfields 6	21,912	2,243	10.2	24,155	1,262	5.2	25,417	175	0.7	25,592	36	0.1	25,628
Commack 10 (pt)	20,607	708	3.4	21,315	90	0.4	21,405	58	0.3	21,463	18	0.1	21,481
South Huntington 13	38,631	472	1.2	39,103	541	1.4	39,644	583	1.5	40,227	642	1.6	40,869
Town Total	**213,643**	**11,903**	**5.6**	**225,546**	**9,215**	**4.1**	**234,761**	**6,328**	**2.7**	**241,089**	**3,670**	**1.5**	**244,759**
Municipalities													
Asharoken Village	613	59	9.6	672	243	36.2	915	262	28.6	1,177	285	24.2	1,462
Huntington Bay Village	1,866	165	8.8	2,031	117	5.8	2,148	58	2.7	2,206	36	1.6	2,242
Lloyd Harbor Village	3,605	236	6.5	3,841	244	6.4	4,085	233	5.7	4,318	250	5.8	4,568
Northport Village	8,031	708	8.8	8,739	424	4.9	9,163	204	2.2	9,367	179	1.9	9,546
Unincorporated Area	**199,528**	**10,735**	**5.4**	**210,263**	**8,187**	**3.9**	**218,450**	**5,571**	**2.6**	**224,021**	**2,920**	**1.3**	**226,941**
Town Total	**213,643**	**11,903**	**5.6**	**225,546**	**9,215**	**4.1**	**234,761**	**6,328**	**2.7**	**241,089**	**3,670**	**1.5**	**244,759**

A-22 Town of Islip: Population Projections & Percent Growth for School Districts and Municipalities by Five Year Periods, 1975–1995.

	Population 1/1/75	75–80 Projected Increase or Decrease No. Persons	Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	Percent	Projected Population 1995
School Districts													
Bay Shore 1	31,953	1,190	3.7	33,143	2,882	8.7	36,025	2,767	7.7	38,792	1,149	3.0	39,941
Islip 2	16,617	1,189	7.2	17,806	2,329	13.1	20,135	2,656	13.2	22,791	986	4.3	23,777
East Islip 3	26,743	1,635	6.1	28,378	1,164	4.1	29,542	1,328	4.5	30,870	1,137	3.7	32,007
Sayville 4	19,341	1,487	7.7	20,828	2,038	9.8	22,866	2,213	9.7	25,079	1,219	4.9	26,298
Bayport-Bluepoint 5 (pt)	8,360	1,190	14.2	9,550	1,747	18.3	11,297	487	4.3	11,784	464	3.9	12,248
Hauppauge 6 (pt)	8,953	1,189	13.3	10,142	1,747	17.2	11,889	332	2.8	12,221	116	0.9	12,337
Connetquot 7	39,474	8,623	21.8	48,097	7,278	15.1	55,375	3,099	5.6	58,474	1,683	2.9	60,157
West Islip 9	33,061	1,041	3.1	34,102	291	0.9	34,393	177	0.5	34,570	464	1.3	35,034
Brentwood 12	77,086	527	0.7	77,613	1,829	2.4	79,442	2,222	2.8	81,664	1,834	2.2	83,498
Central Islip 13	33,138	2,719	8.2	35,857	2,411	6.7	38,268	275	0.7	38,543	1,044	2.7	39,587
Fire Island 14 (pt)	158	0	0.0	158	29	18.4	187	44	23.5	231	0	0.0	231
Sachem 5 (pt)	17,126	6,244	36.5	23,370	4,367	18.7	27,737	5,534	20.0	33,271	1,509	4.5	34,780
Town Total	**312,010**	**27,034**	**8.7**	**339,044**	**28,112**	**8.3**	**367,156**	**21,134**	**5.8**	**388,290**	**11,605**	**3.0**	**399,895**
Municipalities													
Brightwaters Village	3,881	30	0.8	3,911	58	1.5	3,969	22	0.6	3,991	23	0.6	4,014
Ocean Beach Village	93	0	0.0	93	17	18.3	110	18	16.4	128	0	0.0	128
Saltaire Village	35	0	0.0	35	12	34.3	47	15	31.9	62	0	0.0	62
Unincorporated Area	**308,001**	**27,004**	**8.8**	**335,005**	**28,025**	**8.4**	**363,030**	**21,079**	**5.8**	**384,109**	**11,582**	**3.0**	**395,691**
Town Total	**312,010**	**27,034**	**8.7**	**339,044**	**28,112**	**8.3**	**367,156**	**21,134**	**5.8**	**388,290**	**11,605**	**3.0**	**399,895**

A-23 Towns of Riverhead & Shelter Island: Population Projections & Percent Growth for School Districts and Municipalities by Five Year Periods, 1975–1995.

	Population 1/1/75	75–80 Projected Increase or Decrease No. Persons	Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	Percent	Projected Population 1995
Riverhead School Districts													
Shoreham-Wading River 1 (pt)	1,818	557	30.6	2,375	779	32.8	3,154	767	24.3	3,921	439	11.2	4,360
Riverhead 2 (pt)	19,145	1,649	8.6	20,794	2,244	10.8	23,038	2,837	12.3	25,875	3,687	14.2	29,562
Laurel 11 (pt)	221	22	10.0	243	94	38.7	337	230	68.2	567	263	46.4	830
Town Total	**21,184**	**2,228**	**10.5**	**23,412**	**3,117**	**13.3**	**26,529**	**3,834**	**14.5**	**30,363**	**4,389**	**14.5**	**34,752**
Municipalities													
Unincorporated Area	**21,184**	**2,228**	**10.5**	**23,412**	**3,117**	**13.3**	**26,529**	**3,834**	**14.5**	**30,363**	**4,389**	**14.5**	**34,752**
Town Total	**21,184**	**2,228**	**10.5**	**23,412**	**3,117**	**13.3**	**26,529**	**3,834**	**14.5**	**30,363**	**4,389**	**14.5**	**34,752**
Shelter Island School Districts													
Shelter Island 1	1,918	310	16.2	2,228	562	25.2	2,790	534	19.1	3,324	636	19.1	3,960
Municipalities													
Village of Dering Harbor	24	0	0.0	24	6	25.0	30	16	53.3	46	32	69.6	78
Unincorporated Area	**1,894**	**310**	**16.4**	**2,204**	**556**	**25.2**	**2,760**	**518**	**18.8**	**3,278**	**604**	**18.4**	**3,882**
Town Total	**1,918**	**310**	**16.2**	**2,228**	**562**	**25.2**	**2,790**	**534**	**19.1**	**3,324**	**636**	**19.1**	**3,960**

A-24 Town of Smithtown: Population Projections & Percent Growth for School Districts and Municipalities by Five Year Periods, 1975–1995.

	Population 1/1/75	75–80 Projected Increase or Decrease No. Persons	Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	Percent	Projected Population 1995
School Districts													
Smithtown 1	51,886	3,485	6.7	55,371	2,943	5.3	58,314	3,026	5.2	61,340	2,920	4.8	64,260
Kings Park 5	25,941	1,332	5.1	27,273	1,611	5.9	28,884	2,185	7.6	31,069	1,499	4.8	32,568
Three Village 1 (pt)	276	73	26.4	349	128	36.7	477	101	21.2	578	32	5.5	610
Sachem 5 (pt)	3,169	726	22.9	3,895	320	8.2	4,215	67	1.6	4,282	63	1.5	4,345
Hauppauge 6 (pt)	14,016	436	3.1	14,452	575	4.0	15,027	807	5.4	15,834	635	4.0	16,469
Commack 10 (pt)	27,210	363	1.3	27,573	320	1.2	27,893	538	1.9	28,431	698	2.5	29,129
Town Total	**122,498**	**6,415**	**5.2**	**128,913**	**5,897**	**4.6**	**134,810**	**6,724**	**5.0**	**141,534**	**5,847**	**4.1**	**147,381**
Municipalities													
Head of the Harbor Village	1,046	145	13.9	1,191	320	26.9	1,511	403	26.7	1,914	349	18.2	2,263
Nissequogue Village	1,412	363	25.7	1,775	384	21.6	2,159	471	21.8	2,630	317	12.1	2,947
Village of the Branch	1,679	73	4.3	1,752	128	7.3	1,880	235	12.5	2,115	254	12.0	2,369
Unincorporated Area	**118,361**	**5,834**	**4.9**	**124.195**	**5,065**	**4.1**	**129,260**	**5,615**	**4.3**	**134,875**	**4,927**	**3.7**	**139,802**
Town Total	**122,498**	**6,415**	**5.2**	**128,913**	**5,897**	**4.6**	**134,810**	**6,724**	**5.0**	**141,534**	**5,847**	**4.1**	**147,381**

A-25 Town of Southampton: Population Projections & Percent Growth for School Districts and Municipalities by Five Year Periods, 1975—1995.

	Population 1/1/75	75—80 Projected Increase or Decrease No. Persons	Percent	Projected Population 1980	80—85 Projected Increase or Decrease No. Persons	Percent	Projected Population 1985	85—90 Projected Increase or Decrease No. Persons	Percent	Projected Population 1990	90—95 Projected Increase or Decrease No. Persons	Percent	Projected Population 1995
School Districts													
Remsenburg 1	1,516	238	15.7	1,754	290	16.5	2,044	333	16.3	2,377	391	16.4	2,768
Westhampton 2	4,823	715	14.8	5,538	917	16.6	6,455	1,237	19.2	7,692	1,452	18.9	9,144
Quogue 3	1,047	119	11.4	1,166	191	16.4	1,357	190	14.0	1,547	223	14.4	1,770
Hampton Bays 5	7,219	1,430	19.8	8,649	1,909	22.1	10,558	2,093	19.8	12,651	2,457	19.4	15,108
Southampton 6	9,252	869	9.4	10,121	764	7.5	10,885	952	8.7	11,837	1,117	9.4	12,954
Bridgehampton 9	1,749	268	15.3	2,017	351	17.4	2,368	523	22.1	2,891	614	21.2	3,505
Sagaponack 9	678	119	17.6	797	153	19.2	950	305	32.1	1,255	357	28.4	1,612
Eastport-East Manor 11 (pt)	1,257	178	14.2	1,435	183	12.8	1,618	228	14.1	1,846	268	14.5	2,114
Tuckahoe 13	1,504	119	7.9	1,623	229	14.1	1,852	476	25.7	2,328	558	24.0	2,886
East Quogue 17	2,535	476	18.8	3,011	649	21.6	3,660	799	21.8	4,459	938	21.0	5,397
Riverhead 1 (pt)	5,304	923	17.4	6,227	1,314	21.1	7,541	1,903	25.6	9,444	2,233	23.6	11,677
Sag Harbor 5 (pt)	4,355	507	11.6	4,862	687	14.1	5,549	476	8.6	6,025	558	9.3	6,583
Town Total	**41,239**	**5,961**	**14.5**	**47,200**	**7,637**	**16.2**	**54,837**	**9,515**	**17.4**	**64,352**	**11,166**	**17.4**	**75,518**
Municipalities													
North Haven Village	798	119	14.9	917	153	16.7	1,070	95	8.9	1,165	112	9.6	1,277
Quogue Village	959	108	11.3	1,067	153	14.3	1,220	181	14.8	1,401	212	15.1	1,613
Sag Harbor Village (pt)	1,748	258	14.8	2,006	152	7.6	2,158	95	4.4	2,253	112	5.0	2,365
Southampton Village	5,101	233	4.6	5,334	267	5.0	5,601	362	6.5	5,963	424	7.1	6,387
Westhampton Beach Village	2,142	251	11.7	2,393	382	16.0	2,775	618	22.3	3,393	726	21.4	4,119
Unincorporated Area	**30,491**	**4,992**	**16.4**	**35,483**	**6,530**	**18.4**	**42,013**	**8,164**	**19.4**	**50,177**	**9,580**	**19.1**	**59,757**
Town Total	**41,239**	**5,961**	**14.5**	**47,200**	**7,637**	**16.2**	**54,837**	**9,515**	**17.4**	**64,352**	**11,166**	**17.4**	**75,518**

A-26 Town of Southold: Population Projections & Percent Growth for School Districts and Municipalities by Five Year Periods, 1975—1995.

	Population 1/1/75	75—80 Projected Increase or Decrease No. Persons	Percent	Projected Population 1980	80—85 Projected Increase or Decrease No. Persons	Percent	Projected Population 1985	85—90 Projected Increase or Decrease No. Persons	Percent	Projected Population 1990	90—95 Projected Increase or Decrease No. Persons	Percent	Projected Population 1995
School Districts													
Oyster Ponds 2	1,618	274	16.9	1,892	336	17.8	2,228	348	15.6	2,576	456	17.7	3,032
Fishers Island 4	395	0	0.0	395	28	7.1	423	58	13.7	481	98	20.4	579
Southold 5	5,002	685	13.7	5,687	783	13.8	6,470	755	11.7	7,225	781	10.8	8,006
Mattituck-Cutchogue 9	5,954	753	12.6	6,707	1,007	15.0	7,714	1,103	14.3	8,817	1,237	14.0	10,054
Greenport 10	4,289	228	5.3	4,517	280	23.4	4,797	261	5.4	5,058	326	6.4	5,384
Laurel 11 (pt)	898	297	33.1	1,195	308	25.8	1,503	261	17.4	1,764	228	12.9	1,992
New Suffolk 15	577	46	8.0	623	56	9.0	679	116	17.1	795	130	16.4	925
Town Total	**18,733**	**2,283**	**12.2**	**21,016**	**2,798**	**13.3**	**23,814**	**2,902**	**12.2**	**26,716**	**3,256**	**12.2**	**29,972**
Municipalities													
Greenport Village	2,518	68	2.7	2,586	56	2.2	2,642	58	2.2	2,700	130	4.8	2,830
Unincorporated Area	**16,215**	**2,215**	**13.7**	**18,430**	**2,742**	**14.9**	**21,172**	**2,844**	**13.4**	**24,016**	**3,126**	**13.0**	**27,142**
Town Total	**18,733**	**2,283**	**12.2**	**21,016**	**2,798**	**13.3**	**23,814**	**2,902**	**12.2**	**26,716**	**3,256**	**12.2**	**29,972**

A-27 Nassau and Suffolk Counties: Population & Percent Growth for School Districts and Municipalities with Area in Two or More Towns, by Five Year Periods, 1975–1995.

	Population 1/1/75	75–80 Projected Increase or Decrease No. Persons	75–80 Projected Increase or Decrease Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	80–85 Projected Increase or Decrease Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	85–90 Projected Increase or Decrease Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	90–95 Projected Increase or Decrease Percent	Projected Population 1995
School Districts													
Nassau County													
Farmingdale 22	48,489	583	1.2	49,072	313	0.6	49,385	–26	–0.1	49,359	–35	–0.1	49,324
Floral Park 22	23,315	21	0.1	23,336	4	0.0	23,340	25	0.1	23,365	17	0.1	23,382
Jericho 15	15,655	750	4.8	16,405	609	3.7	17,014	143	0.8	17,157	154	0.9	17,311
New Hyde Park 5	25,043	52	0.2	25,095	–17	–0.1	25,078	–15	–0.1	25,063	6	0.0	25,069
North Shore 1	17,071	264	1.5	17,335	109	0.6	17,444	131	0.8	17,575	40	0.2	17,615
Roslyn 3	19,323	54	0.3	19,377	121	0.6	19,498	189	1.0	19,687	123	0.6	19,810
Westbury 1	20,598	317	1.5	20,915	172	0.8	21,087	73	0.3	21,160	24	0.1	21,184
Suffolk County													
Amityville 6	24,684	1,455	5.9	26,139	1,126	4.3	27,265	822	3.0	28,087	106	0.4	28,193
Bayport-Bluepoint 5	12,711	1,247	9.8	13,958	1,866	13.4	15,824	650	4.1	16,474	767	4.7	17,241
Cold Spring Harbor 2	8,639	1,097	12.7	9,736	1,077	11.1	10,813	825	7.6	11,638	610	5.2	12,248
Commack 10	47,817	1,071	2.2	48,888	410	8.4	49,298	596	1.2	49,894	716	1.4	50,610
Eastport-East Manor 11	2,098	521	24.8	2,619	895	34.2	3,514	1,477	42.0	4,991	3,857	77.3	8,848
Fire Island 14	301	57	18.9	358	88	24.6	446	44	9.9	490	0	0.0	490
Half Hollow Hills 5	42,887	2,682	6.3	45,569	2,457	5.4	48,026	1,951	4.1	49,977	1,000	2.0	50,977
Hauppauge 6	22,969	1,625	7.1	24,594	2,322	9.4	26,916	1,139	4.2	28,055	751	2.7	28,806
Laurel 11	1,119	319	28.5	1,438	402	28.0	1,840	491	26.7	2,331	491	21.1	2,822
Riverhead 2	25,382	3,086	12.2	28,468	4,151	14.6	32,619	5,338	16.4	37,957	6,628	17.5	44,585
Sachem 5	62,864	12,682	20.2	75,546	8,835	11.7	84,381	7,773	9.2	92,154	2,583	2.8	94,737
Sag Harbor 5	5,245	564	10.8	5,809	777	13.4	6,586	553	8.4	7,139	647	9.1	7,786
Shoreham-Wading River 1	6,329	2,442	38.6	8,771	2,794	31.9	11,565	2,505	21.7	14,070	2,360	16.8	16,430
Three Village 1	39,757	3,732	9.4	43,489	3,487	8.0	46,976	2,651	5.6	49,627	2,654	5.3	52,281
Municipalities													
Nassau County													
East Hills	8,736	22	0.3	8,758	15	0.2	8,773	12	0.1	8,785	2	0.0	8,787
Floral Park	18,653	10	0.1	18,663	5	0.0	18,668	17	0.1	18,685	8	0.0	18,693
Mineola	22,389	120	0.5	22,509	73	0.3	22,582	17	0.1	22,599	6	0.0	22,605
New Hyde Park	10,298	12	0.1	10,310	–25	–0.2	10,285	–22	–0.2	10,263	–6	–0.1	10,257
Old Westbury	2,761	180	6.5	2,941	251	8.5	3,192	156	4.9	3,348	147	4.4	3,495
Roslyn Harbor	1,252	0	0.0	1,252	–11	–0.9	1,241	6	0.5	1,247	–1	–0.1	1,246
Suffolk County													
Sag Harbor	2,638	315	11.9	2,953	242	8.2	3,195	172	5.4	3,367	201	6.0	3,568

A-28 Nassau and Suffolk Counties: Existing and Projected Population of Drainage Basins by Five Year Intervals, 1975–1995.

Drainage Basins		Population 1/1/75	75–80 Projected Increase or Decrease No. Persons	75–80 Projected Increase or Decrease Percent	Projected Population 1980	80–85 Projected Increase or Decrease No. Persons	80–85 Projected Increase or Decrease Percent	Projected Population 1985	85–90 Projected Increase or Decrease No. Persons	85–90 Projected Increase or Decrease Percent	Projected Population 1990	90–95 Projected Increase or Decrease No. Persons	90–95 Projected Increase or Decrease Percent	Projected Population 1995
Nassau	1	690,299	4,539	0.7	694,838	3,499	0.5	698,337	273	0.0	698,610	5,936	0.8	704,546
	2	585,930	3,163	0.5	589,093	1,398	0.2	590,491	214	0.0	590,705	16	0.0	590,721
	3	58,712	549	0.9	59,261	1,006	1.7	60,267	1,298	2.2	61,565	665	1.1	62,230
	4	50,671	1,246	2.5	51,917	631	1.2	52,548	545	1.0	53,093	361	0.7	53,454
	5	41,078	2,190	5.3	43,268	1,178	2.7	44,446	687	1.5	45,133	725	1.6	45,858
	6	29,258	155	0.5	29,413	192	0.7	29,605	109	0.4	29,714	41	0.1	29,755
Suffolk	1	443,299	20,069	4.5	463,368	17,243	3.7	480,611	10,480	2.2	491,091	5,462	1.1	496,553
	2	315,787	36,090	11.4	351,877	34,092	9.7	385,969	25,014	6.5	410,983	14,016	3.4	424,999
	3A	145,672	26,374	18.1	172,046	26,929	15.7	198,975	23,241	11.7	222,216	22,927	10.3	245,143
	3B	31,509	9,295	29.5	40,804	10,719	26.3	51,523	11,634	22.6	63,157	7,570	12.0	70,727
	4	40,549	2,880	7.1	43,429	2,571	5.9	46,000	1,918	4.2	47,918	1,288	2.7	49,206
	5	24,867	2,138	8.6	27,005	1,349	5.0	28,354	510	1.8	28,864	223	0.8	29,087
	6	25,609	1,700	6.6	27,309	1,294	4.7	28,603	1,003	3.5	29,606	539	1.8	30,145
	7	99,812	5,529	5.5	105,341	6,004	5.7	111,345	5,572	5.0	116,917	4,627	4.0	121,544
	8	27,742	2,400	8.7	30,142	2,248	7.5	32,390	1,752	5.4	34,142	1,914	5.6	36,056
	9	16,149	3,870	24.0	20,019	4,068	20.3	24,087	4,372	18.2	28,459	3,935	13.8	32,394
	10	11,318	2,985	26.4	14,303	3,401	23.8	17,704	3,929	22.2	21,633	4,229	19.5	25,862
	11A	957	83	8.7	1,040	112	10.8	1,152	142	12.3	1,294	184	14.2	1,478
	11B	30,403	5,415	17.8	35,818	7,333	20.5	43,151	9,506	22.0	52,657	13,995	26.6	66,652
	12A	505	100	19.8	605	134	22.1	739	147	19.9	886	172	19.4	1,058
	12B	7,607	1,125	14.8	8,732	1,400	16.0	10,132	1,801	17.8	11,933	2,113	17.7	14,046
	12C	9,240	1,738	18.8	10,978	2,358	21.5	13,336	2,657	19.9	15,993	3,121	19.5	19,114
	13A	2,203	269	12.2	2,472	344	13.9	2,816	364	12.9	3,180	404	12.7	3,584
	13B	15,956	1,954	12.2	17,910	2,365	13.2	20,275	2,428	12.0	22,703	2,709	11.9	25,412
	14	1,918	310	16.2	2,228	562	25.2	2,790	534	19.1	3,324	636	19.1	3,960
	15A	12,338	1,864	15.1	14,202	2,548	17.9	16,750	2,338	14.0	19,088	2,724	14.3	21,812
	15B	16,927	2,153	12.7	19,080	2,594	13.6	21,674	3,053	14.1	24,727	3,570	14.4	28,297
	16A	1,590	389	24.5	1,979	522	26.4	2,501	484	19.4	2,985	563	18.9	3,548
	16B	530	130	24.5	660	174	26.4	834	161	19.3	995	188	18.9	1,183
	17	395	0	0.0	395	28	7.1	423	58	13.7	481	98	20.4	579
Total		**2,738,830**	**140,702**	**5.1**	**2,879,532**	**138,296**	**4.8**	**3,017,828**	**116,224**	**3.9**	**3,134,052**	**104,951**	**3.3**	**3,239,003**

A-29 Nassau and Suffolk Counties: Existing and Projected Gross Residential Density of Towns & School Districts in Persons Per Acre, by Five Year Intervals, 1970–1995.

	School District	Area (Acres)	1970 Population	1970 Gross Density	1975 Population	1975 Gross Density	1980 Population	1980 Gross Density	1985 Population	1985 Gross Density	1990 Population	1990 Gross Density	1995 Population	1995 Gross Density
Town of Hempstead														
1	Hempstead	2,031	31,272	15.40	32,382	15.94	32,977	16.24	33,484	16.49	33,998	16.74	34,514	16.99
2	Uniondale	4,298	34,796	8.10	35,388	8.23	35,567	8.28	35,687	8.30	35,803	8.33	35,855	8.34
3	East Meadow	5,347	59,454	11.12	59,832	11.19	59,917	11.21	59,887	11.20	59,836	11.19	59,746	11.17
4	North Bellmore	2,137	28,906	13.53	29,645	13.87	29,730	13.91	29,730	13.91	29,743	13.92	29,756	13.92
5	Levittown	4,191	59,286	14.15	59,456	14.19	59,516	14.20	59,531	14.20	59,557	14.21	59,583	14.22
6	Seaford	2,064	18,702	9.06	19,165	9.29	19,335	9.37	19,485	9.44	19,588	9.49	19,665	9.53
7	Bellmore	1,407	14,634	10.40	15,216	10.81	15,378	10.93	15,468	10.99	15,455	10.98	15,468	10.99
8	Roosevelt	1,129	16,296	14.43	16,331	14.47	16,352	14.48	16,576	14.68	16,782	14.86	16,988	15.05
9	Freeport	3,453	37,345	10.82	37,536	10.87	37,664	10.91	37,963	10.99	38,246	11.08	38,607	11.18
10	Baldwin	2,676	34,877	13.03	35,318	13.20	35,509	13.27	35,569	13.29	35,595	13.30	35,608	13.31
11	Oceanside	3,638	40,953	11.26	41,786	11.49	41,956	11.53	41,971	11.54	41,984	11.54	41,971	11.54
12	Malverne	1,478	16,366	11.07	16,470	11.14	16,495	11.16	16,525	11.18	16,525	11.18	16,551	11.20
13	Valley Stream	2,107	29,876	14.18	30,283	14.37	30,347	14.40	30,317	14.39	30,356	14.40	30,382	14.42
14	Woodmere-Hewlett	2,248	23,711	10.55	24,183	10.76	24,247	10.79	24,307	10.81	24,358	10.84	24,435	10.87
15	Lawrence-Cedarhurst	4,816	35,178	7.30	35,530	7.38	35,679	7.41	35,799	7.43	35,902	7.45	36,031	7.48
16	Elmont	3,319	44,429	13.39	45,115	13.59	45,226	13.63	45,301	13.65	45,378	13.67	45,455	13.70
17	Franklin Square	1,516	28,059	18.51	28,724	18.95	28,779	18.98	28,809	19.00	28,848	19.03	28,912	19.07
18	Garden City	3,504	25,725	7.34	25,836	7.37	25,874	7.38	25,889	7.39	25,889	7.39	25,902	7.39
19	East Rockaway	751	12,231	16.29	12,121	16.14	12,151	16.18	12,211	16.26	12,262	16.33	12,339	16.43
20	Lynbrook	1,378	20,242	14.69	20,716	15.03	20,810	15.10	20,960	15.21	21,062	15.28	21,165	15.36
21	Rockville Centre	1,965	23,996	12.21	24,682	12.56	24,814	12.63	24,859	12.65	24,872	12.66	24,885	12.66
22	Floral Park (pt)	964	19,753	20.49	20,285	21.04	20,306	21.06	20,321	21.08	20,334	21.09	20,347	21.11
23	Wantagh	2,682	20,513	7.65	20,887	7.79	20,972	7.82	20,972	7.82	20,946	7.81	20,894	7.79
24	Valley Stream	758	14,953	19.73	15,065	19.87	15,107	19.93	15,107	19.93	15,133	19.96	15,210	20.07
25	Merrick	2,575	21,561	8.37	21,836	8.48	21,900	8.50	21,885	8.50	21,859	8.49	21,833	8.48
26	Island Trees	1,460	19,144	13.11	19,189	13.14	19,231	13.17	19,216	13.16	19,203	13.15	19,164	13.13
27	West Hempstead	1,671	18,015	10.78	18,520	11.08	18,529	11.09	18,535	11.09	18,548	11.10	18,574	11.12
28	Long Beach	2,771	38,864	14.03	40,938	14.77	42,108	15.16	43,033	15.53	43,869	15.83	44,592	16.09
29	North Merrick	1,305	15,672	12.01	15,850	12.15	15,905	12.19	15,920	12.20	15,894	12.18	15,881	12.17
30	Valley Stream	1,106	18,198	16.45	18,414	16.65	18,427	16.66	18,427	16.66	18,453	16.68	18,453	16.68
31	Island Park	758	9,130	12.04	9,514	12.55	9,654	12.74	9,759	12.87	9,836	12.98	9,926	13.09
1	Westbury (pt)	23	4	0.17	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
5	New Hyde Park (pt)	159	2,578	16.21	2,598	16.34	2,607	16.40	2,556	16.08	2,517	15.83	2,517	15.83
Town & City Total		**71,804**	**834,719**	**11.62**	**848,816**	**11.82**	**853,069**	**11.88**	**856,059**	**11.92**	**858,631**	**11.96**	**861,209**	**11.99**
Town of North Hempstead														
1	Westbury (pt)	3,443	20,046	5.82	20,593	5.98	20,915	6.07	21,087	6.12	21,160	6.15	21,184	6.15
2	East Williston	2,690	9,357	3.48	9,478	3.52	9,564	3.56	9,621	3.58	9,682	3.60	9,725	3.62
3	Roslyn (pt)	3,362	19,086	5.68	19,198	5.71	19,252	5.73	19,378	5.76	19,573	5.82	19,696	5.86
4	Port Washington	6,905	32,135	4.65	32,843	4.76	33,046	4.79	33,389	4.84	34,009	4.93	34,297	4.97
5	New Hyde Park (pt)	1,431	22,247	15.55	22,445	15.68	22,488	15.71	22,522	15.74	22,546	15.76	22,552	15.76
6	Manhasset	3,152	15,860	5.03	15,989	5.07	16,290	5.17	16,896	5.36	17,540	5.56	17,902	5.68
7	Great Neck	7,134	47,901	6.71	48,763	6.84	49,021	6.87	49,341	6.92	49,523	6.94	49,591	6.95
9	Herricks	2,756	24,766	8.99	24,893	9.03	25,537	9.27	26,063	9.46	26,513	9.62	26,783	9.72
10	Mineola	1,603	27,727	17.30	28,205	17.60	28,355	17.69	28,447	17.75	28,544	17.81	28,562	17.82
11	Carle Place	1,047	12,015	11.48	12,250	11.70	12,272	11.72	12,261	11.71	12,273	11.72	12,269	11.72
1	North Shore (pt)	298	676	2.27	685	2.30	685	2.30	673	2.26	680	2.28	682	2.29
15	Jericho (pt)	450	186	0.41	187	0.42	251	0.56	297	0.66	350	0.78	372	0.83
22	Floral Park (pt)	151	3,005	19.90	3,030	20.07	3,030	20.07	3,019	19.99	3,031	20.07	3,035	20.10
Town Total		**34,422**	**235,007**	**6.83**	**238,559**	**6.99**	**240,706**	**6.99**	**242,994**	**7.06**	**245,424**	**7.13**	**246,650**	**7.17**

A-29 Nassau and Suffolk Counties: Existing and Projected Gross Residential Density of Towns & School Districts in Persons Per Acre, by Five Year Intervals, 1970–1995. (cont'd)

	School District	Area (Acres)	1970 Population	1970 Gross Density	1975 Population	1975 Gross Density	1980 Population	1980 Gross Density	1985 Population	1985 Gross Density	1990 Population	1990 Gross Density	1995 Population	1995 Gross Density
	Town of Oyster Bay													
1	North Shore (pt)	4,888	15,806	3.23	16,386	3.35	16,650	3.41	16,771	3.43	16,895	3.46	16,933	3.46
2	Syosset-Woodbury	8,678	31,784	3.66	34,057	3.92	35,169	4.05	35,455	4.09	35,748	4.12	36,030	4.15
3	Locust Valley-Bayville	9,825	15,174	1.54	15,970	1.63	16,787	1.71	17,236	1.75	17,562	1.79	17,806	1.81
4	Plainview-Old Bethpage	5,413	35,671	6.59	36,494	6.74	36,494	6.74	36,421	6.73	36,286	6.70	36,136	6.68
5	Glen Cove	4,336	25,770	5.94	26,880	6.20	27,878	6.43	28,339	6.54	28,699	6.62	28,981	6.68
6	Oyster Bay-E. Norwich	8,128	13,544	1.67	14,590	1.80	15,640	1.92	16,247	2.00	16,472	2.03	16,829	2.07
7	Nassau C. Hospital	105	125	1.19	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
15	Jericho (pt) ****	7,371	14,961	2.03	15,449	2.10	16,154	2.19	16,717	2.19	16,807	2.27	16,939	2.28
17	Hicksville	4,250	47,488	11.17	47,713	11.23	47,842	11.26	47,878	11.27	47,822	11.25	47,775	11.24
18	Plainedge	1,836	24,320	13.25	24,469	13.33	24,453	13.32	24,421	13.30	24,320	13.25	24,179	13.17
21	Bethpage	2,814	21,794	7.74	22,342	7.94	22,347	7.94	22,340	7.94	22,261	7.91	22,129	7.86
22	Farmingdale (pt)	3,683	45,033	12.23	45,402	12.33	45,495	12.35	45,527	12.36	45,465	12.34	45,418	12.33
23	Massapequa	6,185	60,032	9.71	61,011	9.86	61,114	9.88	61,121	9.88	61,065	9.87	61,018	9.87
2	Cold Spring Harbor (pt)	1,869	1,435	0.77	1,588	0.85	1,601	0.86	1,686	0.90	1,753	0.94	1,828	0.98
3	Roslyn (pt)	25	125	5.00	125	5.00	125	5.00	120	4.80	114	4.56	114	4.56
6	Amityville (pt)	717	6,050	8.44	6,157	8.59	6,265	8.74	6,362	8.87	6,497	9.06	6,591	9.19
Town & City Total		**70,123**	**359,112**	**5.12**	**368,572**	**5.26**	**374,014**	**5.33**	**376,641**	**5.37**	**377,766**	**5.39**	**378,706**	**5.40**
	Town of Babylon													
1	Babylon	4,770	10,965	2.30	11,602	2.43	12,215	2.56	13,057	2.74	13,599	2.85	13,611	2.85
2	West Babylon	4,110	26,151	6.36	27,629	6.72	28,732	6.99	29,200	7.10	29,778	7.25	30,022	7.30
3	North Babylon	3,270	31,456	7.65	33,421	10.22	34,156	10.45	34,250	10.47	34,286	10.49	34,298	10.49
4	Lindenhurst	3,470	43,705	12.60	46,742	13.47	49,315	14.21	51,466	14.83	52,370	15.09	53,102	15.30
5	Copiague	2,920	23,775	8.14	26,220	8.98	28,670	9.82	30,821	10.56	31,219	10.69	31,353	10.74
6	Amityville (pt)	2,200	16,871	7.67	18,527	8.42	19,874	9.03	20,903	9.50	21,590	9.81	21,602	9.82
7	Deer Park	3,670	26,801	7.30	27,385	7.46	27,753	7.56	27,800	7.57	27,908	7.60	27,920	7.61
9	Wyandanch	2,100	12,693	6.04	14,340	6.83	16,300	7.76	18,218	8.68	18,507	8.81	18,519	8.82
5	Half Hollow Hills (pt)	2,720	8,216	3.02	8,970	3.30	9,583	3.52	9,957	3.66	9,993	3.67	10,029	3.69
22	Farmingdale (pt)	2,740	2,937	1.07	3,087	1.13	3,577	1.31	3,858	1.41	3,894	1.42	3,906	1.43
Town Total		**31,970**	**203,570**	**6.37**	**217,923**	**6.82**	**230,175**	**7.20**	**239,530**	**7.49**	**243,144**	**7.61**	**244,362**	**7.64**

**** Excludes C. W. Post Center (LIU)

A-29 Nassau and Suffolk Counties: Existing and Projected Gross Residential Density of Towns & School Districts in Persons Per Acre, by Five Year Intervals, 1970—1995. (cont'd)

	School District	Area (Acres)	1970 Population	1970 Gross Density	1975 Population	1975 Gross Density	1980 Population	1980 Gross Density	1985 Population	1985 Gross Density	1990 Population	1990 Gross Density	1995 Population	1995 Gross Density
Town of Brookhaven														
1	Three Village (pt)	13,540	34,201	2.53	39,481	2.92	43,140	3.19	46,449	3.43	49,049	3.62	51,671	3.82
3	Comsewogue	4,930	17,911	3.63	19,183	3.89	20,211	4.10	21,278	4.32	22,201	4.50	23,313	4.73
4	South Country	10,910	15,007	1.38	16,343	1.50	17,485	1.60	19,855	1.82	22,027	2.02	25,818	2.37
5	Sachem (pt)	10,280	34,102	3.32	42,569	4.14	48,281	4.70	52,429	5.10	54,601	5.31	55,612	5.41
6	Port Jefferson	2,400	6,349	2.65	6,387	2.66	6,558	2.73	6,677	2.78	6,840	2.85	7,408	3.09
7	Mount Sinai	3,170	1,948	0.61	4,803	1.52	7,659	2.42	10,622	3.35	13,337	4.21	14,537	4.59
8	Miller Place	3,800	5,717	1.50	8,947	2.35	11,631	3.06	14,475	3.81	17,190	4.52	19,465	5.12
9	Rocky Point	6,230	8,255	1.33	10,345	1.66	12,059	1.94	13,955	2.24	17,213	2.76	21,257	3.41
11	Middle Country	10,000	40,861	4.09	52,912	5.29	59,195	5.92	63,640	6.36	65,812	6.58	67,328	6.73
12	Middle Island	33,620	13,803	0.41	29,878	0.89	43,016	1.28	57,535	1.71	71,654	2.13	86,817	2.58
21	South Manor	6,110	1,499	0.25	2,054	0.34	2,511	0.41	3,281	0.54	4,693	0.77	7,574	1.24
24	Patchogue-Medford	12,520	35,528	2.84	41,746	3.33	47,343	3.78	53,269	4.25	57,613	4.60	59,635	4.76
30	South Haven	4,530	643	0.14	569	0.13	626	0.14	745	0.16	962	0.21	1,821	0.40
31	West Manor	3,780	118	0.03	188	0.05	302	0.08	598	0.16	1,141	0.30	2,202	0.58
32	William Floyd	10,260	14,525	1.42	26,629	2.60	36,339	3.54	47,302	4.61	57,348	5.59	58,864	5.74
33	Center Moriches	3,000	4,745	1.58	4,805	1.60	4,919	1.64	5,097	1.70	6,075	2.03	7,844	2.61
34	East Moriches	5,040	2,161	0.43	3,059	0.61	3,744	0.74	4,514	0.90	5,709	1.13	7,630	1.88
1	Shoreham-Wading R. (pt)	4,570	2,419	0.53	4,511	0.99	6,396	1.40	8,411	1.84	10,149	2.22	12,070	2.64
2	Riverhead (pt)	2,400	344	0.14	933	0.39	1,447	0.60	2,040	0.85	2,638	1.10	3,346	1.39
5	Bayport-Blue Point (pt)	4,050	4,376	1.08	4,351	1.07	4,408	1.09	4,527	1.12	4,690	1.16	4,993	1.23
11	Eastport-East Manor (pt)	10,440	706	0.07	841	0.08	1,184	0.11	1,896	0.18	3,145	0.30	6,730	0.65
14	Fire Island (pt)	1,350	42	0.03	143	0.11	200	0.15	259	0.19	259	0.19	259	0.19
Town Total		**166,930**	**245,260**	**1.47**	**320,677**	**1.92**	**378,654**	**2.27**	**438,904**	**2.63**	**494,346**	**2.96**	**546,198**	**3.27**
Town of East Hampton														
1	East Hampton	15,130	4,799	0.32	5,576	0.37	6,387	0.42	7,506	0.50	8,428	0.56	9,499	0.63
2	Wainscott	4,510	320	0.07	376	0.08	436	0.10	529	0.12	667	0.15	828	0.18
3	Amagansett	8,160	1,126	0.14	1,360	0.17	1,670	0.20	2,083	0.26	2,452	0.30	2,881	0.35
4	Springs	7,890	2,172	0.28	2,731	0.35	3,470	0.44	4,503	0.57	5,425	0.69	6,496	0.80
5	Sag Harbor (pt)	570	835	1.46	890	1.56	947	1.66	1,037	1.82	1,114	1.95	1,203	2.11
6	Montauk	9,420	1,728	0.18	2,120	0.23	2,639	0.28	3,334	0.35	3,980	0.42	4,730	0.50
Town Total		**45,680**	**10,980**	**0.24**	**13,053**	**0.29**	**15,549**	**0.34**	**18,992**	**0.42**	**22,066**	**0.48**	**25,637**	**0.56**

A-29 Nassau and Suffolk Counties: Existing and Projected Gross Residential Density of Towns & School Districts in Persons Per Acre, by Five Year Intervals, 1970–1995. (cont'd)

	School District	Area (Acres)	1970 Population	1970 Gross Density	1975 Population	1975 Gross Density	1980 Population	1980 Gross Density	1985 Population	1985 Gross Density	1990 Population	1990 Gross Density	1995 Population	1995 Gross Density
Town of Huntington														
1	Elwood	3,870	13,586	3.51	14,044	3.63	14,398	3.72	14,759	3.81	14,934	3.86	14,952	3.86
2	Cold Spring Harbor (pt)	8,090	6,173	0.76	7,131	0.88	8,135	1.01	9,127	1.13	9,885	1.22	10,420	1.29
3	Huntington	6,260	33,862	5.41	36,701	5.86	38,826	6.20	40,629	6.49	41,969	6.70	42,826	6.84
4	Northport	9,520	38,137	4.01	40,700	4.28	43,628	4.58	45,711	4.80	47,035	4.94	47,635	5.00
5	Half Hollow Hills (pt)	16,860	31,769	1.88	33,917	2.01	35,986	2.13	38,069	2.26	39,984	2.37	40,948	2.43
6	Harborfields	4,740	19,551	4.12	21,912	4.62	24,155	5.10	25,417	5.36	25,592	5.40	25,628	5.41
10	Commack (pt)	3,460	19,000	5.49	20,607	5.96	21,315	6.16	21,405	6.19	21,463	6.20	21,481	6.21
13	South Huntington	7,180	38,094	5.31	38,631	5.38	39,103	5.45	39,644	5.52	40,227	5.60	40,869	5.69
Town Total		**59,980**	**200,172**	**3.34**	**213,643**	**3.56**	**225,546**	**3.76**	**234,761**	**3.91**	**241,089**	**4.02**	**244,759**	**4.08**
Town of Islip														
1	Bayshore	5,440	30,291	5.57	31,953	5.87	33,143	6.09	36,025	6.62	38,792	7.13	39,941	7.34
2	Islip	3,160	15,236	4.82	16,617	5.26	17,806	5.63	20,135	6.37	22,791	7.21	23,777	7.52
3	East Islip	7,500	24,545	3.27	26,743	3.57	28,378	3.78	29,542	3.94	30,870	4.12	32,007	4.27
4	Sayville	3,390	17,668	5.21	19,341	5.71	20,828	6.14	22,866	6.75	25,079	7.40	26,298	7.76
5	Bayport-Blue Point (pt)	2,270	7,063	3.11	8,360	3.68	9,550	4.21	11,297	4.98	11,784	5.19	12,248	5.40
6	Hauppauge (pt)	3,760	7,971	2.12	8,953	2.38	10,142	2.70	11,889	3.16	12,221	3.25	12,337	3.28
7	Connetquot	14,520	29,219	2.01	39,474	2.72	48,097	3.31	55,375	3.81	58,474	4.03	60,157	4.14
9	West Islip	3,960	31,478	7.95	33,061	8.35	34,102	8.61	34,393	8.69	34,570	8.73	35,034	8.85
12	Brentwood	10,270	73,352	7.14	77,086	7.51	77,613	7.56	79,442	7.74	81,664	7.95	83,498	8.13
13	Central Islip	5,420	32,149	5.93	33,138	6.11	35,857	6.62	38,268	7.06	38,543	7.11	39,587	7.30
14	Fire Island (pt)	2,050	145	0.07	158	0.08	158	0.08	187	0.09	231	0.11	231	0.11
5	Sachem (pt)	4,360	9,763	2.24	17,126	3.93	23,370	5.36	27,737	6.36	33,271	7.63	34,780	7.98
Town Total		**66,100**	**278,880**	**4.22**	**312,010**	**4.72**	**339,044**	**5.13**	**367,156**	**5.55**	**388,290**	**5.87**	**399,895**	**6.05**
Town of Riverhead														
1	Shorem-Wading R. (pt)	3,540	1,441	0.41	1,818	0.51	2,375	0.67	3,154	0.89	3,921	1.11	4,360	1.23
2	Riverhead (pt)	39,130	17,277	0.44	19,145	0.49	20,794	0.53	23,038	0.59	25,875	0.66	29,562	0.76
11	Laurel (pt)	740	191	0.26	221	0.30	243	0.33	337	0.46	567	0.77	830	1.12
Town Total		**43,410**	**18,909**	**0.44**	**21,184**	**0.49**	**23,412**	**0.54**	**26,529**	**0.61**	**30,363**	**0.70**	**34,752**	**0.80**

A-29 Nassau and Suffolk Counties: Existing and Projected Gross Residential Density of Towns & School Districts in Persons Per Acre, by Five Year Intervals, 1970–1995. (cont'd)

	School District	Area (Acres)	1970 Population	1970 Gross Density	1975 Population	1975 Gross Density	1980 Population	1980 Gross Density	1985 Population	1985 Gross Density	1990 Population	1990 Gross Density	1995 Population	1995 Gross Density
	Town of Shelter Island													
1	Shelter Island	7,350	1,644	0.22	1,918	0.26	2,228	0.30	2,790	0.38	3,324	0.45	3,960	0.54
Town Total		**7,350**	**1,644**	**0.22**	**1,918**	**0.26**	**2,228**	**0.30**	**2,790**	**0.38**	**3,324**	**0.45**	**3,960**	**0.54**
	Town of Smithown													
1	Smithown	17,120	46,459	2.71	51,886	3.03	55,371	3.23	58,314	3.41	61,340	3.58	64,260	3.75
5	Kings Park	6,740	25,106	3.72	25,941	3.85	27,273	4.05	28,884	4.29	31,069	4.61	32,568	4.83
1	Three Village (pt)	470	276	0.59	276	0.59	349	0.74	477	1.01	578	1.23	610	1.30
5	Sachem (pt)	530	2,380	4.49	3,169	5.98	3,895	7.35	4,215	7.95	4,282	8.08	4,345	8.20
6	Hauppauge (pt)	4,280	13,616	3.18	14,016	3.27	14,452	3.38	15,027	3.51	15,834	3.70	16,469	3.85
10	Commack (pt)	5,210	26,820	5.15	27,210	5.22	27,573	5.29	27,893	5.35	28,431	5.46	29,129	5.59
Town Total		**34,350**	**114,657**	**3.34**	**122,498**	**3.57**	**128,913**	**3.75**	**134,810**	**3.92**	**141,534**	**4.12**	**147,381**	**4.29**
	Town of Southampton													
1	Remsenberg	4,760	1,316	0.28	1,516	0.32	1,754	0.37	2,044	0.43	2,377	0.50	2,768	0.58
2	Westhampton Beach	13,680	4,213	0.31	4,823	0.35	5,538	0.40	6,455	0.47	7,692	0.56	9,144	0.67
3	Quogue	4,980	953	0.19	1,047	0.21	1,166	0.23	1,357	0.27	1,547	0.31	1,770	0.36
5	Hampton Bays	7,460	6,041	0.81	7,219	0.97	8,649	1.16	10,558	1.42	12,651	1.70	15,108	2.03
6	Southampton	20,110	8,472	0.42	9,252	0.46	10,121	0.50	10,885	0.54	11,837	0.59	12,954	0.64
9	Bridgehampton	6,560	1,520	0.23	1,749	0.27	2,017	0.31	2,368	0.36	2,891	0.44	3,505	0.53
10	Sagaponack	2,810	578	0.21	678	0.24	797	0.28	950	0.34	1,255	0.45	1,612	0.57
11	Eastport-East Manor (pt)	730	1,085	1.49	1,257	1.72	1,435	1.97	1,618	2.22	1,846	2.53	2,114	2.90
13	Tuckahoe	4,400	1,435	0.33	1,504	0.34	1,623	0.37	1,852	0.42	2,328	0.53	2,886	0.66
17	East Quogue	4,790	2,147	0.45	2,535	0.53	3,011	0.63	3,660	0.76	4,459	0.93	5,397	1.13
2	Riverhead (pt)	11,650	4,603	0.40	5,304	0.46	6,227	0.53	7,541	0.65	9,444	0.81	11,677	1.00
5	Sag Harbor (pt)	7,640	3,791	0.50	4,355	0.57	4,862	0.64	5,549	0.73	6,025	0.79	6,583	0.86
Town Total		**89,570**	**36,154**	**0.40**	**41,239**	**0.46**	**47,200**	**0.53**	**54,837**	**0.61**	**64,352**	**0.72**	**75,518**	**0.84**
	Town of Southold													
2	Oyster Ponds	4,870	1,350	0.28	1,618	0.33	1,892	0.39	2,228	0.46	2,576	0.53	3,032	0.62
4	Fishers Island	2,570	462	0.18	395	0.15	395	0.15	423	0.16	481	0.19	579	0.23
5	Southold	7,410	4,381	0.59	5,002	0.68	5,687	0.77	6,470	0.87	7,225	0.98	8,006	1.08
9	Mattituck	10,630	5,240	0.49	5,954	0.56	6,707	0.63	7,714	0.73	8,817	0.83	10,054	0.95
10	Greenport	6,190	4,053	0.65	4,289	0.69	4,517	0.73	4,797	0.77	5,058	0.82	5,384	0.87
11	Laurel (pt)	1,430	770	0.54	898	0.63	1,195	0.84	1,503	1.05	1,764	1.23	1,992	1.39
15	New Suffolk	800	548	0.69	577	0.72	623	0.78	679	0.85	795	0.99	925	1.16
Town Total		**33,900**	**16,804**	**0.50**	**18,733**	**0.55**	**21,016**	**0.62**	**23,814**	**0.70**	**26,716**	**0.79**	**29,972**	**0.88**

A-30 Town of Hempstead & City of Long Beach: Percent of Total Saturation Represented by Existing and Projected Population of School Districts.

School Districts	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
Hempstead 1	90.4	92.1	93.5	94.9	96.4	35,821
Uniondale 2	100.7*	101.1*	101.3*	101.7*	101.9*	35,245
East Meadow 3	105.1*	105.1*	105.1*	105.0*	104.8*	56,987
North Bellmore 4	101.1	101.4	101.4	101.5	101.5	29,308
Levittown 5	102.9	103.0	103.0	103.1	103.1	57,786
Seaford 6	94.7	95.0	96.2	96.7	97.1	20,246
Bellmore 7	96.4	97.4	97.9	97.9	97.9	15,792
Roosevelt 8	94.1	94.3	95.6	96.7	97.9	17,346
Freeport 9	89.5	89.8	90.5	91.2	92.0	41,956
Baldwin 10	101.2	101.7	101.9	102.0	102.0	34,913
Oceanside 11	103.1	103.5	103.6	103.6	103.6	40,523
Malverne 12	96.1	96.2	96.4	96.4	96.6	17,139
Valley Stream 13	98.3	98.5	98.4	98.6	98.6	30,801
Woodmere-Hewlett 14	95.3	95.5	95.7	95.9	96.3	25,387
Lawrence-Cedarhurst 15	87.8	88.2	88.5	88.7	89.0	40,471
Elmont 16	98.3	98.6	98.7	98.9	99.1	45,878
Franklin Square 17	97.5	97.7	97.8	97.9	98.2	29,456
Garden City 18	99.8*	99.7*	99.5*	99.5*	99.4*	26,061
East Rockaway 19	93.9	94.1	94.6	95.0	95.6	12,913
Lynbrook 20	92.5	92.9	93.6	94.0	94.5	22,402
Rockville Centre 21	97.0	97.5	97.7	97.7	97.8	25,448
Floral Park 22 (pt)	95.7	95.8	95.8	95.9	96.0	21,202
Wantagh 23	102.7	103.2	103.2	103.0	102.8	20,329
Valley Stream 24	96.7	96.9	96.9	97.1	97.6	15,587
Merrick 25	101.2	101.5	101.5	101.3	101.2	21,571
Island Trees 26	103.3	103.6	103.5	103.4	103.2	18,568
West Hempstead 27	97.9	98.0	98.0	98.1	98.2	18,911
Long Beach 28	79.3	81.6	83.4	85.0	86.4	51,600
North Merrick 29	101.3	101.6	101.7	101.6	101.5	15,649
Valley Stream 30	103.9	104.0	104.0	104.1	104.1	17,718
Island Park 31	90.9	92.2	93.2	94.0	94.8	10,467
Westbury 1 (pt)	–	0.0	0.0	0.0	0.0	0
New Hyde Park 5 (pt)	104.0	104.4	102.3	100.8	100.8	2,498
Town and City Total	**96.9***	**97.4***	**97.7***	**98.0***	**98.3***	**875,979**

*Household population only

A-30 Town of Hempstead & City of Long Beach: Percent of Total Saturation Represented by Existing and Projected Population of Municipalities.

Municipalities	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
Atlantic Beach Village	48.9	50.7	52.0	53.7	55.8	3,424
Bellerose Village	86.6	87.5	88.3	88.5	88.7	1,303
Cedarhurst Village	98.2	98.3	98.4	98.5	98.5	7,029
East Rockaway Village	103.5	103.5	103.4	103.5	103.6	11,501
Floral Park Village (pt)	95.3	95.3	95.3	95.4	95.4	17,513
Freeport Village	90.5	90.7	91.4	92.1	92.9	44,867
Garden City Village	100.3*	100.5*	100.5*	100.5*	100.6*	25,510
Hempstead Village	91.8	91.8	93.1	95.8	97.0	44,538
Hewlett Bay Park Village	93.7	94.1	95.1	96.6	98.5	648
Hewlett Harbor Village	95.0	95.9	97.3	97.9	98.3	1,602
Hewlett Neck Village	97.0	97.7	98.4	98.9	98.9	558
Island Park Village	92.4	93.2	93.8	94.3	95.1	5,953
Lawrence Village	92.8	93.3	93.7	94.1	94.3	7,424
Lynbrook Village	90.8	91.2	91.8	92.3	93.0	25,852
Malverne Village	98.2	98.3	98.3	98.4	98.5	10,336
Mineola Village (pt)	100.0	100.0	100.0	100.0	100.0	101
New Hyde Park Village (pt)	100.9	101.2	100.3	99.6	99.6	4,294
Rockville Centre Village	98.7	99.1	99.2	99.3	99.3	28,770
South Floral Park Village	94.6	98.1	99.5	99.8	100.1	1,143
Stewart Manor Village	100.7	100.7	100.7	100.7	100.7	2,195
Valley Stream Village	100.3	100.6	100.5	100.5	100.6	40,814
Woodsburgh Village	89.9	89.9	90.6	91.5	92.8	922
Unincorporated Area	**99.0***	**99.3***	**99.5***	**99.6***	**99.7***	**547,975**
Town Total	**97.6***	**98.0***	**98.2***	**98.5***	**98.7***	**834,272**
City of Long Beach	**83.4**	**85.6**	**87.5**	**89.3**	**91.0**	**41,707**

*Household population only

A-31 Town of North Hempstead: Percent of Total Saturation Represented by Existing and Projected Population of School Districts and Municipalities.

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
School Districts						
Westbury 1 (pt)	94.6	96.1	96.9	97.2	97.3	21,766
East Williston 2	93.7	94.5	95.1	95.7	96.1	10,117
Roslyn 3 (pt)	94.9	95.1	95.7	96.7	97.3	20,240
Port Washington 4	82.6	83.1	84.0	85.5	86.2	39,770
New Hyde Park 5 (pt)	96.2	96.2	96.6	96.7	96.7	23,324
Manhasset 6	72.7	74.1	76.8	79.8	81.4	21,990
Great Neck 7	97.6*	98.1*	98.7*	99.0*	99.2*	50,006
Herricks 9	87.0	89.2	91.1	92.7	93.6	28,613
Mineola 10	97.7	98.2	98.5	98.9	98.9	28,876
Carle Place 11	98.9	99.0	98.9	99.0	99.0	12,392
North Shore 1 (pt)	95.1	95.1	93.5	94.4	94.7	720
Jericho 15 (pt)	20.0	26.8	31.8	37.4	39.8	935
Floral Park 22 (pt)	96.3	96.3	95.9	96.3	96.4	3,147
Town Total	**91.1***	**91.9***	**92.8***	**93.7***	**94.2***	**261,896**
Municipalities						
Baxter Estates Village	92.8	94.3	94.7	95.7	96.9	1,128
East Hills Village (pt)	97.5	97.7	97.9	98.0	98.1	8,942
East Williston Village	98.1	98.1	98.0	98.2	98.2	2,900
Floral Park Village (pt)	95.6	95.9	95.9	96.2	96.2	2,058
Flower Hill Village	93.1	93.8	94.7	95.7	96.0	4,864
Great Neck Village	99.5	99.9	100.1	100.1	100.1	11,262
Great Neck Estates Village	95.1	95.2	95.3	95.5	95.7	3,346
Great Neck Plaza Village	100.7	100.7	100.9	100.9	100.6	6,038
Kensington Village	93.4	93.7	93.9	94.5	95.0	1,709
Kings Point Village	91.2*	92.0*	92.6*	93.1*	93.3*	6,300
Lake Success Village	98.3	98.3	98.3	98.5	98.3	3,315
Manorhaven Village	97.1	97.5	97.9	98.2	98.3	5,961
Mineola Village (pt)	98.7	99.2	99.6	99.6	99.7	22,580
Munsey Park Village	87.7	87.8	88.1	88.8	89.6	3,416
New Hyde Park Village (pt)	99.1	99.1	99.3	99.5	99.4	6,021
North Hills Village	2.7	13.3	26.6	39.1	46.7	9,606
Old Westbury Village (pt)	63.5	67.1	70.8	73.9	95.4	3,557
Plandome Village	90.2	90.8	92.1	93.7	94.6	1,782
Plandome Heights Village	95.0	95.0	95.4	96.0	96.0	1,105
Plandome Manor Village (pt)	99.9	97.7	97.2	98.7	97.5	831
Port Washington North Village	95.1	96.5	99.3	101.5	102.3	3,242
Roslyn Village	88.8	90.3	91.1	92.0	92.8	2,870
Roslyn Estates Village	99.7	99.7	99.0	99.0	98.6	1,449
Roslyn Harbor Village	93.7	93.7	93.3	94.6	95.0	926
Russell Gardens Village	94.7	93.8	95.8	96.2	96.2	1,200
Saddle Rock Village	99.7	99.7	98.4	99.2	98.6	898
Sands Point Village	85.6	88.0	90.0	91.0	91.5	3,506
Thomaston Village	103.6	103.5	103.8	103.8	103.6	2,666
Westbury Village	95.6	97.0	97.5	97.7	97.7	16,524
Williston Park Village	101.8	102.0	102.0	102.1	101.8	9,099
Unincorporated Area	**92.7**	**92.9**	**93.2**	**93.8**	**94.1**	**112,795**
Town Total	**91.1***	**91.9***	**92.8***	**93.7***	**94.2***	**261,896**

*Household population only

A-32 Town of Oyster Bay & City of Glen Cove: Percent of Total Saturation Represented by Existing and Projected Population of School Districts and Municipalities.

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
School Districts						
North Shore 1 (pt)	89.7	91.1	91.8	92.5	92.7	18,270
Syosset-Woodbury 2	89.6	92.5	93.3	94.0	94.8	38,017
Locust Valley-Bayville 3	78.6	82.6	84.8	86.5	87.7	20,314
Plainview-Old Bethpage 4	106.3	106.3	106.1	105.7	105.3	34,330
Glen Cove 5	86.3	89.5	91.0	92.2	93.1	31,140
Oyster Bay-East Norwich 6	68.8	73.8	76.7	77.7	79.4	21,191
Nassau County Sanatorium 7	0	0	0	0	0	0
Jericho 15 (pt)	90.2*	93.4*	95.8*	95.7*	95.3*	17,683
Hicksville 17	102.3	102.6	102.7	102.6	102.5	46,620
Plainedge 18	106.6	106.5	106.4	106.0	105.4	22,950
Bethpage 21	105.8	105.8	105.8	105.4	104.8	21,124
Farmingdale 22 (pt)	104.2	104.4	104.5	104.3	104.2	43,582
Massapequa 23	102.8	103.0	103.0	102.9	102.9	59,323
Cold Spring Harbor 2 (pt)	64.9	68.9	72.6	75.5	78.7	2,323
Roslyn 3 (pt)	109.6	109.6	105.3	100.0	100.0	114
Amityville 6 (pt)	85.8	87.3	88.7	90.6	91.9	7,174
Town and City Total	**95.9**	**97.4**	**98.0**	**98.3**	**98.6**	**384,155**
Municipalities						
Bayville Village	78.8	83.1	85.0	85.8	86.4	8,510
Brookville Village	77.1*	74.7*	79.8*	81.6*	84.1*	4,018
Centre Island Village	43.4	45.9	47.6	48.9	49.9	861
Cove Neck Village	49.0	52.0	54.4	55.9	57.2	710
East Hills Village (pt)	100.0	100.0	100.0	100.0	100.0	19
Farmingdale Village	96.3	97.3	97.8	97.9	97.9	9.801
Lattingtown Village	76.0	78.4	80.5	81.9	83.9	2,387
Laurel Hollow Village	67.9	71.3	73.9	75.5	77.7	2,150
Massapequa Park Village	102.6	102.9	102.8	102.4	102.0	21,894
Matinecock Village	78.2	81.9	85.0	88.1	91.5	1,108
Mill Neck Village	60.9	64.4	68.6	74.0	77.4	1,655
Muttontown Village	40.1	49.9	56.1	58.0	62.0	6,213
Old Brookville Village	53.5	56.6	59.3	62.5	63.6	3,513
Old Westbury Village (pt)	52.5	57.9	70.6	75.3	85.1	955
Oyster Bay Cove Village	37.8	46.4	51.5	58.0	62.7	4,210
Roslyn Harbor Village (pt)	110.0	110.0	108.0	106.3	104.9	334
Sea Cliff Village	96.9	98.6	98.6	98.6	98.7	6,279
Upper Brookville Village	50.8	57.7	64.2	68.9	74.4	2,394
Unincorporated Area	**101.4**	**103.7**	**103.9**	**103.8**	**103.6**	**276,004**
Town Total	**97.0***	**98.2***	**98.7***	**98.9***	**99.1***	**353,015**
City of Glen Cove	**86.3**	**89.5**	**91.0**	**92.2**	**93.1**	**31,140**

*Household population only

A-33 Town of Babylon: Percent of Total Saturation Represented by Existing and Projected Population of School Districts & Municipalities.

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
School Districts						
Babylon 1	86.8	91.4	97.1	101.8	101.8	13,365
West Babylon 2	91.7	95.4	97.0	98.9	99.7	30,117
North Babylon 3	97.0	99.1	99.4	99.5	99.5	34,466
Lindenhurst 4	86.7	91.5	95.5	97.2	98.5	53,889
Copiague 5	81.6	89.2	95.9	97.2	97.6	32,129
Amityville 6 (pt)	86.5	92.8	97.6	100.8	100.8	21,421
Deer Park 7	97.9	99.2	99.4	99.8	99.8	27,967
Wyandanch 9	76.2	86.6	96.8	98.3	98.4	18,823
Half Hollow Hills 5 (pt)	88.4	94.4	98.1	98.4	98.8	10,152
Farmingdale 22 (pt)	79.9	92.5	99.8	100.8	101.1	3,865
Town Total	**88.5**	**93.5**	**97.3**	**98.8**	**99.3**	**246,194**
Municipalities						
Amityville Village	96.8	97.9	98.8	101.1	101.1	11,073
Babylon Village	95.3	97.3	99.2	100.7	101.0	14,236
Lindenhurst Village	87.5	91.8	96.4	97.8	99.2	34,381
Unincorporated Area	**87.7**	**93.3**	**97.2**	**98.7**	**99.0**	**186,504**
Town Total	**88.5**	**93.5**	**97.3**	**98.8**	**99.3**	**246,194**

A-34 Town of Brookhaven: Percent of Total Saturation Represented by Existing and Projected Population of School Districts.

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
School Districts						
Three Village 1 (pt)	64.3*	71.1*	75.7*	78.5*	81.0*	61,380
Comsewogue 3	65.2	68.6	72.3	75.4	79.2	29,443
South Country 4	32.2	34.5	39.1	43.4	50.9	50,729
Sachem 5 (pt)	64.1	72.7	78.9	82.2	83.7	66,423
Port Jefferson 6	72.3	74.2	75.6	77.4	83.8	8,836
Mt. Sinai 7	28.0	44.7	61.9	77.8	84.8	17,149
Miller Place 8	37.6	48.8	60.8	72.2	81.7	23,815
Rocky Point 9	32.8	38.3	44.3	54.6	67.5	31,504
Middle Country 11	71.5	79.9	85.9	88.9	90.9	74,046
Middle Island 12	20.1	29.0	38.7	48.2	58.4	148,556
South Manor 21	7.7	9.5	12.4	17.7	28.5	26,540
Patchogue-Medford 24	56.0	63.5	71.4	77.3	80.0	74,578
South Haven 30	8.6	9,5	11.3	14.6	27.7	6,584
West Manor 31	2.6	4.2	8.4	15.9	30.8	7,160
William Floyd 32	41.8	57.1	74.3	90.1	92.5	63,633
Center Moriches 33	28.4	29.1	30.2	36.0	46.4	16,891
East Moriches 34	12.2	14.9	18.0	22.8	30.4	25,064
Shoreham-Wading River 1 (pt)	25.2	35.7	47.0	56.7	67.4	17,895
Riverhead 2 (pt)	8.9	13.7	19.4	25.1	31.9	10,504
Bayport-Bluepoint 5 (pt)	65.7	66.6	68.4	70.8	75.4	6,623
Eastport-East Manor 11 (pt)	2.0	2.8	4.4	7.3	15.7	42,823
Fire Island 14 (pt)	1.4	1.9	2.5	2.5	2.5	10,533
Town Total	**39.1**	**45.9**	**53.2**	**59.9**	**66.1**	**820,709**

A-34 Town of Brookhaven: Percent of Total Saturation Represented by Existing and Projected Population of Municipalities.

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
Municipalities						
Belle Terre Village	74.0	84.6	90.1	91.1	93.5	1,073
Bellport Village	69.8	68.5	69.9	72.6	75.7	4,089
Lake Grove Village	80.7	88.6	92.7	95.5	98.5	11,599
Old Field Village	50.6	54.1	57.8	62.1	68.3	1,627
Patchogue Village	68.5	67.5	68.9	71.6	74.0	16,464
Poquot Village	39.2	43.5	50.3	56.5	64.1	1,316
Port Jefferson Village	77.6	79.9	81.0	83.2	85.9	7,477
Shoreham Village	68.1	75.1	82.4	89.0	92.2	816
Unincorporated Area	**36.5**	**44.3**	**51.9**	**58.8**	**65.2**	**776,248**
Town Total	**38.4**	**45.9**	**53.2**	**59.9**	**66.1**	**820,709**

A-35 Town of East Hampton: Percent of Total Saturation Represented by Existing and Projected Population of School Districts and Municipalities.

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
School Districts						
East Hampton 1	21.6	24.2	28.4	31.9	35.9	25,831
Wainscott 2	5.9	13.0	15.7	19.9	24.7	6,359
Amagansett 3	11.8	14.2	17.8	20.9	24.6	11,516
Springs 4	11.6	14.7	19.1	23.1	27.6	23,532
Sag Harbor 5 (pt)	21.0	22.4	25.4	27.3	29.4	4,236
Montauk 6	10.1	12.6	16.0	19.1	22.6	20,892
Town Total	**14.1**	**17.3**	**21.1**	**24.5**	**28.5**	**92,366**
Municipalities						
East Hampton Village	39.1	42.6	47.4	51.1	55.0	4,994
Sag Harbor Village (pt)	21.8	22.4	25.4	27.3	29.4	4,085
Unincorporated Area	**12.3**	**15.0**	**19.3**	**22.7**	**26.8**	**83,287**
Town Total	**14.1**	**17.3**	**21.1**	**24.5**	**28.5**	**92,366**

A-36 Town of Huntington: Percent of Total Saturation Represented by Existing and Projected Population of School Districts and Municipalities.

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
School Districts						
Elwood 1	93.2	95.6	97.9	99.1	99.2	15,068
Cold Spring Harbor 2 (pt)	58.5	66.7	74.9	81.1	85.5	12,193
Huntington 3	82.8	87.6	91.7	94.7	96.6	44,319
Northport 4	85.1*	90.6*	94.8*	97.4*	98.5*	48,037
Half Hollow Hills 5 (pt)	78.6*	84.4*	89.4*	93.3*	95.7*	42,889
Harborfields 6	83.6	92.2	97.0	97.7	97.8	26,200
Commack 10 (pt)	102.4	98.5	98.9	99.2	99.3	20,124
South Huntington 13	91.2	92.3	93.6	95.0	96.5	42,362
Town Total	**85.1***	**89.4***	**93.0***	**95.3***	**96.8***	**251,192**
Municipalities						
Asharoken Village	28.2	31.0	42.1	54.2	67.3	2,171
Huntington Bay Village	81.0	88.2	93.3	95.8	97.4	2,303
Lloyd Harbor Village	66.2	70.6	75.0	79.3	83.9	5,444
Northport Village	84.1	91.6	96.0	98.1	100.0	9,544
Unincorporated Area	**86.2***	**90.3***	**93.8***	**96.0***	**97.2***	**231,730**
Town Total	**85.1***	**89.4***	**93.0***	**95.3***	**96.8***	**251,192**

A-37 Town of Islip: Percent of Total Saturation Represented by Existing and Projected Population of School Districts and Municipalities.

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
School Districts						
Bay Shore 1	79.6	82.5	89.7	96.6	99.4	40,166
Islip 2	69.3	74.3	84.0	95.1	99.2	23,969
East Islip 3	83.5	88.7	92.3	96.4	100.0	32,011
Sayville 4	73.2	78.8	86.5	94.9	99.5	26,437
Bayport-Bluepoint 5 (pt)	68.2	77.9	92.2	96.1	99.9	12,259
Hauppauge 6 (pt)	70.5	79.8	93.6	96.2	97.1	12,702
Connetquot 7	64.9	79.1	91.0	96.1	98.9	60,821
West Islip 9	94.1	97.1	97.9	98.4	99.7	35,123
Brentwood 12	87.0*	90.2*	93.1*	96.5*	98.9*	84,409
Central Islip 13	78.6*	87.4*	95.0*	97.0*	99.7*	39,720
Fire Island 14 (pt)	2.1	2.1	2.5	3.1	3.1	7,368
Sachem 5 (pt)	48.0	65.6	77.8	93.3	97.6	35,648
Town Total	**74.5***	**81.8***	**89.0***	**94.5***	**97.3***	**410,633**
Municipalities						
Brightwaters Village	84.2	97.4	98.9	99.4	100.0	4,015
Ocean Beach Village	6.6	6.6	7.8	9.1	9.1	1,403
Saltaire Village	1.8	1.8	2.4	3.1	3.1	1,985
Unincorporated Area	**75.0***	**82.3***	**89.6***	**95.2***	**98.1***	**403,230**
Town Total	**74.5***	**81.8***	**89.0***	**94.5***	**97.3***	**410,633**

* Household population only

A-38 Towns of Riverhead & Shelter Island: Percent of Total Saturation Represented by Existing and Projected Population of School Districts and Municipalities.

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
Riverhead School Districts						
Shoreham—Wading River 1 (pt)	37.7	49.3	65.4	81.3	90.4	4,822
Riverhead 2 (pt)	9.6	10.4	11.6	13.0	14.8	199,239
Laurel 11 (pt)	7.0	7.7	10.7	18.0	26.4	3,142
Town Total	**10.2**	**11.3**	**12.8**	**14.7**	**16.8**	**207,203**
Municipalities						
Unincorporated Area	**10.2**	**11.3**	**12.8**	**14.7**	**16.8**	**207,203**
Town Total	**10.2**	**11.3**	**12.8**	**14.7**	**16.8**	**207,203**
Shelter Island School District						
Shelter Island 1	11.3	13.1	16.4	19.6	23.3	16,983
Municipalities						
Dering Harbor Village	13.5	13.5	16.9	25.8	43.8	178
Unincorporated Area	**11.3**	**13.1**	**16.4**	**19.5**	**23.1**	**16,805**
Town Total	**11.3**	**13.1**	**16.4**	**19.6**	**23.3**	**16,983**

A-39 Town of Smithtown: Percent of Total Saturation Represented by Existing and Projected Population of School Districts and Municipalities.

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
School Districts						
Smithown 1	74.0	79.0	83.1	87.5	91.6	70,132
Kings Park 5	69.5*	76.5*	83.3*	90.3*	96.7*	33,583
Hauppauge 6 (pt)	82.4	85.0	88.4	93.1	96.8	17,005
Commack 10 (pt)	90.0	91.2	92.3	94.1	96.4	30,220
Three Village 1 (pt)	39.9	50.4	68.9	83.5	88.2	692
Sachem 5 (pt)	72.1	88.6	95.9	97.4	98.8	4,397
Town Total	**77.0***	**81.7***	**85.6***	**90.2***	**94.4***	**156,029**
Municipalities						
Head of the Harbor Village	37.3	42.5	53.9	68.3	80.7	2,804
Nissequogue Village	39.8	50.1	60.9	74.2	83.2	3,544
Village of the Branch	64.1	66.9	71.8	80.7	90.4	2,620
Unincorporated Area	**78.9***	**83.5***	**87.3***	**91.2***	**95.0***	**147,061**
Town Total	**77.0***	**81.7***	**85.6***	**90.2***	**94.4***	**156,029**

*Household population only

A-40 Town of Southampton: Percent of Total Saturation Represented by Existing and Projected Population of School Districts and Municipalities.

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
School Districts						
Remsenberg 1	19.5	22.6	26.3	30.6	35.7	7,764
Westhampton 2	30.6	35.1	40.9	48.7	57.9	15,780
Quogue 3	11.3	12.6	14.7	16.7	19.1	9,243
Hampton Bays 5	31.4	37.7	46.0	55.1	65.8	22,960
Southampton 6	21.0	23.0	24.7	26.9	29.5	43,986
Bridgehampton 9	6.8	7.9	9.2	11.3	13.7	25,639
Sagaponack 10	12.0	14.1	16.8	22.2	28.6	5,642
Eastport-East Manor 11 (pt)	42.0	47.9	54.0	61.6	70.6	2,995
Tuckahoe 13	14.5	15.6	17.8	22.4	27.8	10,382
East Quogue 17	21.1	25.1	30.5	37.1	44.9	12,014
Riverhead 1 (pt)	17.1	20.0	24.3	30.4	37.6	31,094
Sag Harbor 5 (pt)	29.0	32.4	37.0	40.1	43.9	15,011
Town Total	**20.4**	**23.3**	**27.1**	**31.8**	**37.3**	**202,510**
Municipalities						
North Haven Village	22.3	25.6	29.9	32.6	35.7	3,577
Quogue Village	12.9	14.4	16.4	18.9	21.7	7,426
Sag Harbor Village (pt)	53.4	61.3	65.9	68.8	72.3	3,273
Southampton Village	35.3	36.9	38.8	41.3	44.2	14,451
Westhampton Village	32.9	36.8	42.7	52.2	63.3	6,506
Unincorporated Area	**18.2**	**21.2**	**25.1**	**30.0**	**35.7**	**167,277**
Town Total	**20.4**	**23.3**	**27.1**	**31.8**	**37.3**	**202,510**

A-41 Town of Southold: Percent of Total Saturation Represented by Existing and Projected Population of School Districts and Municipalities.

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
School Districts						
Oyster Ponds 2	16.8	19.7	23.2	26.8	31.6	9,603
Fishers Island 4	11.4	11.4	12.2	13.9	16.7	3,468
Southold 5	25.7	29.2	33.3	37.2	41.2	19,443
Mattituck-Cutchogue 9	22.8	25.6	29.5	33.7	38.4	26,154
Greenport 10	47.9	50.5	53.6	56.5	60.1	8,949
Laurel 11 (pt)	28.4	37.8	47.5	55.8	63.0	3,162
New Suffolk 15	26.9	29.1	31.7	37.1	43.2	2,142
Town Total	**25.7**	**28.8**	**32.7**	**36.6**	**41.1**	**72,921**
Municipalities						
Greenport Village	79.3	81.5	83.2	85.1	89.2	3,174
Unincorporated Area	**23.2**	**27.2**	**30.4**	**34.4**	**38.9**	**69,747**
Town Total	**25.7**	**28.8**	**32.7**	**36.6**	**41.1**	**72,921**

A-42 **Nassau & Suffolk Counties: Percent of Total Saturation Represented by Existing and Projected Population of School Districts and Municipalities With Area in Two or More Towns.**

	1975 %	1980 %	1985 %	1990 %	1995 %	Saturation Population
Nassau County						
Farmingdale 22	102.2	103.4	104.1	104.0	104.0	47,447
Floral Park 22	95.8	95.8	95.9	96.0	96.0	24,349
Jericho 15	86.2*	89.7*	92.2*	92.4*	92.1*	18,618
New Hyde Park 5	97.0	97.2	97.1	97.1	97.1	25,822
North Shore 1	89.9	91.3	91.9	92.5	92.8	18,990
Roslyn 3	94.9	95.2	95.8	96.7	97.3	20,354
Westbury 1	94.6	96.1	96.9	97.2	97.3	21,766
Suffolk County						
Amityville 6	86.3	91.4	95.3	98.2	98.6	28,595
Bayport-Bluepoint 5	67.3	73.9	83.8	87.2	91.3	18,882
Cold Spring Harbor 2	59.5	67.1	74.5	80.2	84.4	14,516
Commack 10	95.0	97.1	97.9	99.1	100.5	50,344
Eastport-East Manor 11	4.3	5.4	7.3	10.3	18.3	48,465
Fire Island 14	1.7	2.0	2.5	2.7	2.7	17,801
Half Hollow Hills 5	80.6*	86.0*	90.7*	93.8*	95.9*	53,041
Hauppauge 6	77.3	82.8	90.6	94.4	97.0	29,707
Laurel 11	12.7	16.4	20.9	26.5	32.1	8,784
Riverhead 2	11.4	12.8	14.7	17.1	20.1	221,757
Sachem 5	59.0	71.0	79.3	86.6	89.0	106,468
Sag Harbor 5	14.8	16.4	18.6	20.2	22.0	35,330
Shoreham-Wading River 1	27.9	38.6	50.9	61.9	72.3	22,717
Three Village 1	64.0	70.1	75.7	80.0	84.2	62,072
Nassau County						
East Hills	97.5	97.7	97.9	98.0	98.1	8,961
Floral Park	95.3	95.4	95.4	95.5	95.5	19,571
Mineola	98.7	99.2	99.6	99.6	99.7	22,681
New Hyde Park	99.8	100.0	99.7	99.5	99.4	10,315
Old Westbury	61.2	65.2	70.7	74.2	77.5	4,512
Roslyn Harbor	99.4	99.4	98.5	99.0	98.9	1,260
Suffolk County						
Sag Harbor	35.9	40.1	43.4	45.8	48.5	7,358

*Household population only

Appendix B

APPENDIX B

B.0 COMPARISON OF NASSAU-SUFFOLK PROJECTIONS AND THOSE DEVELOPED BY OTHER AGENCIES

The methodology employed by Nassau-Suffolk utilizes best judgements as to the future of the area rather than precise mathematical formulas. Since it starts with small areas, the figures produced are more useful for water quality management planning, school district and municipal planning than are those initially produced for the nation or the state as a whole and apportioned to counties or sub-county areas. Table B-1, which lists the most recent federal, state and regional projections that have included separate figures for Nassau and Suffolk Counties, permits comparison of the results of the markedly different assumptions and methodologies employed. Table B-1 also lists the Nassau County Planning Commission projections of January 1, 1975.

Nassau-Suffolk's projections represent an extension of existing trends. They are not goal oriented as are the Tri-State projections. Nassau-Suffolk's projections are not overly optimistic in respect to the future economic growth of the Northeast, the New York Metropolitan Area and the Nassau-Suffolk Region, and are, therefore, considerably lower than the OBERS (Office of Business Economics-Economic Research Service) projections and somewhat lower than the Regional Plan Association projections. At the same time, the Nassau-Suffolk projections are certainly not as pessimistic as the projections of the New York State Economic Development Board for both Nassau and Suffolk Counties for the entire twenty-year period. The Nassau-Suffolk Regional Planning Board believes that EDB's 1975 estimates so understate the existing population and, by implication, current trends, that many of the subsequent calculations are adversely affected. This is particularly true in the case of Nassau County, for which the 1975 EDB estimate is 3.7% lower than the LILCO estimate used by Nassau-Suffolk, and the 1980 EDB projection is 5.4% lower than the Nassau-Suffolk projection. EDB has projected a sharp reversal of the downward trend in Nassau between 1980 and 1985 and a steady increase in population thereafter, whereas Nassau-Suffolk has projected a gradual increase throughout the planning period. Although consistently lower than the 208 estimates and projections for Suffolk County for the entire twenty year period, the EDB figures are relatively close to those of the Regional Planning Board at the beginning and end of the projection period. Differences in base year population assumptions, projection techniques, apportionment formulas and, in some instances, growth policies seem to have resulted in significant disparities among the six series of Nassau and Suffolk projections throughout the projection period.

The differences between the Nassau County Planning Commission and the Nassau-Suffolk Regional Planning Board projections for Nassau County can be attributed to the projection techniques employed. The cohort-survival approach that was used by Nassau County to develop forecasts by age and sex tends to yield a higher total population than does the land capacity and trend analysis approach, at least for an area such as Long Island.

Table B-1

POPULATION PROJECTIONS FOR THE NASSAU-SUFFOLK S.M.S.A.

Projection Series	Nassau County 1975	1980	1985	1990	1995	2000	Suffolk County 1975	1980	1985	1990	1995	2000
OBERS-LISS 6/73	1,478,535	1,528,231	1,588,902	1,649,752	1,670,284	1,690,995	1,321,110	1,515,190	1,746,741	1,978,291	2,178,649	2,379,006
Regional Planning Assn. 7/73	1,462,533	1,496,266	1,530,000	1,553,333	1,576,666	1,600,000	1,301,333	1,475,666	1,650,000	1,750,000	1,850,000	1,950,000
Port Authority 6/74	1,451,000	1,483,000	1,494,000	1,500,000	–	–	1,271,030	1,401,000	1,525,000	1,631,000	–	–
N.Y.S.E.D.B. 1/78	1,401,966	1,389,122	1,411,433	1,445,343	1,470,643	1,484,499	1,249,299	1,355,916	1,476,813	1,604,443	1,716,370	1,807,333
Nassau C.Plan. Com. 1/75	1,431,800	1,441,700	1,460,900	1,496,052	1,526,635	1,520,309	–	–	–	–	–	–
Tri-State 4/77	1,400,900*	–	–	–	1,419,900	1,470,000	1,255,300*	–	–	–	1,758,600	1,700,000
Nassau-Suffolk 10/76	1,455,979**	1,467,789	1,475,694	1,481,821	1,486,565	–	1,279,690**	1,411,737	1,542,123	1,655,224	1,752,434	–

**Federal State Cooperative Program*
***Long Island Lighting Co. estimate*