FINAL REPORT

GRAND CANAL ECOLOGICAL AND PUBLIC HEALTH ASSESSMENT

Report Tasks 1-6

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Suffolk County Department of Health Services

Division of Environmental Quality

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June 30, 2016

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Abstract

An ecological and public health assessment study was completed in 2016 for the Grand Canal and adjacent wetlands in the Town of Islip, Suffolk County, New York. The objective of the study was to collect and analyze data needed to evaluate both the public and ecological health of the Grand Canal, and to develop a methodology for assessing whether dredging combined with Integrated Marsh Management (IMM) would alleviate documented impairments. Conclusions regarding the environmental condition of the Grand Canal and adjacent wetlands are made, and recommendations for actions to improve the health of the study area are discussed. Data collected as part of the study included: surface water samples, water quality parameters, sediment cores, bathymetric data, tidal flow and flushing characterization data, flora and fauna data (vegetation, benthic, fishery, avian), and wetland characterization data. Past reports and existing data were also reviewed as part of the assessment.

The study found that the Grand Canal has experienced impaired environmental quality due to pollution sources (such as septics and stormwater) and excessive nutrient enrichment which has been exacerbated by canal geometry, inadequate tidal flow and flushing. Cultural eutrophication is evidenced by the poor water quality observed within the canal system, particularly the low levels of dissolved oxygen and elevated nutrient levels (nitrogen and phosphorus). Bacterial indicator testing showed that bacterial contamination is a potentially significant public health issue throughout the Grand Canal, as elevated coliform levels were frequently observed. Additionally, results of chemical analysis of sediments collected from the study area were found to contain some chemical constituents, including DDT and its related breakdown products, as well as various heavy metals. However, concentrations were generally consistent with other surface water bodies in the area. Bathymetric surveys of the Grand Canal indicated reduced channel depths throughout the canal system. The marshes in the study area were found to be severely stressed, particularly due to invasive species proliferation and limited tidal flushing.

The public health assessment indicated that, due to bacterial contamination, surface waters in the Grand Canal are unlikely to be safe for primary contact recreation, and that the quality of the fish inhabiting the Canal may also be compromised (e.g., for purposes of human consumption) due to contamination. Potential human health risks from the chemical contaminants detected in surface water and sediment did not exceed non-cancer thresholds or USEPA target cancer risk range. These impairments are not considered to be unique to the Grand Canal; other canals in Suffolk County have been documented as experiencing similar conditions due to the proximity of homes, recreational activities (e.g., boats), and stormwater runoff. Mosquito breeding public health risk has not been documented.

Dredging and deepening of inner portions of the canal, without widening or deepening of its connections to the Connetquot River or adjacent wetlands, would not improve flushing rates for the canal. It is not feasible to widen the canal entrances because there is residential and commercial properties on each side. In fact, deepening of the canal without increasing water flow could result in greater volumes of stagnant water in the canal and could potentially worsen environmental conditions. There are multiple anthropogenic sources of contamination associated with existing land uses that will continue to affect the canal unless long-term abatement measures are taken.

Erosion of the banks, especially along the man-made berm, is continuing along with shoreline failure from deteriorated bulkheads. These sources of sediments will continue, and dredging could actually accelerate sedimentation by causing increased instability of the canal bottom and banks. Sediment control measures, including shoreline stabilization, are needed to prevent further sedimentation in the canal. Even if dredging were determined to be a beneficial action, standard Suffolk County protocols and procedures relating to set backs from shorelines and bulkheads and maximum allowed side slopes of dredge areas could not be followed in many areas of the canal because the canal is very narrow and its banks contain bulkheads on private property.

The wetlands adjacent to the canal along the south side are experiencing continued serious degradation from inadequate tidal exchange, reduced salinity, and the spread of invasive species. Although the wetland still provides a valuable habitat for water fowl, fish and other wildlife, the quality of the wetland will continue to degrade unless remedial measures are taken. Long-term health and viability of the wetlands can be improved by implementing marsh management which significantly increases tidal exchange into and out of the wetlands. Integrated Marsh Management (IMM) would have multiple benefits of improving the quality of the wetland, improving water quality conditions in the canal, decreasing the potential for mosquito larvae production and need for mosquito control measures, and providing improved coastal resiliency and buffering during coastal storms and long-term sea level rise. Tidal exchange into the wetlands could be increased by removing significant portions or all of the man-made berms presently separating the wetlands from the canal. Significantly improving tidal exchange for the wetland would provide improved flushing of the canal by providing additional volumes of water within the tidal range which would be subject to tidal action on a daily basis. Removing the berm would allow greater volumes of water to enter and exit the canal with each tidal cycle. IMM improvements including berm alterations for the adjacent wetlands would provide long-term water quality and habitat improvements to the canal and associated wetlands.

In summary, this evaluation recommends a preferred action of an integrated marsh management (IMM) program and berm removal, to benefit the health of the proximate marsh, as well as to increase water movement/exchange in the canal. This would help alleviate eutrophic stresses, which are manifested in high nutrient concentrations and low dissolved oxygen. Selective dredging at the mouths of the northern and southern entrances to the canal could further improve circulation, but this action would be ancillary to the primary remedial measure of IMM.

Overall, this evaluation demonstrates that dredging the canal itself would not alleviate potential public health risks from pathogens, or improve an ecological impairment. Source reduction (e.g., upgrade on-site sanitary systems, or connect them to a community sewer system) could decrease discharge of bacteria and nutrients and assist in long-term water quality improvement. Further investigation beyond the scope of this study would be needed to accurately determine level of contribution from on-site sanitary systems, as well as evaluation of alternatives and design of a preferred alternative.

Executive Summary

This report presents the findings and recommendations of an ecological and public health assessment study completed in 2016 for the Grand Canal and adjacent wetlands in the Town of Islip, Suffolk County, New York. The objective of the study was to collect and analyze data in order to evaluate both the public and ecological health of the Grand Canal, and to use these data to develop a methodology for assessing whether dredging combined with Integrated Marsh Management (IMM) will alleviate impairments documented for the study area. Conclusions regarding the environmental condition of the Grand Canal and adjacent wetlands are made, and recommendations for actions to improve both the ecological and public health of the study area are discussed. Data which were collected as part of the study from the Grand Canal and adjacent wetlands included: surface water samples, water quality parameters, sediment cores, bathymetric data, tidal flow and flushing characterization data, flora and fauna data (vegetation, benthic, fishery, avian), and wetland characterization data.

Section One, *Introduction and Overview*, includes an overview of the present study, including study objectives, as well as a description of the study area. Section Two, *Review of Existing Data*, provides a review of existing data on the Grand Canal, including historical aerial photographs and data collected as part of prior studies. This section also describes studies conducted in other canal and wetland systems similar to the Grand Canal. Some of the techniques applied in these systems may also prove successful in the Grand Canal and its adjacent wetlands. Section Two also includes water quality data collected during this study within a reference area (Indian Creek) near the Grand Canal. This reference area was similar to the study area, but the ecological health was considered good. Section Three, *Data Collection and Analysis,* describes the data which were collected as part of the present study. Subsections focus on physical and biological characteristics of the Grand Canal, sediment sampling, water quality sampling, and wetlands characterization and assessment. Section Four, *Public Health Problem Evaluation and Report*, includes a detailed assessment of the public health risks associated with the study area. Section Five, *Ecological Health Evaluation and Report*, includes a detailed assessment of the ecological health of the study area. Section Six, *Assessment of Actions*, proposes a methodology for assessing potential action options for

addressing impairments in the Grand Canal and adjacent wetlands. The need for action in the study area is described, followed by a listing of alternative action options. These actions are evaluated and recommendations are provided. Section Seven, *Conclusion*, summarizes the main findings of the study and provides overall conclusions and recommendations. Technical support documentation provided in Appendices A through H.

The study found that the Grand Canal has experienced impaired environmental quality due to pollution sources (such as septics and stormwater) and excessive nutrient enrichment which has been exacerbated by canal geometry, inadequate stream flow and tidal flushing. This is evidenced by the poor water quality observed within the canal system, particularly the low levels of dissolved oxygen, high levels of bacterial contaminants (coliforms), and elevated nutrient levels (nitrogen and phosphorus). Additionally, sediments collected from the study area were found to contain DDT and metals. Bathymetric surveys of the Grand Canal indicated reduced channel depths throughout the canal system. The marshes in the Grand Canal study area were all found to be severely-stressed, particularly due to invasive species proliferation, limited tidal flushing, and shoreline erosion. Bacterial indicator testing showed that bacterial contamination is a significant public health issue throughout the Grand Canal, as elevated coliform levels were frequently observed. Surface waters in the Grand Canal are unlikely to be safe for primary contact recreation. It should be noted that there are no bathing beaches on the canal. The quality of the fish inhabiting the Grand Canal may also be compromised (e.g., for purposes of human consumption) by the contamination. It is considered likely that many of these impairments are not unique to the Grand Canal; other canals in Suffolk County have been documented as experiencing similar conditions due to the proximity of homes, recreational activities (e.g., boats), and storm water runoff to these waterways.

These impairments have been documented for over a decade in the Grand Canal as evidenced in the 2005 ‘Grand Canal Environmental Assessment Report’ published by Suffolk County Department of Health Services and Suffolk County Department of Public Works. This report was based on data collected in the Grand Canal in 2004. Generally conditions have appeared to have worsened over the past decade.

Summary of Conclusions and Recommendations

The investigation of water quality, sediments, and physical conditions of the Grand Canal performed as part of this study indicated that the subject water body is in a stressed degraded condition resulting from input of containments and nutrients, poor circulation, shoreline erosion, and degraded wetland systems adjacent to the canal. Impaired water quality conditions were observed and further indicated by sample collection and analysis. The overall conclusions of this study and recommendations for follow-up actions are presented below:

- Bacteria levels in canal water are elevated, and discharges from on-site sanitary systems appear to be major contributors. Improvements and upgrade of on-site sanitary systems would decrease discharge of bacteria and nutrients to surface waters and assist in long term water quality improvement. Further investigation beyond the scope of this study would be required to determine the level of contribution from the on-site sanitary systems.
- Dredging and deepening of inner portions of the canal, without widening or deepening of its connections to the Connetquot River or adjacent wetlands, will not improve flushing rates for the canal. However, due to the commercial and residential development at the mouths of the canal, widening these areas is not a feasible option. In fact, deepening of the canal without increasing water flow could result in greater volumes of stagnant water in the canal. The exception would be dredging the shoals located in the southern portion of the canal, which could provide slight increase in tidal exchange by slightly reducing partial barriers to water exchange between the canal and Connetquot River. Improvements would be minimal and short-lived as sediments re-accumulate.
- Dredging would result in the removal of contaminated sediments; however, the removal would not result in improved long-term conditions unless the sources of contamination are controlled (e.g., sanitary waste, stormwater, etc.). There are multiple anthropogenic sources of contamination associated with existing land uses that will continue to affect the canal unless long-term abatement measures are taken.
- Erosion of the banks, especially along the man-made berm, is continuing along with shoreline failure from deteriorated bulkheads. These sources of sediments will continue, and dredging could actually accelerate sedimentation by causing increased instability of

the canal bottom and banks. Sediment control measures, including shoreline stabilization, are needed to prevent further sedimentation of the canal.

- The public health and environmental risk assessments performed for surface water and sediments did not indicate a level of risk higher than would be expected in a water body subject to anthropogenic inputs in a semi-developed area. In other words, the risks from contamination are not higher than usual for similar developed areas in the region.
- The wetlands adjacent to the canal along the south side are experiencing continued serious degradation from inadequate tidal exchange, reduced salinity, and the spread of invasive species. Although the wetland still provides a valuable habitat for water fowl, fish and other wildlife, the quality of the wetland will continue to degrade unless remedial measures are taken.
- Long-term health and viability of the wetlands can be improved by implementing marsh management which significantly increases tidal exchange into and out of the wetlands. Integrated Marsh Management (IMM) would have multiple benefits of improving the quality of the wetland, improving water quality conditions in the canal, decreasing the potential for mosquito larvae production and need for mosquito control measures, and providing improved coastal resiliency and buffering during coastal storms and long-term sea level rise. Tidal exchange into the wetlands could be increased by removing significant portions or all of the man-made berms presently separating the wetlands from the canal.
- Significantly improving tidal exchange for the wetland would provide improved flushing of the canal by providing additional volumes of water within the tidal range which would be subject to tidal action on a daily basis. Removing the berm would allow great volumes of water to enter and exit the canal with each tidal cycle.
- IMM improvements including berm alterations for the adjacent wetlands would provide long-term water quality and habitat improvements to the canal and associated wetlands. IMM measures should include creation of additional channels and areas of open water, removal of invasive species, and grading modifications to provide improved water flow.
- Although not found to be the primary effect on bacterial levels in the canal, direct stormwater discharges contribute to the input of nutrients and other containments. Actions to eliminate direct discharges and provide increased treatment of stormwater runoff,

through application of bio-swales, constructed wetlands, and similar technologies, will contribute to long-term water quality improvements.

- The investigation indicated that significant portions of the canal have debris including tree debris, limbs and cuttings. This debris, especially within the portion of the water column in the tidal range, can restrict water flow and accelerate the sedimentation and accumulation of additional debris. Action to remove the limbs, cuttings and similar debris would improve water flow, reduce accumulation of additional debris, and have short-term benefits to water quality.
- Even if dredging was determined to be a beneficial action, standard Suffolk County protocol and procedures relating to set backs from shorelines and bulkheads and maximum allowed side slopes of dredge areas could not be followed in many areas of the canal because the canal is very narrow and it banks contain bulkheads on private property. Granting of legal releases, hold-harmless agreements and similar legal protection to the County by home owners may protect the County from liability relating to damaged or undermined bulkheads, but would not prevent the physical erosion of the shoreline and accelerated release of sediment to the channel that would occur from shoreline failures relating to bulkhead failures.
- It should be noted that the New York Rising Oakdale / West Sayville Report (March 2014) identified an improvement project that would improve tidal exchange to the Pickman-Remmer Wetland by installing seven 24-inch pipes through the berm and other improvements. Benefits would include improved tidal flow into the wetlands and greater capacity of the wetland to absorb storm surge and stormwater runoff. The findings of the present investigation concur with this finding, except that considerations should be given to providing even greater channels for tidal exchange by removal of the berm or portions of the berm.

Section 1. Introduction and Overview

1.0 Technical Services Requirement

This report, prepared by Cashin Associates, P.C. (CA), presents the findings and recommendations for the Grand Canal Analysis and Assessment Services project requested by Suffolk County Department of Health Services (SCDHS), Division of Environmental Quality (Suffolk County Contract No. 525-5200-1180-00-0001). It has been prepared in accordance with the Technical Specifications and Description of Services for the project.

The main tasks completed included: start-up meeting and monthly progress meetings (Task 1); review of existing data (Task 2); data collection and analysis (Task 3); public health problem evaluation and report (Task 4); ecological health evaluation and report (Task 5); and final project report (Task 6). The findings of these tasks have been presented in interim reports which have been reviewed by the County during the course of the study, and these interim reports have been revised by CA based on County review.

This project report (Task 6) specifically includes: an executive summary; data findings from Tasks 2 and 3; reports generated in Tasks 4 and 5; and a proposed methodology for assessment of whether dredging and integrated marsh management (IMM) will alleviate problems identified with the Grand Canal (identified as part of Tasks 2, 3, 4 and 5). These proposed methods were applied to determine the potential for dredging and IMM to alleviate public and ecological health problems within the Grand Canal and adjacent wetlands.

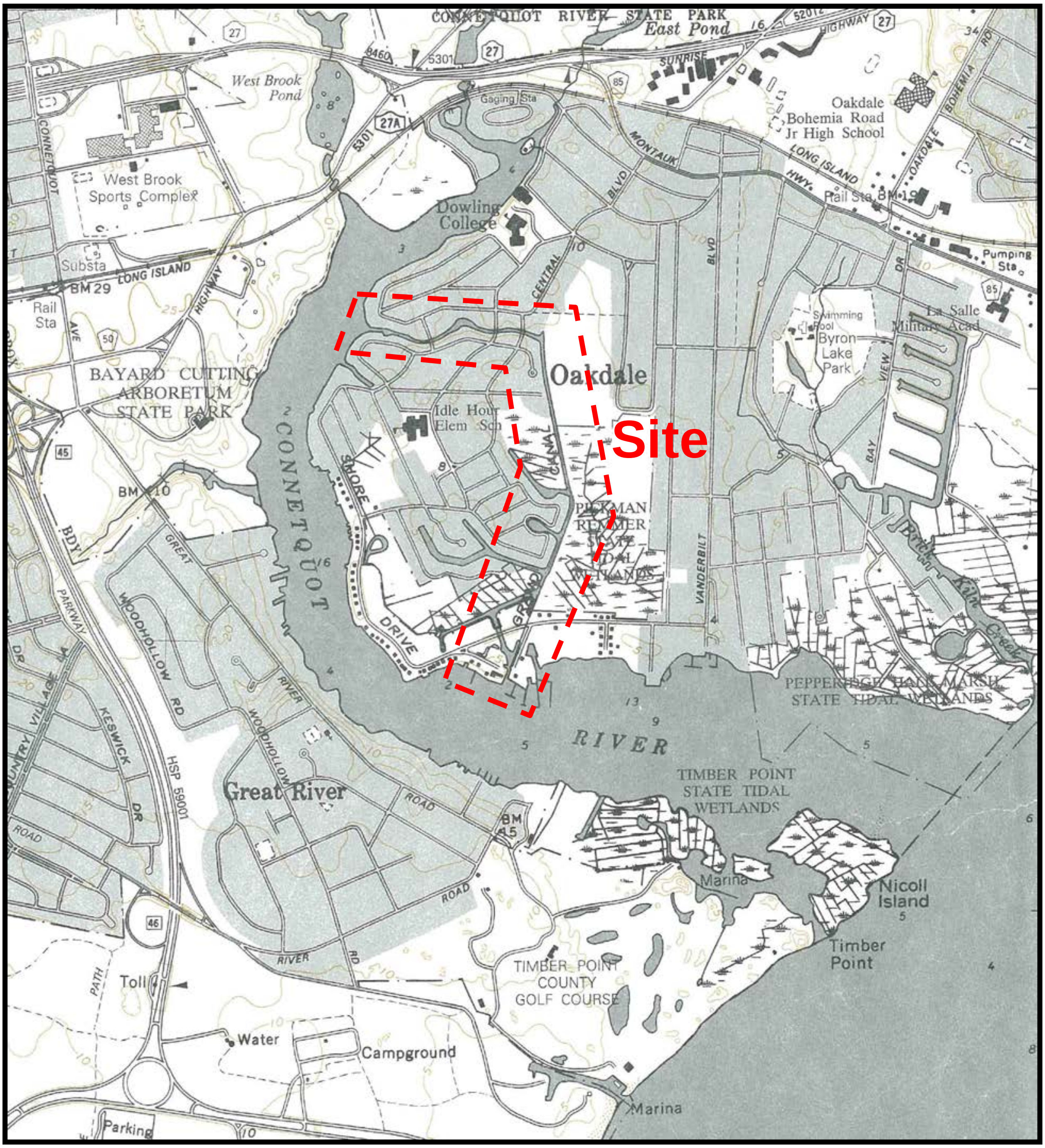
1.1 Study Overview

The report presents the findings of a detailed study assessing the ecological and public health of the Grand Canal and adjacent wetlands, located in Oakdale, New York. In addition, the report proposes procedures and methodologies for assessing whether dredging combined with integrated marsh management (IMM) actions can alleviate any public health problems or improve the ecological health of the canal and adjacent wetlands. These proposed procedures and methodologies are used to evaluate potential courses of action to improve the Grand Canal and associated wetlands. Specific recommendations resulting from this analysis are presented in this project report.

Specifics tasks and subtasks performed as part of the study included: collecting and analyzing sediment cores for grain size distribution and possible contamination; collecting and analyzing surface water samples for various water quality parameters and for possible contamination; conducting a bathymetric survey of the canal system; evaluating tidal flow into the canal system and adjacent wetlands; characterizing adjacent wetlands; documenting the flora and fauna present; and defining specific potential health problems associated with the system, including those related to mosquitos.

1.2 Site Description

The Grand Canal is a man-made waterway consisting of a series of shallow, interconnected canals, located on the east side of the Connetquot River in Oakdale, Town of Islip, New York (Map 1). According to the 'Grand Canal Environmental Assessment Report' (2005) published by Suffolk County Department of Health Services (SCDHS) and Suffolk County Department of Public Works (SCDPW), the canal was built sometime prior to 1920 to serve the former 'Idle Hour' estate of William K. Vanderbilt. The canal system includes a main channel with two openings to the Connetquot River. This main channel, which is the primary subject of this study, is approximately 8,000 feet in length and 20 feet wide and variable in depth. The Grand Canal system also includes several inner finger canals extending into residential areas; these inner canals are connected to the main channel. The Grand Canal is unique in that it has two interfaces that open into the Connetquot River. One opening is in the midsection of the tidal portion of the Connetquot River and the second opening is in the southern section of the tidal portion of the river. This enables the river flow to potentially have an influence on the currents and tidal flow in the Grand Canal.



New York State Department of Transportation
Bay Shore East Quadrangle, New York-Suffolk Co
7.5 Minute Series, 1991, Digital Edition
Scale 1:24000

MAP 1

Grand Canal Study Area

14040.1

The Grand Canal is also integral to a wetland system. The canal's northern opening is surrounded by residential properties and the southern opening is bordered on both sides by commercial properties, including a marina and restaurant. The land area surrounding the northern section of the main canal, that runs east-west, is residential. For the north-south section of the main channel, the land to the west is a mixture of residential properties and tidal wetlands. The adjacent land area to the east is dominated by an extensive tidal and freshwater wetland complex, known as the Pickman-Remmer Wetlands. This wetland complex is owned by the State of New York and is managed by the New York State Department of Environmental Conservation (NYSDEC).

The surrounding area is highly developed predominantly with single family homes that utilize on-site sanitary systems which discharge directly to groundwater. In addition, Dowling College is located immediately up-gradient from the northeastern region of the canal system. Dowling College operates an advanced wastewater treatment plant which discharges to groundwater. The Dowling College wastewater treatment plant was subject to a consent order issued by the County in 2014. In addition to the high-density residential housing and the nearby college, a waterfront restaurant and commercial marina are also located on the banks of the Grand Canal.

1.3 Background Information

For over a decade, the Grand Canal has been the subject of complaints by area residents concerned with potential ecological and public health problems associated with the canal system. Specific issues raised include the potential for mosquito breeding and epizootic activity, possible contamination of the canal system with pesticides, reductions in water quality, shoaling, and reduced tidal flushing. These issues prompted a formal investigation into the potential issues associated with the Grand Canal system by Suffolk County.

In June 2004, a multi-agency strategy was developed to assess the environmental conditions of the Grand Canal. The agencies included in the taskforce were the Suffolk County Executive's Office, Suffolk County Department of Health Services (SCDHS), and Suffolk County Department of Public Works (SCDPW). The study's objective was to document existing ecological conditions in the Grand Canal, to determine whether a risk to public health exists, and to determine if dredging the canal would reduce that risk. Specific tasks carried out for the study included: water quality monitoring to measure dissolved oxygen, salinity and turbidity, and sampling for bacteria, nutrients, and contaminants; mosquito larval surveillance in the canal; and an overview of potential solutions, particularly dredging and integrated marsh management, that may alleviate ecological and environmental problems associated with the canal system.

In 2005, the results of the Suffolk County study were presented by the SCDHS and SCDPW in the 'Grand Canal Environmental Assessment Report'. The report concluded that the water quality in the canal was significantly impacted by nutrient enrichment, and potentially, by pathogen contamination. The excessive levels of nitrogen found in the canal suggested that algal blooms, and the consequential reduction in water clarity and depleted levels of dissolved oxygen, were a common occurrence. Potential sources of contamination included storm water runoff from fertilized lawns and roadways, area wildlife, and perhaps, improperly functioning residential septic systems. The study determined that the effect of these sources may be exacerbated by the canal's low tidal exchange and lack of flushing. The 2005 report concluded that dredging the canal in conjunction with a comprehensive Open Marsh Water Management (OMWM) strategy would provide greater water flows to wetlands, thus potentially reducing mosquito breeding and decreasing the need for annual larviciding, and may enhance the ecology of the canal system.

The suggestion that conditions in the Grand Canal system may collectively represent a public health risk has prompted the need for a more detailed examination of these conditions in order to determine the sources of the impacts and the extent of the health risks. Furthermore, the 2005 study indicated the need for a more detailed analysis of ecological conditions in the canal system and adjacent wetlands. The present study serves to fulfill these needs and presents a critical analysis of possible remediation actions to mitigate the issues identified in the Grand Canal system.

Section 2. Review of Existing Data (Task 2)

2.0 Grand Canal Environmental Assessment Report- 2005

Microbial, chemical, and vector data were collected in 2004 for the Grand Canal system as part of the Grand Canal Environmental Assessment (2005); results were published by SCDHS and SCDPW in the 2005 'Grand Canal Environmental Assessment Report'.

Water quality monitoring was performed at 12 sites within the Grand Canal on four occasions from July to September 2004. Parameters analyzed included nutrients, salinity, coliform bacteria, and various organic constituents (e.g., solvents, pesticides, etc.). Physical measurements (depth, temperature, dissolved oxygen, salinity, secchi) were also recorded at each site. Main findings from the water monitoring were:

- Coliform levels found in the Grand Canal were found to be consistently elevated, with total coliform averages ranging from 290 to 5,713 organisms/100 mL and fecal coliform averages ranging from 130 to 967 organisms/100 mL. Report authors concluded that these levels would make the waters of Grand Canal unsuitable for bathing or shellfishing.
- Average dissolved inorganic nitrogen (DIN) levels found in Grand Canal ranged from 0.09 to 0.67 mg/L. This is considerably higher than long-term DIN levels typically found in the Great South Bay (less than 0.05 mg/l).
- Results were negative for all pesticide analytes, including the larvicide that is used in adjacent wetlands by Suffolk County Vector control.
- The gasoline additive MTBE was detected.

The report summarized that the water quality in the canal is significantly impacted by nutrient enrichment, and potentially, by pathogen contamination. High nitrogen levels and low dissolved oxygen levels were common occurrences. The study also found that although mosquitoes did not breed directly within the Grand Canal, the adjacent wetlands were primary breeding areas. West

Nile Virus affected birds and mosquito breeding pools were identified in the region. However, none of these areas/vectors were identified within the canal system or associated wetlands.

The 2005 report concluded that dredging the Grand Canal in conjunction with a comprehensive Open Marsh Water Management (OMWM) strategy would improve the ecology of the canal system, particularly by improving water quality and reducing the use of pesticides. The report does note, however, that any dredging project must be conducted in a manner which avoids adverse impacts to existing fish and wildlife habitat.

2.1 Historical Aerial Photographs

CA reviewed the history of the Grand Canal using historical aerial photographs. CA reviewed historical aerial photographs for the years 1947 through 2013 (intermittent) which were obtained from the Suffolk County GIS Viewer website. Aerial photographs are included as Appendix B.

In 1947, the Grand Canal appears similarly as it exists today with a few exceptions. The most notable differences are the amount of residential development, the re-configuration of the southern portion of the canal system, and the addition of a finger canal. Similar to all communities located along the south shore of Long Island, residential development in proximity to Grand Canal has increased over the last half century. Prior to 1947, the majority of the residential development was located along the Connetquot River and along the historically existing finger canals. Other areas in the study area were primarily undeveloped.

From 1962 and 1978, the largest amount of new development (mainly residential) in the area was observed; the conversion of undeveloped land and wetlands into developed areas continued through 2010. From 2010 to 2013 no new development appeared in the aerials.

The southern portion of the Grand Canal system has changed significantly over the last half century, especially when the Shore Drive bridge was constructed over the canal. Originally the southern portion of the Grand Canal system ran along what is now Shore Drive. However, sometime between 1947 to 1962, and again sometime between 1962 and 1978, changes were made near the southern entrance of Grand Canal. These cumulative changes altered the straight-line path of the canal where it enters the mouth of the Connetquot River and created a narrow southern entrance with two 90 degree turns. In addition, the original location of the Grand Canal which ran along what is now Shore Drive was physically moved landward approximately 50 to 100 feet. Also, sometime between 1962 and 1978, a new finger canal was excavated between the currently existing roads of Riverview Court and Roxbury Court. These changes resulted in substantial physical restrictions to tidal exchange at the southern entrance from the Connetquot River.

2.2 New York Rising Oakdale/West Sayville Report

In response to the catastrophic damage inflicted by Superstorm Sandy (2012), Hurricane Irene (2011), and Tropical Storm Lee (2011), the State of New York developed a community-driven planning program for reconstruction that focuses on resiliency and sustainability. The New York Rising Community Reconstruction (NYRCR) Program combines local community participation with technical experts to identify the most pressing needs and the most innovative and appropriate solutions. The Oakdale/West Sayville NYRCR, which was finalized in March 2014, is one of 45 plans statewide and one of eight in Suffolk County. The plan identified 12 projects that align with the objectives of the NYRCR program and the local community. The projects included: Living Marsh-Grand Canal Levee Improvement, Check-Valves on Drainage Outfalls, and Public Access to Waterfront/Coastal Restoration, among other projects. These three projects are highlighted here due to how they may relate to this overall study on the Grand Canal and a brief description of each is described below:

The Living Marsh-Grand Canal Levee Improvement project aims to improve the tidal exchange between Grand Canal and the Pickman-Remmer Wetland. The earthen berm created when the Grand Canal was excavated over 100 years ago has closed off the wetland from its natural tidal exchange. The purpose of the Living Marsh-Grand Canal Levee Improvement project is to increase the wetland's capacity to absorb storm surges and stormwater runoff, as well as improve the health of wetland. The project is estimated to cost $410,000 which includes an engineering study to identify the most appropriate method for increased tidal flow. The project also specifically calls for the installation of seven 24-inch pipes through the levee (earthen berm), and a hiking trail on top of the berm. The hiking trail is intended to terminate before the properties located to the south of the berm. However, in a separate project (Multimodal Transportation/Tourism Development), some of the private properties will potentially be included in the NY Rising Buyout Program and the trail could be continued through to Shore Drive.

The Backflow Prevention/Check Valves for Storm Drainage Systems project aims to help control flooding and provide storm surge protection. Vulnerable outfalls would be replaced with new catch basins and in-line check valves that would only allow storm water to flow seaward. The project is estimated to cost $300,000 which includes 12 installations. It is possible that some of the outfall pipes located in the study area could benefit from these types of structure. These areas are very limited in extent, and there effect on tidal flow is not considered substantial, especially considering that the entrance of the canal for Connetquot River is very restricted.

The main entrance to the canal from the Connetquot River is restricted by the narrow opening between the bulkheads of two private properties, Oakdale Yacht Club at the east side and Snapper inn Restaurant on the west side. The width of the opening between the bulkheads is approximately 24 feet, representing one of the narrowest segments of the entire canal. Based on the bathymetric survey, the cross-sectional area of the opening is estimated at 123 square feet. The cross-sectional area of the canal upstream of the Shore Drive Bridge and at approximately 1,800 feet beyond that are 148 and 172 square feet, respectively. Cross-sectional area directly affect the amount of water that can be exchanged on a tidal cycle. The geometry of the entrance represents a restriction to tidal exchange for the canal.

The Public Access to the Waterfront and Coastal Restoration project aims to restore waterfront properties to their natural state that are acquired through the NY Rising Buyout Program. This would include the removal of structures and the restoration of natural shoreline grades with appropriate soils and vegetation. In addition, one or more of the restored properties may be open to the public for recreational purposes. The purpose of this project is to increase storm surge protection, increase resilience and environmental benefits of coastal natural habitats and increase public access to recreational opportunities. The project is estimated to cost $620,000.

2.3 Data on Other Canal and Wetland Systems

2.3.0 Wertheim National Wildlife Refuge

Wertheim National Wildlife Refuge is located on an urbanized watershed in the Town of Brookhaven on the south shore of Long Island approximately 14 miles east of the Grand Canal. The refuge and adjacent wetlands make up the largest continuous salt marsh on Long Island, New York. Similar to the Grand Canal, the Wertheim marshes have been subject to numerous anthropogenic stressors, including urbanization, ditching and tidal restrictions. The marshes also produced several mosquito vector species (Rochlin et al. 2012).

A large scale, long-term integrated marsh management project (2003 to 2010) was undertaken at the Wertheim Refuge. Two treatment marshes within the refuge were subject to several management methods, including reconfiguration of the tidal flow network by creating new tidal channels and redesigning fish habitats to closely resemble natural marsh pools. The new channel network enabled tidal waters to reach high marsh mosquito larval habitats and areas with dense invasive species coverage (*Phragmites australis).* Salinity, water table depth, vegetation, nekton, birds, and mosquitos were monitored for one to three years prior to modification and three to five years post-modification (monitoring occurred from 2003 to 2010). Parameters were also monitored in two adjacent control marshes (Rochlin et al., 2012).

The treatment marshes experienced decreased mosquito production, reduced coverage of *Phragmites australis*, an expansion of native marsh vegetation, increased nekton species abundance, and increased avian and waterbird diversity and abundance. In the treatment marshes, the frequency of finding mosquito larvae decreased 70% after marsh management; the control areas did not see the same decrease. The magnitude of mosquito larvae production decreased in the treatment marshes, but not in the controls. Considerable changes in marsh vegetation were observed in the treatment marshes, particularly a decrease in *Phragmites australis* and an increase in native vegetation. The modifications in the treatment marshes led to significant changes in nekton populations and increases in bird diversity and abundance (Rochlin et al., 2012).

The Wertheim project demonstrated the potential benefits that can be achieved by integrated marsh management approaches (Rochlin et al., 2012). Some of the techniques applied to the treatments marshes in the Wertheim Refuge (e.g., increasing tidal flow into the marsh) may prove successful in other similar marshes, such as the wetlands adjacent to the Grand Canal.

2.3.1 Green’s Creek and Brown’s River

A Watershed Management Plan (WMP) was developed for Green’s Creek and Brown’s River in response to evidence that the waterways may have been impaired (Cashin Associates, 2007). The Plan’s objective was to protect, restore, and enhance water quality and living resources in the canals. Green’s Creek and Brown’s River are adjacent canals located in the Town of Islip, on the south shore of Long Island approximately five miles east of the Grand Canal. Impairments identified as impacting the water quality in Green’s Creek and Brown’s River included nutrient enrichment, toxic substances (e.g., oils, pesticides), pathogens (e.g., *E. Coli)*, and oxygen demanding wastes (e.g., sewage). The 2007 Plan recommended a series of measures to improve Green’s Creek and Brown’s River, including: habitat protection and management, such as tidal flow improvement; invasive species removal; hydrologic improvements; and improvements to fish passages. The Plan also recommended point and nonpoint source pollution management including pesticide use reduction and installation of drainage infrastructure to capture and recharge storm water (Cashin Associates, 2007).

The Grand Canal has experienced some similar impairments and stressors to those of Green's Creek and Brown's River (these issues are discussed in detail throughout this Project Report). Similar impairments include tidal flow restrictions and invasive species proliferation. As a result, some of the recommended action measures for Green's Creek and Brown's River may also be effective at improving the ecological and public health of the Grand Canal. Particularly, the WMP suggests that actions to improve tidal flow in restricted areas of Green's Creek and Brown's River can assist with restoring native vegetative and wildlife habitat.

2.4 Reference Area

CA identified a reference area similar to the Grand Canal study area but where the water quality is considered good, wetlands are considered healthy, and water flow is considered optimal for maintenance of water/wetlands quality. The reference area selected by CA was Indian Creek which is located on the border of West Sayville and Oakdale approximately two miles east of the Grand Canal (Map 2).

CA environmental personnel collected data at the Indian Creek reference area on June 16, and September 3, 2015. This creek was chosen as the reference wetland due to its relatively healthy appearance (e.g., clean and not dominated by *Phramites australis*) and its proximity and similarities to the Grand Canal. Similarities between the canal systems include their tidal ranges, their use for vessel docking, and their integral connections to wetlands. On June 16, 2015 physical water quality parameters were measured in ten locations throughout the reference canal and wetland system that were accessible by kayak. The site locations included two within the main canal (Ref 8 and 9), four along a secondary, dead-end, canal (Ref 1, 2, 5, and 6), two within wetlands via mosquito ditches (Ref 3 and 4), one at the northern most kayak-accessible area (Ref 7), and one taken from the Great South Bay immediately outside the main channel/boat basin. The observations were made during mid-incoming tide and over an inch of rain had fallen on the previous day. Table 1 shows the water quality parameter data for the reference area collected on June 16.

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MAP 2

Indian Creek Reference Area

Table 1. June Reference Area Physical Water Quality

Site ID	Temperature (°C)	Salinity (PSU)	D.O. (mg/L)	Turbidity (FNU)	Depth (feet)	Latitude (°N)	Longitude (°W)
Ref 1	22.37	19.37	2.15	8.30	2	40.72040	73.10015
Ref 2	22.59	21.29	4.56	6.91	2	40.72083	73.10109
Ref 3	23.02	24.19	6.46	9.41	2	40.72069	73.10302
Ref 4	22.88	22.29	6.38	8.03	3	40.72023	73.10342
Ref 5	23.28	24.58	7.16	19.73	3	40.72159	73.10372
Ref 6	23.25	20.21	6.50	6.13	3.5	40.72246	73.10468
Ref 7	19.56	11.53	3.85	5.00	3	40.72851	73.10987
Ref 8	23.30	22.43	6.37	7.05	3.5	40.72208	73.10768
Ref 9	23.46	25.45	7.44	8.52	6	40.72126	73.11078
Ref 10	23.39	24.25	8.14	7.90	8	40.72038	73.11139

On September 3, 2015, physical water quality parameters were measured at two locations within the Indian Creek reference area. Water samples were also collected from Indian Creek on this day for bacterial analysis. This day was selected for reference area bacterial sampling because it was the same day that dry-weather bacterial samples were taken in the Grand Canal. This allowed for fair comparisons to be made between the data from the Grand Canal and the reference area. In the reference area, one water sample was taken at the intersection of the main channel and a secondary channel in a low flow/stagnant area. A second sample was taken from within the main channel at a discharging conduit that connects to the adjacent wetlands. The first sample location, WL-Ref-1 was chosen to simulate the conditions of a trapped/stagnant area of water. The second location was chosen to simulate the conditions of tidal water exchanges within adjacent wetlands. These samples and observations were collected during the beginning of an incoming tide and no rain had been reported for several previous consecutive days. Table 2 shows the physical and bacterial water quality data collected from the reference area on September 3.

Table 2. September Reference Area Physical and Bacterial Water Quality

Site ID*	Temp. (°C)	Salinity (PSU)	D.O. (mg/L)	Turbidity (FNU)	Depth (feet)	Enter-ococci	Total Coliforms	Fecal Coliforms
						(MPN/100mL) 10X Dilution		
Ref-1	24.14	22.56	1.70	8.4	2	776	2400	2400
Ref-2	25.02	22.62	1.62	7.9	3	292	300	300

*GPS coordinates: Ref 1 – 40.72347, 73.10586; Ref 2 – 40.72214, 73.10837

During the June water quality monitoring event, the dissolved oxygen (DO) data were the most notable observations. June DO levels ranged from 2.15 to 8.14 mg/L with an average of 5.9 mg/L. However, the September round of sampling in Indian Creek had much lower dissolved oxygen levels (average of 1.66 mg/L). The average DO was 5.2 mg/L when data from both sampling events were averaged for Indian Creek.

DO levels from Indian Creek were compared to those from the Grand Canal. The highest average daily DO concentration for the Grand Canal sampling events was 3.3 mg/L (details of these sampling events in the Grand Canal are provided in section 3). This comparison suggests that DO levels are generally lower in the Grand Canal than the reference area. Salinity levels appeared to be similar in Indian Creek and the Grand Canal. Daily salinity averages for the Grand Canal sampling events ranged from approximately 18 to 22 PSU; daily averages for Indian Creek (not including the northernmost head waters or the Great South Bay observations) was 18.5 PSU. However, considering the direct freshwater input that was observed at the northernmost sample site in Indian Creek, but the relatively similar daily average salinity levels with the Grand Canal, it is possible that Indian Creek has a much greater tidal exchange with the Great South Bay than the Grand Canal.

With regards to bacterial sampling, data indicated elevated coliform levels in both the reference canal and the Grand Canal. However, the bacterial levels in the Grand Canal exceeded those reported for the reference area. In the reference area, coliform levels were much higher from the sampling site representing a region with stagnant waters compared to the sampling site with flowing waters. This suggests that stagnant areas of the canal are more likely to have elevated bacteria levels. However, caution should be taken when comparing data from one canal to the other due to the multitude of factors (e.g., tidal state, weather, time of day, season, limited sampling at the reference site) which may influence water quality. Therefore, the information and observations garnered from the reference area can only provide anecdotal and preliminary conclusions.

The 'Grand Canal Public Health Evaluation Report and Sediment Risk Assessment' (Appendix C) compares the water quality results from the reference area to those from the Grand Canal in terms of public health impacts. When comparing data from the reference location to that from the Grand Canal, it was found that neither the Grand Canal nor the reference area surface waters were likely to be safe for primary contact recreation due to unsuitable bacteriological quality.

Section 3. Data Collection and Analysis (Task 3)

Field data were collected in the Grand Canal using marine vessels by CA environmental personnel during 2014, 2015, and 2016. Data collection included water samples, sediment cores, benthic samples, a bathymetric survey, a canal feature inventory, and a flow/flushing assessment.

3.0 Physical Characteristics of the Water Body (Subtask 3a)

A hydrographic survey of the Grand Canal was conducted by CA to define physical characteristics of the canal system. This part of the study included a bathymetric survey to provide canal cross sections and profiles, characterization of bottom sediments, an assessment of stream flow and tidal flushing in the canal and adjacent wetlands, as well as identification of any potential restrictions to water flow and flushing. This part of the study also included: an analysis of the canal's benthic community; an Essential Fish Habitat Assessment; and supplemental finfish sampling.

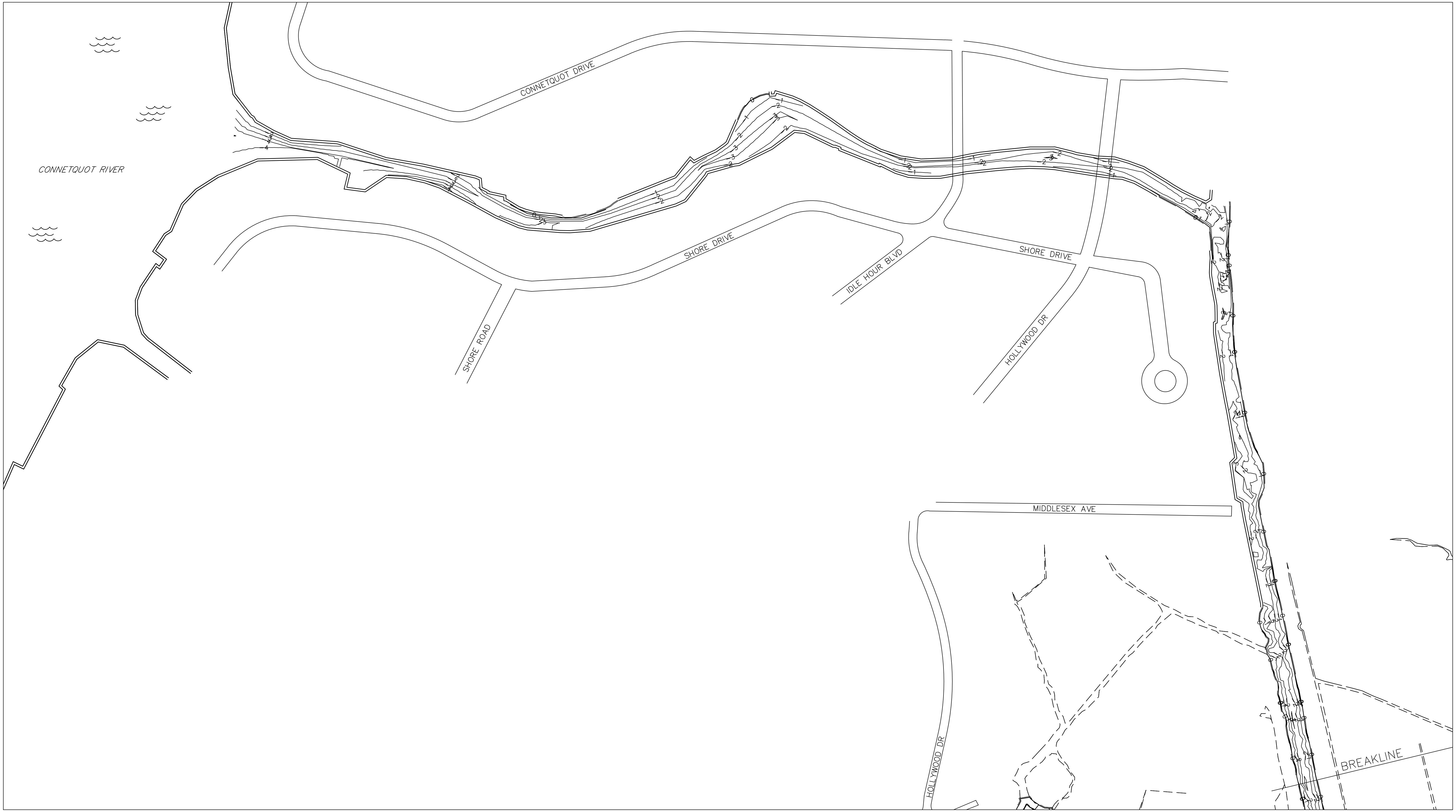
3.0.0 Bathymetric Survey

On October 14, 2014, CA environmental personnel performed a bathymetric survey of the Grand Canal. Supplemental data were also collected during later field data collection events in 2015. Data were collected using an integrated sonar-based depth finder (Garmin 547xs) and vessel-mounted Global Positioning System (GPS) unit. The depth finder was calibrated prior to data collection and its accuracy was routinely verified throughout the bathymetric survey. In the northern section of the Grand Canal between the two low-clearance bridges, bathymetric data were obtained by obtaining individual soundings using a calibrated rod and a hand-held GPS unit.

Soundings were taken approximately every 35 feet across multiple transects in the Grand Canal in order to accurately show bathymetric features and shoaled areas. The work was performed around the day's low tide and all depths were adjusted to mean low water (MLW) to compensate for tidal differences. CA also collected data on key features in the Grand Canal and adjacent wetlands, including bulkheading, tidal wetlands, shoreline, docks, and channel limits.

A total of 845 bathymetric data points were collected during the bathymetric survey event. Bathymetric maps were created from these data, as shown in Map 3. Mapping was based on mean low water (MLW) as dictated by NGVD29 and NAD83 State Plan Coordinates, New York Long Island Zone.

The main section of the Grand Canal was found to vary in width from approximately 75-feet at its widest point (just south of the Shore Drive Bridge) to approximately 30-feet at its narrowest point (just east of the Idle Hour Boulevard Bridge). The main channel of the canal varies in depth from the deepest point of approximately five feet below mean low water (MLW) near the southern entrance to approximately two feet below MLW at its shallowest along the northern transect of the canal (Map 3). The entrance of the canal at the Snapper Inn is actually narrower than the main section of the canal, with a width of about 25 feet.



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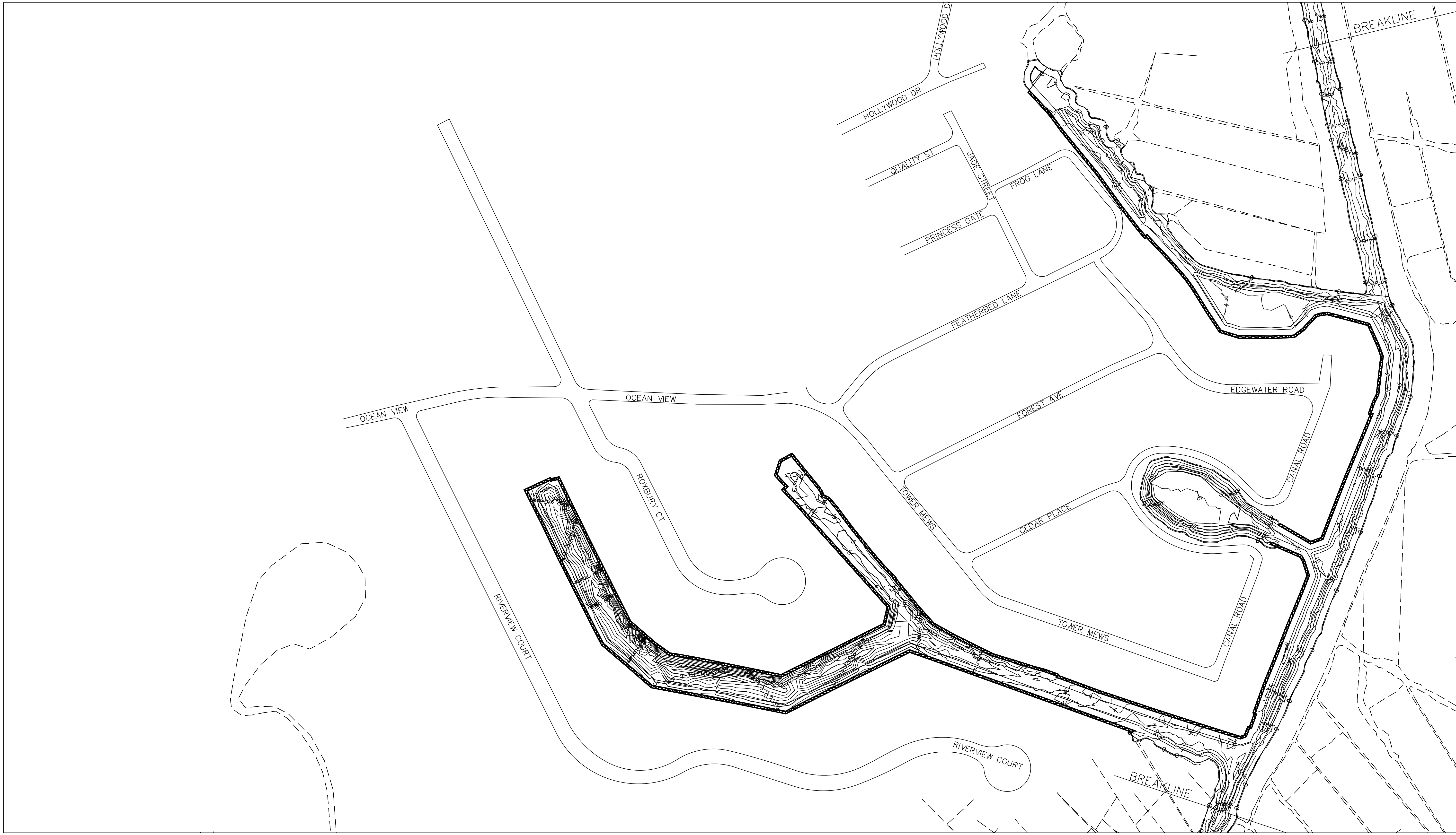
MAP 3

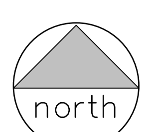
Bathymetry

1 OF 3



MAP 3

Bathymetry



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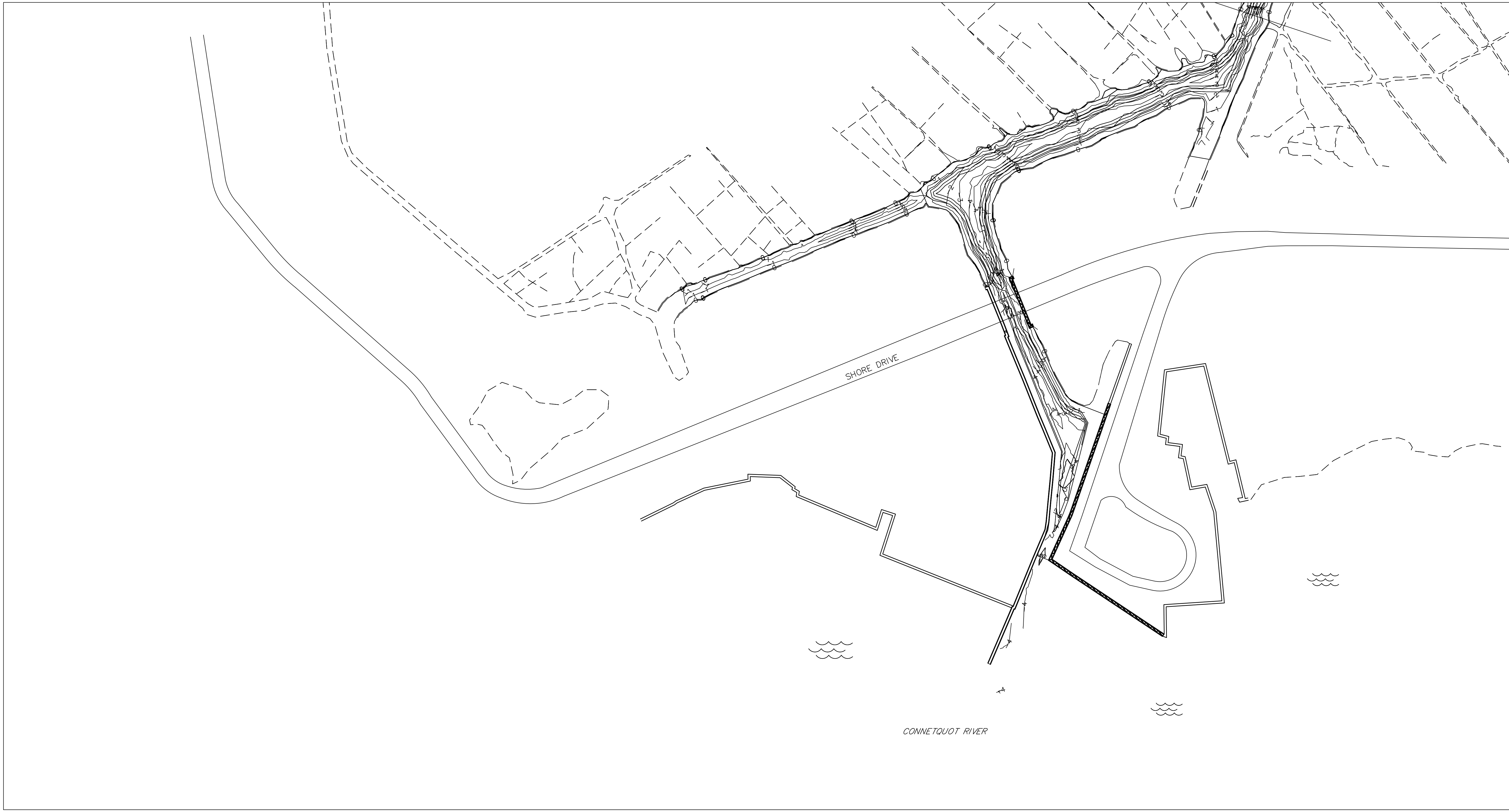

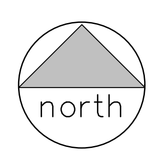

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MAP 3

Bathymetry

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The County's Department of Public Works (DPW) has specified that dredging must be designed with a fifteen foot offset from bulkheads or other structures (e.g., berm) and a slope of one foot vertical by three foot horizontal. Using the bathymetric data, an analysis was run to determine the volume of material that could be dredged throughout the Grand Canal to a maximum depth of five feet. Due to the DPW design requirements, a significant portion of the Grand Canal was deemed ineligible for dredging. Map 3 illustrates the areas that can and cannot be dredged per DPW requirements. CA determined that 12,550 cubic yards of excavation would be required to dredge the entire canal to a maximum depth of five feet, where applicable, in accordance with DPW requirements. If the County decides to remove the berm, the narrow portions of the canal that run along the berm may become eligible for dredging. However, other ineligible areas would still require a variance from the DPW to allow any dredging. Also, control/mitigation of the contaminated fine dredge material that may be suspended during the dredging operation, transportation and locating an acceptable dredge material placement area must be considered.

It is important to note that nearly all viable dredging is at depths currently below mean low water (MLW). Therefore, dredging in the Grand Canal would increase the systems overall volume but reduce the relative tidal volume (i.e., the tidal volume stays the same but total capacity increases) which would further reduce flushing rates. The exception to this would be dredging in the southern portions of the canal where shoaling appears to restrict the inflow of tidal waters. These areas are very limited in extent, and the effect on tidal flow is not considered substantial, especially considering that the entrance of the canal from Connetquot River is very restricted.

The main south entrance to the canal from the Connetquot River is restricted by the narrow opening between the bulkheads of two private properties, the Oakdale Yacht Club at the east side and the Snapper Inn Restaurant on the west side. The width of the opening between the bulkheads is approximately 25 feet, representing the narrowest segment of the entire canal. Based on the bathymetric survey, the cross-sectional area of the opening is estimated at 123 square feet. The cross-sectional areas of the canal upstream of the Shore Drive Bridge and at approximately 1,800 feet beyond that are 148 and 172 square feet, respectively. Cross-sectional areas directly affect the amount of water that can be exchanged on a tidal cycle. The geometry of the entrance represents a restriction to tidal exchange for the canal.

In addition, it was noted during the bathymetric survey that there were large amounts of debris (e.g., trees, limbs, leaf litter) as well as a layer of fine grain mud that was easily resuspended into the water column. This debris appears to be contributing to the reduced flow within the canal and also hinder navigations. This decaying organic material and fine grain mud is reducing the overall health of the canal and actions to improve these conditions are discussed later on in this report. Erosion of the man-made berm along portions of the canal is also resulting in the deposition of sediments and tree debris in the canal.

3.0.0.0 Stream Flow Current and Tidal Flushing

Tidal flushing and circulation/ current patterns are critical properties needed to fully characterize the overall health of tidal wetlands and estuaries. Tidal flushing refers to the amount of water exchanged between two connected bodies of water due to the movement of water caused by tides. This exchange of water helps carry excess nutrients, sediment, and pollutants out of the Grand Canal and associated wetland system. Furthermore, the tidal exchange also increases salinity and dissolved oxygen within the Grand Canal and the associated wetlands. The Grand Canal is unique in that it converges with the Connetquot River at two points (referred to as northern and southern entrances), thus enabling two points of water exchange. The canal feeds surrounding wetland areas, including the eastern wetland area which is restricted by a manmade berm and limited to three unmaintained culverts and one open stream. These unique characteristics are important to consider for understanding the circulatory patterns and ultimate tidal flushing rates of the system.

A current analysis was conducted on September 2, 2015 by CA environmental personnel to determine relative movement of water in the Grand Canal. Neutrally buoyant, numbered flotations were utilized to obtain a visual observation of water movement. Flotations were released into the canal at four locations at low tide and their movement was tracked through high tide. Information resulting from the surface water quality monitoring performed throughout the course of the study also provided insight into the amount of tidal flushing within the Grand Canal.

From the current and tidal flushing study, several important observations were made. First, at the onset of the incoming tide, the southern entrance of the Grand Canal had a stronger influence on currents than the northern entrance. The portion of the canal system that runs along the border of the eastern wetland experienced a northerly net movement of water up to its northern reaches at the onset of incoming tide. Second, the northerly net movement of water (coming from the southern entrance of the Grand Canal) reversed about two to three hours after the onset on incoming tide. This was apparently caused by the increasing tidal influence that the northern entrance of the Grand Canal was exerting on the system. This increased influence of the northern entrance relative to the southern entrance was most likely a result of the extensive hardened banks of the northern portion of the Grand Canal (e.g., bulkheads, berms) compared to the southern portion, whereas the tide rises, the ability of the eastern and western wetlands to receive a higher proportion of the flood waters increased further reducing the southern entrance's influence on the canal system. Lastly, due to this alternating northern/southern tidal influence, an area of stagnant (i.e. trapped) water appeared to exist along a main portion of the canal that runs generally north/south along the border of the eastern wetland.

Within this main portion of the canal system, there are three westward tributaries that comprise the majority of housing development within the canal and also appear to have limited flushing. None of the floatation origin locations were located within these tributaries; however, throughout the study period only one floatation was observed to enter one of the tributaries. These observations suggest that water currents within the canal and wetland system are not uniform, portions of the system have differing flushing rates, and the two entrances appear to create a stagnate area in the canal, preventing a complete flushing of the entire canal system.

In order to estimate the tidal flushing of the Grand Canal, a modified mass-balance equation was utilized. This approach to calculating the tidal exchange applied bathymetric data along with the average historical tidal range to obtain the canal's volumetric difference between mean high and mean low tide. Distinct water masses with different temperatures and salinities do not mix well and are often stratified. Therefore, an assumption regarding how well the canal water mixes with the more saline incoming tidal waters was required in order to better understand how much tidal exchange occurs. This assumption was obtained by utilizing existing salinity time series data to identify a mixing coefficient.

To obtain the volume of water that inundates the wetland areas, estimates were derived with an aerial imagery-based analysis of streams coupled with field based measurements including limited surveying. For the western wetland, this estimation was relatively simple to calculate given the area's unrestricted access to the tidal water. Unlike the eastern wetland where tidal flow is limited to three culverts and one open stream, the western wetland is uniformly level and is routinely and evenly inundated with tidal flood waters. For the eastern wetland, there were two methods for estimating the amount of inundation that occurs: (1) surveying at high and low tide throughout the wetland; and (2) calculating volume exchange based on the culvert and stream dimensions and pressure gradients. Both of these methods were not viable for different reasons. Surveying was not viable due to the tall reeds and other vegetation that greatly limited visibility and therefore the ability to survey effectively. The calculation method based on culvert/stream dimensions was flawed in that there were too many unknown variables to account for including the condition of the culverts and the subsequent level of water flow through them. For simplicity, we chose to assume a tidal exchange of 25% to 75% of the maximum potential based on the volumetric difference between high and low tide.

To better understand the regular mixing that occurs in the Grand Canal system, salinity measurements were taken at low tide and high tide at locations across all depths. In estuaries, a salinity gradient is often observed with fresher, less saline water on the surface that increases with depth. In a partially mixed estuary, salinity and depth will have a gradual and linear relationship. In a more stratified estuary, the change in salinity with depth can be more sudden. Based on observations by CA field personnel, it was determined that the Grand Canal is a partially mixed estuary with a linear relationship. By determining the canal's average salinity and comparing it with the average salinity of the incoming tidal waters, a mixing coefficient (%) can be identified. This coefficient can be incorporated into the mass-balance equation to obtain a much stronger estimate for tidal flushing rate. This method provides a generalized flushing rate for the entire wetland and canal system. The results indicate that approximately 17% to 18% of the total volume of the Grand Canal is replaced with tidal waters from the adjacent Connetquot River and Great South Bay during each tidal cycle. Based on two daily tidal cycles, the flushing rate for the Grand Canal is approximately 2.7 - 2.9 days. However, this flushing rate assumes that newly mixed waters from the previous high tide are retained and only old water is removed. Furthermore, it does not take into account areas of stagnation within the canal or wetland which were observed during the flotation study. Many assumptions had to be made in order to organize this mass-balance equation. This calculation could be improved with more accurate bathymetric data of the wetlands, a specific mean high water level for the Grand Canal (currently using Great River's MHW), a more thorough canal-wide and tidal-sourced salinity characterization, and an understanding of the direct freshwater inputs to the system. Another option would be to utilize fluorescent dye and measure its decay over time. This option, however, was beyond the scope of this project. The table below summarizes the results and data utilized for the tidal flushing calculations.

- Grand Canal & Wetlands
  - Total Volume 19,259,637 gallons
- Grand Canal (excluding wetlands)
  - Tidal Volume - 3,606,450 gallons
- Western Wetlands
  - Tidal Volume - 434,446 gallons
- Eastern Wetlands
  - Max Tidal Volume - 593,601 gallons
  - Actual Tidal Volume - 148,400 – 445,201 gallons
- Mixing Coefficient - 0.81
- Tidal Flushing Estimate
  - Flushing Volume 3,393,330 - 3,633,739 gallons, 17.6 - 18.9% of total volume
- Flushing Rate - 2.7 – 2.9 days

The water quality data collected by CA in the Grand Canal (described in Section 3) as part of the tidal water monitoring study indicated that water temperature, salinity, and dissolved oxygen (DO) levels in the Grand Canal are somewhat related to tidal fluctuations. Generally higher water temperatures, salinity, and DO levels were observed at high-tide and mid-outgoing tide conditions versus low-tide and mid-incoming tide conditions. However, the variations in readings over time and across the stations did not indicate a significant level of tidal flushing in the Grand Canal. The County's continuous water quality monitoring data provided pertinent information relating to stream flow and currents. When the depth of water observation were analyzed the canal system was determined to have an asymmetric tidal regime that was flood-dominated. A flood-dominated tidal regime is one in which the incoming tidal time period is shorter than the outgoing tidal period despite the same amount of water being exchanged. This requires the incoming tide to move at a faster rate than the outgoing which leads to net import of sediments. This net import of sediments is due to the nature of the carrying capacity of a fluid whereas faster moving fluids can carry more sediment and upon slowing down the sediments drop out of the water column.

3.0.1 Benthic Community

Benthic species play a critical role in the functioning of estuaries. Benthic communities are made up of a diverse group of organisms whose remineralization of organic matter into nutrients is critical in maintaining a high production rate in estuaries. This information can be used to assess if dredging the canal should be part of the chosen remediation method and to assess potential impacts of dredging to the benthos community.

3.0.1.0 Benthic Community Sampling Methodology

Spatially explicit benthic community composition and sediment grain size surveys were collected twice during 2015 (spring and fall event). CA environmental personnel collected the benthic samples on October 7, 2014 and June 4, 2015. Five sites were sampled during each event and two replicates were taken at each site for a total of ten samples. In order to get a diverse benthos representation of the project site, sample locations were determined based on sediment characteristics. GPS coordinates for each sample location were recorded and sample locations are provided in Map 4. The benthic sampling protocols (e.g., number of samples, location of samples, sampling procedure) were developed in accordance with the Description of Services for the project.

Both the community composition (benthic) and sediment grain size sampling utilized a 15.24 x 15.24 cm (6 x 6 inch) Ponar® grab dredge to collect minimally disturbed sediment for subsequent sub-sampling. Upon retrieving the sample to the surface, the grain size sub-sample was separated and stored in Nasco Whirl-Paks® for later analysis. The remainder of each sample was passed through a 500-µm sieve, placed in a Hubco cloth soil sample bag, and amended with a pre-mixed rose Bengal and 10% buffered formalin solution in the field prior to storage. Benthic samples were analyzed and retained organisms were enumerated under a compound-dissecting microscope. All organisms were identified to the lowest possible taxonomic level.

A grain size distribution analysis was performed for each sediment sub-sample from each location to determine the percentages of specific grain size classes (gravel, sand, silt and clay). Sediment size classes were as follows:

Gravel – sediment larger than 2.0 millimeter (mm).

Sand – sediment between 0.05mm and 2.0 mm.

Silt/Clay – sediment smaller than 0.05mm.

The distribution investigation was determined using wet sieving and pipette analysis. Samples collected for grain size analysis were passed first through a two millimeter sieve and then through a 63 micro-meter sieve to provide the gravel and sand fractions of the sediment, respectively. The sub-samples were washed through both sieves with a total of 1000mL of water. The sediment and water that was washed through the sieves was collected in a graduated cylinder. These portions of sediment remaining in each sieve after being washed through were then transferred to pre-weighed vessels for dry weight determination.

MAP 4

Benthic Community Sampling Locations

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The next step in the grain size distribution analysis was to determine the silt and clay sediment fraction. To obtain the silt and clay fraction, the sediment and 1000 mL of water were agitated within the graduated cylinder. Aliquots were taken from the 20 cm. depth after agitation and transferred to a pre-weighed vessel for dry weight determination. All grain size fraction vessels (gravel, sand, silt and clay) were dried at 80 degrees Celsius for at least four hours. After drying, all vessels were weighed. The weight of the vessel alone was subtracted from the weight of the vessel with sediment to obtain the weight of the material fraction within the vessel. The percent composition for each fraction was then found from total dry weight by division.

3.0.1.1 Spring Benthic Community Analysis Results

Spring benthic samples were collected on June 4, 2015 from a total of five sites with two replicates at each site (totaling ten samples) (Map 4). A total of 222 benthic organisms were collected from all ten samples. A total of ten species were identified during the spring event. *Ampelisca spp.* was the most abundant species with 127 benthic organisms found in six of the ten samples collected. *Myodocopido spp.* was the next most abundant species with 31 organisms found in two of the ten samples. Replicate 1a had the highest species richness with a total eight different organisms identified. Table 3 depicts the spring benthic organism abundance by species and sample.

Table 3. Spring 2015 Benthic Species Abundance and Richness

Species	**Sample ID**									
	1a	**1b**	**2a**	**2b**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**
Eteone heteropoda	-	-	-	-	1	-	-	-	2	2
LIyanassa obsoleta	1	-	-	-	-	-	-	-	-	1
Ampelisca spp (abdita/vadorum)	28	11	4	3	-	-		-	64	17
Cerapus tubularis	-	-	-	-	3	-	-	-	-	-
Microdelutopus gryllotalpa	2	1	1	-	-	-	-	-	-	-
Lysianopsis alba	8	-	5	-	-	-	-	-	5	-
Exogone dispar	3	1	-	-	-	-	-	-	-	3
Capitella capitata	2	-	-	-	7	3	-	-	4	1
Steblospio beneficti	8	-	-	-	-	-	-	-	-	-
Myodocopida spp.	19	-	-	-	-	-	-	-	-	12
Species Richness	**8**	**3**	**3**	**1**	**3**	**1**	**0**	**0**	**4**	**6**
Total Abundance	**71**	**13**	**10**	**3**	**11**	**3**	**0**	**0**	**79**	**36**

The sediment samples collected during the spring event were analyzed for grain size distribution. Grain size distribution samples were sieved and separated into percentage weight based on three soil classifications: gravel, sand and silt/clay. The specific breakdown of the soil classifications was as follows and percentage per classification is depicted in Table 4.

Table 4. Grain Size Distribution Analysis for The Spring Benthic Sampling Event

Sample Site	% Gravel	% Sand	% Silt & Clay
1	21.09	74.77	4.14
2	0.00	49.13	50.87
3	5.91	63.78	31.31
4	0.00	54.89	45.11
5	0.00	41.17	58.83

Gravel was present in two out of the five sample sites and Site 1 recorded the highest percentage of gravel (21.09%). Sand was present in all sample sites with Site 1 having the highest percentage of sand (74.77%). Silt/clay was also present in all sites with Site 5 having the highest percentage of silt/clay (58.83%). Only Site 1 had a combined gravel and sand content above 90%.

3.0.1.2 Fall Benthic Community Analysis Results

Fall benthic samples were collected October 7, 2015 from a total of five sites with two replicates at each site (totaling ten samples) (Map 4). A total of 98 benthic organisms were collected from all ten samples; this is less than half of the amount of organisms collected during the spring event. A total of 11 species were identified during the fall event; this is one more species than was identified during the spring event. *Ampelisca spp.* was the most abundant species with 79 organisms found in five of the ten samples collected. *Luimbrineris tenuis* was the next most abundant species with only six organisms in two of the ten samples. Replicate 2a had the highest species richness with a total four different species identified. Table 5 depicts the fall benthic organism abundance by species and sample.

Table 5. Fall 2015 Benthic Species Abundance and Richness

Species	Sample ID									
	1a	**1b**	**2a**	**2b**	**3a**	**3b**	**4a**	**4b**	**5a**	**5b**
Eteone heteropoda	-	-	1	-	1	-	-	-	-	-
LIyanassa obsolete	1	1	-	1	-	-	-	-	-	-
Epitonium spp.	1	-	-	-	-	-	-	-	-	-
Panopeus spp.	1	-	-	1	-	-	-	-	-	-
Ampelisca spp (abdita/vadorum)	-	-	52	23	4	-		-	64	17
Exogone dispar	-	-	1	-	-	-	-	-	-	-
Capitella capitate	-	-	1	-	-	-	-	1	-	1
Heteromastus filiformis	-	-	-	-	-	-	3	-	-	-
Lumbrineris tenuis	-	-	-	-	-	-	3	3	-	-
Acteocina canaliculata	-	-	-	-	-	-	1	-	-	-
Erichsonella filformis	-	-	-	-	-	-	-	1	-	-
Species Richness	**3**	**1**	**4**	**3**	**2**	**0**	**3**	**2**	**1**	**2**
Total Abundance	**3**	**1**	**55**	**25**	**5**	**0**	**7**	**5**	**64**	**18**

The sediment samples collected during the fall event were analyzed for grain size distribution. Grain size distribution samples were sieved and separated into percentage weight based on three soil classifications: gravel, sand and silt/clay. The specific breakdown of the soil classifications was as follows and percentage per classification is depicted in Table 6.

Table 6. Grain Size Distribution Analysis for the Fall Benthic Sampling Event

Sample Site	% Gravel	% Sand	% Silt & Clay
1	28.05	64.33	7.62
2	0.00	54.75	45.25
3	13.51	81.23	5.26
4	0.00	50.74	49.26
5	0.00	46.09	53.91

Gravel was present in two out of the five sample sites and Site 1 recorded the highest percentage of 28.05%. Sand was present in all sample sites with Site 3 having the highest percentage of 81.23%. Silt/clay was also present in all sites with Site 5 having the highest percentage of 53.91%. Site 1 and Site 3 each had a combined gravel and sand content above 90%.

3.0.1.3 Spring and Fall Benthic Community Comparison

A comparative analysis between spring and fall species richness and total abundance revealed that the spring event had a higher species richness and total abundance in six out of the ten samples collected (Figures 1 and 2). Site 1a in the spring event appears to have the highest species richness from all samples collected in spring and fall with a total of eight different species identified. Site 5a had the highest total abundance for both spring and fall events. The presence of *Ampelisca spp*. appears to be the reason for high total abundance in 5a for both of the sampling events. This species accounted for 81% of the total number of benthic organisms collected in the spring and 100% of benthic organisms collected in the fall at site 5a. Overall, a total of 320 benthic organisms were identified for the spring and fall events and 64% of the organisms were the *Ampelisca spp*.

A 2013 benthic survey in the Forge River indicated a similar benthic species composition to that found for the Grand Canal. However based on the limited number of samples taken from the Grand Canal (in accordance with the Description of Services), formal comparisons between the two datasets cannot be made.

Figure 1. Benthic Species Richness in Spring and Fall

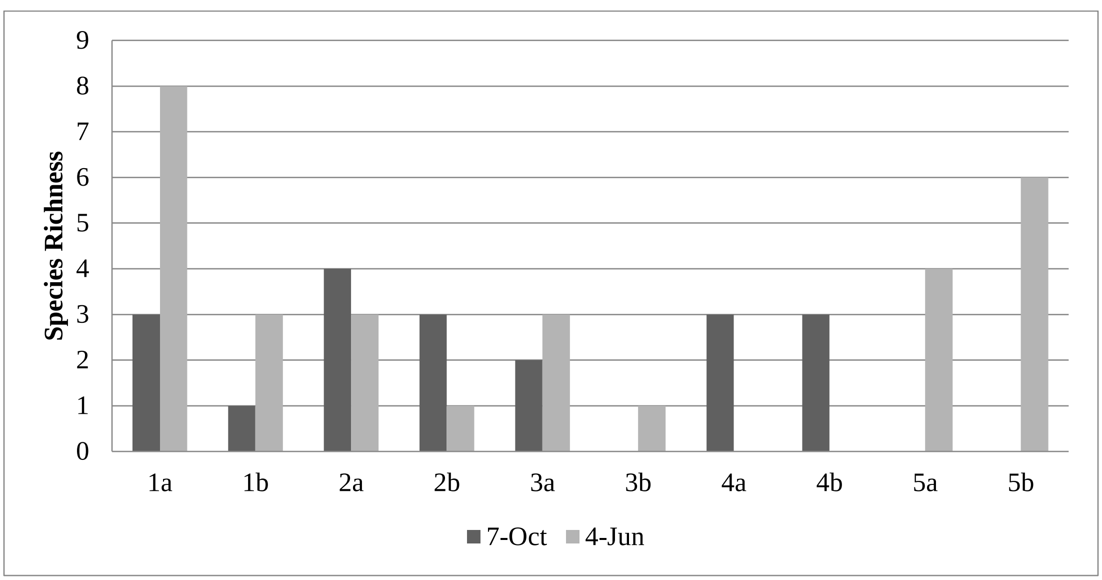
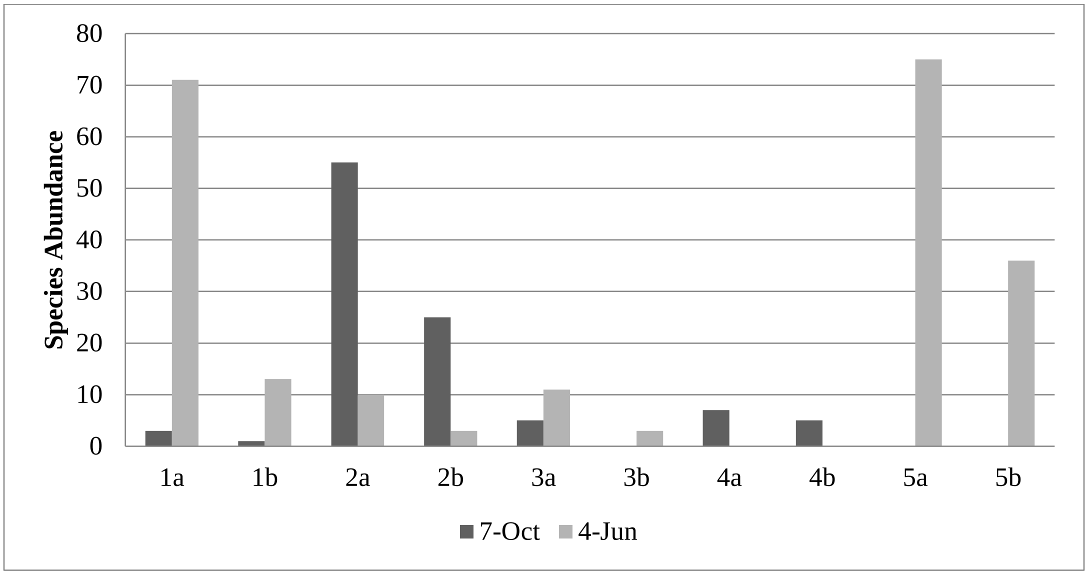


Figure 2. Benthic Species Abundance in Spring and Fall



3.0.2 Fisheries

An Essential Fish Habitat Assessment (EFH) of Grand Canal and adjacent wetlands was performed in conformance with the 1996 amendments to the Magnuson-Stevens Fishery Management and Conservation Act (ACT). The EFH is provided in Appendix D. The 1996 amendments to the Act set forth a number of new mandates for the National Marine Fisheries Service (NMFS); in particular, eight regional fishery management councils (Councils) and other federal agencies were charged with identifying and protecting important marine and anadromous fish habitats. The Councils, with assistance from NMFS, are required to delineate EFH for all managed species. Federal action agencies which fund, permit or carry out activities that may adversely impact EFT are required to consult with NMFS regarding the potential effects of their actions on EFH, and respond in writing to the NMFS recommendations.

The Grand Canal project study area is located within an area designated as an EFH for the Northeast Council's Coastal Pelagics and Northeast Groundfish Management Plans. The EFH for the Grand Canal found that direct impacts of dredging in the study area could include temporary substrate disturbance, temporary water quality degradation, and possible temporary disturbance and displacement of some benthic fauna species. However, due to the limited project size, location, and proposed construction window, if any dredging activities were conducted, they would be expected to have little or no impact on any of the important marine and anadromous species located in the area designated with an Essential Fish Habitat for the Northeast Council's Coastal Pelagics and Northeast Groundfish Management Plans. The only species listed in the Grand Canal study area that may be slightly affected by possible dredging actions would be the winter flounder which tends to start their inshore migration to spawning grounds in late fall to early winter. Because adults and juveniles are mobile, it is expected that they will avoid the study area during any dredging disturbances. Furthermore, because dredging is expected to be conducted in winter months when the winter flounder does not inhabit the study area, little adverse impacts are expected (Appendix D).

To supplement the EFH of the Grand Canal, CA conducted finfish sampling within the Grand Canal study area.

3.0.2.0 Fisheries Sampling

In addition to conducting the EFH, CA collected supplemental fisheries data was collected utilizing several sampling methodologies. The purpose of this survey was to provide an absence/presence qualitative analysis of the fish assemblage in the Grand Canal.

Fish sampling was conducted by CA environmental personnel on a total of seven days in 2014 and 2015: October 14, 2014; July 7, 2015; September 1, 2, 3, and 17, 2015; and October 22, 2015. The following sampling methods were utilized: throw nets, seine nets, gill nets of various size, minnow traps, eel traps, and crab traps. Sampling was conducted during an incoming high tidal cycle, in accordance with the 'Grand Canal Ecological and Public Health Assessment Technical Specifications and Description of Services'. To supplement these data, further fisheries sampling was performed during other tidal cycles. To limit fish mortality, sample collection time did not exceed four hours for each sampling event.

Table 7 lists all of the finfish species captured or observed during the survey. Table 8 lists all incidental by-catch (non-finfish species) captured or observed during the finfish survey. A description of the fish and invertebrate species captured or observed in the Grand Canal study area during the finfish survey is provided in Appendix D. In addition, a photo of each species is shown in Appendix D. All photographs were taken by CA staff during the Grand Canal finfish survey with the exception of the Atlantic Needlefish which was only observed swimming (i.e., never captured during survey).

Table 7. Finfish Species Captured or Observed During Finfish Survey

Common Name	Scientific Name
Atlantic Silverside	*Menidia menidia*
Bay Anchovy	*Anchoa mitchili*
Bluefish	*Pomatomus saltaatrix*
Mummichug	*Fundulus heteroclitus*
American Eel	*Anguilla rostrate*
Atlantic Menhaden	*Brevoortia tyannus*
Oyster Toadfish	*Opsanus tau*
Sheepshead Minnow	*Cyprinodont variegates*
Banded Killifish	*Fundulus diaphanus*
Naked Goby	*Gobiosoma bosc*
Winter Flounder	*Psuedopleuronectes americanus*
Atlantic Needlefish	*Strongylura marina*
Black Drum	*Pogonias cromis*

Table 8. Incidental Invertebrate By-Catch Captured or Observed During The Finfish Survey

Common Name	Scientific Name
Blue Crab	*Callinectes sapidus*
Mud Crab	*Panopues spp.*
Sand Shrimp	*Crangon septemspinosa*
Grass Shrimp	*Hippolyte spp.*

3.1 Sediment Sampling Plan and Analysis (Subtask 3b)

3.1.0 Development of Sediment Sampling Plan

A Sediment Sampling Plan was prepared which incorporated the information needs and sampling requirements of the NYSDEC's Division of Marine Habitat Protection and Division of Solid and Hazardous Material. The plan was developed based on the NYSDEC TOGS 5.1.9 'In-Water and Riparian Management of Sediment and Dredge Material' document and NYSDEC Remedial Program Soil Cleanup Objectives. The Sediment Sampling Plan was also based on findings from bathymetric data collection performed by CA as part of Task 3 of this project. The Sediment Sampling Plan can be found in Appendix E.

3.1.1 Submittal and Approval from the NYSDEC

After being approved by SCDHS, the Sediment Sampling Plan was submitted to the NYSDEC. It was approved by NYSDEC on December 22, 2015.

3.1.2 Coring, Sampling, and Examination of Sediment

A total of 30 sediment samples for subsequent laboratory analysis were collected from the Grand Canal on December 21 and 22, 2015 by CA environmental personnel in accordance with the approved Sediment Sampling Plan. Samples were collected with an AMS Core Sampler. This instrument collects samples by obtaining a core of the sediment bottom. Sediment is contained in a clear cylinder to allow for visual inspection of sediment stratification which occurs with depth.

A total of ten sample sites were selected throughout the canal for sediment core sampling; GPS coordinates for each sample location were recorded and Map 5 shows these survey locations. At each of the ten sites, three different segment samples were collected using the AMS coring instrument. The three segment samples from each location were as follows: one sample of the material to be dredged (top layer of sediment) (ID “A”); one sample of zero to six inches below the dredge depth (ID “B”); and one sample from six to 12 inches below the dredge depth (ID “C”). The sampling methodology used was based on that described in the protocol of the NYSDEC TOGS 5.1.9 ‘In Water and Riparian Management of Sediment and Dredge Material’ document.

After collection, the sediment samples were immediately labeled and preserved on ice; the first two sub-samples were analyzed (20 samples) and the third (10 samples) was archived for possible further analysis, depending on initial testing results. Samples were analyzed for grain size distribution and Total Organic Carbon (TOC) content.

In the event that the grain size and TOC analysis determined that the composition of any of the sediment sample was at least 90 percent sand or larger, and less than one-half percent TOC, no further testing was required. All samples falling below these threshold values were tested for priority pollutant parameters, as identified by NYSDEC. If the priority pollutant analysis from the dredge material and the first six inches below dredge depth revealed priority pollutant constituents above NYSDEC recommended limits, the archived samples were to be analyzed. Laboratory analyses for TOC and pollutants were performed by York Analytical Laboratories, Inc. Laboratory analyses for grain size distribution was performed by Long Island Analytical Laboratories, Inc. Both laboratories are New York Certified Laboratories. Chain-of-custody procedures were followed for all samples.

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MAP 5

Sediment Core Sampling Locations

3.1.2.0 Grain Size Distribution

Grain size distribution is represented in the form as percent retained in relationship to certain sieve parameters: gravel (Sieve Size 2 inch – ¼ inch); sand (Sieve Size #10 – #200); and silt/clay (Sieve Size <200). According to Long Island Analytical Laboratories, Inc., a certain percentage of material is lost during the dry sieving process which is why the total percent retained may be less than 100% (the dry sieve standard allows for that loss as long as it is less than 10%). Sample ID "A" represents the material to be dredged and "B" represents zero to six inches below the dredge depth.

According to the NYSDEC protocol, all of the samples analyzed for grain size met the required composition of at least 90% sand or larger material (less than 10% of the material passes through the No. 200 sieve). The 90% sand or larger material is calculated based on the total percentage of material retained during the analysis. Based on these grain size results, none of the samples needed to be tested for contaminant parameters identified and in accordance with the testing methods provided in the NYSDEC 'Technical & Operational Guidance Series (TOGS) 5.1.9 In-Water and Riparian Management of Sediment and Dredge Material' document. Grain size distribution results for the sediment cores are shown in Table 9.

Table 9. Grain Size Distribution Analysis for Sediment Cores

Sample ID	%Gravel	%Sand	%Silt/Clay	Total % Retained	Sample ID	%Gravel	%Sand	%Silt/Clay	Total % Retained
GC 1A	15.80	82.23	0.79	98.10	**GC 6A**	2.78	91.14	3.30	97.22
GC 1B	1.07	97.75	2.38	98.20	**GC 6B**	10.27	84.17	2.85	97.29
GC 2A	1.46	87.47	9.12	98.05	**GC 7A**	3.28	90.41	3.38	97.07
GC 2B	0.00	93.49	4.26	97.75	**GC 7B**	0.00	93.68	4.27	97.95
GC 3A	0.00	91.13	5.69	96.82	**GC 8A**	0.64	89.58	7.22	97.44
GC 3B	9.38	88.43	1.89	99.70	**GC 8B**	12.48	83.76	2.60	98.84
GC 4A	5.53	90.72	2.87	98.43	**GC 9A**	0.00	94.30	2.60	96.90
GC 4B	3.67	93.64	2.39	100	**GC 9B**	12.06	86.23	1.31	99.60
GC 5A	9.79	86.40	2.53	98.72	**GC 10A**	0.00	96.53	2.67	99.20
GC 5B	18.99	75.86	3.83	98.68	**GC 10B**	0.00	91.58	5.94	97.52

3.1.2.1 Total Organic Carbon (TOC)

According to the NYSDEC protocol, two of the sediment samples met the required less than 0.5% of TOC requirement. Based on these results, 18 samples did not meet the minimum TOC requirement and therefore needed to be tested for contaminant parameters identified and in accordance with the testing methods provided in the NYSDEC 'Technical & Operational Guidance Series (TOGS) 5.1.9 In-Water and Riparian Management of Sediment and Dredge Material' document. TOC analysis results are shown in Table 10. The two samples meeting the TOC requirement are underlined in Table 10.

Table 10. TOC Results for The "A" And "B" Segments For Each of the 10 Sample Sites

Sample ID	Percent	Sample ID	Percent	Sample ID	Percent	Sample ID	Percent
GC 1A	0.1390	**GC 3B**	0.0441	**GC 6A**	0.1910	**GC 8B**	0.1120
GC 1B	0.0713	**GC 4A**	0.0944	**GC 6B**	0.0799	**GC 9A**	0.1250
GC 2A	0.0702	**GC 4B**	0.0606	**GC 7A**	0.0625	**GC 9B**	0.0733
GC 2B	0.0749	**GC 5A**	0.0754	**GC 7B**	0.0772	**GC 10A**	0.0642
GC 3A	0.0258	**GC 5B**	0.0555	**GC 8A**	0.0917	**GC 10B**	0.0502

3.1.2.2 Sediment Cores Primary Pollutants Analysis Results

Sediment core primary pollutant analysis was performed on the "A" (dredge material) and "B" (zero to six inches below dredge depth) samples; testing was not required to be completed on the archived samples from six to 12 inches below the dredge depth (ID "C").

The results of the sediment chemistry were compared to the NYSDEC's 'Sediment Quality Thresholds for In-Water/Riparian Placement' guidelines and the following classifications:

- Class A – No Appreciable Contamination (No Toxicity Aquatic Life);
- Class B – Moderate Contamination (Chronic Toxicity to Aquatic Life); and
- Class C – High Contamination (Acute Toxicity to Aquatic Life).

The sum of DDT and its constituents (DDE and DDD) were detected in the dredge material for Sites GC 1 through GC 8. The dredge sediment in Site GC 1 met Class B criteria and Sites GC 2 through GC 8 met or exceeded Class C criteria. The highest concentrations were detected in Sites GC 4 through GC 6. These three sites are located directly adjacent to the Pickman-Remmer wetlands and these higher concentrations may be associated with sediment transport from these wetlands. The concentrations of this constituent in the sediment below the dredge material were lower than the dredge material, but still in Class B and Class C criteria. No DDT, DDE or DDE were detected in Sites GC 9 or GC 10.

Several metals were also detected in the dredge material and sediment below the dredge material. The metals met Class A and Class B criteria. Specific metals detected were: copper, arsenic, chromium, lead, nickel, zinc, and mercury. These metals may have been introduced into the canal system from a variety of sources. For instance, copper, arsenic and chromium may have been partially introduced into the sediment by the chromated copper arsenate (CCA) wood material used to construct bulk heading and anti-fouling paints. Lead, zinc, and mercury may have been partially introduced into the sediment from boating activities, such as the use of leaded gasoline. The results of the laboratory analysis for the sediment core samples collected by CA are provided and discussed in greater detail, especially with regards to their potential impacts of human health, in the 'Grand Canal Public Health Evaluation Report and Sediment Risk Assessment' (Appendix C).

3.2 Water Quality Analysis (Subtask 3c)

3.2.0 Water Quality Monitoring Plan

A Water Quality Monitoring Plan was prepared which outlined a series of surface water sampling events for the Grand Canal. The draft plan was submitted to SCDHS for review prior to sampling. The Water Quality Monitoring Plan can be found in Appendix F.

The Grand Canal surface water samples were analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), herbicides, pesticides, and several nutrients (total and dissolved nitrogen, total and dissolved phosphorus, and dissolved total inorganic nitrogen). Laboratory analyses for surface water samples were performed by York Analytical Laboratories, Inc., a New York Certified Laboratory. The surface water samples were also analyzed for three bacterial indicators (enterococci, total coliform, and fecal coliform). The bacterial analyses were performed by Long Island Analytical Laboratories, Inc., a New York Certified Laboratory. Chain-of-custody procedures were followed for all samples. Laboratory results for the water quality samples have been included in Appendix C. Physical water parameters of temperature, salinity, dissolved oxygen, and turbidity were taken at every sample location during each sampling event.

3.2.1 Additional Potential Contaminants Identification and Review

3.2.1.0 Tidal Stage Monitoring

To characterize water quality in the Grand Canal relative to tidal influence, surface water monitoring was conducted by CA environmental personnel during four tidal stages (low tide, midpoint of incoming tide, high tide, midpoint of outgoing tide), in accordance with the approved Water Quality Sampling Plan. The tidal monitoring was conducted by CA environmental personnel during two separate sampling events on July 15, 2015 and August 27, 2015.

A total of 11 sample sites were selected throughout the canal for tidal stage surface water quality sampling; GPS coordinates for each sample location were recorded and sample locations are shown in Map 6. At each of the 11 sites, water samples were collected during each of four tidal stages, resulting in a total of 44 water samples per sampling event (for a total of 88 samples over both sampling days). The sampling methodology used was based on Suffolk County's sampling protocol. The water samples were immediately labeled and preserved on ice after collection.

VOCs and SVOCs were detected in surface water samples collected from 11 locations within the Grand Canal Study on July 15 and August 27, 2015. Of the chemicals detected, most were noted in less than five percent of the samples collected and most at maximum concentrations that were less than 1 µg/L. The following chemicals were detected in more than five percent of the samples (three or more samples in either sampling event): Acrolein, cis-1,2-Dichloroethene (cis-1,2-DCE), Bis(2-ethyl hexyl)phthalate (BEHP), Ethylbenzene, Toluene, Benzene, Fluoranthene, Xylenes, and 1,2,4-Trimethylbenzene. Of these chemicals, BEHP, acrolein, and benzene were detected in the July 2015 samples at maximum concentrations exceeding the USEPA tap-water RSLs. BEHP, acrolein, and benzene were detected in the August 2015 samples at maximum concentrations exceeding the tap-water regional screening levels (RSLs). Because the Grand Canal is not a drinking water source, these comparisons are for reference only.

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MAP 6

Tidal Stage Surface Water Sampling Locations

The most frequently detected VOCs in the tidal stage monitoring samples were acrolein and toluene. Acrolein was detected in seven of 44 July samples and in 23 of 44 August samples. It can enter the aquatic environment by its use as an aquatic herbicide and is also formed during the gasoline and oil combustion. Toluene, the most frequently detected BTEX compound (benzene, toluene, ethylbenzene, and xylenes), is a common laboratory contaminant and is also incorporated into fuels and used as solvents. BTEX compounds were found in six or more of the 88 samples analyzed and are common indicators of fuel-related contamination.

The results of the laboratory analysis for the surface water samples collected by CA are provided and discussed in greater detail, especially with regards to their potential impacts of human health, in the 'Grand Canal Public Health Evaluation Report and Sediment Risk Assessment' (Appendix C).

3.2.1.1 Field Inventory of Canal

CA environmental personnel conducted an inventory of Grand Canal features and shoreline structures to identify the presence of culverts, shoreline hardening structures (e.g., bulk heads), and drainage/storm water outfalls. This inventory was performed on September 2, 2015; additional data were collected later in 2015 and in early 2016. The results of this inventory are shown in Map 7. A significant portion of the wooden bulkheads are in disrepair, particularly in the northern extents of the canal system.

The majority of private property located on the Grand Canal has wooden bulk heads. Approximately half of the wooden bulkheads are in disrepair and dredging in these areas may exacerbate these conditions. Many of the bulkheads are in serious disrepair. The man-made berm which runs along the Pickman-Remmer wetland system has three culverts and one open stream that connects the canal to the wetland system. The three culverts are in disrepair and have a very limited function in terms of tidal exchange. The berm itself is experiencing erosion in many areas on the canal side. Areas of soil loss and exposed tree roots from undermining are evident. The erosion of the berm appears to be resulting from the long-term instability of the side slopes of the man-made soil structure, as well as action by boat wakes and storm tides. The stream connecting the wetlands and the Grand Canal appears to provide the most tidal exchange to the wetland.

The bulkheads along the private properties have numerous stormwater outfalls, as well as smaller outfalls which are likely the drainage pipe from basement sump pumps in private homes. Further details and photographic documentation is provided in Map 7.

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MAP 7

Grand Canal Feature Inventory and Shoreline Structure Map

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3.2.1.2 Storm Water Runoff Monitoring

To determine the contaminant load from storm water runoff into the Grand Canal, CA environmental personnel conducted a Storm Water Runoff Monitoring (SWRM) study, in accordance with the Water Quality Monitoring Plan. This study involved the collection of surface water samples prior to and during a significant rainfall event (at least 0.5 inches of precipitation). CA performed sampling for the wet event on August 11, 2015. This date was selected because the Grand Canal experienced heavy precipitation on this date. The samples were collected within the first three hours of steady precipitation.

To provide baseline data, CA performed sampling for the dry event on September 3, 2015. The same sampling sites were used as those during the wet event (Map 8). This date was selected for sampling as it followed a period of dry weather (at least 72 hours without rainfall). This dry event allows for an understanding of existing environmental conditions in the Grand Canal prior to any potential contamination by storm water runoff.

Sample areas for the storm water runoff study were selected based on the presence of areas with direct outfall and/or drainage, as indicated in the field inventory of the canal. A total of six sample sites were selected throughout the canal for stormwater runoff water quality sampling; GPS coordinates for each sample location were recorded and sampling locations are shown on Map 8. At each site, water samples were collected, resulting in a total of six water samples per sampling event (for a total of 12 samples over both sampling days). The sampling methodology was based on that Suffolk County’s sampling protocol. The water samples were immediately labeled and preserved on ice after collection.

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MAP 8

Storm Water Runoff Surface Water Sampling Locations

VOCs and SVOCs were detected in the storm water runoff surface water samples. The chemical detections were similar to those found during the tidal cycle sampling. The BEHP and acrolein concentrations for the dry sampling event generally exceeded those for the wet sampling event, suggesting a possible dilution of loading concentrations as a consequence of the precipitation event. The BTEX, PAHs, and 1,2,4-trimethylbenzene detections are indicative of contributions from one or more anthropogenic sources of contamination (e.g., fuel-related or combustion sources, surface water run-off from asphalt-paved areas, etc.). Three organic chemicals (tert-butyl alcohol, chloromethane, and carbon disulfide) were detected in the stormwater runoff study samples.

The results of the contaminant laboratory analysis for the surface water samples collected by CA are provided and discussed in greater detail, especially with regards to their potential impacts on human health, in the 'Grand Canal Public Health Evaluation Report and Sediment Risk Assessment and Sediment Risk Assessment' (Appendix C).

3.2.1.2 Surface Water Quality Results- Bacterial Contamination

The Grand Canal surface water samples were analyzed for three bacterial indicators (enterococci, total coliform, and fecal coliform) by Long Island Analytical Laboratories, Inc. The bacterial analysis for the surface water samples indicated that bacterial levels frequently exceeded the standard values for all indicators in all months. The New York water quality standards for coliforms (6 CRR-NY 703.4) state that:

- For Total Coliforms (measured as number per 100 millimeters [ml]) "the monthly median value and more than 20 percent of the samples from a minimum of five examinations, shall not exceed 2,400 and 5,000, respectively."

- For Fecal Coliforms (measured as number per 100 ml) “the monthly geometric mean from a minimum of five examinations shall not exceed 200.”

Additionally, USEPA’s 2012 Recreational Water Quality Criteria recommend that:

- Enterococci should not exceed a geometric sample mean of 30-35 colony forming units (cfu)/100 ml or a statistical threshold value (STV; a value that should not be exceed by more than 10% of samples) of 110-130 cfu/100 ml. The range of values represent two recommendations based on differing acceptable illness rates from recreational activities in contaminated waters.

For fecal coliform, data reported for all sampling locations with the exception of one, including the reference locations, exceeded the value of 200 colonies/100 ml. Data ranged from 130-16,000 colonies/100ml. The results for samples collected from the Grand Canal during the tidal studies tended to be higher than those reported for other locations. The interpretation of the fecal coliform dataset for the July 15, 2015 sampling event is complicated by the fact that the analytical laboratory reported most results as “>1600 cfu/100 ml”. Based on the results from the 2005 report sample dilution did not appear to be necessary. However, after receiving the first round of sampling results (July 15, 2015) all subsequent samples were diluted 10x to allow for more accurate results. The fecal coliform values recorded in 2015 were considerably higher than those recorded in 2004 as part of the prior 2005 Grand Canal environmental assessment. The 2005 report states that fecal coliform levels ranged from 130 to 967 colonies/100 ml. These results suggest that fecal coliform levels have considerably worsened in the Grand Canal over the past decade.

For total coliforms, August samples often exceeded 2,400 and frequently 5,000 colonies/100 ml. Data ranged from 130-16,000 colonies/100ml. The results indicated that samples collected from the Grand Canal during the tidal studies tended to be higher than those reported for other locations. The data reported for GC-North and GC-South (the Connequot River locations) and WL-Ref-2 did not exceed the benchmarks presented. This may suggest that these high bacterial levels are from sources within the canal system, possibly residential septic systems.

The total coliform values recorded in 2015 were considerably higher than those recorded in 2004 as part of the prior Grand Canal environmental assessment. The 2005 report states that total coliform levels ranged from 290 to 5,713 colonies/100 ml. These results suggest that total coliform levels have considerably worsened in the Grand Canal over the past decade.

For enterococci, the majority of samples exceeded 35 and 130 colonies/100 ml. Data ranged from 10-13,000 colonies/100ml. The data reported for GC-North and GC-South (the Connequot River locations) did not exceed the benchmarks presented; however, the results for the reference stations did exceed the benchmarks.

Results from the "dry" and "wet" sampling events did not suggest a significant difference in the bacteriological loading in surface water run-off to the Canal from dry versus wet conditions.

These results suggest that bacterial contamination is a significant issue throughout the Grand Canal. The SWRM study also suggests that the primary sources of bacterial contamination is not likely from stormwater run-off. Although the data for the Connetquot River locations (GC North and GC South) is limited, the results for the Grand Canal are significantly higher than those reported for the Connetquot River. However, results for the reference locations also indicate that the issue is not entirely unique to the Canal area. Additional follow-up investigations would be necessary to determine, more definitely, the potential sources of contamination. Sewage odors were observed by CA environmental personnel during field sampling events; these odors could be indicative of failing residential septic systems. Other potential sources may include fecal contamination from waterfowl. In terms of bacteriological quality, neither the Grand Canal nor the reference area surface waters are likely to be safe for primary contact recreation.

It should be noted that the shoreline and immediate vicinity of the canal are occupied by a substantial number of single family homes which utilize on-site sanitary systems for domestic wastewater disposal. Although a sanitary survey of these systems was not performed as part of this investigation, it can be assumed that a large number of the systems consist of cesspools, given the general age of the neighborhood residences. Based on the prevalent lot sizes in the neighborhood, many on-site sanitary systems are estimated to be within 100 to 200 feet of the surface waters of the canal. The low elevation of the land area surrounding the canal indicates that the systems are in predominantly shallow groundwater conditions. Examination of aerial photographs indicates that there are approximately 390 houses in the immediate vicinity of the canal, approximately 140 of which are on the immediate shoreline of the canal or its tributaries. Approximately 40 houses have on-site sanitary systems within 100 feet of the surface waters associated with the canal, and approximately 130 houses would have sanitary systems within 200 feet of the canal shoreline. The proximity of on-site systems to surface waters, combined with shallow groundwater conditions and presumed age of the systems, indicates a high potential for release of bacterial and nutrient contaminants to surface waters through groundwater flow and possible system failures.

The results of the bacterial laboratory analysis for the surface water samples collected by CA are provided and discussed in greater detail, especially with regards to their potential impacts of human health, in the 'Grand Canal Public Health Evaluation Report and Sediment Risk Assessment and Sediment Risk Assessment' (Appendix C).

3.2.1.3 Surface Water Quality Results- Physical Parameters

Table 11 depicts the average physical water quality parameters recorded during the tidal cycle surface water assessment sampling. The average temperatures recorded during each sampling event were equivalent to temperatures that would be expected in a canal along the south shore of Long Island during late summer. Generally, water temperature readings collected during the high tide and mid-outgoing tide were greater than those reported for low tide and mid-incoming conditions.

Table 11. Average Physical Water Quality Parameters for Tidal Stage Sampling Events

Date	Tidal Cycle	Average				
		Temp (°C)	DO (mg/l)	Salinity (ppt)	Turbidity (NTU)	Depth (feet)
7/15/15	Low	26.07	1.95	17.79	8.90	5.61
	Mid-incoming	26.24	2.36	18.81	9.83	5.90
	High	26.91	4.39	19.43	10.19	6.21
	Mid-outgoing	26.75	4.47	19.09	10.98	5.55
8/27/15	Low	25.21	1.62	20.98	10.78	5.45
	Mid-incoming	25.41	1.88	21.56	11.25	5.76
	High	25.84	3.69	21.47	14.25	6.07
	Mid-outgoing	26.19	5.12	21.27	12.69	5.74

The average dissolved oxygen (DO) varied from a low 1.62 mg/l during the low tide to a high of 5.12 mg/l during the mid-outgoing tide on August 27, 2015. The lowest average DO readings occurred during the low tide during both sampling events. The average DO readings during the low and incoming off low tidal cycles indicated that the canal was experiencing a state of hypoxia (DO less than 3 mg/l). For saltwater, USEPA (2000) recommends a minimum DO level of 2.3 mg/l as a limit for continuous 24-hour exposure to protect juvenile and adult aquatic life (the value would be approximately two mg/L for a 12 hour exposure). Therefore, the low DO levels in the Grand Canal have the potential to impact the development and health of aquatic organisms.

Average salinity readings indicated moderate increases in salinity with tidal inflow. Most salinity readings in July were between 16 and 20 practical salinity units (PSU) whereas most of the August readings were between 20 and 22 PSU. The readings at the sampling stations located closest to the Connetquot River were generally more variable than those reported for the other stations and likely reflect tidal influences.

It can be concluded from the water quality data collected as part of the tidal water monitoring study that water temperature, salinity, and DO levels are somewhat related to tidal fluctuations. Generally higher water temperatures, salinity, and DO levels were observed at high-tide and mid-outgoing tide conditions versus low-tide and mid-incoming tide conditions. However, the variations in readings over time and across the stations did not suggest a significant level of tidal flushing in the Grand Canal.

Table 12 depicts the physical water quality parameters recorded during the storm water runoff sampling events. The water temperature collected during the dry event appeared to be similar to that of the tidal cycle assessment. Unfortunately, the temperature probe malfunctioned during the wet event and no data were collected.

Table 12. Average Physical Water Quality Parameters for Storm Water Runoff Sampling Events

Event	Sample Site	Average				
		Temp (°C)	DO (mg/l)	Salinity (ppt)	Turbidity (NTU)	Depth (feet)
Dry Event	SW-1	25.45	1.43	20.78	6.6	3
	SW-2	25.82	2.15	21.87	6.1	4.8
	SW-3	26.21	2.36	22.21	6.2	4.6
	SW-4	26.96	2	24.07	5.1	5.8
	SW-5	26.34	2.03	22.58	8	3
	SW-6	25.59	1.06	21.33	7.6	2
	Average	**26.06**	**1.84**	**22.14**	**6.60**	**3.87**
Wet Event	SW-1	N/A	4.15	16.24	11	3
	SW-2	N/A	4.21	17.7	9.4	4.8
	SW-3	N/A	3.87	19.68	16.3	4.6
	SW-4	N/A	2.77	18.74	20.2	5.8
	SW-5	N/A	2.33	19.56	6.9	3
	SW-6	N/A	2.76	16.83	10.7	2
	Average	**N/A***	**3.35**	**18.13**	**12.42**	**3.87**

***Note: Temperature probe malfunction during the wet sampling event and no temperature data was collected.**

DO readings were generally lower during the dry sampling event (1.06 to 2.36 mg/L) compared to the wet sampling event (2.33 to 4.21 mg/L). During the dry event, the DO readings (average of 1.84 mg/l) indicated that the canal was experiencing a state of hypoxia (DO less than three mg/l). The DO during the wet event appeared to have increased as a result of the storm water input and had an average DO of 3.35 mg/l.

Salinity was higher during the dry sampling event (20.78 to 24.07 PSU) compared to the wet sampling event (16.24 to 19.68 PSU). This is most likely a result of the introduction of freshwater from the rainfall and storm water runoff.

Turbidity levels were generally lower during the dry sampling event (5.1 to 8 NTU) compared to the wet sampling event (6.9 to 20.2 NTU). The turbidity readings during the wet event were almost twice those observed during the dry event. This turbidity increase during the wet event likely resulted from the input of sedimentation associated with storm water runoff.

The results of the water quality analysis for the surface water samples collected by CA are provided and discussed in greater detail in the ‘Grand Canal Public Health Evaluation Report and Sediment Risk Assessment’ (Appendix C).

3.2.1.4 Review of Continuous Monitoring of Physical Water Quality Parameter Data

The SCDHS and SCDPW used Sonde meters at two continuous monitoring locations in the Grand Canal to collect water quality data every 15 minutes. Parameters recorded included temperature, dissolved oxygen, salinity, and water displacement.

The continuous data collected in 2013 and 2014 are provided and discussed in the ‘Grand Canal Public Health Evaluation Report and Sediment Risk Assessment and Sediment Risk Assessment and Sediment Risk Assessment’ (Appendix C); a map showing data collection locations is also provided in this report. A review of these data indicated that salinity and temperature readings showed general daily fluctuations with the tidal cycle. Daily DO values ranged from fully saturated with oxygen (eight to nine mg/L) to nearly anoxic (less than two mg/L). The low DO levels varied throughout the tidal cycle and do not appear to be related to tidal exchanges. There are several factors that can affect DO levels in a water body: volume and velocity of water of water flowing in the water body; climate/season; the type and number of organisms in the water body; dissolved or suspended solids; amount of nutrients in the water; organic wastes; riparian vegetation (shading); variations in phytoplankton biomass; photosynthesis and respiration rates; and ground water inflow.

In order to fully understand the reason for the large variation in daily DO levels a more in depth analysis beyond the scope of this study would need to be performed. However, review of the limited water quality data that was collected during this study indicated that it is likely that the daily DO levels are being affected by nutrient input and bacteria levels. The data recorded by the Sondes was also utilized in the current analysis discussion found in Section 3.0.0.0.

3.3 Wetlands Characterization and Assessment (Subtask 3d)

A wetland assessment was performed to document a number of baseline conditions for hydrology, vegetation, soils and avian species within the wetlands associated with the Grand Canal, and to provide an assessment of the current health of those wetlands. The full 'Wetland Habitation Condition and Health Assessment Report' has been included as Appendix H. This report includes all complete maps and figures associated with the report. Here the report is summarized and key findings are described; key tables are also included here, while the rest of the maps, figures, and tables can be found in the full report (Appendix H).

The specific sub-tasks performed as part of the wetlands characterization and assessment included:

- Background data collection and review;
- Landscape analysis and cover type mapping;
- Field data collection; and,
- Wetland habitat characterization, assessment of stressors, and health evaluation

The wetland habitat assessment utilized available maps, aerial photography, and background reports and data, as well as field data collected on site to document and assess conditions of the Grand Canal marsh system.

The methodology used in the wetland habitat characterization and health assessment followed the United States Environmental Protection Agency's (USEPA) 3-tiered approach to wetland assessments, which combines: 1) landscape-level analysis; 2) a rapid assessment and scoring of overall wetland health; and, 3) a component of more intensive field-based data collection for user-defined parameters (USEPA, 2015).

3.3.0 Landscape Analysis and Cover Type Mapping

A habitat cover type map for the study area was produced using Geographic Information System (GIS) wetland data and was based on a desktop overlay and evaluation of the relevant spatial data. The data layer included potential locations of wetlands that are hydrologically-connected to the Grand Canal and that could be potentially affected by future project activities. Preliminary wetland boundaries were overlaid onto satellite imagery maps and hardcopies were produced for use by biologists in the field to assess boundaries and identify any needed boundary modifications.

Biologists classified the wetland type per the widely accepted Cowardin wetland classification system (Cowardin et. al., 1979) and dominant plant community type, and also noted the locations of abutting upland areas as well as large infestations of the invasive species common reed (*Phragmites australis*). Six vegetated community types, and two open water types (excluding the Grand Canal) covering 131 acres, were differentiated and mapped in the Grand Canal study area to create a project cover type map and included: Forest_Scrub-shrub; Intertidal marsh; High marsh_pool_panne; High marsh_Marsh elder (*Iva frutescens*); Common reed_stunted growth form; Common reed_tall growth form; Pond; and Tidal channels.

In addition, significant features such as culverts and sampling station locations were recorded using GPS and included as additional layers on the cover type map and related project area figures. All maps and figures have been provided in the 'Wetland Habitation Condition and Health Assessment Report' (Appendix H).

3.3.1 Field-Based Data Collection

The condition of the marshes adjacent to the Grand Canal were further described through field data collection of parameters focused on the overall conditions and health of the marsh. These data were used to define baseline conditions for the marsh, diagnose areas of wetland degradation, and to develop standards to assess future wetland habitat restoration efforts.

3.3.1.0 Vegetation

Vegetation sampling was performed throughout the marshes associated with the Grand Canal. The goal of the vegetation survey effort was to (a) document the characteristics of vegetation within the dominant plant communities in the project area; (b) establish baseline conditions which will help the County to evaluate/anticipate if changes are/will occur on the marsh; and, (c) ensure the County is aware of the presence of invasive species in the project area. Various vegetation metrics were collected as part of the vegetation study, including a list of all live and dead standing vascular plants and macro-algae species (with distinction made between native and non-native species), stem density, plant height, and percent (%) cover of bare ground, trash, rock, micro-algae, fungus, dead plant material (not standing), and wrack.

Wetland communities within each of the three major marsh areas of the site (east, southwest, northwest sites), were delineated for survey based on the dominant plant species present, resulting in four major community types: intertidal marsh; high marsh/pool/panne; high marsh/marsh elder; and common reed. Each of these community types were targeted during survey efforts, which involved surveys at 26 sampling points established along seven transects; for a total of 78 1m^2 data plots.

Estuarine emergent marsh wetlands were found to comprise 88 acres in the Grand Canal study area: 50 acres in the east marsh complex; 16 acres in the southwest complex; and, 12 in the northwest complex. The common reed community type dominated in all three marsh complexes, comprising 70% of all emergent wetlands in the project area. These reed community types have been described in detail in the 'Wetland Habitation Condition and Health Assessment Report'. Within each complex, common reed comprised 39 acres (78%) of the wetlands found in the east marsh, eight acres (66%) of the wetlands in the northwest marsh, and eight acres (50%) of wetlands in the southwest marsh. Additionally, although not considered a wetland marsh community type, tidal channels (excluding the Grand Canal) cover 3.5 acres of the east marsh, 0.7 in the northwest marsh, and 0.9 acres in the southwest marsh (Table 13).

Table 13. Acres of Marsh Community Types and Tidal Channels in Grand Canal Marsh Complexes

Community Type	East Marsh	Southwest Marsh	Northwest Marsh
Intertidal Marsh	0	2.0	0
High Marsh_Pool_Panne	7.2	2.5	3.5
High Marsh_Marsh Elder	3.6	3.7	0.7
Common Reed	38.7	8.0	7.9
Tidal Channels	3.5	0.9	0.7
Total	53.1	17.0	12.8

3.3.1.1 Soil

Soil metrics were collected throughout the marshes associated with the Grand Canal. The goal of the soil survey effort was to (a) document the characteristics of soils within the dominant plant communities in the project area; and (b) establish baseline conditions which will help the County to evaluate/anticipate if changes are/will occur on the marsh. Specific soil metrics assessed included compaction, electrical conductivity, and organic matter. Details of the soil survey and associated maps are provided in the 'Wetland Habitation Condition and Health Assessment Report' (Appendix H).

Soils within approximately 53% of the study area (which includes a portion of developed areas adjacent to the marsh complexes) were classified as TM (Tidal Marsh). Tidal marsh refers to a frequently flooded/ponded hydric soil with deep organic composition. The remaining soils were found along the marsh margins and urban areas and were comprised primarily of highly disturbed, filled and/or graded soils covering approximately 12% of the study area, and areas of coastal sandy-loam/loamy-sand soil types which occurred within undeveloped forest-scrub-shrub communities and covered about 35 % of the site.

Based on field data collection, soils throughout the marsh complexes were typical of the TM soil unit type and were comprised of highly saturated deep organic material, greater than 18 inches deep. When evaluated with a soil penetrometer, less than 200 pounds per square inch (psi) of resistance was encountered, indicating no compaction, as is typical for moist soils with high organic composition. Where slight resistance was encountered, it was primarily due to a dense root system, not compacted soil or fill material. There are undoubtedly some areas within the marsh complexes, particularly along the marsh edges and berm, which contain fill material as evidenced by areas of exposed gravel and dumped fill. But these are uncommon and do not appear to be driving factors in the health or vegetative composition within the marsh.

Salinity analyses, which is often identified as one of the major contributing factors that drives the vegetative communities present on a site, were inconclusive. Typical salinity levels in intertidal and high marsh areas of estuarine tidal marsh systems in New York range from 18–30 parts per thousand (ppt). Results for the study area ranged from 9.4 to 12.6 and appeared to indicate that the marsh system is mesohaline (i.e., salinity from five to 18 ppt). Results were not consistent with reported salinities for the Long Island area and an alternate, more intensive, survey approach should be investigated for future marsh salinity monitoring.

3.3.1.2 Avian Survey

An avian survey was performed to document the presence of bird species in the project area to identify which species are utilizing habitats associated with the Grand Canal. The goal of the avian survey effort was to document the presence of bird species in the project area to: (a) identify which species are utilizing habitats associated with the Grand Canal; (b) help the County to evaluate/anticipate if there are birds which may be negatively affected by changes to the marsh; and, (c) ensure the County is aware of the presence of any state or federally-listed species in the project area.

Avian surveys were performed by qualified biologists on March 16-17, May 21-22, and June 25-26, 2015. Surveys closely followed the methodology of the US Geologic Survey (USGS) Standardized North American Marsh Bird Monitoring Protocol (Conway, 2009), and US Fish and Wildlife Service (USFWS) Landbird Monitoring Protocol (Knutson, 2008). The focus of the survey effort was to identify as many bird species possible in the project area. As such, surveys included several methods (point counts and area searches) which were performed under different tidal amplitude conditions, and the points were placed in locations that captured the broadest area and as many different habitat types as possible at any given survey point. Birds were recorded if seen/heard within the marsh and open water complexes of the study area and adjacent upland/developed habitats. Survey locations and detailed results from the avian survey are provided in the ‘Wetland Habitation Condition and Health Assessment Report’ (Appendix H).

The study area falls within the NYSCDEC-designated South Shore Tidal Wetlands Bird Conservation Area (NYSDEC, 2004). The area is designated as such due to its unique assemblages of tidal salt marshes, upland habitats and open water creeks, channels and ditches, which are known to support a diverse mix of uncommon bird species, while the uplands provide critical migration habitat for birds crossing the ocean and bays.

Sixty-three bird species were observed in the study area, including 36 unique species identified in March before many of the migrant species had arrived, 52 observed in May, and 47 in June. Survey results excluded species that were observed flying over the site unless the species was known to be utilizing marsh resources (e.g., northern harrier, swifts and swallows, and terns seen foraging over the marsh open water areas). The species most commonly observed during all Grand Canal survey events were common grackle (*Quiscalus quiscula*), red-winged blackbird (*Agelaius phoeniceus)*, and song sparrow (*Melospiza melodia*). Focused evening surveys for nocturnal species detected two separate eastern screech owls (*Megascops asio*). While many of the species observed within the study area utilize a diversity of habitats during their life cycle, 24 species are closely associated with marsh and open water habitats of the study area and are the most susceptible to changes in the availability and quality of marsh habitats.

Correspondence with federal and state natural resource agencies did not reveal any rare, threatened or endangered species that are known to be present, or were identified as likely to occur in the study area (NYSEDC 2014, USFWS 2015). However, two listed birds, the northern harrier and common tern were observed foraging over the marsh surfaces and open water areas of the Grand Canal during survey events. In addition, several ospreys (a state species of special concern), were also documented during surveys. Two man-made osprey nest platforms are located adjacent to Shore Road along the south border of the study area and a natural nest is located within the Grand Canal marsh complex study area; all were active during the 2015 breeding/nesting season.

Efforts did not include surveys for other wildlife species, although several medium to large-sized mammal species that are generalists and commonly associated with highly-developed urban settings were noted. Based on direct observation, or as evidenced by tracks or scat, additional wildlife species in the study area include: white-tailed deer (*Odocoileus virginianus*); raccoon (*Procyon lotor*); muskrat (*Ondatra zibethicus*); red fox (*Vulpes vulpes*); gray squirrel (*Sciurus carolinensis*); and, chipmunk (*Tamias striatus*). Numerous sighting of the non-native house cat (*Felis catus*) were also observed throughout the study area, and a cat feeding station is located within 100 ft. of bird survey point #9.

3.3.1.3 Site Characterization and Assessment of Stressors

Concurrent to all field survey efforts, biologists gathered information to identify potential stressors in the study area. Evaluation parameters included field evidence of stressors affecting key marsh functions such as: altered hydroperiod, which included ditches/channelization, deeply cut or slumping channels, drains/culverts/pipes, upland plant species encroaching into wetlands, vegetation die-off, tidal restrictions, dikes, fill, filamentous algae, excavation, riprap, inlets/outlets; storm water input such as habitat/vegetation disturbance, such as mowing, cutting, herbicide use, excessive herbivory, insect damage, and invasive species; and, residential stressors, for example.

3.3.1.4 Photo-documentation

The wetland survey effort also included the establishment of photo-stations to document baseline conditions and to facilitate visual comparisons of baseline and future marsh conditions. Four photographs were collected per photo station facing each cardinal direction (i.e., N, S, E and W) in sequence. Additional photographs were collected as needed to document overall marsh conditions in the vicinity of each transect. GPS coordinates of photo station locations are provided in the photographic documentation in the 'Wetland Habitation Condition and Health Assessment Report' (Appendix H).

3.3.1.5 Field Verification of Cover Type Map

Wetland biologists performed systematic field verifications, or "ground-truthing", of the wetland cover type maps while on site for avian and vegetation survey efforts performed between March and October, 2015, to confirm that the preliminary wetland layer was an accurate representation of wetland boundary shapes and sizes. Preliminary wetland boundaries were overlaid onto satellite imagery maps and hardcopies were produced for use by biologists in the field to assess boundaries and identify any needed boundary modifications. In addition, an IPad™ was preloaded with the preliminary wetland boundaries which allowed biologists to identify their real-time location in the field relative to locations of wetland boundary lines to facilitate the wetland verification effort. Where necessary, revisions to wetland locations and boundaries were documented on hardcopy maps and used to update the project GIS wetland data layer using ArcMap™ 10.1.

3.3.2 Wetland Condition and Health Assessment Report

The 'Wetland Habitation Condition and Health Assessment Report' has been included as Appendix H. The goal of the wetland condition and health assessment was to: (a) document the overall health of wetlands in the project area; (b) identify the stressors affecting wetland health; and (c) establish baseline conditions which will help the County to evaluate/anticipate if changes are/will occur on the marsh. The Report includes the identification of stressors and factors affecting the marsh and recommendations for potential restoration efforts. It also provides detailed results of the field data collection, including all data tables, maps, field data collection forms, and photographic documentation.

Field based information regarding site stressors and actual data from the vegetation and soil surveys were combined with a landscape evaluation to produce a wetland score by closely following the methodology of the Mid-Atlantic Tidal Rapid Assessment Method (Mid-TRAM 2010). The approach uses high resolution variables that can be quickly assessed to help predict stress responses and relationships. The assessment includes metrics in four major attribute categories that are significant in driving the overall health of a wetland: buffer, hydrology, habitat/plant community (biotic and physical structure), and shoreline characteristics (Table 14).

Table 14. Attributes evaluated for the Grand Canal marsh complexes

Attribute	Metric	Description
Buffer/Landscape	Percent of Perimeter with 5m-Buffer	Percent of perimeter that abuts at least 5m (16 ft.) of natural or semi-natural condition land cover
Buffer/Landscape	Average Buffer Width	The average buffer width that is in natural or semi-natural condition
Buffer/Landscape	Surrounding Development	Percent of developed land within 250 m (280 ft.) from the edge of the area
Buffer/Landscape	Landscape Condition	Landscape condition within 250 m (820 ft.) surrounding the area based on the nativeness of vegetation, disturbance to substrate and extent of human visitation
Buffer/Landscape	Barriers to Landward Migration	Percent of landward perimeter of wetland that has physical barriers preventing wetland migration inland
Hydrology	Ditching & Draining	The presence of ditches in the wetland area
Hydrology	Fill & Fragmentation	The presence of fill or wetland fragmentation from anthropogenic sources in the wetland
Hydrology	Wetland Diking / Tidal Restriction	The presence of dikes, berms, culverts or other tidal flow restrictions
Hydrology	Point Sources	The presence of localized sources of pollution
Habitat	Bearing Capacity	Soil resistance measured with a penetrometer
Habitat	Vegetative Obstruction	Visual obstruction by vegetation < 1 m (3 ft.)
Habitat	Number of Plant Layers	Number of plant layers in the wetland based on plant height
Habitat	Percent Dominant/Co-dominant Invasive Species	Percent of co-dominant invasive species in the wetland
Habitat	Percent Invasive	Percent cover of invasive species in the wetland
Shoreline	Shoreline Alteration	Percent of shoreline that has been unnaturally altered
Shoreline	Shoreline Erosion	Score based on amount of shoreline that is eroding/stable/accreting

The 'Wetland Habitation Condition and Health Assessment Report' concluded that the marshes in the Grand Canal study area are all severely-stressed, particularly when compared to large salt marsh complexes in less disturbed landscape settings. Each assessed marsh in the Grand Canal Pickman-Remmer system is surrounded by intensive development which has reduced protective buffers, halted the ability of the marsh to shift landward with increasing sea levels, and has subjected the marshes to inputs of contaminants, sediments, freshwater, yard waste and other debris. All marshes are artificially ditched, two of the three marshes (northwest and east) have significant restrictions in tidal flow from the Grand Canal (which itself is somewhat restricted), and all are experiencing some shoreline erosion from wave action. In addition, field observations and review of aerial photographs indicate that invasive common reed occurs throughout all marsh complexes and is dominant in two of the three systems (east and northwest). Furthermore, review of historical photolog aerial photographs indicate that significant loss of wetlands in the Grand Canal study area has occurred over time.

3.4 Mosquito Analysis (Subtask 3e)

A mosquito analysis was performed for the Grand Canal system which involved a review of existing mosquito data for Suffolk County and data collected from the Grand Canal system, as well as a health risk analysis. The discussion of this analysis and its findings are described in Section 4 of the 'Grand Canal Public Health Evaluation Report and Sediment Risk Assessment', which has been included as Appendix C. The Report describes the potential impact on human health in relation to diseases carried by mosquitoes and analyzes the health impacts associated with the routine use of pesticides in the study area. The risk assessment for the mosquito health risk assessment was based on the West Nile Virus (WNV) data collected for the Grand Canal Study Area by the SCDHS Arthropod-Borne Disease Laboratory (ABDL) in 2013 and 2014. The analysis indicated that the risk of WNV in the Grand Canal area is very low. The methodology for this assessment, description of data sources, and detailed results are described in the 'Public Health Problem Evaluation and Report and Sediment Risk Assessment and Sediment Risk Assessment' (Appendix C). The report also discusses the presence of pesticides found in surface water samples collected in the Grand Canal by CA in 2015. The chemical profile of the Grand Canal surface waters indicated low-level contamination with pesticides.

Section 4. Public Health Problem Evaluation and Report (Task 4)

The potential for adverse human health impacts resulting from direct contact with surface waters and sediments, consumption of biota taken from the study area, and/or exposure to mosquitos (or other biological agents [e.g., bacteria]) within the Grand Canal study area was assessed. The evaluation involved analysis of chemical, microbiological, and vector data for the study area. Most of the data examined for the health assessment was collected by CA in 2014, 2015 and 2016, and is described in Section 3 of this document. The discussion of the public health analysis and its findings are described in the 'Grand Canal Public Health Evaluation Report and Sediment Risk Assessment' (Appendix C).

The public health evaluation for the Grand Canal found that water quality in the canal has been significantly impacted by nutrient enrichment; nitrogen and phosphorus levels were found to exceed recommended benchmarks (description of benchmarks provided in Appendix C). Dissolved oxygen (DO) readings were frequently below levels necessary for healthy aquatic life. In terms of bacteriological quality, neither the Grand Canal nor the reference area surface waters (collected from an area east of the Grand Canal study area) are likely to be safe for primary contact recreation. Additionally, the quality of the fish inhabiting the Grand Canal may be compromised (e.g., for purposes of human consumption) by the microbiological contamination. It should be noted that the bacterial levels in the Canal significantly exceeded those reported for the reference area locations.

Based on the chemical monitoring for standard-list volatile and semi-volatile organic chemicals and pesticides in the Grand Canal, the chemical profile of the study area surface waters indicated low-level contamination by typical anthropogenic sources (e.g., surface water run-off). None of the cancer risk estimates for the surface waters of the Canal (developed assuming occasional swimming in or occasional consumption of fish taken from the Canal) exceeded the USEPA's target risk range. However, the cancer risk estimates for the fish ingestion exposure pathway did exceed the conservative end of the USEPA cancer risk management range. None of the risk estimates for the direct contact exposure pathways (i.e., assuming occasional swimming) exceeded the USEPA's target risk range.

4.0 Presentation of Data Evaluation in the Public Health Assessment (Subtask 4a)

The public health evaluation for the Grand Canal and adjacent wetlands was performed using the physical, chemical, and microbiological data collected from the Grand Canal and adjacent wetlands under Tasks 2 and 3 of the project. Additionally, the public health evaluation considered data (including vector data) provided by SCDHS and data readily available as a result of internet web searches. Descriptions of the specific data used for the public health assessment have been described throughout the 'Grand Canal Public Health Evaluation Report and Sediment Risk Assessment' (Appendix C).

4.1 Development of Public Health Evaluation Methodology (Subtask 4b)

The methodology for the Grand Canal health evaluation report was developed in conjunction with Suffolk County's Department Division of Environmental Quality. A detailed description of the methodology has been provided in Section 2 of the 'Grand Canal Public Health Evaluation Report and Sediment Risk Assessment' (Appendix C).

Table 15. Key Public Health Factors That Can Be Improved Through Actions

Category	Impaired Factor	Threshold for Action	Predicted Improvement by Action
Water Quality	Direct Human Contact	• Exceedance of recommended thresholds of NY Codes, Rules and Regulations 6CRR-NY 703.3, 703.4, and 703.5.	Increasing water flow into the canal and surrounding wetlands will help improve the overall water quality regarding health risks. Action must be taken to eliminate anthropogenic sources of contamination that are contributing to the organic chemical, nutrient, and microbiological loading into the surface waters of the canal. These sources may affect residents and recreational uses through direct contact such as dermal contact and incidental ingestion; or indirect exposure such as consumption of biota taken from the canal.
	Consumption of Biota	• Exceedance of recommended thresholds of NYDOH LI Health Advice on Eating Fish You Catch. • Exceedance USEPA Recreational Screening levels (direct contact and fish consumption).	
'Sediment Management	Sediment Contaminations	• Exceedance of recommended thresholds of NYS Codes, Rules and Regulations 6NYCRR Part 375 • Exceedance of recommended thresholds of	Analysis of the sediment appears to indicate elevated levels of pesticides and metal, and removing of the fine sediments within the canal may eliminate some of these contaminants. However, it would be difficult to remediate and control the resuspension of

		NYSDEC Technical and Operational Guidance Series (TOGS0 5.1.9.)	this sediment into the water column which may increase human health concerns. In addition, if action is not taken to eliminate the anthropogenic sources of these contaminates the issues causing this contamination will continue to exist.
Viral Infection	Mosquito Breeding	SCDHS sampling and testing resulting in positive presence of Vector Borne Disease	By initiating the recommended action of Integrated Marsh Management (IMM) which has been proven to be an effective method to reduce mosquito breeding. IMM practices in the surrounding wetlands may result in the reduction of mosquito breeding and reduce the need for chemical treatment.

4.2 Application of Public Health Evaluation Methodology to Study Area Data (Subtask 4c)

The public health evaluation for the Grand Canal was performed in accordance with the methodology established in the work plan. A detailed description of the methodology has been provided in Section 2 of the 'Grand Canal Public Health Evaluation Report and Sediment Risk Assessment' (Appendix C).

4.3 Preparation of Draft Report (Subtask 4d) and Preparation of Revised Draft Report (Subtask 4e)

A draft of the public health report was submitted to the County in November 2015. The draft report was reviewed by Suffolk County's Department Division of Environmental Quality. Comments were incorporated into the revised version, which is included here as an Appendix.

Section 5. Ecological Health Evaluation and Draft Report (Task 5)

In 2006, Suffolk County enacted a resolution (#1040-2006) to add Ecological Health and Marine Productivity as Acceptable Criterial for County Dredging Projects. This resolution enabled these factors to be used as a criterion for justification of county dredging projects as being 'in the public interest'. The document titled 'Environmental Dredging Factors Considered for Improving Environmental Quality, Ecological Health and Marine Productivity' was used as a guide to perform an analysis and evaluation of the ecological health of the Grand Canal and adjacent wetlands. This document formulates a process for the evaluation of Environmental Dredging Factors for determining whether a proposed dredging project is necessary to increase flushing rates to protect or enhance marine ecology and productivity.

The ecological health evaluation for the Grand Canal included a discussion of physical conditions in the canal, breeding potential for mosquitos, flow rates, contaminant levels, as well as other factors which could harm the ecological health and productivity of the Grand Canal and adjacent wetlands. The evaluation also described changes in the canal system since the Grand Canal Assessment Final Report (2005) was published. The discussion of this analysis and its findings are presented in the 'Grand Canal Ecological Health Evaluation Report', which has been included as Appendix I.

The ecological health evaluation for the Grand Canal found that the Grand Canal is impaired in all three broad categories of factors (water quality, sediment, habitat/living resources). These findings were based primarily on the data collected and analyzed by CA from 2014 through 2016. Table 15 summarizes some of the key environmental factors that can be improved by actions (e.g., IMM, removal of berm, dredging) in the Grand Canal.

Table 16. Key Environmental Factors That Can Be Improved Through Actions

Category	Impaired Factor	Predicted Improvement by Actions
Water Quality	High levels of Coliform	Although increasing water flow into the canal and surrounding wetlands will help to improve the overall water quality. Action must be taken to eliminate the sources of the coliform input such as treatment of stormwater runoff and residential septic system improvements.
	Low levels of dissolved oxygen	Increasing tidal flow (oxygenated water) into the canal and surrounding wetlands will help to increase the overall dissolved oxygen level in the canal. However, action should be taken to reduce nutrient input into the canal system which is most likely the source that initiates the biological reaction that results in the decrease dissolved oxygen levels in the canal system.
	Nutrient (nitrogen and phosphorus) enrichment	Although increasing water flow into the canal and surrounding wetlands will help to improve the overall water quality. Action must be taken to eliminate the sources of the nutrient enrichment, such as treatment of stormwater runoff and residential septic system improvements.
Sediment Management	Sedimentation resulting in reduced channel depth.	Although, some of the sedimentation may be a result of material entering the system through the southern and northern canal entrances. The majority of sedimentation appears to be the result of failing bulkheads and erosion to the berms separating the canal from the adjacent wetlands. Even if dredging was to be considered in order to deepen the canal, without addressing the issues of failing bulkheads and berm erosion, the canal will continue to experience sediment deposition.
	Sediment contaminations	Analysis of the sediment appears to indicate elevated levels of pesticides and metals. The sources of these containments reflect contributions from a wide variety of anthropogenic sources, including routine pesticide use, emissions from common combustion sources, CCA treated lumber for bulkheads and recreational boating activities. Although, removing of the fine contaminated sediment within the canal may improve the benthic community diversity, difficulty in remediating and controlling the re-suspension of this material into the water column may increase

		human health concerns. In addition to removal issues, the transport and deposition of this material will also need to be evaluated.
Habitat/Living Resources	Highly stressed wetlands	Increasing tidal flow into the surrounding wetlands will help to improve the overall habitat and increase the diversity of flora and fauna within the wetland system. Removal of the berms surrounding the wetlands adjacent to the canal will increase the movement of tidal driven water flow into and out of the existing wetland. In addition, allowing for flood waters to move onto a larger area will help remediate flooding issues for the residents surrounding the canal.
	Mosquito Breeding	Integrated Marsh Management (IMM) has been proven to be an effective way to reduce mosquito breeding. Incorporating IMM practices in the surrounding wetlands may result in the reduction of mosquito breeding and reduced chemical treatment to the surrounding wetlands.

Section 6. Assessment of Actions (Task 6)

6.0 Proposed Methodology for Assessment

In order to assess potential action options for the Grand Canal, current conditions in the Grand Canal and adjacent wetlands must be first assessed in terms of ecological and public health. Data collection must be performed in order to determine if the Grand Canal is experiencing impaired conditions. Examples of data that should be collected and analyzed from throughout the study area include: water quality parameters (e.g., dissolved oxygen, salinity); hydrographic data (e.g., water depth, bottom sediment composition); tidal flushing and stream flow data; flora data (e.g., vegetation types, presence of invasive species); fauna data (e.g., benthic community composition, fisheries); sediment contamination; and water contamination, among others. Current conditions for the Grand Canal were assessed and described in this study.

Next, if impairments are found or if existing conditions are expected to lead to future impairments, potential action options to address these issues must be proposed. Analyses should be then undertaken to determine if existing impairments in the Grand Canal may be improved through the listed potential actions. Table 16 outlines the proposed methodology for assessing action options in the Grand Canal.

Table 17. Methodological Approach for Assessing Action Options in The Grand Canal

Step	Description
1. Define study area	Define study area (e.g., location, size)
2. Review existing data	Review existing data pertaining to study area (e.g., historical photographs, prior studies)
3. Collect and analyze data	a. Determine data necessary to assess current condition of study area -Data should address physical, biological, and chemical conditions -Data should enable an assessment of the study area's ecological and public health condition b. Collect and analyze data
4. Determine need for action	a. Based on analyzed data, determine condition of study area, particularly if impairments exist b. Define objectives of potential actions (e.g., improve ecological health of study area)
5. List potential actions	Determine action options for achieving objectives
6. Define additional data requirements	a. Determine what additional data are necessary to fully assess action options b. Collect these data to allow for informed decision making c. Define uncertainties and assumptions of action assessment
7. Evaluate action options	Evaluate potential action options in terms of: - Potential to address impairments in study area - Financial costs of action - Stakeholder concerns
8. Assess impediments to success	a. Physical constraints to alternative actions (e.g. private, deteriorated bulkheads, channel width/bulkhead set-backs) b. Regulatory approvals from involved agencies (e.g. NYSDEC tidal wetland permits) c. Continued anthropogenic sources of contamination (e.g. stormwater, septics)
9. Select preferred action	Select the best action option
10. Implement selected action	a. Implement selected action b. Conduct regular monitoring of key parameters to assess effects of action c. If action is not achieving desired outcomes, identify reasons why

6.1 Need for Action

In order to assess potential action options for the Grand Canal, current conditions in the Grand Canal and adjacent wetlands were assessed in terms of ecological health (see section 3 of this report as well as Appendix I ‘Grand Canal Ecological Health Evaluation Report’ and Appendix H ‘Wetland Habitat Condition and Health Assessment Report’) and public health (see Appendix C ‘Grand Canal Public Health Evaluation Report and Sediment Risk Assessment’). Numerous factors were examined to determine if the Grand Canal has been experiencing impaired conditions, and effort was placed on determining whether these impairments may be improved through various actions. The objectives of conducting actions within the Grand Canal would be to address the numerous impairments identified within the Grand Canal.

Based on field data and the wetland health assessment (Appendix H), the marshes in the study area were all found to be severely-stressed, particularly when compared to large salt marsh complexes in less disturbed landscape settings. Each assessed marsh in the Grand Canal Pickman-Remmer system is surrounded by intensive development which has reduced protective buffers, halted the ability of the marsh to shift landward with increasing sea levels, and has subjected the marshes to inputs of contaminants, sediments, freshwater, yard waste and other debris. All marshes are artificially ditched, two of the three marshes (northwest and east) have significant restrictions in tidal flow from the Grand Canal (which itself is somewhat restricted), and all are experiencing some shoreline erosion from wave action. In addition, invasive common reed occurs throughout all marsh complexes and is dominant in two of the three systems (east and northwest). Furthermore, a review of historic aerial images (Suffolk County, 2015) and hydric soil mapping (USDA, 2014) show significant loss of wetlands in the Grand Canal study area.

Results from water quality monitoring conducted in the Grand Canal study area as part of the present study (data collected in 2014, 2015, and 2016), as well as data collected in 2004 as part of the prior Grand Canal environmental study, indicated that the canal and connected tidal areas are significantly impacted by sediment and nutrient enrichment, as evidenced by low dissolved oxygen levels, high levels of nitrogen and phosphorus, elevated coliform bacteria levels, elevated levels of volatile organic compounds (VOCs) and semi-volatile organics (SVOCs), highly turbid water, and brown algae blooms. The data generally indicated that water quality conditions in the Grand Canal have worsened over the past decade. Results from the sediment monitoring conducted in the Grand Canal study area as part of the present study (data collected in 2015), as well as data collected in 2004 as part of the prior Grand Canal environmental study, indicated that some sediments from the Grand Canal were contaminated with DDT and its constituents at moderate to high levels, indicating chronic to acute toxicity to aquatic life. The sediment analysis also indicated that some samples had moderate metal contamination.

These impaired water quality and sediment conditions can be harmful to both public and ecological health. Poor tidal flushing, petroleum products used in boats, and storm water runoff input from adjacent developed areas and storm drains have been identified as significant contributing factors to impairments in the Grand Canal. During this study, limited tidal flushing, stagnant areas of the canal and marshes, brown algal blooms, possible input of sanitary system effluents from residences, storm water runoff via storm drains into marshes, oil sheen on marsh and open water surfaces, and erosion, were all observed.

6.2 List of Potential Actions

It can be concluded that the Grand Canal and adjacent wetlands are experiencing severe impairments. To address these impairments, several potential actions may be undertaken. Table 17 describes several potential action options for the Grand Canal. It should be noted that although the Canal is considered to have severe impairments, the extent of impairments is comparable to that found in other surface waters subject to similar anthropogenic impacts.

Table 18. Potential Actions for the Grand Canal

Action	Description	Potential Results
Alternative 1: No Action **(Not Preferred)**	No additional action to improve conditions in the canal.	If no action is taken to improve ecological and public health risks in the canal, the conditions within the canal will continue to worsen.
Alternative 2: Channel Dredging only. **(Not Preferred)**	Dredge the channel within the canal to a 5-foot below mean low water depth.	The major sediment deposition within the interior of the canal system appears to be the result of deteriorated bulkheads and berm erosion. Without these two sources being addressed the sedimentation within the canal will continue with or without dredging.
Alternative 3. IMM and Berm Alteration (**Preferred Action**)	Initiate an Integrated Marsh Management Program (IMM) and entire/partial berm removal	An IMM action will benefit the overall health of flora and fauna inhabiting the wetlands associated with the canal system. Partial or total removal of the berm that is currently restricting water movement into the wetlands will help to increase water movement/exchange in the canal by opening up a larger surface area for the water to flow into during tidal exchanges. This will also help to mitigate residential flooding issues during storm events. .
Alternative 4. IMM, Berm Alteration, and Selective Dredging (**Action if needed)**	In addition to the preferred action above, selectively dredging areas where sediment deposition appears to be restricting water movement.	Selective dredging would most likely pertain to areas at the mouth of both the northern and southern entrances of the canal were sediment may be entering the canal system from the bay and river. Sediment buildup across these areas may be restrictive to water flow entering the canal.

As indicated in the above table, the preferred method to improve ecological and health risk issues associated with Grand Canal is to initiate an IMM action and berm alteration. The alteration of the berm will allow water entering the canal to disperse into the wetland permitting a larger volume of tidal water to enter the system. This larger volume of water entering the canal system with each tidal cycle will help increase the flushing capacity of the canal and help improve water quality. An IMM will increase the amount of tidal water that disperses throughout the wetland which will help mitigate invasive flora species that flourish in low salinity environments as well as increasing the diversity of fauna that feed on insects and their larva (such as mosquitos).

However, it should be noted that although this alternative will help improve water quality within the canal and its associated wetlands by increasing the area within the canal system to water flow, it is imperative that the anthropogenic sources creating the ecological and human health risks be addressed. If these sources are not mitigated, any action will have a limited effectiveness. It should be noted that the narrow configuration of the south entrance may place upper limits on the amount of water exchange that can be achieved under this alternative.

6.3 Additional Data Requirements

Additional work is needed to fully evaluate the options and assess the cost-benefits of the various management recommendations. A detailed assessment of the financial costs of the proposed actions (Alternatives 2 through 4 in Table 18) in the Grand Canal must be performed. The financial cost may dictate which action is undertaken, or the order that they are performed. For instance, it may be feasible to first perform Alternative 3, determine the impacts, and then, if necessary, conduct selective dredging (Alternative 4) at a later time. Similarly, it is necessary to secure funding for the project.

More research is necessary to define contaminant sources to the Grand Canal, particularly for bacterial contaminants. Even if dredging and berm removal were performed, contaminant may still be entering and impairing the study area if contaminant sources are not addressed. It will, therefore, be important to identify these contaminant sources and address them in conjunction with the other action options selected.

6.4 Action Evaluation

The ‘2005 Grand Canal Ecological Health Evaluation Report’ (Appendix I) concluded that dredging and IMM in the Grand Canal may alleviate the numerous documented impairments. However, further investigations conducted during this study appear to indicate that an aggressive IMM action in combination with berm alterations will be more effective in improving the ecological and human health risk currently impacting the canal system. IMM will facilitate fish access and reduce stagnant waters in wetlands, both of which may reduce mosquito breeding near the Grand Canal. Increased tidal flow through potential actions, particularly berm removal, may also help to reduce the retention time of bacteria and nutrients within the canal, resulting in lower observed coliform and nutrient levels, as well as improve impaired water quality parameters, such as DO. Increased tidal flow and IMM can also serve to improve the health of the wetlands near the Grand Canal by: reducing common reed populations; increasing native vegetation; increasing vegetative diversity; and improving wildlife maneuverability throughout marshes adjacent to the Grand Canal. Lastly, selective dredging can serve as a means to remove obstructions within the canal system (e.g., shoaling at the entrances of canal, debris) that may be restricting water movement into the canal from the Great South Bay and Connetquot River.

The ‘Wetland Habitat Condition and Health Assessment’ (Appendix H) concluded that removal of portions of the man-made berm along the west perimeter of the east marsh complex to allow for increased tidal flow throughout the marsh would likely improve the health of the marsh system and potentially also provide flood control. This removal would allow water to enter the natural marsh system where it can be contained and slowly absorbed. The Report recommends that berm removal be conducted first, and then, if necessary, dredging can be implemented later.

IMM, including berm removal, will facilitate fish access and reduce stagnant waters in wetlands, both of which may reduce mosquito breeding near the Grand Canal. Increased tidal flow through potential actions, particularly berm removal, may also help to reduce the retention time of bacteria and nutrients within the canal, resulting in lower observed coliform and nutrient levels, as well as improve impaired water quality parameters, such as DO. Increased tidal flow and IMM can also serve to improve the health of the wetlands near the Grand Canal by: reducing common reed populations; increasing native vegetation; increasing vegetative diversity; and improving wildlife maneuverability throughout marshes adjacent to the Grand Canal.

The ‘Grand Canal Public Health Evaluation Report and Sediment Risk Assessment’ (Appendix C) also concluded that potential actions may be an effective way to improve tidal flow to the canal and wetlands, and therefore potentially reduce negative risks to human health from the Grand Canal. The report found that in terms of bacteriological quality, the surface waters in the Grand Canal are unlikely to be safe for primary contact recreation. Additionally, the quality of the fish inhabiting the Grand Canal may be compromised (e.g., for purposes of human consumption) by the microbiological contamination.

The Essential Fish Habitat Assessment (Appendix D) for the Grand Canal concluded that the proposed action in the Grand Canal would have no indirect adverse impacts or cumulative adverse impacts to EFH species. The only species listed in the Grand Canal study area that may be slightly affected by possible proposed actions would be the winter flounder which tends to start their inshore migration to spawning grounds in late fall to early winter. Because adults and juveniles are mobile, it is expected that they will avoid the study area during any dredging disturbances. Furthermore, because proposed action is expected to be conducted in winter months when the winter flounder does not inhabit the study area, little adverse impacts are expected.

6.5 General Recommendations

It can be concluded that the Grand Canal and adjacent wetlands are severely stressed and experiencing multiple impairments. The stressors contributing to these conditions must be addressed in order to retain the remaining functions and values provided by the study area and to prevent further decline of the Grand Canal. Therefore, Alternative # 1 (No Action) and Alternative #2 (Channel Dredging Only) are not recommended for the study area.

The recommended action to help improve the ecological and human health issues in the Grand Canal is to implement Alternative #3 (IMM and Berm Alteration). This desired action option was based on its ability to achieve multiple objectives, including ecological restoration, habitat enhancement, invasive plant control in wetlands, and public health improvements. However, as stated in other sections of this report, if the anthropogenic sources creating the ecological and human health risks are not addressed, the canal and surrounding wetlands will continue to receive inputs impacting the system. Implementation of these actions in the Grand Canal will require coordination between various municipal agencies and the public, securing sources of funding for the project, and developing procedures for monitoring and assessing the results of the implemented action.

To address the declining condition of the Grand Canal and adjacent marshes, the following general recommendations are offered:

1. Increase tidal flow into the canal and marsh system through IMM and berm removal or alteration.
2. Identify and address sources of bacterial contamination to the Grand Canal (e.g., residential septic systems).
3. Address locations of storm water inputs into the Grand Canal and marsh system and assess them for opportunities to reduce sediment loading, contaminates, and freshwater input into marshes.
4. Identify and address sources of trash, debris, cuttings, and fertilizer use.
5. Identify opportunities to reduce wave action from boats, jet skis, etc., which are contributing to shoreline erosion and degradation of bulkheads and berms.
6. Continue monitoring. Increase level of effort and/or add sampling efforts for parameters deemed most important in restoration efforts.

6.6 Assumptions and Uncertainties

Several uncertainties regarding potential impacts of action options remain and should be further examined to resolve knowledge gaps. In particular:

- Bridges, culverts, bulkheads and retaining walls along the Grand Canal may be exposed and/or undermined if limited dredging operations were to be considered.
- Effect of deepening the canal will have on existing deteriorated bulkheads and their continuing contribution to sediment deposition in the canal, if limited dredging were to be considered.
- Potential release of toxins into the water column from the dredged sediments during the dredging operation.
- Disposal needs of dredge material if dredging is undertaken, locations may be limited and costs are high.
- Consequence of a potential increase in boat size, use, and traffic on the environment and adjacent residences (noise, activity levels, contaminants), if dredging were to be considered.
- Impacts of faster flow on existing marsh shorelines and developed upland areas along canal.
- Deepening channel may have some marginal benefits to tidal flow in the canal, but over the long-term this may not benefit wetlands and could result in greater volume of stagnant water in the canal.

Section 7. Conclusions and Recommendations

This ecological and public health assessment of the Grand Canal was based on sediment, water quality, and wetland/living resource analyses which was completed in 2016 for the Grand Canal and adjacent wetlands. These results were also compared to findings from data collected from the Grand Canal in 2004 to determine how conditions have changed over the past decade. It can be concluded that the canal system is severely impaired in terms of water quality, sediments, and habitat/living resources.

The Grand Canal has experienced impaired environmental quality due to pollution sources (such as septics and stormwater) which is exacerbated by canal geometry, inadequate stream flow and poor flushing. This is evidenced by the poor water quality observed within the canal system, particularly the low levels of dissolved oxygen, high levels of bacterial contaminants (coliforms), and high nutrient enrichment. Water quality in the canal has been significantly impacted by nutrient enrichment which can adversely affect marine productivity, and dissolved oxygen readings were often found below levels necessary for healthy aquatic life. These impairments in water quality have been documented for over a decade in the Grand Canal as evidenced in the 2005 report on the Grand Canal. Although the 2005 report concluded that water quality in the Grand Canal was impaired, generally conditions have been observed to have worsened over the past decade. In addition to poor water quality, sediments sampled from multiple locations throughout the Grand Canal were found to be acutely and chronically toxic to aquatic life. Therefore, these toxic sediments are impairing the ecological quality of the Grand Canal.

Bathymetric surveys of the Grand Canal indicated reduced channel depths throughout the canal system, which may impact tidal flow and also impede navigation. Observations documented during the current Grand Canal study by environmental field personnel also indicted an abundance of debris within the canal.

The marshes in the Grand Canal study area are all considered to be severely-stressed, particularly when compared to large salt marsh complexes in less disturbed landscape settings. Each assessed marsh in the Grand Canal Pickman-Remmer system is surrounded by intensive development which has reduced protective buffers, halted the ability of the marsh to shift landward with increasing sea levels, and has subjected the marshes to inputs of contaminants, sediments, freshwater, yard waste and other debris. All marshes are artificially ditched, two of the three marshes (northwest and east) have significant restrictions in tidal flow from the Grand Canal (which itself is somewhat restricted), and all are experiencing some shoreline erosion from wave action. In addition, the invasive common reed occurs throughout all marsh complexes and is dominant in two of the three systems (east and northwest). Furthermore, significant loss of wetlands in the Grand Canal study area has been observed over time.

With regards to public health, the results from the bacterial indicator testing indicated that bacterial contamination is a significant issue throughout the Grand Canal, as elevated coliform levels were frequently observed. Surface waters in the Grand Canal are unlikely to be safe for primary contact recreation. Additionally, the quality of the fish inhabiting the Grand Canal may be compromised (e.g., for purposes of human consumption) by the microbiological contamination.

IMM in conjunction with berm removal or alteration is proposed as an approach which will alleviate the numerous ecological and public health impairments in the Grand Canal. IMM will facilitate fish access, increase tidal flow and reduce stagnant waters in wetlands, both of which may reduce mosquito breeding near the Grand Canal. Increased tidal flow may also help to reduce the retention time of bacteria and nutrients within the canal, resulting in lower observed coliform and nutrient levels, as well as improve impaired water quality parameters, such as DO. IMM can also serve to improve the health of the wetlands near the Grand Canal by: reducing common reed populations; increasing native vegetation; increasing vegetative diversity; and improving wildlife maneuverability throughout marshes adjacent to the Grand Canal. Lastly, limited dredging of the Grand Canal can increase canal navigability by deepening channels and removing debris, but dredging will not ultimately increase tidal flow or address sources of contamination to the canal system.

A summary of the study conclusions and recommendations for follow-up actions are presented below:

- Bacteria levels in canal water are elevated, and discharges from on-site sanitary systems appear to be major contributors. Improvements and upgrade of on-site sanitary systems would decrease discharge of bacteria and nutrients to surface waters and assist in long term water quality improvement. Further investigation beyond the scope of this study would be required to determine the level of contribution from the on-site sanitary systems.
- Dredging and deepening of inner portions of the canal, without widening or deepening of its connections to the Connetquot River or adjacent wetlands, will not improve flushing rates for the canal. However, due to the commercial and residential development at the mouths of the canal, widening these areas is not a feasible option. In fact, deepening of the canal without increasing water flow could result in greater volumes of stagnant water in the canal. The exception would be dredging the shoals located in the southern portion of the canal, which could provide slight increase in tidal exchange by slightly reducing partial barriers to water exchange between the canal and Connetquot River. Improvements would be minimal and short-lived as sediments re-accumulate.
- Dredging would result in the removal of contaminated sediments; however, the removal would not result in improved long-term conditions unless the sources of contamination are controlled (e.g., sanitary waste, stormwater, etc.). There are multiple anthropogenic sources of contamination associated with existing land uses that will continue to affect the canal unless long-term abatement measures are taken.
- Erosion of the banks, especially along the man-made berm, is continuing along with shoreline failure from deteriorated bulkheads. Increased sedimentation will result in the filling in of the canal if dredging were to be performed. These sources of sediments will continue, and dredging could actually accelerate sedimentation by causing increased instability of the canal bottom and banks. Sediment control measures, including shoreline stabilization, are needed to prevent further sedimentation of the canal.

- The public health and environmental risk assessments performed for surface water and sediments did not indicate a level of risk higher than would be expected in a water body subject to anthropogenic inputs in a semi-developed area. In other words, the risks from contamination are not higher than usual for similar developed areas in the region.
- The wetlands adjacent to the canal along the south side are experiencing continued serious erosion from inadequate tidal exchange, reduced salinity, and the spread of invasive species. Although the wetland still provides a valuable habitat for water fowl, fish and other wildlife, the quality of the wetland will continue to degrade unless remedial measures are taken.
- Long-term health and viability of the wetlands can be improved by implementing marsh management which significantly increases tidal exchange into and out of the wetlands. Integrated Marsh Management (IMM) would have multiple benefits of improving the quality of the wetland, improving water quality conditions in the canal, decreasing the potential for mosquito larvae production and need for mosquito control measures, and providing improved coastal resiliency and buffering during coastal storms and long-term sea level rise. Tidal exchange into the wetlands could be increased by removing significant portions or all of the man-made berms presently separating the wetlands from the canal.
- Significantly improving tidal exchange for the wetland would provide improved flushing of the canal by providing additional volumes of water within the tidal range which would be subject to tidal action on a daily basis. Removing the berm would allow greater volumes of water to enter and exit the canal with each tidal cycle, although the narrow south opening of the canal with the Connetquot River will limit the full extent of tidal exchange which can be achieved.
- IMM improvements including berm alterations for the adjacent wetlands would provide long-term water quality and habitat improvements to the canal and associated wetlands. IMM measures should include creation of additional channels and areas of open water, removal of invasive species, and grading modifications to provide improved water flow.
- Although not found to be the primary effect on bacterial levels in the canal, direct stormwater discharges contribute to the input of nutrients and other containments. Actions to eliminate direct discharges and provide increased treatment of stormwater runoff,

through application of bio-swales, constructed wetlands, and similar technologies, will contribute to long-term water quality improvements.

- The investigation indicated that significant portions of the canal have debris including tree debris, limbs and cuttings. This debris, especially within the portion of the water column in the tidal range, can restrict water flow and accelerate the sedimentation and accumulation of additional debris. Action to remove the limbs, cuttings and similar debris would improve water flow, reduce accumulation of additional debris, and have short-term benefits to water quality.
- Even if dredging was determined to be a beneficial action, standard Suffolk County protocol and procedures relating to set backs from shorelines and bulkheads and maximum allowed side slopes of dredge areas could not be followed in many areas of the canal because the canal is very narrow and it banks contain bulkheads on private property. Granting of legal releases, hold-harmless agreements and similar legal protection to the County by home owners may protect the County from liability relating to damaged or undermined bulkheads, but would not prevent the physical erosion of the shoreline and accelerated release of sediment to the channel that would occur from shoreline failures relating to bulkhead failures.
- It should be noted that the New York Rising Oakdale / West Sayville Report (March 2014) identified an improvement project that would improve tidal exchange to the Pickman-Remmer Wetland by installing seven 24-inch pipes through the berm and other improvements. Benefits would include improved tidal flow into the wetlands and greater capacity of the wetland to absorb storm surge and stormwater runoff. The findings of the present investigation concur with this finding, except that considerations should be given to providing even greater channels for tidal exchange by removal of the berm or portions of the berm.

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