SUFFOLK COUNTY
COMPREHENSIVE
WATER RESOURCES
MANAGEMENT PLAN

Section 7
COASTAL RESILIENCY

Section 7
Coastal Resiliency

"As an island that juts out into the Atlantic, we are as vulnerable to climate change as any place in the world.... This is not an academic exercise for Long Island.... This is an existential challenge we are facing."
-Steve Bellone (https://www.youtube.com/watch?v=erqy9_23oNs&sns=em)

Figure 7-1 Distressed Dolphin – Gilgo Beach, Long Island *(photo by Jedidiah Dale)*

Superstorm Sandy made it personal. Perched on the coastline, as so many Long Islanders are, we're the proverbial canaries in a coal mine. We've been watching sea level rise and beach erosion for some time now. Sandy pressed the pedal of climate change to the metal and blew away long-standing dunes, surging over depleted wetlands on its way to steamroll Long Island's 'mainland,' leaving billions in damage in its wake. Down the coast, calamity burned one hundred ten Breezy Point houses to the ground. "*Never send to as*k for *whom the bell tolls*," Donne wrote. "*It tolls for thee*."

Figure 7-2 Exposed Sub-foundation of Old Gilgo Coast Guard Station after Sandy Swept Away 8 Foot Depth of Sand

We now know that 900 mile-wide Superstorm Sandy was the largest Atlantic storm in recorded history fueled by unprecedented late-season, ocean-expanding warmth (+5°F) augmented by elevated levels of atmospheric moisture which was driven into a most unusual left turn by a "3-sigma" blocking high over Greenland following the largest Arctic sea ice melt in human history plus the unprecedented near total melt during four days in July, 2012 of the Greenland ice sheet. Note the elements of climate change contributing to storm intensity: elevated atmospheric temperature, warmer, expanded ocean waters, increased precipitation, sea-level rise compounded by land subsidence, and coastal degradation. Whither coastal resiliency?

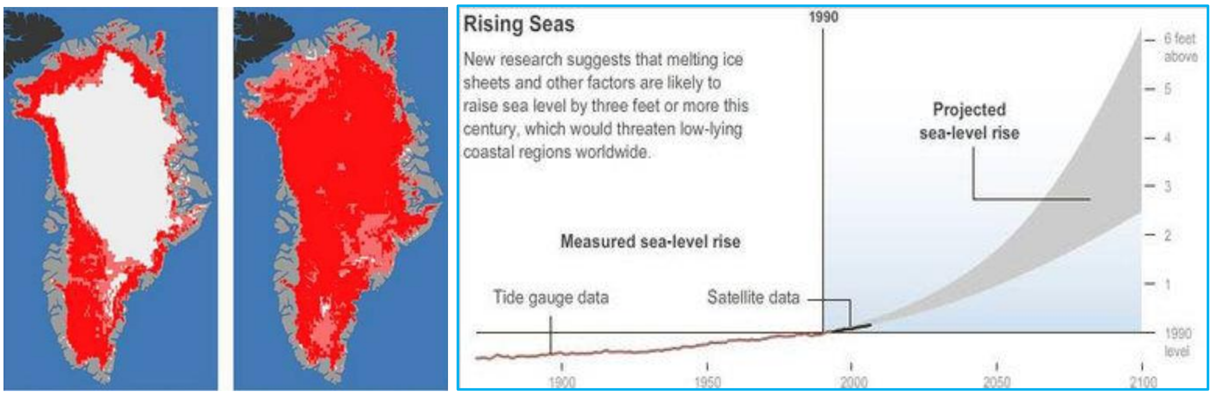


Figure 7-3 In advance of Sandy, NASA Satellite Images of Unprecedented Greenland Ice Sheet Melt from July 8-12, 2012, Melt Area Going from 40% of the Ice Sheet to 97% (Previous Maximum 55%) NASA; CNES; Center for Remote Sensing of Ice Sheets, U Kansas

7.1 Coastal Facts

According to the National Oceanic and Atmospheric Administration (NOAA) 39% of the United States' population, 123 million people, live in coastal counties, and that number is expected to rise to 134 million by 2020, on the basis of an analysis NOAA conducted with the United States Census Bureau. The United States Commission on Ocean Policy weighs in with a larger percentage – 52% living in less than 25% of the United States land mass in coastal communities (www.oceancommission.gov).

The United States was founded on the coast, and more than ever, coastal regions remain key to the U.S. economy. "Shore adjacent counties comprise 37% of overall employment on just 17.5% of United States land area" (another variation). Coastal states account for 81.5% of the U.S. population and 83.4% of economic output. In 2012, the coastal zone counties accounted for 51% of employment in coastal states, 42% of total national employment, 57% of gross domestic product (GDP) in coastal states, 48% of national GDP. U.S. coastal states together produce a GDP larger than that of any other single country (National Ocean Economics Program, www.oceaneconomics.org). "Predictions suggest that 25% of homes within 500 feet of the coast could be lost to erosion in the next 60 years, at a potential cost of $530M each year." (C. Landry, "Coastal Erosion as a Natural Resource Management Problem: The State of Economic Science and Policy," Center for Coastal Systems Informatics and Modeling, East Carolina University, 2010) While beach replenishment averaged $0.14B/year, coastal tourism and recreation alone contributed $78.5B/year to the U.S. GDP.

Table 7-1 Employment and GDP in Coastal Communities – Nationwide and New York State

Region	Employ-ment (million)	GDP ($trillion)	Population (million)	Land Area (million sq. miles)
United States (national)	131.7	$15.57	313.9	3.54
All coastal states	107.3	$12.99	255.8	2.02
Coastal States % U.S.	81.5%	83.4%	81.5%	57.0%
Shore-adjacent counties	48.8	$6.60	116.5	0.62
Shore-adjacent % U.S.	37.0%	42.4%	37.1%	17.5%
Watershed counties	67.0	$8.73	162.3	1.06
Watershed % U.S.	50.9%	56.1%	51.7%	30.0%

	Employment	Wages ($billion)	GDP ($billion)
State	8,563,653	$536.7	$1,205.9
Shore-adjacent	6,506,129	$442.1	$1,015.8
Shore-adjacent % of State	76.0%	82.4%	84.2%

US employment, GDP, population & land area vs coastal areas, www.oceaneconomics.org; 2012 New York shore-adjacent counties, 2012 population 75.5%

7.2 Coastal Vulnerability/Sea Level Rise

We are moving into uncharted and, to a significant degree, uncharitable waters. Sea level rise is a Sandy-like storm surge in slow motion—an inexorable, decade-by-decade phenomenon that hardly creates a sense of immediate crisis. Under normal, everyday circumstances, 3 feet separate the water level and the top of the quay. Should even the most moderate predictions of sea level rise be accurate, levels will rise 2 feet between now and 2100, leaving but a foot between the water level and the top of the quay. Less moderate predictions warn of a sea level rise of 6 feet. The most recent report from the Intergovernmental Panel on Climate Change (IPCC, 2013) predicts that climate warming will cause a mean increase of 1.4 to 2.4 feet in sea level by 2100. The National Research Council (2012) predicts an even larger increase of 1.7 to 4.6 feet by 2100.

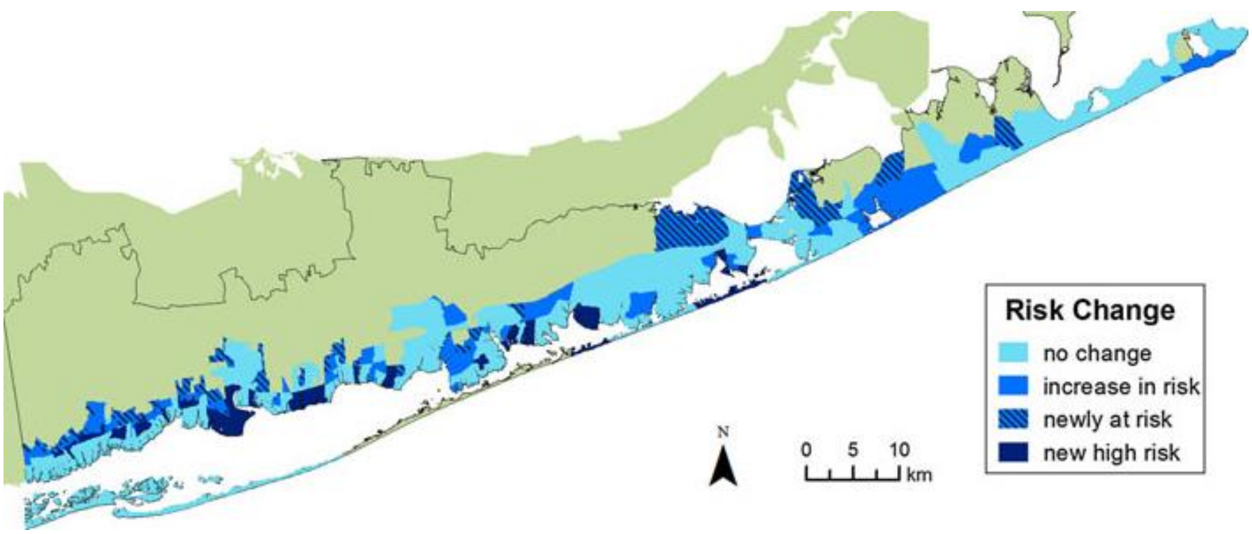


Figure 7-4 Predicted Future Storm Surge Risk Resulting from Sea Level Rise

"Modest and probable sea level rise (.5 meters by 2080) vastly increases the numbers of people (47% increase) and property loss (73% increase) impacted by storm surge." (C. Shepard, et al, "Assessing future risk: quantifying the effects of sea level rise on storm surge risk for the southern shores of Long Island, New York," Nat Hazards 60:727–745, 2012). Recent observations concerning climate change include:

- Temperatures in the Northeast have increased by almost 2°F (0.16°F per decade), and precipitation increased by approximately five inches, or more than 10%, 0.4"/decade (K. Kunkel, et al, 2013: "Regional Climate Trends and Scenarios for the U.S. National Climate Assessment: Part 1," Climate of the Northeast U.S. NOAA Technical Report NESDIS 142-1, 2013).

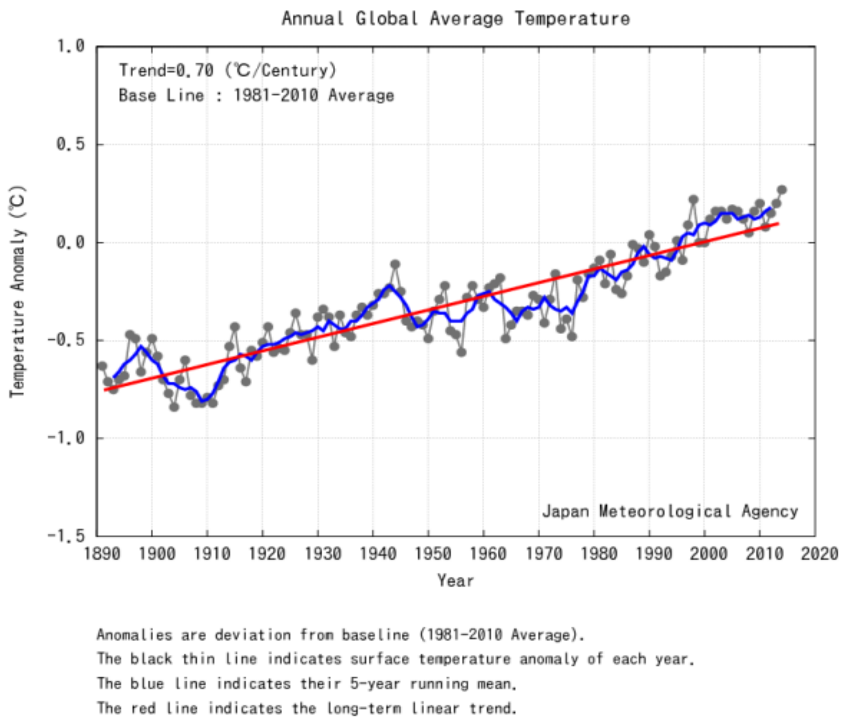


Figure 7-5 Increase in Average Global Temperature

- Coastal flooding has increased due to a rise in sea level of approximately 1 foot since 1900.

- Sea level rise of two feet, without any changes in storms, would more than triple the frequency of dangerous coastal flooding throughout most of the Northeast. Sea level rise along most of the coastal northeast exceeds the global average of approximately 8 inches and is expected to exceed the global average rise due to local land subsidence, with the possibility of even greater regional sea level rise if the Gulf Stream weakens, as some models suggest (J. Church, et al., "Understanding Sea-Level Rise and Variability," Blackwell, 2010).

- The New York State Sea Level Rise Task Force Report to the Legislature (2010) observes that local sea levels are affected by ocean currents, gravitational forces, prevailing winds, and rise and fall of the land mass, i.e. subsidence, with the coastal land mass of New York slowly sinking at 1.35 mm/year (http://www.ngs.noaa.gov/CORS_Map/).

- Recent research suggests that changes in ocean circulation in the North Atlantic – specifically, a weakening of the Gulf Stream – may also play a role (A. Sallenger, et al., "Hotspot of accelerated sea-level rise on the Atlantic coast of North America," Nature Climate Change, 2, 884-888, doi:10.1038/nclimate1597, 2012).

- Recently, there has been a steeper rise in extreme precipitation in the Northeast than in any other region in the United States. The rate of increase from 1895 to 2011 has been 0.4"/decade (Horton et al., 2014). But from 1958 to 2010, the Northeast saw more than a 70% increase in the amount of precipitation falling in very heavy events (P. Groisman, "Recent trends in regional and global intense precipitation patterns. Climate Vulnerability," R. Pielke, Sr., Ed., Academic Press, 2013).

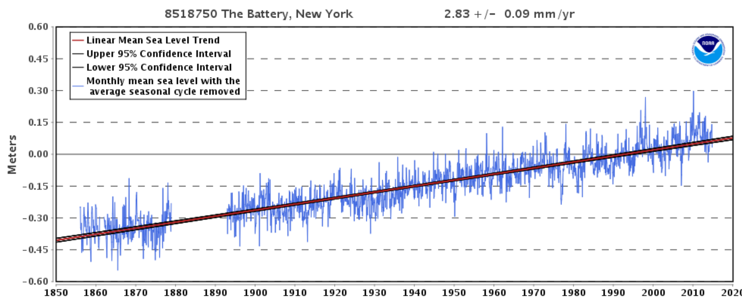


Figure 7-6 Water Floods the Brooklyn Battery Tunnel in Lower Manhattan as Hurricane Sandy Pounds 10/29/12

Gauges at the New York City Battery indicate that sea level in the 2000s is 4 to 6 inches higher than in the early 1960s. Mean sea level data from 1856 to 2013 is equivalent to a change of 0.93 feet in 100 years.

Table 7-2 Sea Level Projections – Montauk Point Region/"Climate Change in New York State"

Baseline (2000-2004) 0 inches	Low Estimate (10th Percentile)	Middle Range (25th to 75th Percentile)	High Estimate (90th Percentile)
2020s	2 in	4 to 8 in	10 in
2050s	8 in	11 to 21 in	30 in
2080s	13 in	18 to 39 in	58 in
2100	15 in	21 to 47 in	72 in

Source New York State Energy Research and Development Authority (Sept, 2014)

- As ocean temperatures continue to rise, the range of suitable habitat for many commercially important fish and shellfish species is projected to shift northward. For example, cod and lobster fisheries south of Cape Cod are expected to have significant declines. (P. Frumhoff et al., "Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Synthesis Report of the Northeast Climate Impacts Assessment," Ch. 3: 'Marine impacts' Union of Concerned Scientists, 2007)" Hospitable habitats will be shrinking for some species, like coldwater brook trout, and expanding for others like warmwater bass.

- Beach and dune erosion, both a cause and effect of coastal flooding, is also a major challenge in the Northeast (F Buonaiuto, et al. 2011 "Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation in New York State," Ch. 15: Coastal zones, 2011, M. Phillips & A. Jones, "Erosion and tourism infrastructure in the coastal zone: Problems, consequences and management." Tourism Management 27:517-524, 2006).

- Since the early 1800s, there has been an estimated 39% decrease in marsh coverage in coastal New England (K. Gedan, et al., 2009: "Centuries of human-driven change in salt marsh ecosystems." Annual Review of Marine Science, 2009). Impervious surfaces and coastal barriers such as seawalls limit the ability of marshes to expand inland as sea levels rise. (R. Nicholls, & A. Cazenave, 2010: "Sea-level rise and its impact on coastal zones," Science, 328, 2010).

- Temperatures are warming across New York State, with an average rate of warming over the past century of 0.25 °F per decade.

- Vector-borne diseases are an on-going concern. Most incidents of Lyme disease in the U.S. occur in the Northeast. Several studies have linked tick activity and Lyme disease incidence to climate, specifically abundant late spring and early summer moisture (G. McCabe & J. Bunnell, "Precipitation and the occurrence of Lyme disease in the northeastern United States," Vector-Borne and Zoonotic Diseases, 4, 2004). West Nile Virus (WNV) is another vector-borne disease likely to be impacted by climate changes because longer, warmer summers would favor increases in the duration and intensity of virus activity. The human population in the northeast subject to infestations of the Asian Tiger mosquito (ATM), is projected to increase from the current 5% to 16% in the next two decades and from 43% to 49% by the end of the century (I. Rochlin, et al., "Climate change and range expansion of the Asian tiger mosquito (Aedes albopictus) in northeastern USA: Implications for public health practitioners," PLoS ONE, 8, e60874, doi:10.1371/journal.pone.0060874, 2013). This range expansion is significant because this species, besides being a significant biting pest, is a competent vector for WNV and tropical viruses such as dengue (DEN) and Chikungunya (CHIKV). The ATM was the likely vector for a local case of DEN in Suffolk County in 2013, demonstrating that the appearance and expansion of the ATM in the northeast brings with it the possibility of DEN and CHIKV transmission where it previously had not been a concern. Higher average sea level and increased frequency of intense coastal flooding may change populations of mosquitoes associated with coastal wetlands such as the WNV and Eastern Equine Encephalitis (EEE) vectors Culex salinarius and Aedes sollicitans. The management of coastal wetlands to improve coastal resiliency needs to take into account how management efforts could impact associated mosquito species.

- Northeast Farms, subject to the most substantial increase in heavy rainfalls in the country, directly suffer crop damage, in addition to the fact that wet springs can delay planting which delays harvest dates and reduces yields (J. Hatfield, et al., "Climate impacts on agriculture: Implications for crop production" Agronomy Journal, 103, 2011). In the future, farmers may also face insufficient water as summers become hotter and growing seasons lengthen. (K. Hayhoe, et al., "Past and future changes in climate and hydrological indicators in the US Northeast," Climate Dynamics, 28, 2007) (D Wolfe, et al., 2011: Ch. 7: Agriculture. Responding to Climate Change in

New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation in New York State," Ch 7: Agriculture Blackwell Publishing, 2011).

- Increased weed and pest pressure associated with longer growing seasons and warmer winters will present earlier arrival and increased populations of some insect pests such as corn earworm. The "invasive" weeds with the so-called C3 photosynthetic pathway, benefit more than crop plants from higher atmospheric carbon dioxide, and become more resistant to herbicide control (L. Ziska & K. George, "Rising carbon dioxide and invasive, noxious plants: Potential threats and consequences. World Resource Review, 16, 2004). Glyphosates, like Roundup, the most widely-used herbicide, lose their efficacy with weeds nourished by increased carbon dioxide (L. Ziska, et al., 1999: "Future atmospheric carbon dioxide may increase tolerance to glyphosate," Weed Science, 47, 1999).
- The impacts of sea level rise and coastal flooding on infrastructure are summarized by **Table 7-3** on the following page.

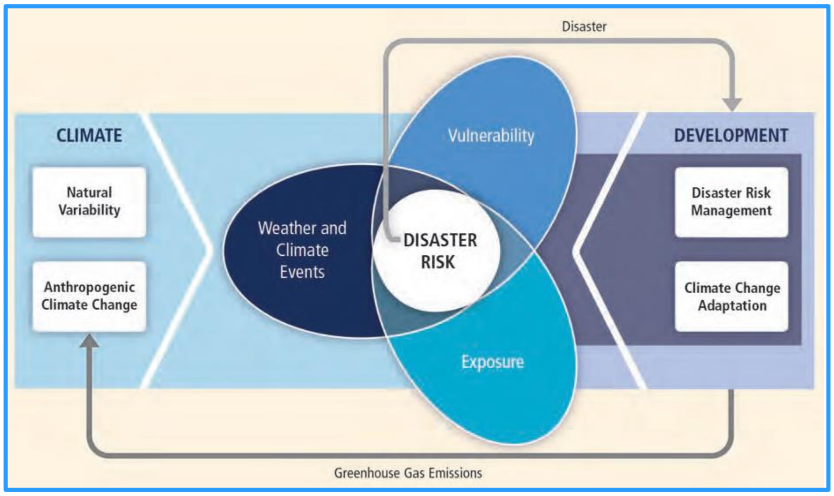


Figure 7-7 Intergovernmental Panel on Climate Change Summary for Policymakers
(C. B. Field, et al, 2014)

It should be noted that there are discrepancies in estimates in terms of sea level rise over the past century which, in turn, impacts projections for the coming century. A team of researchers from Harvard and Rutgers report in Nature that sea level rise over the 20th century may, in fact, be 5 inches rather than 6 inches. This small difference of one inch translates into a huge difference in water, on the order of two quadrillion gallons. If these findings are correct, it goes a long way in explaining where all this water could conceivably have come from as it was not explicable in terms of ice melt or expanding oceans due to warming (C. Hay, et al., "Probabilistic reanalysis of twentieth-century sea-level rise," Nature (2015), doi:10.1038/nature14093).

Table 7-3 Impacts of Sea Level Rise and Coastal Floods on Coastal Infrastructure

Table 16.1. Impacts of sea level rise and coastal floods on critical coastal infrastructure by sector. Sources: Horton and Rosenzweig 2010,[51] Zimmerman and Faris 2010,[52] and Ch. 25: Coasts.

Communications	Energy	Transportation	Water and Waste
Higher average sea level			
• Increased saltwater encroachment and damage to low-lying communications infrastructure not built to withstand saltwater exposure • Increased rates of coastal erosion and/or permanent inundation of low-lying areas, causing increased maintenance costs and shortened replacement cycles • Cellular tower destruction or loss of function	• Increased coastal erosion rates and/or permanent inundation of low-lying areas, threatening coastal power plants • Increased equipment damage from corrosive effects of saltwater encroachment, resulting in higher maintenance costs and shorter replacement cycles	• Increased saltwater encroachment and damage to infrastructure not built to withstand saltwater exposure • Increased coastal erosion rates and/or permanent inundation of low-lying areas, resulting in increased maintenance costs and shorter replacement cycles • Decreased clearance levels under bridges	• Increased saltwater encroachment and damage to water and waste infrastructure not built to withstand saltwater exposure • Increased release of pollution and contaminant runoff from sewer systems, treatment plants, brownfields, and waste storage facilities • Permanent inundation of low-lying areas, wetlands, piers, and marine transfer stations • Increased saltwater infiltration into freshwater distribution systems
More frequent and intense coastal flooding			
• Increased need for emergency management actions with high demand on communications infrastructure • Increased damage to communications equipment and infrastructure in low-lying areas	• Increased need for emergency management actions • Exacerbated flooding of low-lying power plants and equipment, as well as structural damage to infrastructure due to wave action • Increased use of energy to control floodwaters • Increased number and duration of local outages due to flooded and corroded equipment	• Increased need for emergency management actions • Exacerbated flooding of streets, subways, tunnel and bridge entrances, as well as structural damage to infrastructure due to wave action • Decreased levels of service from flooded roadways; increased hours of delay from congestion during street flooding episodes • Increased energy use for pumping	• Increased need for emergency management actions • Exacerbated street, basement, and sewer flooding, leading to structural damage to infrastructure • Episodic inundation of low-lying areas, wetlands, piers, and marine transfer stations

Source: Climate Change Impacts in the United States – The Third National Climate Assessment

7.3 Coastal Resiliency & Risk Management

The National Research Council (NRC) defines *resilience* as "the ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events." Our coasts have always held both economic and intrinsic value for Long Islanders, but it is only recently that we've come to appreciate the expanse of its defensive role. In "Reducing Coastal Risk on the East and Gulf Coasts, (2014)" the NRC, in a broad five-year roadmapping of issues for the U.S. Army Corps of Engineers, identifies two strategies for managing coastal storm risks, one remaining in place, the other for retreating (p xi):

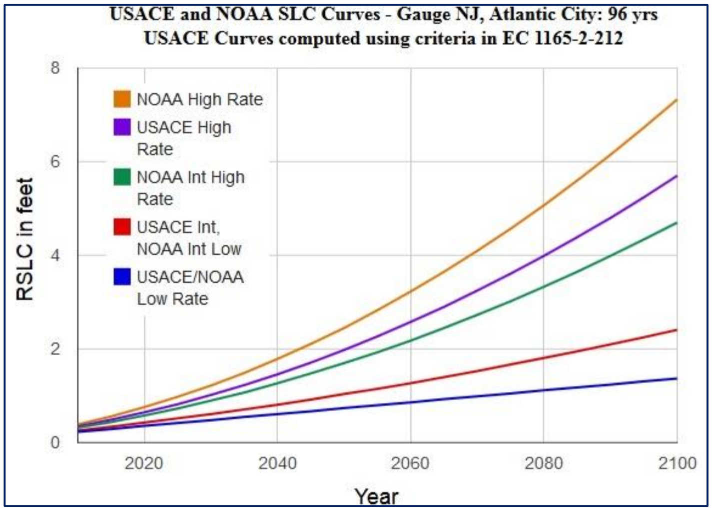
1. "One set of strategies aims to reduce the probability of flooding or wave impact. These include hard structures, such as seawalls, levees, flood walls, and storm surge barriers, and nature-based risk reduction strategies, such as beach nourishment, dune building, and restoration or expansion of natural areas, such as oyster reefs, salt marshes, and mangroves."

2. "Another set of strategies aims to reduce the number of people or structures in areas at risk or to make them less vulnerable to coastal storms. These include design strategies, such as elevating or floodproofing buildings and "nonstructural strategies" such as relocation and land-use planning to steer future development or redevelopment away from high hazard areas...."

To date, provision of substantial post-disaster aid has largely trumped proactively managing risk. But as NRC observes, "Given the existing investment, strategic importance, and intrinsic desirability of living in coastal areas, it is unrealistic to believe that we will abandon most of these areas in the foreseeable future." At this point, it is incumbent upon us to deploy "Strategies that reduce the consequences of coastal storms, such as hazard zoning, building elevation, land purchase, and setbacks, have high documented benefit-cost ratios... between 5:1 and 8:1 for nonstructural and design strategies that reduce the consequences of flooding." From 2004 and 2012, federal funds for such strategies constituted but 5% of disaster relief funds, compounded by a lack of alignment of risk, reward, resources, and responsibility across innumerable federal agencies.

7.3.1 Strategic Retreat/ Staying Put

"At one point, you have to say maybe Mother Nature doesn't want you here. Maybe she's trying to tell you something," Gov. Andrew Cuomo observed, in earmarking $400M for a buyout program of vulnerable coastal houses in early February, 2013. By mid-October, 2014, there were only 505 takers for a total of $212M. Given the market value of many of the buyout houses, the $420K selling price was a distinct premium over market, but one which, nonetheless, did not attract significant uptake, the vast majority of those eligible opting to stay put.



http://www.globalchange.gov/browse/sea-level-rise-tool-sandy-recovery

Figure 7-8 Sea Level Rise Projections

Rolling Easements (2009), as defined by EPA's James Titus "are government regulations or transfers of property rights that decrease or eliminate the continued use and enjoyment of coastal property as sea level rises." With "rising sea level inundating low-lying lands, eroding beaches, and exacerbating coastal flooding,…" rolling easements, aka 'strategic retreat,' are proffered as a primer on "approaches for ensuring that wetlands and beaches can migrate inland, as people remove buildings, roads, and other structures from land as it becomes submerged." It comes with the caveat that the proposed tools are not what *should* be wielded, but what *could* be. 'Rolling easements' would "allow wetlands, beaches, and other coastal habitats to migrate naturally as the sea encroaches inland; move people out of harm's way; and prevent new construction in vulnerable areas." The three ways "to limit the portion of our coast eventually subject to shore protection are:

1. Setbacks. Prevent development of some lands vulnerable to sea level rise, either through regulation or by purchasing land (or development rights) from the current owners.

2. Rolling easements. Make no effort to restrict land use but prevent shore protection of some coastal lands either through regulation or by transferring any right to hold back the sea from owners inclined to do so to organizations that would not.

3. Laissez-faire. Make no effort to prevent either development or shore protection, but curtail government subsidies for both, and hope that eventually the forces of nature and economics will lead owners to allow their lands to be submerged.

Table 7-4 Summary of Recorded Rolling Easement Options (J Titus, EPA, 2009)

Interest	Who can own or enforce it?	Type of Purpose	Objective	Caveat
Shoreline migration conservation easement	Government or land trust	Conservation or recreation	Prohibit shore protection. May also have provisions for removing homes.	May be costly to enforce unless carefully drafted.
Legal covenant	Developer, maybe a neighbor	Any	Prohibit shore protection or provide for access to migrate inland. But court cannot enforce the agreement; only awards provable damages for failure to comply.	Strict rules for when covenant can be created known as "privity." Damages only.
Equitable covenant (equitable servitude)	Developer, maybe a neighbor	Any	Prohibit shore protection or ensure that access migrates inland.	Easier to create than legal covenant, but court may decide not to enforce if harm to owner is greater than benefit to neighbor.
Future interest in land[1]	Anyone	Limit duration of land ownership	Terminate ownership when sea rises or shore retreats enough to submerge parcel.	Abolished in some states. Careful drafting needed to show purpose.
Rolling affirmative easement	Neighbor or state	Any	Access along the shore migrates inland; remove structures that block access	Must be clear about intention to migrate inland.
Rolling boundary	Neighbor	Any	Boundary between landowners migrates with shore; preserve width of road or conservation buffer.	Few examples other than for public trust lands.
Abate nuisance or quiet title in court	Neighbor or state	Abate nuisance or enforce a right	Private owner asks court to prevent shore protection or allow access along shore based on common law.	Requires a court to make new law, which courts usually decline.
Rolling conservation easement[2]	Government or land trust	Conservation or recreation	Amend existing conservation easements to also prohibit shore protection.	May be costly to enforce unless carefully drafted.
Transferable development rights[3]	Government	Any	Compensate owner who yields land to rising sea, with right to develop new coastal lot.	Difficult to define where to transfer the development.

Typical characteristics of rolling easements along eroding beaches may include:

- No shoreline armoring;
- A rolling design boundary (e.g. dune vegetation line), seaward of which the owner's property rights are reduced;
- No new structures seaward of the rolling design boundary;
- Encouragement or requirement to remove preexisting structures when erosion leaves them seaward of the rolling design boundary;
- Warnings about the policy to prospective buyers of coastal property;
- Provisions for public access; or
- An indication whether beach nourishment and adding sand to dunes are allowed.

Maine, Massachusetts, and Rhode Island have each adopted some form of "rolling easement" to ensure that wetlands or dunes migrate inland as sea level rises thus reducing the risk of loss of life and property.

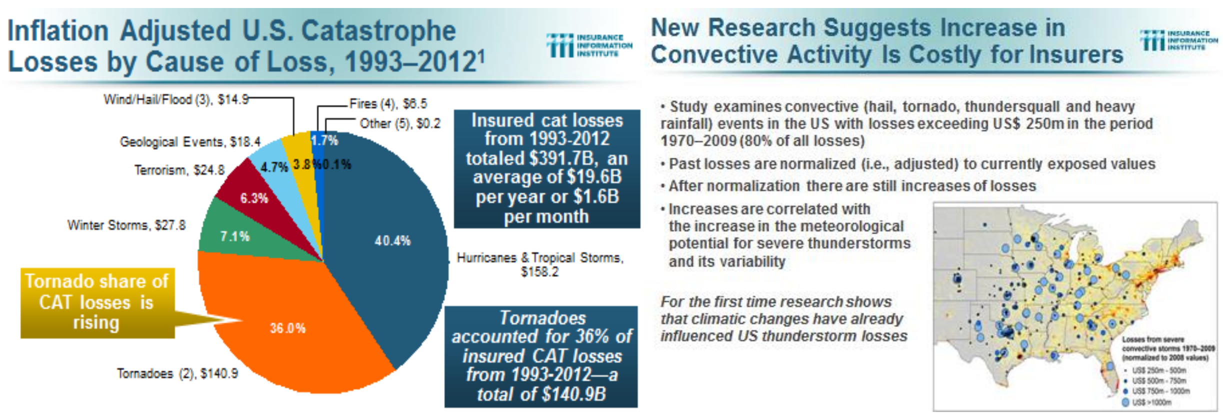


Figure 7-9 Tornado-related Loss is on Par with Hurricanes for Inland Areas that are Far Less Densely Populated than Coasts

From 30,000 feet, rolling easements certainly seem sensible in principle. Down at ground zero, however, how will it work in practice? "The big thinkers have emerged in force since Hurricane Sandy. Environmentalists and academics call for a retreat from rising tides and vulnerable seashores. FEMA pores over flood photos, redefining the areas of highest risk. And city engineers and lawyers revisit building and zoning codes. All hope to ensure that whatever rises from the debris can survive future assaults by extreme weather....

"But for all the policy debates, the actual decisions that will shape these communities are already being made by individual homeowners across New York and New Jersey, providing reason to be skeptical that any cohesive, unified vision of a rebuilt coastline will eventually emerge (D Halbfinger, "*On Ravaged Coastline, It's Rebuild Deliberately vs. Rebuild Now*," NY Times, 12/21/12)."

While New York's buyout program got just beyond the halfway mark of its objective with decided price enticement, the Governor's Office for Storm Recovery reported on 10/15/14 that 9,554 households were for elevation. Core Logic's real estate database places these after-the-fact figures in advance of Sandy's land fall on 10/29/12 with Suffolk County, according to Core Logic, host to four of the top ten vulnerable zip codes dollar-wise in the greater NY/NJ metro area, and six of the top twenty-five.

Rank	Zip Code – Area Name	Properties Affected	Total Structure Value
2	11795 – West Islip, NY	1,348	$2,002,034,875
3	11706 – Bay Shore, NY	897	$1,714,557,225
7	11901 – Riverhead, NY	477	$1,268,159,500
8	11789 – Oakdale, NY	1,178	$1,137,802,500
22	11757 – Lindenhurst, NY	3,044	$649,684,250
24	11978 - Westhampton Beach, NY	1,119	$608,256,870

Figure 7-10 Long Beach, Long Island Elevation

Ed Wright's home withstood storm, having been built on pilings while 18 neighbors' homes are obliterated.

Vulnerable coastal properties are not just primary assets in most cases, they also constitute substantial revenue streams for local municipalities that would otherwise become extremely strapped if they were left with large numbers of properties abandoned in 'strategic retreat'. Given that 76% of New York housing is shore-adjacent the challenges of sea level rise, in this context alone, are daunting.

The most delimiting aspect of strategic retreat is existing infrastructure compounded by the inflexibility of related federal disaster funding provisos. On Long Island, owing principally to the gravity factor, sewage treatment plants (STP), have been stationed in proximity to the coast. The 70 million gallon per day (mgd) capacity Bay Park STP with average flow 50 mgd was overtopped by Sandy and went off-line for 56 hours, spewing over two hundred millions of gallons of raw and partly raw sewage into channels and waterways and backflowing into homes.

Bergen Point Wastewater Treatment Plant on Great South Bay

FEMA has allocated $789M to remediate Bay Park above and beyond pre-Sandy condition, even as estimates from other sources peg the tab at double, to which a $690 ocean outfall needs to be added to divert the secondary-treated effluent away from bay and wetlands. In the realm of rolling easements, this would be the opportune time to decommission the coastal plant and relocate further inland, beyond future storm surges. But that plant is needed back on line yesterday and all the associated costs of relocating labyrinthine connecting pipes and pumps places the cost out of reach and fails to factor for the time it takes to do an engineering project of this magnitude. There are any number of policy proposals that make sense in the long run, but toilets need to be flushed now.

7.3.2 Fire Island to Montauk Point (FIMP)

The Fire Island to Montauk Point (FIMP) project (area shown by **Figure 7-11**), on the drawing boards since 1964 in various iterations, was allocated $700M by the Superstorm Sandy relief bill. Preliminary projections approximate $450M going for road and house elevations, with 7 million cubic yards (cy) of sand borrowing from the Atlantic going to a $207 million, 19 mile-long, 9.5 foot berm to 15 foot dune line interfaced with beach nourishment, plus $60M for green infrastructure projects.

The U.S. Army Corps of Engineers (USACE) has concluded that, “As a consequence of the historically severe coastal erosion during Hurricane Sandy, the dune and berm system along Fire Island is now depleted and particularly vulnerable to overwash and breaching during storm events, which increases the potential for devastating storm damage to shore and particularly back bay communities along Great South Bay and Moriches Bay…. The effects of Hurricane Sandy on the barrier island have made project implementation within the Fire Island Inlet to Moriches Inlet imperative to restore and augment the barrier island to a level to provide storm damage protection to both the barrier island and back bay inhabitants. (“Fire Island Emergency Stabilization Project,” USACE-NY Dist., 12/13).

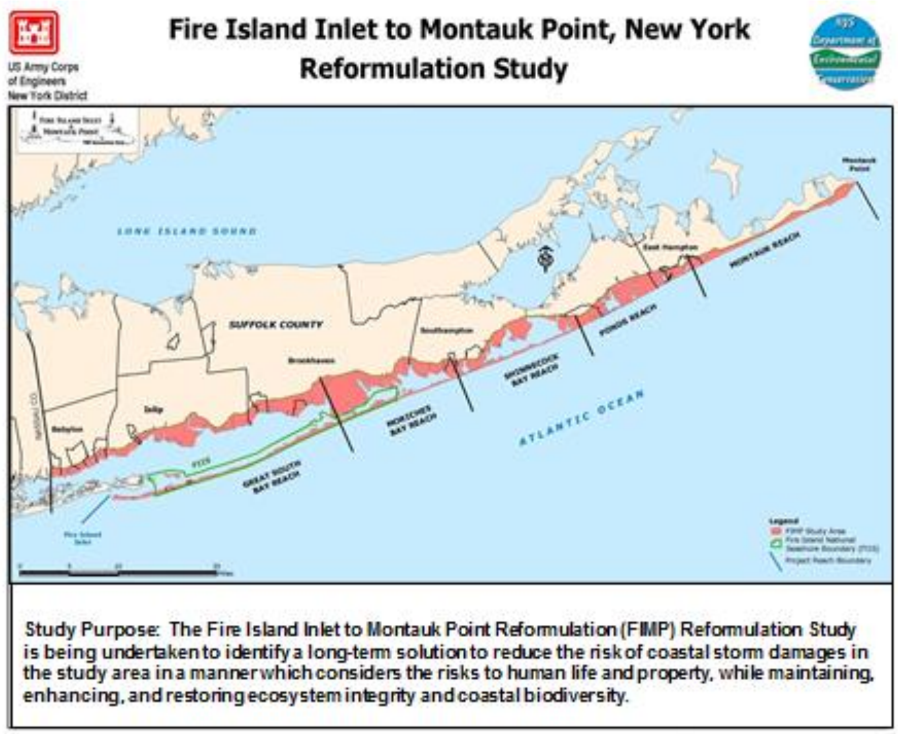


Figure 7-11 Fire Island to Montauk Point Reformulation Study Area
(*Source: USACOE 2006, Final Report Atlantic Coast of Long Island, Fire Island Inlet to Montauk Point, New York Reformulation Study*)

On September 11, 1964, Congress established 26 miles of Fire Island as Fire Island National Seashore (*Public Law 88-587*). Today, Fire Island National Seashore encompasses marine and upland habitat, 17 residential communities, New York's only federally designated wilderness. Fire Island National Seashore stretches 31 miles from Democrat Point and Robert Moses State Park on the west to Moriches Inlet on the east. A barrier island, it stands facing the Atlantic Ocean while protecting the waters of Great South Bay and the mainland of Long Island. Sitting on the fringes of the largest population concentration in the United States, Fire Island is a place rich in marine life, waterfowl, and other wildlife. It is a place to enjoy recreational pursuits, as well as a little solitude. In 1980, a 7-mile stretch from Smith Point West to Watch Hill was designated by Congress as wilderness, accessible only by foot, the only area in New York State to be honored in this manner.

The boundaries of the seashore extend 1,000 feet into the Atlantic Ocean and 4,000 feet into the Great South and Moriches Bays. The islands and marshlands adjacent to Fire Island are also included in the Fire Island National Seashore (FIIS). A General Management Plan (GMP) and the Final Environmental Impact Statement (EIS) on the General Management Plan were accepted in 1978, and have served as the basis for park management. The GMP is currently under revision, but not yet finalized.

The management strategy for the FIIS recognizes that significant areas of shorelines and back lands on Fire Island have been affected by human manipulation and population growth and now support stable communities. One of the planning premises is "Fire Island is a culturally manipulated barrier island system, and it cannot be managed as if natural processes had been totally unimpeded." National Park Service (NPS) policies generally allow for manipulation of the existing environment: 1) when directed by Congress, 2) in some emergencies when human life and property are at stake, or 3) to restore native ecosystem functioning that has been disrupted by past or ongoing human activities. Fait accompli.

The authorizing law for the Fire Island National Seashore also contains specific language that requires that any plan for shore protection within the boundary of Fire Island National Seashore be mutually agreeable with the Secretary of the Interior and the Secretary of the Army, as a requirement for the project to proceed. Superstorm Sandy's damage to Robert Moses State Park was severe: most of the Park's beaches were significantly eroded by severe wind, wave, and tidal action, and a portion of the Park's iconic traffic circle was destroyed.

Long Island's Atlantic-facing shores are blessed with two lines of defense – barrier beaches and wetlands. The iconic Fire Island is among those formidable barriers. Robert Moses State Park, at the western end and Smith Point County Park at the eastern end attract over four million visitors per year. In between, the FIIS, New York's only federally designated wilderness, stretches over 26 miles of marine life and upland habitat with 17 communities of 4,500 houses nestled along its perimeter. With its 1,000 miles of tidal shoreline, Suffolk is especially focused on mitigating the risk posed periodically by surrounding waters, especially in the wake of Hurricane Sandy.

Table 7-5 FIMP Annual Cost for Non-Structural and Beach Nourishment Plans

(5.125% interest over 50 yrs.)

	Plan 3.a	**Plan 3.g / (TFSP)**
Cost Category	Inlet Mgmt, BCP 13 @SB, NS2R, 15ft Dune @ GSB & MB	Inlet Mgmt, BCP 13 @ SB, BCP 9.5 @ OPWA, MFT, & SPCP, NS3R, 15 ft Dune @ GSB & MB
Beach Fill	$160,200,000	$139,200,000
Nonstructural	$407,200,000	$550,800,000
Road Raising	$14,900,000	$14,900,000
Total First Cost	*$582,400,000*	*$705,000,000*
Total IDC	$26,600,000	$29,400,000
Total Investment Cost	*$609,000,000*	*$734,400,000*
Interest and Amortization	$34,000,000	$41,000,000
Operation & Maintenance	*$9,300,000*	*$8,900,000*
Renourishment	*$12,900,000*	*$11,000,000*
Subtotal	*$56,200,000*	*$60,900,000*
Annual Breach Closure Cost	*$0*	*$1,000,,000*
Major Rehabilitation	*$0*	*$0*
Total Annual Cost	*$56,200,000*	*$61,900,000*

The most credible of objections raised by some who favor unconditional strategic retreat from coastal areas relates to concerns of near-shore sand borrowing for beach nourishment. This concern was underscored by the storm mitigation of underwater ridges of the seafloor off Long Island. John Goff, from the Institute for Geophysics at the Jackson School of Geosciences at University of Texas, Austin detected these rows of sand ridges, comparable to underwater sand dunes up to 10 feet high that run parallel to shore for as far as a half-mile. “I think of these ridges as kind of cushioning the blow,” Goff notes. “After the hurricane, they were still there and there wasn’t any substantial erosion of the shore face (http://www.jsg.utexas.edu/news/?p=5028).”

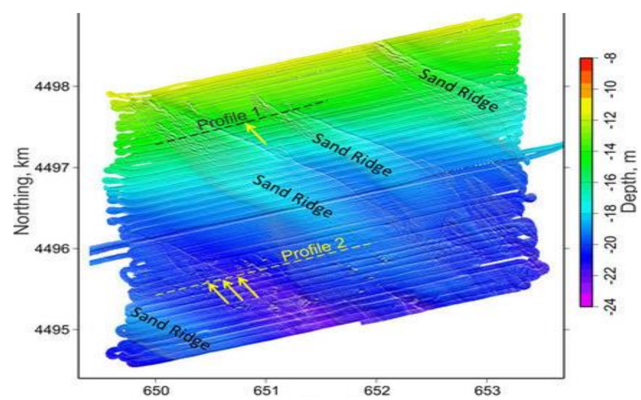
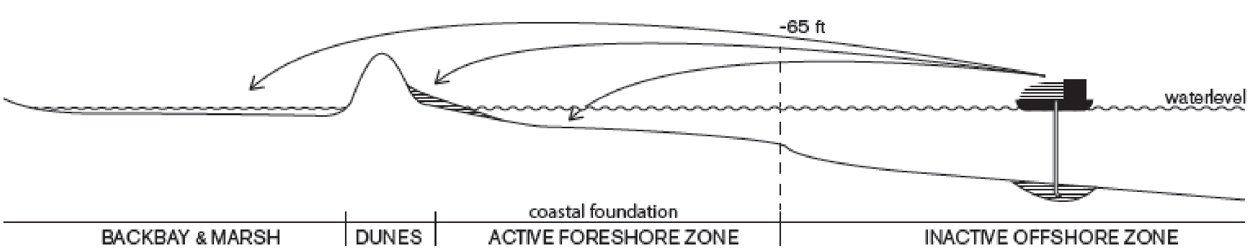


Figure 7-12 Stratigraphy of the Shallow Seabed Using Ultra-high Resolution Seismic Reflection Systems (CHIRP)

In April 17th comments to USACE, the U.S. Geological Survey (USGS) stated that “the coastal sediment budget is vastly improved from the preliminary DEA (Draft Environmental Assessment).” Joe Vietri, Corps Chief of Planning Policy, assures that the initial borrow area will be low impact and that future sites will be selected in close consultation with USGS and the Minerals Management Service: “This is a single, one time fill placement to stabilize this vulnerable section of shoreline while we complete the entire Reformulation effort.”



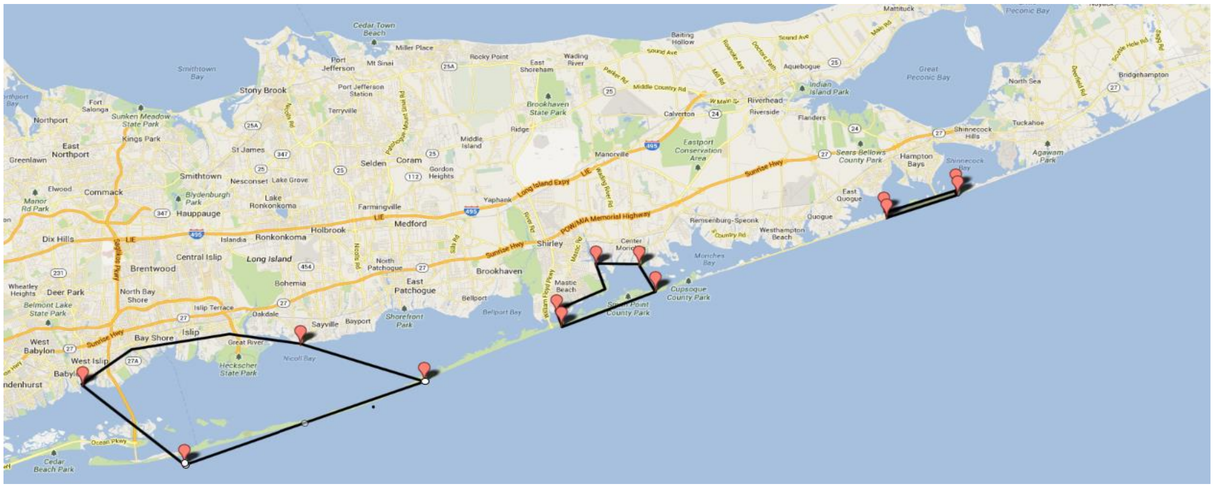
At present, beach nourishments are taken from the active foreshore zone and do not result in a net sand addition to the active zone. Future nourishments are to be taken from the (inactive) offshore zone, which will result in a net sand addition to the active zone.

Most of the Corps' efforts related to coastal risk mitigation within the last two decades have focused on beachfront areas, with a heavy reliance on beach nourishment as the primary means of coastal risk reduction (p. 59)…. Pre- and post- storm surveys following Hurricane Sandy in New Jersey in 2012 revealed that both beach width and dune height were critical in preventing breaches and overwash, even in locations that were not nourished (Coastal Research Center, 2013). A well-maintained dune in Seaside Park survived the storm, while dunes in nearby municipalities that did not have aggressive dune-building programs suffered overwash, leading to the loss of many homes (Committee on U.S. Army Corps of Engineers, "*on the East and Gulf Coasts,*" National Research Council, p74, 2014)

The value of beach fill and dune building in protecting against moderate-energy hurricanes was dramatically revealed in North Carolina as a result of Hurricanes Bertha and Fran in 1996 and Dennis and Floyd in 1999. Hurricanes Dennis and Floyd caused no damage to buildings behind three USACE-constructed dune projects, but damaged or destroyed over 900 buildings located outside the project dunes (Rogers, 2007). Federal Insurance Administration claims for damage caused by storm surge and wave attack and overwash resulting from Hurricanes Bertha and Fran revealed far less damage to structures in locations protected by USACE beach nourishment projects than in adjacent unprotected locations (USACE, 2000a). Dunes constructed on barrier islands, however, could reduce the possibility for overwash or breaching, potentially lessening the likelihood of bay flooding. ("*Reducing Coastal Risk,*" *op cit.,* p75)

Interagency workshops were co-hosted in the summer of 2013 by the US Army Corps of Engineers and the School of Marine and Atmospheric Sciences at Stony Brook University to identify opportunities for restoration and enhancement of coastal processes and habitats. Dune habitat was considered essential for storm risk reduction, though cost/benefit should be closely scrutinized. Rehabilitation and creation of wetlands in the lagoonal systems drew strong support, with the caveat that improved water quality is elemental to long-term success. Concentration of Corps efforts on three large restoration areas – Great South Bay, Smith's Point, and Shinnecock Bay, shown on **Figure 7-13,** was deemed the best bang for the buck environmentally with the greatest likelihood of success.

The group strongly supported the creation and/or rehabilitation of wetlands for shoreline of the lagoonal systems both on the mainland and barrier beaches, as they afford storm protection and ecological functioning. Wetlands buffer the impact of storm induced waves, accommodate sea level rise, provide habitat for shorebirds and other species, and reduce the impact of pollution. Wetlands restoration on the backside of the barrier islands would allow for some overwash fans that would then develop into wetlands. Buying shoreline properties to create relatively large land tracts on which to construct restoration projects would be particularly beneficial for storm risk reduction. To facilitate restoration of near shore transport processes and marsh transgression and development, bulkheads and groins should be removed.



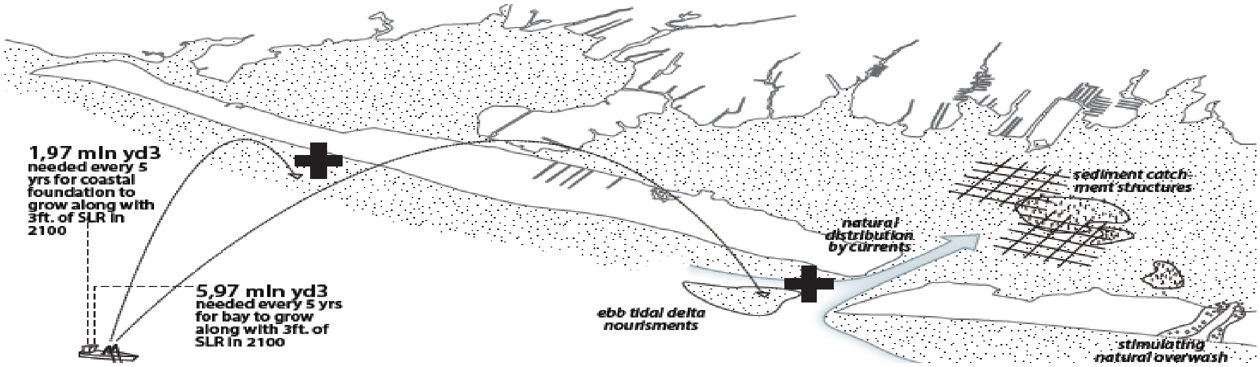
Great South Bay **Smith's Point** **Shinnecock Bay**

Figure 7-13 Proposed Restoration Areas

Improved water quality is key to wetland enhancement and elemental to so-called soft storm mitigation solutions such as the introduction of oyster reefs or clam beds. Breach enhanced cross-bay circulation, rationalized coastal land use and reduction of pervasive cesspool/septic nitrogen pollution is also key. There was a call for Corps review of its breach policy. Elements of FIMP green infrastructure that will need to be evaluated include:

- Do soft solutions work?
- Does bayside marsh reduce flooding?
- How much does marginal water quality impact marsh development?
- Will oyster reefs used as wave attenuators survive in marginal water quality?
- What are the long-term benefits of breaches?
- Are artificial dunes as effective as natural dunes?
- Can artificial dune technology be improved?

7.3.3 Rebuild by Design



The schematic above proposes a way of 'growing along with sea level rise.' It is one component of "Living with the Bay, *A Comprehensive Regional Resiliency Plan for Nassau County's South Shore*" that was awarded $125M by Rebuild by Design, sponsored by U.S. Housing and Urban Development (HUD). "Living with the Bay" was conceived by the Interboro Team, which includes the 'Dutch contingent' from Deltares, TU Delft, Bosch Slabbers and Palmbout Urban Landscapes (http://www.rebuildbydesign.org/project/interboro-team-final-proposal/).

Interboro posits that, "to grow along with 3 feet of sea level rise in 2100, both the coastal foundation that holds the beach and dunes in place and the bay bottom need extra sediment. The coastline protecting the urban areas will need 1.97 million cubic yards every five years and the bay demands 5.97 million cubic yards every five years to grow along, unless islands are allowed to shift landwards. Sediment inflow toward the bay can be stimulated by ebb-tidal delta nourishments, stimulating natural overwash and breaches, and by improving the catchment of sediment, for example by catchment structures."

As a phase one project, Interboro proposes to manage a dynamic coastline with the installation of a sand engine in Jones Inlet that will feed the littoral drift westward to Long Beach. The sand engine, or sand motor, has been deployed in the Netherlands along the coast at Zuid-Holland to Ter Heijde where a huge volume of sand has been deposited. The expectation has been that wind, waves and current will spread, gradually shaping the coast and fully incorporating into broader, safer beach/ dunes. "The Sand Motor - Passionate Research" depicts how the Netherlands project is working (https://www.youtube.com/watch?v=wtY4_QXcVsM&feature=youtu.be). The Dutch expended 70M euros ($100M in July 2011 exchange rate) for 21.5M cubic meters (28M cubic yards). The December 2013 FIMP report allocates $74.4M for 6.99M cubic yards or $3.6/cubic yard for the Dutch/Sand Engine/ approach versus $10.7/cubic yard for the USACE/FIMP engineered beach and dune. Though apples/oranges, tracking comparisons between beach dynamics five to ten to twenty years out would be illuminating.

Longshore Migration of Sediment

On Long Beach Island to the west of Jones Inlet, the Interboro team proposes building a system of ditches along the medians of north/south streets so that the rising water from Hewlett Bay can recede back into the ocean instead of flowing up onto land and destroying property. Moreover, it is their sense that drowning of the marshland will only be stopped when plates grow along with sea level rise which will:

- Work with ebb-tidal delta nourishments that function as local sand-engines;
- Stimulate natural distribution via currents by influencing the tidal prism;
- Create sediment catchment structures;
- Stimulate natural over-washes; and
- Make use of the natural sediment transport along the coastline and the existing sediment surplus at the top of the barrier islands.

The outer road is slightly heightened, increasing the safety for the houses behind it. An open wadi system buffers the rainwater.

"The **Eco-Edge** is, in essence, a strategy that can be incorporated within the whole bay area. Long Beach Barrier Island is highest at the ocean side, with an elevation of approximately 12 feet, and lowest at the bay-shore, with an elevation of approximately 6 feet, just barely above the high tide water level in the bay. On the ocean side, we propose to build on the ongoing work by USACE and complement the beach replenishment and dune construction along the ocean shore. On the bay shore, we propose a smart recreational dike landscape that over time is able to protect the entire bay shore. The dike landscape consists of 6 to 8 protective compartments (ring levees) that over time can be built successively. As a second component of our project, we propose a system of stormwater retention parallel to the beach and the bay, in the form of controlled open flooding areas that double as open space resources. As a third component, we propose to improve the local network perpendicular to the beach, recreational levee, and central boulevard, so that the streets provide more water storage and more filtering water…. The Long Beach sewage treatment plant can be decommissioned once the ocean outfall for the Bay Park sewage treatment plant is in place.

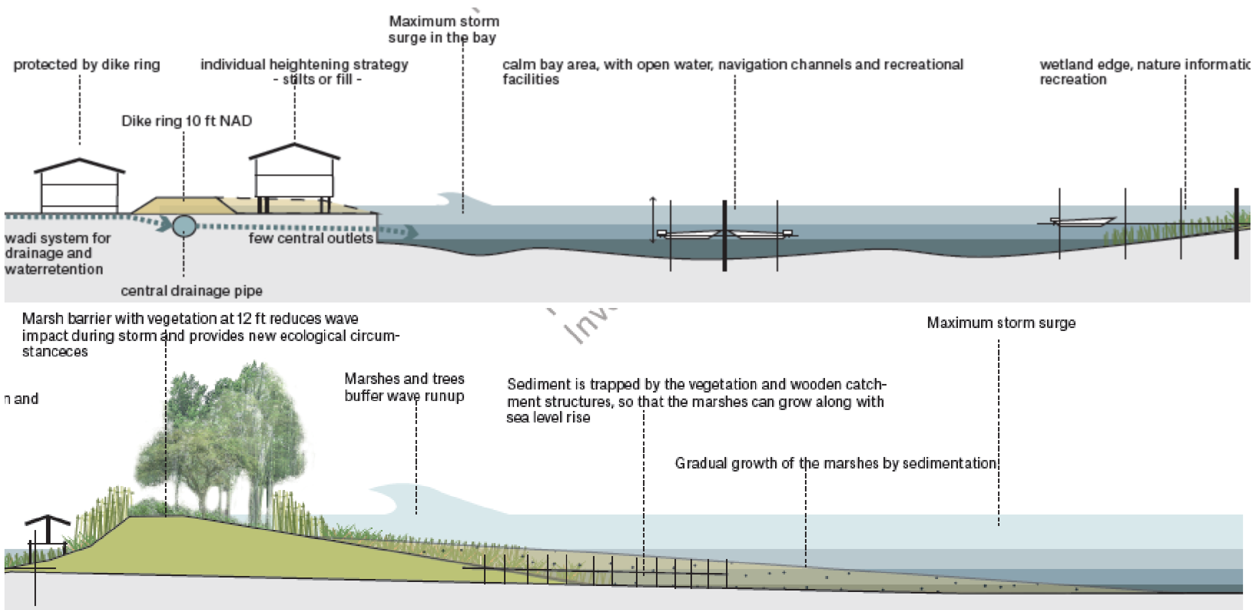
"The flood risk within the bay is not just a story of high water levels but also one of low-lying areas and the lack of sediment. The strategy on the large scale shows that nourishing the ebb-tidal delta and the channels can supply the sediment demand within the bay. The wooded marsh ridges help to catch this sediment and allow the vulnerable marshes to grow. The constructed ridges provide a habitat that is almost not present within this area. On top of that, they also reduce the surge by 2 feet and the wave run up by another 2 feet. The dike ring is not just a structure. It creates a new water drainage system with retention ponds and swales.

"It designs with nature, constructing higher ridges and low-impact sediment catchment structures (simple wooden structures) and providing enough sediment on the ebb-tidal delta and in the channels. The tides and currents will disperse the sediment, and the "right" sediment particles will fall in the right places. It combines water retention with water safety. Dike rings provide new rainwater storage possibilities alongside and beneath them. They can drain, retain, and store water. It creates high evacuation roads. It combines the individual heightening strategies with a "backbone' structure (the dike ring) so that the investment is beneficial for a larger area. This approach consists of three levels (http://www.rebuildbydesign.org/project/interboro-team-final-proposal/):

- The larger system from which the design provides sediment;
- The eco edge/marshes that reduce the surge by 2 feet and the wave impact by at least 50 percent and
- The dike rings that keep the communities safe and allow them to restructure the urban fabric/individual parcels to bring them to a safe level."

Note that the cost estimate for the (partial) projected total for 'Living with the Bay' comes in at $1,874M. With less than 7% of the interim estimate in hand, Interboro is clearly obliged to cast about for other potential funding/financing which they identify as:

- Tax Increment Financing (TIF),
- Insurance receipts,
- Specific tax or fee, i.e. 'stormwater tax' and
- The 'availability payment' model of Public-Private Partnerships (evaluated in greater detail in Section 2 "Ways & Means").



This cross-section demonstrates how measures are interconnected and, thus, optimize the environment.

7.3.4 New York Rising Community Reconstruction Program

The New York Rising Community Reconstruction (NYRCR) Program "empowers the State's most impacted communities with the technical expertise needed to develop thorough and implementable reconstruction plans to build physically, socially, and economically resilient and sustainable communities." The NYRCR Program, announced by Governor Cuomo in April of 2013, allocates more than $650M to that end for 102 communities severely damaged by Hurricane Irene, Tropical Storm Lee, and Superstorm Sandy. NYRCR Oakdale/West Sayville is one of eight such communities in Suffolk County. $3M has been allocated for resiliency projects and another $3M was awarded for the "Best Use of Green Infrastructure to Bolster Resilience" as illustrated in the following pages.

PROPOSED PROJECT: "Living" Marsh – Grand Canal Levee Improvement

Project Description

"The purpose of the project is to improve tidal exchange to an approximately 87-acre salt marsh wetland area so as to increase its capacity to absorb storm surges and stormwater runoff as well as provide an improvement in the health of the wetlands, including a reduction of invasive species.

"The wetland, owned by New York State and known locally as the Pickman-Remmer Wetlands, was closed off from regular tidal exchange by the creation the Grand Canal in Oakdale. As a result, approximately, 31% (27 acres) of this marsh is now dominated by the invasive species *Phragmites australis.* The Grand Canal Levee is an earthen berm structure that was built over a hundred years ago when the canal was excavated as part of the development of the W.K. Vanderbilt Estate. The excavation occurred through a large tidal wetland area and significantly altered the hydrology of the area. The levee runs in a north-south direction along the Grand Canal. The portion of the wetland located east of the levee was the area that was most affected by the structure, in which tidal exchange was almost completely cut-off and restricted to a few relatively small pipes and openings that were added later, possibly as part of a vector control project. These openings have deteriorated over time and have become blocked with silt and organic debris.

"The project will reestablish tidal exchange by inserting strategic openings within the levee located along the east side of the Grand Canal. The project would also provide limited public access such as wildlife viewing and hiking trails in environmentally compatible locations. The project is anticipated to provide public benefits for the community through storm surge protection, improvement of publicly owned wetlands and the addition of recreational and tourism benefits through the development of a hiking trail along the top of the levee. The installation of drainage pipes though the levee or excavated openings along with the construction of a hiking trail are both considered technically feasible.

'The proposed project includes funding for an engineering study to determine the most appropriate method to increase tidal flow. The proposed project specifically includes the installation of seven new pipes through the levee to hydraulically improve the tidal exchange between the Grand Canal and the wetlands.

Grand Canal, Oakdale, looking north—levee extends along the right side of the canal

Estimated Project Costs

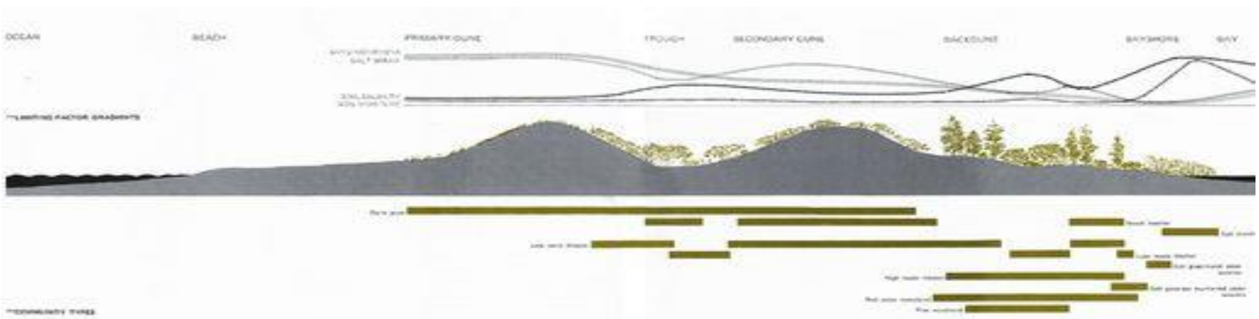
"The capital and soft costs of this project are estimated at $410,000. About half of this estimate is for construction of the seven culverts. The balance is for "soft" costs including an environmental engineering study, design, permitting, and contingency. Annual operating and maintenance costs are estimated at $4,500. With an expected useful life expectancy of 30 years, the conceptual life cycle cost is estimated to be $545,000. The trail will also help to stimulate tourism as the first phase of a proposed "South Shore Gold Coast Heritage Trail" system, which is proposed to extend from the Bayard Cutting Arboretum in Great River, through Oakdale to Green's Creek in West Sayville.

Environmental Benefits

"These wetlands are dependent on tidal flow (notably, salt/ brackish water) to maintain a diverse population of plant and animal species. Restricted tidal flow alters the natural balance of tidal wetlands resulting in a change of vegetation including the proliferation of invasive species. This is visible in the wetlands today with approximately 27 acres of the 87-acre Pickman—Remmer wetlands dominated by *Phragmites australis*, known as common reed, which can out-compete native salt marsh vegetation and reduce available food and shelter for saltmarsh dependent wildlife. The improvement of health of the wetlands is vital to the important role they serve of filtering out pollutants and excess nutrients, thereby improving surface and groundwater quality (Professional guidance of Jacob/Cameron Engineering was provided through NYRCR)."

7.4 Wetland Stewardship Strategy

"We're finding out these wetlands are not just for fishing and recreation and boating, but they are actually like our mangroves. They're our protection and they're failing." Jim Ruocco, Operation S.P.L.A.S.H. (Stop Polluting, Littering and Save Harbors). "Even if a narrow strip of marshland would have little impact on storm surge, it could reduce wave energy in a storm, writes Dr. Joannes J. Westerink, a civil engineer at the University of Notre Dame. "The scales of motion are much smaller" with waves, he said, and even if the wetland were overrun by storm surge, it would "attenuate waves very effectively," he added. "And waves can knock the socks off your infrastructure."



"Marshes were not made to be filled; they constitute a present value and a real danger to human habitation."
-Ian McHarg, ***Design with Nature***

Suffolk County's Wetland Stewardship Strategy (WSS) targets the 17,000 acres of salt marshes in the County in order to:

- Improve tidal regime and flux between estuary and marsh;
- Allow improved tidal exchange in the marsh interior;
- Enhance conditions for proper marsh accretion and resilience to sea level rise;
- Provide high quality habitat for salt marsh biota, and
- Enable biological control of larval salt marsh mosquitoes and of Phragmites.

Beneficial outcomes of the WSS include:

- Increased cover, health, and vigor of native vegetation;
- Improved nutrient fluxes buffering;
- Enhanced use of the marsh by wildlife including estuarine nekton; and
- Reduction in mosquito production.

With improved conditions for native vegetation and proper sediment capture, the marsh is expected to be resilient to sea level rise. The County's Vector Control and Wetlands Management Long Term Plan is available on-line:
http://apps.suffolkcountyny.gov/health/suffolkvectorplan/pdf/final/Revised%20Long-Term%20Plan.pdf

The eight years of post-restoration monitoring results for the Wertheim Restoration Project continue to indicate that the newly created tidal network has improved marsh and vegetation health in the previously degraded portions of the marsh by increasing the cover of native plant species and decreasing the cover of phragmites (Rochlin et al. 2012, Integrated Marsh Management): a new perspective on mosquito control and best management practices for salt marsh restoration). Recovery from areas impacted by construction has occurred. In addition significant reductions in mosquito production and consequent decrease of pesticide applications to the salt marshes have been also achieved at Wertheim. Most recent data may be found at: http://apps.suffolkcountyny.gov/health/suffolkvectorplan/index.html.

While the barrier islands form Suffolk County's first line of defense, hundreds of thousands of South Shore residents have historically been protected by coastal wetlands which make up the critical second line of defense. "Tidal wetlands can protect coastal communities from storm damage by reducing wave energy and amplitude, slowing water velocity, and stabilizing the shoreline through sediment deposition. More than half of normal wave energy is dissipated within the first three meters of marsh vegetation such as cord grass. In addition, given sufficient sediment deposition, wetlands are able to build elevation in response to sea-level rise, providing a buffer against climate change and coastal submergence." -**NYS 2100 Commission Report**, Governor Andrew Cuomo. **Figure 7-14** summarizes the processes that affect wetlands development.

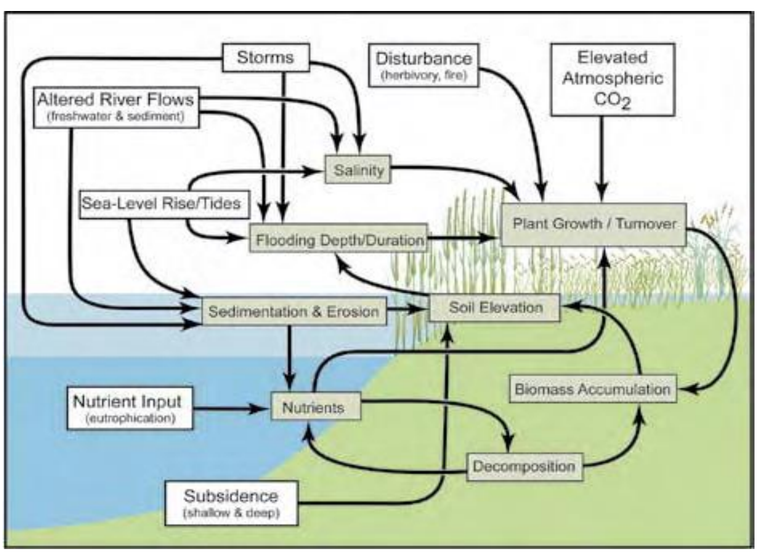


Figure 7-14 Drivers and Processes that Influence Vertical Wetlands Development
(Coastal Sensitivity to Sea-Level Rise: A Focus on the MidAtlantic Region, J Titus, 2009)

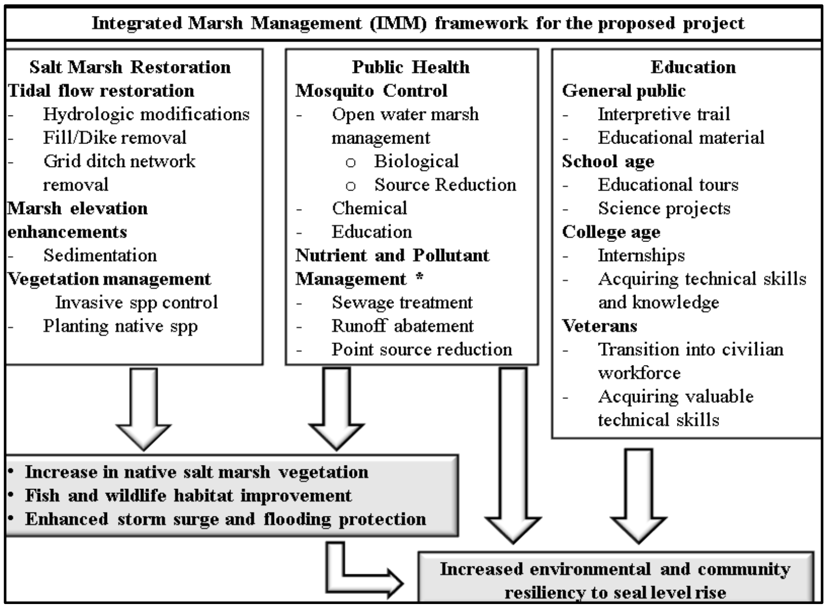
SECTION 7 COASTAL RESILIENCY

The resilience of large expanses of Long Island tidal marshes is threatened by tidal restrictions, waterlogging, extensive mudflat and panne formation, and invasive plants. The Nature Conservancy (TNC) collaborated with Columbia University to produce a trend analysis of tidal marsh in the Great South Bay between 1974 and 2008. On Captree Island, high marsh has receded by 20.4% (33 acres), intertidal marsh by 20.3% (35 acres), and total natural vegetated marsh by 20.4% (54 acres). Pannes, shallow depressions that contain very high concentrations of salt, constitute, as of 2008, 13% of the island.

Reducing, then reversing wetland loss, will improve fish and wildlife habitat, while buffering adjacent coastal communities to impacts of storms and sea-level rise. Rehabilitated wetlands also allay public health threats engendered by mosquito proliferation. In the bargain, recreational opportunities are showcased, underscoring the socioeconomic and ecosystem value of salt marshes. Restoring the entire wetlands ecosystem of the Great South Bay would recreate the kinds of conditions that once hosted a multi-billion dollar shellfish industry that is now moribund.

The primary management techniques proposed for Captree and Oak Island have been successfully applied by Suffolk County and include:

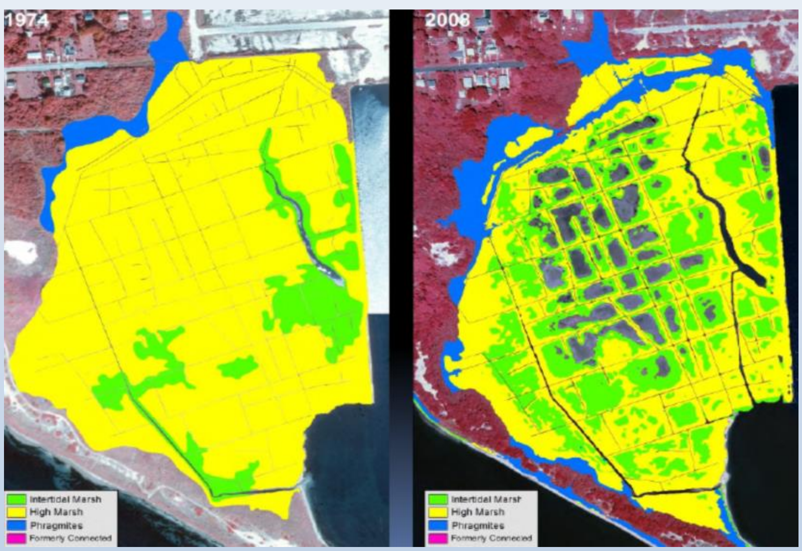
- Restoring tidal flow by creating channels, sometimes out of mosquito ditches, that will improve tidal regime and hydraulic exchange between the bay, estuary, and marsh interior;
- Creating shallow connecting channels and small ponds to prevent waterlogging of the marsh, allowing access for native killifish that will control mosquito larvae, reducing the need for chemical control;
- Spreading excavated material on the marsh and filling obsolete grid ditches will provide elevation for desirable vegetation and enhance marsh accretion and resilience to sea level rise and storm surges.



"Enhancing coastal resiliency through integrated salt marsh management along the south shore of Long Island, New York" Suffolk County was granted $1,310,000 by the National Fish & Wildlife Foundation/ Department of Interior to restore 400 acres of wetlands and enhance its capacity to rebuild 1,500 more acres.

Project Goals and Objectives

The primary goal of this project is to develop and implement sustainable salt marsh rehabilitation methodologies. Such on-going stewardship of the tidal wetlands will enhance resiliency of coastal ecosystems and communities in the face of rising sea levels and extreme storm events (Deegan et al 2012). Approximately 1,500 acres of tidal wetlands will be evaluated and 200 to 400 acres will be rehabilitated during the 2 years of the project. The diverse components of this project will coalesce under the conceptual umbrella of Integrated Marsh Management (IMM) (Rochlin et al. 2012b; Fig. 2). IMM has been field tested by the core team of Suffolk County applicants at Wertheim National Wildlife Refuge (NWR) and recently adopted by US Fish & Wildlife Service (FWS) as part of their approach for expanding salt marsh habitat restoration on the remainder of their refuges on Long Island (funded through DOI grant). The project's primary goal can be realized by extending the use of IMM techniques to wider swathes of County marshes in a sustainable manner.



Smith's Pont panne formation, 1974-2008 (Cameron Engineering)

IMM is an approach to tidal wetlands management that seeks to maximize multiple benefits and reconcile competing management goals. The IMM approach to project design involves convening strategic stakeholders into an interagency team that will plan the project based on the site-specific considerations and stakeholder goals and mandates. Marsh management techniques are then chosen and tailored to the needs of that site.

The primary management techniques already in use at Wertheim and proposed for this project include:

- Restoring tidal flow by creating tidal channels that closely resemble natural tidal creeks. Existing mosquito ditches are sometimes converted for this purpose;
- Creating small ponds that closely resemble natural salt marsh ponds to create habitat for fish and wildlife;
- Creating shallow connecting channels to prevent waterlogging of the marsh, allow access to ponds by estuarine fish and allow access to the marsh for native killifish that will control mosquito larvae;
- Using excavated material to fill obsolete grid ditches, and
- Spreading excavated material on the marsh surface to provide the proper elevation for desirable vegetation and eliminate habitats for mosquito larvae.

Results published by the core team on the pilot project at Wertheim NWR demonstrate that techniques deployed promoted growth of desirable vegetation while improving fish and wildlife habitat. In addition, production of mosquito larvae was reduced to levels where the need for pesticide application was dramatically reduced and could be eliminated with some minor additional work. The IMM framework can also include additional marsh management techniques, such as vegetation control or planting where indicated. The cooperative, interagency management approach effectively lends itself to partnerships while incorporating educational and training goals into the overall management scheme (IMM Figure 2).

The resilience of large areas of Long Island tidal marshes is threatened by tidal restrictions, waterlogging, extensive mudflat and panne formation and invasive plants. Moreover, many of these wetlands produce mosquitoes in large enough numbers to require regular pesticide application. The preponderance of these challenges can be redressed using the IMM approach. Rehabilitating these wetlands to a level of resilience engendered by healthy native vegetation is key to keeping pace with sea level rise. Additionally, reducing, then reversing wetland loss, will improve fish and wildlife habitat, while mitigating vulnerability by buffering adjacent coastal communities to impacts of storms and sea-level rise. Rehabilitated wetlands also allay public health concerns engendered by mosquito proliferation, even as they showcase recreational opportunities that underscore the socioeconomic and ecosystem value of salt marshes.

7.5 Drainage Strategies in Chronically Flooded Areas

"We elevate our houses, but we're still living in Venice." –South Shore resident on chronic flooding

Green infrastructure measures can reduce, capture, and treat stormwater at its source via green roofs, bioswales, permeable pavement and contain/retain/drain strategies. Communities across Suffolk County, such as the Villages of Babylon and Lindenhurst, have determined that there is a cost/benefit that can accrue from these measures. *The National Institute of Building Sciences has delineated examples of savings accruing from Low Impact Development which deploys natural and engineered infiltration and storage techniques to control storm water where it is generated (http://www.wbdg.org/resources/lidtech.php).*

Of particular utility to chronically flooded areas of the South Shore are porous surfaces. Permeable Interlocking Concrete Pavers (PICPs) higher initial installation cost compared to asphalt is counterbalanced by a lifespan three to five times longer and requires less maintenance so, in effect, permeable pavers will have a similar uniform annual cost as well-maintained asphalt over 65 years. Though useful for traffic calming, pavers may generate more noise, be more difficult to navigate for bicycles, and more challenging for utility companies to restore after repair. As 17 percent of Berkeley, CA is paved over by streets and sidewalks, they've opted to follow the examples of Portland, OR; Warrenville, IL; Oakland, CA; and Moline, IL. Moreover, as seen in the Port of Oakland, pavers are significantly more durable than flowed cement. The Port has a routine traffic flow of multiple containers—with up to 240 tons per load area and 200,000 lbs. containers stacked three to four high, far more than that carried by the most trafficked streets. (http://www.icpi.org/sites/default/files/03_Feb_Port_of_Oakland.pdf; http://www.ci.berkeley.ca.us/uploadedFiles/Public_Works/Level_3_-_Sidewalks,_Streets_-_Utility/Permeable%20Pavers%20and%20Climate%20Action%20Plan%2012-15-09.pdf)

Interboro's 'Green Corridor' component of its Rebuild by Design proposal addresses drainage via a stretch of Sunrise Highway from Valley Stream to Freeport. Presently underdeveloped, its post-Sandy feature is that it is high and dry, just beyond the reach of a category 2 surge, a 6-foot sea level rise, and the FEMA flood zone. The corridor is also highly impermeable: its roads and parking lots are a major source of both flooding and polluted stormwater runoff. In addition to transit-oriented, walkable, mixed-use downtowns and relief from river choke-points, the 'Green Corridor' proposes to reuse abandoned water infrastructure under Sunrise Highway for water storage and flow augmentation. This abandoned system, which includes a 72-

inch steel force main, a 48-inch cast iron main, a 36-inch cast iron main, and a network of pumping stations, once provided Brooklyn with its drinking water from Long Island's aquifers.

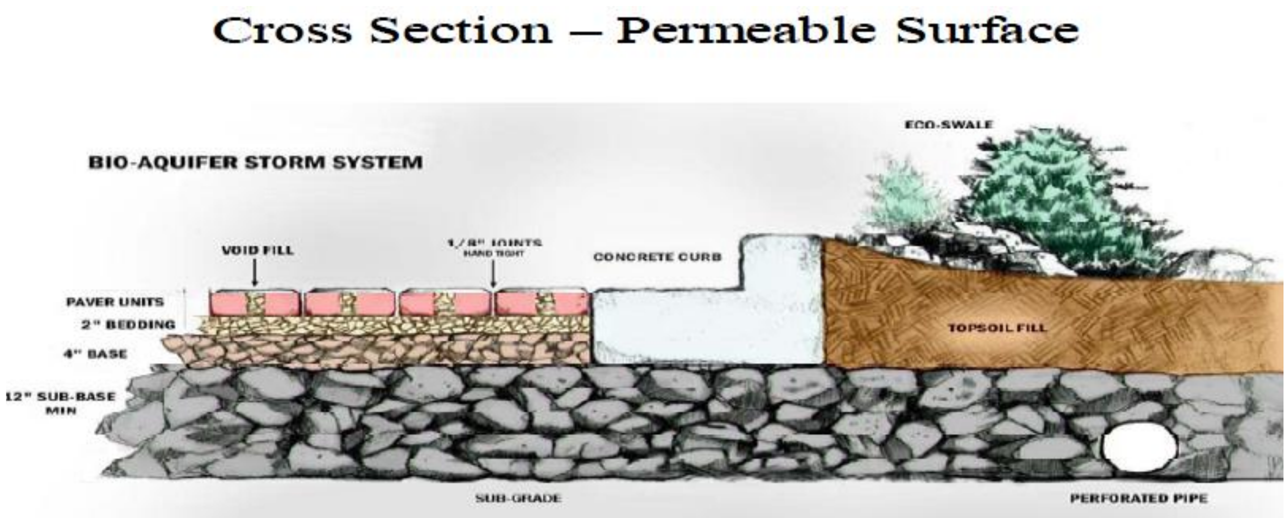


Figure 7-15 Portland Street with Pavers in Parking Lanes and Lindenhurst Library with Porous Parking Lot

7.6 Hard Defenses

Green infrastructure has gained increasing favor over the hard defenses of gray infrastructure.

"As sea level rises, shoreline armoring eventually eliminates ocean beaches (IPCC, 1990), estuarine beaches (Titus, 1998), wetlands (IPCC, 1990), mudflats (Galbraith *et al.,* 2002), and very shallow open water areas by blocking their landward migration. By redirecting wave energy, these structures can increase estuarine water depths and turbidity nearby and thereby decrease intertidal habitat and submerged aquatic vegetation (J. Titus *et al.,* "Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region," US Climate Change Science Program, 2009)."

Table 7-6 Permeable Interlocking Concrete Pavers (PICP)

Reason for Improvement	Root Cause	Mitigation Focus	Benefit to City
Improve long term durability of street paving materials	Clay soil seeps up into the stones and gravel base of older streets, causing instability. This leads to cracks, allowing storm water to create potholes	PICPs will allow for up to a 50-100 year life cycle for properly constructed street vs. less than 17 years for asphalt (shorter on major or collector streets).	PICP construction is **45% to 60% more expensive** on like-to-like construction (reconstructed street). However, **durability is nearly 3-5x longer (50 -100 year life cycle).**
Reduce storm water street flooding	Hardscaped streets force all water into storm drains in short time intervals	PICPs will slow the velocity of water into storm drains by absorbing water into gravel base and sub-base before reaching storm drains, thus reducing downstream flooding	Help reduce the need to build larger storm drains ($80M total cost from past estimates but with a near term $11m capital budget and annual $1.3M expense budget)
Reduce the speed of traffic on city streets	Increased traffic volumes and pace of urban life have led to injuries and traffic deaths on our hardscaped city streets	PICP implementations in Portland, OR; Warrenville, IL; and the Netherlands have seen the reduction of traffic speed and increased overall driver and pedestrian awareness	Help **reduce the average rate of speed from 30 MPH to 25 MPH** without police enforcement costs
Reduce greenhouse gases by 80% by the year 2030.	Oil based asphalt adds to the increase of greenhouse gases through production and the need for constant repair - **currently 783 metric tons of CO_2 are produced annually with current paving methods**	PICPs will incrementally reduce greenhouse gases by using "green cement" that sequesters CO_2 into cement and "smog eating" titanium dioxide paver coatings - allowing for increased use of electrical vehicles. PICPs reduce surface heat gain through the use of light colored pavers and absorb heat through open space between pavers	Help meet City's greenhouse goals by year 2030 and help reduce dependence on fossil fuels
Reduce sidewalk repair cost from tree roots heaving cement.	Hardscaping seals the surface. Tree roots which require water and air, must break through, entering sanitary and storm drains, lifting asphalt and cement	PIPCs enable roots to sink vertically down and still drink and breath	Help reduce $778K annual capital budget associated with sidewalk repair costs (mostly associated with tree root break-through)
Reduce impact of storm water runoff into San Francisco Bay	50% of heavy metals in Bay originates from hardscaped streets according SF Bay RWQCB	PICP implementation will help trap and filter heavy metals in base and sub base of PICP constructed streets	Reduce street sweeping frequency/costs (SF Bay RWQCB proposes an increase to weekly sweeping to mitigate heavy metal issue - clean cities budget is $3.5m annually)

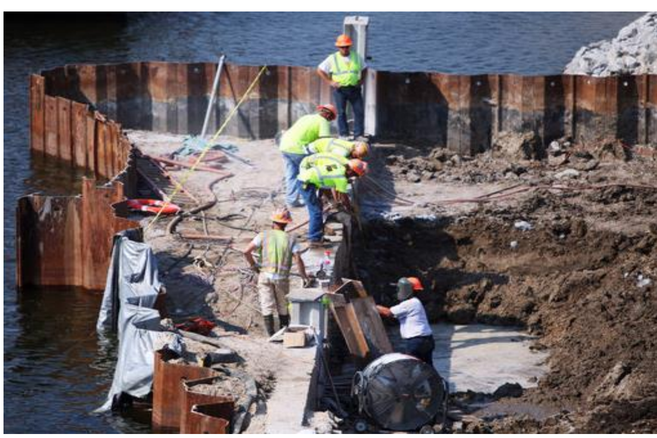
Source: City of Berkeley, 12/15/09)

There remains, however, a distinct place for hard defenses. The massive Dutch Maeslantkering, the movable storm surge barrier whose gates are each the length of the Eiffel Tower, was built in 1997 at a cost over $0.5B and used only once - successfully. The Dutch engineering firm, Arcadis, helped design a $1.1 billion, two-mile-long barrier that protected New Orleans from a 13.6-foot storm surge from Hurricane Isaac in 2006. All the barriers closed, all the levees held, all pumps worked and the Lower Ninth Ward which had been devastated by Hurricane Katrina, was left unscathed.

Malcolm Bowman, a physical oceanographer at the State University of New York at Stony Brook, has been saying for years that New York City needs harbor-spanning storm-surge barriers, one at Throgs Neck, to keep surges from Long Island Sound out of the East River, and a second one spanning the harbor south of the city. Arcadis has prepared just such a conceptual design for a storm-surge barrier in the Verrazano Narrows. The proposed Outer Harbor Gateway, with fourteen gates out of stone and concrete, would extend six miles across Lower New York Bay. "A giant barrier across the bay is not practical or affordable," concluded Mayor Bloomberg.

Table 7-7 Shoreline Armoring Alternatives *Source: U.S. Climate Change Science Program, January 2009. Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region)*

Response Measure	Method for Protection or Retreat	Key Environmental Effects
Shoreline armoring that interferes with waves and currents		
Breakwater	Reduces erosion	May attract marine life; downdrift erosion
Groin	Reduces erosion	May attract marine life; downdrift erosion
Shoreline armoring used to define a shoreline		
Seawall	Reduces erosion, protects against flood and wave overtopping	Elimination of beach; scour and deepening in front of wall; erosion exacerbated at terminus
Bulkhead	Reduces erosion, protects new landfill	Prevents inland migration of wetlands and beaches; wave reflection erodes bay bottom, preventing submerged aquatic vegetation; prevents amphibious movement from water to land
Revetment	Reduces erosion, protects land from storm waves, protects new landfill	Prevents inland migration of wetlands and beaches; traps horseshoe crabs and prevents amphibious movement; may create habitat for oysters and refuge for some species
Shoreline armoring used to protect against floods and/or permanent inundation		
Dike	Prevents flooding and permanent inundation (when combined with a drainage system)	Prevents wetlands from migrating inland; thwarts ecological benefits of floods (e.g., annual sedimentation, higher water tables, habitat during migrations, productivity transfers)
Tide gate	Reduces tidal range by draining water at low tide and closing at high tide	Restricts fish movement; reduced tidal range reduces intertidal habitat; may convert saline habitat to freshwater habitat
Storm surge barrier	Eliminates storm surge flooding; could protect against all floods if operated on a tidal schedule	Necessary storm surge flooding in salt marshes is eliminated




Adjusting to Venetian Living on the South Shore

With vast numbers of people living in coastal areas and waterways, the call for car and a watercraft to be combined was waiting to be made. The Gibbs **Aquada** (among other entries) is a high-speed amphibian which can top 100 mph on land and 30 mph on water, and takes a mere 6 seconds to morph from sportscar to jetboat. Conceived for a waterside living, the British-built Aquada is powered by a 175hp, V6 engine with an auto transmission linked to a fully-enclosed jet propulsion system. Getting into the water is simply a matter of driving down a boat ramp and pushing the button - the accelerator becomes the throttle and jet propulsion takes over. At $411,000, this is a concept car, obviously not ready for the mass market. (www.gizmag.com/four-new-amphibious-vehicles/2797/)

Around 4,000 Amphicars were produced in 1960s with President Lyndon Johson one of the car's many celebrity owners.

The Floating House will rest upon a 65-foot by 22-foot buoyant concrete hull, and can float atop the water like a non-movable houseboat. In addition, if located on a flood-plain, it can rest atop stilts or on a non-floating flood-resistant thick concrete base. The design has the two story home's living quarters contained within a 45-foot by 16-foot cross-laminated timber frame, with a thick layer of insulation and triple-glazed windows. The interior comprises two bedrooms, a study, a bathroom, living room, and a kitchen. A "crow's nest" observation area is situated on the rooftop/upper deck. Powered by solar, a rainwater-harvesting tank is situated on the roof to provide a renewable source for most of the home's non-drinkable water requirements, according to Carl Turner Architects (http://paperhouses.co./blog/entry/http-paperhouses.co-pages-turner).

Pointing to the waterfront reinforcement already in place in New Orleans and the Fox Point Hurricane Barrier in Providence, the managing partner of Long Island's Cameron Engineering proposes that, "movable steel barriers could be constructed across East Rockaway, Jones, Fire Island, Moriches, and Shinnecock inlets. Under normal conditions, the barriers would be open for tidal circulation, to maintain bay water quality, to permit recreational and commercial boat traffic, and to allow outflow from the bays during a nor'easter. The barriers would be closed only in advance of major storms.... Providence, R.I., has had a 3,000-foot-long barrier since 1966. The 17-foot-high barrier in Stamford, Conn., stopped Sandy's 11-foot surge from causing many millions of dollars in damage." (J. Cameron & D. Berg, "Movable barriers can protect Long Island's South Shore," Newsday, 9/15/13). Moreover, as a component of FIMP, the Corps has proposed elevating coastal roads that could double as storm-resistant berms.

The USACE's summary of the range of structural and non-structural measures to address storm-related flooding, wave attention and erosion is included here as **Table 7-8.**

Table 7-8 Summary of Structural and Non-Structural Measures to Reduce Storm-Related Risks

Table IV-4. Coastal Storm Risk Management and Resilience Attributes Associated with the Full Array of Measures

Aggregated Measure Type[1]	Category[2]	Coastal Storm Risk Management Function			Multi-Benefits[3]	Resilience
		Flooding	Wave Attenuation	Erosion		Adaptive Capacity[4]
Acquisition (building removal) and relocation[5]	Non-STR	High	High	High	High	High
Building retrofit (e.g., floodproofing, elevating structures, relocating structures, ringwalls)	Non-STR	High	Low	Low	Low	Low
Enhanced flood warning and evacuation planning (early warning systems, emergency response systems, emergency access routes)	Non-STR	Low	None	None	Low	High
Land use management/ conservation and preservation of undeveloped land, zoning, and flood insurance	Non-STR	Medium	None	None	High	Medium
Deployable floodwalls	STR	Medium	None	None	None	Low
Floodwalls and levees	STR	High	Low	None	Low	Low
Shoreline stabilization (seawalls, revetments, bulkheads)	STR	Low	High	High	Low	Low
Storm surge barriers	STR	High	Medium	None	Low	Low
Barrier island preservation and beach restoration (beach fill, dune creation)	STR/NNBF	High	High	Medium	High	High
Beach restoration and breakwaters	STR/NNBF	High	High	High	High	Medium
Beach restoration and groins	STR/NNBF	High	High	High	High	Medium
Drainage improvements (e.g., channel restoration, water storage/retention features)	STR/NNBF	Medium	Low	Medium	Medium	Low
Living shorelines	STR/NNBF	Low	Medium	Medium	High	High
Overwash fans (e.g., back bay tidal flats/fans)	NNBF	Low	Medium	High	Medium	High
Reefs	NNBF	Low	Medium	Medium	High	High
Submerged aquatic vegetation	NNBF	Low	Low	Low	High	Medium
Wetlands	NNBF	Low	Medium	Medium	High	High

1 *An extensive list of management measures was compiled as part of the NACCS Measures Working Meeting in June 2013. The measures presented here represent an aggregated list of the categories of measures and corresponding conceptual parametric unit cost estimates.*

2 *STR = structural measure, Non-STR = nonstructural measure, and NNBF = Natural and Nature-Based Features measure. Multiple measures are listed if the aggregated measure type is made up of a combination of measures.*

3 *Multi-benefits focus on socioeconomic contributions to human health and welfare above and beyond the risk management benefits already highlighted in this table (i.e., flooding, wave attenuation, etc.). These benefits could include increased recreational opportunities, development of fish and wildlife habitat, provisioning of clean water, production of harvestable fish or other materials, etc.*

4 *Adaptive capacity is the assessment of a measure's ability to adjust with changing conditions and forces (including sea level change) through natural processes, operation and maintenance activities, or adaptive management, to preserve the measure's function.*

5 *Acquisition, relocation, and buyouts do not actually prevent flooding and erosion but remove the population and associated development from its effects.*

NACCS: Resilient Adaptation to Increasing Risk 57

http://www.nad.usace.army.mil/Portals/40/docs/NACCS/NACCS_main_report.pdf

Looming large over how we respond to the challenges of coastal living is how the costs will be borne. The Dutch have a national commitment to coastal resiliency because as the American economist working for the Dutch points out, “the entire nation is at risk if the western portion floods,” and so they are all in it together. Not so in the United States where, increasingly, it is up to every individual to either sink or swim. The National Flood Insurance Program, in particular, has come under assault and premiums were set to go to so-called market rates as stipulated by the 2012 Biggert-Waters flood insurance bill. After some premiums in Louisiana reportedly jumped as high as $28,000, a bipartisan vote, in January of 2014, set up a congressional four year "timeout" for large premium increases.

Premiums will, at some point, increase markedly, especially for houses in flood zones that have not elevated and become FEMA-compliant. At that point, the high road/low road of an ad-hoc market place will drive the latter out of town. Simultaneously, municipalities will sink or swim based on their capacity and determination to take proactive measures that minimize lost revenues and eroding property values. The latest County initiative to extend sewering and institute an upgraded on-site wastewater treatment program will start to reverse the nitrogen loading that has been degrading wetland defenses. Furthermore, with FIMP slated to support 4,000 house elevations, elevated roadways and more robust barrier beaches and wetlands, municipalities must prepare road maintenance programs that deploy porous surfaces in conjunction with more pervious landscaping and bioretention to minimize the flooding that has rendered coastal habitation increasingly vexing. To that end, projects coming out of Rebuild by Design, NY Rising and various Sandy grants will provide templates and proof of concept for villages, town and the county to emulate.

This page intended to be blank.