MARSH CONSERVATION PLANNING FOR STONY BROOK HARBOR NY AND WEST MEADOW CREEK NY

NEIWPCC

December, 2023

NOTICE

This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement (LI-00A00384) to NEIWPCC in partnership with the Long Island Sound Study (LISS). The contents of this document do not necessarily reflect the views and policies of NEIWPCC, LISS or the EPA, nor does NEIWPCC, LISS or the EPA endorse trade names or recommend the use of commercial products mentioned in this document.

ACKNOWLEDGEMENTS

Preparation of this document was organized by Jonathan Clough of Warren Pinnacle Consulting, Inc. with close oversight from Victoria O'Neill of NEIWPCC and with the significant assistance of Elizabeth Hornstein, the Sustainable and Resilient Communities (SRC) Professional for Suffolk County. Cover photos courtesy of the Town of Smithtown (credit Kelly Steele, top), (Ward Melville Heritage Organization, lower left), and Gabrielle Lindau (lower right).

Completion of this document would not have been possible without the assistance of our stakeholder group who provided us with material and feedback on drafts over several months of meetings:

- David Barnes (Environmental Protection Director, Town of Smithtown)
- Jamie Carroll (Suffolk County Parks)
- Abigail Choi (Brookhaven Councilmember Kornreich's Office)
- Phoebe Clark (Audubon New York)
- Alan Duckworth (Town of Brookhaven)
- Steve Englebright (Former NY Assemblyman)
- Peter Fountaine (Town of Brookhaven)
- Alexa Fournier (NYSDEC)
- Katie Friedman (Save the Sound)
- Katharine Griffiths (Avalon Park)
- Louise Harrison (Save the Sound)
- George Hoffman (Setauket Harbor Task Force)
- Elizabeth Hornstein (NYSG)
- Tom Iwanejko (Suffolk County)
- Shauna Kamath (NYSDEC)
- Michael Kaufman (Vice Chair Suffolk County Planning Commission)
- Amani Khan (Brookhaven Councilmember Kornreich's Office)
- Kristen Laccetti (EPA)
- Gabrielle Lindau (WMHO)
- Megan Lung (Save the Sound)
- Diana Lynch (Suffolk County Parks)
- Kaitlin Mattei (Seatuck)
- Kathy McShane (Principal Environmental Analyst, Town of Smithtown)
- Judy Ogden (Village of Head of the Harbor)
- Camilo Salazar (Suffolk County)
- Samarra Scantlebury (NYSDEC)
- Michael Utevsky (Head of the Harbor)

CONTENTS

Executive Summary 1
Project Introduction 3
Objective 3
Approach 3
Marsh Resources 4
Introduction 4
Public vs. Private Ownership 7
Benefits from Local Marshes & Adjacent Habitat 8
Habitat 8
Birds 9
Nekton Habitat 10
Avoidance of Marsh-Habitat Fragmentation 11
Rare, Threatened or Endangered Species 11
Water quality protection (Nutrient Sequestration and Denitrification) 12
Wave Attenuation 13
Recreation and Cultural Value 13
Threats to Stony Brook Harbor Marshes 14
Invasives 14
Historic Marsh-Loss Trends 15
Sea-Level Rise and Changing Intertidal Footprint 16
Water Quality 17
Dredging and Sediment Supply 18
Harbor Road Culvert 19
Development 19
Marsh Conservation Planning 21
Marsh Restoration 21
Managing Current Marsh Resources 22
Improve Water Quality 23
Planning for Marsh Migration 23
Living Shorelines 25
Local Regulation 27
Outreach 27
References 28
Appendix A: Fact Sheets for Stony Brook Harbor and West Meadow 32
Appendix B: Historic Trends from Various Portions of the Study Area 36

EXECUTIVE SUMMARY

Stony Brook Harbor and West Meadow Creek, located in the Villages of Nissequogue and Head of the Harbor and the Towns of Smithtown and Brookhaven in Suffolk County, are rich with marsh resources. This area is home to over 350 acres of intertidal and high-marsh habitat. In large part because of these marshlands, this region is recognized as an ecologically significant area, is home to many endangered and threatened species, and was designated a Long Island Sound Study Stewardship Area. The vast majority of wetlands in this region are publicly owned or are part of the private preserve owned by the Ward Melville Heritage Organization.

The coastal marshes of Stony Brook Harbor and West Meadow Creek provide many benefits—both human-centered and ecological. Some of the services that these marshes provide include

- **Habitat:** "Stony Brook Harbor and West Meadow comprise one of the largest and most diverse coastal wetland ecosystems on the north shore of Long Island, of regional significance, and is important to many fish and wildlife species throughout the year" (NY Department of State 2005). The marshlands in this area provide critical bird, nekton and shellfish habitat, and form the base of the food web for gamefish, and predator species, such as ospreys. There have been several rare threatened and endangered species observed on site including common tern, least tern, osprey, diamondback terrapin, and piping plover.
- **Water-Quality Protection:** Tidal marshes are important for improving water quality. In particular they can sequester organic carbon and nutrients that may otherwise lead to additional climate disruption or degradation of estuarine systems.
- **Wave attenuation/Flood damage reduction:** By stabilizing sediment through their above and belowground biomass, marshes have been shown to reduce coastal retreat and reduce wave heights during storm events.
- **Recreation and Cultural Value:** The cultural value of the salt marsh habitat in Stony Brook Harbor is important to residents and visitors alike. Their recreational value includes fishing, shellfish harvesting, swimming, boating, beach combing, and birding. The Ward Melville Heritage Organization (WMHO) provides educational programs that highlight the value of the coastal ecology as well as the historical significance of the settlements around it. Marshlands also provide a charismatic environmental backdrop for recreational boating which is very important to the region.

Unfortunately, there are multiple lines of evidence that intertidal marshes in the study area have been declining over the past several decades. Based on infrared photointerpretation, Cameron Engineering & Associates (2015) found that over 20% of regularly-flooded marshes were lost from 1974 to the mid-2000s. Historic loss is likely due to a combination of moderate sea-level rise, lower sediment supply, and excessive nutrients resulting in the decomposition of root biomass. Given predictions of accelerating sea-level rise through the end of the century, model results suggest that current marshes will remain under stress and potentially be subject to additional losses. Losses of predicted marshes under sea-level rise could be offset, however, if some adjacent land is made available for marsh migration

Additional threats to intertidal marshes include

- **Invasive species:** Examples include *Phragmites*, perennial pepperweed, and Japanese knotweed.
- **Water quality:** Excess nutrients, such as nitrogen, can lead to marsh erosion; limited water flows can exacerbate nutrient buildup. Nutrients, such as nitrogen present in lawn fertilizer or wastewater, can enter the harbor via overland runoff or groundwater seepage.
- **Dredging and Sediment Supply:** Dredging can change patterns of sediment deposition; a consistent suspended sediment supply is critical to the maintenance of marsh habitat, especially when marshes are trying to keep pace with sea-level rise.

- **Impediments to Tidal Water Flows:** One example is the Harbor Road Culvert at the south of the study area that reduces tides and salt water penetration to lands behind the culvert.
- **Development:** Development can threaten coastal marshes either due to coastal hardening or the addition of excessive nutrients and sediments to the waterway.

Fortunately, communities have several tools available to them that can be used to protect existing wetlands, to ensure that adjacent habitat is protected for future marsh migration, to create new wetland habitats, and to restore historical marshes that have been lost. Some of these tools are summarized below:

- **Marsh restoration** is the process of modifying former wetland locations to promote current and future marsh habitation. Marsh restoration remains a top priority of state and local governments. Within Stony Brook Harbor, marsh losses in the 1950s and 1960s were extensive to the north of Porpoise Channel due to dredge and fill operations undertaken at that time. This location would therefore be a prime candidate for marsh restoration. The selection of a marsh restoration site in Stony Brook Harbor should be informed by hydraulics and sediment supply. Any marsh restoration project needs to ensure that adequate sediment supply exists for the project to be successful. One potential tool that could be used to promote sediment trapping is the construction of artificial oyster reefs adjacent to restored marsh (where appropriate).
- **Managing Current Marsh Resources:** As environmental and physical characteristics change, the careful management of the extensive current marsh resources in Stony Brook Harbor and West Meadow Creek will be critical to ensure that these habitats continue to thrive. Some steps that can be taken to manage marsh resources include **invasive-species control**, planning and managing habitat change under changes in future sea-levels, and taking steps to modify the hydrology of existing marshes to improve marsh health and increase sedimentation rates. In south Stony Brook Harbor, common reed or *Phragmites* has forced out native plants and disrupted the ecology of the harbor. In this location, upgrading the Harbor Road culvert, mentioned above, would restore salt water flows and should help mitigate the spread of *Phragmites*.
- **Water Quality Improvements:** As noted above, water quality is important to marsh health as excess nutrients will generally increase marsh loss and erosion rates. Local towns are already taking measures to improve the management of stormwater runoff and reduce pollutant discharges into the harbor. Education is another important tool that can be used to improve water quality. Activities by residents to update septic systems, and reduce nitrogen from their properties (such as rain barrels, rain gardens, and native-plant gardens) will reduce the flow of nitrogen going into the water. There are several local rewards and incentive programs available to encourage these activities.
- **Land Conservation and Easements:** Land-conservation prioritization should consider those properties that have high potential for future marsh habitat given the likelihood of future sea-level rise. Easements can be established to prevent future development on the parcels (or specifically on the portion of the parcels that have potential to become a marsh habitats); this is often less costly than outright land purchase. Much of Stony Brook Harbor has relatively steep slopes meaning that extensive marsh migration onto uplands is unlikely to occur. Based on available marsh-migration modeling, there are two primary locations that marsh expansion is likely: at the north end of West Meadow Creek, and on the northern shore of Stony Brook Harbor (Village of Nissequogue).
- **Living Shorelines:** A living shoreline is a shoreline that has been stabilized and often increased in elevation using natural materials and usually including vegetation. When looking towards future sea-levels, a living shoreline is a form of landscape modification that potentially provides both ecological restoration of habitat and benefits to coastal resilience and upland infrastructure.

- **Local Regulation:** Local towns and planning boards can consider marsh health within land-use planning and zoning decisions. Guidance is available from the New York State Department of State through a document titled "Model Local Laws to Increase Resilience" (2019).

There are many federal, state, and local funding opportunities that are available to finance some of the marsh conservation options discussed above. Funding opportunities are potentially available for each step of the project including grant writing, engineering, and finally construction of shovel-ready projects. An accounting of many of these funding sources is present towards the end of this document.

PROJECT INTRODUCTION

Conservation of coastal wetlands can provide a wide range of benefits to coastal communities, from increased resilience to storm events, to providing suitable habitats for animals and plants that are important ecologically and economically. Tidal wetlands are capable of sequestering carbon and other nutrients; they also filter upland and runoff waters from pollutants and sediments and provide a protective buffer to reduce shoreline erosion due to wave action. Marsh and natural areas can also be important for their social, historical, and recreational role within coastal communities.

Despite their value, tidal marsh areas have been degraded or lost over time as a result of human activities. In addition, changes in climatic and ecological conditions and pressures from infrastructure development complicate effective conservation planning and management. For example, the accelerating rate of sea-level-rise (SLR) due to climate change requires coastal managers to consider not only existing tidal flooding conditions, but also potential changes that may occur in the future. In particular, marshes can respond to increased inundation by migrating inland and colonizing areas that were previously at higher elevations. However, in many coastal communities, marsh migration can be complicated by the fact that land is not available or developed areas may require proper restoration. *(Background text courtesy of Propato et al. 2018)*

OBJECTIVE

The objective of this project is to provide Long Island Sound municipalities, communities, and marsh-conservation groups with predicted changes to wetland habitat under a wide range of sea-level rise scenarios at select, large wetland complexes. These results are integrated with land-ownership information to assist in developing suitable marsh conservation plans that work towards increasing coastal resiliency.

APPROACH

This work leverages existing Sea Level Affecting Marshes Model (SLAMM) numerical and map based projections of the potential effects of sea-level rise on the wetland communities, for the entirety of coastal New York State (Clough et al. 2016), (Propato et al. 2018)).

To better assist communities in planning and decision making these data are summarized in fact sheets and a stakeholder interactive viewer that includes marsh land cover projections and tax parcel information (http://warrenpinnacle.com/LIMaps/).

Additionally, in cooperation with municipalities or other marsh-conservation stakeholder groups, marsh conservation plans have been developed for Stony Brook Harbor in Suffolk County, NY, Oyster Bay and Cold Spring Harbors in Nassau County and Suffolk County, and Glen Island in Westchester County NY. The goal of these plans is to inform local municipalities and marsh-conservation groups as to where they might focus their conservation efforts to maximize the provision of marsh ecosystem services under sea-level rise conditions.

MARSH RESOURCES

INTRODUCTION

Stony Brook Harbor and West Meadow Creek, located in the Villages of Nissequogue and Head of the Harbor and the Towns of Smithtown and Brookhaven in Suffolk County on the North Shore of Long Island are rich with marsh resources (Figure 1). Estimates of existing marsh based on the National Wetlands Inventory and current potential marsh habitat suggest that there are over 186 acres of regularly-flooded (intertidal) marsh habitat and approximately 166 acres of high marsh habitat (irregularly-flooded marshes, see Propato et al. 2018). Most of the high marshes are located in West Meadow Creek while Stony Brook Harbor, further southwest in the study area, has more intertidal marsh habitat (Figure 2).

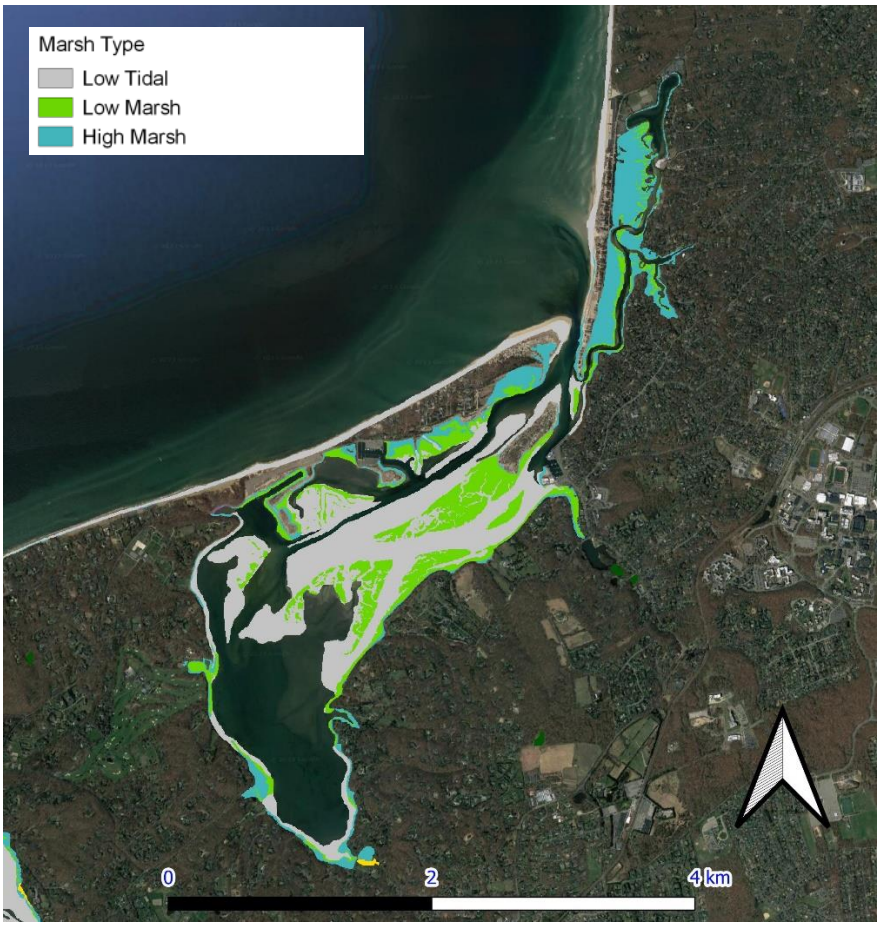


Figure 1. Estimated Marsh Habitat based on National Wetland Inventory and SLAMM modeling (Satellite imagery from Google)

Because of its environmental significance, Stony Brook Harbor was designated a Long Island Sound Study Stewardship Area. The marshes of Stony Brook Harbor are ecologically important because of their productivity and provision of habitat and food resources for a wide variety of wildlife, including serving as nurseries for aquatic species. Stony Brook Harbor marshes also provide habitat for several endangered and threatened species. For example, the imperiled saltmarsh sparrow relies on high-marsh habitat for nesting. West Meadow Creek was designated "honorable mention" status as a priority saltmarsh sparrow habitat by Atlantic Coast Joint Venture (2023). The diamondback terrapin is also a State "species of special concern" and is seen throughout the harbor and in West Meadow Creek, and especially where fresh water enters the harbor (Swanson and Bowman, 2017).

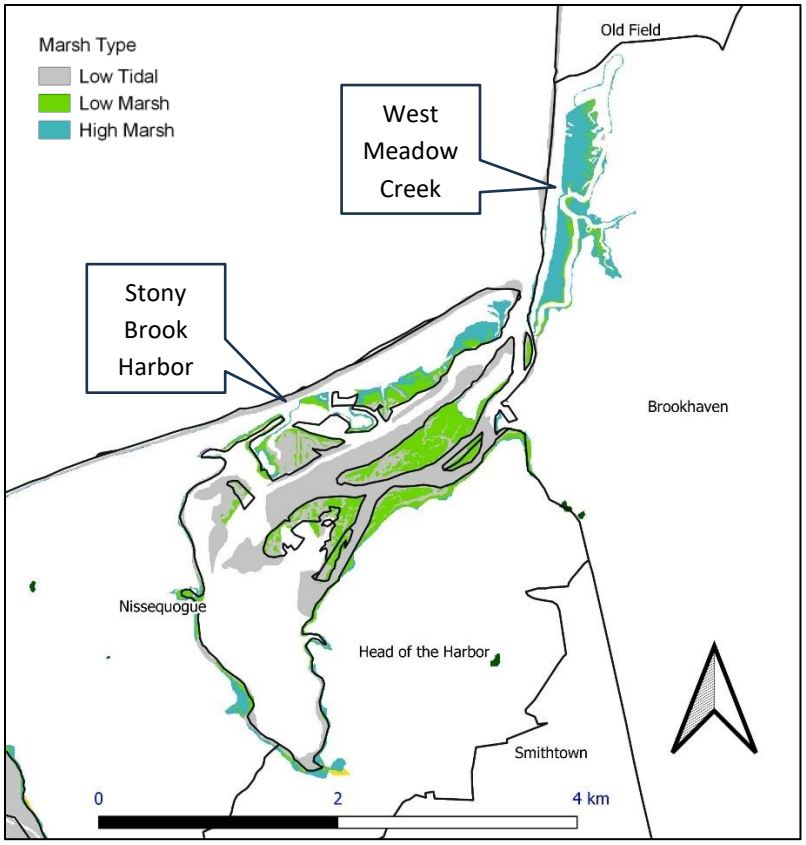


Figure 2. Current marsh habitat and potential marsh habitat overlaid on Stony Brook Harbor and relevant municipalities

Stony Brook harbor is a shallow embayment with a large tidal amplitude, not easily navigable by vessels except in dredged areas. Over the past 80 years or so the nature of Stony Brook Harbor has been altered due to ongoing channel dredging. These modifications have opened the area to recreational boating, which provides considerable public benefits, but dredging has also changed the landscape and altered the currents within the waterbody. Especially in the 1950s and 1960s, some marshes in Stony Brook Harbor were lost due to the dredging of the harbor and the placement of dredge spoils. This first dredging of the harbor was carried out using clamshell dredgers, a technology that releases considerably more sediment into the water column than hydraulic dredges used more recently (Johnson and Parchure 1999). That initial sediment release likely smothered clam and oyster beds. In addition, dredge spoils were placed directly on top of existing marsh lands. The placement of dredge spoils over marsh lands, and the addition of dry strips of land to allow the clamshell dredgers to access the channel, are clearly visible when comparing a 1947 photo to an aerial photo taken in 1962 (Figure 3, upper left and right). It is estimated that over 74 acres of emergent wetlands were lost due to destruction or burial during the first two decades of dredging (Cademartori, 2001) The Long Beach boat ramp and parking area were also constructed at that time, largely over existing marsh lands. Youngs Island at the mouth of the harbor was constructed using sand from dredging (Figure 3, lower left) which has impacted tidal flow both into and out of the harbor.

The West Meadow Creek wetlands were conserved largely through the preservation efforts of Dr. Erwin J. Ernst, a teacher, professor, and environmental scientist. In the mid-1960s, the Town of Brookhaven was planning to create a marina in West Meadow Creek where the wetlands stand. Dr. Ernst convinced Ward Melville, a local philanthropist and businessman, to save the wetlands from being developed and, once purchased, the 88-acres was designated as a wetlands preserve. The preserve was deeded to the Ward Melville Heritage Organization and now houses a conservation center with classrooms, touch tanks, and distance-learning technology.

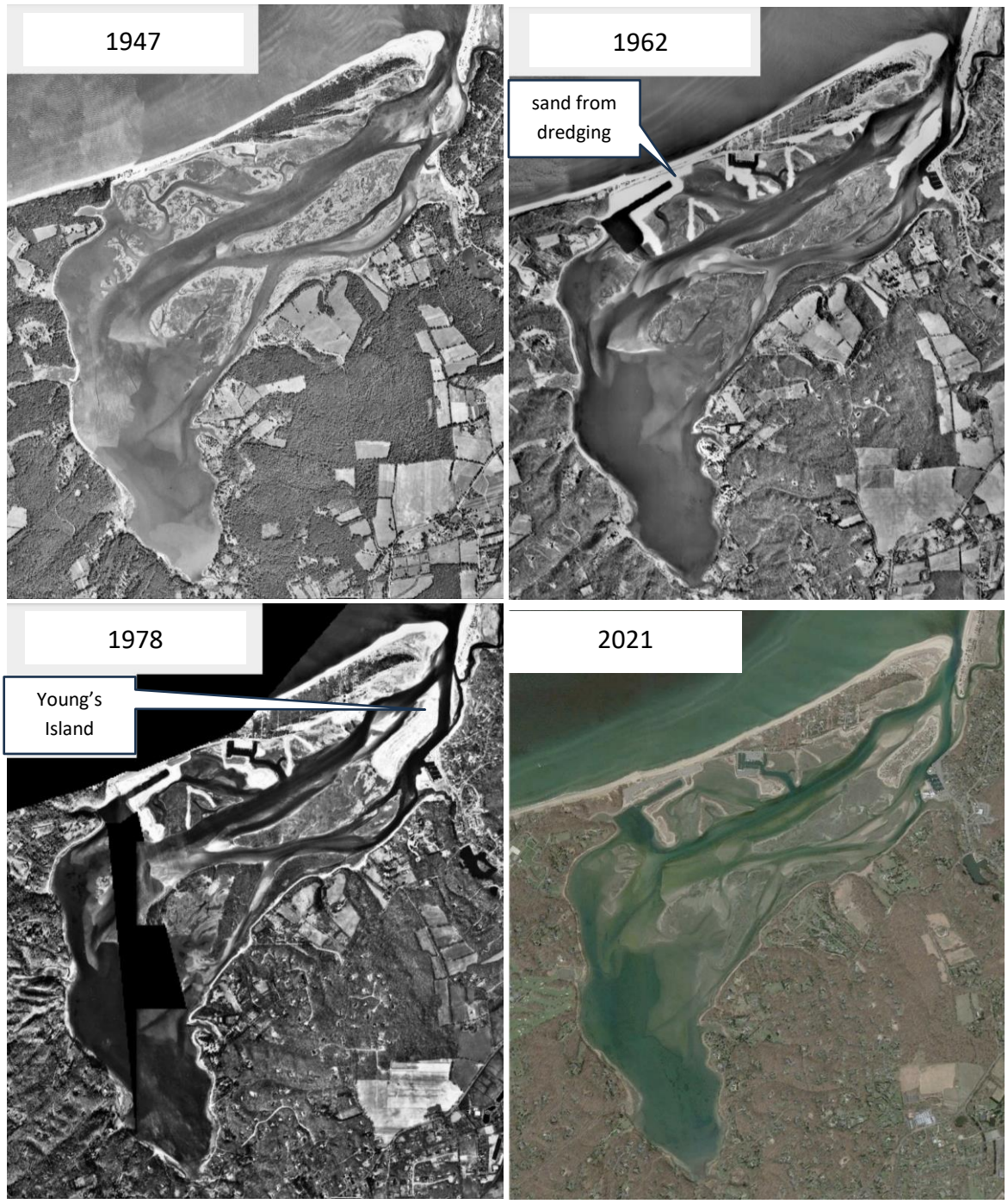


Figure 3. Historic Aerial Imagery of Stony Brook Harbor showing dredge spoil placement starting in 1962. (Suffolk County GIS, 2023)

There are some lines of evidence that intertidal marshes in the study area have been declining over the past several decades. For example, an evaluation of the recent historic trends in these marshes suggests that "high marsh" habitat has remained fairly constant, while lower-elevation intertidal marsh has seen moderate losses since the 1970s. Specifically, based on infrared photointerpretation, Cameron Engineering & Associates (2015) found that over 20% (over 50 acres) of regularly-flooded marshes were lost from 1974 to the mid-2000s.

Historic loss is likely due to a combination of moderate sea-level rise, lower sediment supply, and excessive nutrients resulting in the decomposition of root biomass (Cameron Engineering & Associates 2015). Given predictions of accelerating sea-level rise through the end of the century, current marshes will remain under stress and will potentially be subject to additional losses. Losses of predicted marshes under sea-level rise can potentially be offset, however, if some adjacent land is made available for marsh migration (See Appendix A). As will be discussed below, such actions can potentially have benefits both in terms of ecological restoration of habitat, and also in terms of coastal resilience and protection to infrastructure further upland.

This report provides recommendations as to how to manage the threats to Stony Brook Harbor marshes and how to potentially provide corridors for upland marsh migration so that ecosystem services may be maintained even if current wetlands become displaced.

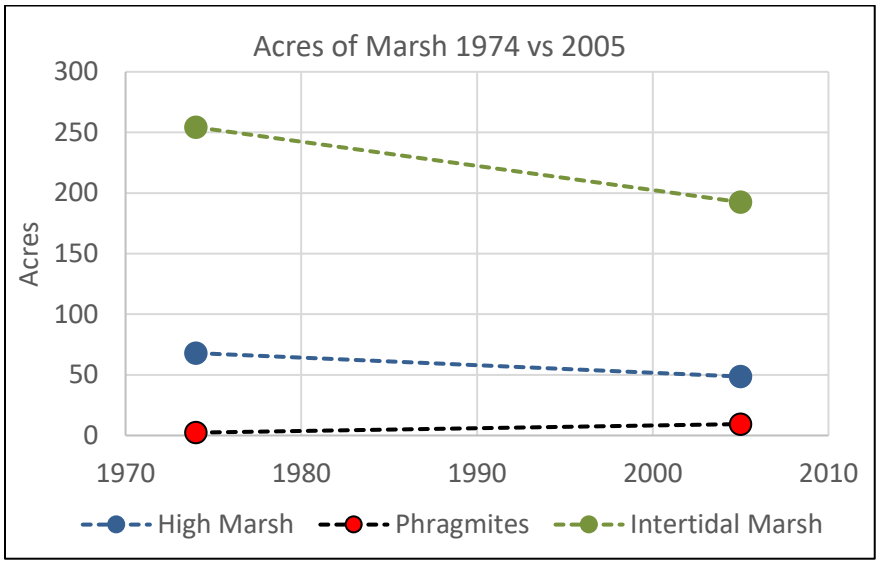


Figure 4. Acres of Marsh in the study area in 1974 and in the mid 2000s (An aggregate of sites 104-108 from Cameron Engineering 2015).

PUBLIC VS. PRIVATE OWNERSHIP

Most of the current wetlands in Stony Brook Harbor are publicly owned. The "low marsh" in Stony Brook Harbor, are generally seaward of Mean High Water, so are owned by the State of New York under NY's Public Lands Law (Personal Communication, Jennifer Juengst, Smithtown Town Attorney). In West Meadow Creek, the Ward Melville Heritage Organization (formerly the Stony Brook Community Fund) is the main landowner of the land currently occupied by marsh, with ownership of approximately 88 acres (Figure 5). Another 18 acres of West Meadow Creek marsh is owned by the Town of Brookhaven. A parcel-by-parcel map displaying public vs. private ownership can be found on the Marsh Fate Interactive Viewer -- warrenpinnacle.com/LIMaps. (Note, ownership designations in this viewer are based on tax parcels only, and do not illustrate NY State ownership seaward of Mean High Water.)

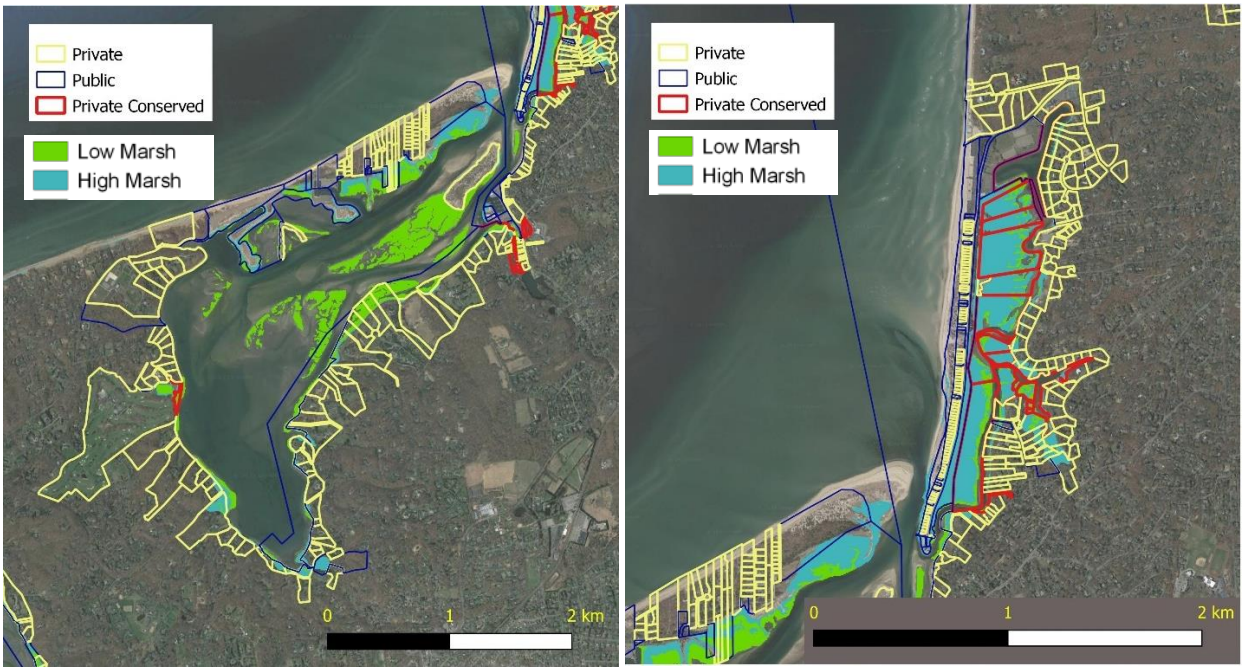


Figure 5. Public and Private Ownership of wetlands in the study area as estimated by tax maps. Stony Brook Harbor (left) and West Meadow Creek (right). Boundary data source: Suffolk County Real Property Tax Service Agency Copyright 2019. The ownership of Youngs Island is listed as "unknown." Lands held seaward of MHW are generally owned by the State of New York under NY's Public Lands Law.

BENEFITS FROM LOCAL MARSHES & ADJACENT HABITAT

Coastal marshes of New York provide both human-centered and ecological benefits. Recently, an expert and stakeholder panel developed an "ecosystem service list" from New York State marshes and included the following categories (Propato et al. 2018):

- Habitat
- Water-Quality Protection
- Wave attenuation/Flood damage reduction
- Recreation
- Political/Cultural/Historic value

Discussion of these specific benefits, and how they pertain to Stony Brook Harbor follows.

HABITAT

Stony Brook Harbor was designated as a "Significant Coastal Fish and Wildlife Habitat" by the New York State Department of State in 1987 and 2005. The associated assessment form notes that "Stony Brook Harbor and West Meadow comprise one of the largest and most diverse coastal wetland ecosystems on the north shore of Long Island, of regional significance, and is important to many fish and wildlife species throughout the year" (NY Department of State 2005). These legal designations were intended to ensure proper decision making by government and private interests so as to achieve protection, preservation and restoration for the purpose of maintaining viable habitats (Personal Communication, Jennifer Juengst, Smithtown Town Attorney). Stony Brook Harbor was also recognized as a Regionally Important Natural Area under the Long Island Sound Coastal Management Program" (https://dos.ny.gov/long-island-sound-coastal-management-program)

Much of the acknowledged habitat importance is due to the significant presence of intercoastal salt marsh within the area. Smooth cordgrass (*Spartina alterniflora*) and saltmeadow cordgrass (*Spartina patens*) are the two dominant plant species that often provide the foundation of marsh ecology. Marsh grasses are considered ecosystem engineers which, by definition, are organisms that have the ability to alter or change the surrounding habitat, and therefore affect the livelihood of other organisms in the surrounding area (Jones et al. 1994, 1997). Marsh grasses produce detritus (decaying plant material), and this is stored in the organic matter of the sediment. This organic matter is rich with nutrients and minerals that cascade up the food chain, and provides energy to the upper-level species.

The salt marsh can be divided into several different habitat types in the transition zone between the Sound and upland terrain, which are described by the New York Natural Heritage Program. These habitats include salt scrub, high salt marsh, low salt marsh and salt panne.

- ***Salt Scrub***- This shrubby habitat occurs at the transition between salt marsh and upland areas. Typical plants include groundsel tree (*Baccharis halimifolia*), marsh elder (*Iva frutescens*) and seaside goldenrod (*Solidago sempervirens*); however, this habitat is often heavily invaded by non-native common reed (*Phragmites australis*) (New York Natural Heritage Program).
- ***High Salt Marsh***- The high salt marsh is dominated by saltmeadow cordgrass or salt hay (*Spartina Patens*). Many high salt marsh areas were historically mowed for hay. The high salt marsh is typically flooded by particularly high tides, and it may not be flooded every day. Other plants such as glassworts (*Salicornia spp.*), smooth cordgrass *(Spartina alterniflora)*, and spikegrass (*Distichlis spicata*) may be present (New York Natural Heritage Program). The saltmarsh skipper (*Panoquina panoquin*), a butterfly that uses spikegrass as a host plant, is found in this habitat (Glassberg 1999).
- ***Low Salt Marsh***- The low salt marsh, which is often flooded by tides several times daily, is dominated by smooth cordgrass (*Spartina alterniflora*). Common animals include Atlantic ribbed mussels (*Geukensia demissa*) and fiddler crabs (*Uca pugnax*), which can be very abundant (New York Natural Heritage Program).
- ***Salt Panne-*** Salt pannes are shallow pools within the salt marsh ecosystem that rarely drain. As the water evaporates, the salt concentration can become much higher than in the surrounding ecosystem. The habitat is generally composed of standing water and mud.

BIRDS

Marsh habitat is a critical component for the success of numerous bird species found throughout the Long Island Sound. Furthermore, a study of New York area bird colonization found that bird-species habitat increased with proximity to marsh, salt marsh, *Phragmites*, and protected areas (Benscoter et al. 2019). These species include various ducks, geese, cormorants, herons, egrets, rails, and sparrow species. Salt marshes provide a foraging site for many bird species as marshes support the base of the estuarine food chain. While some birds directly feed on the marsh plants, most will feed on other organisms inhabiting the salt marsh – algae, invertebrates, shellfish, and finfish.

Marsh birds utilize the salt marsh in Stony Brook Harbor as predation refuge, breeding, mating, and/or nesting grounds, or a rest stop along the Atlantic Flyway. In fact, the 2005 Coastal Fish & Wildlife Habitat Assessment Form for New York State states that Stony Brook Harbor and West Meadow are among the most important waterfowl wintering areas in Suffolk County:

> "Mid-winter aerial surveys of waterfowl abundance for the 11-year period from 1986-1996 indicate average annual concentrations of over 333 birds (784 in peak year), including approximately 111 American black duck (418 in peak year), along with lesser numbers of scaup (lesser and/or greater), mallard, Canada goose, long-tailed duck, bufflehead, common goldeneye, and red-breasted merganser." (New York Department of State, 2005)

Because of the importance of its habitat, Stony Brook Harbor has been identified by the National Audubon Society as part of a global priority "Important Bird Area" (Audubon Society 2013).

Birds are drawn to salt marshes partially by the diversity of marsh plant species. This diversity increases the complexity of physical structure of the habitat, and therefore decreases competition by opening more niches for birds to utilize. Wading birds, such as great blue heron (*Ardea Herodias*) and black crowned night heron (*Nycticorax nycticorax*) may feed within the mudflat and intertidal low marsh habitat consisting of smooth cordgrass (*Spartina alterniflora*). Additionally, in the Long Island Sound, the invasive plant species, common reed (*Phragmites australis)*, provides habitat for some bird species (Benoit and Askins 1999).

High marsh habitat consisting of saltmeadow cordgrass (*Spartina patens*), Spikegrass (*Distichlis spicata*), and black needle rush (*Juncus gerardii*), are especially important bird habitat for several species – including the highly threatened saltmarsh sparrows (*Ammospiza caudacuta).* Species like the saltmarsh sparrow rely on the high marsh habitat for nesting. Due to habitat loss and sea-level rise caused by climate change, saltmarsh sparrow populations have been in rapid decline, with 80% of the population disappearing in the past fifteen years (Atlantic Coast Joint Venture. 2021). As previously noted, West Meadow Creek has been specified as an honorary mention location for prioritization of habitat for saltmarsh sparrow (Atlantic Coast Joint Venture. 2021).

In addition West Meadow Creek is home to turkey vultures in spring and summer, adult and juvenile great blue heron, egret, night heron, and recently a juvenile bald eagle. Over the past decade, bald eagles have been seen with increasing frequency at the harbor, consistent with the growing population of this species in coastal Long Island (Personal communication, John Turner, Seatuck Environmental Association, November 2023). Furthermore, many shore birds move back and forth between the harbor area and Long Beach and the sandflats of West Meadow Beach during low tide (Personal Communication, Nicole Pocchiare, August 2023).

Predator species, such as ospreys (*Pandion haliaetus)*, form the top of the salt marsh food chain relying on fish and mammals found within these ecosystems. Osprey populations declined severely throughout their range prior to 1971 due to the use of DDT, an insecticide, that when ingested by the animal caused their egg shells to thin and break, reducing productivity. In 1972, the United States banned the use of the chemical and osprey populations slowly began to recover. Today, osprey pairs can be found throughout Long Island estuaries including one nest within 1000 meters of Stony Brook Harbor and at least three active nests that use West Meadow Creek for hunting fish (Long Island Osprey Watch, 2022; Personal Communication Nicole Pocchiare August, 2023). In addition, there are three osprey nests on the edge of Stony Brook Harbor at Long Beach in Smithtown that were inhabited this year. (Personal Communication, Kathy McShane, December 2023).

Nekton and Shellfish Habitat

Nekton are aquatic organisms that are able to swim in the water column, independent of currents or wind energy – including invertebrates, fish, reptiles, and mammals. Nekton communities adjacent to salt marshes heavily rely on the marshes for foraging, predation refuge, and breeding sites. Important fishery species rely on the marsh as a nursery habitat for their young. Salt marsh edge is considered especially important habitat relative to interior marsh. For example, Peterson and Turner (1994) found evidence that "shorelines adjacent to marsh habitat are critical to various life history stages of ecologically- and commercially-important species."

Intercoastal marshes also provide shellfish habitat. Shellfish species, including Atlantic ribbed mussels, blue mussels, and eastern oysters, are often found in marshes either attached to hard substrates, or even in some cases on the root structure of smooth cordgrass. Salt marshes are an important habitat for shellfish recruitment, settlement and survival as the water column provides necessary nutrients and substrate for the larvae. Shellfish larvae are a type of

nekton species, which spend part of their life cycle swimming within the water column until settlement. Once settled and anchored, in the case of oysters and mussels, they feed by filtering nutrients from the water column.

In general, salt marshes are inhabited by many important recreational and commercial fishery species. Some species reside in the marsh system throughout their life (mummichog, striped killifish, sheepshead minnow, Atlantic silversides), some reside as young (winter and summer flounder, tautog, and black sea bass), some migrate in and out during different life stages (American eel), and some migrate in from the open water to spawn (American shad, alewife, striped bass). Some migrating species are called diadromous fish, in which they spend part of their life in salt water environments and part of their life in freshwater environments. A coastal fish and wildlife assessment from New York State found that Stony Brook Harbor provides nursery and foraging areas for winter flounder, bluefish, blackfish, Atlantic silversides, and striped killifish (New York Department of State 2005).

Another species that relies on tidal-wetland habitats is the diamondback terrapin (*Malaclemys terrapin*). This small brackish-water turtle is endemic to tidal wetlands, estuarine embayments, tidal flats, and tidal creeks from Massachusetts to the Gulf Coast of the United States. Adult terrapin feed on fish, invertebrates, shellfish and crustaceans within tidal marsh systems and nest on coastal sandy beaches near tidal marshes during the summer nesting season. Juvenile terrapin reside in the upper reaches of tidal creeks and tidal marshes until adulthood (Ernst et, 1994). As the only brackish water turtle found in North America, diamondback terrapin are a key member of Long Island's tidal ecosystems. Terrapin populations are in decline or unknown throughout their range (Seigel and Gibbons, 1995) and, as a result, the taking of terrapin is prohibited in New York State as of May 1st, 2018 (NYSDEC). Stony Brook Harbor is prime habitat for terrapins (Swanson and Bowman, 2017). Indeed, based on extensive observations and longstanding study, Stony Brook Harbor is known to have a robust population of diamondback terrapins, and is likely one of the most significant embayments in coastal New York for this species (Personal communication, John Turner, Seatuck Environmental Association, November 2023).

Avoidance of Marsh-Habitat Fragmentation

Larger-size marshes are especially important for bird and other wildlife habitat. A study of marsh utilization by birds in the Connecticut River found that colonization is directly related to the size of the marsh (Craig and Beal 1992). Furthermore, this study found that rare birds were more likely to colonize larger rather than smaller marshes.

Rare, Threatened or Endangered Species

Stony Brook Harbor and West Meadow Creek provides a habitat for many rare, threatened, and endangered species including the following species observed on-site (GEI Consultants, Inc., 2013):

- Common term (*Sterna hirundo*) State Endangered
- Least tern (*Sternula antillarum*) State Endangered
- Roseate tern (*Sterna dougallii*) Federal and State Endangered
- Osprey (*Pandion haliaetus*) State Species of Special Concern
- Diamondback terrapin (*Malaclemys Terrapin Terrapin)* State Species of Special Concern
- Piping Plover (*Charadrius melodus)* State Endangered; Federal Threatened

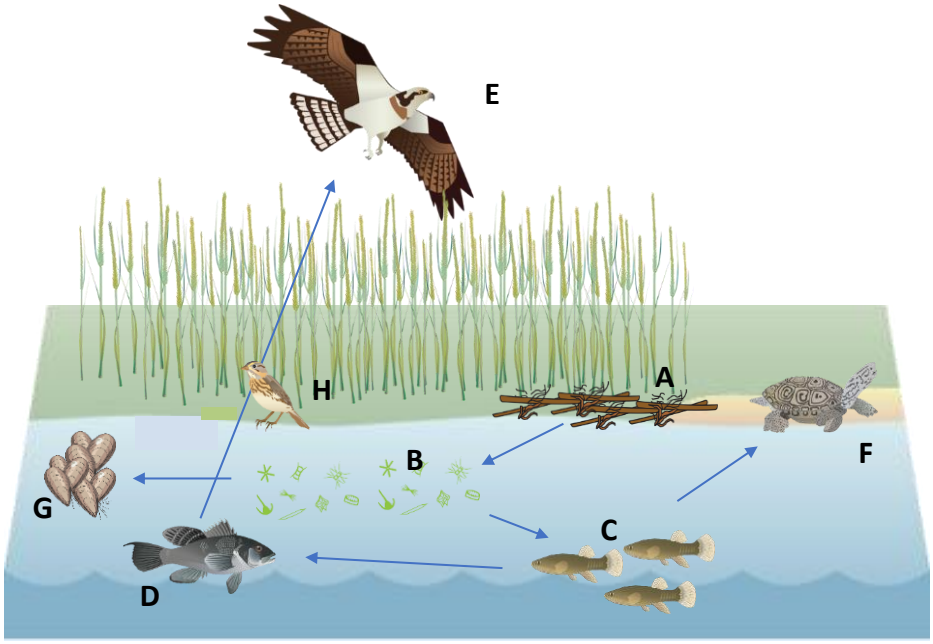


Figure 6. Conceptual Diagram of a Salt Marsh Food Web

The dominant salt marsh species, smooth cordgrass is the base of the food chain – providing organic matter in the form of detritus (A). The detritus is consumed by plankton species (B), which is then consumed by small fish species, such as striped killifish (C), and filter feeders, such as ribbed mussels (G) that are consumed by crabs and shorebirds. Two additional pathways are created because smaller fish species are valuable food sources for larger predatory species, like black sea bass (D) and the diamondback terrapin (F). The black sea bass is consumed by the top of the food chain – the osprey (E). The saltmarsh sparrow (H) also consumes insects, amphipods and spiders found in the high-marsh habitat. Figure Courtesy of Cayla Sullivan, USEPA.

West Meadow Creek was designated "honorable mention" status as a priority saltmarsh sparrow habitat by Atlantic Coast Joint Venture (2023). The beach and creek form a protective sanctuary where horseshoe crabs, diamondback terrapins, and New York State endangered piping plovers breed. Least Terns also historically nested on Youngs Island before the area was colonized by the invasive "tree of heaven." (Personal Communication Phoebe Clark, September 2023)

WATER QUALITY PROTECTION (NUTRIENT SEQUESTRATION AND DENITRIFICATION)

Tidal marshes are important for improving water quality. In particular they can sequester organic carbon and nutrients that may otherwise lead to additional climate disruption or eutrophication of estuarine systems (Loomis and Craft 2010).

Marshes have the ability to sequester, or store, nutrients in their biomass (above and belowground) and sediment, and therefore remove it from the water column. Nutrient sequestration includes carbon, nitrogen, and phosphorus. More specifically, salt marshes are hotspots for blue carbon storage, which are aquatic vegetated ecosystems that are able to store large amounts of carbon (Nellemann et al. 2009). In the United States, northeastern salt marshes have the ability to sequester about 41 to 152 g/m^2/year of carbon (Drake et al. 2013). This storage mechanism prevents carbon from being released into the atmosphere as carbon dioxide (CO_2) or methane (CH_4), which are dominant greenhouse gases. Blue carbon storage has the ability to mitigate global warming impacts, and reduce future increases in carbon emissions.

Denitrification is another nutrient-removal mechanism of salt marsh, in which excess nitrogen is removed from the ecosystem and released into the atmosphere. Bacteria that reside in marsh sediment convert nitrate (NO_3) – a form of nitrogen that can contribute to excess algae growth, into nitrogen gas (N_2) – which occurs naturally in the atmosphere. Denitrification rates can significantly vary regionally (Valiela et al. 2000), and are highest during the summer season (Velinsky et al. 2017). In the Long Island Sound, about 60% of the total nitrogen cycle is either buried in sediments or removed through denitrification (Vlahos et al. 2020).

Through nutrient sequestration and nutrient cycling, marsh habitat helps to create a stable and healthy environment for both wildlife and humans. For example, salt marsh nutrient cycling can help prevent eutrophic conditions from occurring. Eutrophic conditions occur when there are excess nutrients, often in the form of nitrogen or phosphorus, in the water column. High nutrient conditions create hypoxic conditions, harmful low levels of dissolved oxygen, via algal blooms. Excessive algae growth and subsequent decomposition depletes the oxygen levels in water and can cause massive fish kills. Such die-offs cascade throughout the food chain and pose detrimental effects on many other marsh organisms.

Unfortunately, if marshes are consistently exposed to nutrient levels that are too high, this can be devastating to their own viability. Specifically, under consistently eutrophic conditions, marshes have been found to produce more above-ground growth than roots, and the belowground biomass of bank-stabilizing roots is reduced (Deegan et al, 2012). This can result in marsh collapse and conversion to non-vegetated mudflats. Deegen et al, 2012 noted that "current nutrient loading rates to many coastal ecosystems have overwhelmed the capacity of marshes to remove nitrogen without deleterious effects." In summary, marshlands can both improve local water quality, but also are vulnerable to excess nutrients if external sources are not controlled.

WAVE ATTENUATION

One key ecosystem service provided by salt marshes is a reduction of the impacts of waves on coastal erosion. Wave action can be significantly reduced on coastal shorelines as marshes act as a buffer zone and absorb the energy. By stabilizing sediment through their above and belowground biomass, marshes have been shown to reduce coastal retreat (O'Donnell. 2017).

This service is especially beneficial to coastal communities that face great risks with climate change implications, including increases in extreme weather events (e.g., storms, hurricanes, etc.). For example, a 2017 study found that wetlands prevented hundreds of millions of dollars in direct flood damage during Hurricane Sandy and also that properties behind a marshes, on average, saved 16% in flood losses every year compared to properties where marshes had been lost (Narayan et al, 2017). Another study of Hurricane Sandy found that the presence of marsh vegetation substantially mitigated infrastructure damage to the shoreline and that relative structural loss was correlated to the percent of wetland cover (Sheng et al. 2021).

RECREATION AND CULTURAL VALUE

During our stakeholder meetings, the cultural value of the salt marsh habitat in Stony Brook Harbor was called out as being significant several times. The impact that this habitat has on the sense of place and the quality of living for residents is a central theme in the book *Between Stony Brook Harbor Tides: The Natural History of a Long Island Pocket Bay*. This book notes that "Generations of people, of all ages, have enjoyed the recreational opportunities that the harbor affords, including fishing, shell fishing, swimming, boating, beach combing, and birding." (Swanson and Bowman 2017)

Significant educational resources are also organized around the ecology, history, and culture of Stony Brook Harbor. For example, the Ward Melville Heritage Organization (WMHO) provides programs that highlight the value of the

coastal ecology as well as the historical significance of the settlements around it. WHMO staff facilitate the actions of a youth-corps volunteer group as well as offering on-site field trips.

Shellfishing provides a particularly important cultural and economic value to the harbor. The Town of Smithtown notes that it "… has conducted a shellfish aquaculture program in the harbor for over 30 years. Juvenile clams and oysters are purchased annually in the spring, grown out in Town aquaculture systems until late fall, and then are seeded into Stony Brook Harbor. Over 800,000 shellfish are seeded annually by the Town, with the majority of them being hard clams (*Mercenaria mercenaria*). This is done to supplement natural shellfish stocks and to enhance shellfish harvesting opportunities for residents." (McShane, 2023)

Recreational boating is also important to the culture of Stony Brook Harbor, with a boat ramp located in the Town of Stony Brook (at Shore Road) and two boat ramps available off of Long Beach Road in Nissequogue. There are 309 marina slips available in the town of Smithtown (185 in the Town marina and the remainder in the Smithtown Bay Yacht Club) and over 180 marina slips available between the Stony Brook Yacht Club and the Stony Brook Marine Service (McShane, 2023). Boating in the harbor is wake limited to help prevent shoreline and marsh-edge erosion (Village of Head of the Harbor General Legislation §161-9).

It should be noted that the area surrounding Stony Brook Harbor is situated on the ancestral territory of Setalcott and Nissequogue Native Americans. A "Stony Brook Site" shell midden provides evidence that the tidal wetlands and tidal creeks have been a valuable food resource to humans in this region for over 3000 years (TBR News Media. 2016). In recognition of this history, the Ward Melville Heritage Organization offers a program "Living Off the Land, a Day in the Life of a Native American Family" based on data derived from an archeological dig from the 1960s. Colonists displaced the Setalcott and Nissequogue tribes from their native lands in the 1600's. These tribes remain displaced from their native lands today and are unable to access the lands around Stony Brook Harbor due to the privatization of much of the shoreline. The Setalcott Nation holds a powwow in Setauket every year and continues to fight for recognition and restored access to their ancestral lands.

THREATS TO STONY BROOK HARBOR MARSHES

Stony Brook Harbor marshes have been evolving over time and some loss of intertidal marsh appears to have occurred in recent decades. Looking forward there are several threats that must be considered in a marsh management plan including invasive species, sea-level rise, water quality, sediment supply and the impacts from development.

INVASIVES

Within coastal marshes invasive species can gain a toehold during times of habitat stress, succession, or transition. Some of the invasive species that are present in Stony Brook Harbor include the common reed, perennial pepperweed, the green crab, and the tree of heaven.

Common reed (*Phragmites* sp.) is a highly invasive plant capable of degrading tidal ecosystems, and one that is having impacts on Stony Brook Harbor marshes, especially to the south of the harbor. Non-native, more aggressive variants of common reed have the potential to force out native plants and disrupt the ecological balance of the marsh. Common reed generally does poorly in highly saline environments. However, it begins to prosper and spread when freshwater and nutrients are made available. As will be discussed below, restoration of salt-water flows or physical invasive species removal are two strategies that can be used against *Phragmites* to ensure that the ecological role of coastal marshes is maintained.

In the marshes in the southern portion of Stony Brook Harbor, *Phragmites* is estimated to have increased from under one acre to over six acres from the mid-1970s to the mid-2000s (Cameron Engineering & Associates 2015). According

to a 2022 proposal from Head of the Harbor the situation has continued to worsen: "Phragmites beds have exploded in density and occupy much more of the tidal marsh than historically existed, and spartina beds have dramatically shrunk." (Village of Head of the Harbor 2022). That proposal goes on to recommend integrated mitigation of Phragmites primarily by restoration of salt-water flows and culvert replacement. One method to reduce the impact of Phragmites beds can be to reduce bed elevations, or to cut channels, allowing for increased salt water flows to penetrate. Currently many of the beds containing Phragmites are located at elevations above those that would expose their roots to salt water, partially because of organic sediments trapped from the surrounding hillside (M. Kaufman, personal communication, August 18, 2023).

In West Meadow Beach, a different invasive species threat is presented by perennial pepperweed (*Lepidium latifolium*). Perennial pepperweed is a highly invasive plant that poses a threat to coastal ecosystems by creating dense stands that displace native plants and wildlife (GEI Consultants, 2013). Perennial pepperweed tends to occur at the upper boundary of coastal marshes and the lower boundary of dry lands. These infestations have the potential to reduce habitat quality and natural diversity within these sensitive areas.

A similar concern Is raised by the presence of Japanese knotweed, that is common on the northern end of West Meadow Beach. While Japanese knotweed is not adequately salinity-tolerant to compete with saline or brackish marshes, it can significantly reduce biodiversity at the marsh to upland boundary.

The invasive green crab (Carcinus maenas) is also present in and adjacent to Stony Brook Harbor marshes (McCarty-Glenn, 2017). This species has minimal predators, destroys seagrass, and outcompetes local species for food and habitat (NOAA 2023). By widening burrows within marshes, the green crab also has the potential to increase marsh erosion as live belowground biomass is reduced (Aman and Grimes, 2016). However, the green crab may not be an extensive burrower itself, primarily utilizing and enlarging burrows made by smaller crabs (Szura et al. 2017). Active management of burrowing crab species may be achieved through targeted trapping. This approach is costly, however, and would need to be maintained indefinitely, as it is unlikely to eliminate the species (Ens et al. 2022).

When managing and conserving coastal marsh habitat, specific conservation plans should consider the potential effects of these and other invasive species and discuss the actions that can be taken to control them. One complexity in terms of invasive-species management, is the need for all owners to control these species and manage their sites. Otherwise, there is the significant likelihood of recontamination of "cleaned" sites from adjacent sites that are still overrun by invasive species. A general invasive-species resource for Long Island is also available through the Long Island Invasive Species Management Area group (liisma.org). This organization provides strategies that focus on the prevention and eradication of new invasive species infestations before they can become established.

HISTORIC MARSH-LOSS TRENDS

An evaluation of relatively-recent historic trends across the study area suggests that "high marsh" habitat has remained fairly constant, while over 20% of intertidal low marsh has been lost between 1974 and the mid-2000s (Cameron Engineering & Associates 2015). The same historic-trends analysis also looked at individual portions of the study area (Appendix B) and the following general observations can be made:

- Approximately 20 acres of marshes in West Meadow Creek were converted from high to low marsh during the 30-year period evaluated.
- The islands south of Porpoise Channel have lost over 50% of intertidal marsh since the 1970s (going from 106 acres to 49 acres). (While this assessment was made through comparison of tidal-coordinated infrared photography, several stakeholders suggested that the extent of this loss has been overestimated.)
- At the northern portion of Stony Brook Harbor, marshes have remained fairly constant, but there have been some increases in high marsh and decreases in low marsh habitat.

- Through the mid-2000s, the southern portion of the Harbor had the largest increase in Phragmites habitat and minor losses in other marsh types.

Overall, this historic-trends analysis paints a picture of evolving marshlands with intertidal marsh being most vulnerable to erosive losses and ponding. A USGS New York Coastal Wetland Synthesis tool for coastal New York indicates that the intertidal marsh in the study area, and especially the area surrounding Porpoise Channel, has the highest ratio of unvegetated to vegetated lands and also has the lowest elevation relative to sea-level (Figure 8). These analyses suggest that the intertidal portion of the study has undergone the greatest marsh loss in the past and is likely the most vulnerable to future sea level rises.

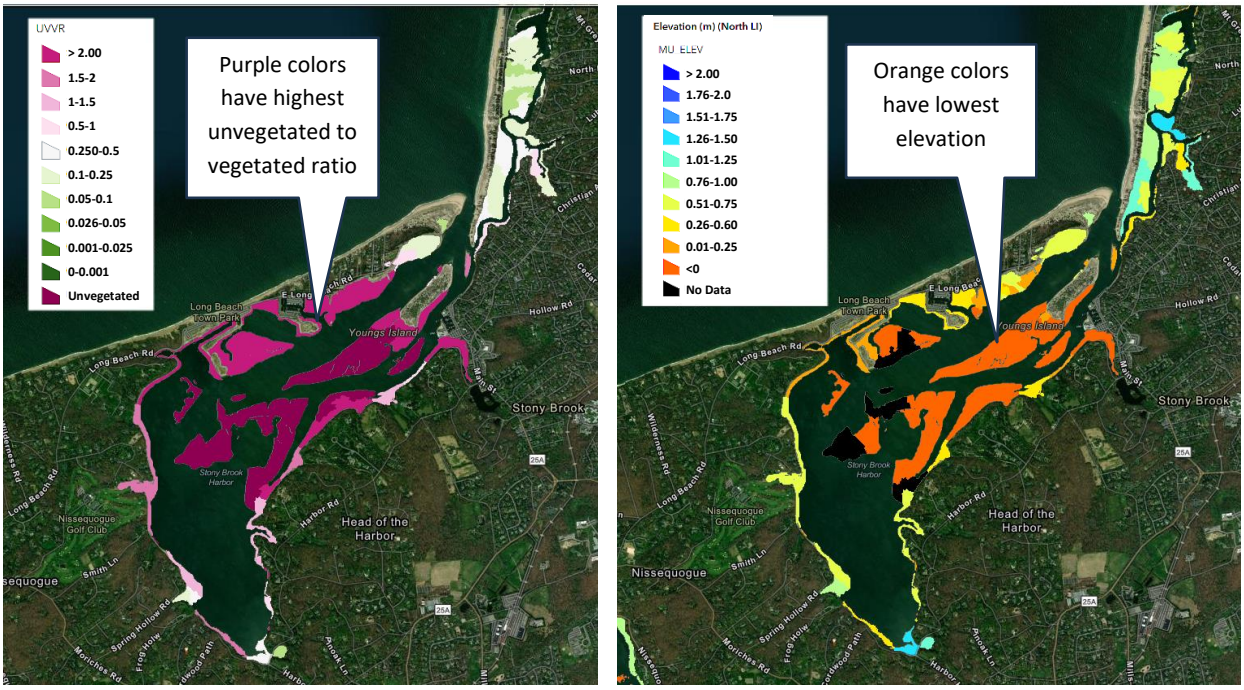


Figure 7. Unvegetated to Vegetated Ratio in the study area (UVVR, left) and Relative Elevation in meters (right). Source: USGS 2020

SEA-LEVEL RISE AND CHANGING INTERTIDAL FOOTPRINT

A prediction of future marsh fate under future sea-level rise suggests that the marshes of Stony Brook will continue the historic trends discussed above (Propato et al., 2018). Under a moderate SLR scenario, intertidal marsh is predicted to be most vulnerable to overall marsh losses while high marshes are largely converted to the lower-elevation regularly-flooded marshes (Figure 8). The fact sheets presented in Appendix A further elaborate on estimated marsh fate under multiple sea-level rise scenarios and the potential for marsh migration onto adjacent uplands. In addition, a full set of model results spanning multiple sea-level rise scenarios and uncertainty-analysis simulations can be found in the Marsh Interactive Fate Viewer that is part of this project: (http://warrenpinnacle.com/LIMaps/).

Figure 8. Current-Condition wetlands and marshes (left) vs. predicted in 2100 (right) under a medium SLR scenario (37 inches of SLR) Note: the "Low Tidal" category reflects unvegetated tidal flats as identified by the National Wetlands Inventory.

WATER QUALITY

Poor water quality can affect marsh ecosystem services in several ways. Excess nutrients can change the way that marsh grasses grow which can lead to marshes that are vulnerable to erosion (Deegan et al, 2012). Limited water flows and circulation can exacerbate nutrient buildup and can also allow for fresh water to accumulate; this will potentially result in a transition of marsh species and allow for Phragmites invasion. Finally, a high bacteria count in water can close off waterbodies to shellfishing and other recreational activities.

Stony Brook Harbor has moderate issues with water quality. While the harbor itself is not included in the Long Island water-quality report card (Save the Sound, 2022, https://soundhealthexplorer.org/fishable/) it is located within the "Western Basin" portion of the Sound. The report card gives this zone a B+ grade, but also notes that this area is "…densely populated and showing signs of human impact," with dissolved oxygen being the biggest indicator of impairment (Save the Sound, 2022). The 2021 NYSDEC waterbody assessment for Stony Brook Harbor is category SA, which indicates that Stony Brook Harbor is suitable for harvesting shellfish and for primary contact recreation. However, the southernmost end of Stony Brook Harbor is closed to shellfishing due to excessive coliform bacteria levels (NYSDEC 2021).

Consistent with the above lines of evidence, an examination of dissolved nitrogen data for Stony Brook Harbor between 2010 and 2020 found a range of concentrations between 0.12 and 0.58 mg/L dissolved nitrogen, SCDHS 2022). This means the estuary varies somewhere between a "good" characterization and a "moderately impaired" characterization (NJDEP 2014). There did appear to be a minor downward trend in concentrations over the decade.

The Suffolk County Subwatersheds Wastewater Plan (Suffolk County 2020) recommends a 60% reduction in nitrogen to achieve optimal water quality.

The long-term presence of intercoastal marshes in Stony Brook Harbor and West Meadow Creek suggests that water quality is generally acceptable for marsh habitat and should be appropriate for marsh restoration programs. However, further reductions in nitrogen will likely help marshes to thrive and produce robust root structures in the future. In the south, additional improvements in water flows could increase salinity and reduce Phragmites advancement. In general water quality considerations should be part of any future marsh restoration plan in the study area.

DREDGING AND SEDIMENT SUPPLY

A marsh to open-water interface is inherently dynamic as it stands at the intersection of sediment supply (which increases marsh area) and lateral erosion by waves (that reduces area, Fagherazzi et al. 2013). Dredging has changed this dynamic in Stony Brook Harbor and had a direct impact on marsh health. In addition to the direct burial of marshes in the 20th century, water circulation and sediment deposition patterns were altered, especially due to the construction of Young's Island (Swanson and Bowman 2017). Stony Brook Harbor generally has abundant sediment supply, especially sand, as evidenced by the rate that dredged channels fill, and the sandbar north of the harbor's entrance to Long Island Sound (M. Kaufman, personal communication, August 18, 2023). A tidal asymmetry in the harbor (the harbor is "flood-dominated") causes more sand to be transported into the harbor on incoming tides than is removed by outgoing tides (Zarillo and Park, 1987). However, where this sediment settles, and the rate that this sediment settles on marshes, can vary spatially and is sensitive to changes in the bathymetry of the system (Swanson and Bowman 2017).

A 2001 Thesis by Gregg Cademartori explored the interaction between sea levels and sedimentation rate through radiometric analysis of salt marsh peat cores in select locations of Stony Brook Harbor. The thesis found, in part, that

- From 1900 to 1950 the rate of sediment Stony Brook Harbor marshes had accretion rates that were slower than the rate of regional sea level rise;
- From 1950 to 2000, concurrent with dredging projects and increased storm activity, the marshes at times outpaced the rate of sea level rise.
- For the last 10-20 years of the 20th century, the marsh was again being outpaced. (Cademartori 2001)

This work highlights the importance of suspended sediment supply to the maintenance of marsh habitat. In general, coastal marshes are estimated to be resilient to moderate levels of sea-level rise if adequate sediment supply is available (Kirwan and Megonigal 2013). Dredged channels can, however, attract sediment at a cost to adjacent wetlands. For example, available models suggest that increasing the depth of dredging in Stony Brook Harbor to greater than six feet would result in channels with slower velocities that would attract more sediment and fill more rapidly (Swanson and Bowman, 2017- Chapter 5 "Dredging Scenarios," Georgas 2001). Furthermore, dredging deeper channels will potentially mobilize contaminated sediments, and affect the oxygenation and salinity of waters within the harbor (Swanson and Bowman, 2017). A hydrodynamic study of the impacts of dredging on Stony Brook Harbor suggests that over dredging will increase water velocity in non-dredged regions of the harbor and significantly change the wetting and drying regime which could destabilize the interior wetlands in the study area (Georgas 2001).

Future dredging operations should be designed with marsh health and marsh sediment supply in mind. Existing hydrodynamic and sediment-fate models can be utilized to examine how sediment will redistribute during tidal flows under various dredging scenarios. Dredge spoils could potentially be a useful resource in nourishing or restoring

marshes, especially those in the north that were lost due to historical dredging and burial. Plans could also consider the construction of artificial oyster beds to modify water flows locally and to promote the accumulation of sediments in adjacent wetlands.

HARBOR ROAD CULVERT

Intertidal marsh habitat can be limited by the presence of road crossings and the loss of tidal water flows through pinch points and culverts (Brockmeyer et al. 1996). In Stony Brook Harbor, the Village of Head of the Harbor is working to obtain funding to replace an undersized culvert located at the south of the study area (Village of Head of the Harbor 2022). This culvert prevents some seawater from accessing the marshes to the south and likely has exacerbated the expansion of invasive Phragmites beds in this location. A 2019 Nature Conservancy study of the Harbor Road Culvert found that the degree of tidal restriction, and the impact on aquatic-organism passage, was severe (Nature Conservancy 2019). Restoring tidal flows to the area behind this culvert is likely to have both current benefits, in terms of marsh composition, and future benefits as the marsh will be better-able to trap sediment and respond to future sea-level rises.

DEVELOPMENT

The character of development adjacent to Stony Brook Harbor has changed considerably in the past 75 years. In 1954, the surrounding lands were largely agricultural, whereas currently large-lot single family housing dominates the landscape (Figure 9). Development can threaten coastal marshes either based on coastal hardening or the addition of excessive nutrients and sediments to the waterway.

When sea-level rise threatens residential and commercial development, landowners are likely to build new vertical walls or berms to keep coastal waters out, or to rebuild vertical walls that currently exist. This type of building prevents lateral wetland migration, producing a coastal “squeeze,” and will likely result in significant wetland losses (Nicholls et al., 1999). Fortunately, through much of the study area, relatively steep slopes down to the waterline suggest that adjacent houses will not be subject to regular flooding even under moderate to higher sea-level rise scenarios (Appendix A). However, the entire Long Beach peninsula of Nissequogue is vulnerable to flooding as it is a relatively low-elevation sand spit. Because of low land elevations, some coastal hardening may be likely to occur along Long Beach Road north of Stony Brook Harbor and along West Meadow Beach to the west of West Meadow Creek. In these areas, as will discussed below, there may be opportunities to create protective living shorelines that create dual benefits both to landowner’s investments and marsh ecology.

As noted above, water quality metrics are moderate in Stony Brook Harbor with limited nutrient impairment but there is also room for improvement. As additional home sites are developed, and additional lawns are created, fertilizer and other lawn care products can wash into adjacent waterways exacerbating water quality issues. Road runoff and septic systems from adjacent residential development also create problems. Nutrients such as nitrogen present in lawn fertilizer or wastewater can enter the harbor via overland runoff or groundwater seepage. It is possible, in this study area, that current zoning will prevent much further development that will worsen water quality, but subdivision of large lots still poses a risk. As discussed below, there are financial incentives available for local homeowners to reduce nitrogen from their properties through the Long Island Garden Rewards Program (NEIWPCC 2023) and the Suffolk County Septic Improvement Rebate Program. An additional potential role of local municipalities could also be the offering of rebate programs for homeowners to improve local water quality.

Figure 9. Aerial Photographs of Stony Brook Harbor in 1954 (top) and 2023 (bottom)
Photo sources: (top) NYSDEC, (bottom) Copyright Google 2023

MARSH CONSERVATION PLANNING

Marsh conservation planning can include strategies to protect existing wetlands, to ensure that adjacent habitat is protected for future marsh migration, to create new wetland habitats, or to restore historical marshes that have been lost. The strategies involved generally fall into the categories of "marsh restoration," "land purchases and easements," "local or state regulation," and "managing current resources (including water quality improvements)." Education is also important to ensure that community members recognize the critical ecological role of salt marshes and these marshes' impact on regional character. Modeling and data analysis will ensure that conservation plans have an eye towards anticipated future conditions.

MARSH RESTORATION

Marsh restoration is the process of modifying former marsh locations to promote current and future marsh habitation. This process is often undertaken to restore critical habitats or to provide flooding protection, among other benefits. Over the past several decades, the design and implementation of salt marsh restoration projects in the northeast United States has been rapidly increasing (Niedowski, 2000).

Marsh restoration remains a top priority of state and local governments. For example, "Theme 2" within the 2015 Long Island Sound Study Comprehensive Conservation & Management Plan aims to restore and protect the Sound's ecological balance in a healthy, productive, and resilient state for the benefit of both people and the natural environment. Within this Theme there is a "Tidal Wetland Extent Ecosystem Target" that commits to restoring 515 additional acres of tidal wetlands by 2035 from a 2014 baseline. To date, Long Island Sound Study partners have restored 166 acres of tidal wetland habitat, approximately one third of the way toward the 2035 goal. The New York State Ocean Action Plan also commits to protection and restoration of tidal wetland habitat. Goal 1 of the plan strives to ensure the ecological integrity of the ocean ecosystem and, within this goal (Objective A, Action 3) the plan proposes to monitor tidal wetland loss (trends), water quality, and implement restoration in estuaries and embayments. In 2000, New York State established salt-marsh restoration and monitoring guidelines to improve standards of practice and outcomes for these projects: https://www.dec.ny.gov/docs/wildlife_pdf/saltmarsh.pdf.

As discussed in the section on dredging above, marsh losses in the 1950s and 1960s were extensive to the north of Porpoise Channel due to dredge and fill operations undertaken at that time (Figure 3). This location would therefore be a prime candidate for marsh restoration. More recently, since the 1970s, the majority of marsh losses have occurred on the islands south of Porpoise Channel (Cameron Engineering 2015). These locations can also be examined for restoration potential.

The selection of a marsh restoration site in Stony Brook Harbor should be informed by hydraulics and sediment supply. Any marsh restoration project needs to ensure that adequate sediment supply exists for the project to be successful. For example, Liu and coworkers found that, among many variables, the success of coastal wetlands restoration and nature-based solutions was primarily driven by sediment availability (Liu et al. 2021). Hydrodynamic sediment modeling can be utilized to examine which locations, if restored, would be most likely to accumulate adequate sediment to survive and to offset potential future sea-level rises. Such modeling could also examine whether the addition of sediment to new or existing marshes would result in additional sediment accumulation in the boating channel to the north of the islands. If the channel were to accumulate sediment more rapidly this would require more frequent and costly (economically and environmentally) dredging operations.

Another mechanism that can be used to promote sediment trapping is the construction of artificial oyster reefs. Such construction has been shown to reduce erosion, trap suspended sediment, and support adjacent saltmarsh expansion (Chowdhury et al., 2019). Oyster reefs have been established in the Bronx River to the south (NYC Parks; NYNJ Harbor Estuary Program) and are being planned for City Island (City Island Oyster Reef Program). This

technique is also being used in Alley Point Park in Queens to reverse erosive losses on the edge of the tidal wetland there. Save the Sound is planning an oyster-reef restoration as part of a living shoreline in Little Neck Bay, Queens. A nearby living shoreline installation in Stratford Point Connecticut measured significant soil accumulation and wave attenuation (30-40%) after the installation of reef balls and planting of marsh grasses (Mattei 2022). Potential drawbacks to this approach in Stony Brook Harbor would be the necessity for enforcement to prevent shellfish harvesting or potential impacts to navigation if the reefs are not sited properly. Further study would be required to determine the appropriateness of this technique in Stony Brook Harbor and the optimal positioning of an artificial reef.

Managing Current Marsh Resources

As environmental and physical characteristics change, the careful management of the extensive current marsh resources in Stony Brook Harbor and West Meadow Creek will be critical to ensure that these habitats continue to thrive. Some of the steps that can be taken to manage marsh resources include invasive-species control, planning and managing habitat change under changes in future sea-levels, and taking steps to modify the hydrology of existing marshes to improve marsh health and increase sedimentation rates.

Invasive species encroachment to marshes has been noted in the south of the study area, with a Phragmites outbreak in the area of the Harbor Road Culvert, and to the northeast of the study area, with a perennial pepperweed outbreak in West Meadow Creek (See “Invasives” under “Threats” above.) Local municipalities are already working to improve these problems. For example, the Village of Head of the Harbor is seeking funding to replace the culvert by Harbor Road to increase tidal flow and help reduce Phragmites there. Following culvert replacement, further marsh management techniques may be required to address the Phragmites infestation on Suffolk County Park lands behind the culvert. The Town of Brookhaven has also submitted a proposal for invasives management in the coastal forest adjacent to West Meadow Creek.

Over the coming decades, many of the irregularly-flooded marshes in the study area are considered highly likely to convert to more-highly-saline regularly flooded marshes under future sea-level rise (Appendix A). Should this conversion become inevitable it will be important to manage the marshes under these times of stress and habitat transition. Habitat transitions are often times where marsh loss can occur due to marsh collapse and ponding, and invasive species can gain an inroad. Plantings of native species and monitoring for invasive species will be important during times of conversion. Another option would be to consider thin-layer sediment placement, living shorelines, and other sediment-balancing options that will allow marshes to keep up with SLR and to avoid loss of habitat rather than managing transitions.

Another management technique that has the potential to improve current marsh health and to ensure that wetlands are best prepared for moderate sea-level rise would be to improve the hydrological connectivity of the marsh. Most commonly, the use of runnels, or shallow channels, are used in this process. These channels can assist in vegetation regrowth as flooded ponds become open to daily tidal exchange (McKown et al. 2023). The improved connectivity also can reduce mosquito habitat (Besterman et al. 2022). This technique has been applied throughout the Northeast (Besterman et al. 2022) and been successfully applied in Suffolk County, for example at Gardiner’s Park in Bay Shore NY. (Maher et al. 2022). Notably, deeper ditches, such as historical mosquito ditches, have the potential to cause sediment oxidation and loss of elevation that can reduce a marshes’ resilience to sea-level rise (Vincent et al., 2013). Where deeper ditches exist, ditch-remediation techniques are being developed to allow these ditches to re-mend, creating a shallower ditch that assists in drainage while also promoting natural re-vegetation (Burdick et al., 2018).

It is also worth noting that much of the spatial data for existing marshes are several decades old or incomplete. For example, the National Wetlands Inventory data, which form the basis for marsh-acreage estimates in this report, are based on 2004 aerial photographs. Data about marsh density and speciation are also limited. Comprehensive surveys of threatened or endangered species on site have not been undertaken or are out of date. For these reasons, gathering more complete baseline data will be useful to prescribe the most beneficial management techniques, and will be required to support the engineering plans behind any specific management action.

Improve Water Quality

As previously noted, water quality is important to marsh health as excess nutrients will generally increase marsh loss and erosion rates. Adjacent development may impair local water quality as nutrients, especially nitrogen, wash out of neighboring lawns, septic systems, and roadways. While additional high-density development adjacent to Stony Brook Harbor is probably unlikely due to current zoning regulations, the Suffolk County goal remains to reduce 60% of nitrogen loadings into the Harbor from existing developments (Suffolk County 2020). Again, local towns are already assessing and working on this problem. For example, The Town of Smithtown, in partnership with the Villages of Head of the Harbor and Nissequogue, and its consultants Nelson & Pope, and Nelson Pope Voorhis, undertook a Feasibility Study to develop long-term strategies for stormwater management and erosion control in the Cordwood Path Watershed which discharges into Stony Brook Harbor (Nelson and Pope, 2022). The Cordwood Path watershed discharges 164.4 lbs. of Total Nitrogen/year, 49.3 lbs. of Total Phosphorous/year, 6,534 lbs. Total Suspended Solids (TSS)/year and 4,788 billion Fecal Coliform/year. The Town of Smithtown, the Village of Nissequogue and the Village of Head of the Harbor are now seeking funding to implement two of the recommended green-infrastructure projects from this study, which will help to reduce pollutant discharges into Stony Brook Harbor.

There is a role for education in improving water quality in Stony Brook Harbor as well. Updating residential septic systems around Stony Brook Harbor could reduce nitrogen loading to Stony Brook Harbor by as much as 40% (Suffolk County, 2019). A Suffolk County Septic Improvement Rebate Program is available to provide financial assistance for homeowners to upgrade to nitrogen-reducing septic systems. Additionally, homeowners can reduce nitrogen from their properties using such measures as rain barrels, rain gardens, and native plant gardens that reduce rainwater flowing across their yards (and in the case of gardens pull nitrogen out of rainwater) and therefore reduce the amount of nitrogen flowing into surface waters (NEIWPCC 2023). Landowners adjacent to Stony Brook Harbor and West Meadow Creek are eligible for the Long Island Garden Rewards Program, which offers financial rewards for homeowners who add green alternatives, including rain gardens, native plantings, and rain barrels, to their properties to reduce stormwater runoff and nitrogen loadings (LIRPC 2023).

Planning for Marsh Migration

To protect marsh ecosystems, private lands with current and future marsh habitats can be prioritized for purchase and future public ownership. In general, land without structures and restricted to human uses compatible with conservation provides the simplest means and greatest potential for wetland migration (Spidalieri, 2020). Additionally, easements can be established to prevent future development on the parcels (or specifically on the portion of the parcels that have potential to become a marsh habitat) and this is often less costly than outright land purchase.

To date, several parcels have been protected and restored within the West Meadow Creek and Stony Brook Harbor watershed. In the early 2000s, the Town of Brookhaven and the Stony Brook Community Fund (now the Ward Melville Heritage Organization) removed 92 of 95 beach cottages from Trustees Rd at West Meadow Beach, essentially restoring open space and beach habitat to the nature preserve. In addition to this work, the New York State Department of Environmental Conservation (NYSDEC) and the Long Island Sound Study (LISS) have targeted

properties for protection along the north shore of Stony Brook Harbor in Nissequogue. The State and federal partners have acquired roughly 6 acres of land using the NYS Environmental Protection Fund and LISS funding. These parcels are composed of tidal wetland, beach, and scrub shrub habitat. These properties satisfy the goals of the NYS Open Space Conservation Plan and the LISS Comprehensive Conservation & Management Plan (CCMP). Since 2015, the LISS and its partners have protected more than 4,600 acres (900 acres in NY) through acquisitions and easements as part of their CCMP initiative to protect 7,000 acres by 2035.

Public and private partnerships can be key to conserving current and future marsh habitats. Spidalieri (2020) cites three reasons that public-private ownerships may be imperative: governments may have restrictions in terms of their ability to gain title to lands; property owners are often more willing to work with non-governmental entities; and, it can be costly for local governments to maintain properties when some level of human intervention is required to help wetlands become established.

One possible source of funding within New York State is the Regional Economic Development Councils (REDC) that offers grants for land preservation and heritage and also water-quality improvement. (REDC 2021). The Long Island Sound Futures Fund also provides grants to restore the health and living resources of Long Island Sound. (See **Funding Sources for Marsh Conservation** on pages 25 and 26.)

Much of Stony Brook Harbor has relatively steep slopes meaning that extensive marsh migration onto uplands is unlikely to occur. Based on available marsh-migration modeling, there are two primary locations that marsh expansion is likely to occur under various sea-level rise scenarios (Propato at al. 2018, Appendix A).

West Meadow Creek North

- Includes Suffolk County lands (for horses)
- Old Field Club

Stony Brook Harbor North, Village of Nissequogue

- Includes some developed lands
- Could be a potential Living shoreline location

A full accounting of where and when marsh habitat would be predicted to expand on these lands, the parcel sizes and ownership, and where marshes have the potential to migrate under multiple sea-level rise scenarios may be found in the Marsh Interactive Fate Viewer that was created as part of this project: (http://warrenpinnacle.com/LIMaps/).

Looking South towards Porpoise Channel from North of Stony Brook Harbor (Photo Credit Vicky O'Neill)

Funding Sources for Marsh Conservation

Below are federal, state, and local funding opportunities that could be utilized to implement the above recommendations in this plan.

Long Island Sound Futures Fund

https://www.nfwf.org/programs/long-island-sound-futures-fund

Grants are available for habitat restoration, resilience, and water quality improvements. Grants range from $50K - $1.5M. Eligible applicants include non-profit 501(c) organizations, state government agencies, local government, municipal government, Tribal Governments and Organizations, and educational institutions. The Long Island Sound Futures Fund typically opens in early March, with applications due in May.

Long Island Sound Resilience Grant Writing Assistance Program

https://bit.ly/LISResilienceRFPInfo

This is a new opportunity for municipalities, community organizations, and nonprofits to get match-free monetary support to hire a grant-writing consultant to prepare applications for resilience and sustainability-focused projects benefiting Long Island Sound coastal communities. Awards up to $9,950 per application are available with funding provided directly to the consultant. Applications are accepted on a rolling basis. Applicants are encouraged to apply at least 6-8 weeks in advance of the grant opportunity deadline they would like to pursue.

NYS Consolidated Funding Application

https://apps.cio.ny.gov/apps/cfa/

A wide range of grant programs are available under the Consolidated Funding Application, released annually in May, including:

- NYSDEC Water Quality Improvement Project (WQIP) Program

  The Water Quality Improvement Project (WQIP) program is a competitive, reimbursement grant program that funds projects that directly improve water quality or aquatic habitat, promote flood risk reduction, restoration, and enhanced flood and climate resiliency, or protect a drinking water source. This program provides funding for project implementation/construction. Eligible applicants include municipalities, soil and water conservation districts, and non-profit organizations (for certain categories).

- Non-Agricultural Nonpoint Source Planning and Municipal Separate Storm Sewer System (MS4) Mapping Grant (NPG)

  The Non-Agricultural Nonpoint Source Planning and MS4 Mapping Grant (NPG) is a competitive, reimbursement grant program that funds planning reports for nonpoint source water quality improvement projects and mapping of Municipal Separate Storm Sewer Systems (MS4s). The program aims to prepare nonpoint source projects for construction and application for implementation funding, and to encourage and support cooperation among regulated MS4s to complete mapping of their stormwater system. Eligible applications include municipalities and soil and water conservation districts.

- NYSDEC Climate Smart Communities Grant Program

  The Climate Smart Communities (CSC) Grant program was established in 2016 to provide 50/50 matching grants to cities, towns, villages, and counties of the State of New York for eligible climate change mitigation, adaptation, and planning and assessment projects. This program provides grants of up to $2M for implementation of climate adaptation projects, including relocation or retrofits of critical infrastructure, living shorelines and other nature-based solutions, and replacing or right-sizing of flow barriers. Grants of up to $200K are also available for planning projects that build local capacity to respond to climate change and move municipalities toward designation as certified Climate Smart Communities. Municipalities do not need to be a registered or certified as a Climate Smart Community to apply for a grant.

- NYS Department of State (DOS) Local Waterfront Revitalization Program (LWRP) Grants

  Grants are available for eligible villages, towns, and cities located along New York's coasts or designated inland waterways, or counties (with the consent and acting on behalf of one or more eligible villages, towns, cities) to advance the preparation or implementation of strategies for community and waterfront revitalization through the following grant categories: 1) Preparing or Updating a Local Waterfront Revitalization Program (LWRP) 2) Updating an LWRP to be more Resilient to Climate Risks 3) Preparing an LWRP Component, including a Watershed Management Plan, and 4) Implementing a Local Waterfront Revitalization Program or a completed LWRP Component

- NYS Environmental Facilities Corporation Green Innovation Grant Program (GIGP)

  Competitive grants are awarded annually to projects that improve water quality and mitigate the effects of climate change through the implementation of one or more of the following green practices: Green Stormwater Infrastructure, Energy Efficiency, Water Efficiency and Environmental Innovation. Eligible green infrastructure practices include bioretention, restoration of floodplains, riparian buffers, streams or wetlands, permeable pavement, stormwater harvesting and reuse, and stormwater street trees. Eligible applicants include municipalities, private entities, soil and water conservation districts, and state agencies. The maximum percentage grant is up to 90% of eligible project costs for a green stormwater infrastructure project in a municipality that meets the Median Household Income criteria, or that serves, protects, or benefits an environmental justice area. All other green infrastructure projects are eligible to receive up to a maximum of 75% of total eligible project costs.

NYSDOT Grants

https://www.dot.ny.gov/

The New York State Department of Transportation offers various grants, including the Bridge NY Program, that provide funding to improve the resilience of surface transportation infrastructure, including culverts. NYSDOT grants could be used to fund the replacement of the Harbor Rd. culvert.

NYS Environmental Bond Act

https://www.ny.gov/programs/clean-water-clean-air-and-green-jobs-environmental-bond-act

The unprecedented $4.2 billion Clean Water, Clean Air, and Green Jobs Environmental Bond Act prioritizes investments in environmental justice, climate change mitigation, shoreline restoration, flood resilience, water quality, open space conservation, recreational resources, and green jobs. State agencies, local governments, and partners will be able to access Environmental Bond Act funding over a multi-year process.

Suffolk County Water Quality Restoration and Protection Program

https://www.suffolkcountyny.gov/Departments/Economic-Development-and-Planning/Planning-and-Environment/Water-Quality-Improvement

This is an annual program that provides grants from $50-$250K for both planning/design and construction. Priority project types vary slightly from year to year but generally include wastewater treatment improvements; green stormwater infrastructure implementation; nature and nature-based infrastructure for coastal resilience; and habitat restoration, reclamation, and connectivity. Eligible applicants are any County Department, any municipality within Suffolk County, and any non-profit organization within Suffolk County.

Funding for Land Acquisitions

Long Island Sound Study, NYS, and Town of Brookhaven have all actively targeted priority lands for protection and may be able to provide funding for further acquisitions in the future.

USDA NRCS Wetland Reserve Easements

https://www.nrcs.usda.gov/programs-initiatives/wre-wetland-reserve-easements

These grants provide funding to support land-conservation easements on wetlands that were previously degraded due to agricultural uses. Private property owners are eligible

Living Shorelines

As noted above, north of Stony Brook Harbor and south of Long Beach is one location where a living shoreline could be used to protect land and infrastructure. A living shoreline is a coastline that has been stabilized and increased in elevation while using natural materials, including vegetation. When looking towards future sea-levels, a living shoreline is a form of landscape modification that potentially provides both ecological restoration of habitat and benefits to coastal resilience and upland infrastructure.

State guidance is available to assist local governments and landowners implement natural-resilience measures to reduce risk from flooding and erosion. Also, recent legislation requires the State of NY to give preference to nature-based solutions when permitting shoreline management projects (Act 5221-A).

- *Tidal Wetlands Guidance Document: Living shoreline Techniques in the Marine District of New York State*, 2017: https://www.dec.ny.gov/docs/fish_marine_pdf/dmrlivingshoreguide.pdf
- *Using Natural Measures to Reduce the Risk of Flooding and Erosion, 2020, Guidance from NYSDEC and NYSDOS:* https://www.dec.ny.gov/docs/administration_pdf/crranaturalmeasuresgndc.pdf

Local Regulation

To benefit marsh conservation and expansion, local towns and planning boards can consider marsh-fate modeling within land-use planning and zoning decisions. Town comprehensive plans can prioritize the preservation of marshes due to their specific habitat services and their general enhancement of a town's unique character. Furthermore, regulation of local water quality can be important for marsh-ecosystem viability. Local efforts to reduce plastic contamination in marshes can improve marsh ecosystem functioning and increase the ecological and recreational value of local wetlands.

A partial list of legal tools that state and local governments can consider (from Spidalieri, 2020) is:

- Zoning;
- Setbacks;
- Restrictions on hard-armoring projects/support for living shoreline projects;
- Rolling easements;
- Transfer of development rights or land swaps.

As an additional reference, New York State Department of State has produced a document called "Model Local Laws to Increase Resilience" (2019). This document includes chapters dedicated to coastal shoreline protection measures and wetlands and includes model laws with legal language that municipalities can use and adopt into a local code.

Outreach

In addition to the strategies discussed above, outreach and education about the benefits of salt-marsh habitats can bolster local support for marsh preservation. Educational topics can include options for adjacent property owners, or owners with potential future marsh migration on their lands. Sharing research about the effectiveness of marsh lands for erosion control, or as wave-attenuating barriers, could increase acceptance of sharing property lines with salt marshes.

Other topics for outreach include the importance of sustainable lawn care practices (reduced or no fertilizer use) to local water quality and ecological viability. In 2016 NYSDEC formed a fertilizer management workgroup as part of the Long Island Nitrogen Action Plan (LINAP). This group's recommendations are available at https://www.dec.ny.gov/docs/water_pdf/linapfertilizer.pdf (LINAP 2019). In addition, outreach on Suffolk County's Septic Improvement Program would be beneficial. Additional information about actions that homeowners can take to protect Stony Brook Harbor can be found on the Long Island Sound Study website.

REFERENCES

Aman, J., and K. W. Grimes. 2016. "Measuring impacts of invasive European green crabs on Maine salt marshes: a novel approach." Report to the Maine Outdoor Heritage Fund; Wells National Estuarine Research Reserve: Wells, ME, USA, 19.

Atlantic Coast Joint Venture. (2021). "Saltmarsh Sparrow." https://acjv.org/saltmarsh-sparrow-2/.

Audubon Society 2013. Fact sheet for Nissequogue River Watershed and Smithtown Bay, site 847. https://netapp.audubon.org/iba/Reports/847 accessed July 2023.

Beniot, L. K. and R. A. Askins. 1999. Impact of the spread of Phragmites on the distribution of birds in Connecticut tidal marshes. Wetlands 19: 194-208

Benscoter, A. M., J. M. Beerens, and S. S. Romañach. 2019. Coastal marsh bird habitat selection and responses to Hurricane Sandy. Wetlands and Climate Change 40: 799-810

Besterman, A. F., R. W. Jakuba, W. Ferguson, D. Brennan, J. E. Costa, and L. A. Deegan. 2022. "Buying time with runnels: a climate adaptation tool for salt marshes." *Estuaries and Coast*s, 45 (6): 1491–1501. Springer.

Brockmeyer, R. E., J. R. Rey, R. W. Virnstein, R. G. Gilmore, and L. Earnest. 1996. "Rehabilitation of impounded estuarine wetlands by hydrologic reconnection to the Indian River Lagoon, Florida (USA)." *Wetlands ecology and management*, 4: 93–109. Springer.

Burdick, D, Adamowicz S, Moore, G. Peter, C. Betchelder, D. Pau, N, and Wilson, G. 2018. Ditch Remediation Pilot Studies in National Wildlife Refuges of the Northeast. University of New Hampshire, USFWS, Northeast Wetland Restoration. http://nbnerr.org/wp-content/uploads/2018/09/Ditch_remediation_pilot_studies_in_National_Wildlife_Refuges_of_the_Northeast_D._Burdick.pdf

Cademartori, G. M. 2001. "Temporal Changes and Future of the Salt Marshes of a North Shore Long Island Pocket Bay." Thesis. State University of New York at Stony Brook, May 2001.

Cameron Engineering & Associates, LLP. (2015). "Long Island Tidal Wetlands Trends Analysis prepared for the New England Interstate Water Pollution Control Commission."

Clough, J., Polaczyk, A., and Propato, M. (2016). "Modeling the potential effects of sea-level rise on the coast of New York: Integrating mechanistic accretion and stochastic uncertainty." Environmental Modelling & Software, 84, 349–362.

Craig, R. J., and Beal, K. G. (1992). "The influence of habitat variables on marsh bird communities of the Connecticut River estuary." The Wilson Bulletin, JSTOR, 295–311.

Deegan, L. A., D. S. Johnson, R. S. Warren, B. J. Peterson, J. W. Fleeger, S. Fagherazzi, and W. M. Wollheim. 2012. "Coastal eutrophication as a driver of salt marsh loss." Nature, 490 (7420): 388–392.

Drake, K., H. Halifax, S. C. Adamowica, and C. Craft. 2015. Carbon sequestration in tidal salt marshes of the northeast United States. Environmental Management 56: 998-1008

Ens, N. J., B. Harvey, M. M. Davies, H. M. Thomson, K. J. Meyers, J. Yakimishyn, L. C. Lee, M. E. McCord, and T. G. Gerwing. 2022. "The Green Wave: reviewing the environmental impacts of the invasive European green crab (Carcinus maenas) and potential management approaches." Environmental Reviews, 30 (2): 306–322. Canadian Science Publishing 1840 Woodward Drive, Suite 1, Ottawa, ON K2C 0P7.

Ernst, C.H., J.E. Lovich, and R.W. Barbour. 1994. Turtles of the United States and Canada. Smithsonian Institution Press. Washington and London. 578 pp.

Fagherazzi, S. 2013. "The ephemeral life of a salt marsh." *Geology*, 41 (8): 943–944. https://doi.org/10.1130/focus082013.1.

GEI Consultants, Inc. P.C. 2013. "Perennial Pepperweed Management Plan West Meadow Beach, Town of Brookhaven." Town of Brookhaven.

Georgas, N. 2001. "Tidal Hydrodynamics and Bedload Transport in a Shallow, Vegetated Harbor (Stony Brook Harbor, Long Island, New York): A Modeling Approach with Management Implications." PhD Thesis. State University of New York at Stony Brook.

Glassberg, J. 1999. Butterflies Through Binoculars: The East. Oxford University Press, New York, New York. 400 pp.

Johnson, B. H., and T. M. Parchure. 1999. Estimating dredging sediment resuspension sources. US Army Engineer Waterways Experiment Station.

Jones, C. G., J. H. Lawton, and M. Shachak. 1994. Organisms as Ecosystem Engineers. Oikos 69: 373-386.

Jones, C. G., J. H. Lawton, and M. Shachak. 1997a. Positive and negative effects of organisms as physical ecosystem engineers. Ecology 78: 1946-1957.

Kirwan, M. L., and J. P. Megonigal. 2013. "Tidal wetland stability in the face of human impacts and sea-level rise." Nature, 504 (7478): 53–60.

LIRPC 2021. "Long Island Regional Planning Council, Long Island Garden Rewards Program." https://lirpc.org/garden-rewards-program/ Accessed July 2023.

Liu, Z., S. Fagherazzi, and B. Cui. 2021. "Success of coastal wetlands restoration is driven by sediment availability." Communications Earth & Environment, 2 (1): 44. Nature Publishing Group UK London.

Long Island Osprey Watch, 2022. "Nest #8722" https://www.osprey-watch.org/ accessed August, 2023.

Loomis, M. J., and Craft, C. B. (2010). "Carbon Sequestration and Nutrient (Nitrogen, Phosphorus) Accumulation in River-Dominated Tidal Marshes, Georgia, USA." Soil Science Society of America Journal, 74(3), 1028.

Maher, N., C. Salazar, and A. Fournier. 2022. "Advancing salt marsh restoration for coastal resilience: a learning exchange." *Wetlands Ecology and Management*, 30 (5): 1033–1047. Springer.

McCarty-Glenn, Mica. 2017. "The effect of parasitism and predation on phenotypically plastic traits of the marine gastropod *Tritia obsoleta*" Stony Brook University, May 2017.

McKown, J. G., D. M. Burdick, G. E. Moore, C. R. Peter, A. R. Payne, and J. L. Gibson. 2023. "Runnels Reverse Mega-pool Expansion and Improve Marsh Resiliency in the Great Marsh, Massachusetts (USA)." Wetlands, 43 (4): 35. Springer.

McShane, Kathy, 2023, Town of Smithtown, Personal Communication.

Narayan, S., M. W. Beck, P. Wilson, C. J. Thomas, A. Guerrero, C. C. Shepard, B. G. Reguero, G. Franco, J. C. Ingram, and D. Trespalacios. 2017. "The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA." *Scientific Reports*, 7 (1). https://doi.org/10.1038/s41598-017-09269-z.

NEIWPCC 2023. "Long Island Garden Rewards Program" https://neiwpcc.org/long-island-garden-rewards-program/ Accessed July 2023.

Nellemann, C. and E. Corcoran. 2009. Blue Carbon: The role of healthy oceans in binding carbon: a rapid response assessment. UNEP/Earthprint.

Nelson and Pope, 2022. Stormwater Management Feasibility Study, Cordwood Path and Park, Prepared for Town of Smithtown and New York State Department of State, December 2022.

New York Natural Heritage Program. (2019). "High Salt Marsh." https://guides.nynhp.org/high-salt-marsh/. Accessed on March 2 2021.

New York Natural Heritage Program. (2019). "Low Salt Marsh." https://guides.nynhp.org/high-salt-marsh/. Accessed on March 2 2021.

New York Natural Heritage Program. (2019). "Salt Panne." https://guides.nynhp.org/high-salt-marsh/. Accessed on March 2 2021.

New York Natural Heritage Program. (2019). "Salt Scrub." https://guides.nynhp.org/high-salt-marsh/. Accessed on March 2 2021

New York State Department of State. (2019). "Model Local Laws to Increase Resilience Developed pursuant to the Community Risk and Resiliency Act (CRRA)." Office of Planning, Development, and Community Infrastructure. Accessed March 31, 2021

Nicholls, R. J., Hoozemans, F. M., and Marchand, M. (1999). "Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses." Global Environmental Change, Elsevier, 9, S69–S87.

Niedowski, N. L., 2000. New York State salt marsh restoration and monitoring guidelines. New York State Department of State, Division of Coastal Resources. https://www.dec.ny.gov/docs/wildlife_pdf/saltmarsh.pdf.

NJDEP 2014. "Assessment Criteria for Nutrients in Selected Northeast Estuaries" January 2014. https://www.nj.gov/dep/barnegatbay/docs/assessment-criteria-for-nutrients-in-selected-northeast-estaries.pdf accessed July 2023.

NOAA 2023 "Look Out for Invasive Crab!" https://www.fisheries.noaa.gov/alaska/habitat-conservation/look-out-invasive-crab, accessed July 2023.

NY Department of State. 2005. "New York State Significant Coastal Fish and Wildlife Habitat Narrative for Stony Brook Harbor and West Meadow."

NYSDEC 2021. "Stony Brook Harbor and West Meadow Creek (Segment ID 1702-0047) Waterbody Segment Assessment Factsheet Based on the 2021 CALM" Revised December 07, 2021. https://www.dec.ny.gov/data/WQP/PWL/1702-0047.html accessed July 2023.

O'Donnell, J. E. 2017. "Living shorelines: a review of literature relevant to New England coasts." *Journal of Coastal Research*, 33 (2): 435–451. The Coastal Education and Research Foundation.

Peterson, G. W., and Turner, R. E. (1994). "The Value of Salt Marsh Edge vs Interior as a Habitat for Fish and Decapod Crustaceans in a Louisiana Tidal Marsh." Estuaries, 17(1), 235.

Propato, M., Clough, J. S., and Polaczyk, A. (2018). "Evaluating the costs and benefits of marsh-management strategies while accounting for uncertain sea-level rise and ecosystem response." PloS one, 13(8), e0200368.

REDC 2021: Regional Economic Development Councils *2021 REDC Guidebook.* https://regionalcouncils.ny.gov/sites/default/files/2021-05/2021REDCGuidebook_Final.pdf accessed August 2023

Save the Sound 2022. "Long Island Sound Report Card 2022" Sound Health Explorer, https://www.savethesound.org/wp-content/uploads/2022/11/Save_the_Sound_2022_LIS_Report_Card_FINAL_11_09_22.pdf (Accessed July 2023).

Szura, K., R. A. McKinney, C. Wigand, A. Oczkowski, A. Hanson, J. Gurak, and M. Gárate. 2017. "Burrowing and foraging activity of marsh crabs under different inundation regimes." *Journal of Experimental Marine Biology and Ecology*, 486: 282–289. Elsevier.

Seigel, R.A. and J.W. Gibbons. 1995. Workshop on the ecology, status, and management of the Diamondback terrapin (Malaclemys terrapin), Savannah River Ecology Laboratory, 2 August 1994: Final Results and Recommendations. Chelonian Conservation and Biology. 1(3):240-243.

Sheng, Y. P., Rivera-Nieves, A. A., Zou, R., and Paramygin, V. A., 2021. "Role of wetlands in reducing structural loss is highly dependent on characteristics of storms and local wetland and structure conditions." *Scientific reports*, Nature Publishing Group, 11(1), 1–14.

Spidalieri, K. 2020. Where the Wetlands Are—And Where They Are Going: Legal and Policy Tools for Facilitating Coastal Ecosystem Migration in Response to Sea-Level Rise. *Wetlands* Volume 40, Issue 6, p.1765–1776 (Marsh Resilience Summit 2020). https://doi-org.dbgateway.nysed.gov/10.1007/s13157-020-01280-x

Suffolk County 2019. "Revised Draft Subwatersheds Wastewater Plan Executive Summary." Suffolk County Department of Health Services August 2019. Page 111.

Suffolk County 2020. "Final Subwatersheds Wastewater Plan." Suffolk County Department of Health Services July 2020.

Suffolk County Department of Health Services (SCDHS), 2022. Surface water quality monitoring data provided by the SCDHS Office of Ecology, Yaphank, N.Y.

Suffolk County GIS, 2023. "Historic Aerials" https://gisapps.suffolkcountyny.gov/gisviewer/ Accessed August, 2023.

Swanson, R. L., and M. J. Bowman. 2017. *Between Stony Brook Harbor tides: the natural history of a Long Island pocket bay*. State University of New York Press.

TBR News Media. 2016. "Go back in history at West Meadow Beach." Accessed August 7, 2023. https://tbrnewsmedia.com/go-back-in-history-at-west-meadow-beach/.

The Nature Conservancy 2019 "Long Island Road Stream and Tidal Crossing Improvement Project, Site 504, Tidal Crossing Score Summary." https://tinyurl.com/TNC504 (Accessed July 2023).

USGS 2020, "U.S. Coastal Wetland Synthesis Geonarrative." https://geonarrative.usgs.gov/uscoastalwetlandsynthesis/ accessed July 2023.

Valiela, I., M. Geist, J. McClelland, and G. Tomasky. 2000. Nitrogen loading from watersheds to estuaries: Verification of the Waquoit Bay nitrogen loading model. Biogeochemistry 49: 277

Velinsky, D. J., B. Paudel, T. Quirk, M. Piehler, and A. Smyth. 2017. Salt marsh denitrification provides a significant nitrogen sink in Barnegat Bay, New Jersey. Journal of Coastal Research 78: 70-78

Viehman, S., J. L. Vander Pluym, and J. Schellinger. 2011. Characterization of marine debris in North Carolina salt marshes. Marine Pollution Bulletin 62: 2771-2779

Village of Head of the Harbor 2022. "Stony Brook Harbor Marsh Restoration, Project Description."

Vincent, R. E., D. M. Burdick, and M. Dionne. 2013. "Ditching and Ditch-Plugging in New England Salt Marshes: Effects on Hydrology, Elevation, and Soil Characteristics." Estuaries and Coasts, 36 (3): 610–625. https://doi.org/10.1007/s12237-012-9583-y.

Vlahos, P., M. M. Whitney, C. Menniti, J. R. Mullaney, J. Morrison, and Y. Jia. 2020. Nitrogen budgets of the Long Island Sound estuary. Estuarine, Coastal and Shelf Science 232: 106493

Zarillo, G. A., and M.-J. Park. 1987. "Sediment transport prediction in a tidal inlet using a numerical model: application to Stony Brook Harbor, Long Island, New York, USA." *Journal of Coastal Research*, 429–444. JSTOR.

Aerial View Looking Southeast towards Porpoise Channel.
Photo courtesy of the Town of Smithtown (credit Kelly Steele)

APPENDIX A: FACT SHEETS FOR STONY BROOK HARBOR AND WEST MEADOW

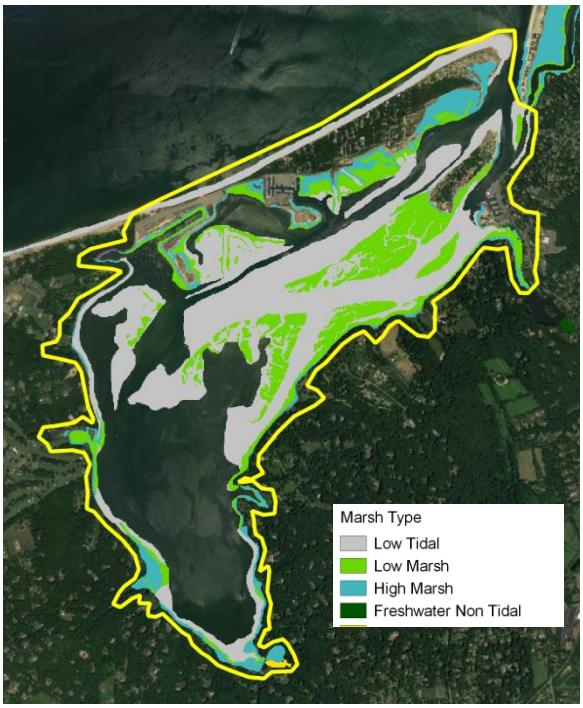
STONY BROOK HARBOR: PROJECTED INUNDATION AND LANDCOVER CHANGES DUE TO SEA LEVEL RISE

As of 2004, the most recent land cover data available, the Stony Brook Harbor area near St. James, NY includes approximately 642 acres of wetlands (marshes and unvegetated flats), of which **240** acres are vegetated marshes, while the rest are mudflats and beaches. Under several possible sea level rise (SLR) scenarios, current marsh coverage is predicted to suffer significant coverage losses since the majority of marsh lands have relatively low elevations compared to sea level. In addition:

- Areas of high-elevation marshes are predicted to be replaced by lower marsh (more saline);
- Increasing areas of marsh may be lost to wetland flats and/or open water; and
- Dryland areas are predicted to be increasingly regularly inundated.

A total of 229 tax parcels, in and adjacent to the wetland area, may be affected by increased inundation. The Village of Nissequogue and the Town of Smithtown are the main landowners of the public land currently occupied by marsh, but many privately owned parcels could be affected by increased inundation.

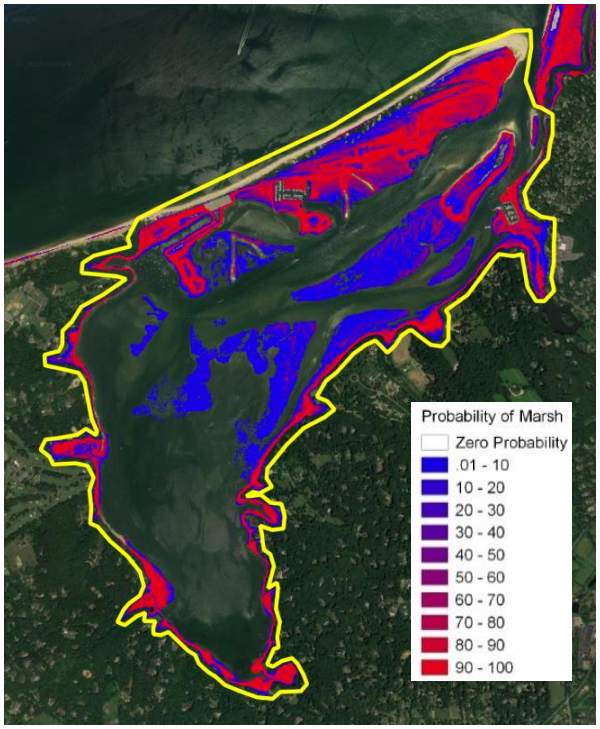
ONLINE VIEWER
For more detailed information about each tax parcel, please visit our on-line viewer http://warrenpinnacle.com/LIMaps/



2023 satellite image of Stony Brook Harbor with current marsh coverage (Sources: NWI; Satellite imagery from Google).

Because SLR and model inputs are uncertain, the map on the right shows an estimate of how likely an area may be to accommodate marsh habitat in 2100 (assuming land is made available or restored). *Red areas are more likely to be marsh at 2100 than blue ones*.

The model predicts marsh habitat based on the likelihood of regular inundation (e.g. at least once per month) given model, data, and SLR uncertainty. Hundreds of model simulations with different assumptions about model inputs and data error were aggregated to produce this map.



Probability of marsh habitat map, year 2100

WETLAND LOSSES

- Existing marsh area, that in 2004 covered **240** acres, is predicted to be reduced by **137** acres by 2100 (this is the average of all uncertainty-analysis simulations). However, an additional **68-96** acres of marsh could be converted to tidal flats or open water in the 10% most extreme scenarios (i.e. modeled scenarios with the highest sea level rises).
- In addition, approximately **193** acres of current tidal flats or beaches are predicted to become open water by 2055, increasing to **441** by 2100.

	Owner Type	2004	2055	2100
Existing marsh area (acres)	Public	193	132	75
	Private	46	38	27
Average new marsh area in undeveloped dry land (acres)	Public	0	22	43
	Private	0	15	44
Average new marsh area in developed dry land (acres)	Public	0	5	16
	Private	0	2	6
Total potential marsh area (acres)		240	214	211

Average marsh habitat predicted given SLR in the years 2055 and 2100. Private areas include also tax parcels with unknown owner.

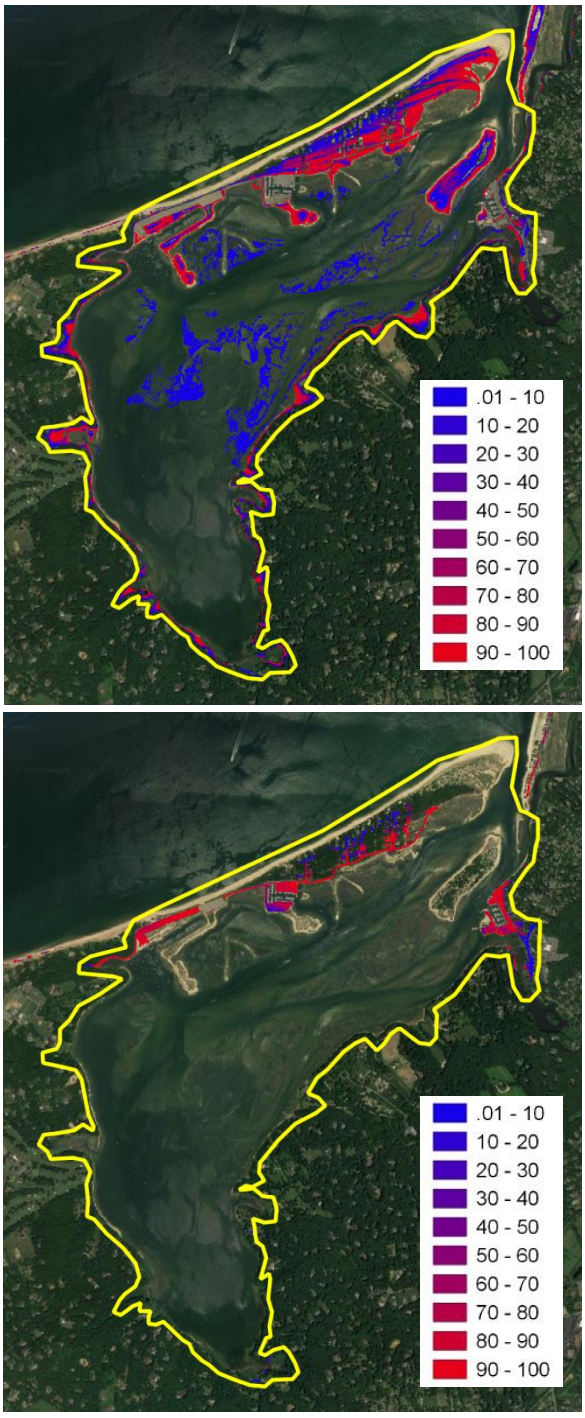
POTENTIAL FOR MARSH MIGRATION

Wetland losses can be offset by **marsh migration** in areas that are currently dry land but predicted to become regularly inundated in the future.

- On average, **37** acres of new marsh could be expected to establish in current undeveloped dryland by 2055, or up to **87** acres by 2100. The maximum possible area of new marsh would be **220** acres under the highest SLR scenario.
- In addition, properly restored developed dry land could accommodate the establishment of an average **7** acres of marsh by 2055 and **22** acres by 2100, with a possible maximum area of **31** acres. (Note, some of these developed areas include roads that may be maintained as such in the future.)

SUMMARY

Although the **240** acres of marsh (as of 2004) are predicted to remain viable under a wide range of possible sea level rise increases, by 2100 marsh areas may be reduced to a total of **6** acres under more extreme scenarios. However, marsh losses could be offset by the migration of marshes onto newly-inundated dry lands. If **marsh migration** is allowed, an average of **44** acres of current dry land could accommodate new marsh by 2055 and **109** acres by 2100 (This number could stretch to **251** acres of new marsh under more extreme SLR scenarios).



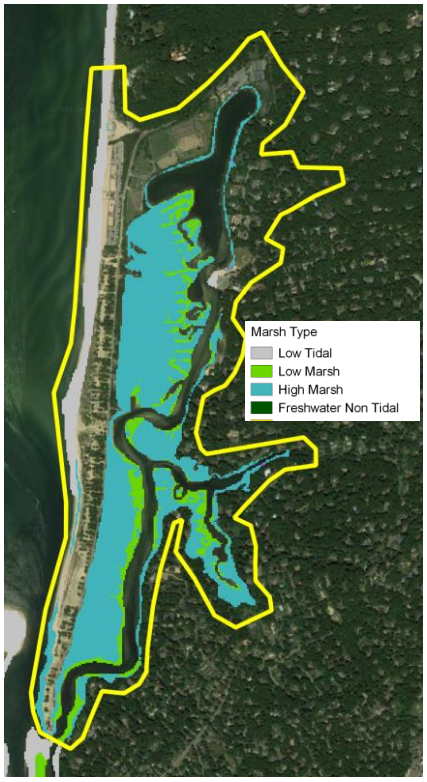
Areas that could accommodate marsh establishment by 2100. top: in currently undeveloped dry land areas, bottom: in developed ones. Colors show probability of marsh habitat.

WEST MEADOW CREEK: PROJECTED INUNDATION AND LANDCOVER CHANGES DUE TO SEA LEVEL RISE

As of 2004, the most recent land cover data available, the West Meadow Creek area near Stony Brook, NY includes approximately 130 acres of wetlands (marshes and unvegetated flats), of which **108** acres are vegetated marshes, while the rest are beaches. Much of this marsh is relatively high in elevation (irregularly-flooded emergent marsh.) Because of its current elevation, under several possible sea level rise (SLR) scenarios, current marsh coverage is predicted to keep up with sea level. However:

- Areas of high-elevation marshes are predicted to be replaced by lower marsh (more saline resulting in a different habitat type);
- Increasing areas of marsh may be lost to wetland flats and/or open water; and
- Dryland areas are predicted to be increasingly regularly inundated.

A total of 266 tax parcels, in and adjacent to the wetland area, may be affected by increased inundation. The Ward Melville Heritage Organization is the main landowners of the land currently occupied by marsh, with approximately 88 acres. Another 18 acres of marsh is owned by the Town of Brookhaven. A significant number of privately owned parcels could be affected by increased inundation.



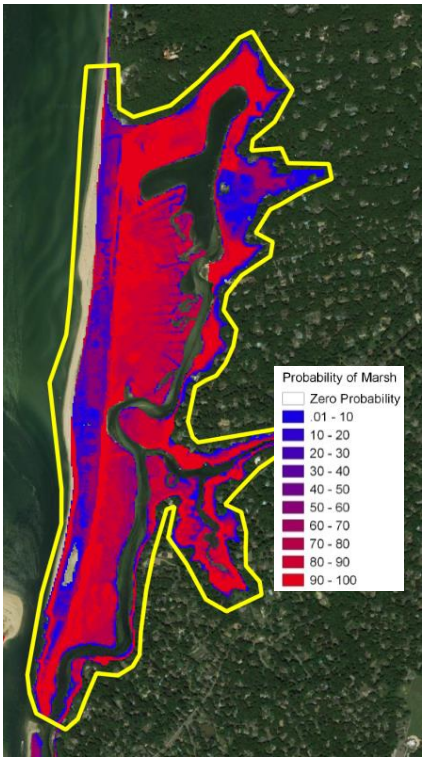
2023 satellite image of West Meadow Creek with current marsh coverage (Sources: NWI; Satellite imagery from Google).

ONLINE VIEWER

For more detailed information about each tax parcel, please visit our on-line viewer http://warrenpinnacle.com/LIMaps/

Because SLR and model inputs are uncertain, the map on the right shows an estimate of how likely an area may be to accommodate marsh habitat in 2100 (assuming land is made available or restored). *Red areas are more likely to be marsh at 2100 than blue ones*.

The model predicts marsh habitat based on the likelihood of regular inundation (e.g. at least once per month) given model, data, and SLR uncertainty. Hundreds of model simulations with different assumptions about model inputs and data error were aggregated to produce this map.



Probability of marsh habitat map, year 2100

WETLAND LOSSES

- Existing marsh area, that in 2004 covered **108** acres, is predicted to be reduced by **27** acres by 2100 (this is the average of all uncertainty-analysis simulations). However, an additional **55-74** acres of marsh could be converted to tidal flats or open water in the 10% most extreme scenarios (i.e. modeled scenarios with the highest sea level rises).
- In addition, approximately **5** acres of current tidal flats or beaches are predicted to become open water by 2055, increasing to **16** by 2100.

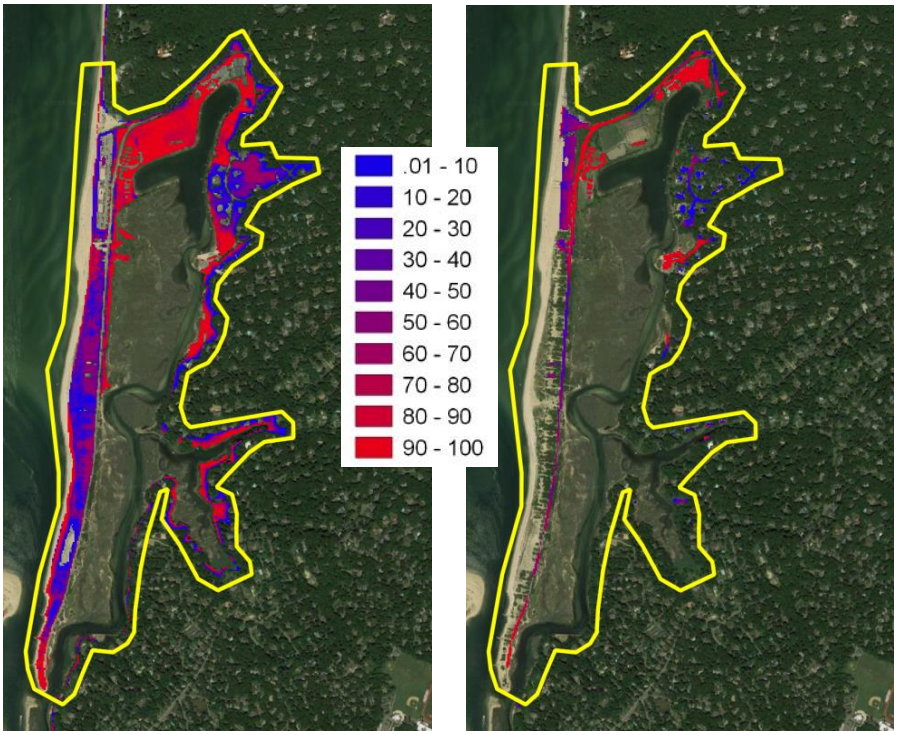
	Owner Type	2004	2055	2100
Existing marsh area (acres)	Public	19	16	14
	Private	90	87	68
Average new marsh area in undeveloped dry land (acres)	Public	0	7	23
	Private	0	7	22
Average new marsh area in developed dry land (acres)	Public	0	1.2	4.2
	Private	0	3.1	4.9
Total potential marsh area (acres)		108	122	136

Average marsh habitat predicted given SLR in the years 2055 and 2100. Private areas include tax parcels that are owned by the Ward Melville Heritage Organization Fund and an unknown owner.

POTENTIAL FOR MARSH MIGRATION

Wetland losses can be offset by **marsh migration** in areas that are currently dry land but predicted to become regularly inundated in the future.

- On average, **14** acres of new marsh could be expected to establish in current undeveloped dryland by 2055, or up to **45** acres by 2100. The maximum possible area of new marsh would be **80** acres under the highest SLR scenario.
- In addition, properly restored developed dry land could accommodate the establishment of an average **4** acres of marsh by 2055 and **9** acres by 2100, with a possible maximum area of **14** acres. (Note, some of these developed areas include roads that are likely to be maintained as such in the future.)



Areas that could accommodate marsh establishment by 2100. left: in currently undeveloped dry land areas, right: in developed ones. Colors reflect the probability of marsh habitat.

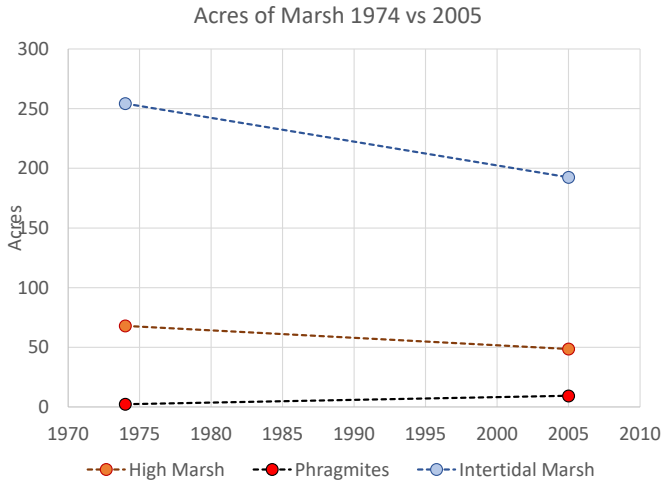
SUMMARY

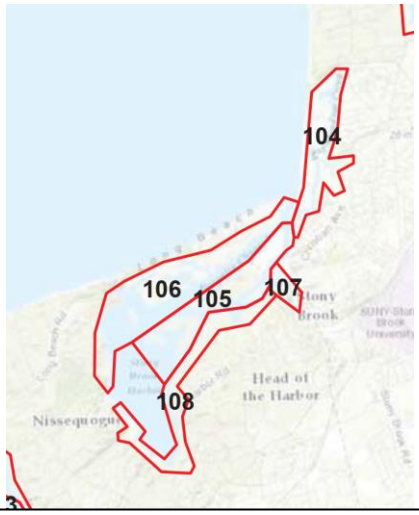
Although the **108** acres of marsh (as of 2004) are predicted to remain viable under a wide range of possible sea level rise increases, by 2100 marsh areas may be reduced to a total of **8** acres under more extreme scenarios. However, marsh losses could be offset by the migration of marshes onto newly-inundated dry lands. If **marsh migration** is allowed, an average of **19** acres of current dry land could accommodate new marsh by 2055 and **54** acres by 2100 (This number could stretch to **94** acres of new marsh under more extreme SLR scenarios).

APPENDIX B: HISTORIC TRENDS FROM VARIOUS PORTIONS OF THE STUDY AREA

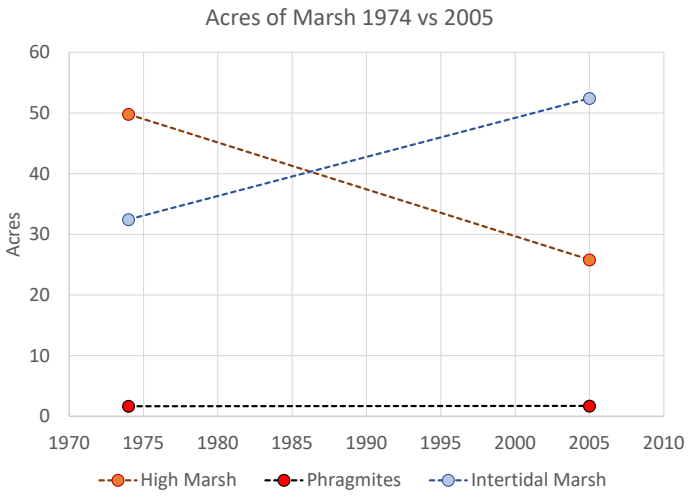
In 2015 Cameron Engineering & Associates prepared a Long Island Tidal Wetlands Trends Analysis for the New England Interstate Water Pollution Control Commission. This analysis classified color-infrared imagery from 1974 and 2005 using the same process, noting "the red and infrared bands of the electromagnetic spectrum are particularly suited for effectively differentiating between tidal wetland species" (Cameron Engineering & Associates 2015). Results for the entire study area have been aggregated and graphed in the figure below and each of the study areas is also graphed in the following pages.

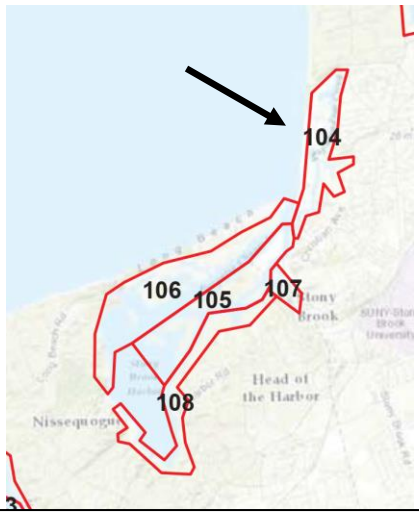
Stony Brook Harbor and West Meadow
(Sites 104-108)



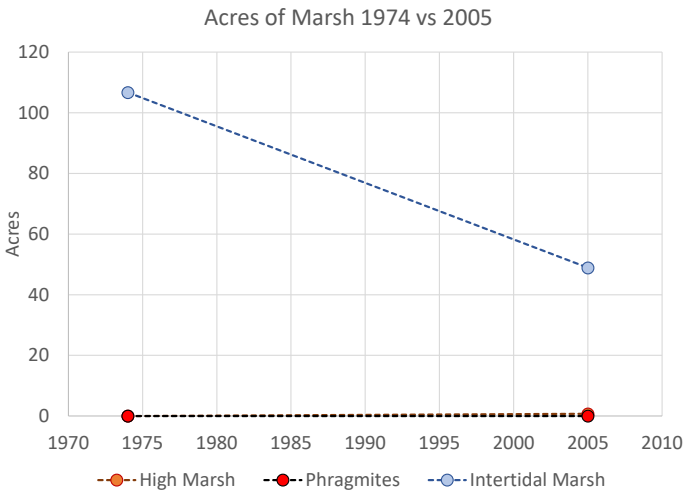


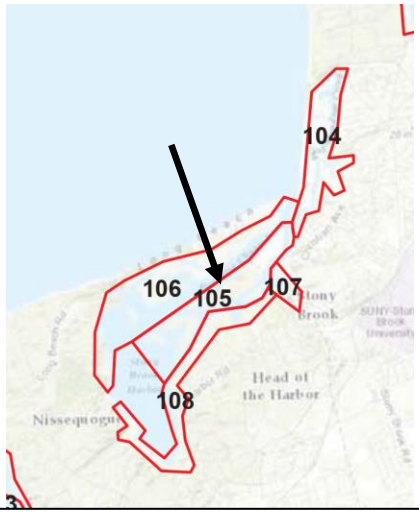
West Meadow Creek (104)





Porpoise Channel (105)

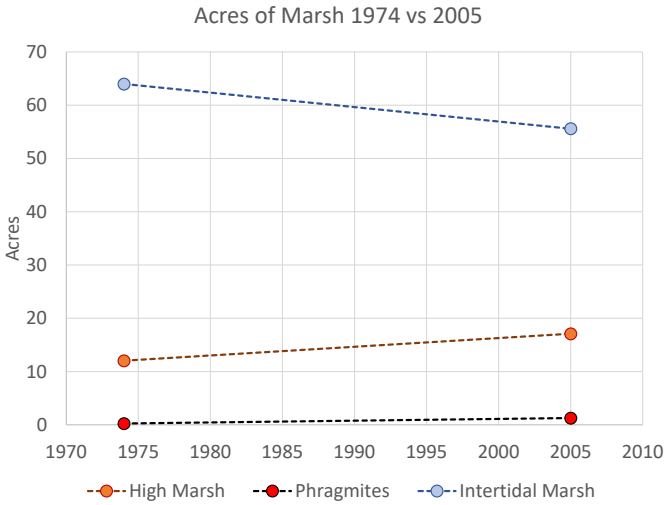


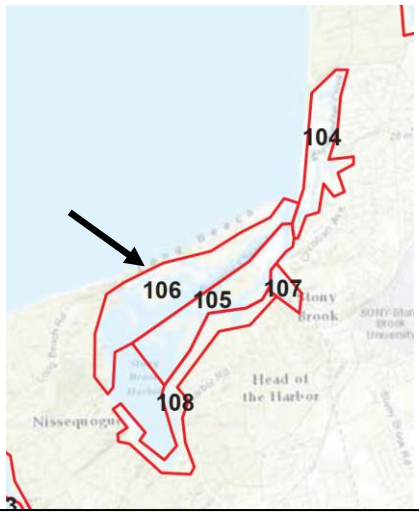


Note this area includes the marsh islands south of Porpoise Channel as well.

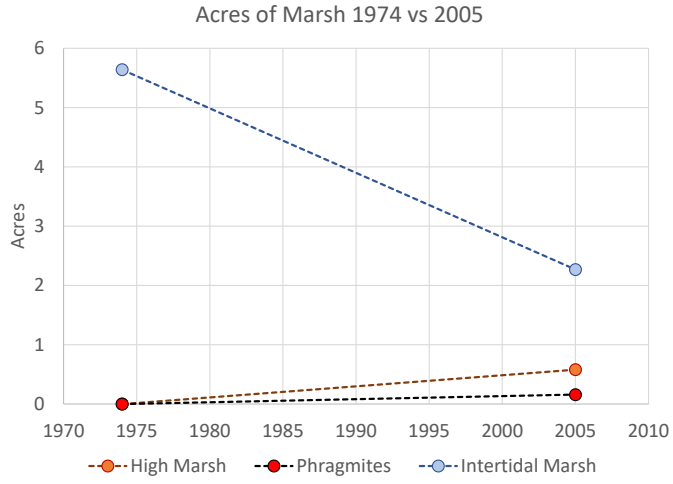
For the Porpoise Channel area (105), several stakeholders suggested that the extent of this loss was overestimated by this analysis.

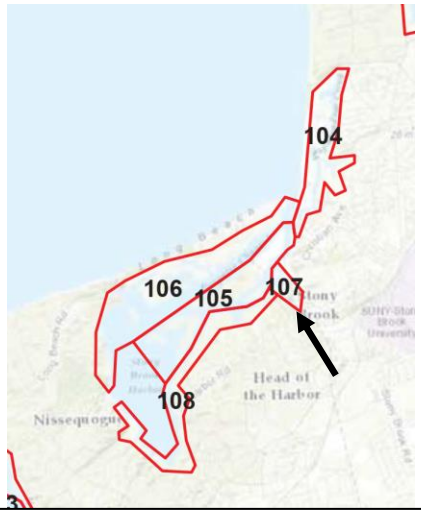
Stony Brook Harbor North (106)





Stony Brook Creek (107)





Stony Brook Harbor South (108)