MARSH CONSERVATION PLANNING FOR OYSTER BAY AND COLD SPRING HARBOR NY

NEIWPCC

December 22, 2023

NOTICE

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Long Island Sound Study
A Partnership to Restore and Protect the Sound

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 Sarah Schaefer-Brown and Elizabeth Hornstein, the Sustainable and Resilient Communities (SRC) Extension Professionals for Nassau and Suffolk Counties. The cover photo of the marsh at Frost Creek is courtesy of Alexa Fournier**.**

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:

- Garrett Chelius (Town of Huntington)
- Sara Covelli (Town of Oyster Bay)
- Rob Crafa (OBCHPC)
- Christopher DeNatale (Bayville Environmental Conservation Commission)
- Mayor Daniel Devita (Village of Laurel Hollow)
- Alexa Fournier (NYSDEC)
- Katie Friedman (Save the Sound)
- Carol Harrington (Deputy Mayor Village of Lattingtown)
- Louise Harrison (Save the Sound)
- Elizabeth Hornstein (SRC Extension Professional for Suffolk County)
- Jane Jackson (North Shore Land Alliance)
- Heather Johnson (Friends of the Bay)
- Shauna Kamath (NYSDEC)
- Glenn Kempa (Friends of the Bay)
- Kim Koerner (Town of Oyster Bay)
- Kristen Lacetti (USEPA)
- Barry Lamb (Friends of the Bay)
- Nicole Maher (The Nature Conservancy)
- Mary Beth Mills-Curran (St. John's Church)
- Joyce Novak (Village of Bayville Environmental Conservation Commission)
- Gideon Pollach (St. John's Church)
- Samarra Scantleberry (NYSDEC)
- Sarah Schaefer-Brown (SRC Extension Professional for Nassau County)
- Mayor Larry Schmidlapp (Village of Centre Island)
- Steve Schott (Suffolk CCE)
- Christine Suter (Friends of the Bay)
- Mary Gay Townsend

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EXECUTIVE SUMMARY

Oyster Bay and Cold Spring Harbor are located on northern Long Island, span several towns and villages, and are rich with marsh resources. This 39 square-mile watershed is primarily located within the Town of Oyster Bay, its incorporated villages, and unincorporated hamlets. Estimates of current marsh habitat include approximately 78 acres of regularly-flooded marsh (intertidal marsh) and 206 acres of irregularly-flooded marsh (higher-elevation marsh, often brackish.) Marsh systems examined in this report also include those in Frost Creek in the Village of Lattingtown (Figure 1).

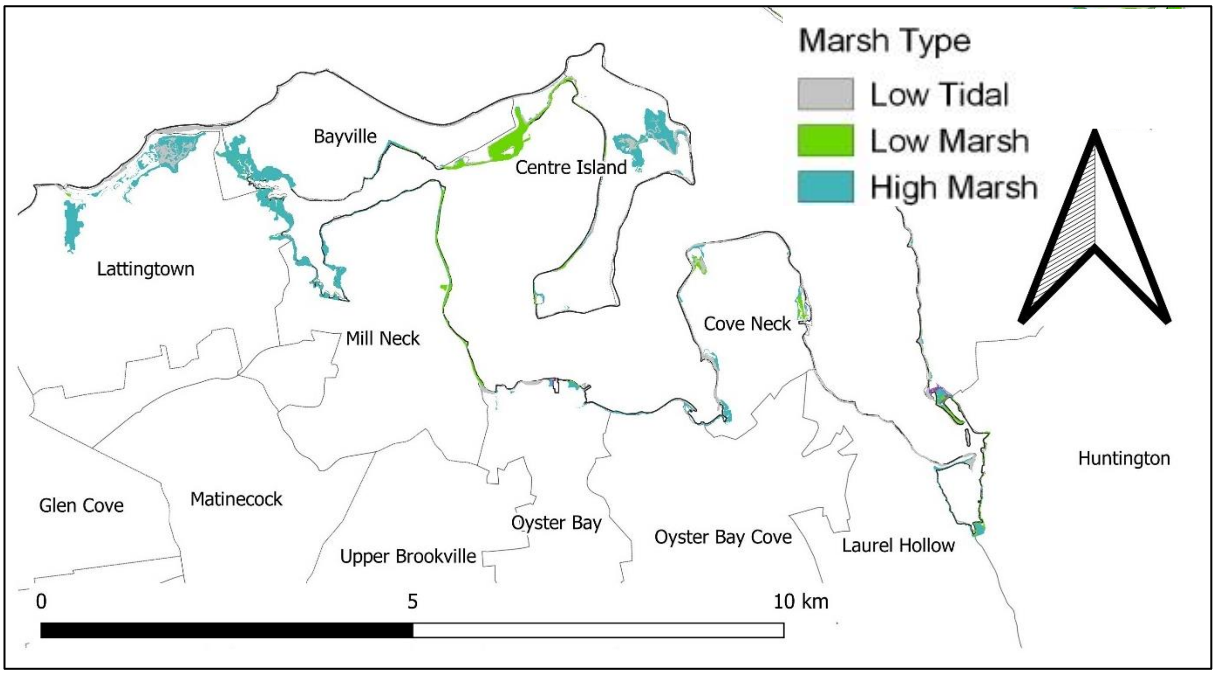

Figure 1. Current marsh habitat and potential marsh habitat overlaid on Oyster Bay and Cold Spring Harbor and relevant municipalities

Like all coastal marshes, the marshes of Oyster Bay and Cold Spring Harbor are dynamic and have been evolving over time. An evaluation of recent historic trends in these marshes (1974 to the mid-2000s) suggests that "high marsh" habitat has remained fairly constant, while intertidal low marsh has been subject to moderate losses since the 1970s. Exacerbating this trend, current marsh resources will be under additional pressure in coming decades as sea levels are predicted to rise at an elevated pace. For this reason, managing current and potential-future marsh habitats will be important to ensure that the ecosystem services that are provided by these marshes can be maintained.

Working with the stakeholder group for this project, seven locations were identified as focal areas to discuss in terms of specific characteristics and marsh-management options. The seven locations chosen (roughly west to east) were Frost Creek, Mill Neck Creek, West Shore Road, Bayville Bridge to Centre Island, Centre Island, Shore Road, and Lower Cold Spring Harbor (Figure 2).

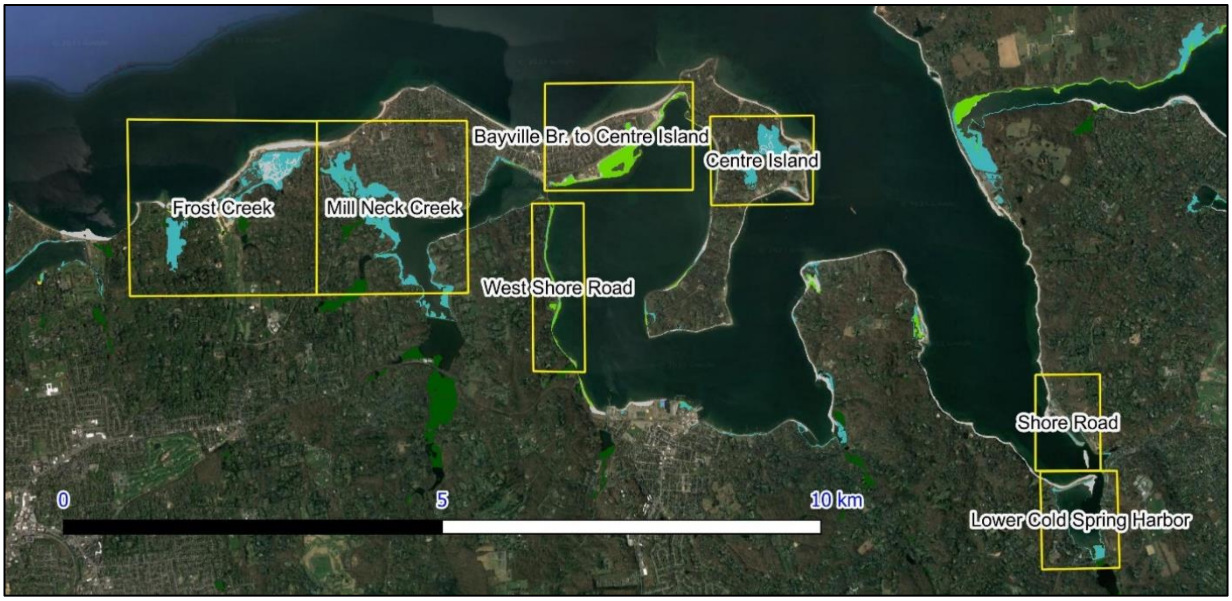

Figure 2. Seven focal areas for marsh management planning. (Satellite imagery from Google)

The coastal marshes of Oyster Bay and Cold Spring Harbor provide numerous benefits—both human-centered and ecological. Some of the services that these marshes provide include:

- **Wave Attenuation:** Wave action can be significantly reduced on coastal shorelines adjacent to marshes because coastal marshes can act as a buffer zone and absorb wave energy. This may be especially relevant to The Village of Bayville and the West Shore Road locations that suffered coastal storm damage from Hurricane Sandy, in 2012, among other storms. In 2015, the US Army Corps of Engineers estimated that Bayville will sustain over 7 million dollars in annualized storm damages without further mitigation measures in place (NYSDEC and USACE 2016, Appendix C).
- **Habitat:** The marshlands in this region provide significant bird habitat, and form the base of the food web for gamefish, and predator species, such as ospreys. These marshes are also inhabited by shellfish species, including Atlantic ribbed mussels, blue mussels, and eastern oysters. Many important recreational and commercial fishery species are supported by the marshes. Another local species that relies on tidal-wetland habitats is the diamondback terrapin.
- **Rare and Endangered Species:** There are many federal and state-designated endangered and threatened species that are supported directly or indirectly by the marshland habitat of Oyster Bay and Cold Spring Harbor, including bald eagle, peregrine falcon, least tern, harbor porpoise, and saltmarsh sparrow.
- **Recreation and Natural-Area Proximity:** The marshes of this region have long provided a draw for kayaking, fishing, and wildlife viewing.
- **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.

As noted, marshes are dynamic systems, and there is some evidence that marsh habitat has declined over recent decades. Potential threats to marshes are considered in this plan to preserve marsh habitat and maximize ecosystem services. These threats include invasive and non-native species that will take over native marsh habitat. One notable example is Phragmites (common reed) that poses a threat to lower-salinity locations when water drainage is insufficient. Water quality can also pose a threat to marshes; when nutrient levels are too high, marshes produce less roots and erosive losses occur more frequently. Water quality is variable throughout this study area, with better quality indicators in the central waters of Oyster Bay and more problematic water-quality indicators for Mill Neck Creek and Inner Cold Spring Harbor. Hardened shorelines and vertical walls to protect infrastructure are another threat to adjacent coastal marsh, especially under conditions of rising sea levels. An additional unintended impact of hardened shorelines and seawalls can be the lateral transmission of wave energy that promotes erosion in adjacent natural areas.

Finally, sea-level rise (SLR) and the changing intertidal footprint will challenge marshes in several ways. Some of the lower-elevation marshes are likely to see erosion to open water; some of the higher-elevation marshes are predicted to go through an ecosystem transition to lower-elevation more-saline marsh. Appendix A in this report presents a summary of model predictions designed to estimate the fate of coastal marshes under an uncertain sea-level rise, and to show locations that may support marsh habitat in the future. These model results suggest that predicted losses of marshes under sea-level rise can potentially be offset if some adjacent land is made available for marsh migration. Therein lies a challenge, however, as adjacent lands are often privately owned or are used for residential or recreational purposes.

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. These tools include the managing of current marsh resources (including making improvements in water quality), land purchases and easements to enable marsh migration, local regulation, and marsh restoration.

Marsh restoration is the process of modifying former wetland locations to promote current and future marsh habitation. Marsh restoration remains a top priority of federal, state and local governments. Within the focal areas of this study, historical marsh losses have apparently been most significant in Inner Cold Spring Harbor and along West Shore Road, potentially making these the most appropriate locations to propose marsh restoration. Furthermore, any marsh restoration project needs to ensure that adequate sediment supply exists for the project to be successful.

As environmental and physical characteristics change, careful management of the extensive current marsh resources in Oyster Bay and Cold Spring Harbor 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. As noted above, managing water quality will also be an important management technique. Water-quality improvements are especially important for Inner Cold Spring Harbor and Mill Neck Creek.

Land-conservation priorities can 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.

Working with stakeholders, specific recommendations for each of the seven focal areas have been made and are shown below in Table ES1.

Table ES1: Summary of marsh-system focal areas, primary threats, and proposed marsh conservation actions

Marsh System	Primary Threats	Proposed Management Actions
Frost Creek	• sea-level rise • erosional losses	• baseline marsh inventory • work with local landowners to plan for SLR • land protection and easements to enable marsh migration
Mill Neck Creek	• water quality • sea-level rise	• local water quality regulation and improvements • monitor marsh health and density • improve local culverts and connectivity (Beaver Brook)
West Shore Road	• erosional loss from storms • sea-level rise	• living shoreline project to mitigate waves and provide ecosystem services
Bayville Bridge to Centre Island	• storm damage to marshes • water quality	• manage/repair current marshes • land protection and easements in select locations to enable marsh migration • local water-quality regulation and improvements
Centre Island	• potential for ecosystem transition under SLR	• gather data on baseline marsh health • continue to work with local landowners to manage and conserve private marshlands
Shore Road	• low elevation dry land at risk from sea-level rise • stormwater outflow issue	• combined bioswale and living shoreline on North Shore Land Alliance plot
Inner Cold Spring Harbor	• historical marsh loss exacerbated by sea-level rise • water quality	• gather data on marsh health • consider marsh restoration in areas where marshes were lost • advocate for local water quality improvements

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, planning, engineering, and finally construction on 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 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 intersects marsh land cover projections and tax parcel information has been developed (http://warrenpinnacle.com/LIMaps/).

Additionally, in cooperation with municipalities or other marsh-conservation stakeholder groups, three marsh-migration conservation plans have been developed, in addition to two marsh conservation plans that were developed in 2021 focused on additional marsh complexes. 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.

OVERVIEW OF MARSH RESOURCES

Oyster Bay and Cold Spring Harbor are located on northern Long Island, span several towns and villages, and are rich with marsh resources (Figure 3). The complex watershed is approximately 39 square-miles located in Nassau and Suffolk Counties. Approximately 80 percent of the watershed is located within the Town of Oyster Bay, its incorporated villages, and unincorporated hamlets (Friends of the Bay 2011). Estimates of current marsh habitat based on the National Wetlands Inventory indicate that this study area includes approximately 78 acres of regularly-flooded marsh (intertidal marsh) and 206 acres of irregularly-flooded marsh (higher-elevation marsh, often brackish.)

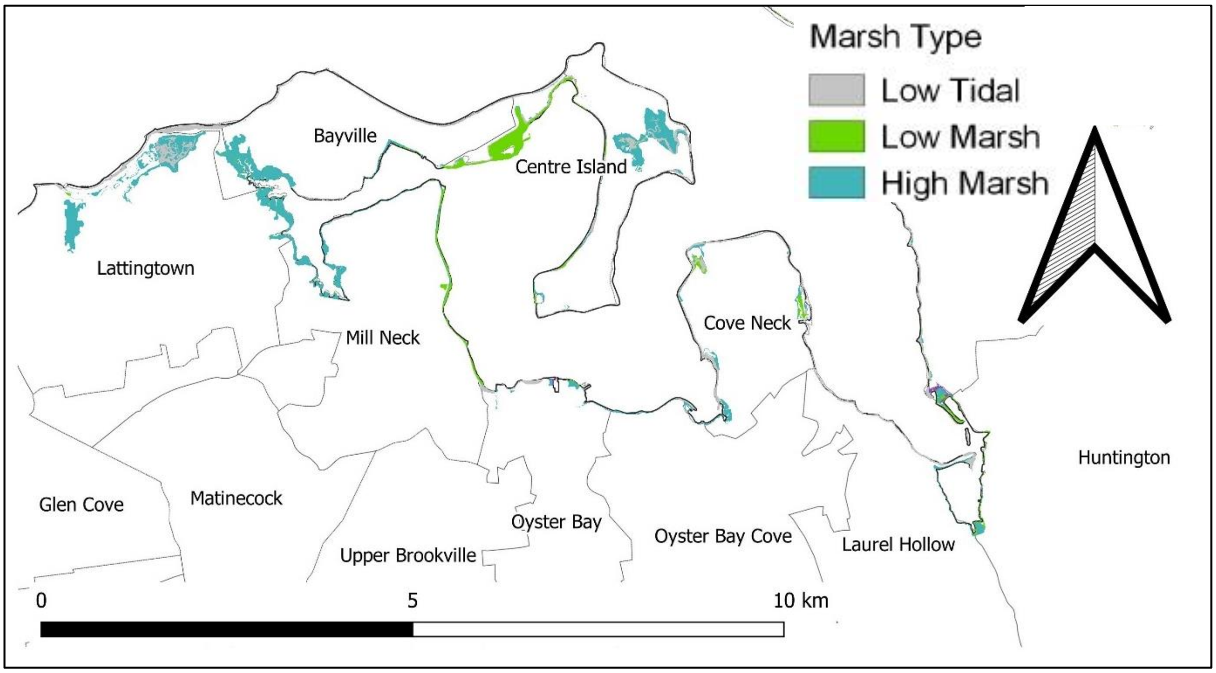

Figure 3. Current marsh habitat and potential marsh habitat overlaid on Oyster Bay and Cold Spring Harbor and relevant municipalities

While marshes in Oyster Bay and Cold Spring Harbor have remained a stable presence, the quantity and nature of these marshes have been evolving. An evaluation of the recent historic trends in these marshes suggests that "high marsh" habitat has remained fairly constant, while intertidal low 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 (Figure 4).

Exacerbating this trend, existing marsh resources will continue to be under pressure in coming decades as sea levels are predicted to continue rising at an elevated pace (see Appendix A). Nutrient loading, sediment supply issues, and wave erosion can also cause marsh losses independent of sea-level stressors (Fagherazzi, 2013). For this reason, managing current marsh habitats and associated watersheds, and understanding where marshes may be predicted to migrate under sea-level rise scenarios will be important to ensure that the ecosystem services that are provided by these marshes can be maintained.

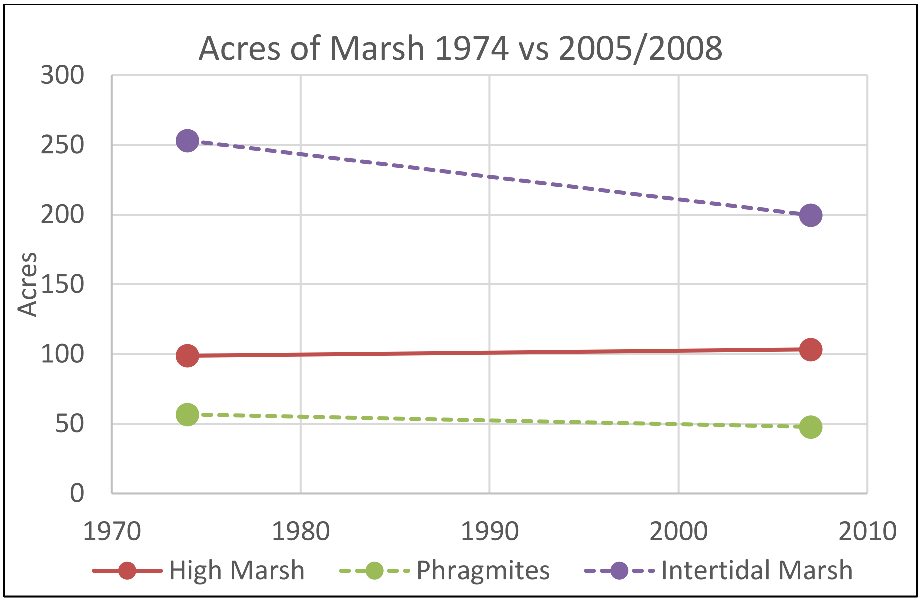

Figure 4. Acres of Marsh in the study area in 1974 and in the mid 2000s (An aggregate of sites 240-259 from Cameron Engineering 2015).

Salt marshes are highly productive systems, and therefore provide a multitude of services and resources to various wildlife – including finfish, shellfish, birds, mammals, reptiles, and other invertebrates. This immense productivity is driven by the high biomass and diversity of the marsh grasses. In addition, high marsh habitat can provide habitat for endangered or threatened species. For example, species like the highly threatened saltmarsh sparrow rely on high marsh habitat for nesting. Several saltmarsh sparrow sightings have occurred in Oyster Bay and there are multiple locations in the study area that are predicted to have a high likelihood of saltmarsh sparrow residency (Figure 5).

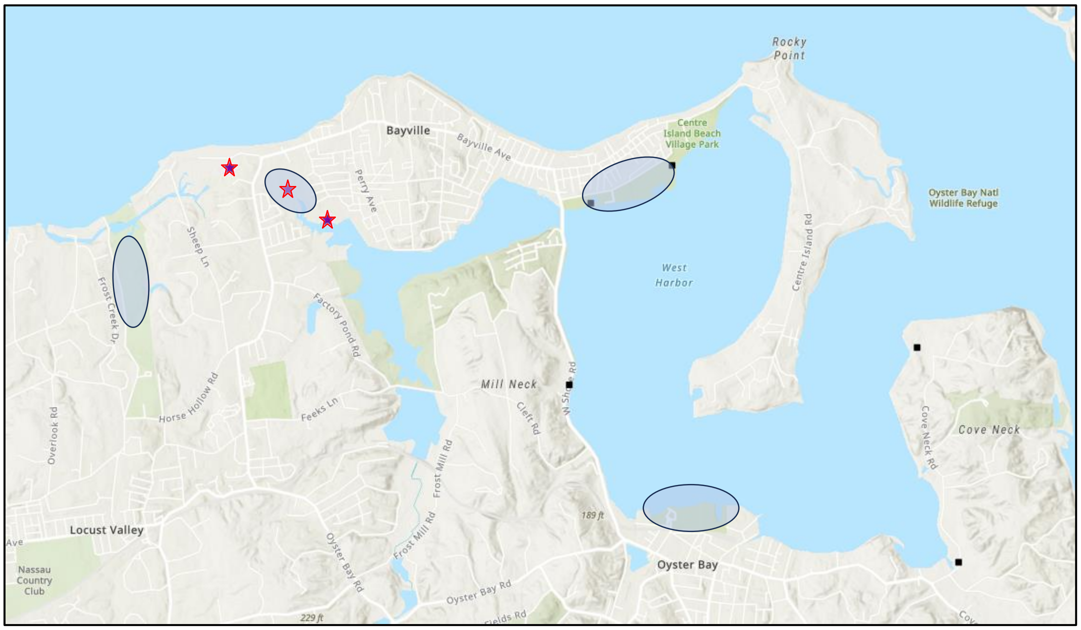

Figure 5. Saltmarsh Sparrow observations (red stars) and the general locations of predicted occupancy areas (blue ovals) within the study area. Atlantic Coast Joint Venture (2023)

As further evidence for the ecological importance of the marshes in this region, the majority of the marshes in Oyster Bay and Frost Creek are part of the Oyster Bay National Wildlife Refuge. This refuge was donated to the US Fish and Wildlife Service by the Town of Oyster Bay in 1968 because of its value as a habitat for migratory birds, particularly wintering waterfowl (USFWS 2006). The State of New York has designated the Oyster Bay area as a Significant Coastal Fish and Wildlife Habitat. Marine wildlife common to the refuge includes harbor seals, diamondback terrapins, and several species of sea turtles along with abundant shellfish and finfish (USFWS 2006). The Long Island Sound Study has identified all of Oyster Bay (Mill Neck Creek, Beekman Beach, and Oyster Bay National Wildlife Refuge) as a Stewardship Area because of its high ecological and recreational importance to the Sound.

It should be noted that the original inhabitants of the lands surrounding Oyster Bay and Cold Spring Harber Stony Brook Harbor were Delaware-Munsee speaking Indians whom the Dutch called the Matinecocks (Town of Huntington, undated). Colonists displaced native peoples from their native lands in the 1600's, and today this tribe is generally unable to access native lands due to the privation of much of the shoreline.

FOCAL AREAS FOR THIS REPORT

When initially defining "named marshes" for this project (which are separately evaluated and plotted in the marsh interactive fate viewer) 10 unique locations were identified (Figure 6). For each of these named marshes, a user can use the [online tool] developed by this project to plot current marsh habitat and predicted future marsh habitat given uncertain sea-level rise. Fact sheets were also developed for each of these sites, regarding marsh-fate modeling, and are presented in Appendix A of this report.

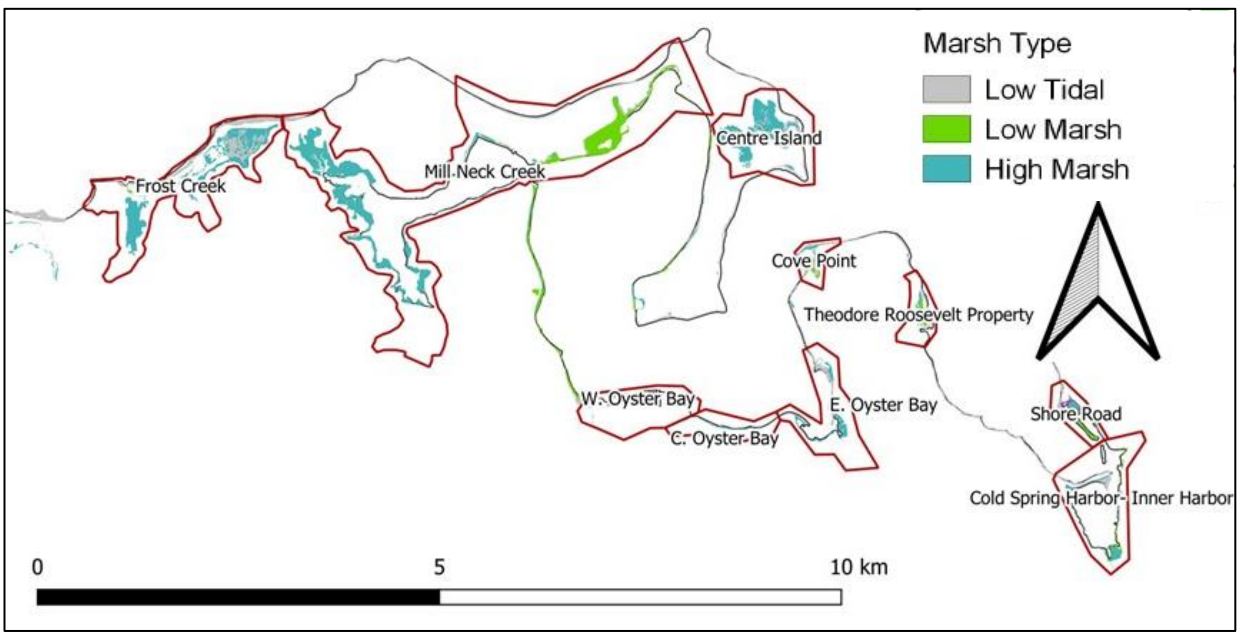

Figure 6. "Named Marshes" within the study area as defined within the Marsh Fate Interactive Viewer ([warrenpinnacle.com/LIMaps])

Working with the stakeholder group for this project, seven locations were identified as focal areas to discuss in terms of specific characteristics and marsh-management options. The seven locations chosen (roughly west to east) were Frost Creek, Mill Neck Creek, West Shore Road, Bayville Bridge to Centre Island, Centre Island, Shore Road, and Lower Cold Spring Harbor (Figure 7). In this document, each of these locations will be examined independently as to its predicted fate under sea-level rise, and its specific challenges and opportunities for marsh management.

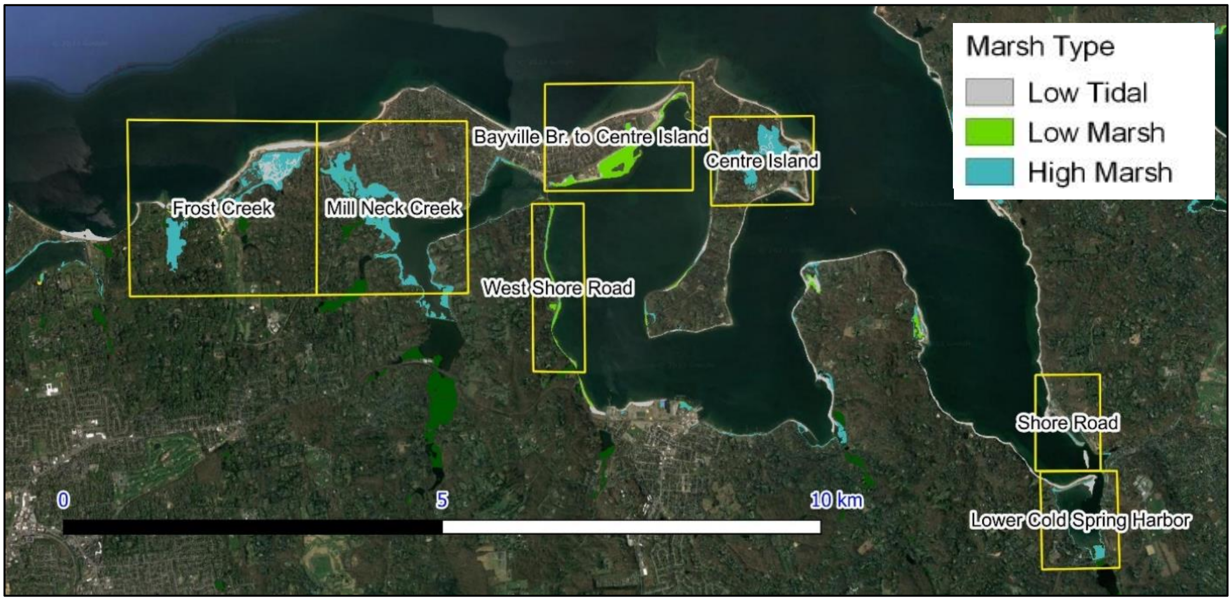

Figure 7. Seven focal areas for marsh management planning. (Satellite imagery from Google)

While these seven locations were identified as specific areas to consider in terms of specific management actions, there remain several other important marsh systems within the Oyster Bay and Cold Spring Harbor region. These marsh systems include Tiffany Creek (included as part of "Eastern Oyster Bay" in Figure 6 above), the Theodore Roosevelt Property, Cove Point, and Lloyd Harbor, to the northeast of the study area.

Frost Creek

Frost Creek is located in the Village of Lattingtown NY and includes approximately 73 acres of high-marsh habitat. Frost Creek tidal waters travel past a golf course before they reach the largest area of marsh in the northeast of this focal area (Figure 8). Most of these northeastern marshlands are part of the Oyster Bay National Wildlife Refuge. The tidal connection to these marshes has been historically dredged and the original path of the inlet was altered by the construction of an historic boat mooring area which has now been abandoned (Mushake 2010).

An additional large area of high-marsh habitat is present to the southwest of the study area and is partially owned by the Village of Lattingtown and is partially privately owned. This area has a high water table, and is saturated by the combined sources of fresh water from springs further inland and salt water coming from the Long Island Sound into Frost Creek. There is a canal system in this region that was historically maintained by Nassau County's mosquito prevention unit. This system has not been maintained for approximately 20 years and this has caused the canals to be clogged with vegetation restricting water flow out toward the Sound (Personal Communication, Carol Harrington, August 2023).

The Creek Club golf course is located in the south-central portion of the Frost Creek focal area and has several acres of potential high-marsh habitat along with some acreage of freshwater non-tidal marshlands. Built during the 1920s, The Club has recently been a partner in coastal marsh management, working to clear Phragmites infestations and plant native grasses. Notably, the Club has found it difficult to maintain soil and vegetation along the northern banks of Frost Creek and is currently consulting with an environmental firm to solve this problem (Personal Communication, Carol Harrington, August 2023). The Club does include many acres of low-lying lands that could be vulnerable to sea-level rise in the future (See Appendix A.)

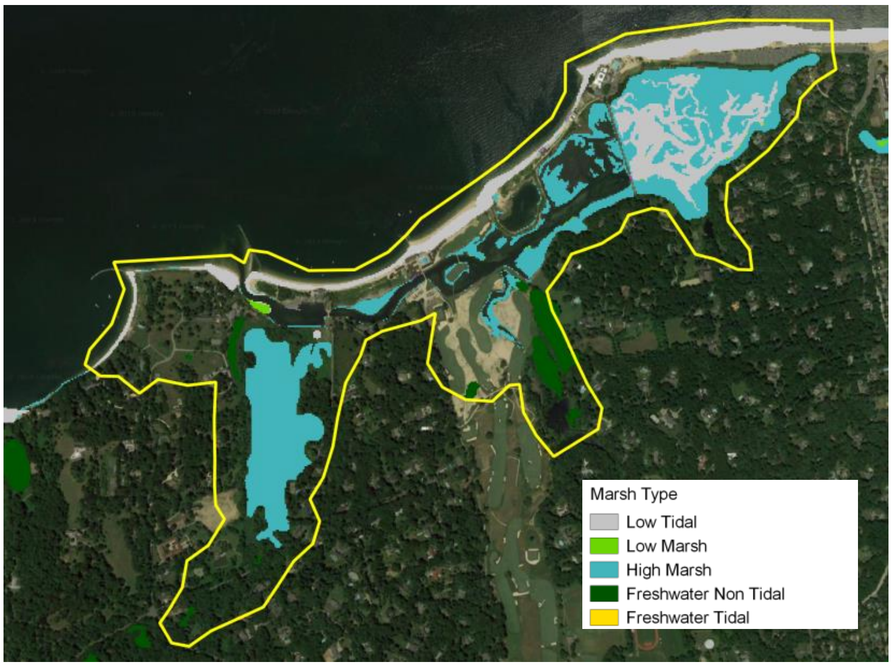

Figure 8. Satellite image of Frost Creek with current marsh coverage (Sources: NWI; Satellite imagery from Google).

MILL NECK CREEK

The Mill Neck Creek focal area includes both Mill Neck Creek and Oak Neck Creek which is the northerly tributary to Mill Neck Creek, and land in the Villages of Bayville, Mill Neck, and Lattingtown, NY. This location contains over 95 acres of irregularly-flooded marsh and scrub-shrub wetland habitat (Figure 9).

Mill Neck Creek is a narrow coastal bay that empties into the western side of Oyster Bay Harbor. Most of Mill Neck Creek is included in the Oyster Bay National Wildlife Refuge, and the wetlands are an integral part of the Oyster Bay Harbor ecosystem providing habitat for wintering winter waterfowl populations, and many other fish and wildlife species. The northwest portion of Mill Neck Creek (Oak Neck Creek) is owned as undeveloped Nassau County parkland and is bordered by moderately dense residential development on the north and east sides, and by large estates and undeveloped woodlands to the west and south (Bayville Village Board, 2002). Habitat in this area serves as an important nursery and feeding habitat for various marine species, such as scup, bluefish, Atlantic silversides, menhaden, winter flounder, and blackfish (Bayville Village Board, 2002). As noted above, several sightings of the highly threatened saltmarsh sparrow have occurred in this area, and Mill Neck Creek is predicted to have a high likelihood of saltmarsh sparrow residency (Figure 5). The wetland also contributes organic matter and nutrients to commercial oyster beds, located in Oyster Bay Harbor (Bayville Village Board, 2002).

There is a notable culvert located to the south of the study area north of Beaver Lake. This culvert marks the boundary of marsh habitat according to National Wetland Inventory, and marsh migration south into Beaver Lake may require additional restoration of tidal flows at this location. At this culvert, a fish passage was installed through a partnership of the New York State Department of Environmental Conservation, The Nature Conservancy, Friends of the Bay, USFWS and the Long Island Sound Study at Beaver Lake dam in 2017. The fish passage opened up 1.5 miles of stream corridor and 110 acres of associated wetlands to migratory fish (Fuss & O'Neill, 2017). However, there are additional culverts upstream on Beaver Brook (further south) that likely restrict the passage of aquatic organisms.

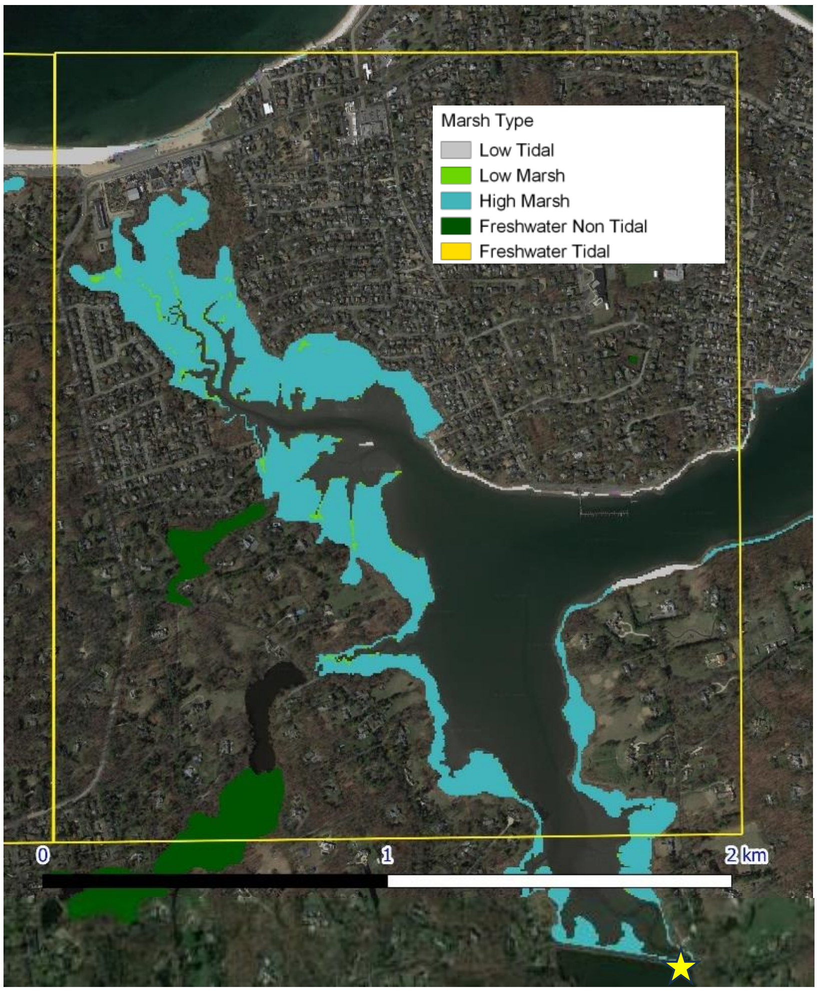

Figure 9. Satellite image of Mill Neck Creek with current marsh coverage (Sources: NWI; Satellite imagery from Google). The approximate location of the Beaver-Lake Dam culvert is marked with a star at the bottom of the image.

WEST SHORE ROAD

The West Shore Road focal area is located in the Village of Mill Neck NY and contains approximately three acres of high marsh in a thin north-south strip (Figure 10). This location has been proposed as the site of a living shoreline within the Oyster Bay/Cold Spring Harbor Complex to potentially provide dual benefits of flood protection and ecological restoration. The town of Oyster Bay's proposal outlines nature-based solutions including wetland marsh plantings and oyster reef structures (Town of Oyster Bay, undated). Project goals are to address the threats of key habitat loss, flooding and coastal erosion, and the impacts of excess nutrients from stormwater pollution. The Town continues to be interested in restoring and expanding key habitat and improving infiltration through marsh wetland and oyster habitat restoration at this site.

In addition to the larger wetland parcels pictured below, there are also some unregulated (due to the size) wetlands that empty into Oyster Bay on the west side of West Shore Road. Due to their size and unregulated status, these wetlands are in danger of being developed.

Figure 10. Left: satellite image of West Shore Road with current marsh coverage (Sources: NWI; Satellite imagery from Google); Right: Photo taken of the fringing marsh taken from West Shore Road (Photo Credit Sarah Schaefer-Brown).

BAYVILLE BRIDGE TO CENTRE ISLAND

The marshes on the south of Bayville in the focal area that spans from Bayville Bridge to the Village of Centre Island include nearly 50 acres of intertidal marsh habitat (Figure 11). These marshes fringe the southern shore in the eastern end of the Village of Bayville between the Oak Neck upland and the Centre Island Village Beach and Turtle Cove. This tombolo area was formed by the long-shore currents in Long Island Sound transporting sandy deposits from the main Oak Neck portion of Bayville to the east to eventually connect with Centre Island. While the area generally includes rapidly-draining soils, due to the low elevations and gentle slopes it is susceptible to flooding during heavy rains and coastal storms. The Bayville Bridge was first constructed in 1898 adding a shorter access route from the south to the Village.

The Town of Oyster Bay has been proactive in managing and establishing new marsh grasses in this location. For example, in 2014-2016 the Town worked with NYSDEC personnel to transplant and establish new marsh grasses at Centre Island Beach. In total, 6,000 new Spartina plugs were planted to the east and west of the swim area and 3,000-square feet of existing Spartina were transplanted to approved areas at Centre Island Beach, resulting in additional marsh habitat and improved water filtration (Town of Oyster Bay, Personal Communication, December 2023).

Figure 11. Satellite image of Marshes South of Bayville with current marsh coverage (Sources: NWI; Satellite imagery from Google).

CENTRE ISLAND

The Centre Island marshes are primarily high marshes, with over 55 acres of habitat identified as current or potential irregularly-flooded marsh habitat (Figure 12). The Village of Centre Island consist primarily of residential land use, the Village is connected to the west to the Village of Bayville by the narrow isthmus and most of the coastline of the Village is within the Oyster Bay National Wildlife Refuge. The majority of the marshlands to the east are owned by the Village of Centre Island. Those inland to the west are privately owned by a homeowner's association made up of 10-12 property owners (personal communication, Mayor Schmidlapp, October 2023).

In the year 2000, a self-regulating tide gate was installed between the two marshes pictured in Figure 10 below. The existing culvert had been restricting tidal flow to inner marsh. The tide gate functions as intended but it does regularly become clogged with Phragmites and debris and needs to be cleaned out frequently.

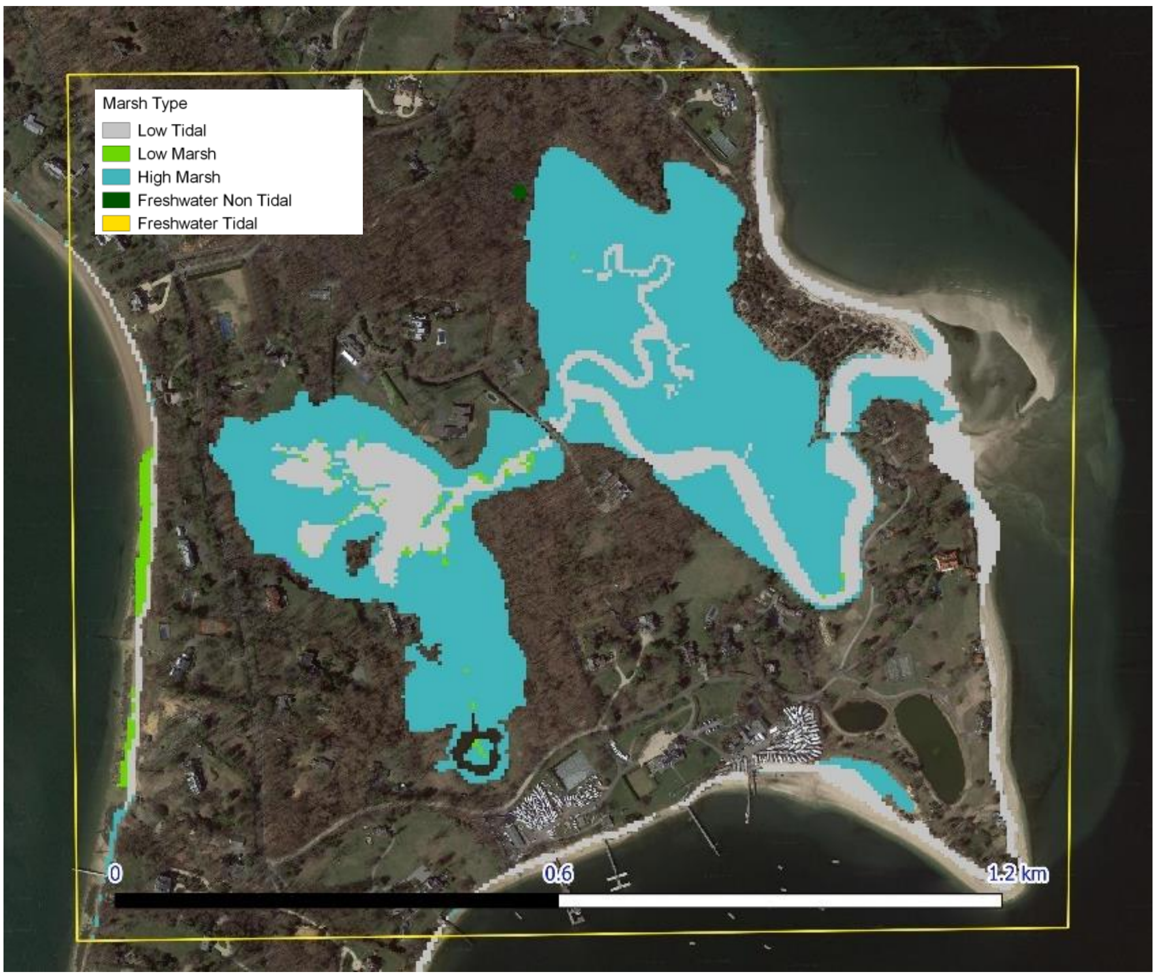

Figure 12. Satellite image of Centre Island with current marsh coverage (Sources: NWI; Satellite imagery from Google).

Shore Road

Based on the National Wetland Inventory, the Shore Road focal area does not currently include tidal emergent marsh, being dominated by the low-tidal category that includes non-vegetated tidal flats and beaches (Figure 13). However, the potential for future marsh habitat is strong at this location. As will be discussed later in this report, a fairly large portions of this area may convert to marsh habitat by the end of the century, and much of that land is held by North Shore Land Alliance (see Figure 26).

Figure 13. Satellite image of Shore Road with current wetland coverage (Sources: NWI; Satellite imagery from Google).

INNER COLD SPRING HARBOR

The Lower Cold Spring Harbor study area includes over 10 acres of current and potential high marsh habitat including the Saint John's Marsh at the south of the focal area (Figure 14). The Saint John's Marsh is a 6-acre irregularly-flooded marsh (high marsh) located at the head of Cold Spring Harbor. Historical aerial imagery has shown that the marsh has undergone some landward retreat in recent decades (Friends of the Bay, 2018).

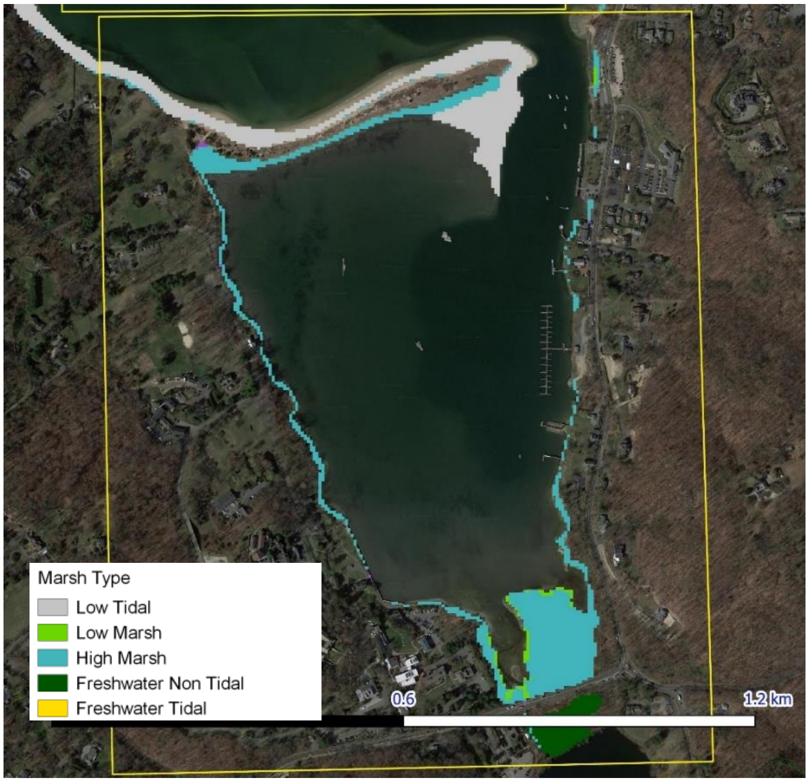

Figure 14. Top, Satellite image of South Cold Spring Harbor with current and potential marsh coverage (Sources: NWI; Satellite imagery from Google). Bottom: Photo looking north from Saint John's Marsh (Source Sarah Schaefer-Brown)

BENEFITS FROM LOCAL MARSHES & ADJACENT HABITAT

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

- Wave attenuation/Flood damage reduction
- Habitat
- Rare, Threatened, and Endangered Species
- Recreation and Natural-Area Proximity
- Water Quality Protection

Discussion of these benefits, and specifically how they pertain to Oyster Bay and Cold Spring Harbor follows.

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 (Shepard et al 2011). By stabilizing sediment through their above and belowground biomass, marshes have been shown to reduce coastal retreat. 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.). The presence of marsh vegetation substantially mitigates infrastructure damage to the shoreline as relative structural loss is correlated to the percent of wetland cover (Sheng et al. 2021).

The village of Bayville is especially prone to regular flooding. As a 2016 coastal storm risk management study notes: "Bayville has experienced coastal storm damage due to Hurricane Irene (2011), Tropical Storm Lee (2011), and Hurricane Sandy (2012). The majority of damage was the direct result of inundation; however, Bayville is also susceptible to damages caused by wave attack and beach erosion as evidenced by the effects of the powerful nor'easter of December 1992" (NYSDEC and USACE 2016). By maintaining and enhancing the tidal marsh south of flooded lands, the extent of additional flooding may be reduced. For example, the neighborhoods north of West Harbor Drive are protected from wave impacts from the south by existing marshes (Figure 11).

Another location in the study area that is protected by existing marsh lands is West Shore Road (Figure 10). This road was partially washed away during Hurricane Sandy in 2012; and expansion of and augmentation of marsh lands to the east of the road should help protect the road and the property behind it from additional damages.

HABITAT

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 (*lva 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, 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 Oyster Bay and Cold Spring Harbor as predation refuge, breeding, mating, and/or nesting grounds, or a rest stop along the Atlantic Flyway. The diversity of marsh plant species 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 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 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). Several saltmarsh sparrow sightings have occurred in Oyster Bay (in the area of Mill Neck Creek and Frost Creek) and, as noted above, there are several locations in the study area that are predicted to have a high likelihood of saltmarsh sparrow residency (Figure 5).

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 and there is at least one pair of nesting bald eagles in the Mill Neck Creek area.

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.

Nekton and Shellfish Habitat

Nekton are aquatic organisms that are able to swim in the water column, independent of currents or wind energy – including zooplankton, 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 vs. interior is considered especially important habitat. 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."

Shellfish species, including Atlantic ribbed mussels, blue mussels, and eastern oysters, are 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 that spend part of their life cycle swimming within the water column until settling occurs. Once settled and anchored down, they feed by filtering nutrients from the water column.

Marshes are also 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). These migrating species are called diadromous fish, and they spend part of their life in salt water environments and part of their life in freshwater environments. For example, alewife spend their life in saltwater and migrate into the marshes to reproduce in the freshwater reaches of tidal rivers and streams. In this case, salt marshes provide a connector pathway for these fish species to complete their migration in order to successfully reproduce. A remnant alewife spawning run has been documented within Mill Neck Creek at the fish passage constructed in 2017 on Cleft Road at Beaver Lake. This run has been bolstered by several years of alewife stocking by NYSDEC, Hofstra University, Cold Spring Harbor Fish Hatchery, and Seatuck Environmental Association at the site. There is an ongoing effort to assess and recommend modifications, where appropriate, to improve resiliency and aquatic organism passage at the culverts on Beaver Brook upstream of Beaver Lake within Shu Swamp Preserve and Upper Francis Pond Preserve.

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 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).

Within Oyster Bay, beaches on the south shore of Bayville are known to be nesting sites for diamondback terrapin but raccoon predation has recently prevented successful hatching. The town has been tracking terrapins in the area with the help of Friends of the Bay. Terrapin nest covers were also created to deter predation and the town is currently creating environmental signage to encourage the pubic help with Terrapin monitoring.

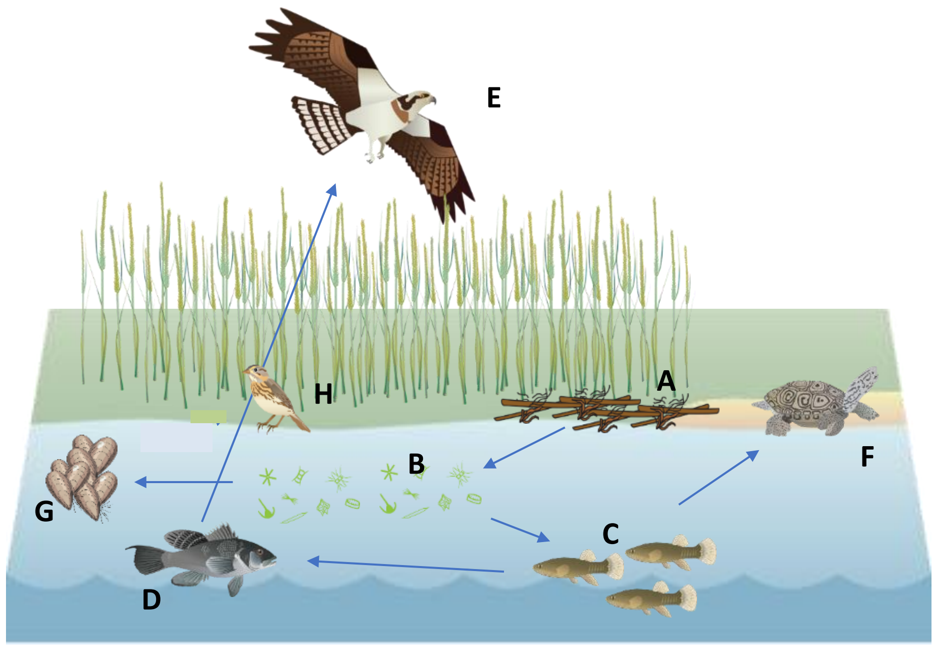

Figure 15. Conceptual Diagram of a Salt Marsh Food Web

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. From there, two additional pathways are created, where 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 then further 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.

SHELLFISHING

The Oyster Bay/Cold Spring Harbor Complex has the potential to be the site of one of the most economically important shellfisheries in the State. Up until fairly recently, up to 90% of New York's oyster crop and up to 33% of the State's hard clam crop was harvested from the National Wildlife Refuge at this site (Friends of the Bay, 2011). However, harvests have gone into a precipitous decline over the last ten years. It is unclear if this decline has been due to predators, impacts from dredging, or other environmental factors. However, there are ongoing efforts to restore oysters in the harbor and a healthy marsh system will be a vital part of restoring this ecosystem service to the region. To ensure the compatibility of shellfish harvesting with the health of adjacent marsh habitat, towns may consider regulating the harvesting within a certain distance of the shoreline to prevent marsh vegetation from being dug up and or damaged.

RARE, THREATENED, OR ENDANGERED SPECIES

There are many federal and state-designated endangered and threatened species that are supported directly or indirectly by the marshland habitat of Oyster Bay and Cold Spring Harbor, including the following species

- Bald eagle (Federal and State threatened)
- Peregrine falcon (State endangered)
- Northern harrier (State threatened)
- Hawksbill (Federal and State endangered)
- Harbor Porpoise (State species of special concern)
- Least tern (State threatened)
- Black skimmer (State species of special concern)
- Kemp's ridley sea turtle (Federal and state endangered)
- Atlantic loggerhead sea turtles (Federal and state threatened)
- Saltmarsh sparrow (State High Priority Species of Greatest Conservation Need)

A thorough list of threatened and endangered species in the study area may be found in Appendix A of the USFWS Comprehensive Conservation Plan for Oyster Bay (USFWS 2006).

Recreation and Natural-Area Proximity

Healthy marsh ecosystems provide a draw for human recreation, fishing, and wildlife viewing. There are recreational benefits provided by nearly all of the marsh areas listed in this document. A few examples follow:

- Over fifty thousand anglers visit the Oyster Bay National Wildlife Refuge each year to fish for species including striped bass, weakfish, blackfish, mackerel, and flounder (USFWS 2006). Access is available from town launches and via Long Island Sound.
- Kayaking is popular in Oyster Bay with paddlers using town boat launches. Cold Spring Harbor is a top priority for a Suffolk County Blueway Trail that provides routes for non-motorized boats taking into account features such as scenic locations, good birdwatching, nearby businesses and parking (NYS Department of State, 2021).
- Motorized boating is possible through the public access point at Theodore Roosevelt Memorial Park at the Oyster Bay Western Waterfront Waterway Access Site (NYSDEC)
- Opportunities for paddling, sailing, environmental education, and tours aboard the National Historic Landmark oyster sloop the CHRISTEEN are available at The Waterfront Center at Theodore Memorial Park.
- The Theodore Roosevelt Sanctuary & Audubon Center in Oyster Bay offers year-round environmental educational experiences, including estuary exploration and guided tours.

Figure 16. . Recreational Boaters accessing the water via Beekman Beach in Oyster Bay (photo credit Victoria O'Neill)

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 gasses. Blue carbon storage has the ability to mitigate global warming impacts, and prevent 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 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 ecosystem health. Specifically, under consistently eutrophic conditions, marshes have been found to produce more above-ground growth than roots, and the below-ground biomass of bank-stabilizing roots is reduced (Deegan et al, 2012). This can result in marsh collapse and conversion to non-vegetated mudflats. Deegan and coworkers (2012) noted that “current nutrient loading rates to many coastal ecosystems have overwhelmed the capacity of marshes to remove nitrogen without deleterious effects.”

THREATS TO OYSTER BAY AND COLD SPRING HARBOR MARSHES

INVASIVES

Invasive and non-native species have the capability to degrade existing marshes and limit the ecological services that they can provide. For example, common reed (*Phragmites* sp.) is a highly invasive plant capable of degrading tidal ecosystems, and one that is having impacts on the coastal marshes of Oyster Bay and Cold Spring Harbor. Non-native, more aggressive variants of Common Reed can dominate ecosystems formerly occupied by native marshes. Once established, common reed can force out native plants and disrupt the delicate ecological balance of the marsh. For example, in the USFWS Comprehensive Conservation Plan for Long Island NWR Complex, Phragmites control is recommended because of its negative impacts on black ducks and other wintering waterfowl (USFWS 2006).

Common reed generally does poorly in highly saline environments. However, it begins to prosper and spread when freshwater and nutrients are made available. For this reason, restoration of tidal flows and increase of salinity to locations impacted by Phragmites is often part of a control regiment. There are patches of Phragmites found throughout the study area. One notable patch is located within the St. John's high marsh in Oyster Bay Harbor. The presence of Phragmites there could be connected to the salinity-lowering impact of fresh waters south of that marsh. As of the early 2000s, Frost Creek also had over 20 acres of Phragmites, a larger acreage than non-impacted high marsh (Figure 18).

Even if they are not invasive species, overabundant wildlife populations can threaten local marshes. Swans and Geese in particular consume large quantities of *Spartina* rhizomes, a consideration that should be included in marsh management or marsh restoration plans. For example, there is an ongoing problem with mute swans nesting on Saint John's Marsh in inner Cold Spring Harbor that potentially contributes to marsh retreat there. Appropriate fencing is sometimes a successful strategy in limiting overgrazing (USFWS 2006).

A local resource for invasive species management is available through LIISMA (Long Island Invasive Species Management Area, https://liisma.org/). This regional partnership provides information about local invasive-species identification, removal techniques, and laws and regulations that are relevant to managing invasive species.

WATER QUALITY ISSUES

There were four locations in Oyster Bay and Cold Spring Harbor that were individually assessed for water quality by the Save the Sound (Save the Sound, 2022, as summarized in Table 1).

Table 1. 2022 Save the Sound Health Explorer Grades for Oyster Bay and Cold Spring Harbor

	Oxygen	Chl-a	Clarity	Seaweed	Oxygen Saturation	**Overall**
Mill Neck Creek	A	D	F	F	F	**D**
Oyster Bay	A	D	B	C	A	**B**
Inner Cold Spring Harbor	A	F	B	B	F	**D**
Outer Cold Spring Harbor	B	D	A	C	B	**C+**

Source: https://soundhealthexplorer.org/fishable/

In general, water quality is better in the (often deeper) central waters of Oyster Bay and Outer Cold Spring Harbor with more problematic water-quality indicators for Mill Neck Creek and Inner Cold Spring Harbor. While oxygen levels are high throughout the study area, chlorophyll *a* levels are also high which is usually an indication of high nutrient levels. Water clarity, an indication of organic matter and suspended sediments, was generally good in the study area with the notable exception of Mill Neck Creek. Levels of seaweed and other macrophytes were generally considered to be excessive throughout the bay and harbor.

These somewhat-poor grades indicate that nutrient loadings continue to have a negative impact on the water quality overall. A study by Stony Brook University in 2020 found that Cold Spring Harbor was one of two waterbodies in Nassau County “with the greatest need of N mitigation” (Stony Brook University, 2020). The Nassau County Nine Element Plan identified wastewater from onsite septic systems as the largest source of nitrogen to all north shore bays. Septic and cesspool discharges from unsewered residential and commercial areas have resulted in degradation of water quality in Oak Neck Creek and the contiguous sections of Mill Neck Creek (Fucci and Gobler, 2022). When there are excess nutrients in the water column, algae growth is stimulated (indicated by high levels of chlorophyll-a and seaweed).

Other sources of nutrient loadings include stormwater discharges and waterfowl populations. For example, significantly elevated levels of fecal coliform bacteria have been measured near the outflow of Mill Pond and the Mill River and Beekman Creek in Oyster Bay which flow out into Oyster Bay Harbor. It is likely that waterfowl populations and stormwater discharges are contributing to the elevated levels at those locations. In inner Cold Spring Harbor, the Cold Spring Harbor Fish Hatchery provides an additional source of nitrogen loadings though efforts have been made to reduce the nitrogen loadings from this site.

As noted above, salt marshes can mitigate nutrient-loading impacts through nutrient sequestration or removal, however there is a threshold and, once exceeded, degradation occurs. In addition to posing a direct threat to coastal marshes, water quality also inhibits the ecosystem services that marshes can provide. For example, based on the NYSDEC Waterbody Inventory/Priority Waterbodies List, Cold Spring Harbor, Oyster Bay Harbor, and Mill Neck Creek are all considered impaired bodies of water for shellfishing, public bathing, and recreational use (NYSDEC 2001). Specific locations closed to shellfishing are shown in red in Figure 17 below.

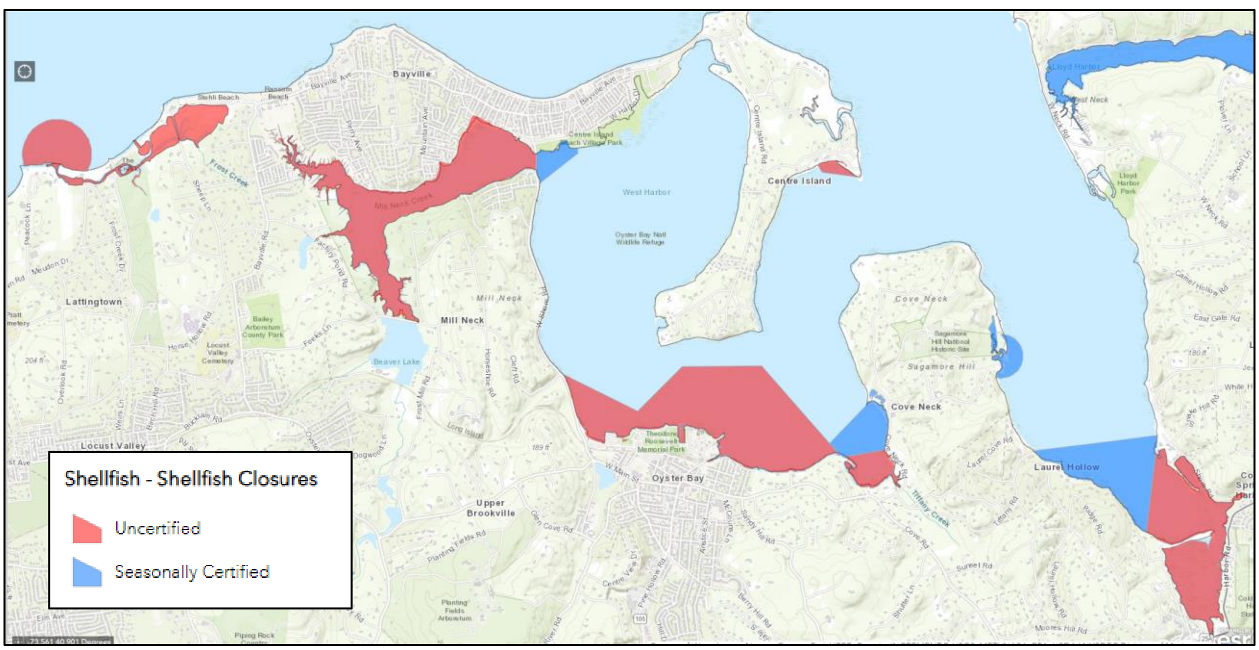

Figure 17. Locations in the study area closed for shellfishing due to water-quality issues (red regions). Source: NYSDEC 2023

When managing marshes within Oyster Bay and Cold Spring Harbor, and prior to undertaking marsh-restoration activities, it is likely worth assessing water quality further to ensure that high nutrient levels do not prevent a good outcome. Concrete steps taken to improve water quality will ensure that marshes can thrive in the study area. These actions will also provide benefits to the food web supported by these marshes, and human recreational and commercial fishing operations within the study area.

Unpermitted Uses

The marshes of Oyster Bay and Cold Spring Harbor are often adjacent to residential development and there are many recreational users of the wetlands and waterways. This raises the potential for damage to the marsh systems through historical or unpermitted uses. For example, there are a combination of permitted (grandfathered) and unpermitted docks in the National Wildlife Refuge. In other locations, unpermitted stormwater trenches may lead into the marshes resulting in fresh-water concentration and Phragmites infestation. Further monitoring of human activities and regulatory enforcement may need to be part of a marsh-management strategy in parts of the study area.

Development and Hardened Shorelines

Hardened shorelines and vertical walls to protect infrastructure can present a threat to adjacent coastal marsh. This type of building prevents lateral wetland migration, producing a coastal "squeeze," and will likely result in significant wetland losses under conditions of SLR (Nicholls et al., 1999). An additional unintended impact of hardened shorelines and seawalls can be the lateral transmission of wave energy that promotes erosion in adjacent natural areas. Furthermore, a seawall or any other type of shoreline armoring, can reduce access and availability of nesting and nursery habitat for marine species and foraging habitat for birds and deprive the shoreline and adjacent shoreline of sediment.

Within the study area, West Shore Road is protected by ``a seawall and, until a recent road elevation project, had major flooding issues during incidents of severe storm surge. The shoreline parallel to the seawall has experienced significant erosion. This is one location where a living shoreline has been proposed by the town of Oyster Bay to replace and supplement hardened shorelines. As will be discussed below, living shorelines are designed to provide marsh habitat on the water side, and also to raise elevation enough on the landward side to protect against storms and rising sea levels.

West of the Bayville Bridge along Mill Neck Creek, the Village's shoreline has been hardened by bulkheads and other structures associated with marina and oyster farming activities. Most of the private homes and lots that border on Mill Neck Creek in this area are subject to storm-related waves and currents, and the wave action generated by vessel wakes. Almost all of these residential properties have been reinforced and hardened in one way or another by the individual homeowners, which has abated erosion.

On the western side of lower Cold Spring Harbor, seawall construction has also been undertaken and recently augmented to protect Cold Spring Harbor Laboratory and its associated infrastructure.

Sea-Level Rise and Changing Intertidal Footprint

Appendix A presents a summary of SLAMM model predictions designed to estimate the fate of coastal marshes under an uncertain sea-level rise, and to show locations that may have elevations that could support marsh habitat in the future. These model results suggest that predicted losses of marshes under sea-level rise can potentially be offset if some adjacent land is made available for marsh migration. 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/).

Many of the marshes in the study area are currently irregularly-flooded marshes, meaning that these marshes are high enough in elevation relative to the tide range that they are not flooded daily. These types of marshes do have additional "elevation capital" to spend against future sea-level rise, so model predictions generally suggest that they will convert to regularly flooded marshes rather than be completely lost. However, a successful transition to a healthy regularly-flooded marsh during this time of conversion is uncertain. The response of marshes to changes in marsh flooding levels, and nutrient and sediment delivery levels remains a complex and uncertain relationship subject to many variables (Mozdzer et al. 2020; Fagherazzi et al. 2013). Some changes that could be a result include an increase of belowground sediment decomposition under conditions of higher salinity; invasive species may take advantage of the habitat transition to establish foothold in the wetland.

In terms of marsh edge erosion to open water, the existing marshes in Frost Creek, Mill Neck Creek, and Bayville are predicted to be most vulnerable to future sea-level rise relative to other marshes in the study area. This is primarily a function of their marsh type, and the elevation of the marshes relative to sea-levels and tide ranges (Appendix A).

SUMMARY OF MARSH CONSERVATION PLANNING

There are many tools available to local governments, planners, and NGOs that can be used to protect existing coastal wetlands, and to ensure that adjacent habitat is protected for future marsh migration. These strategies will generally fall into the categories of "managing current resources (including water quality improvements)," "land purchases and easements," "local or state regulation," and "marsh restoration." 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. When looking towards future conditions, a living shoreline can potentially provide both ecological restoration of habitat and the co-benefits to coastal resilience and upland infrastructure.

MANAGING CURRENT RESOURCES

Managing current resources includes mitigation of the threats to existing coastal marshes. This can include improving water quality issues through education, outreach, and regulation. Local towns may also choose to cite marsh vulnerability when creating water quality rules and considering septic upgrade regulations Another important management tool is the monitoring and removal of invasive species within salt marshes.

To reduce nitrogen in the Oyster Bay/Cold Spring Harbor Watershed, the 2011 Watershed Action Plan recommended the following priority actions (Friends of the Bay 2011):

- Develop model municipal land-use codes and regulations;
- Promote low-impact development and green infrastructure approaches for private development and municipal stormwater infrastructure;
- Implement buffer restoration projects around streams and ponds; and
- Strengthen septic-system regulations.

There is an important role for education in improving water quality in the Oyster Bay-Cold Spring Harbor complex. Updating residential septic systems around these harbors, and expanding the service areas of existing sewage treatment plants, could significantly reduce nitrogen loading. Suffolk County and Nassau County Septic Rebate Programs are available to provide financial assistance for homeowners to upgrade to nitrogen-reducing septic systems. Additionally, existing 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 therefore reduce the amount of nitrogen going to the water (NEIWPCC 2023). In an example of such land use and outreach, a rain garden was installed at Theodore Roosevelt Park in Oyster Bay in partnership with Friends of the Bay and the Nassau County Soil and Water Conservation District. Recently, this installation was used to educate local landowners about how rain gardens work, while soliciting their help in maintaining the rain garden (Town of Oyster Bay, 2023). Landowners adjacent to Oyster Bay and Cold Spring Harbor are eligible for the Long Island Garden Rewards Program, which offers financial rewards for homeowners on Long Island who add green alternatives to their properties that reduce stormwater runoff and nitrogen loadings (LIRPC 2023).

In 2022, the Town of Oyster Bay revitalized three rain gardens across from the Western Waterfront Center, adjacent to Beekman Beach and south of West Shore Road. 100 volunteers helped complete this project with the objectives of improving aesthetics, increasing stormwater infiltration, and serving as a demonstration site for residents (Town of Oyster Bay, undated).

A general recommendation of the plan is to expand outreach to improve meaningful involvement of relevant partners in the implementation of projects and management decision-making. Stakeholders noted the importance of reaching out to local garden glub members as well as local yacht clubs (that often have environmental committees) to further build community cooperation for water quality and marsh restoration projects. In addition, they suggested that, prior to embarking on projects, conservation teams should meet with other Long Island communities that are working on marsh conservation projects to better understand what is and what is not working.

Land Purchases and Easements

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, and usually more economically, 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). (See **Funding Sources for Marsh Conservation** on pages 28 and 29.)

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. As noted above, 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.

The New York State Department of State has produced a document called "Model Local Laws to Increase Resilience" (2019). This document includes a chapter dedicated to coastal shoreline protection measures and includes model laws with legal language that municipalities can use and adopt into a local code. Stakeholders noted that the training and education of incorporated village officials is especially important because they often have control over which lands can be developed, and the nature of that development.

One local example of water-quality regulation initiatives comes from the Village of Oyster Bay Cove. This municipality now requires property owners constructing new buildings or making significant changes to update buildings to install low-nitrogen septic systems (Sheeline, W. 2023). As other municipalities take similar steps, the combined result will be enhanced quality and function of coastal marsh ecosystems and the services that they provide. At the statewide level, recent legislation requires the State of NY to give preference to nature-based solutions when permitting shoreline management projects (Act 5221-A).

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. Funding opportunities are potentially available for each step of a project including grant writing, engineering, and finally construction on shovel-ready projects.

New York State Funding Finder

https://www.dec.ny.gov/pubs/127486.html

The Funding Finder, developed by the NYSDEC Division of Water in conjunction with the Long Island Sound Study, is designed to simplify the process of finding grant opportunities. This Excel-based tool enables grant seekers to filter grant opportunities based on criteria that meets their specific needs.

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://longislandsoundstudy.net/about/grants/grants-and-grant-writing-assistance-opportunities/long-island-sound-resilience-grant-writing-assistance-program/

This is an 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 are up to $9,950 per application directly to the consultant. Applications are accepted on a rolling basis. Applicants are encouraged to apply for grant writing assistance as soon as you decide to a pursue a grant opportunity or as soon as the grant opportunity opens, typically a minimum of 6-8 weeks prior to the grant opportunity deadline.

Long Island Sound Resilience Planning Support Program

https://longislandsoundstudy.net/about/grants/grants-and-grant-writing-assistance-opportunities/long-island-sound-resilience-grant-writing-assistance-program/

This is a new opportunity for municipalities, community organizations and nonprofits to get assistance identifying and developing sustainability and resilience focused projects. This program aims to help communities assess local climate risks, conceptualize project ideas, and conduct preliminary planning efforts/steps in order to be well positioned to access funding to design and implement successful sustainability and resilience focused projects.

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.

- 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.

NYS Environmental Bond Act

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

For shovel-ready projects, 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.

Nassau County Soil and Water Conservation District Part C Funding-

The Nassau County Soil and Water Conservation District funds a limited number of mission-aligned projects every year. Eligible applicants include local governments in Nassau County and not-for-profit organizations. Projects must meet one or more of the follow criteria in Nassau County:

> Conserve or improve soils; Improve water quality of our groundwater and/or surface water; Control and prevent soil erosion and/or prevent floodwater and sediment damages; Conservation, development, utilization, and disposal of water; Preserve, increase, or improve natural resources including trees and plants; Control or eliminate invasive plants or wildlife; Control and abate NPS water pollution; Preserve wildlife.

Funding for Land Acquisitions

Long Island Sound Study, North Shore Land Alliance, NYS, and Town of Huntington 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

MARSH RESTORATION

Marsh restoration is the process of modifying former wetland locations to promote current and future marsh habitation. This process is often undertaken to restore critical habitats or 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 79.7 acres of tidal wetland habitat and are 15.5% 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.

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.

- *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

The selection of a marsh restoration or living shoreline site 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.

FOCAL AREAS

For each of the seven focal areas discussed above, a different set of current and future threats to these marshes have produced a different set of recommendations for marsh-conservation planning, as will be detailed below.

FROST CREEK

Based on analysis of historic vs. current infrared photography, Frost Creek marshes have been subject to some losses since the 1970s (Cameron Engineering 2015). Similar to several other marshes in the study area, the analysis suggests that Frost Creek has historically seen higher loss rates for intertidal marshes than it has for high marsh habitat (Figure 18).

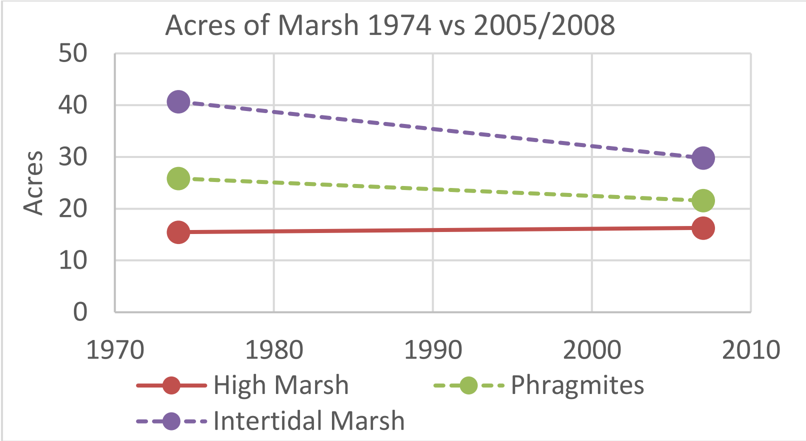

Figure 18. Acres of Marsh in Frost Creek in 1974 vs, the mid 2000s (Site 259 from Cameron Engineering 2015).

In Frost Creek, future marsh losses due to sea-level rise, could potentially be offset by marsh expansion on to land that is currently dry (Figure 19). Some of this potential expansion is onto private lands held in the south central and southwestern portion of the study area. (The full map of public vs. private ownership may be found on the Marsh Fate Interactive Viewer -- warrenpinnacle.com/LIMaps)

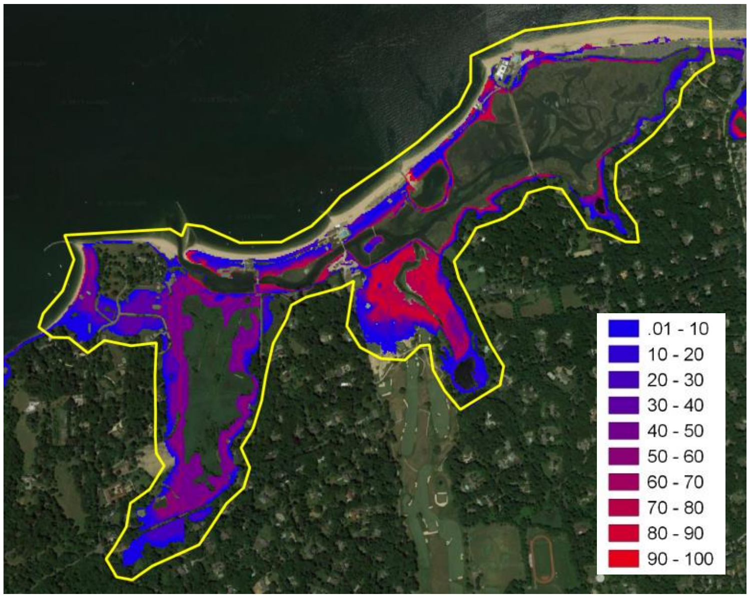

Figure 19. Probability current Frost Creek dry land will have the elevation and frequency of flooding to support marsh habitat in 2100

Marsh management at this site could focus on management of existing marsh resources while also working with public and private landowners to plan for the impacts of future sea levels. As discussed above, it will be important to understand the potential impacts of sea-level rise on the irregularly-flooded marshes at this site. To that end, a baseline inventory of marsh and marsh health will help to disentangle the complex reaction to changing water levels and salinity and nutrient loads. To date, several long-term monitoring programs exist within the complex. NYSDEC monitors three Surface Elevation Tables (SETs) for marsh accretion and subsidence and USGS monitors tidal range within the Creek at Sheep Lane.

The predicted flooding of the Creek Club golf course, central in this study area, provides both a potential threat and an opportunity. Instead of focusing on vertical wall development to reduce the impacts of sea-level, living shorelines could also be developed to provide both ecosystem and flood-prevention benefits.

MILL NECK CREEK

Based on the analysis from Cameron Engineering & Associates, marshes at Mill Neck Creek have remained relatively resilient over the last 30 plus years (Figure 20). However, the water quality data for this portion of the study area is worse than the rest of the study area, receiving F grades for water clarity, seaweed, and oxygen saturation, and a D grade for chlorophyll *a* (Save the Sound, 2022). While current marshes are predicted to have high enough elevations to counter moderate future sea-level scenarios, the combined stressors of sea-level rise and high nutrient levels have the potential to cause more marsh loss than predicted.

One of the most important courses of action for this focal area will be to continue to focus on water quality improvements while monitoring marsh health and density under these dual stressors. Benefits to marsh habitat in Beaver Lake and further through the Mill Neck Creek complex should be considered as part of the ongoing effort to assess culvert impacts. In particular, stakeholders have recommended modifications to improve resiliency and aquatic organism passage at the culverts on Beaver Brook upstream of Beaver Lake within Shu Swamp Preserve and Upper Francis Pond Preserve.

Another top priority of partners in the area, including the Oyster Bay Cold Spring Harbor Protection Committee, is to extend the service area of the Glen Cove Sewage Treatment Plant. In particular, service should be extended to the western downtown area of the Village of Bayville, close to Mill Neck Creek, called "The Stands". The businesses and apartments on this stretch of Bayville Avenue are on septic systems that regularly overflow and are inundated and there is a major concern about pollution in the nearby Oak Neck and Mill Neck Creek.

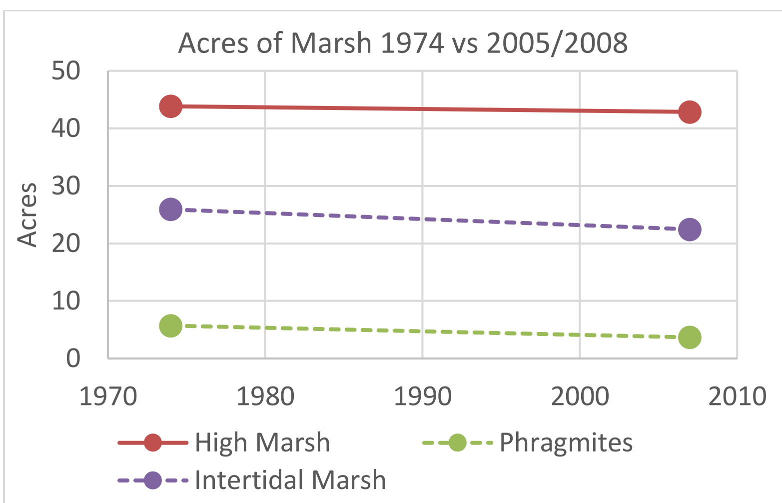

Figure 20. Acres of Marsh in Mill Neck Creek in 1974 vs, the mid 2000s (Site 258 from Cameron Engineering 2015).

WEST SHORE ROAD

The West Shore Road location is already showing some impacts from the combined impacts of sea-level rise and storm surges. The road was partially washed away during Hurricane Sandy in 2012 and has been rebuilt and raised since that time. Even prior to Sandy, the marsh edge adjacent to West Shore Road was subject to considerable erosion. Historic trends analysis suggests that approximately one third of intertidal marsh was lost from the mid-1970s to the mid-2000s (Figure 21).

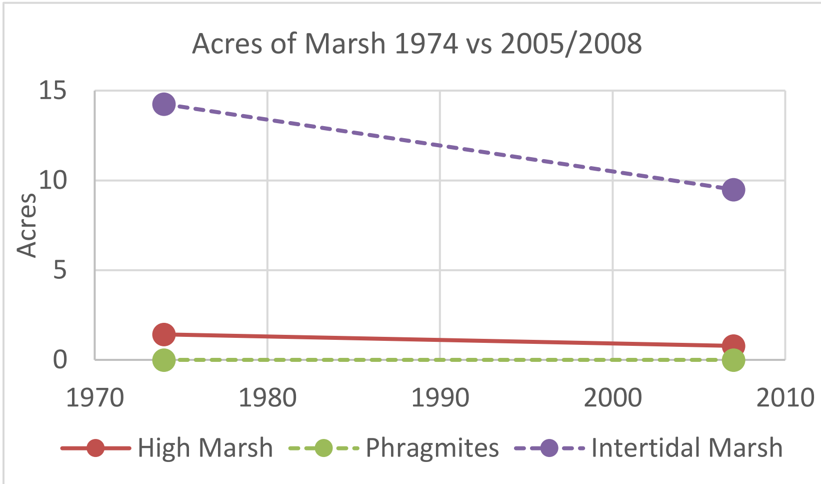

Figure 21. Acres of Marsh in Mill Neck Creek in 1974 vs, the mid 2000s (Site 258 from Cameron Engineering 2015).

To counter these impacts, a living shoreline would likely provide benefits in terms of erosive losses, flood protection, and ecological restoration. The Town-proposed living shoreline that includes marsh plantings and oyster reef structures would provide these benefits and could also reduce nutrients from stormwater pollution. A modeling/data analysis could also be undertaken to understand the provision of sediment to such a project-- the odds of success for nature-based solutions are significantly improved when there is sufficient sediment availability (Liu et al. 2021).

Bayville Bridge to Centre Island

Similar to Mill Neck Creek, this portion of the study area has seen minimal losses of marshes, even in the more-vulnerable lower-elevation intertidal marshes (Figure 22).

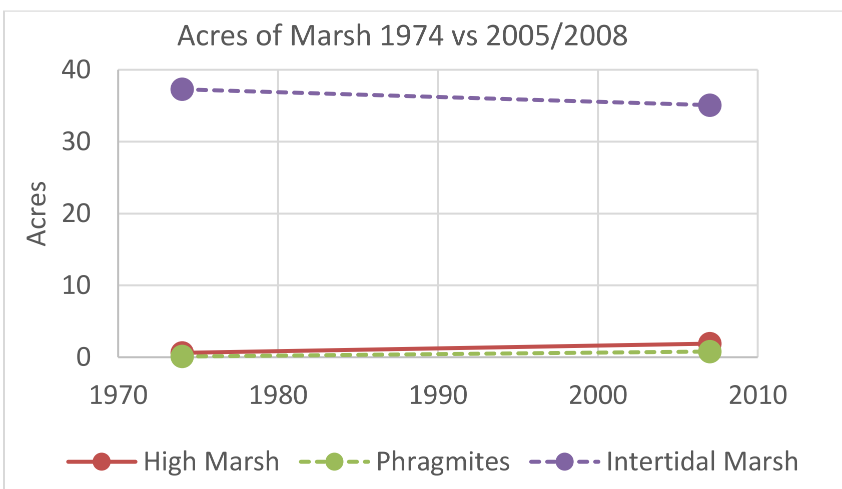

Figure 22. Acres of Bayville Bridge to Centre Island Marsh in 1974 vs, the mid 2000s (Site 254 and 255 from Cameron Engineering 2015).

Under moderate SLR scenarios, the Bayville marshes are predicted to persist and there is also some potential expansion of marshes onto adjacent dry land (Figure 23). Future marsh management of some of these adjacent publicly-owned drylands could support marsh migration, for example implementing a living shoreline design that would also provide flood-protection benefits.

Figure 23. Current condition potential marsh habitat (top) vs. estimated marsh habitat expansion and impervious-land flooding in 2085 (bottom, under 0.74 meters of SLR)

Within Bayville, there will potentially be work required to manage existing marsh resources that currently provide wave-attenuation benefits. For example, the Bayville Local Waterfront Revitalization Program recommends that stakeholders "repair and replant areas along the south shore of Bayville where gaps have formed in the existing line of marsh vegetation. These vegetative gaps allow high intensity waves to reach the shore and cause damaging erosion" (Bayville Village Board, 2002). Other methods to increase sedimentation and marsh elevation in the marshes to increase resilience to SLR and protect infrastructure to the north should be considered.

Finally, support of water quality improvements (reducing nutrient loads) to protect marshlands from degradation and to improve recreation potential can be an important consideration in managing and conserving the marshes of Bayville.

Centre Island

The majority of marshlands on Centre Island are located towards the middle of the island with coastal water supplied from the east (Figure 24, top). The largest marsh area to the east is owned by the Village of Centre Island, a site with approximately 24 acres of marshes. The rest of the marshes on this part of the island are privately owned (warrenpinnacle.com/LIMaps).

Historic trends for Centre Island marshes have been favorable for the most part, with intertidal marsh increasing and invasive Phragmites decreasing since the mid-1970s (Figure 25). Under conditions of sea-level rise, the marshes are also predicted to be fairly resilient, with the largest change being a significant change in the flooding regime of the westward marshes (conversion from irregularly-flooded to regularly-flooded marshes). As noted above, this conversion has the potential to require some management depending on how the marsh platform reacts to additional inundation and salinity. However, management of these west-side marshes may be complicated by the fact that they are currently privately owned. There is some potential for future expansion of marshes onto dry lands by the end of the century, especially to the southeast of the study area (see "Future marsh migration at Centre Island" in Appendix A at the end of this document).

Marsh management actions for Centre Island can include gathering data on baseline marsh health, speciation, and density so that future changes in marsh habitat can be measured to assist in management. It is probably also worth researching whether select parcels and associated marshlands could be converted into public lands for the purposes of marsh management, and to protect dry lands that could serve as marsh-migration pathways. As noted above, the most vulnerable marshes on the island seem to be privately owned and on the west side of the island. Land purchases and land easements may be tools that can be leveraged to assist in the management of these parcels. Finally, the self-regulating tide gate located between the two largest marsh areas will continue to require monitoring to ensure that it does not stop functioning if it becomes clogged with Phragmites and debris.

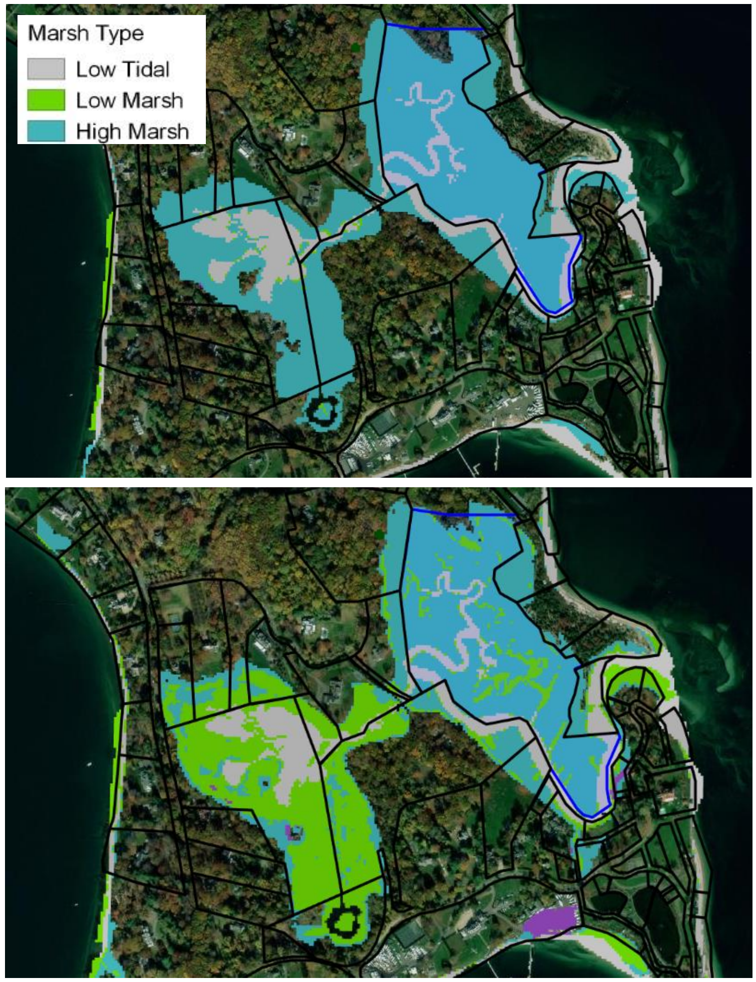

Figure 24. Current condition potential marsh habitat (top) vs. 2085 prediction under 0.74 meters of SLR. Black lines are property boundaries.

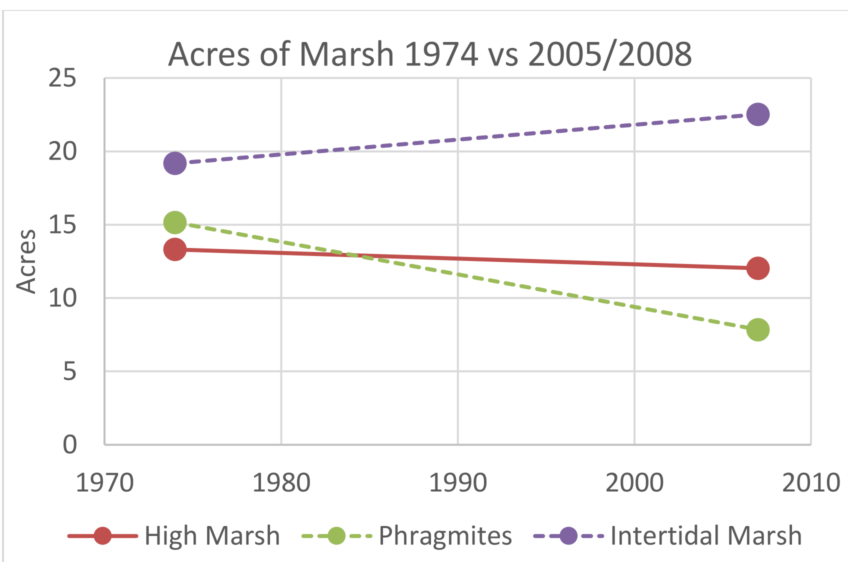

Figure 25. Acres of Centre Island Marsh in 1974 vs, the mid 2000s (Site 251 from Cameron Engineering 2015).

SHORE ROAD

The Shore Road focal area is somewhat different than the other focal areas in this report because it does not currently contain significant emergent marsh habitat. However, there are fairly large portions of this area that are predicted to have potential marsh habitat by the end of the century as well as impervious areas that are predicted to be flooded at least monthly (Figure 26).

The North Shore Land Alliance (NSLA) holds a plot of particular interest which is generally predicted to be flooded enough to support marsh habitat by the end of the century (Figure 26). The NSLA parcel has potential to be future marsh habitat and also can provide an important benefit to water quality on site. In a recent proposal, NSLA suggested the construction of a bioswale gully on the same parcel to reduce erosion on site and reduce pollution into Cold Spring Harbor. While the project has not yet been funded, the need for action has not abated. During rain events, up to 35 cubic feet per second of untreated runoff from surrounding roads delivers hydrocarbons, nitrogen, phosphorus and other pollutants through a pipeline directly to Cold Spring Harbor (North Shore Land Alliance, 2015).

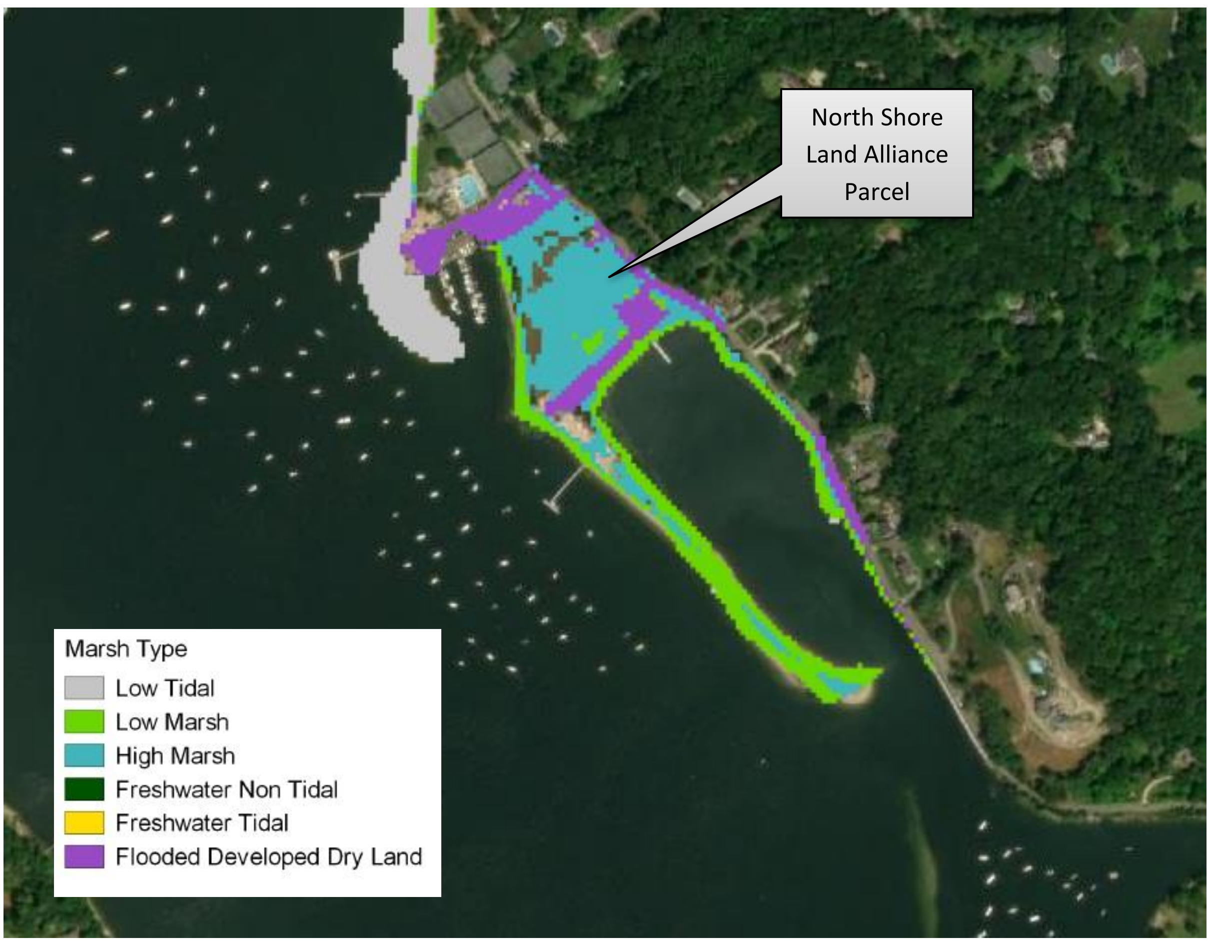

Figure 26. Shore Road area: predicted land cover in 2085 under 0.74 meters of SLR, a moderate sea-level rise scenario.

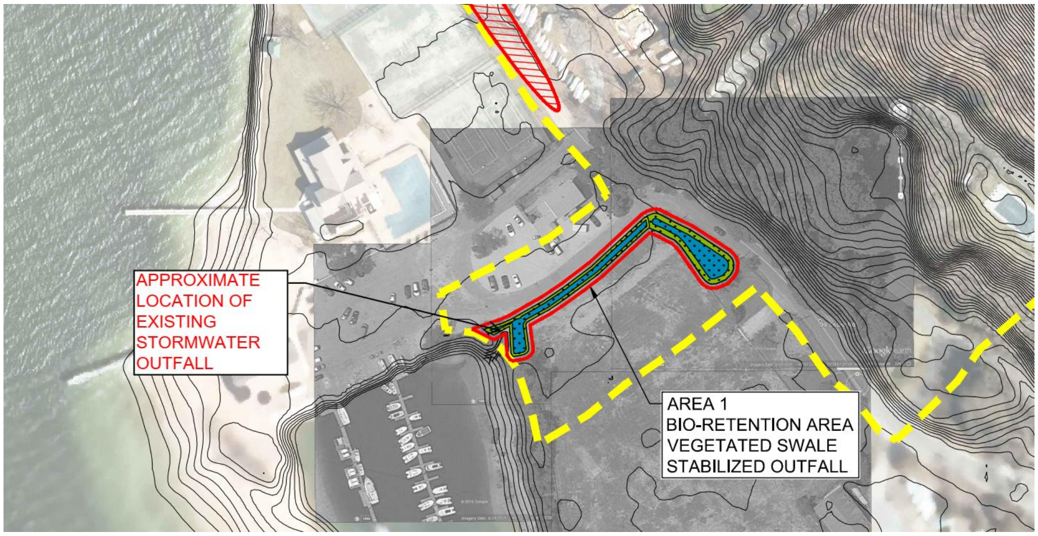

Figure 27. Proposed Bioswale Gully on North Shore Land Alliance Plot. (North Shore Land Alliance, 2015)

Marsh conservation in the Shore Road site should focus primarily on the North Shore Land Alliance parcel. This site has the elevation required for marsh habitation in the near future and is owned by willing partners in terms of promoting ecology through site management. Construction of the proposed bioswale at this site should have a measurable impact on Cold Spring Harbor water quality, which is in need of improvement based on the water quality assessment cited above. A bioswale plan would also be compatible with other portions of the site being modified into a living shoreline to provide marsh ecosystem services and to protect the roads and infrastructure behind the lot.

INNER COLD SPRING HARBOR

The largest contiguous marsh in the inner-cold spring harbor focal area is the high-marsh habitat of Saint John's Marsh. Model results suggest that, under many additional sea-level rise scenarios, this marsh is likely to convert to regularly-flooded marsh. In terms of marsh management, one important goal for this site should therefore be to set the groundwork to manage for increased salinity and inundation. One way to manage this is to produce a "baseline" study of marsh health and speciation.

As noted above, Inner Cold Spring Harbor has some problematic water quality indicators-- measured chlorophyll *a* and oxygen saturation. Water quality in the harbor is affected by pollutants from groundwater and overland flows originating well south of the study area. The Cold Spring Harbor watershed, that drains through the culvert under North Hempstead Turnpike (25A), encompasses hundreds of households. This watershed extends several miles south to the Town of Oyster Bay Golf Course and nearly to the Northern State Parkway (GEI Consultants, March 2021). Because of this, Cold Spring Harbor water quality is impacted by excess nutrients from septic systems, and additional pollutants from lawn-care choices, made over several densely-populated square miles. Further investigation of how to improve local water quality and its potential effect on marsh health is likely warranted for this study area.

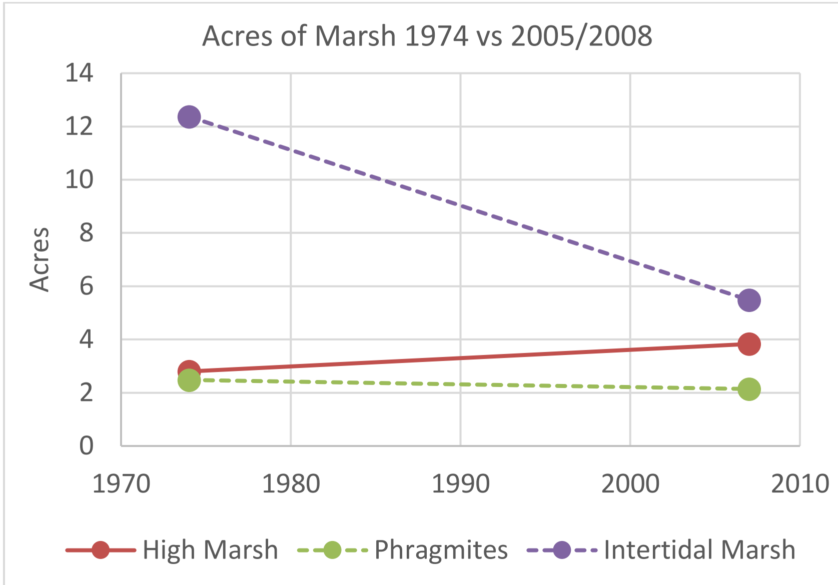

Figure 28. Acres of Marsh in Lower Cold Spring Harbor in 1974 vs, the mid 2000s (Sites 240-242 from Cameron Engineering 2015).

In this focal area, Cameron Engineering & Associates (2015) found that over half of intertidal marshes were lost from 1974 to the mid-2000s (Figure 28). It is possible that restoration of some of these adjacent regularly-flooded marshes could be beneficial at this site. Restored intertidal marshes could provide protection from erosion and additional sediment to the existing high marshes. However, a full assessment of local sediment supply and dynamics would first need to be undertaken to ensure that new-marsh plantings would be likely to succeed over time.

Saint John's Marsh, Photo Credit Sarah Schaefer-Brown

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Looking South over Lattingtown Marshes. Photo Credit Jonathan Clough

APPENDIX A: FACT SHEETS- SLR AND THE MARSHES OF OYSTER BAY AND COLD SPRING HARBOR

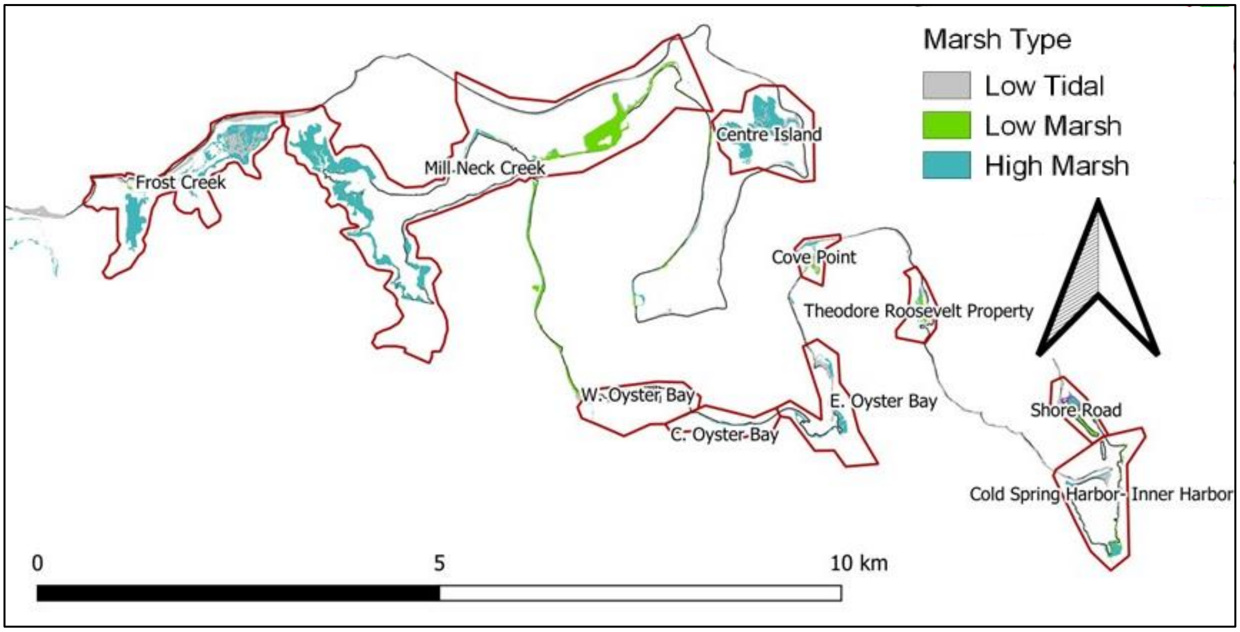


Figure 29. "Named Marshes" within the study area as defined within the Marsh Fate Interactive Viewer (warrenpinnacle.com/LIMaps)

As part of the Marsh Interactive Fate Viewer, fact sheets were developed for ten marshes throughout the Oyster Bay and Cold Spring Harbor region. These fact sheets are designed to illustrate the estimated fate of coastal marshes under an uncertain sea-level rise, and to show locations that may have elevations that could support marsh habitat in the future. Those fact sheets may be found on the following pages:

Frost Creek: 45
Mill Neck Creek 47
West Oyster Bay 49
Central Oyster Bay 51
East Oyster Bay 53
Centre Island 55
Cove Point 57
Theodore Roosevelt Property 59
Shore Road 61
Cold Spring Harbor 63

Future marsh migration at Frost Creek

PROJECTED INUNDATION AND LANDCOVER CHANGES DUE TO SEA LEVEL RISE

Currently the Frost Creek area near Lattingtown, NY includes approximately 109 acres of wetlands (marshes and unvegetated flats), of which **73** acres are vegetated marshes, while the rest are mudflats and beaches. Under many possible sea level rise scenarios, current marsh coverage is predicted to keep up with sea level, with an average of 16 acres predicted to be lost by 2100. Despite this:

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

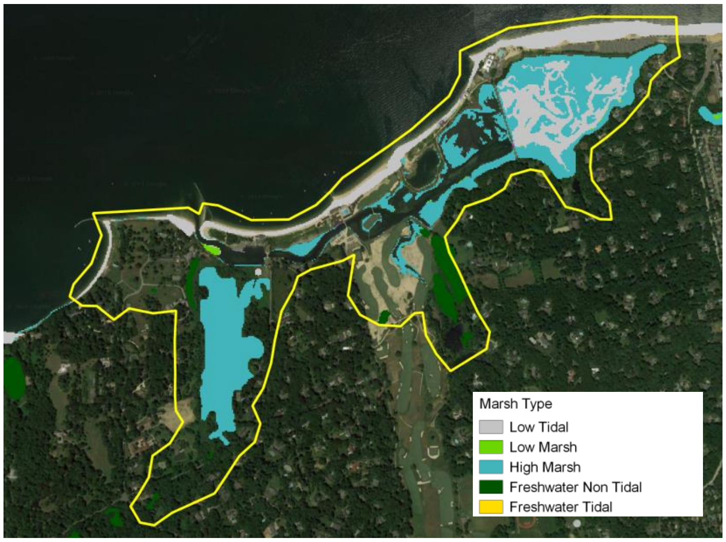


Figure 30. Satellite image of Frost Creek with current marsh coverage (Sources: NWI; Satellite imagery from Google).

A total of 119 tax parcels, in and adjacent to the wetland area, may be affected by increased inundation due to future sea-level rise. Land currently occupied by marsh is mainly federal land or owned by the Village of Lattingtown. However, several 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/

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 dry lands are made available or restored). *Red areas are more likely to be marsh at 2100 than blue ones*.

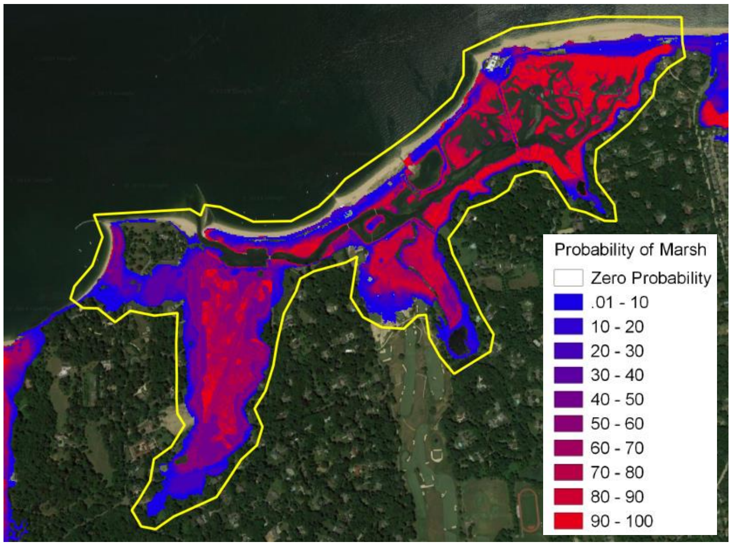


Figure 31. Probability of marsh habitat map, year 2100

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.

WETLAND LOSSES

- Existing marsh area, currently covering **73** acres, is predicted to be reduced by **16** acres by 2100 (this is the average of all uncertainty-analysis simulations). However, an additional **35-54** 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 **7** acres of current tidal flats or beaches are predicted to become open water by 2055, increasing to **29** by 2100.

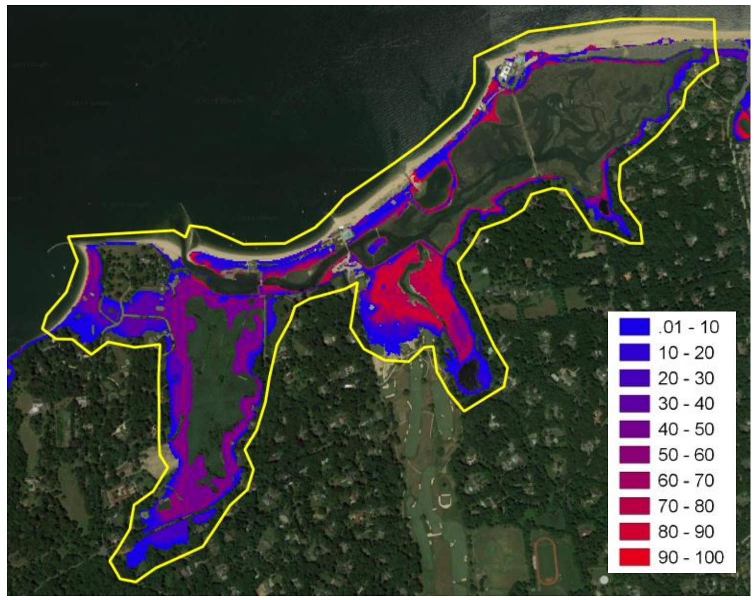
	Owner Type	2004	2055	2100
Existing marsh area (acres)	Public	60	60	47
	Private	13	13	10
Average new marsh area in undeveloped dry land (acres)	Public	0	2	10
	Private	0	9	32
Average new marsh area in developed dry land (acres)	Public	0	0	1
	Private	0	0	3
Total potential marsh area (acres)		73	83	102

Table 2. Average marsh habitat predicted given SLR in the years 2055 and 2100

POTENTIAL FOR MARSH MIGRATION

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

- On average, **10** acres of new marsh could be expected to establish in current undeveloped dryland by 2055, or up to **42** acres by 2100. The maximum possible area of new marsh would be **113** acres under the highest SLR scenario.
- In addition, properly restored developed dry land could accommodate the establishment of an average **3** acres by 2100, with a possible maximum area of **17** acres. (Note, some of these developed areas include roads that may be maintained as such in the future.)



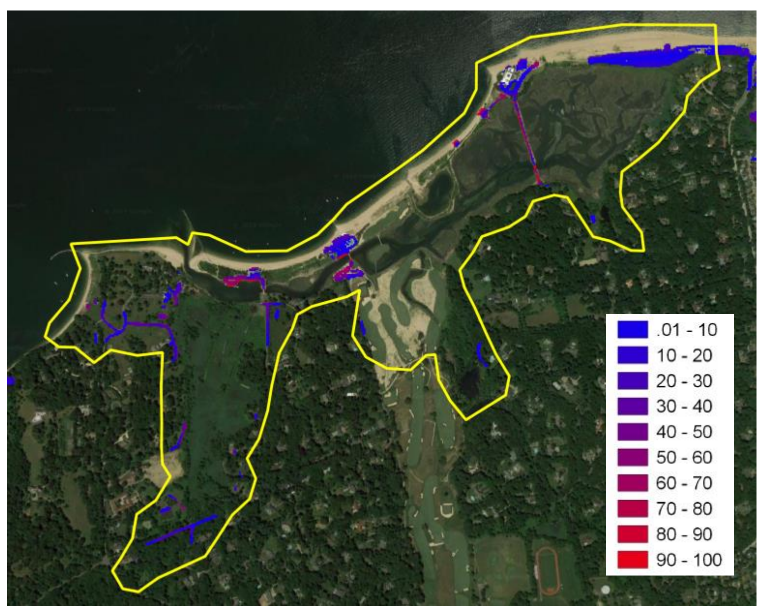


Figure 32. Areas that could accommodate marsh establishment by 2100. top: in currently undeveloped dry land areas, bottom: in developed ones.

SUMMARY

Although much of the current **73** acres of marsh can remain viable under moderate sea level rise increases, by 2100 marsh areas could be reduced to **3** 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 **11** acres of current dry land could accommodate new marsh by 2055 and **45** acres by 2100. (This number could stretch to **129** acres of new marsh under more extreme SLR scenarios).

Future marsh migration at Mill Neck Creek

PROJECTED INUNDATION AND LANDCOVER CHANGES DUE TO SEA LEVEL RISE

Currently the Mill Neck Creek area near Mill Neck, NY and Bayville, NY includes approximately 153 acres of wetlands (marshes and unvegetated flats), of which **138** acres are vegetated marshes, while the rest are mudflats and beaches[1]. Under several possible sea level rise scenarios, current marsh coverage is predicted to keep up with sea level. However:

- Areas of high-elevation marshes are predicted to be replaced by low marsh;
- 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 1546 tax parcels, in and adjacent to the wetland area, may be affected by increased inundation. Nassau County is the main landowner of the public land currently occupied by marsh, but many privately owned parcels could be affected by increased inundation.

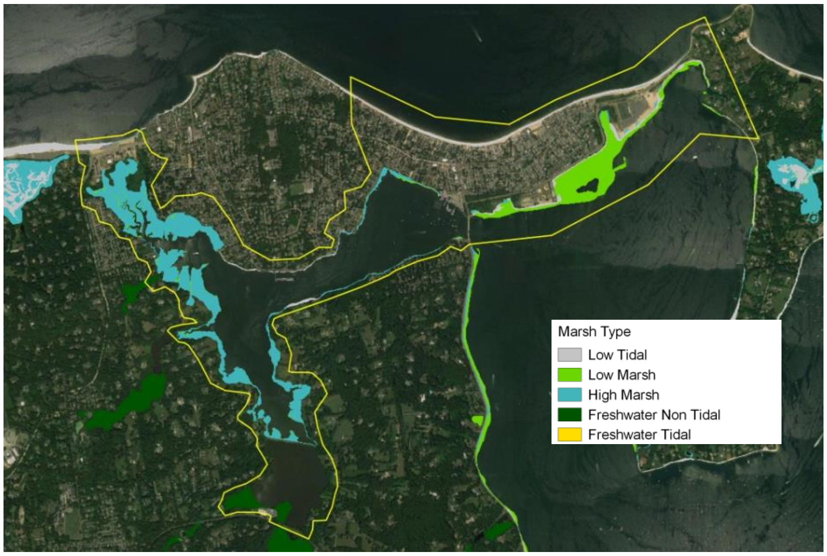


Figure 33. Satellite image of Mill Neck Creek with current marsh coverage (Sources: NWI; Satellite imagery from Google).

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*.

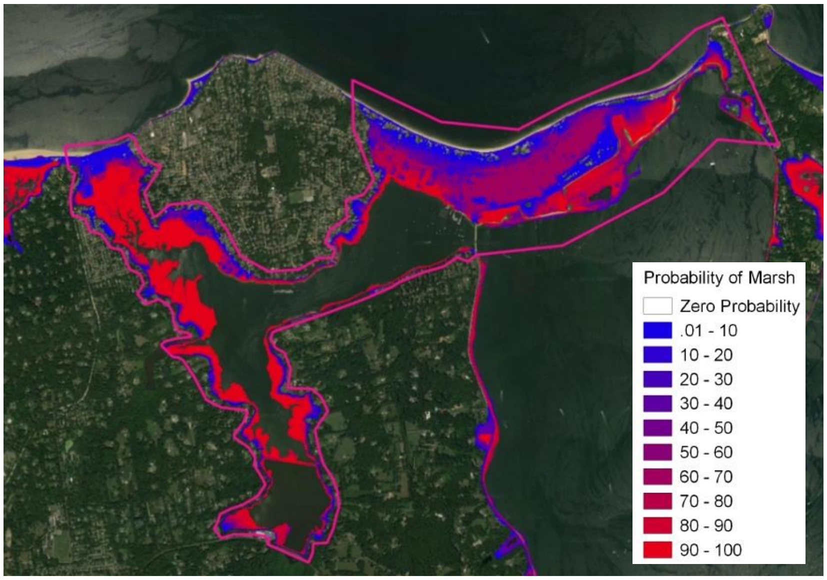


Figure 34. Probability of marsh habitat map, year 2100

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.

[1] Some marsh areas on the west shore of the study area are not accounted for in these numbers as they are not included in any tax parcels in the Nassau Parcel data. See the on-line viewer for more detailed information.

WETLAND LOSSES

- Existing marsh area, currently covering **138** acres, is predicted to be reduced by **14** acres by 2100 (this is the average of all uncertainty-analysis simulations). However, another **28-83** 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 **19** acres of current tidal flats or beaches are predicted to become open water by 2055, increasing to **50** by 2100.

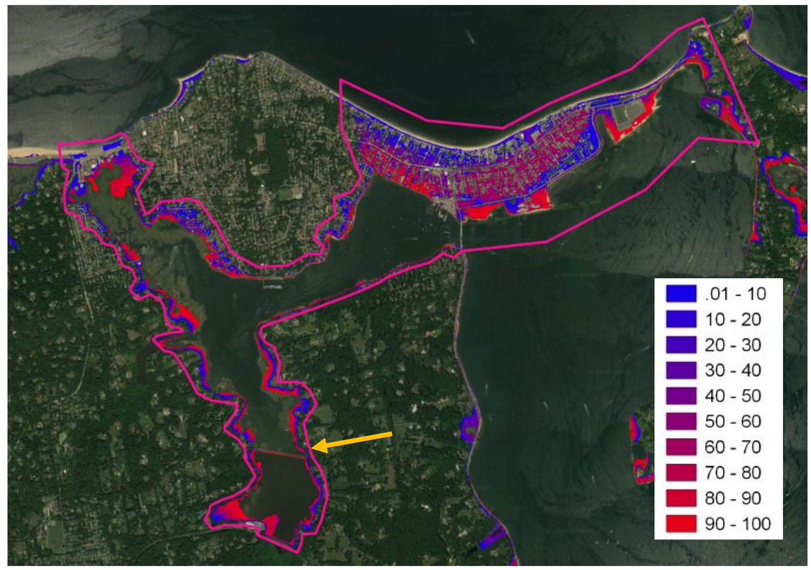
	Owner Type	2004	2055	2100
Existing marsh area (acres)	Public	84	83	70
	Private	54	54	53
Average new marsh area in undeveloped dry land (acres)	Public	0	12	36
	Private	0	17	85
Average new marsh area in developed dry land (acres)	Public	0	1	11
	Private	0	2	25
Total potential marsh area (acres)		138	170	281

Table 3. Average marsh habitat predicted given SLR in the years 2055 and 2100. Private areas include also tax parcels with unknown owner type.

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, **29** acres of new marsh could be expected to establish in current undeveloped dryland by 2055, or up to **121** acres by 2100.
  The maximum possible area of new marsh would be **239** acres under the highest SLR scenario.
- Marsh migration south into Beaver Lake may require restoration of tidal flows through the culvert there (orange arrows on Figure 35) so that waters can pass with minimal restriction.
- In addition, properly restored developed dry land could accommodate the establishment of an average **3** acres of marsh by 2055 and **37** acres by 2100, with a possible maximum area of **87** acres. (Note, some of these developed areas include roads that may be maintained as such in the future.)



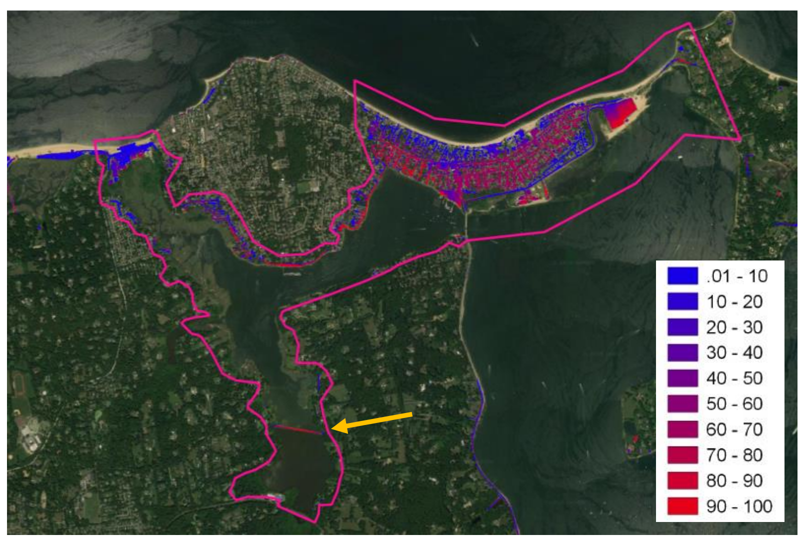


Figure 35. Areas that could accommodate marsh establishment by 2100. top: in currently undeveloped dry land areas, bottom: in developed ones.

SUMMARY

Although the current **138** acres of marsh 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 **41** 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 **33** acres of current dry land could accommodate new marsh by 2055 and **157** acres by 2100. (This number could stretch to **326** acres of new marsh under more extreme SLR scenarios).

Future marsh migration at western Oyster Bay

PROJECTED INUNDATION AND LANDCOVER CHANGES DUE TO SEA LEVEL RISE

Currently (as of 2004, the most recent land cover data available) the western Oyster Bay study area includes approximately 7 acres of wetlands (marshes and unvegetated flats), of which 4 acres are vegetated marshes, while the rest are beaches. Under most possible sea level rise scenarios, current marsh coverage is predicted to keep up with sea level. These irregularly-flooded marsh lands have relatively high elevations compared to sea levels so they can withstand some sea-level rise. However:

- Areas of high-elevation marshes are predicted to be replaced by low marsh;
- 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 192 tax parcels, in and adjacent to the wetland area, may be affected by increased inundation. Most land currently occupied by marsh is publicly owned, but many privately owned parcels could be affected by increased inundation in the future.

Figure 36. Satellite image of western Oyster Bay 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.

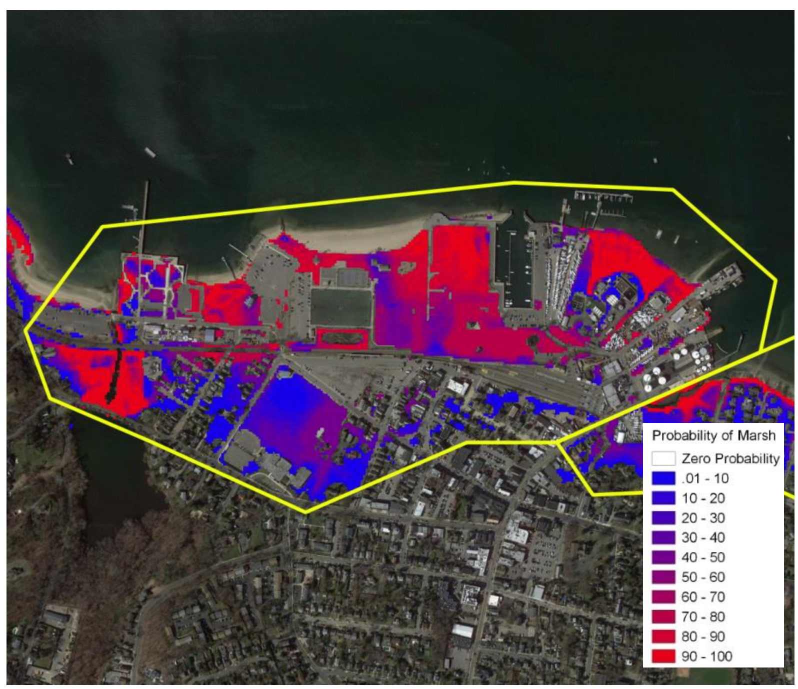


Figure 37. Probability of marsh habitat map, year 2100

WETLAND LOSSES

- Existing marsh area, currently covering 4.0 acres, is only predicted to be reduced by 0.2 acres by 2100 (this is the average of all uncertainty-analysis simulations). However, an additional 1.4 acres of marsh could be converted to tidal flats or open water in the most extreme SLR scenarios modeled.
- In addition, approximately 0.2 acres of current tidal flats or beaches are predicted to become open water by 2055, increasing to 1.0 by 2100.

	Owner Type	2004	2055	2100
Existing marsh area (acres)	Public	3.8	3.9	3.6
	Private	0.2	0.1	0.1
Average new marsh area in undeveloped dry land (acres)	Public	0.0	3.0	18.4
	Private	0.0	0.8	4.0
Average new marsh area in developed dry land (acres)	Public	0.0	2.6	16.8
	Private	0.0	1.3	8.5
Total potential marsh area (acres)		4.0	11.7	51.4

Table 4. Average marsh habitat predicted given SLR in the years 2055 and 2100. Private areas include also tax parcels with unknown owner type.

POTENTIAL FOR MARSH MIGRATION

Predicted 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, 4 acres of new marsh could be expected to establish in current undeveloped dryland by 2055, or up to 22 acres by 2100. The maximum possible area of new marsh would be 38 acres under the highest SLR scenario modeled.
- In addition, properly restored developed dry land could accommodate the establishment of an average 4 acres of marsh by 2055 and 25 acres by 2100, with a possible maximum area of 42 acres. (Note, many of these developed areas include roads and buildings that may be maintained as such in the future.)

SUMMARY

Although the current (as of 2004) 4 acres of marsh are predicted to remain viable under a wide range of possible sea level rise increases, by 2100 marsh areas could be reduced to a total of 2 acres under more extreme scenarios. Potential marsh losses could be offset by the migration of marshes onto newly-inundated dry lands. If **marsh migration** is allowed, an average of 8 acres of current dry land could accommodate new marsh by 2055 and 48 acres by 2100. (This number could stretch to 80 acres of new marsh under more extreme SLR scenarios).

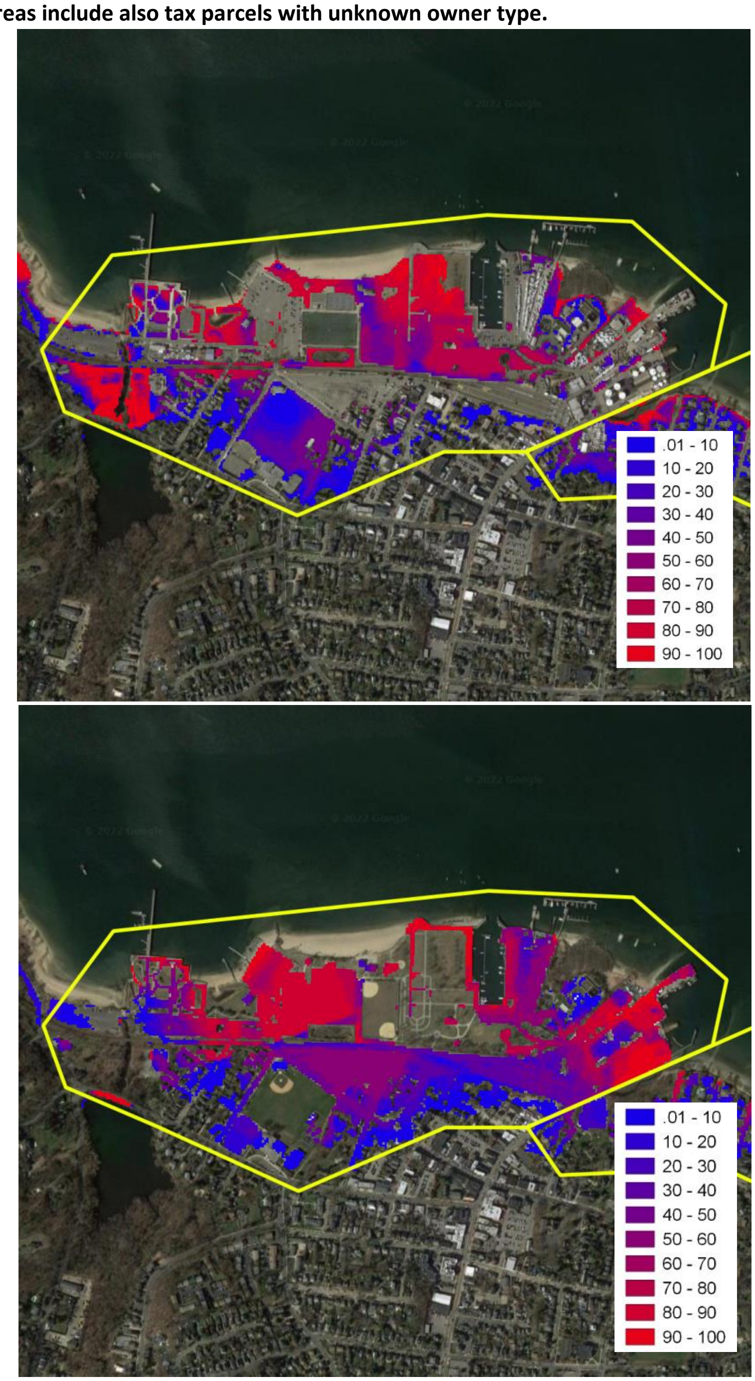


Figure 38. Areas that could accommodate marsh establishment by 2100. top: in currently undeveloped dry land areas, bottom: in developed ones.

Future marsh migration at central Oyster Bay

PROJECTED INUNDATION AND LANDCOVER CHANGES DUE TO SEA LEVEL RISE

Currently the central Oyster Bay study area has less than one acre of land appropriate for wetlands habitation (assumed to be vegetated marshes in Figure 1). Under most possible sea level rise scenarios, this potential marsh coverage would be predicted to keep up with sea level. These irregularly-flooded lands have relatively high elevations compared to sea levels so they can withstand some sea-level rise. However, within the study area, dryland areas are predicted to be increasingly regularly inundated.

A total of 108 tax parcels, in and adjacent to the wetland area, may be affected by increased inundation. In this portion of Oyster Bay, the parcels are all privately owned.

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

Figure 39. Satellite image of central Oyster Bay 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.

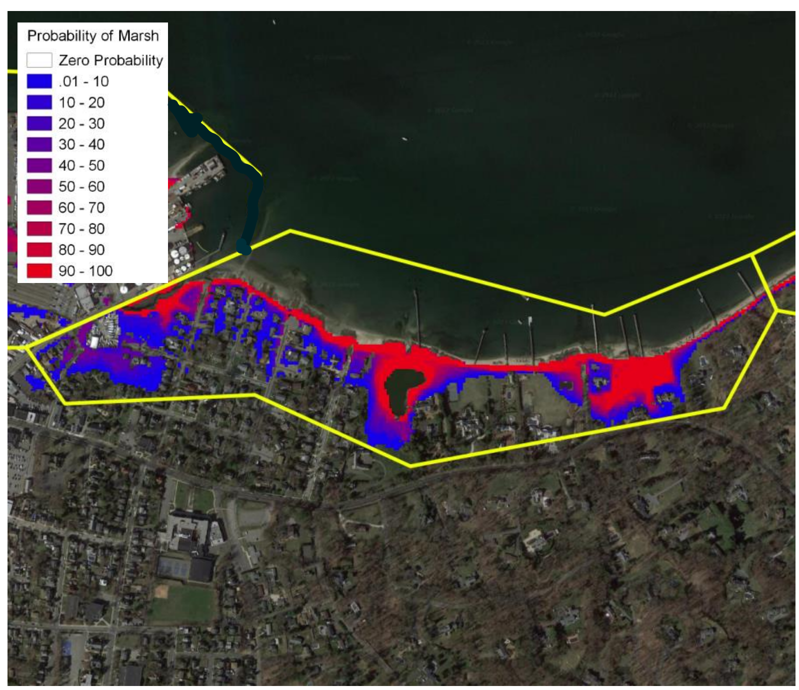


Figure 40. Probability of marsh habitat map, year 2100

WETLAND LOSSES

- Existing (potential) marsh area, currently covering 0.7 acres, is only predicted to be reduced by 0.1 acres by 2100 (this is the average of all uncertainty-analysis simulations).
- In addition, approximately 0.8 acres of current tidal flats or beaches are predicted to become open water by 2055, increasing to 1.1 acres by 2100.

	Owner Type	2004	2055	2100
Existing marsh area (acres)	Public	0.7	0.7	0.6
	Private	0.0	0.0	0.0
Average new marsh area in undeveloped dry land (acres)	Public	0.0	2.5	7.8
	Private	0.0	0.0	0.0
Average new marsh area in developed dry land (acres)	Public	0.0	0.0	0.8
	Private	0.0	0.0	0.0
Total potential marsh area (acres)		0.7	3.2	9.2

Table 5. Average marsh habitat predicted given SLR in the years 2055 and 2100. Private areas include also tax parcels with unknown owner type.

POTENTIAL FOR MARSH MIGRATION

Under sea-level rise, the central Oyster Bay study area has some potential for marsh migration. In other words, this study area has locations that are currently dry land but that are predicted to become regularly inundated in the future.

- On average, 2.5 acres of new marsh habitat could be expected to establish in current undeveloped dryland by 2055, or up to 7.8 acres by 2100. The maximum possible area of new marsh would be 14.5 acres under the highest SLR scenario.
- In addition, properly restored developed dry land could accommodate the establishment of an average 0.8 acres of marsh by 2100, with a possible maximum area of 3.0 acres under the highest SLR scenario examined. (Note, some of these developed areas include roads and buildings that may be maintained as such in the future.)

SUMMARY

Low elevations of dry lands at this study area make it somewhat vulnerable to future sea-level rise. If **marsh migration** were to be allowed, an average of 2.6 acres of current dry land could accommodate new marsh by 2055 and 8.5 acres by 2100. (This number could stretch to 17.4 acres of new marsh under the highest SLR scenario examined).

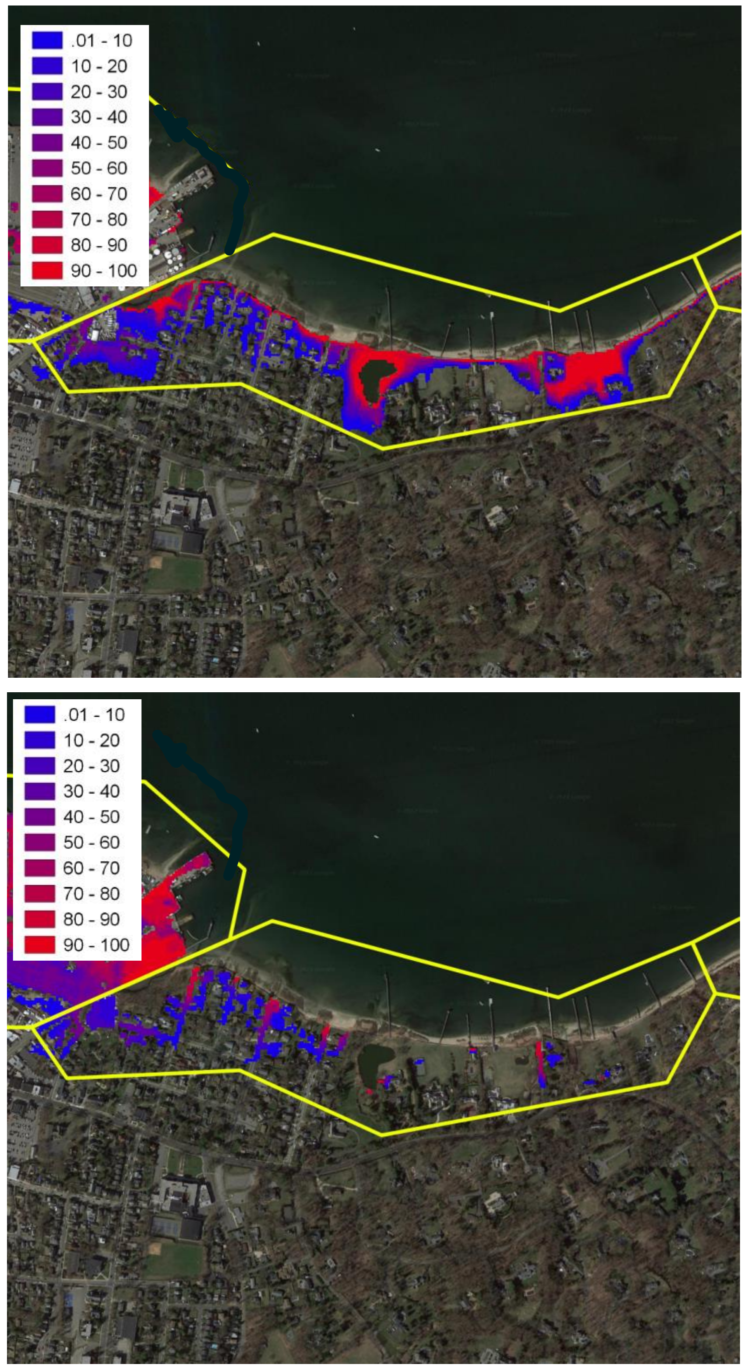


Figure 41. Areas that could accommodate marsh establishment by 2100. top: in currently undeveloped dry land areas, bottom: in developed ones.

Future marsh migration at eastern Oyster Bay

PROJECTED INUNDATION AND LANDCOVER CHANGES DUE TO SEA LEVEL RISE

Currently (as of 2004, the most recent land cover data available) the eastern Oyster Bay study area (including Tiffany Creek marshes) includes approximately 12 acres of wetlands (marshes and unvegetated flats), of which 9 acres are vegetated marshes, while the rest are beaches or tidal flats. Under most possible sea level rise scenarios, current marsh coverage is predicted to keep up with sea level. These irregularly-flooded marsh lands have relatively high elevations compared to sea levels so they can withstand some sea-level rise. However:

- Areas of high-elevation marshes are predicted to be replaced by low marsh;
- 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 63 tax parcels, in and adjacent to the wetland area, may be affected by increased inundation. The vast majority of the tax parcels and acreage in this study area is privately owned.

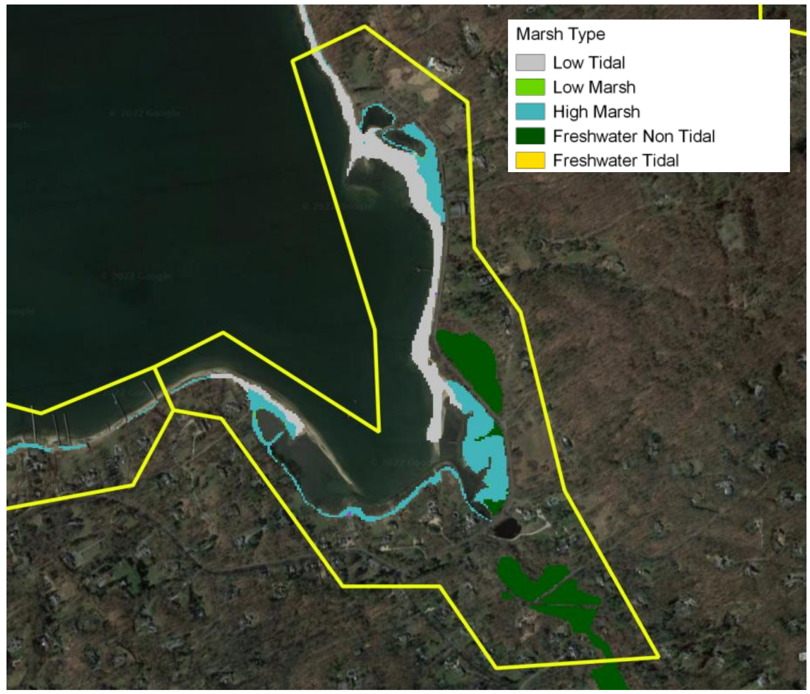


Figure 42. Satellite image of eastern Oyster Bay with current marsh coverage (Sources: NWI; Satellite imagery from Google).

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.

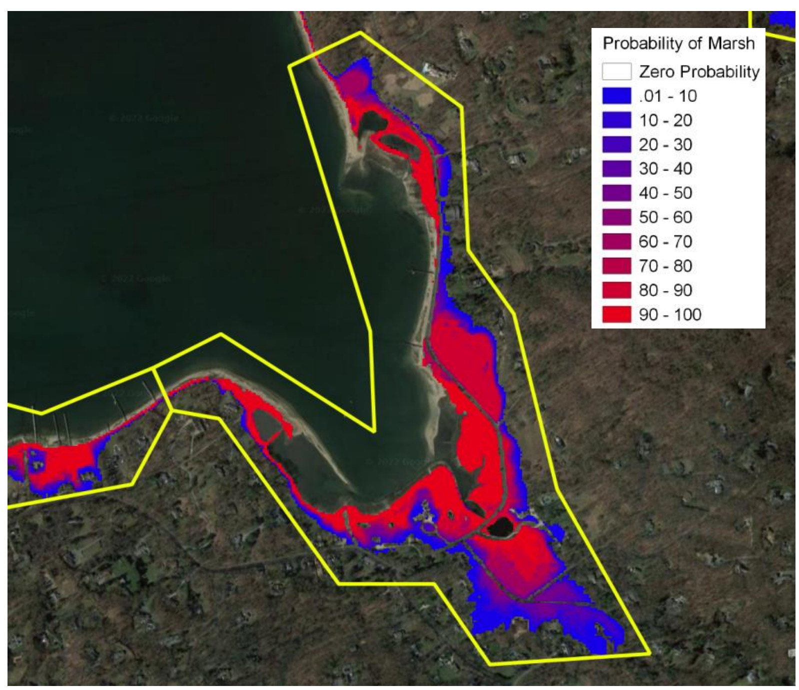


Figure 43. Probability of marsh habitat map, year 2100

WETLAND LOSSES

- Existing marsh area, currently covering 11.5 acres, is only predicted to be reduced by 0.6 acres by 2100 (this is the average of all uncertainty-analysis simulations). However, an additional 0.5 acres of marsh could be converted to tidal flats or open water in the highest SLR scenario modeled.
- In addition, approximately 0.2 acres of current tidal flats or beaches are predicted to become open water by 2055, increasing to 1.0 by 2100.

	Owner Type	2004	2055	2100
Existing marsh area (acres)	Public	0.0	0.0	0.0
	Private	8.8	8.5	8.2
Average new marsh area in undeveloped dry land (acres)	Public	0.0	0.0	0.0
	Private	0.0	5.8	22.8
Average new marsh area in developed dry land (acres)	Public	0.0	0.0	0.0
	Private	0.0	0.2	1.0
Total potential marsh area (acres)		8.8	14.4	32.0

Table 6. Average marsh habitat predicted given SLR in the years 2055 and 2100. Private areas include also tax parcels with unknown owner type.

POTENTIAL FOR MARSH MIGRATION

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

- On average, 5.8 acres of new marsh could be expected to establish in current undeveloped dryland by 2055, or up to 23 acres by 2100. The maximum possible area of new marsh would be 36 acres under the highest SLR scenario.
- In addition, properly restored developed dry land could accommodate the establishment of an average 0.2 acres of marsh by 2055 and 1.0 acres by 2100, with a possible maximum area of 2.0 acres. (Note, some of these developed areas include roads and buildings that are likely to be maintained as such in the future.)

SUMMARY

Although the current (as of 2004) 9 acres of marsh are predicted to remain viable under a wide range of possible sea level rise increases, by 2100 marsh areas could be reduced to a total of 8 acres under more extreme scenarios. Potential marsh losses could be offset by the migration of marshes onto newly-inundated dry lands. If **marsh migration** is allowed, an average of 6 acres of current dry land could accommodate new marsh by 2055 and 24 acres by 2100. (This number could stretch to 38 acres of new marsh under more extreme SLR scenarios).

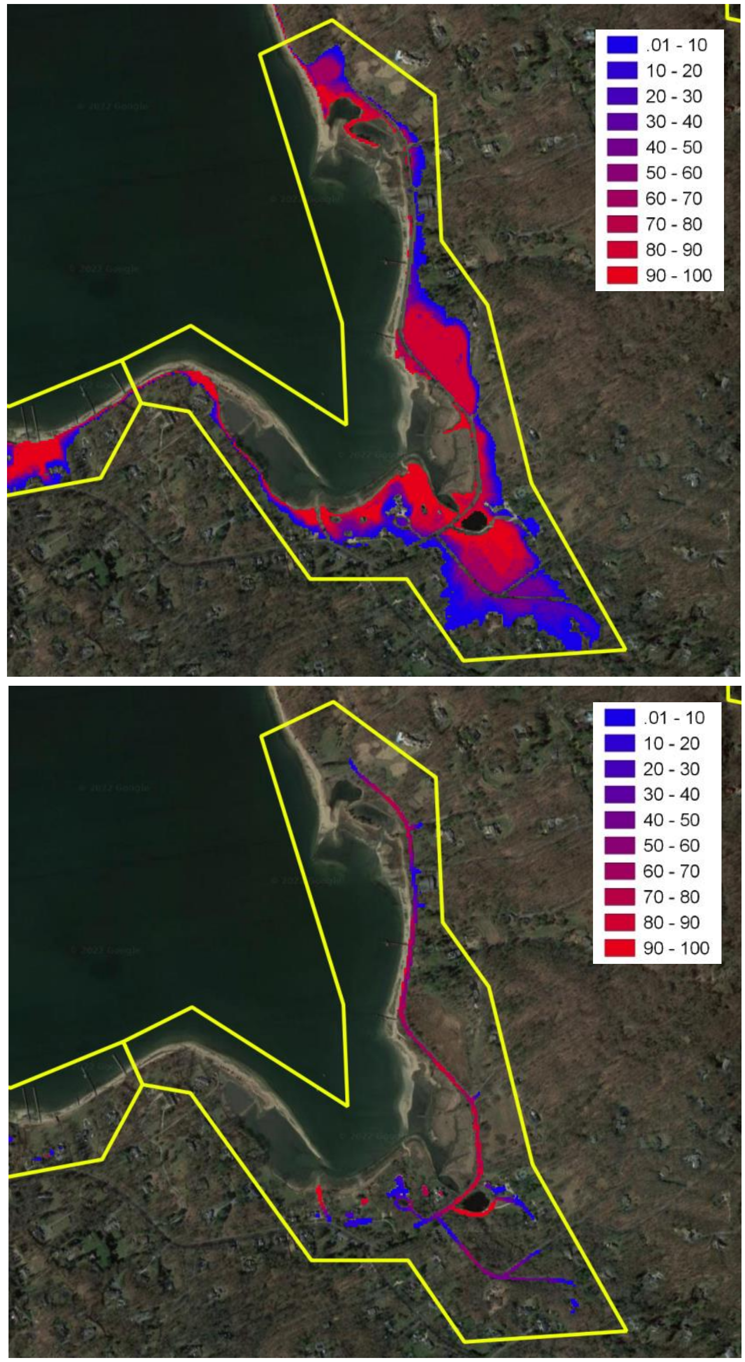


Figure 44. Areas that could accommodate marsh establishment by 2100. top: in currently undeveloped dry land areas, bottom: in developed ones.

Future marsh migration at Centre Island

PROJECTED INUNDATION AND LANDCOVER CHANGES DUE TO SEA LEVEL RISE

Currently (as of 2004, the most recent land cover data available) the Centre Island, NY study area includes approximately 72.9 acres of wetlands (marshes and unvegetated flats), of which 55.2 acres are irregularly-flooded vegetated marshes, and the rest are tidal flats or beaches. Under most possible sea level rise scenarios, current marsh coverage is predicted to remain despite higher water levels. These irregularly-flooded marsh lands have relatively high elevations compared to sea levels so they can withstand some sea-level rise. However:

- Many areas of high-elevation marshes are predicted to be replaced by low marsh;
- 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 83 tax parcels, in and adjacent to the wetland area, may be affected by increased inundation. All of these parcels are private except for one: the large region of marshes to the east of the study area is owned by the Incorporated Village of Centre Island.

Figure 45. Satellite image of Centre Island 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.

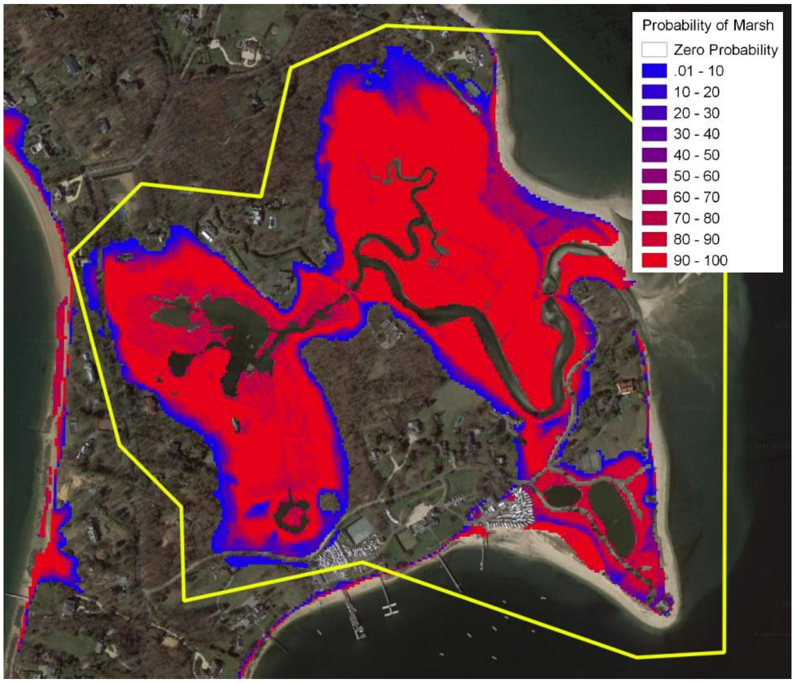


Figure 46. Probability of marsh habitat map, year 2100

WETLAND LOSSES

- Existing marsh area, currently covering 55 acres, is only predicted to be reduced by 3.4 acres by 2100 (this is the average of all uncertainty-analysis simulations). However, an additional 14 acres of marsh could be converted to tidal flats or open water in the most extreme SLR scenario modeled.
- In addition, approximately 1.5 acres of current tidal flats or beaches are predicted to become open water by 2055, increasing to 4.7 acres by 2100.

	Owner Type	2004	2055	2100
Existing marsh area (acres)	Public	23.9	23.8	23.1
	Private	31.4	31.4	28.8
Average new marsh area in undeveloped dry land (acres)	Public	0.0	0.6	1.2
	Private	0.0	8.1	24.5
Average new marsh area in developed dry land (acres)	Public	0.0	0.0	0.0
	Private	0.0	0.8	3.0
Total potential marsh area (acres)		55.2	64.7	80.7

Table 7. Average marsh habitat predicted given SLR in the years 2055 and 2100. Private areas include also tax parcels with unknown owner type.

POTENTIAL FOR MARSH MIGRATION

Predicted 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, 8.7 acres of new marsh could be expected to establish in current undeveloped dryland by 2055, or up to 26 acres by 2100. The maximum possible area of new marsh would be 39 acres under the highest SLR scenario.
- In addition, properly restored developed dry land could accommodate the establishment of an average 0.8 acres of marsh by 2055 and 3.0 acres by 2100, with a possible maximum area of 4.3 acres. (Note, some of these developed areas include roads that are likely to be maintained as such in the future.)

SUMMARY

Although the current (as of 2004) 55.2 acres of marsh are predicted to remain viable under a wide range of possible sea level rise increases, by 2100 marsh areas could be reduced to a total of 37.7 acres under more extreme scenarios. Potential marsh losses could be offset by the migration of marshes onto newly-inundated dry lands. If **marsh migration** is allowed, an average of 9.5 acres of current dry land could accommodate new marsh by 2055 and 28.8 acres by 2100. (This number could stretch to 43.7 acres of new marsh under more extreme SLR scenarios).

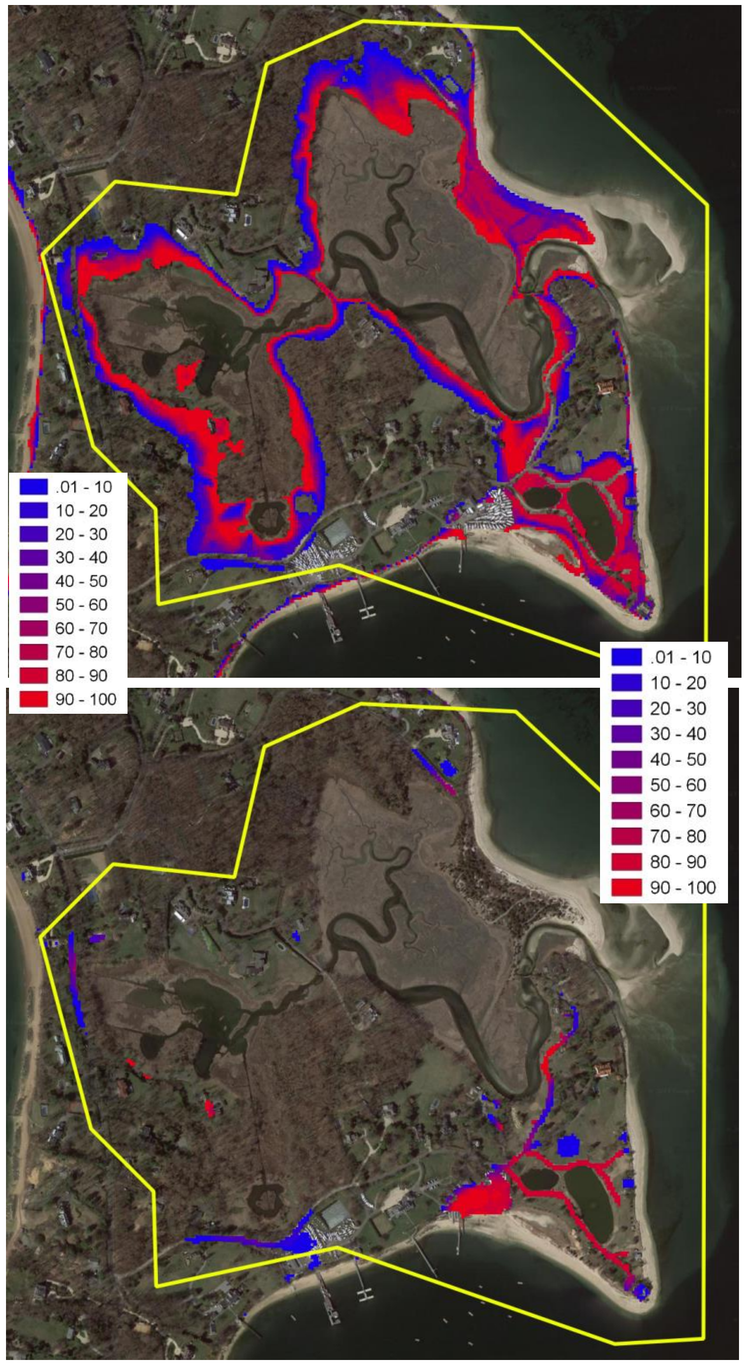


Figure 47. Areas that could accommodate marsh establishment by 2100. top: in currently undeveloped dry land areas, bottom: in developed ones.

Future marsh migration at Cove Point

PROJECTED INUNDATION AND LANDCOVER CHANGES DUE TO SEA LEVEL RISE

The Cove Point study area is located within the town of Oyster Bay. As of 2004, the most recent land cover data available, the Cove Point study area includes approximately 10.5 acres of wetlands (marshes and unvegetated flats), of which 5.2 acres are vegetated marshes, while the rest are beaches and tidal flats. Under most possible sea level rise scenarios, current marsh coverage is predicted to keep up with sea level. These irregularly-flooded marsh lands have relatively high elevations compared to sea levels so they can withstand some sea-level rise. However:

- Areas of high-elevation marshes are predicted to be replaced by low marsh;
- 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 19 tax parcels, in and adjacent to the wetland area, may be affected by increased inundation. The majority of tax parcels in this study area are privately owned.

ONLINE VIEWER

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

Figure 48. Satellite image of Cove Point 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.

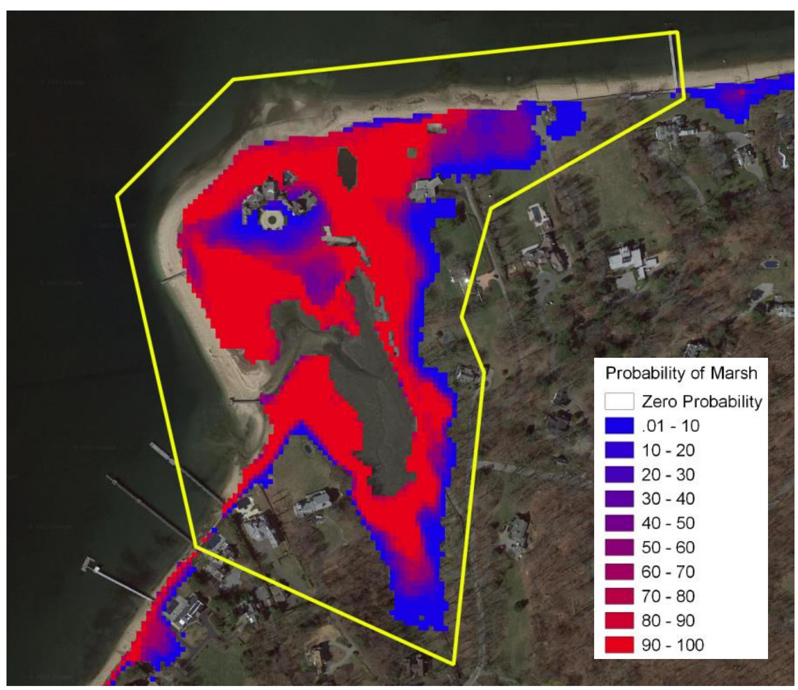


Figure 49. Probability of marsh habitat map, year 2100

WETLAND LOSSES

- Existing marsh area, currently covering 5.2 acres, is only predicted to be reduced by 0.4 acres by 2100 (this is the average of all uncertainty-analysis simulations). However, an additional 1.3 acres of marsh could be converted to tidal flats or open water in the highest SLR scenario modeled.
- In addition, approximately 0.7 acres of current tidal flats or beaches are predicted to become open water by 2055, increasing to 2.1 acres by 2100.

	Owner Type	2004	2055	2100
Existing marsh area (acres)	Public	0.0	0.0	0.0
	Private	5.2	5.3	4.9
Average new marsh area in undeveloped dry land (acres)	Public	0.0	0.0	0.0
	Private	0.0	3.0	7.1
Average new marsh area in developed dry land (acres)	Public	0.0	0.0	0.0
	Private	0.0	0.3	0.6
Total potential marsh area (acres)		5.2	8.5	12.6

Table 8. Average marsh habitat predicted given SLR in the years 2055 and 2100. Private areas include also tax parcels with unknown owner type.

POTENTIAL FOR MARSH MIGRATION

Predicted 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, 3.0 acres of new marsh could be expected to establish in current undeveloped dryland by 2055, or up to 7.1 acres by 2100. The maximum possible area of new marsh would be 10.7 acres under the highest SLR scenario.
- In addition, properly restored developed dry land could accommodate the establishment of an average 0.3 acres of marsh by 2055 and 0.6 acres by 2100, with a possible maximum area of 1.0 acres. (Note, some of these developed areas include roads and buildings that may be maintained as such in the future.)

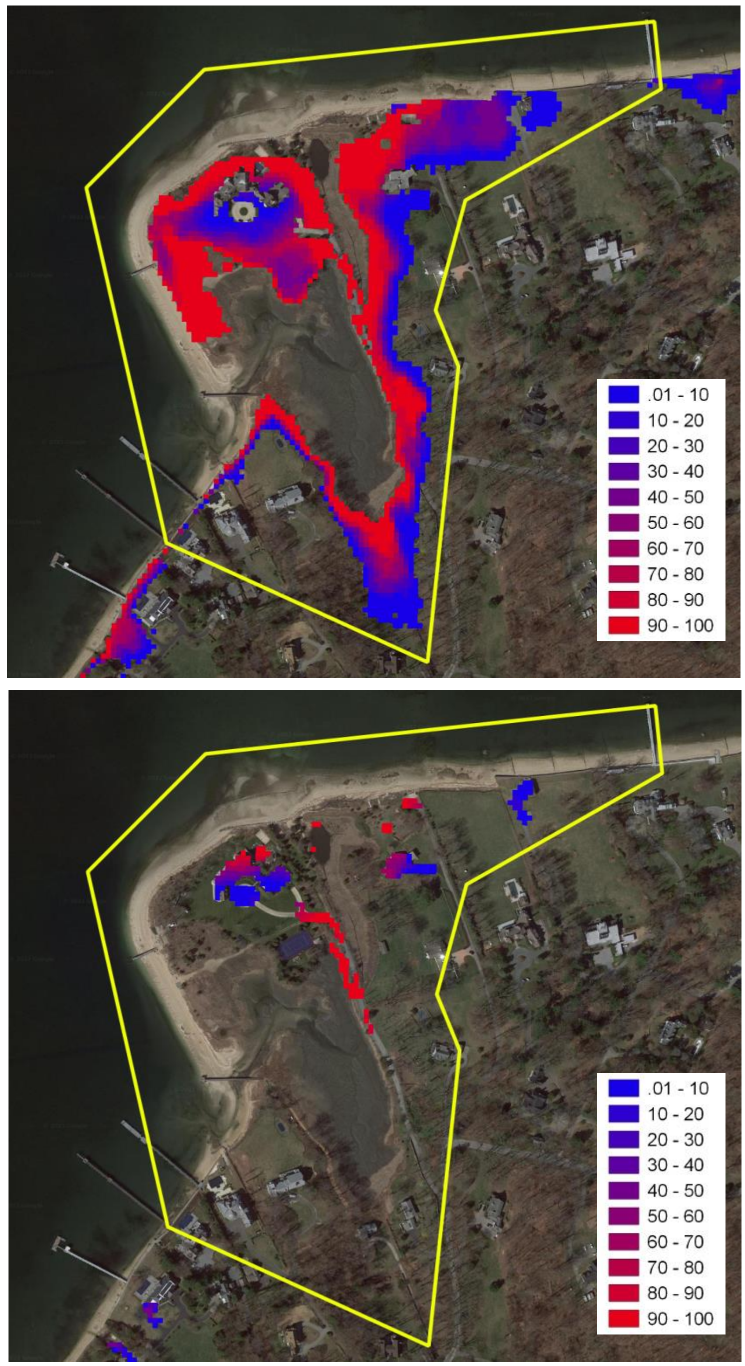


Figure 50. Areas that could accommodate marsh establishment by 2100. top: in currently undeveloped dry land areas, bottom: in developed ones.

SUMMARY

Although the current (as of 2004) 5.2 acres of marsh are predicted to remain viable under a wide range of possible sea level rise increases, by 2100 marsh areas could be reduced to a total of 3.6 acres under more extreme scenarios. Potential marsh losses could be offset by the migration of marshes onto newly-inundated dry lands. If **marsh migration** is allowed, an average of 3.2 acres of current dry land could accommodate new marsh by 2055 and 7.7 acres by 2100. (This number could stretch to 11.7 acres of new marsh under more extreme SLR scenarios).

Future marsh migration at the Theodore Roosevelt Property

PROJECTED INUNDATION AND LANDCOVER CHANGES DUE TO SEA LEVEL RISE

The Theodore Roosevelt Property is located at Sagamore Hill, Oyster Bay, NY. As of 2004, the most recent land cover data available, the study area including the Theodore Roosevelt Property includes approximately 11 acres of wetlands (marshes and unvegetated flats), of which 7 acres are vegetated marshes, while the rest are beaches and tidal flats. Under most possible sea level rise scenarios, current marsh coverage is predicted to keep up with sea level. These marsh lands have relatively high elevations compared to sea levels so they can withstand some sea-level rise. However:

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

Figure 51. Satellite image of Theodore Roosevelt Property with current marsh coverage (Sources: NWI; Satellite imagery from Google).

A total of 8 tax parcels, in and adjacent to the wetland area, may be affected by increased inundation. Portions of the study area are privately owned and parts are owned by the federal government.

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.

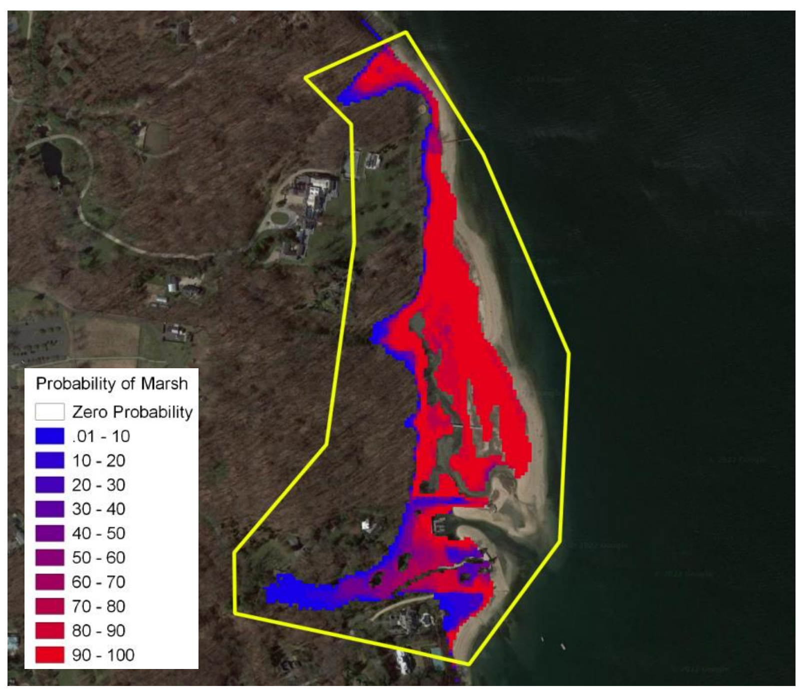


Figure 52. Probability of marsh habitat map, year 2100

WETLAND LOSSES

- Existing marsh area, currently covering 6.5 acres, is only predicted to be reduced by 0.3 acres by 2100 (this is the average of all uncertainty-analysis simulations). However, an additional 2.5 acres of marsh could be converted to tidal flats or open water in the highest SLR scenario considered.

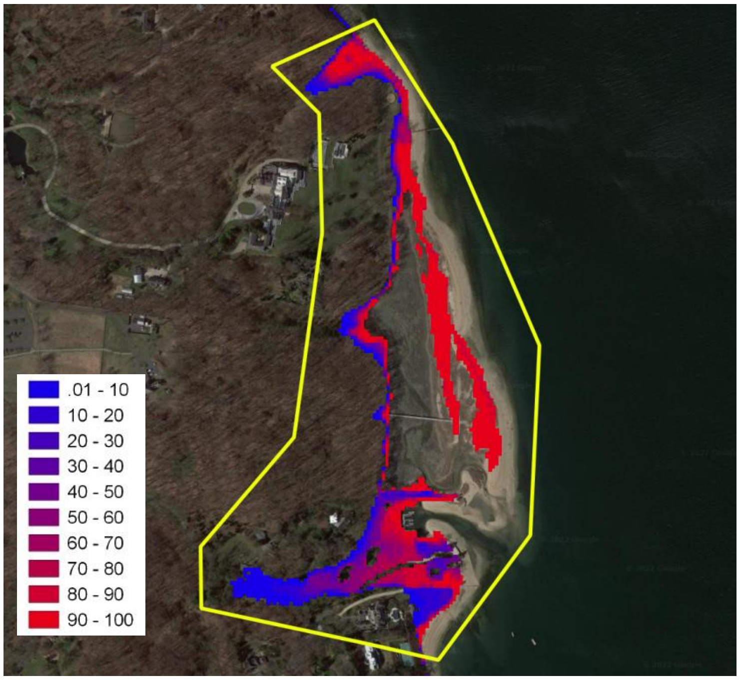
	Owner Type	2004	2055	2100
Existing marsh area (acres)	Public	3.8	3.9	3.6
	Private	2.7	2.8	2.6
Average new marsh area in undeveloped dry land (acres)	Public	0.0	1.4	2.3
	Private	0.0	1.9	5.7
Average new marsh area in developed dry land (acres)	Public	0.0	0.0	0.0
	Private	0.0	0.0	0.2
Total potential marsh area (acres)		6.5	9.9	14.4

Table 9. Average marsh habitat predicted given SLR in the years 2055 and 2100. Private areas include also tax parcels with unknown owner type.

POTENTIAL FOR MARSH MIGRATION

Predicted 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, 3.3 acres of new marsh could be expected to establish in current undeveloped dryland by 2055, or up to 8.0 acres by 2100. The maximum possible area of new marsh would be 11.6 acres under the highest SLR scenario.
- In addition, properly restored developed dry land could accommodate the establishment of an average 0.2 acres by 2100, with a possible maximum area of 0.4 acres. (Note, some of these developed areas include roads or buildings that may be maintained as such in the future.)



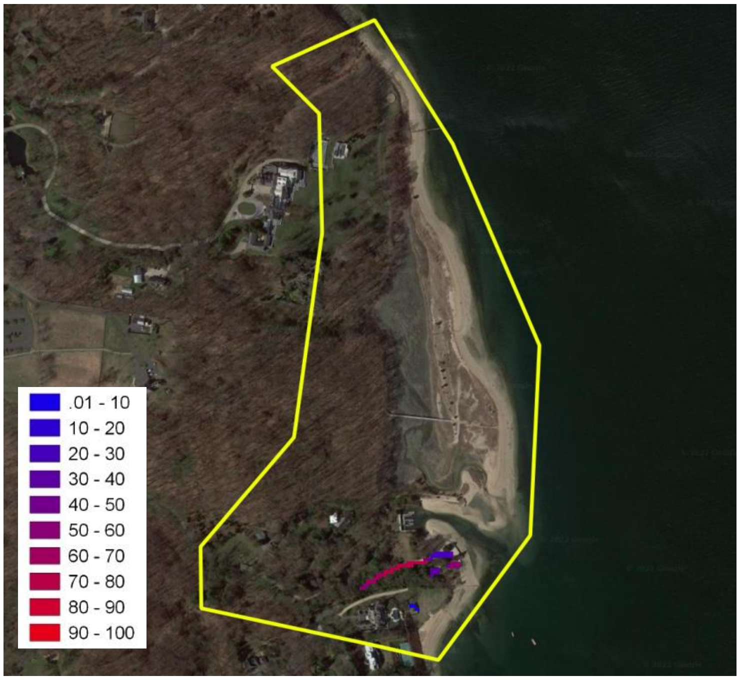


Figure 53. Areas that could accommodate marsh establishment by 2100. top: in currently undeveloped dry land areas, bottom: in developed ones.

SUMMARY

Although the current (as of 2004) 6.5 acres of marsh are predicted to remain viable under a wide range of possible sea level rise increases, by 2100 marsh areas could be reduced to a total of 3.6 acres under more extreme scenarios. Potential marsh losses could be offset by the migration of marshes onto newly-inundated dry lands. If **marsh migration** is allowed, an average of 3.3 acres of current dry land could accommodate new marsh by 2055 and 8.2 acres by 2100. (This number could stretch to 11.9 acres of new marsh under the most extreme SLR scenario).

Future marsh migration at Shore Road

PROJECTED INUNDATION AND LANDCOVER CHANGES DUE TO SEA LEVEL RISE

As of 2004, the most recent land cover data available, the Shore Road study area, in the town of Cold Spring Harbor, NY, includes approximately 6.0 acres of wetlands (marshes and unvegetated flats). Just under half of this acreage (2.6 acres) is land at an elevation that has the potential for vegetated marsh habitat. The rest of the study area is predicted to be beaches or tidal flats. Under higher sea level rise scenarios, some loss of potential wetland habitat is. In addition:

- Areas of potential high-elevation marshes are predicted to be replaced by low marsh;
- 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 26 tax parcels, in and adjacent to the wetland area, may be affected by increased inundation. The inner parcels (dry lands) are primarily privately owned.

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.

Figure 54. Satellite image of Shore Road with current marsh coverage (Sources: NWI; Satellite imagery from Google).

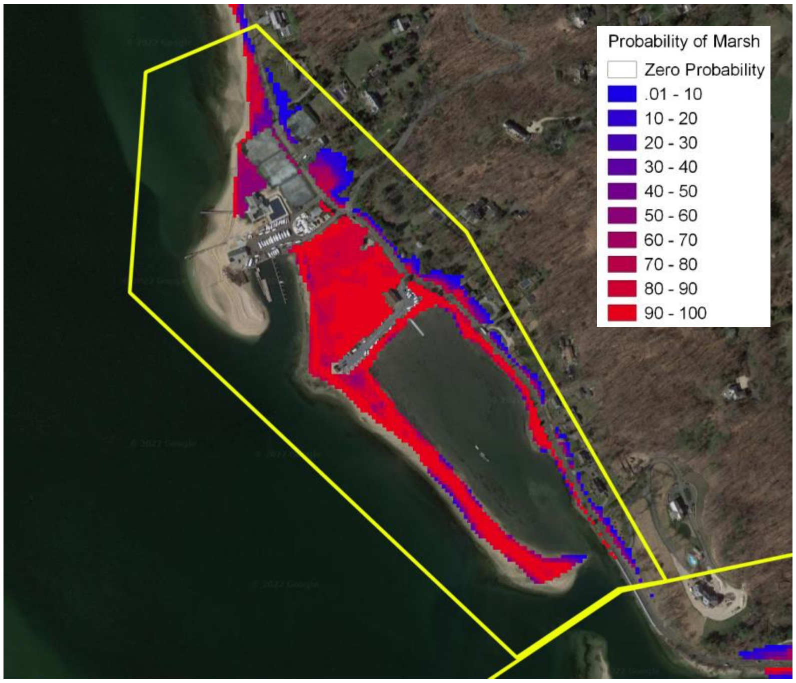


Figure 55. Probability of marsh habitat map, year 2100

WETLAND LOSSES

- Potential existing marsh area, currently covering 2.6 acres, is only predicted to be reduced by 0.6 acres by 2100 (this is the average of all uncertainty-analysis simulations). However, an additional 1.1 acres of marsh could be converted to tidal flats or open water in most extreme SLR scenario modeled.
- In addition, approximately 0.2 acres of current tidal flats or beaches are predicted to become open water by 2055, increasing to 1.1 by 2100.

	Owner Type	2004	2055	2100
Existing marsh area (acres)	Public	0.4	0.4	0.3
	Private	2.2	2.1	1.7
Average new marsh area in undeveloped dry land (acres)	Public	0.0	0.1	0.1
	Private	0.0	2.5	6.7
Average new marsh area in developed dry land (acres)	Public	0.0	0.0	0.0
	Private	0.0	1.0	3.5
Total potential marsh area (acres)		2.6	6.2	12.4

Table 10. Average marsh habitat predicted given SLR in the years 2055 and 2100. Private areas include also tax parcels with unknown owner type.

POTENTIAL FOR MARSH MIGRATION

Predicted 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, 2.6 acres of new marsh could be expected to establish in current undeveloped dryland by 2055, or up to 6.8 acres by 2100. The maximum possible area of new marsh would be 8.5 acres under the highest SLR scenario.
- In addition, properly restored developed dry land could accommodate the establishment of an average 1.0 acres of marsh by 2055 and 3.5 acres by 2100, with a possible maximum area of 4.7 acres. (Note, some of these developed areas include roads and buildings that may be maintained as such in the future.)

SUMMARY

Although the current (as of 2004) 2.6 acres of marsh are predicted to remain viable under a wide range of possible sea level rise increases, by 2100 marsh areas could be reduced to a total of 1.0 acres under more extreme scenarios. Potential marsh losses could be offset by the migration of marshes onto newly-inundated dry lands. If **marsh migration** is allowed, an average of 3.7 acres of current dry land could accommodate new marsh by 2055 and 10.3 acres by 2100. (This number could stretch to 13.2 acres of new marsh under more extreme SLR scenarios).

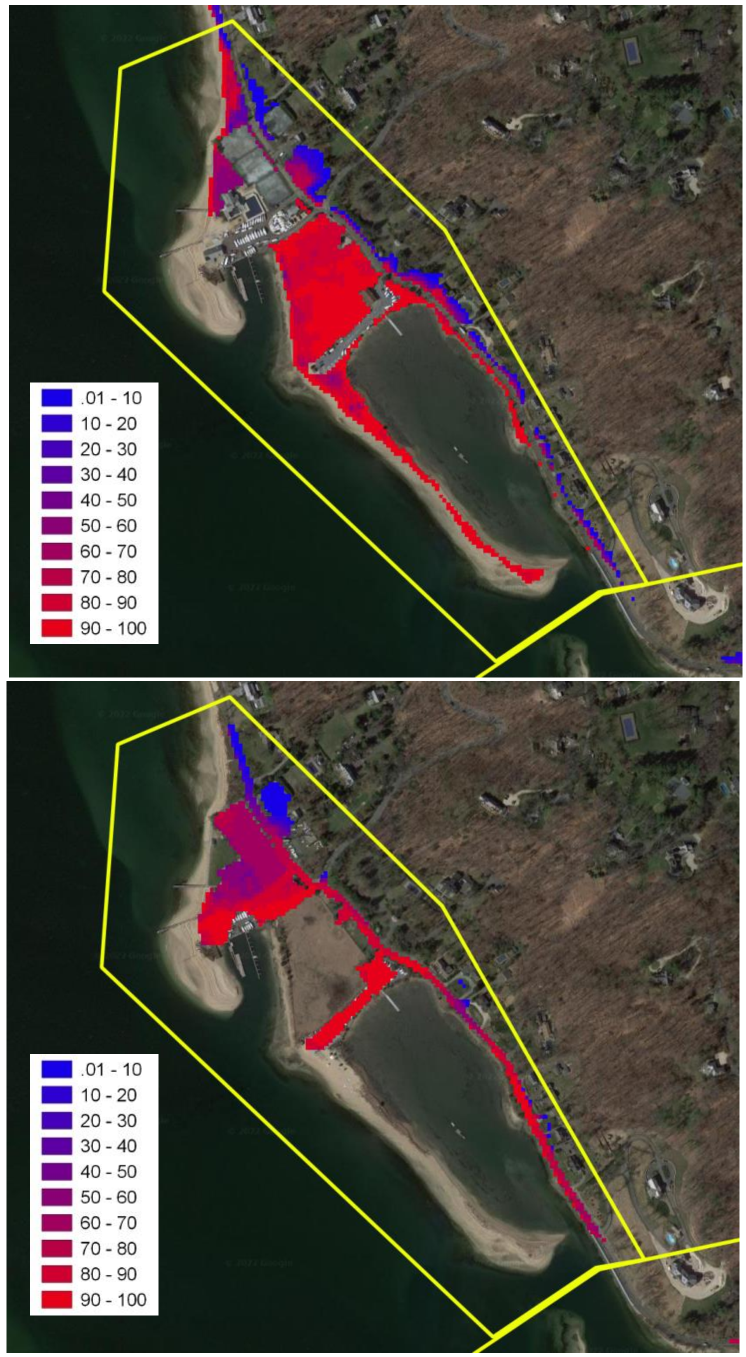


Figure 56. Areas that could accommodate marsh establishment by 2100. top: in currently undeveloped dry land areas, bottom: developed dry lands predicted to be regularly flooded

Future marsh migration at Cold Spring Harbor – Inner Harbor

PROJECTED INUNDATION AND LANDCOVER CHANGES DUE TO SEA LEVEL RISE

The study area of "inner Cold Spring Harbor" is partially in the town of Oyster Bay in Nassau County, and partially in the town of Huntington, Suffolk County, NY. As of 2004, the most recent land cover data available, the inner harbor study area includes approximately 15 acres of wetlands (marshes and unvegetated flats), of which 10 acres are vegetated marshes, while the rest are beaches or tidal flats. Under most possible sea level rise scenarios, current marsh coverage is predicted to keep up with sea level. These irregularly-flooded marsh lands have relatively high elevations compared to sea levels so they can withstand some sea-level rise. However:

- Areas of high-elevation marshes are predicted to be replaced by low marsh;
- 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 99 tax parcels, in and adjacent to the wetland area, may be affected by increased inundation. The Town of Huntington owns several large parcels to the east of the study area.

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.

Figure 57. Satellite image of inner Cold Spring Harbor with current marsh coverage (Sources: NWI; Satellite imagery from Google).

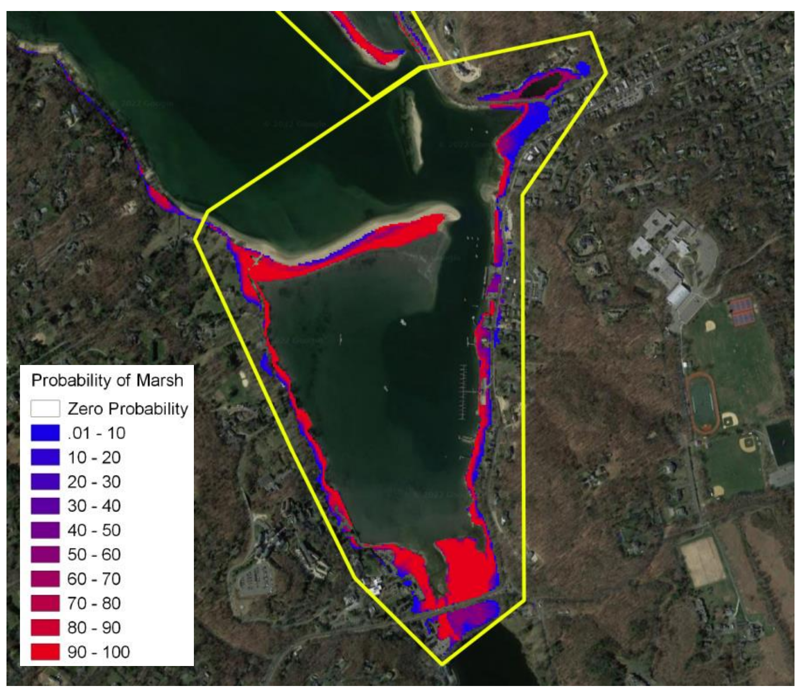


Figure 58. Probability of marsh habitat map, year 2100

WETLAND LOSSES

- Existing marsh area, currently covering 10 acres, is only predicted to be reduced by 1 acre by 2100 (this is the average of all uncertainty-analysis simulations). However, an additional 2 acres of marsh could be converted to tidal flats or open water in the highest sea-level rise scenario investigated.
- In addition, approximately 2 acres of current tidal flats or beaches are predicted to become open water by 2055, increasing to 4 by 2100.

POTENTIAL FOR MARSH MIGRATION

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

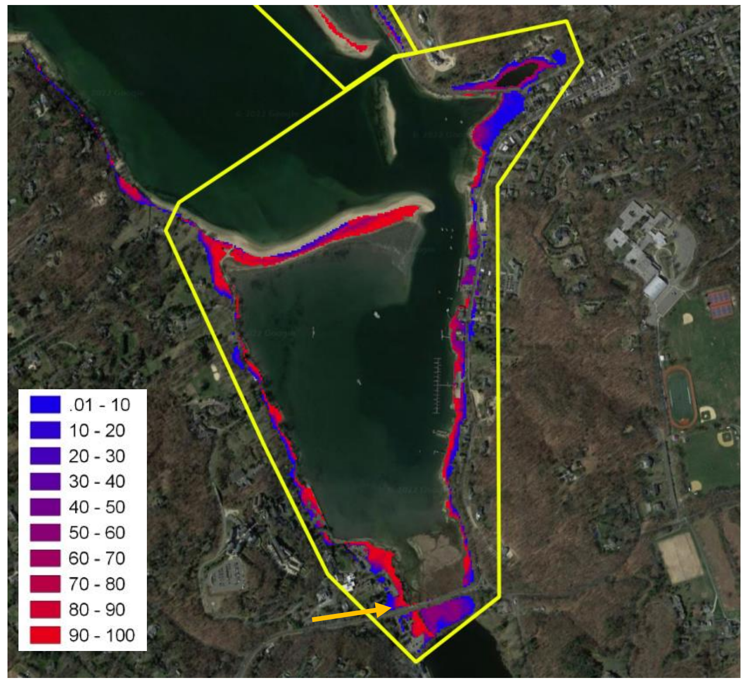
- On average, 4 acres of new marsh could be expected to establish in current undeveloped dryland by 2055, or up to 12 acres by 2100. The maximum possible area of new marsh would be 19 acres under the highest SLR scenario.
- Future marsh migration south of the North Hempstead Turnpike (orange arrows on Figure 59) would require that tidal flows continue to cross under that bridge with minimal restriction.
- In addition, properly restored developed dry land could accommodate the establishment of an average 0.3 acres of marsh by 2055 and 2 acres by 2100, with a possible maximum area of 3.4 acres. (Note, some of these developed areas include roads and buildings that may be maintained as such in the future.)

SUMMARY

Although the current (as of 2004) 10 acres of marsh are predicted to remain viable under a wide range of possible sea level rise increases, by 2100 marsh areas could be reduced to a total of 7 acres under more extreme scenarios. Potential marsh losses could be offset by the migration of marshes onto newly-inundated dry lands. If **marsh migration** is allowed, an average of 4 acres of current dry land could accommodate new marsh by 2055 and 14 acres by 2100. (This number could stretch to 22 acres of new marsh under more extreme SLR scenarios).

	Owner Type	2004	2055	2100
Existing marsh area (acres)	Public	1.0	0.8	0.6
	Private	9.4	9.2	8.6
Average new marsh area in undeveloped dry land (acres)	Public	0.0	0.3	1.4
	Private	0.0	3.6	10.5
Average new marsh area in developed dry land (acres)	Public	0.0	0.0	0.2
	Private	0.0	0.3	1.6
Total potential marsh area (acres)		10.4	14.3	22.7

Table 11. Average marsh habitat predicted given SLR in the years 2055 and 2100. Private areas include also tax parcels with unknown owner type.



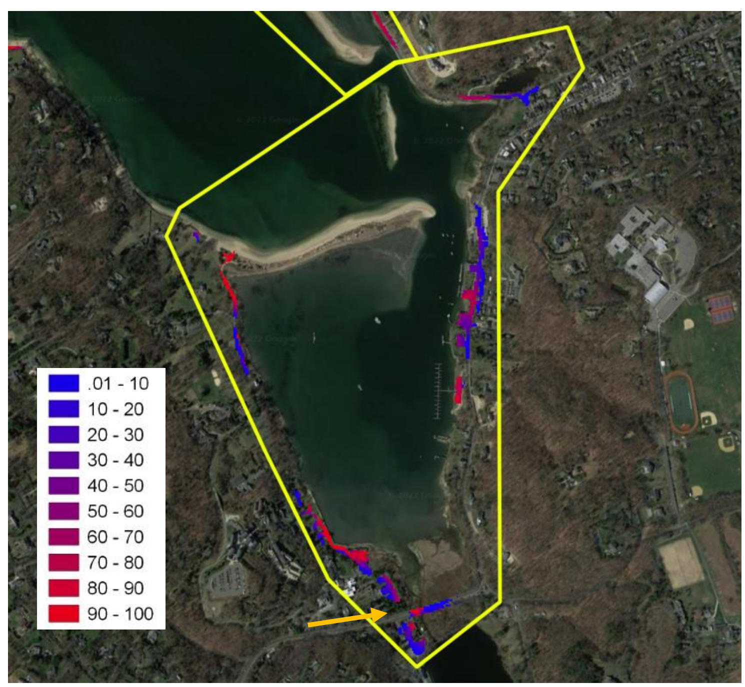


Figure 59. Areas that could accommodate marsh establishment by 2100. top: in currently undeveloped dry land areas, bottom: in developed ones.