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Transportation and Sanitation Drivers of Land Use/Land Cover Change: Loss of the Jamaica Bay Wetlands

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Transportation and Sanitation Drivers of Land Use/Land Cover Change:
Loss of the Jamaica Bay Wetlands

by

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TABLE OF CONTENTS

.LIST OF FIGURES

FIGURE		PAGE

FIGURE		PAGE

ABSTRACT

This thesis presents an analysis (1830-2014) of the historical events of land use/land cover change in the Jamaica Bay estuary, identification of the agents of change, and a perspective on the potential drivers of transportation and sanitation in land use/land cover change. The concept of drivers of land use land/cover change is used as the conceptual framework for this analysis.

At the time of colonization, a mile wide swath of wetlands surrounded Jamaica Bay. Beginning in the mid-1800s, the local landscape began a complete and irrevocable change as the wetlands were land filled for other uses. Analysis was conducted neighborhood-by-neighborhood and showed that changes were not uniform across sites. Land managers fell into three distinct groups: private-residential, private-commercial, and public, each responded differently to drivers of change. The study looked primarily at sanitation and transportation as factors of land use change. These drivers impacted the decisions made by land managers at different levels: proximate - endogenous, underlying – exogenous, and modifying.

The historical analysis was performed using primary and secondary data including histories, historical maps, and newspaper articles. Triangulation, a method that calls for a combination of two or more aspects of research, was used to improve the robustness and comprehensiveness of the research.

What is apparent from this research is that the development of the current mass transit network was strongly influenced by the investment in transportation that was made by private real estate. The anticipated profit from the development along the Atlantic

Ocean was a strong motivation for private investment in both real estate and transportation. In general, the neighborhoods along the north shore were not as attractive for real estate development and were not co-developed with a transit system. This made them more resistant to land use/land cover change.

Key words: Brooklyn – Queens – historical maps - historical ecology – public/private decision makers – real estate - GIS

II. INTRODUCTION

On the southwestern shore of Long Island, New York, there is a coastal lagoon called Jamaica Bay. The Bay is a large open body of water known for its wetlands and the multitude of wildlife it supports. The inhospitable wetlands kept the development of Jamaica Bay estuary in check for decades, leaving enough of the wild to be incorporated into the Jamaica Bay Wildlife Refuge in 1938. In 1948, title was transferred to the New York City Parks Department. Then, in 1972, it became part of the newly formed Gateway National Recreation Area (Philips, 2013).

Yet the Bay and its surrounding wetlands did not go unscathed. The wetlands that surrounded the Bay like a broad collar disappeared. Transportation and the disposal of refuse and sewage were major drivers of land use/land cover change and modification of the Jamaica Bay estuary. Originally a source of food and fodder, the wetlands made way for agriculture and eventually became an urban landscape with polluted waters.

Major earthworks to build roads, railroads, seaports, and airports required massive amounts of landfill and the dredging of channels. The Bay's wetlands offered an inexpensive location for the City to dispose of its burgeoning rubbish as landfill. The rapid exchange of water by the diurnal tides between the Bay and the ocean seemed to be a solution to the city's sewage problems. However, with the restructuring of the Bay through landfill, dredging and the continued westward growth of the Rockaway Peninsula, the tidal exchange with the oceans slowed and the waters became polluted

(Gordon et al., 2001). The wetlands of the Bay also offered large the expanses of undeveloped land needed for building airports (Masefield, 1972)

In 1844, there were 20,000 acres/31 square miles of open water and 20,600 acres/32 sq. miles of wetlands used primarily for food and fodder. By 2004, they were reduced to 16,000 acres/25 sq. miles of open water and only 4,000 acres/6 sq. miles of wetlands. The result was a loss of 26 sq. miles of wetlands and 7 sq. miles of open water. The 26 sq. miles of former wetlands were converted with landfill and urbanized, becoming airports, roads, housing, and parks. The remaining wetlands and open water were used for recreation and the dispersal of combined sewer overflow (CSO), two conflicting functions.

Native American presence on the Bay gave way to the Dutch colonists in the mid 1600s. The Dutch, like their predecessors, made little alterations to the landscape (Swanson, West-Valle, & Decker, 1992). The early colonists continued using the wetlands for primary purposes, like food and hay for grazing. Over time the wetlands lost their value as a primary food source and were considered to be of little or no value. In the early 1900s, pollution closed the Bay to the harvesting of fish and shellfish which was once a major industry (Jamaica Bay, foul with sewage, closed to oyster beds; 300,000 bushels gone.1921). New York City, at that time confined to the island of Manhattan, grew at an astonishing rate. With little infrastructure, refuse and sewage became tremendous problems, leaving the city deep in trash and overwhelmed by foul odors (Miller, 2000). The countryside became an important respite, and as transportation improved vast stretches of the Jamaica Bay shore became the home of new developments (Bellot, 1918).

Much of the current research on Jamaica Bay is focused on the existing wetlands. Its focus is to understand the causes of the loss of wetlands, the restoration of wetlands habitats and to make the wetlands more sustainable. Other literature about the Bay is historical.

This thesis looks at the history of the Bay from the perspective of land use/land cover change. It is about the lost wetlands that cannot be restored or replaced. The following is a historical, social and economic analysis of the lost wetlands. The questions addressed here are:

- What caused the loss of Jamaica Bay's wetlands?
- How did transportation and sanitation, two drivers of land use/land cover change, affect the Bay?
- What were the consequences, both expected and unexpected?

In an effort to answer these questions this thesis focuses on the land managers, whose decisions changed the Jamaica Bay landscape, and the factors that influenced their decisions. In particular, it targets the roles of transportation and sanitation and their influence on the changing attitudes that resulted in the loss of the wetlands.

Land use/land cover change is an ongoing process. An understanding of the factors that resulted in irrevocable loss of wetlands may be of aid to future land use managers. Learning from past experiences helps to establish effective future policies.

This thesis borrows from both historical ecology and land use/land cover change perspectives. It uses historical ecology methods to portray Jamaica Bay at the moment when the decisions to change the land cover were made. It uses drivers of land use/land cover change to explain why and what is happened. Historical maps and secondary data allow for the examination of land use/land cover change from the early 1800s to the present, the period during which anthropogenic activities were responsible for most of the changes in the Bay. GIS was liberally used to aid in visualizing the significant changes that took place.

III LITERATURE REVIEW

A. STUDY AREA

The Jamaica Bay estuary is the largest wetlands and natural open space in New York City. It is the westernmost coastal lagoon along the south shore of Long Island (Anthony et al. 2009). (Figure III.A-1) The narrow Rockaway Inlet links Jamaica Bay to the Lower New York Bay and Atlantic Ocean (Tiner 2011). Today the Bay is almost land-locked due to the westward migration of the Peninsula, resulting in a very narrow inlet compared to the size of the Bay (Benotti, Abbene, and Terracciano 2007).

Lagoons are quiet bodies of predominantly salt and brackish water located behind barrier islands and linked to the open ocean (Anthony et al. 2009). (Figure III.A.-2) Water quality is affected by evaporation, precipitation, groundwater, runoff, and exchanges with the ocean. Lagoons have low flushing rates due to their restricted exchange with the ocean. Even so, bay - ocean exchange is still the most significant factor affecting water quality (Anthony et al. 2009).

The southern expanse of Jamaica Bay is bound by barrier islands, the largest being the Rockaway Peninsula. The Rockaway Peninsula is one of many coastal barrier islands, spits, and peninsulas that formed from sediment along the northern Atlantic coast (Tiner, 2011). (Figure III.A.-3) On Long Island alone there are 75 miles of barrier islands stretching along the island's south shore.

Barrier islands are stretches of sand that form parallel to the coast. They can be completely detached from the mainland, as are Fire Island and Long Beach, or attached to the mainland, as is the Rockaway Peninsula. Before anthropogenic modification, Jamaica Bay's barrier islands were covered with shifting sand dunes and Atlantic Cedars, protecting the Bay from the wind and waves of the Atlantic Ocean (Bellot, 1918; Cogbill, Burk, & Motzkin, 2002; Laderman, Brody, & Pendleton, 1989).

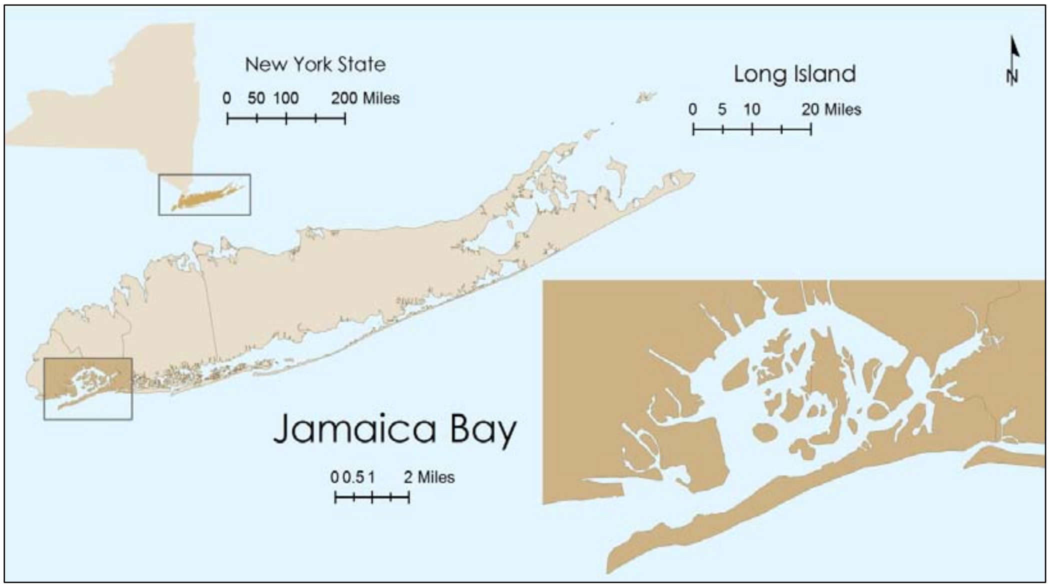


Figure III.A.-1 Location Map

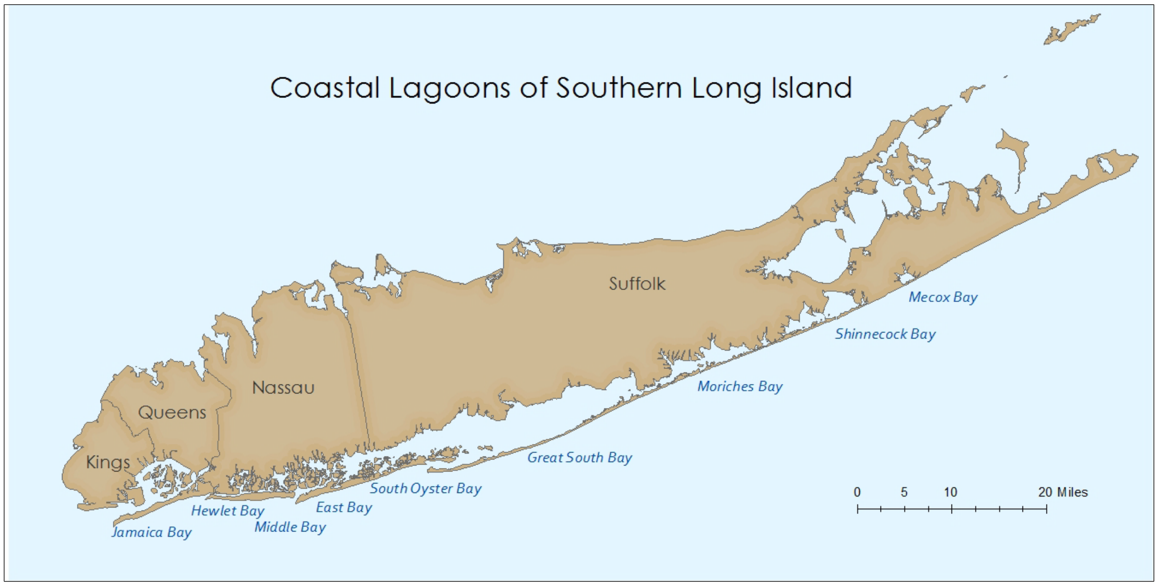


Figure III.A.-2 Coastal Lagoons of Southern Long Island

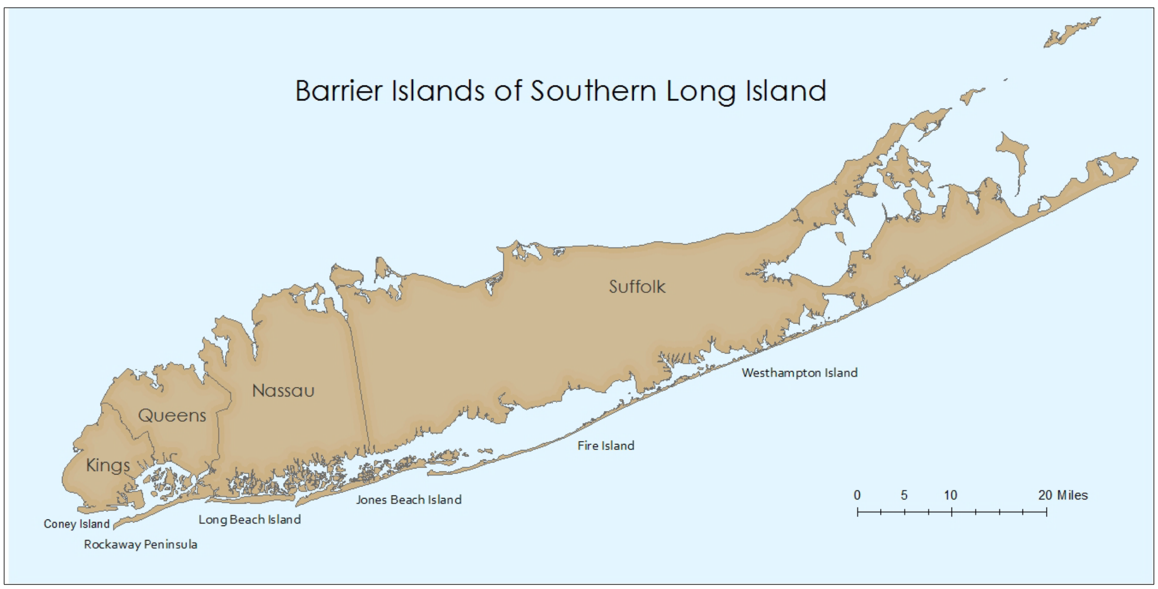


Figure III.A.-3 Barrier Islands

During the past 150 years there have been three major theories about barrier island formation based on the works of Élie de Beaumont, Grove Karl Gilbert, and William John McGee. Élie de Beaumont's (1845) offshore bar theory is that barrier islands are formed by waves approaching the coast. (Figure III.A.-4) As waves approach the shore, their energy, stirs up bottom sediment. Then as the waves break over shallower water, they lose energy and deposit sediment on the higher ground. Grove Karl Gilbert's (1885) spit accretion theory says that sediment originates from sources along the shore and is deposited by currents along the shore. According to this idea, Long Island's barrier islands were created by the deposition of sand along the southern shore of Long Island from sediment created from the eroding bluff along Montauk. William John McGee's (1890) beach ridge submergence theory is that barrier islands evolve from beach ridges that are created during times of lower sea levels. As sea levels rises, the areas behind the ridges are flooded (U.S. Army Corps of Engineers 2006). However, it is the constant action of longshore drift (the transportation of sediment along the coast by currents propelled by wind) that maintains and elongates the existing barrier islands of Long Island (U.S. Army Corps of Engineers 2006; Cody, Auwaerter, and Curry 2009).

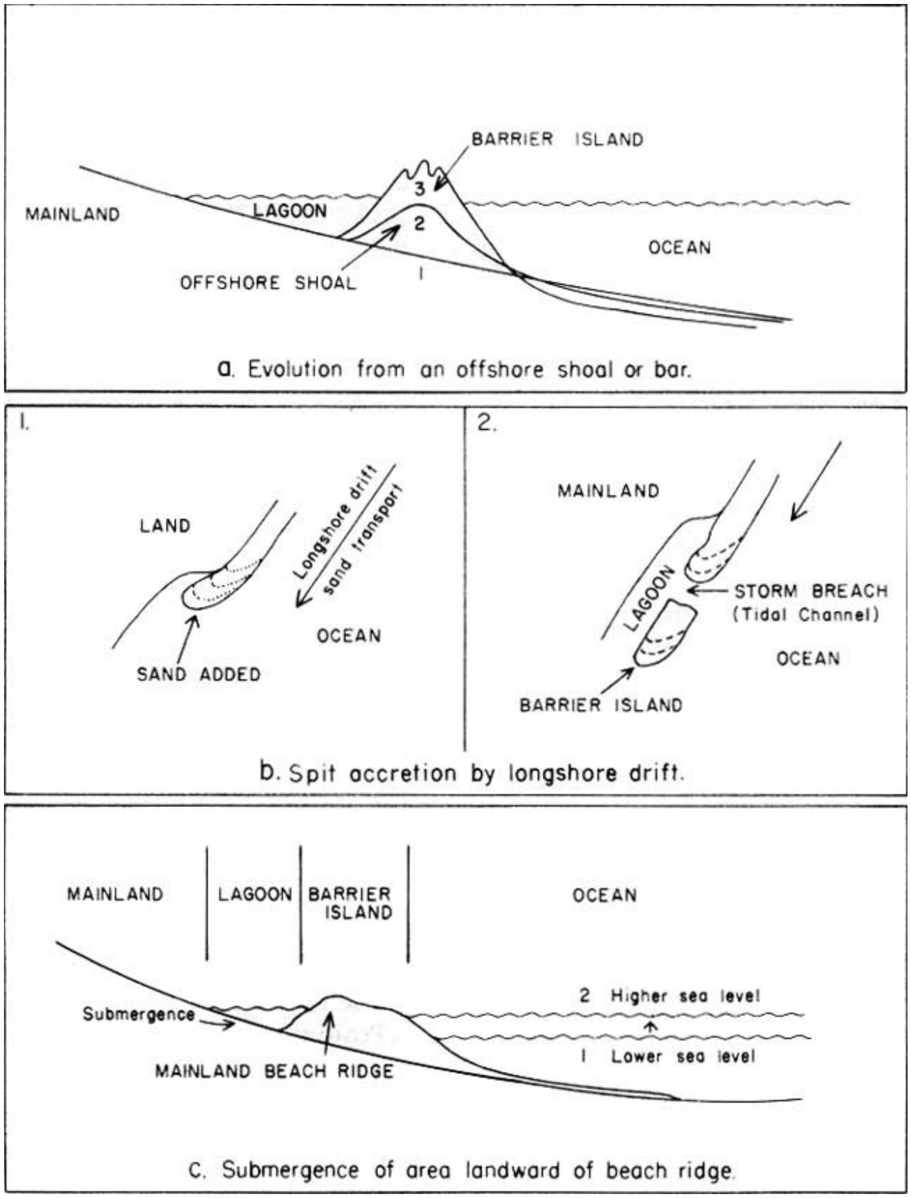


Figure III.A.-4 "Theories of Barrier Island Origin: (a) evolution from an offshore shoal or bar, (b) evolution by spit accretion resulting from longshore drift of sand, and (c) evolution by flooding of area landward of mainland beach sand ridges during a rise in sea level" (U.S. Army Corps of Engineers, 2006).

The Bay was formed 20,000 years ago as the continental ice sheet began to retreat (de Blij & Muller, 1993). The southernmost edge of the Wisconsin Episode glaciations reached as far south as Long Island. Over several advances and retreats of the glacier, it left behind rubble that it had pushed south each time it expanded. In its wake it left behind two terminal moraines that run the length of Long Island. Smaller debris, like sediment, sand, and mud, was carried out by the melting water, leaving large sandy outwash plains, including the southern portion of Long Island with Jamaica Bay and its wetlands (Tiner, 2011). (Figure III.A.-5)

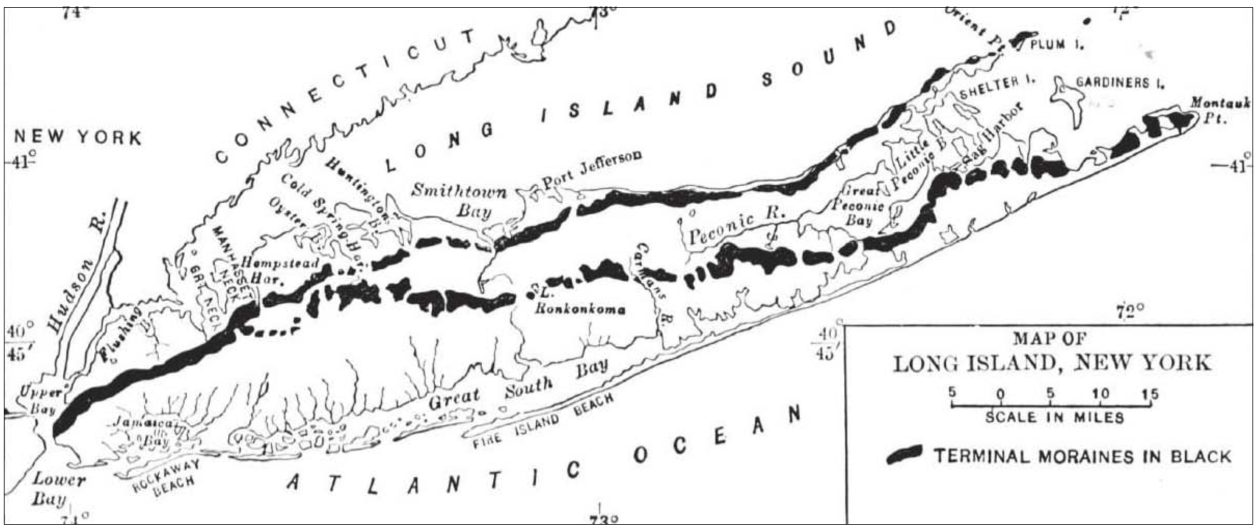


Figure III.A.-5 Terminal moraines of Long Island, New York (Bowman, 1911).

During the last ice age, significant amounts water existed as snow and ice, resulting in sea levels 350 feet lower than they are today. With the final retreat of the glacier, approximately 12,000 years ago, the melting of the snow and ice caused the low lying plains to flood as sea levels rose. Modern sea levels were achieved about 6,000 years ago forming Jamaica Bay (Cody, Auwaerter, & Curry, 2009; de Blij & Muller, 1993)

Over time Jamaica Bay, as well as the other bays that dot Long Island's southern coast, began to develop barrier islands which separated it from the Atlantic Ocean. The barrier island system is one of significant instability. Storms and currents constantly reshape the barrier islands, opening and closing access to the bays. Barren Island, Plumb Beach, and Pelican Beach were all, at one time or another part of Jamaica Bay's barrier island system (Cody et al., 2009). By 1839, Barren Island, Pelican Beach, and Plumb Beach were joined by natural activities creating Plumb Inlet, which separated it from Coney Island. By the nineteenth century, Barren Island, formerly a barrier island, was transformed into an interior island. Storms and longshore currents resulted in the continual westward migration of the Rockaway Peninsula, extending it beyond Barren Island (Cody et al., 2009). The elongation of the Peninsula was assisted by the addition of structures such as jetties and groins that were constructed to protect communities built along the Atlantic shore (Cody et al., 2009).

There are numerous classification systems for wetlands. The United States Fish and Wildlife Service, FWS, adopted the Cowardin wetlands classification system (Cowardin, 1992). Cowardin identifies Jamaica Bay as an estuarine system. Estuarine systems are usually semi-enclosed habitats that have some access to open ocean and also have a source of fresh water. Jamaica Bay's access to the ocean is the Rockaway Inlet (Cowardin, 1992). Fresh water is provided by Long Island's high water table and the Bay's location as the catch basin for the Jamaica Bay watershed (JBWPP, 2007). (Figure III.A.-6)

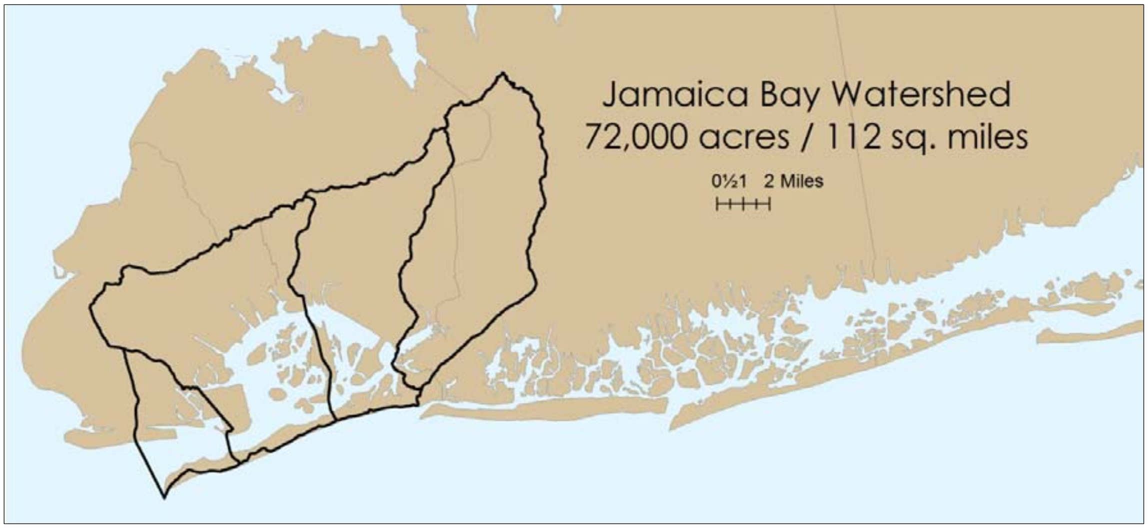


Figure III.A.-6 Jamaica Bay Watershed

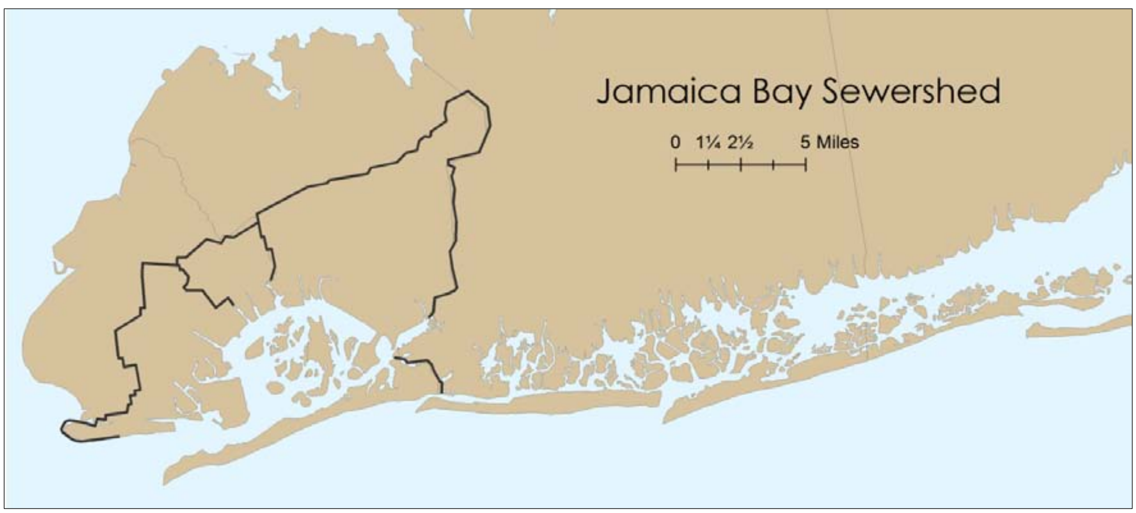


Figure III.A.-7 Jamaica Bay Sewershed

Estuarine systems include both sub-tidal and intertidal wetland systems. Sub-tidal systems are permanently flooded while tidal wetlands are flooded by the tides. Elevation dictates the frequency of inundation, influencing the type of vegetation and types of wetlands (Cowardin, 1992).

The coastal wetlands of New York, New Jersey and Long Island were formed between 2,000 and 11,000 years ago. The Jamaica Bay wetlands are the youngest, having been formed 2,000 years ago (Peteet, Pederson, Kurdyla, & Guilderson, 2006; Varekamp & Thomas, 1998).

The wetlands on the eastern end of the Bay are older than those on the western end (Peteet et al., 2006). This is possibly reflective of the increased protection of the Bay from the open ocean by the westward elongation of the Rockaway Peninsula (Peteet et al., 2006).

III. LITERATURE REVIEW

B. WETLANDS OF JAMAICA BAY

According to Cudmore (2011), the contiguous United States has lost half of its original wetlands. He estimates that in 1780 the wetlands covered 221 million square miles - - an area almost as large as the state of Texas. Then in the mid-1980s, the National Wetlands Inventory estimated that there were only 104 million square miles remaining.

Jamaica Bay's geographic location at the heart of the intersection of the New York Bight, the Hudson River, and the Raritan River Estuary, results in a concentration of marine, estuarine, and migrating species. The surrounding inhospitable urban terrain funnels wildlife to the Bay, creating an area of fecundity and diversity. Hundreds of species of birds have been seen in the Bay. Estimates are that 1/2 of all species of birds on the East Coast have been seen in the Bay at one time or another (Dowhan, 1997). The Bay offers refuge to many threatened and endangered species. Improved water conditions have seen the return of marine mammals, including whales and seals, just outside the Bay, where the Hudson Raritan Estuary, the Lower and Upper Hudson Bay, and the New York Bight meet (Ross, 2011).

Jamaica Bay was given little thought by those who colonized and later urbanized the city. The wetlands were considered to be worthless, waterlogged land that was too costly to reclaim (Carlson, 2010). They were of value only as dumping grounds for sewage, chemicals, and garbage. However, attitudes, understanding, and knowledge started to change over the years and in 1972 the Clean Water Act was signed into law (Casagrande, 2006).

There are geographically-based and environmentally-based systems for the classification of aquatic resources. Geographically-based systems define spatially explicit eco-regions. Environmentally-based systems are based on watershed characteristics (U.S. Environmental Protection Agency, 2002). One of the most widely accepted definitions of wetlands is that of the U.S. Fish and Wildlife Service. It is a combination of the two (Dahl & Allord, 1996; U.S. Environmental Protection Agency, 2002):

> "Land where an excess of water is the dominant factor determining the nature of soil development and the types of animals and plant communities living at the soil surface. It spans a continuum of environments where terrestrial and aquatic systems integrate." (Cowardin, 1992)

The main characteristics of wetlands as defined by Cowardin are inundation, salinity of the water, soil type, and the types of plants and animals. Combined, they are the basis for the recognition and description of wetland environments (Cowardin, 1992).

North American mid-Atlantic salt marshes exist in the intertidal zone where they are flooded by high tides and exposed by low tides. Within this intertidal zone are distinct ecological communities, including tidal pools, coastal shoals, mud flats, oyster reefs, seagrass beds, low marsh, and high marsh (Alderson et al., 1999; Walsh & LaFleur, 1995). The daily ebb and flow of diurnal tides, changing tidal amplitudes, changes in nutrient levels and salinity, along with scour and sediment accretion, create a difficult environment where few plant and animal species succeed. This variability, along with hydrologic flow, creates the patterns and shapes of vegetation found in the Bay. The plant species that are able to adapt tend to be found in abundance, creating an environment low in vegetative diversity

Concern over the stability of the Jamaica Bay wetlands began about 100 years ago as wetlands loss accelerated. The high marsh surrounding the Bay suffered the greatest loss. The low marsh was spared from development for decades, as the cost of modifying this habitat made doing so unattractive. Historically, the Bay was filled with low marsh islands traversed by tidal creeks and interspersed with tidal pools. Today only Joco Marsh and Silver Hole Marsh (Figure III.B.-1) are ecologically and structurally close to the marsh islands that existed before anthropogenic intervention. The others are significantly altered. The wetlands extended 1 – 1½ miles around the Bay. The predominant marsh figure of the Bay today is the hundreds of acres of fringing low marsh that hug the shore as well as the hummocks within the Bay (Alderson et al., 1999) . The high marsh that surrounded the Bay like a mile wide collar no longer exists.

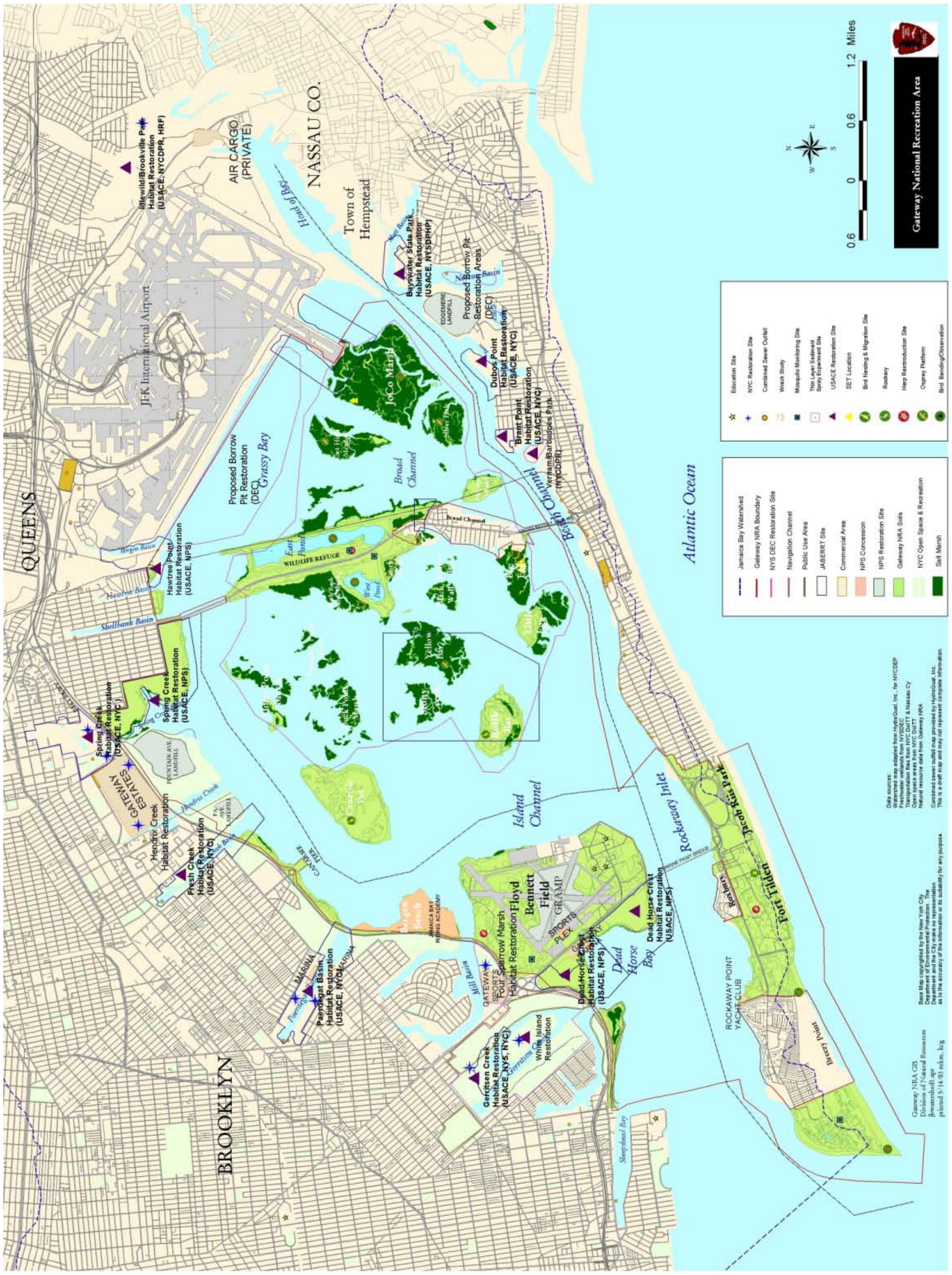


Figure III.B.-1 Jamaica Bay Parks and Wetlands (NYC Department of Environmental Protection (DEP), 2003)

III LITERATURE REVIEW

C. IMPORTANCE OF WETLANDS

Ecosystem Services

An ecosystem is a dynamic complex of biotic and abiotic factors working together as a unit. The biotic factors are all living things such as plants, animals, and microorganisms. Abiotic factors are the nonliving, the physical, and the chemical components of an environment, such as weather, air, soil, minerals, etc. As living things, human beings are included in the definition and composition of an ecosystem. This complex system is also known as a community (Alcamo, Bennett, & Millennium Ecosystem Assessment, 2003).

Human beings reap many benefits from ecosystems. These benefits are known collectively as ecosystem services and include any positive benefit that wildlife or a system provides (Alcamo et al., 2003).

The Millennium Ecosystem Assessment (MA) popularized the concept of ecosystem services (Barbier et al., 2011). They divided ecosystem services into four broad categories: provisioning, regulating, cultural, and supporting services (Alcamo et al., 2003). (Figure III.C.-1)

Provisioning services are the products obtained from an ecosystem. They include food, fresh water, and raw materials as well as genetic, medicinal, and energy resources. Foods include crops from agriculture, as well as seafood, game, spices, etc. Raw materials can be lumber, skins, fodder, jute, hemp, silk, and cotton. Energy sources range from wood and hydropower to natural gas, and oils. Medicinal resources include pharmaceuticals and natural medicines (Alcamo et al., 2003).

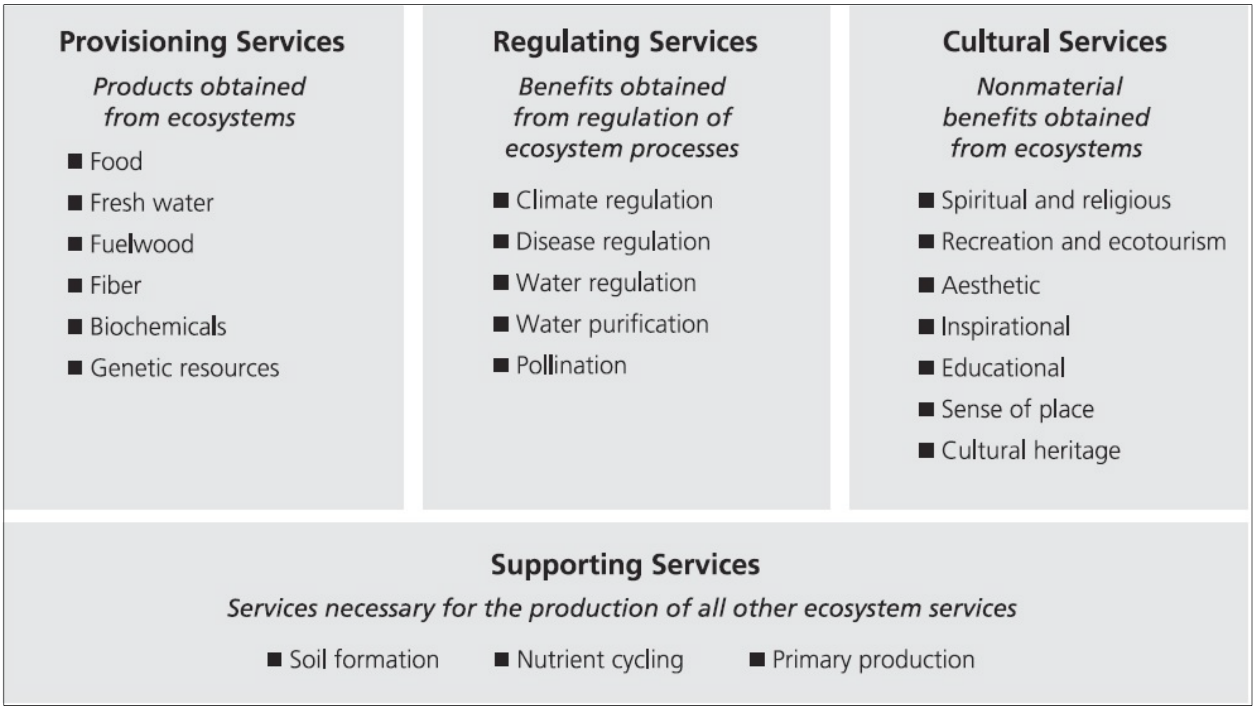


Figure III.C.-1 Ecosystem Services as Defined by the Millennium Ecosystem Assessment (Alcamo et al., 2003)

Regulating services are the benefits provided by ecosystem processes that provide improved air quality, water purification, erosion and flood control, carbon storage, climate regulation, etc.

Cultural services include artistic, religious and spiritual inspiration, influences on education and social relations and aesthetic values. Cultural services also include recreational opportunities such as outdoor sports, tourism, and bird watching (Alcamo et al., 2003).

Supporting services are those that are necessary for all the other ecosystem services. They function in the background indirectly and over long periods of time.

Supporting services are such things as photosynthesis for the production of oxygen, soil formation, and nutrient cycling.

Coastal lagoon ecosystems exist along low-lying coasts and make up 13% of coastal regions all around the world. Anthony et al. (2009) talks at great length about the social values of lagoons and divides them into four categories: pragmatic, scholarly, inspirational, and tacit. (Anthony et al., 2009) (Figure III.C.-2)

Pragmatic values are the most tangible and are the easiest to quantify. They include commercial, recreational, and tourism uses. They also include underlying ecosystem services that support human use such as fish habitats that support commercial fishing. In addition they also include services that provide protection to shorelines from wind, waves, and storms.

Scholarly values are those of scientific inquiry and the study of history to aid in our understanding of lagoons, their ecosystems, and provisions. Inspirational values impact our creativity and artistic expression. Tacit values, the most difficult to quantify, are what we appreciate through our senses, such as listening to the sounds of the birds or the pleasure of seeing the landscape. A sense of place, that which makes a place special and unique, is also a tacit value (Anthony et al., 2009).

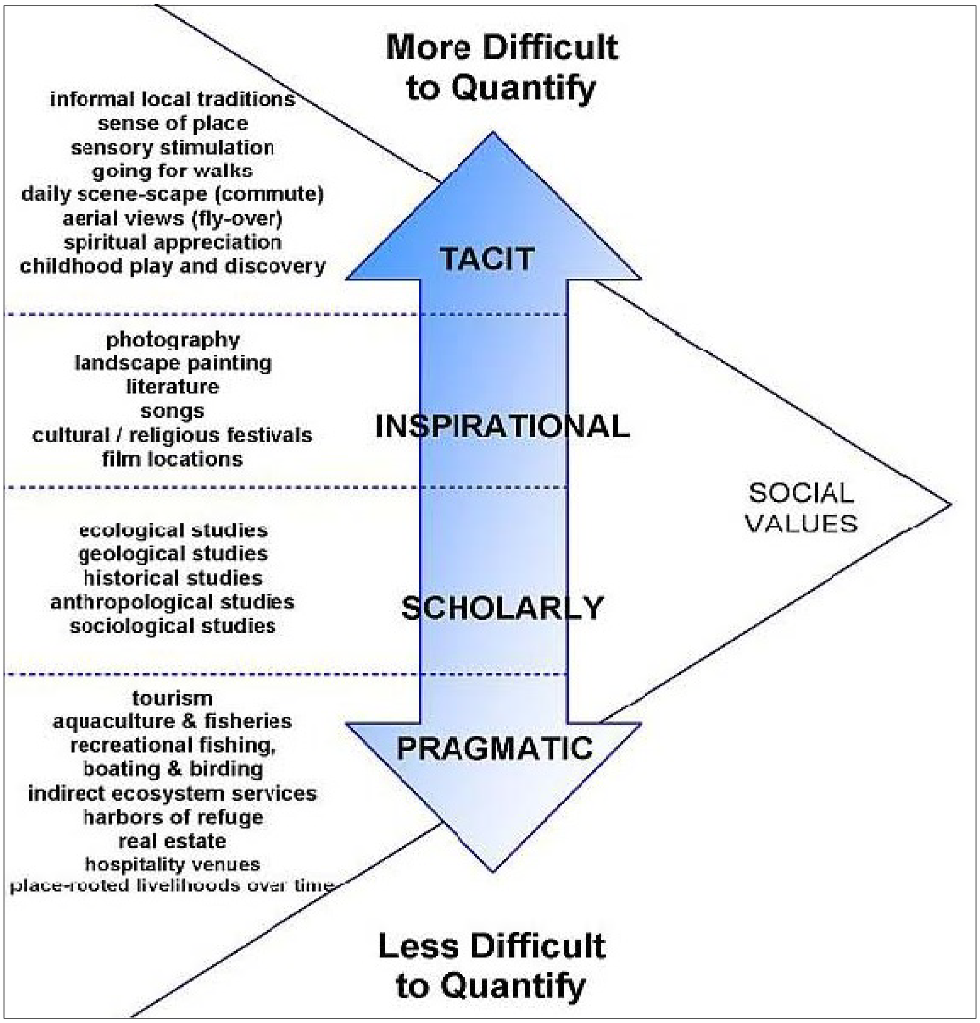


Figure III.C.-2 Social Value Characteristics of Lagoons (Anthony et al., 2009)

Ecosystem Services of Wetlands

Barbier et al. (2011) identifies and values the ecosystem services provided by coastal and estuarine ecosystems. Their definition of an ecosystem service is any way or anything where "nature makes a contribution to human well-being, either entirely on its own or through joint use with other human inputs." This definition encompasses both the direct and indirect services provided. Problems arise when trying to attribute values to ecosystem services, the most common being that most are not bought and sold. Any method used involves three sequential/interrelated steps:

1. Determine how to characterize change in the ecosystem structure.
2. Trace how these changes affect flows of the ecosystem service to people.
3. "Use existing economic valuation methods to assess the changes in human well-being." (Barbier et al., 2011) (pg. 171)

Barbier et al. (2011) "charts the ecosystem series, processes, and functions, (important controlling components)[sic] along with examples, and identifies the drivers of change for many different ecosystems found in estuaries and coastal systems around the world." They include sand beaches and dunes, mangroves, coral reefs, seagrass beds, and salt marshes, all features that at one time existed in Jamaica Bay. Following are the charts composed by Barbier et al. (2011) for salt marsh (Figure III.C.-3), seagrass beds (Figure III.C.-4) and, sand and dune ecosystems (Figure III.C.-5).

Ecosystem services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples	Human drivers of ecosystem change
Raw materials and food	generates biological productivity and diversity	vegetation type and density, habitat quality, inundation depth, habitat quality, healthy predator populations	£15.27· $ha^{-1}\cdot yr^{-1}$ net income from livestock grazing, UK (King and Lester 1995)	marsh reclamation, vegetation disturbance, climate change, sea level rise, pollution, altered hydrological regimes, biological invasion
Coastal protection	attenuates and/or dissipates waves	tidal height, wave height and length, water depth in or above canopy, marsh area and width, wind climate, marsh species and density, local geomorphology	US\$8236·$ha^{-1}\cdot yr^{-1}$ in reduced hurricane damages, USA (Costanza et al. 2008)	
Erosion control	provides sediment stabilization and soil retention in vegetation root structure	sea level rise, tidal stage, coastal geomorphology, subsidence, fluvial sediment deposition and load, marsh grass species and density, distance from sea edge	estimates unavailable	
Water purification	provides nutrient and pollution uptake, as well as retention, particle deposition	marsh grass species and density, marsh quality and area, nutrient and sediment load, water supply and quality, healthy predator populations	US\$785–15 000/acre capitalized cost savings over traditional waste treatment, USA (Breaux et al. 1995)†	
Maintenance of fisheries	provides suitable reproductive habitat and nursery grounds, sheltered living space	marsh grass species and density, marsh quality and area, primary productivity, healthy predator populations	US\$6471/acre and \$981/acre capitalized value for recreational fishing for the east and west coasts, respectively, of Florida, USA (Bell 1997) and \$0.19–1.89/acre marginal value product in Gulf Coast blue crab fishery, USA (Freeman 1991)†	
Carbon sequestration	generates biogeochemical activity, sedimentation, biological productivity	marsh grass species and density, sediment type, primary productivity, healthy predator populations	US\$30.50·$ha^{-1}\cdot yr^{-1}$‡	
Tourism, recreation, education, and research	provides unique and aesthetic landscape, suitable habitat for diverse fauna and flora	marsh grass species and density, habitat quality and area, prey species availability, healthy predator populations	£31.60/person for otter habitat creation and £1.20/person for protecting birds, UK (Birl and Cox 2007)	

† One acre = 0.4 ha.

‡ Based on Chumra et al. (2003) estimate of permanent carbon sequestration by global salt marshes of 2.1 Mg C·$ha^{-1}\cdot yr^{-1}$ and 23 September 2009 Carbon Emission Reduction (CER) price of the European Emission Trading System (ETS) of €12.38/Mg, which was converted to US\$2000.

Figure III.C.-3 Ecosystem Services of Salt Marsh (Barbier et al., 2011)

Ecosystem services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples	Human drivers of ecosystem change
Raw materials and food	generates biological productivity and diversity	vegetation type and density, habitat quality	estimates unavailable	eutrophication, overharvesting, coastal development, vegetation disturbance, dredging, aquaculture, climate change, sea level rise
Coastal protection	attenuates and/or dissipates waves	wave height and length, water depth above canopy, seagrass bed size and distance from shore, wind climate, beach slope, seagrass species and density, reproductive stage	estimates unavailable	
Erosion control	provides sediment stabilization and soil retention in vegetation root structure	sea level rise, subsidence, tidal stage, wave climate, coastal geomorphology, seagrass species and density	estimates unavailable	
Water purification	provides nutrient and pollution uptake, as well as retention, particle deposition	seagrass species and density, nutrient load, water residence time, hydrodynamic conditions, light availability	estimates unavailable	
Maintenance of fisheries	provides suitable reproductive habitat and nursery grounds, sheltered living space	seagrass species and density, habitat quality, food sources, hydrodynamic conditions	loss of 12 700 ha of seagrasses in Australia; associated with lost fishery production of AU$235 000 (McArthur and Boland 2006)	
Carbon sequestration	generates biogeochemical activity, sedimentation, biological productivity	seagrass species and density, water depth, light availability, burial rates, biomass export	estimates unavailable	
Tourism, recreation, education, and research	provides unique and aesthetic submerged vegetated landscape, suitable habitat for diverse flora and fauna	biological productivity, storm events, habitat quality, seagrass species and density, diversity	estimates unavailable	

Figure III.C.-4 Ecosystem Services of Seagrass Beds

(Barbier et al., 2011)

Ecosystem services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples	Human drivers of ecosystem change
Raw materials	provides sand of particular grain size, proportion of minerals	dune and beach area, sand supply, grain size, proportion of desired minerals (e.g., silica, feldspar)	estimates unavailable for sustainable extraction	loss of sand through mining, development and coastal structures (e.g., jetties), vegetation disturbance, overuse of water, pollution, biological invasion
Coastal protection	attenuates and/or dissipates waves and reduces flooding and spray from sea	wave height and length, beach slope, tidal height, dune height, vegetation type and density, sand supply	estimates unavailable	
Erosion control	provides sediment stabilization and soil retention in vegetation root structure	sea level rise, subsidence, tidal stage, wave climate, coastal geomorphology, beach grass species and density	US$4.45/household for an erosion control program to preserve 8 km of beach, for Maine and New Hampshire beaches, USA (Huang et al. 2007)	
Water catchment and purification	stores and filters water through sand; raises water table	dune area, dune height, sand and water supply	estimates unavailable	
Maintenance of wildlife	biological productivity and diversity, habitat for wild and cultivated animal and plant species	dune and beach area, water and nutrient supply, vegetation and prey biomass and density	estimates unavailable	
Carbon sequestration	generates biological productivity, biogeochemical activity	vegetative type and density, fluvial sediment deposition, subsidence, coastal geomorphology	estimates unavailable	
Tourism, recreation, education, and research	provides unique and aesthetic landscapes, suitable habitat for diverse fauna and flora	dune and beach area, sand supply, wave height, grain size, habitat quality, wildlife species, density and diversity, desirable shells and rocks	US$166/trip or $1574 per visiting household per year for North Carolina beaches, USA (Landry and Liu 2009)	

Figure III.C.-5 Ecosystem Services of Sand Beach and Dunes

(Barbier et al., 2011)

Jamaica Bay's Ecosystem Services

Native Americans and early colonists relied on ecosystem services provided by Jamaica Bay's wetlands. The Bay was a fecund estuary supporting hundreds of species of birds, schools of fish, mammals, reptiles, and amphibians (Cudmore, 2011). Native Americans feasted on salmon, herring, alewife and shellfish, including clams, lobsters, crabs, and oysters. Oyster shells were also used for currency and trade (Black, 1981; Cudmore, 2011).

When the colonists arrived they used the large schools of fish as fertilizer for farmland (Black, 1981). They harvested salt hay as fodder for livestock, and cord grass was used for thatching roofs. Stands of cedar trees were felled for lumber. Wild game, birds, fish, and shellfish were hunted, collected, and harvested for food. Tidal streams provided power for grist mills. Later the Bay was used for the disposal of waste and, for a while, the tides aided in circulating the waters, keeping the Bay fresh. (Barbier et al., 2011; Black, 1981; Cudmore, 2011)

At one time Jamaica Bay consisted of extensive salt marsh, sand and dunes, and eel grass bed ecosystems. Eel grass beds no longer exist in the Bay, many sand and dune complexes are tamed and controlled as recreational beaches, and large expanses of salt marsh have been reduced to fringing marsh and hummocks within the Bay. Today, none of those provisions serve us. The fisheries are closed due to pollution. We no longer use salt hay or cord grass. The large schools of fish no longer exist, and mills are things of the past.

However we now know more about the ecosystem services that Jamaica Bay provides. While they might be different, we find that the benefits are as important as ever:

- Jamaica Bay is a habitat for fish and birds. The marshes act as nurseries, providing refuge from predators and food to more than 80 species of fish and shellfish (Alcamo et al., 2003; Barbier et al., 2011).
- Jamaica Bay is a habitat for birds migrating along the Atlantic flyway as well as the 62 species of birds that breed in the Bay (Alcamo et al., 2003; Barbier et al., 2011).
- The wetlands mitigate flooding and control shoreline erosion by acting as buffers from waves, tides, winds, and storms (Adamo, Caughman, Chase, Coady, & Frame, 2007; Alcamo et al., 2003; Barbier et al., 2011).
- Jamaica Bay filters pollutants from the water which releases nitrogen gas, a process that reduces the amount of nitrogen and organic matter in the water (Alcamo et al., 2003; Barbier et al., 2011).
- Spartina, the predominant flora in the marsh, produces ten tons of organic matter a year. This adds to the food cycle and supports other organisms.
- The carbon fixation from algae and phytoplankton converts inorganic carbon into organic compounds (Alcamo et al., 2003; Barbier et al., 2011).
- Public transit makes Jamaica Bay accessible to all of New York City and provides opportunities for education and recreation, such as hiking, bird watching, and kayaking (Adamo et al., 2007).

III. LITERATURE REVIEW

D. LAND USE/LAND COVER CHANGE AND MODIFICATION

Land use/land cover change (LULCC) is also known as land change science. It attempts to explain the who, what, where, when, and why of human impact on the surface of the earth.

Land use is characterized by the human activities on a particular land cover type. These activities are driven by the need to secure resources, and consequently impact ecological processes, thus affecting land cover function (Veldkamp & Fresco, 1996). Classifications of land use change according to scale, becoming simplified as the unit of measure grows. Several of the major land use activities responsible for changes in land cover are agriculture, pasture/grazing, and urbanization (Geist et al., 2006; Loveland et al., 1999).

A definition of land cover is the earth's surface, including subsurface, groundwater, and near surface water and their biotic and abiotic characteristics which include soil, topography, human structures, and vegetation (Lambin, Geist, & Rindfuss, 2006). Land cover change is the replacement of one classification of land cover for another, such as wetlands to farmland or farmland to urban. Land cover modification affects the character but doesn't necessarily change the land cover type, yet it can strongly affect changes in land use by changing biodiversity or by the pollution of land, water, or air (Lambin, Geist, & Lepers, 2003).

Due to its complexity, land change science has not yet developed a unifying theory (Lambin et al., 2006), but it does require investigation into driving forces, actors, and land change (Hersperger, Gennaio, Verburg, & Bürgi, 2010). Land use/land cover change looks at land change as a coupled human-environmental system, which requires an understanding of both anthropogenic and biophysical influences.

One method used by land change researchers is the use of box-and-arrow frameworks. These diagrams aid in understanding the complexity and relationships of factors involved in land change science. The following are examples of two types of box-and-arrow frameworks. The first is from Lambin (2006) and demonstrates a generalized framework (Figure III.D-1). The second is from Bennett (2008) and specifically addresses coupled human/natural systems in Yellowstone National Park (Figure III.D.-2).

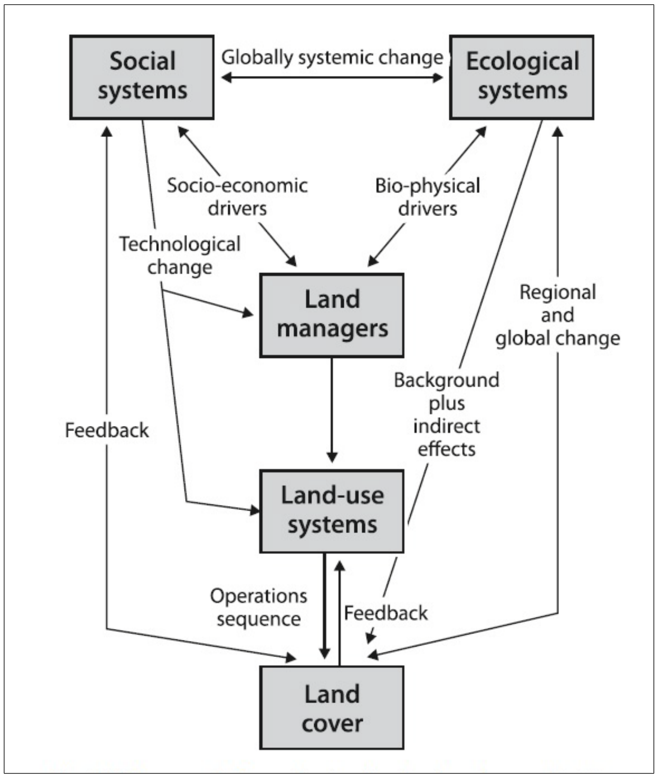


Figure III.D.-1 General Box-and-Arrow Framework (Lambin et al., 2006).

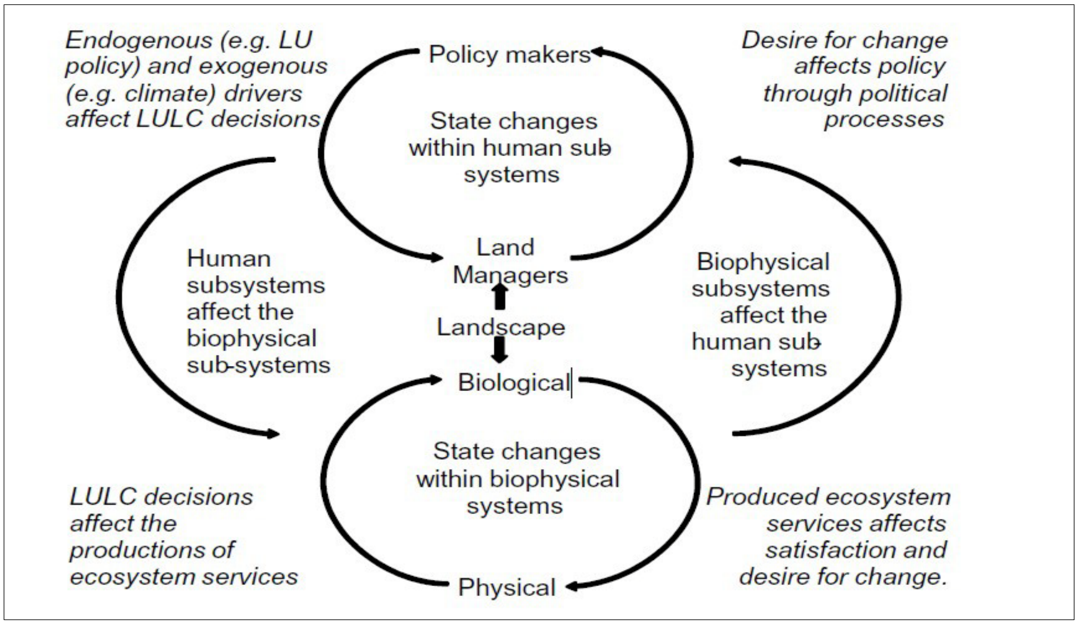


Figure III.D.-2 A Box-and-Arrow Framework Describing Coupled Human/Natural Systems in Yellowstone National Park (Bennett & McGinnis, 2008).

There are several core components that can help in understanding the causes of land use/land cover change:

Understanding what influences human behavior and decision making.

Identifying environmental and social factors.

Learning how the above interact to influence decision making (Lambin, 2007).

Research takes place along three spectrums: spatial, temporal, and institutional. The spatial spectrum ranges from local to global, the temporal from decades to millenniums, and institutional ranges from individual to global.

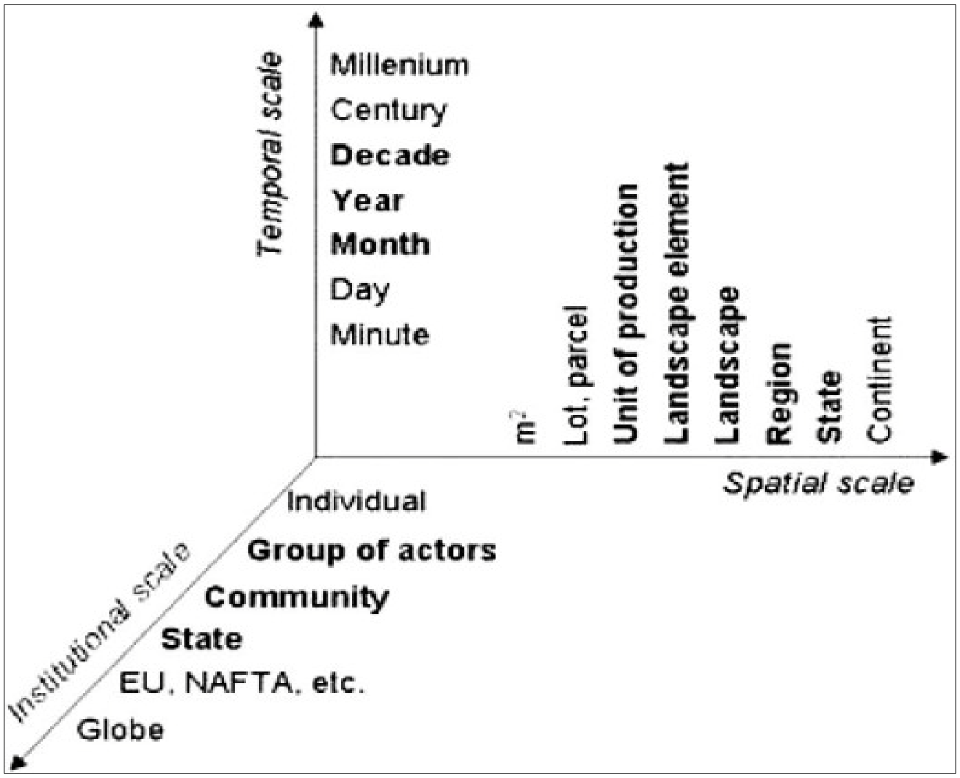


Figure III.D.-3 Scales of Time, Space and Organization

(Bürgi, Hersperger, & Schneeberger, 2004).

Although recent efforts have been increasingly focused on global impacts of change, research depends on local and regional studies for data and the development of models and theories. On smaller spatial scales research can be more specific and detailed. But as the spatial scale increases, the theories become more generalized and abstract (Briassoulis, 2000). (Figure III.D.-3)

Satellite imagery has taken on an important role in land change science. It has added a new dialogue: that of pixel-based research that now exists alongside of place-based research. Yet, much historical research took place before the advent of satellite imagery.

Historical research helps us to understand the how and why of past changes and explains existing patterns of cause and effect. Historical place-based research is used in the formulation of theories, helps in the current management of our resources, and provides the information needed to make models and projections of future scenarios (Lambin et al., 2003; Sisk, 1998).

Interest in this subject has increased significantly with the growing awareness of the influence of land use/land cover change on climate and other macro-environmental systems. Land surface processes influence the climate through a surface atmosphere energy exchange. They affect the carbon cycle as possible sources and sinks. On a more regional level, the recycling of precipitation through enviro-transpiration, (the loss of water vapor from both evaporation and water vapor released by plants), cools both the soil and plants, thus lowering local temperatures (Lambin et al., 2006; Lambin & Geist, 2006). Other global concerns are biodiversity, the decline of soil quality, and sustainability (the capability of the environment to support human life). These concepts and more make it an important component of research on global environmental change and sustainability.

Land use/land cover change is a multidisciplinary science and includes such fields as anthropology, botany, demography, ecology, economics, history, GIS, and more (Rindfuss et al., 2008). Its theories build on the different facets of human–environmental systems and interactions, including political structures and social attitudes (Bürgi et al., 2004). According to Bürgi et al. (2004, 857-868) there are three predominant traditions of land use change theory: "urban and regional economics and regional science, sociological and political economy, and nature-society theories". This comes from Briassoulis (2000), who established these three “theorizing traditions” based on how a land use land change theory is constructed to describe a phenomenon.

The Walker and Solecki (2004) research is an example of an urban economic and regional science theme. Walker and Solecki (2004) use historical analysis and urban theory to explain the loss of wetlands in the Florida Everglades. This class of theories draws from economics and its concept of utility. Macro and micro economic approaches deal accordingly with global or regional studies.

Sociological and political economic theories emphasize the importance of social relationships, networks, and changes in culture and social structure. They draw from the social sciences such as anthropology and psychology (Briassoulis, 2000; Bürgi et al., 2004).

Nature–society theories are more expansive. They are concerned with the interactions between nature, economy, society/agents, and culture (Briassoulis, 2000; Bürgi et al., 2004). It is within nature-society theories that the conversation of global environmental change takes place; in particular, the role of mankind’s effect on the environment (Briassoulis 2000). There are also many local studies of land use/land cover change in the nature-society tradition that “cannot claim the status of theory.” (Briassoulis, 2000)

The consequences of human activity have been direct and indirect changes in land cover for millennia (Ellis, 2013). According to Lambin, Geist and Lepers (2003), anthropogenic activities have affected 50% of all ice-free land over the past 10,000 years. Ramankutty (2006) talks of the three stages of mankind’s history.

During the Paleolithic age human beings used stone tools and learned to control fire.

The Neolithic age is identified by the human domestication of plants and animals.

The Anthropocene age started around 300 years ago with mankind's appropriation of fossil fuels and the resulting land use/land cover change and modification (Ramankutty et al., 2006).

Native Americans affected land cover change through fire and agriculture thousands of years before the European colonization (Delcourt & Delcourt, 1997; van Wagtendonk, 2007). They were primarily hunter-gathers and farmers of the native species and their impact on the environment was minimal (Sisk, 1998). It is in the last 300 years that the most significant changes in land use/land cover change have taken place (Ramankutty et al., 2006). This coincides with the colonization of the New World and the land use/land cover change history of Jamaica Bay.

> The term driver is used to identify the causes of land use/land cover change. Drivers are classified as either proximate or indirect-underlying drivers. Proximate drivers are concrete, the "how and why" of land use/land cover change, and are often endogenous (local in nature). Underlying drivers are often exogenous with broader influences coming from outside, and are the contextual influences of change (Lambin, 2007).
>
> "Understanding of the causes of land-use change has moved from simplistic representations of two or three driving forces to a much more profound understanding that involves situation-specific interactions among a large number of factors at different spatial and temporal scales." (Lambin et al., 2003).

Approaching land use/land cover change as a complex interdisciplinary study improves our "understanding of the nature of interactions between the social–economic–cultural and the biophysical environment" (Dearing, Braimoh, Reenberg, Turner, & van der Leeuw, 2010). The study of land use/land cover change is part of the much larger picture of sustainability science (Dearing et al., 2010). Sustainability science looks at the challenges that we face in the future and helps us meet "the needs of present and future generations while substantially reducing poverty and conserving the planet's life support systems" (Kates, 2011).

III. LITERATURE REVIEW

E. DRIVERS OF LAND USE/LAND COVER CHANGE

Knowing how people make land change decisions and how anthropogenic and biophysical factors influence those decisions is the core of understanding in the complex relationships of cause-and-effect on decision makers (Geist et al., 2006). Global understanding of land use/land cover change depends on regional and local research that focuses on understanding decision makers and the factors that influence them. From these studies basic causal factors are identified. These causal factors are not quite the same across the literature. According to Lambin, Geist, and Rindfuss (2006) the LUCC study identifies them as technology, economics, political, institutional, demographics, and socio –cultural influences; while Bürgi, Hersperger, and Schneeberger (2004) lists them as socioeconomic, political, technological, natural, and cultural driving forces.

Bürgi, Hersperger, and Schneeberger (2004) define drivers as the forces or keystone processes that cause observed landscape change and categorizes them as primary, secondary, and tertiary. This aligns with Geist et al. (2006)'s distinction of drivers as proximate, underlying, and modifying. Proximate drivers directly cause change. Underlying drivers influence the decisions of agents making the changes. Modifiers are more finely nested (Bürgi et al., 2004; Geist et al., 2006). (Figure III.E.-2)

Understanding drivers, their interaction, and their effect on decision makers is complicated by the following:

- Drivers can be either / or a combination of proximate and underlying.

- Drivers are often affected by the spatial and temporal scale of the study.
- Long term influences often affect trends over time, while rapid change results in a more immediate response.
- Drivers do not operate in isolation.
- Mediating factors can influence the relationships between drivers. Bürgi, Hersperger, and Schneeberger (2004) refer to mediating factors as tertiary factors.
- Biophysical, economic, and social factors are dynamic (Bürgi et al., 2004; Geist et al., 2006).
- Factors that influence one region may not affect another to a similar degree.
- The same factors can result in differing outcomes.
- Change can also be an unexpected or unanticipated side effect (Bürgi et al., 2004).

An example that is often used to show the complex interaction of drivers is from Geist and Lambin (2002) showing drivers and their relationships that cause deforestation (Figure III.E.-1).

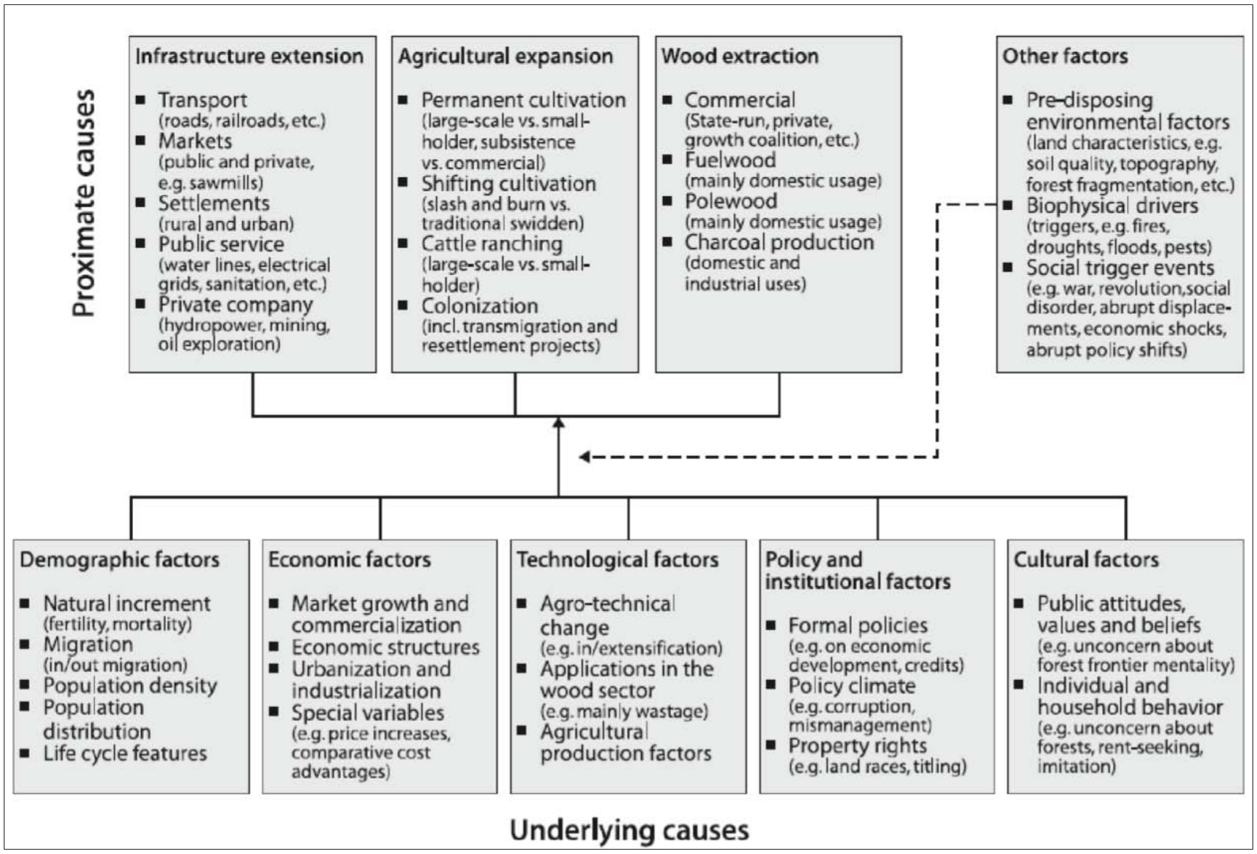


Figure III.E.-1 List of Drivers in the Study of Deforestation

(Geist and Lambin 2002)

A broad description of the drivers as identified by Lambin, Geist, and Rindfuss (2006) follows:

Biophysical factors include the full set of biotic and abiotic characteristics of the environment, including climate change, biodiversity, topology, hydrology, and more. Biophysical factors can limit or provide opportunities. For example, the amount of rainfall and slope dictates the suitability of land for agriculture and the preferred type of crop.

Economic factors on a local or regional level include items such as taxes, cost of production, and transportation. Market demand and fuel costs are important influences on both local and global scales while the impact of foreign exchange rates is felt more on a global scale.

Demographic drivers are not necessarily driven by population growth, but to aspects of the population. The size of household, level of technology, affluence, and other modifications all affect consumption. Migration causes a more rapid shift in total population than birth and death rates. The more affluent an urban population is, the more they are removed and unaware of their effect on natural resources.

Technology, infrastructure, and invention can significantly affect changes in land use/land cover. The technological evolution from horse to steam to electricity has increased the speed and range at which people, resources, and products now travel. The search for fossil fuels is causing severe disruption to the earth's surface and accidents have inflicted ecological damage. Roads have made areas that were previously inaccessible into avenues for development, logging, homesteading, and poaching.

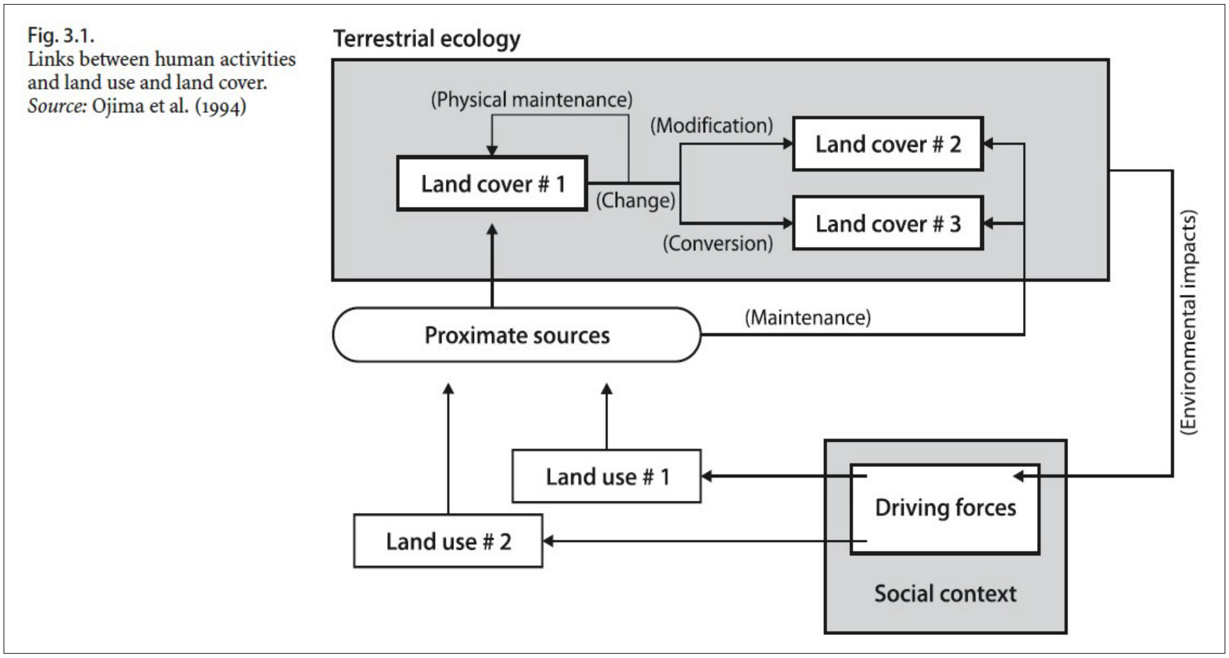


Figure III.E.-2 Role of Proximate and Underlying Drivers

(Geist et al., 2006).

Cultural factors tend to be underlying influences that affect attitudes and values. At a more profound level, different cultures had/have different concepts of humankind's relationship with the environment. Native Americans lived in small communities and experienced an "immediate reciprocal relationship" with their environment (Harkin & Lewis, 2007). The Dutch, who first colonized New York, saw the wetlands as a valuable commodity. The salt mash was communal property and was shared among the inhabitants (Black, 1981). Later on, wetlands were considered to be a nuisance. According to statements made by the U.S. Supreme Court in the early 1900s, wetlands were the cause of much disease, and removing them was a legitimate act (Cudmore, 2011).

Institutions can act as drivers and/or decision makers (also known as agents, land managers, or planners). "Decision-makers influence some drivers and are influenced by other drivers. The first are the endogenous drivers and the latter are the exogenous ones." (Alcamo et al., 2003)(pg 84). Decision makers exist along a scale from individual to global (Alcamo et al., 2003; Bürgi et al., 2004).(Figure III.D.-3) "Local decision-makers can directly influence the choice of technology, changes in land use, and external inputs, but have little control over prices and markets, property rights, technology development, or the local climate. National or regional decision-makers have more control over many indirect drivers, such as macroeconomic policy, technology development, property rights, trade barriers, prices, and markets" (Alcamo et al., 2003)(pg 85). Bürgi, Hersperger, and Schneeberger (2004) list institutions in increasing scale: individuals, groups of actors, community, state, EU, NAFTA, etc. to global (Figure III.D.-3). Geist et al. (2006) further defines institutions to include not only political institutions, but also legal and economic entities and policies as well nonmarket institutions:

> "Property rights regimes, decision making systems for resource management (e.g., decentralization, democratization, and the role of the public, of civil society, and of local communities in decision making), information systems related to environmental indicators as they determine the perception of changes in ecosystems, social networks representing specific interests related to resource management, conflict resolution systems concerning access to resources, and institutions that govern the distribution of resources and thus control economic differentiation." (Geist et al., 2006).

III. LITERATURE REVIEW

F. LAND USE/LAND COVER CHANGE OF WETLANDS

Since land use/land cover change is generally interested in anthropogenic changes, an assumption can be made that it focuses on changes that have taken place during the last 200 to 300 years – the Anthropocene era. Many studies focus on changes over the full era Bromberg and Bertness (2005), Squires (1990), Walsh and LaFleur (1995), and Grossinger et al. (2007), while others look at a shorter periods of time Levin, Elron and Gasith (2009) and Adamo et al. (2007).

Long term studies include the use of historical maps (Bromberg & Bertness, 2005) as well as primary and secondary historical data (Grossinger, Striplen, Askevold, Brewster, & Beller, 2007). Long term research of wetlands has inherent problems with data quality. Bromberg and Bertness (2005) outline several of these problems:

- Over the years the definition of wetlands has changed.
- Often there is no distinction between the different types of wetlands.
- Baseline data by which to quantify loss "predates human effects".
- The quality of data predating the USGS Surveys is unreliable.
- It is difficult to assess the accuracy of old maps.

In general, research tends to focus on either quantifying change (Boger, Connolly, & Christiano, 2012) or explaining it (Solecki et al., 1999; Walker & Solecki, 2004).

Salt marshes once covered much of the coastal northeastern U.S. (Bromberg & Bertness, 2005; Nixon, 1982). For reasons outlined by Bromberg and Bertness (2005), estimates of salt marsh loss since European colonization have been difficult to quantify. However, it is safe to say that the loss has been severe (Bromberg & Bertness, 2005; Nixon, 1982). Two national wetlands inventories that look at loss from the beginning of European colonization using historical data are by Dahl (1900) and Gosselink and Baumann (1980) (Dahl, 1990; Gosselink & Baumann, 1980). These studies estimate that by 1990 the loss of wetlands in the United States was approximately 50% (Bromberg & Bertness, 2005).

The research of Keryn Bromberg and Mark Bertness, Daniel Walsh and Donald Squires are studies of wetlands loss in the northeast since the colonization of the New World (Bromberg & Bertness, 2005; Squires, 1990; Squires, 1992; Walsh, 1991b; Walsh & LaFleur, 1995).

Bromberg looks at wetland loss in New England, (Massachusetts, New Hampshire, and Maine) by comparing historical maps with current land use data. Walsh is interested in New York City landfills and researches literature regarding the disposal of municipal solid waste, then compares the data to historical maps to identify the landfills. Squire looks at wetland loss along the Hudson River and estuaries, then compares current and historical topographic maps produced by the USGS.

The research of Bromberg and Bertness (2005) quantifies wetland loss. It ascribes a correlation between the loss of wetlands and urbanization. Squires (1990), quantifies the wetland loss and attributes population as a major driver. Walsh (1991) quantifies wetlands by mapping landfills, thereby ascribing to waste disposal the role of a primary driver of land use/land cover change.

Types of Research

All of the above research focuses on the quantification of change. Other researchers focus on the causes of land use/land cover change. For example, Walker and Solecki (2004) compare von Thünen's bid rent model with historical analysis to explain changes in the Florida Everglades. Stein et al. (2007), uses historical ecology and its use of primary sources to identify anthropogenic activities along the southern California coast. Solecki et al. (1999) looks at the human – environmental linkage, drawing data from primary and secondary sources along the full range of land use /land change drivers, including environmental, social, economic, etc., to explain changes in the Florida Everglades.

The wetlands within Jamaica Bay are currently experiencing a serious decline. This is prompting an extraordinary effort of local research (Adamo et al., 2007; Boger et al., 2012; Hartig, Gornitz, Kolker, Mushacke, & Fallon, 2002; Kolker, Hartig, Mushacke, Fallon, & Gornitz, 2010). Much of the recent work in wetland loss focuses on the modifications of existing wetlands. It tries to explain which anthropogenic and biophysical factors are affecting their health. Current research explores the effects of nitrogen loading, dredging, and other physical modifications (Callaghan et al., 2010; Mudd, 2011; Zedler & Callaway, 2000), predation by geese, snails, and crabs (Holdredge, Bertness, & Altieri, 2009; Smith III & Odum, 1981), and the effect of climate change and sea level rise (Gornitz, Couch, & Hartig, 2001; Hartig et al., 2002).

Dahl and Allord (1996) and Solecki et al. (1999) examine the effect of drivers of land use change over time. Specific drivers do not necessarily change over time; however, the importance of a driver may. In their analysis of wetland loss, both Solecki et al. (1999) and

Dahl and Allord (1996) identify five chronological stages in which the importance of drivers shift. (Figure III.F.-1). The differences relate to the scale of their studies. Dahl and Allord (1996) are looking at change on a national scale while Solecki, et al. (1999) research is local in nature.

Looking at the drivers of land use/land cover change (socioeconomic, political, technological, natural, and cultural) and comparing them with the stages identified by Dahl and Allord (1996) and Solecki et al. (1999) one can see the overlap and influences they have on each other.

Solecki, et al. (1999) 305-33 Florida Everglades	**Dahl and Allord (1996) 12-26 United States**
	1600 to 1800 Colonial settlement
1845–1900 Frontier settlement—basic needs; direct utilization	1800 to 1860 Westward expansion
1900–1930 Drainage and land conversion—economy; land use; population; resource management; competition	1860 to 1900 Agriculture moves west
1930–1950 Flood control and consolidation—external inputs; governance; quality of life; social structure and organization; technology	1900 to 1950 Changing technology
1950–1970 Postwar boom, flood control, and water supply—land use; legal institutions; pollution; quality of life	1950 to present Changing priorities and values
1970–1995: Period of limits—environmental ethic; governance; pollution; resource competition; values	

Figure III.F.-1 Comparison of the 5 Chronological Stages in Land Use/Land Cover Change

(Dahl & Allord, 1996; Dahl, 2011; Solecki et al., 1999)

III. LITERATURE REVIEW

G. FRAMEWORK

The Bürgi, Hersperger, and Schneeberger (2004) paper, "Driving Forces of Landscape Change – Current and New Directions", provides a working framework for this thesis. They identify the major difficulties in land change science which are: the need to the study process, forecasting change, management of different types of data, and the inclusion of culture as a driver of change. They believe these issues can be addressed by using drivers to understand land use/land cover change.

Land change science documents and interprets change over time by making history an important part of understanding land change. At any point in time, existing land use and land cover is the result of previous natural and anthropogenic influences. The dynamic character of nature and society make land change and land use an ongoing, ever-changing process (Bürgi et al., 2004).

The complexity of land change makes it an inherently difficult science. Along with understanding the forces influencing decisions, it is also important to understand the relationship between people and their environment (Bürgi et al., 2004).

The study of drivers needs to be responsive to the concept of scale. Spatial scales can determine whether a factor is proximate, underlying, or modifying. It also determines whether institutions are decision makers or drivers. In addition, different drivers act along different temporal scales. This discussion of scale warrants repeating an illustration from Bürgi, Hersperger, and Schneeberger (2004). (Figure III.G.-1)

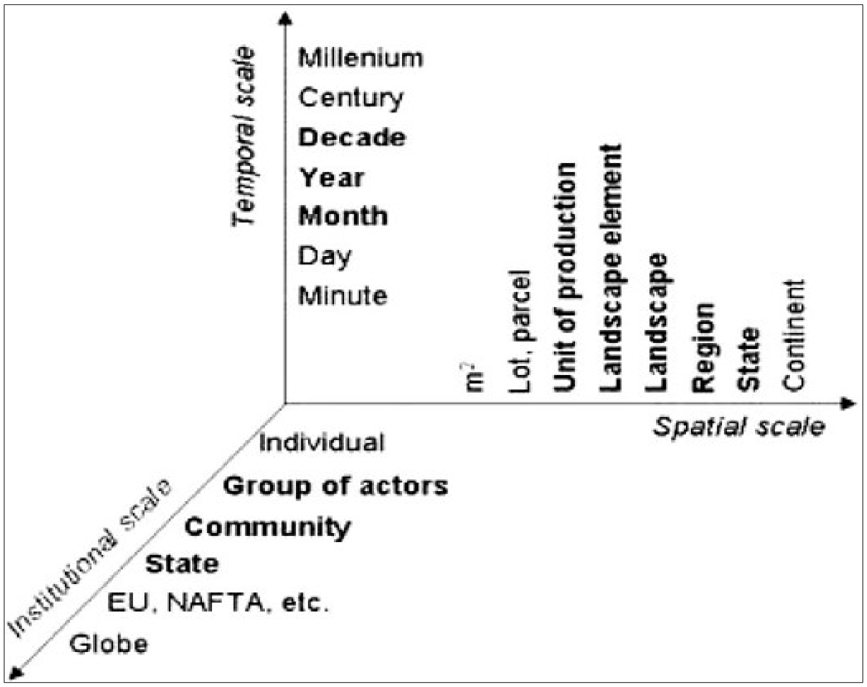


Figure III.G.-1 Scales of Time, Space and Organization

(Bürgi et al., 2004)

Most land use/land cover change is affected by driving forces from all five groups of drivers: biophysical, cultural, economic, technological, and demographic. Yet, in some cases researchers choose to work with a subset of drivers-- usually those that they think are most important. In such situations, it behooves the researcher to give a rational explanation for his choice (Bürgi et al., 2004).

Studying land change across administrative boundaries can provide insight into the role of decision makers and the function of drivers to specific locations. Some landscapes are inherently dynamic, such as wetlands, where natural succession causes changes over time. These types of changes allow the biotic elements time to adapt. This is in direct contrast to anthropogenic changes that can happen at a much faster pace. Land change can also be an unexpected consequence, therefore, it should be noted when it is accidental.

If possible, research should focus on causality rather than correlation. Understanding causality requires research which integrates qualitative and quantitative data. Integrating different types of data is an inherent problem in land change science. Land change research is problem oriented and often uses general systems theory to explain it (Bürgi, Hersperger, and Schneeberger, 2004). In response to these issues, Bürgi, Hersperger, and Schneeberger (2004) suggest a standard three-step framework for the study of land change:

1. "System definition": The aim of the study: this includes a definition of the study area, its extent, temporal resolution, and a description of the area in question.
2. "System analysis": The identification of land change, actors/institutions, and drivers.
3. "System synthesis": Where causal links between actors, institution, and drivers are established.

This study focuses on the wetlands that historically surrounded Jamaica Bay rather than the wetlands within the Bay. The existing wetlands are already the subject of much research. Rather than looking at land use/land cover change across a range of temporal periods, this thesis identifies when the perceived value of wetlands shifted from being valueless to being a property worth developing. It looks across administrative boundaries at the neighborhoods that surround Jamaica Bay, that were predominantly wetlands in the

1800s. It charts change neighborhood by neighborhood, focusing on decisions made at a particular location at a particular moment in time. It does not depend on a static profile of drivers as these, too, change from neighborhood to neighborhood.

Two drivers, sanitation and transportation, are explored as significant causes of land use/land cover change and modification. In Jamaica Bay, the influences of sanitation and transportation shift between primary and secondary drivers in their effect on decision makers. Left alone, wetlands are dynamic systems and have the ability to adjust to change; however, decisions made by land managers have effectively eradicated the wetlands that surround Jamaica Bay.

Transportation as a primary and secondary driver includes changes in technology, improvement in access, and the building or proposed building of infrastructure. Transportation transitions from horses, to steam to electrical to fossil-fuel technology. Modes of transportation transition from horse and carriage to steamboats to trolleys and trains to airplanes. Sanitation as a proximate driver includes the process of dealing with refuse, sewage, and municipal solid waste along with the consequential issues, indirect drivers of health and disease. Infrastructure--either the lack of and/or the construction of--influenced decision makers. Here, the intent is to explore the drivers in the foreground, shedding light as to how they have affected land use change in the past.

IV. METHODS

Historical Perspective

Studies of land use/land cover change emerge from a long history of studies of man's relationship to the earth. This relationship has been framed by three overlying themes; environmental determinism, possibilism, and adaptionism. Environmental determinism began with the Greeks and Romans. It proposed that the physical environment influenced human social development (emphasizing the role of nature). Possibilism replaced environmental determinism. It posited that while the physical environment had some influence on culture it was predominately determined by social conditions (emphasizing the human influence). Adoptionism arose in the 19th century with the work of George Perkins Marsh and others. It proposed a third view that integrated the roles of nature and culture. Adoptionism believed that nature and culture interacted with and modified each other (Briassoulis, 2000).

From adoptionism evolved one of the major themes of geography: human-environment interaction. Its three principles are:

Dependency – human dependency on the environment

Adaptation – human adaptation to the environment

Modification - human modification of the environment (Briassoulis, 2000).

This makes the understanding of human–environment interaction integral to land use/land cover change research (Lambin & Geist, 2006).

Anthropogenic activities are causing rapid changes to our environment (Metzger, Rounsevell, Acosta-Michlik, Leemans, & Schröter, 2006). These changes in climate, ecosystem processes, biogeochemical cycles, biodiversity, and other global processes are known collectively as global change (Lambin et al., 1999). Anthropogenically induced land use/land cover change has been identified as one of the most significant influences of global change (Metzger et al., 2006) making land use change science essential for future sustainability (Lambin et al., 1999).

Theories

As mentioned in the literature review, Briassoulis (2000) groups land use change theories into three theorization traditions; urban, sociological, and nature-society. Each tradition has its own perspective on drivers, be it economic, social, or environmental. Within each tradition the range of theories is broad. (Figure IV.-1)

Theorization Tradition	Approach/Theory	
Sociological and Political Economy	Functionalist–Behaviorist Theoretical Approach	Human Ecological Theories
		Planning Theories
	Institutional–Structuralist Theoretical Approach	Urban Social Movements
		Urban Land Nexus Theory
		Crisis Theory
	Core–Periphery Theories	Modernization Theories
		Stages Theory of Economic Growth
		Core Periphery Model
		Internal Colonialism
		World System Theory
	Unequal Exchange and Dependency Theories	Unequal Exchange
		Unequal Development
		Dependency Theory
		Unequal Regional Exchange
		The Theory of the Spatial Division of Labor
		Uneven Development
	Uneven Development–Capital Logic Theory	

Theorization Tradition	Approach/Theory	
Urban and Regional Economics	Micro-Economic Theoretical Approach	Agricultural Land Rent Theory
		Urban Land Market Theory
		Agent-Based Theories
	Macro-Economic Theoretical Approach	Spatial Economic Equilibrium Theory
		Regional Disequilibrium Theory
		Keynesian Regional Development Theory
	Other Theoretical Approach in Regional Science	Social Physics
		Urban and Regional Ecology
Nature – Society	Humanities Based Theories	Frontier Thesis
		Environmental/Cultural Anthropology
		Environmental Psychology
	Natural Science Based Theories	Environmental Determinism
		Cultural Ecology
		The Berkeley School
	Social Science Based Theories	Culture of Mass Consumption Theory
		Ecological Revolutions
		Multidisciplinary Approaches

Figure IV.-1 Classification of Theories of Land Use/Land Cover Change (Briassoulis, 2000)

Reasoning

Land use/land cover change science uses predominately inductive research. As a relatively new field it has yet to come up with a comprehensive theory, and as such, historical analysis tends to be inductive.

Inductive reasoning, the core of empirical research, begins with the collection of observational data. From this data researchers look for patterns with which they can form hypotheses of land use/land cover change. The distillation of regional inductive research through the meta-analysis of global change studies has found possible causalities of land use/land cover change. These hypotheses are then tested to be either true or untrue (Overmars, de Groot, & Huigen, 2007).

Deductive reasoning begins with a hypothesis of land use/land cover change. Hypothesis testing then determines if the hypothesis is true or untrue (Overmars et al., 2007). Overmars, de Groot, and Huigen (2007) clarify that there is no distinct divide between inductive and deductive modeling. Instead, they exist along a scale within which empirical research looks for possible correlations to define research parameters (Lambin & Geist, 2006).

Problems exist in both empirical research and hypothesis testing. Empirical research can depend on more readily available data (for example, data collected by someone else) that might not be as accurate as primary data sources. With hypothesis testing focusing on a particular theory, there is the possibility of overlooking other processes in play. Location and its unique characteristics increase the complexity of the relationships among drivers, and between drivers and agents of land use change. This makes it more difficult to identify patterns and to develop of theories (Lambin & Geist, 2006). To overcome some of these problems Briassoulis (2000) calls for an integration of inductive and deductive reasoning. (Figure IV.-2)

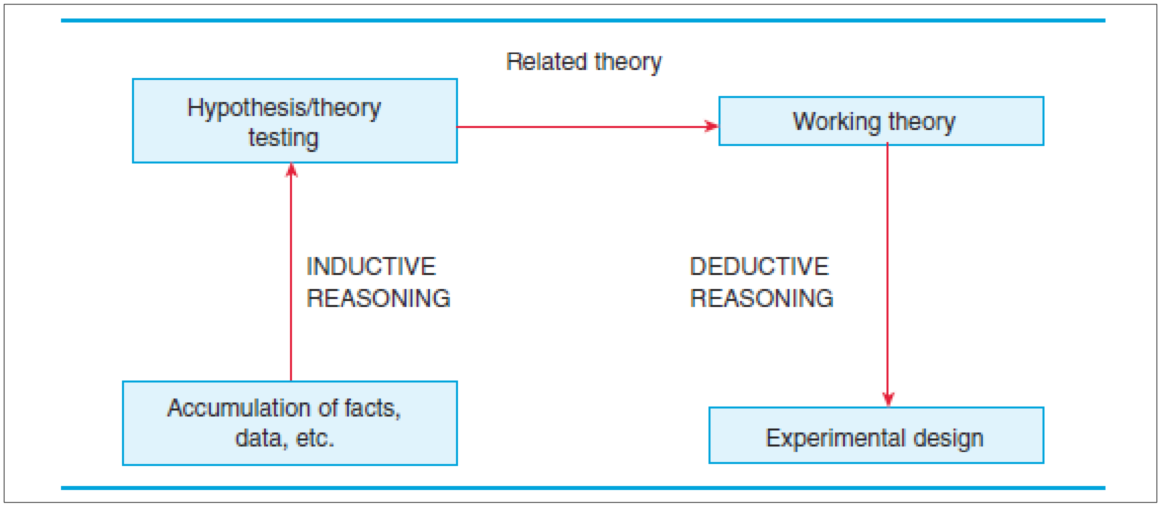


Figure IV.-2 Integrating inductive and deductive methods (Gray, 2004)

Land use/land cover change looks for theories based on causality. However due to complexity, and the multiple difficulties inherent in studying change, causality cannot always be identified. This leaves research focused on correlation, hypothesis that needs to be further tested. In some cases, the inclusion of inferential reasoning and a narrative of circumstantial evidence are warranted. They also recommend the inclusion of the following to aid in change science:

> "Comparative studies across administrative boundaries; the inclusion of impeding and stabilizing factors that restrain change; the identification of inherent dynamic as well as extrinsic forces in play; study of "attractor" or why some areas are more prone to change than others; and precursors to aid in the prediction of change (Bürgi et al., 2004)."

Approach to Data

According to Swetnam, Allen, and Betancourt (1999) data is either natural or documentary. (Figure IV.-3) Natural information is the result of biotic and abiotic processes derived from such studies as palynology, dendrochronology, and paleoethnobotany. Documentary data is societal and includes materials that are written, mapped, photographed, etc. (T. W. Swetnam, Allen, & Betancourt, 1999). Land use change research is at the crux of documentary and natural data, using both to establish base line information and an understanding of change.

The study of land use change has evolved from being one-dimensional to being complex, making simplification difficult (Lambin & Geist, 2006). Bürgi, Hersperger, and Schneeberger (2004) recommend the integration of narrative, quantitative, and qualitative data to address this complexity. Narrative data comes from participatory research as well as historical documents. It is local in nature, focusing on the individual at the institutional level. GIS, with its ability to manage large amounts of quantifiable data, is of value in both hypothesis testing and empirical research in land use/land cover change. Quantifiable data compared with qualitative provides greater confidence as does the use of multiple sources of data (T. W. Swetnam et al., 1999).

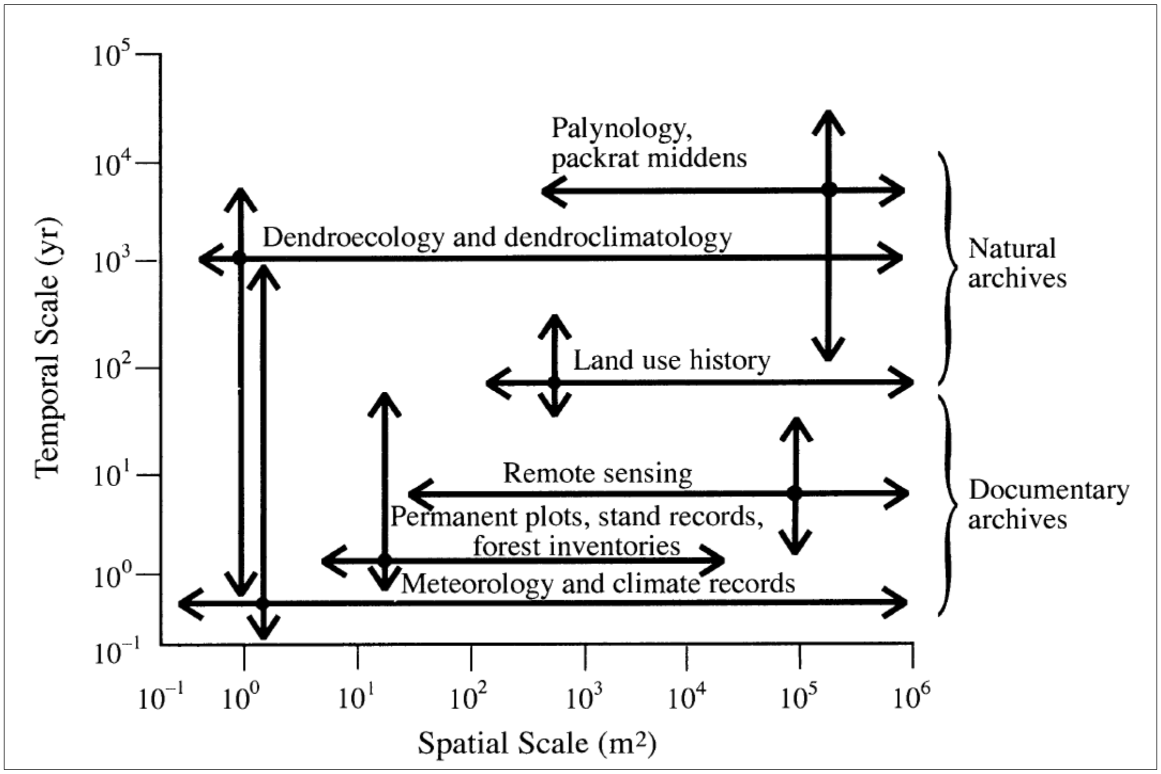


Figure IV.-3 Data and Type of Research Depending on Spatial and Temporal Scale. (T. W. Swetnam et al., 1999)

Research Methods

There are three basic approaches to land use/land cover change studies: descriptive, agent-based and a systems approach (Briassoulis, 2000; Lambin et al., 1999). Research can be a synthesis of all three approaches or to a particular method of interaction. It is limited by the number of researchers, their fields of study, and available funding (Agarwal, Grove, Evans, & Schweik, 2002; Lambin & Geist, 2006)

Descriptive research draws from qualitative and/or quantitative data. It looks at history and provides empirical and interpretive information. It is also a platform for exploring random events (Lambin et al., 1999). Modeling relies on quantitative data, creating a representation of the driving forces and/or decision makers of change (Lambin & Geist, 2006). These models are inductive, searching for correlations within datasets, or can use hypotheses to drive analysis. (Overmars et al., 2007).

Models are developed along many lines of research, making classification difficult. Some effort has been made to categorize them along different axes: land change process (e.g. deforestation, urbanization desertification), simulation technique (e.g. spatial, temporal, agent-based), agent-based or underlying theory as in Briassoulis (2000) (Lambin & Geist, 2006). Agent-based research aims to understand the decision-making process of land managers and systems science looking at the complexity of institutions and society across scales (R. D. Swetnam et al., 2011)

Methods of Establishing Historic Land Cover and Estimating Land Cover Change

Studies in land use/land cover change, historical ecology, and ecosystem services use documentary and natural data to create a historical ecological image from which to measure change. (Figure IV.-3) For example the Land-Use and Cover-Change Project (LUCC) examines land use/land cover change over 350 years, using the past 300 to predict the future 50+ years. This often takes the form of maps which are used in GIS and other modeling techniques from which to measure past change and estimate future change (T. W. Swetnam et al., 1999).

Skaloš et al. (2011), Grossinger et al. (2007), Verheyen et al. (1999), Borde et al. (2003), Bromberg and Bertness (2005), Gimmi, Lachat, and Bürgi (2011) and Levin, Elron, and Gasith (2009) use a combination of historical and contemporary maps in their research. GIS is then employed to georeference or project maps to a common projection, then land cover/covers of interest are digitized (Borde, Thom, Rumrill, & Miller, 2003; Bromberg & Bertness, 2005; Gimmi, Lachat, & Bürgi, 2011; Grossinger et al., 2007; Levin, Elron, & Gasith, 2009; Skaloš et al., 2011; Verheyen, Bossuyt, Hermy, & Tack, 1999). Several of these research papers analyzed discreet units, rather than addressing the study area as a whole. This allowed each unit to evolve uniquely and required a separate historical review of each unit of the study.

Methods to Study Change

The methodology used in this thesis relies heavily on two papers: The first is Solecki et al. (1999) Human–Environment Interactions in South Florida's Everglades Region: Systems of Ecological Degradation and Restoration. The second method is Grossinger et al. (2007) Historical Landscape Ecology of an Urbanized California Valley: Wetlands and Woodlands in the Santa Clara Valley.

All three study areas, the Everglades, Santa Clara Valley, and the topic of this thesis, Jamaica Bay, have experienced a significant loss of their respective wetlands. More than 50% of the Florida Everglades have been lost to agriculture and drainage, 80% of the Santa Clara study area has been urbanized, and Jamaica Bay has lost all of its surrounding wetlands to urbanization.

Solecki provides a temporal historical narrative based on his human-environmental framework. He uses history to explain societal-anthropogenic influences to changes made to the Florida Everglades. Solecki produces a temporal analysis. The factors of change may stay the same over time; however, their respective influences change from epoch to epoch. In contrast, this thesis looks at wetland change through a different lens. Rather than looking at change over time, it looks at change across political units (neighborhoods). While drivers may be similar across units, this allows greater insight into the role of decision-makers in their response to drivers.

Grossinger et al. (2007) expands on the work of the previously mentioned papers that quantify land use/land cover change. Using primary and secondary data, a complex ecological profile of the Santa Clara Valley is constructed. Triangulation helps to control data quality by looking at multiple sources of data. In this thesis, ecological profiles are created for each political unit (neighborhood) at the time that it occurred. This offers greater insight to the actions of drivers at different times.

With the theoretical tradition of nature society as outlined by Briassoulis (2000), an inductive approach is used to understand societal influences on land cover change. Collecting and reviewing the large quantity of data needed in such an approach requires the efforts of multiple researchers, as in both Solecki's and Grossinger's research. In an effort to manage the scope and volume of this work, several decisions were made.

1. While an attempt was made not to preconceive which were the primary drivers of change, research would focus on the effects of two major drivers: transportation and sanitation
2. A descriptive/qualitative study method was chosen.
3. The analysis would tend to be more societal-anthropogenic rather than a natural-biophysical analysis.

V. APPLICATION OF METHODS

The work ofn this thesis began with the collection of historical maps. In an effort to organize the data an assumption was made that historical boundaries would be grandfathered in to contemporary political boundaries. This appeared to be true when the historical towns surrounding Jamaica Bay were compared to the New York City Community Districts Map. As a result, the organization of the neighborhoods is driven by the historical towns of Brooklyn and Queens and consists of 6 units: Flatbush, Flatlands, Gravesend, Jamaica, Hempstead, and a section devoted specifically to airports. (Queens, at the time of this inquiry included the town of Hempstead).

Numerous histories of the region were located. An effort was made to collect histories written at different times. The writing of histories changes over time. The material that is considered important changes as do the resources available to historians. This resulted in a collection of histories ranging from the early 1800s to 2014. As the histories were studied, key facts regarding land use land/cover change were identified, then researched further using additional histories and primary data including historical newspaper articles, historical maps and government reports.

In order to more clearly visualize the changes in land cover, historical maps that chronologically identified changes in land use/land cover change were identified and made into basemaps. This thesis presents six sets of 30 chronological basemaps based on those historical maps. There is one set for each of the five historical townships and one set for the entire Jamaica Bay estuary. They are included in appendices A through G.

In addition to the chronological historical basemaps, several other types of basemaps were made: soil survey maps of New York City, historical wetlands cover maps, contemporary wetlands cover maps, and a map using PLUTO data. All of the basemaps are duplicated for each of the 5 neighborhood subgroups of Flatbush, Flatlands, Gravesend Jamaica, and Hempstead.

Two different GIS software programs were used in the creation of the basemaps. GIS required the construction of several shapefiles to include, historical wetlands cover, and neighborhood boundaries. Many data sources were used to create these layers.

Triangulation, a mixed method technique was used to provide robustness and depth to the research.

The following is a description of the major process involved in researching this thesis. It begins with the organization of data, then the selection of historical maps, GIS, and ends with a discussion of triangulation.

V. APPLICATION OF METHODS

A. ORGANIZATION OF RESEARCH

In this thesis the neighborhoods that surround Jamaica Bay are grouped according to the original townships of Kings and Queens Counties. (Figure V.A.-1) (Figure V.A.-2) Neighborhood boundaries are not political and, as such, are not clearly defined. Depending on the source boundaries change, names change and communities come and go. When looking at maps over time, the discrepancies become even greater.

The six townships of Kings County were settled by the Dutch from 1645 to 1661. They consisted of Brooklyn (Breuckelen 1646), Bushwick (Boswijck in 1661), Gravesend 1645, Flatbush (Midwout in 1652), Flatlands (New Amersfoort in 1647), and New Utrecht (in 1657). The towns bordering the Bay were Flatbush, Flatlands, and Gravesend.

Originally, Queens County included the present-day Nassau County. The original five townships of Queens County were: Flushing (Vlissingen 1643), Hempstead (the Dutch granted a patent to the English 1644), Jamaica (Rustdorp in 1656), Newtown (Middenbugh in 1652), and Oyster Bay (charter from the English in 1667). Jamaica and Hempstead fronted the Bay.

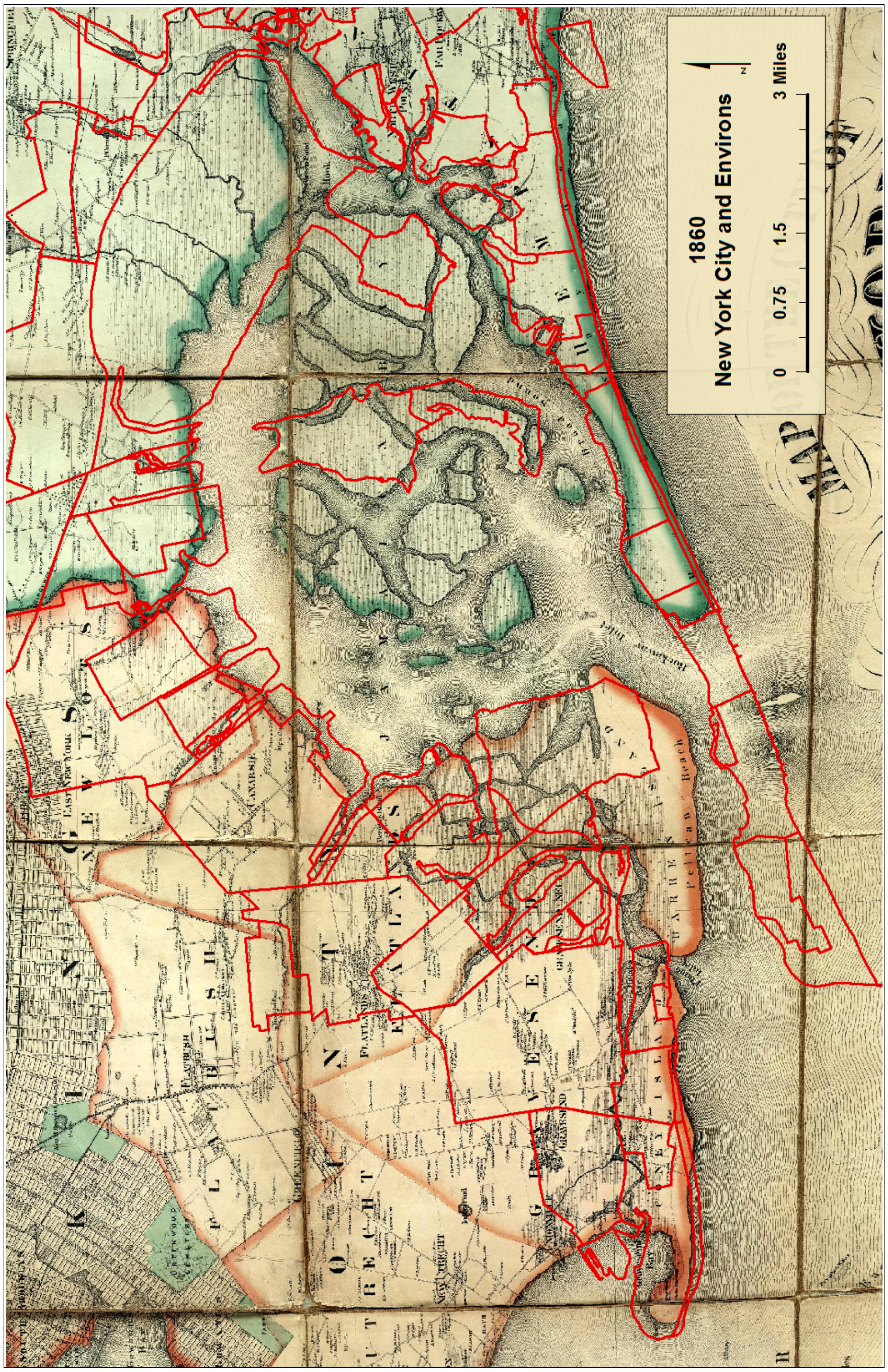


Figure V.A.-1 Townships Surrounding Jamaica Bay in 1860

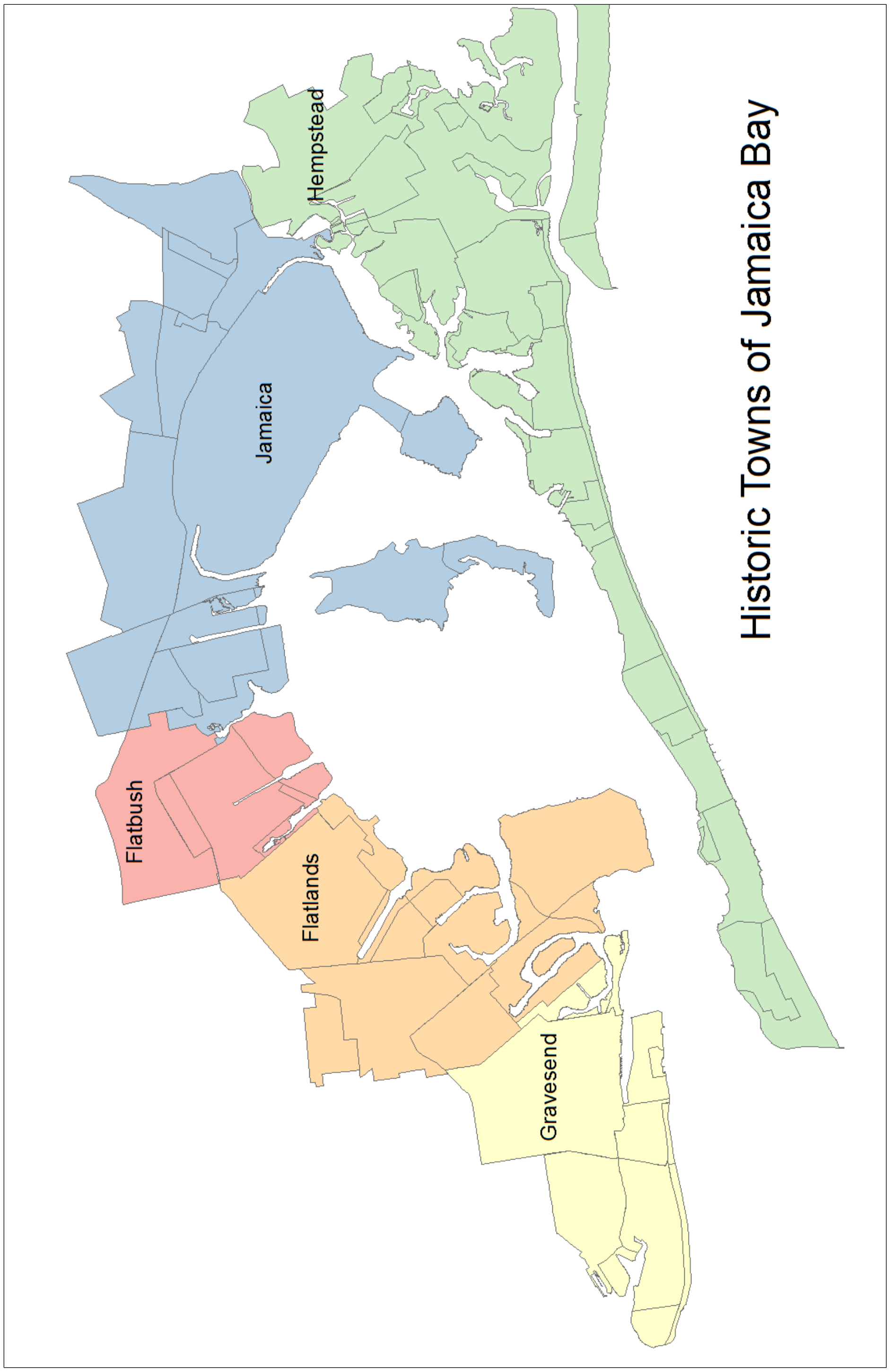


Figure V.A.-2 Historical Political and Current Neighborhood Boundaries

The geographic boundaries of the neighborhoods are primarily based on two books: “The Neighborhoods of Brooklyn” and “The Neighborhoods of Queens” (Copquin, 2007; Jackson & Manbeck, 2004). The selection of neighborhoods and their boundaries were also affected by historical information, New York City Community Districts, and Google maps (Copquin, 2007; Jackson & Manbeck, 2004). (Figure V.A.-3)

Figure V.A.-3 New York City Community Districts

The New York City community districts generally follow the original townships of Kings and Queens Counties: Districts 13 and 15 (Gravesend), District 18 (Flatlands), District 5 (New Lots), District 10 (Jamaica), and District 14 (Hempstead).

Parks, while significant in area, are not included in this thesis. The drivers behind their development, including the influence of Robert Moses, are different than those which affected urban development for commercial and residential purposes and deserve an exploration in their own right. The wetlands within the Bay are the subject of much study and are also not included in this paper.

The following is a list organizing the neighborhoods as they are covered in this thesis.

Flatbush (Figure V.A.-4)

- Fountain Avenue and Pennsylvania Avenue Landfills
- Spring Creek

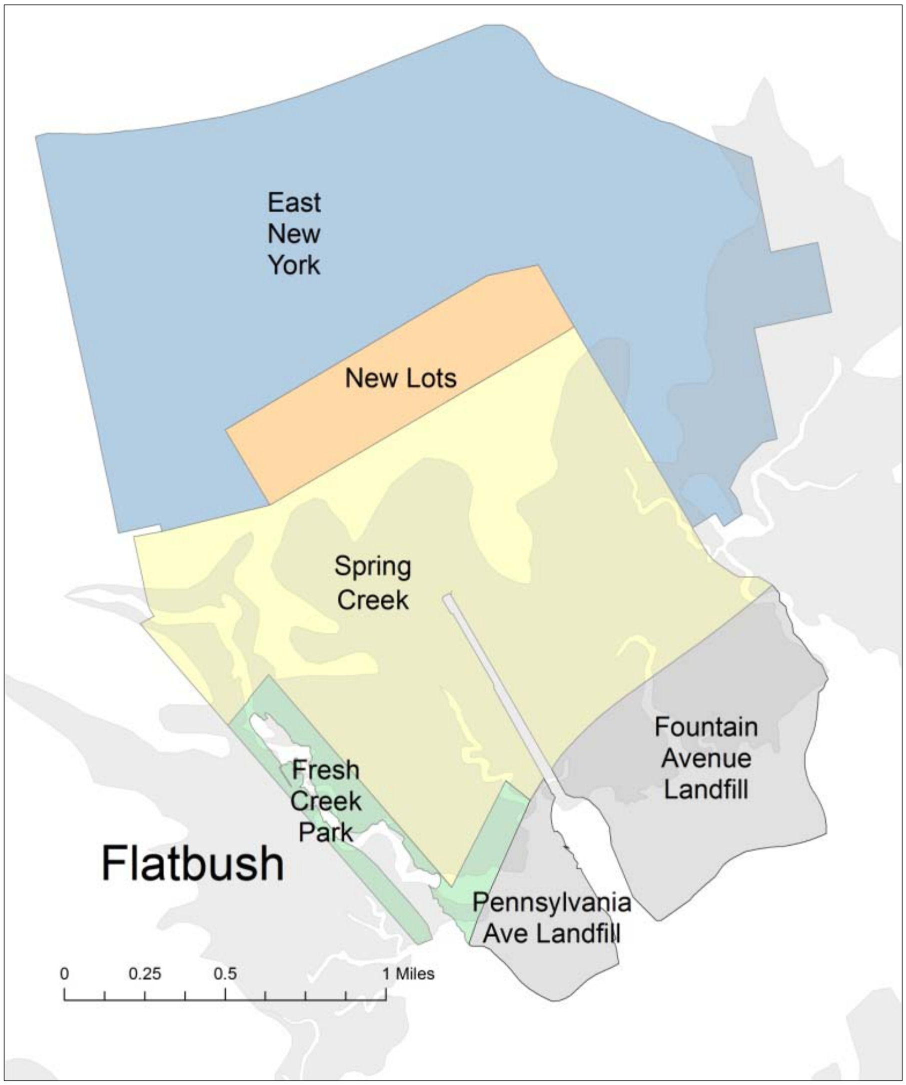


Figure V.A.-4 Neighborhoods of Flatbush and Historical Wetlands

Flatlands (Figure V.A.-5)

- Bergen Beach
- Canarsie
- Georgetown
- Mill Basin

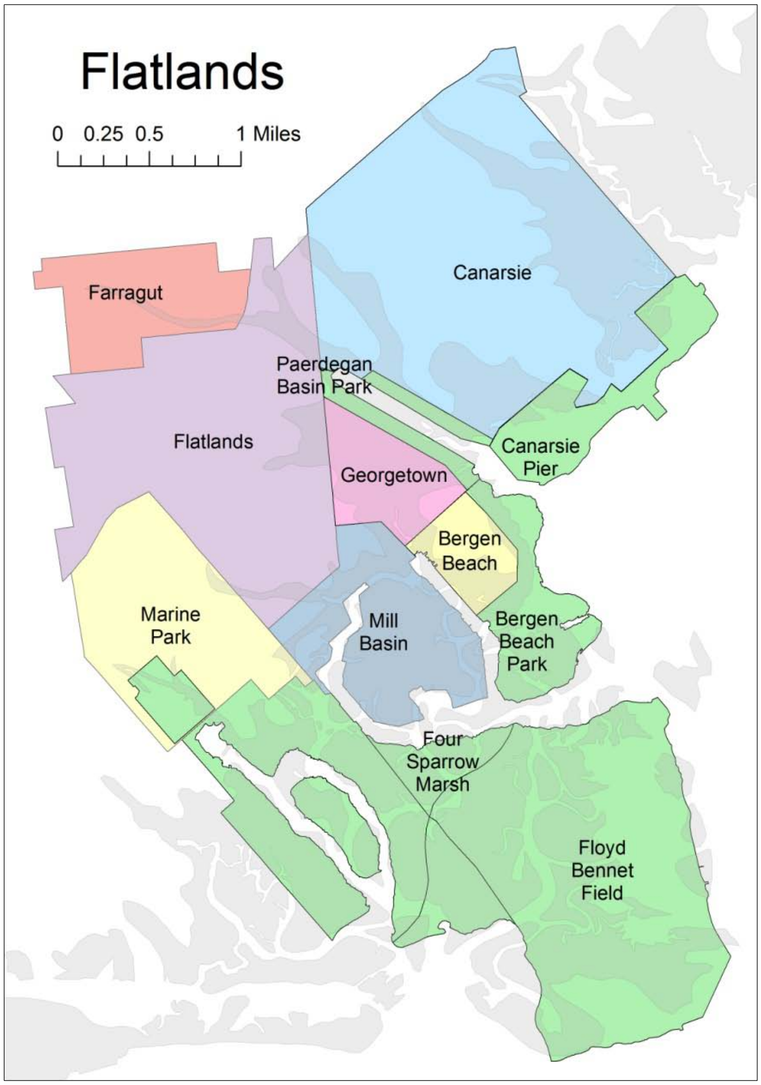


Figure V.A.-5 Neighborhoods of Flatlands and Historical Wetlands

Gravesend (Figure V.A.-6)

- Coney Island
    - Brighton Beach
    - West Brighton Beach
    - Manhattan Beach
    - Seagate
- Gravesend
- Gerritsen Beach
- Sheepshead Bay

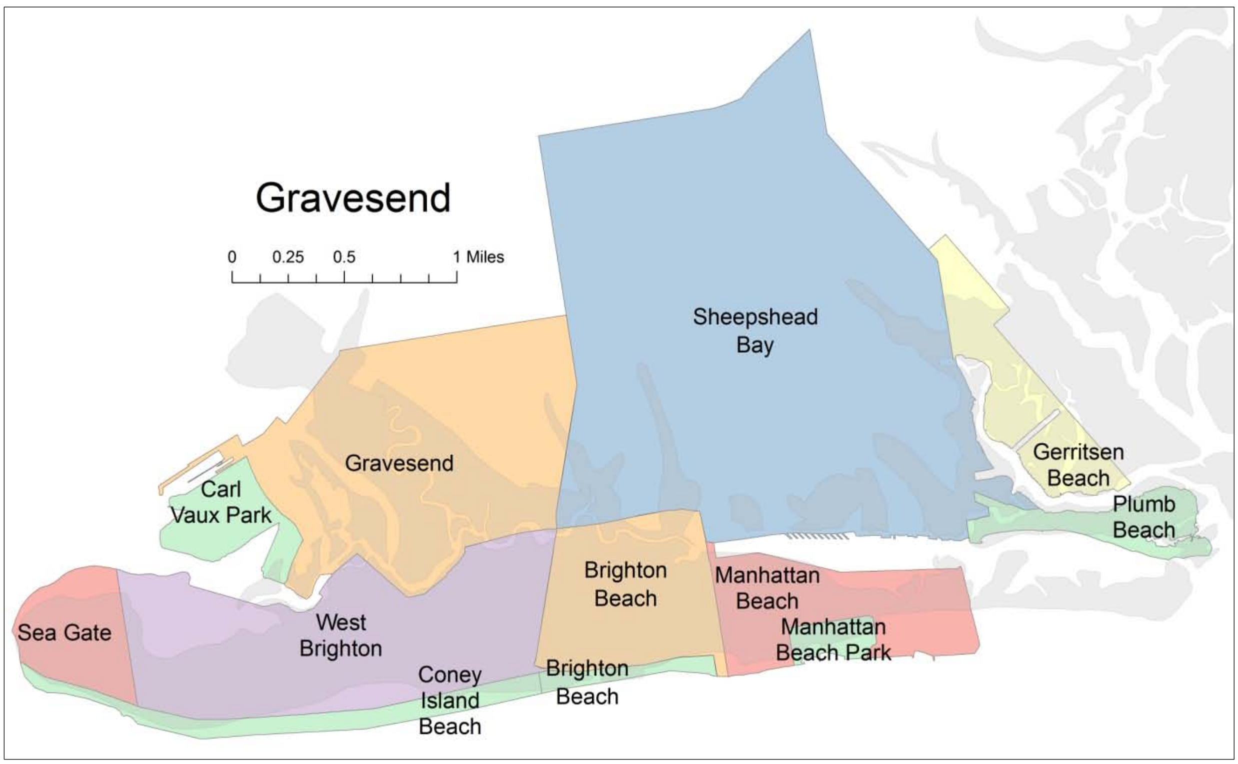


Figure V.A.-6 Neighborhoods of Gravesend and Historical Wetlands

Jamaica (Figure V.A.-7)

- Broad Channel
- Hamilton Beach
- Lindenwood
- Howard Beach
- Ramblersville (approximately 25 acres)

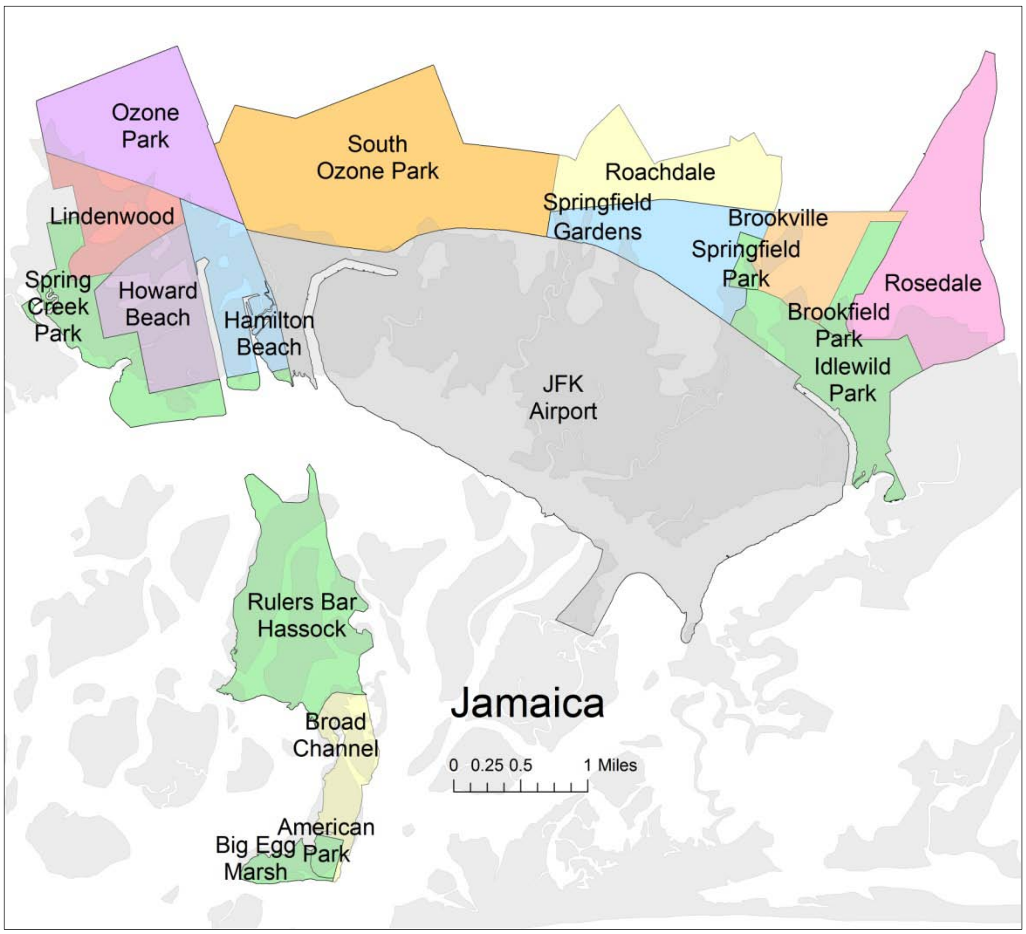


Figure V.A.-7 Neighborhoods of Jamaica and Historical Wetlands

Hempstead (Figure V.A.-8)

- Rockaway Peninsula:
    - Arverne, Queens
    - Bayswater
    - Breezy Point, Queens
    - Edgemere, Queens
    - Far Rockaway
    - Hammels/Rockaway Beach, Queens
    - Seaside/Rockaway Park, Queens
    - Neponsit, Queens
    - Roxbury, Queens
- Rockaway Neck:
    - Lawrence, Nassau
    - Inwood, Nassau
    - Cedarhurst, Nassau
    - Woodmere, Nassau

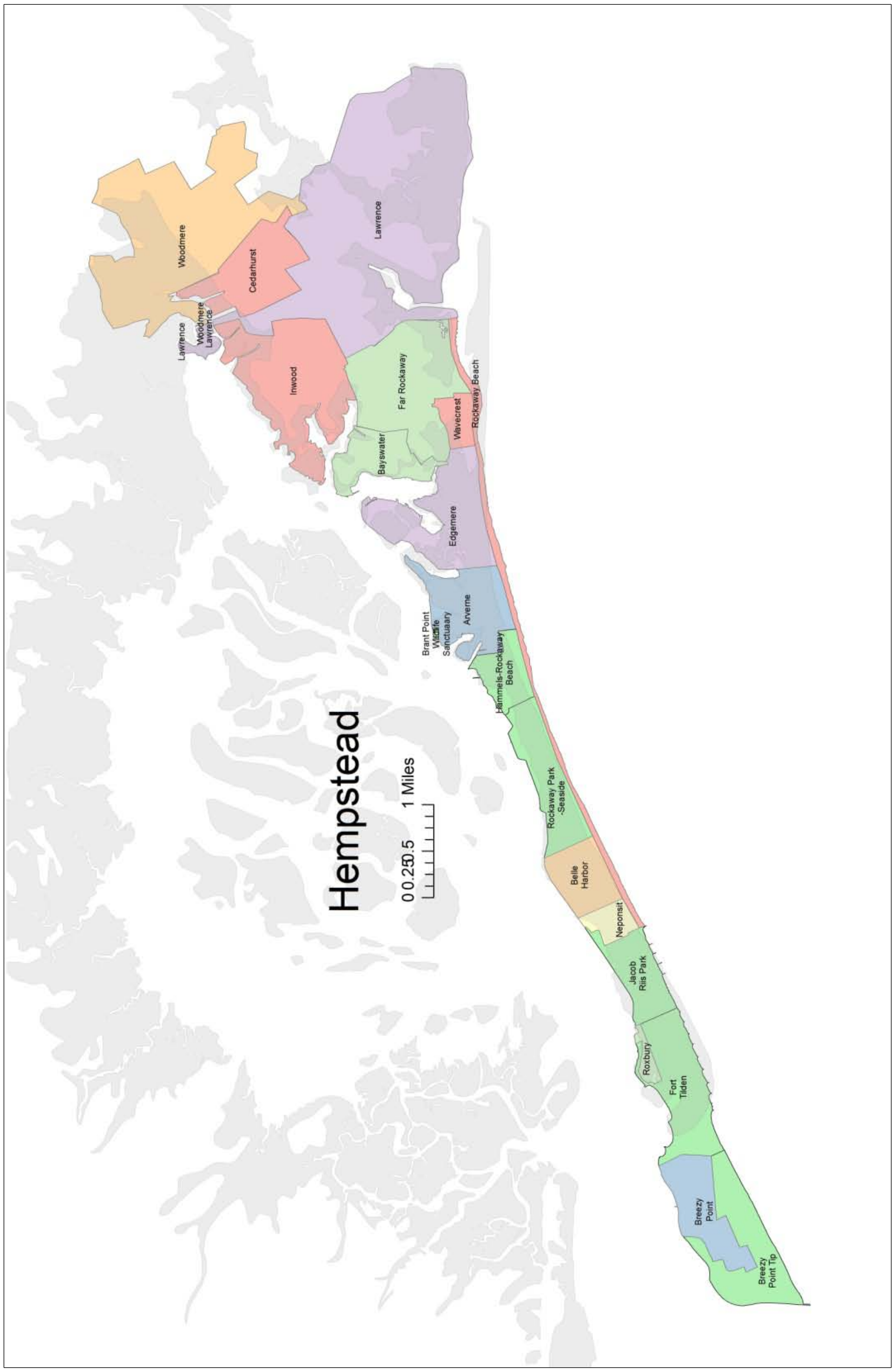


Figure V.A.-8 Neighborhoods of Hempstead and Historical Wetlands

Airports: (Figure V.A.-9)

- Floyd Bennett Field
- John F. Kennedy International Airport
- Airports were also located in the Rockaways: Rockaway Airport in Edgemere, Rockaway Naval Air Station (formerly located in what is now Jacob Riis Park), and the Fort Tilden Blimp Field (Masefield, 1972).

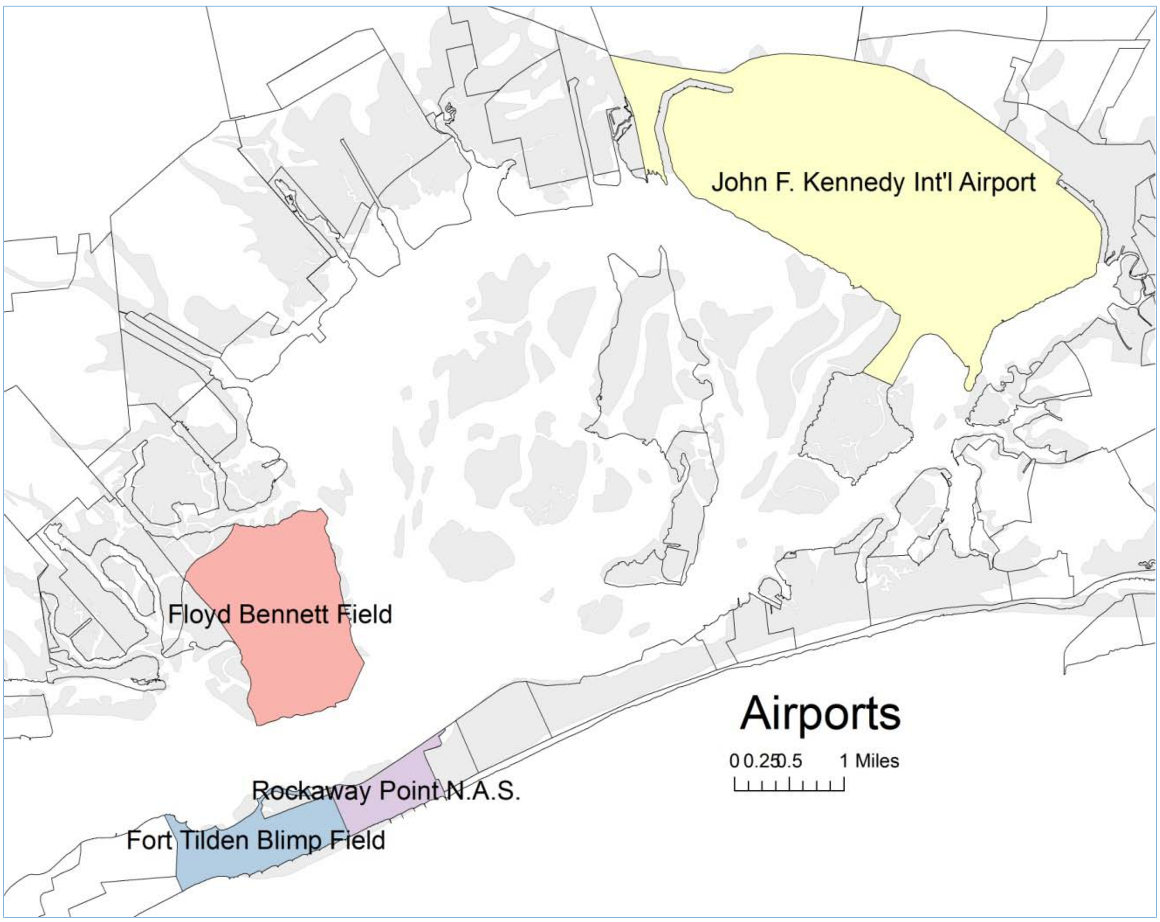


Figure V.A.-9 Airports and Historical Wetlands

V. APPLICATION OF METHOD

B. MAP SELECTION

Since the actual epoch was to be determined by historical analysis, maps were collected from as early as 1777. As research progressed maps were both removed and added as the period of the research became better defined. Eventually, the map range was established from 1811 to 2014. Additional maps were added as it became important to illustrate specific land use/land cover changes. This substantially increased the number of reference maps used. The study area is the entire breadth of the Bay, including its historical wetlands and tributaries. If a map did not cover the entire extent, they still might be selected to illustrate a particular feature or area. Maps that provided information of some, if not all, of the following were considered: land cover, political boundaries, cities, and landholders.

Important map characteristics included scale, file size, map extent, readability, and content. The preferred scale was 1:20,000 or less, and as large a file size as possible. However at times this was overlooked when the map illustrated important information that was not available elsewhere. This was more common for the earlier maps from 1811 to 1827.

Map Sources

Several hundred maps were initially collected for this project. They came from a variety of sources including public and private ownership, government agencies, and commercial websites. (Figure V.B.-1)

Type	Location	Link
Public	Harvard Map Collection	http://hcl.harvard.edu/libraries/maps/
Public	Lionel Pincus and Princess Firyal Map Division, NYPL	http://digitalcollections.nypl.org/divisions/lionel-pincus-and-princess-firyal-map-division
Public	Norman B. Leventhal Map Center, Boston Public Library	http://maps.bpl.org
Public	Wildlife Conservation Society	www.wcs.org
Private	David Rumsey Historical Map Collection	www.davidrumsey.com
Government	Library of Commerce	www.loc.gov
Government	National Oceanic and Atmospheric Administration (NOAA)	www.noaa.gov
Government	The New York Statewide Digital Orthoimagery Program	https://gis.ny.gov/gateway/mg/
Government	United States Geological Society (USGS)	www.usgs.gov

Type	Location	Link
Government	United States Department of Agriculture (USDA)National Agriculture Imagery Program (NAIP)	*https://lta.cr.usgs.gov/NAIP*
Commercial	Nationwide Environmental Title Research, LLC (NETR)	*http://www.netronline.com/*

Figure V.B.-1 Sources of maps

The Harvard Map Collection is one of the oldest sources of cartographic materials in the United States. This large collection consists of more than 500,000 items, of which only a small number have been digitized, and even fewer georeferenced. Georeferenced maps are available from the Harvard Geospatial Library, and the others are downloadable from their Virtual Collection.

The Lionel Pincus and Princess Firyal Map Division of the New York Public Library was established in 1898. It contains over 400,000 sheet maps and 20,000 books and atlases. The Virtual Collection consists of approximately 20,000 maps. The NYPL Warper website allows viewers to georeference and download historical maps. Maps are available to download as KML, or tiff files.

The Norman B. Leventhal Map Center, Boston Public Library, has a collection of 200,000 historical maps and 5,000 atlases. Like most collections, only a selection are available to be viewed on the internet and downloaded. Maps are downloaded as jpg files.

The David Rumsey Historical Map Collection database has over 61,000 downloadable maps from their historical map collection. The collection focuses on 18th and 19th century maps of the Americas (David Rumsey Map Collection.2015). Rumsey maps are available for downloads in both .sid and .jpg formats.

The Wildlife Conservation Society manages the Mannahatta Project. Mannahatta is a historical ecological profile of New York City at the time of Henry Hudson. WCS provided a high-resolution copy of "New York and Environs", one of the keystone maps used in this thesis (Wildlife Conservation Society, 2015).

The Geography and Map Division of the Library of Commerce is the largest cartographic collection in the world. It serves federal, state, and local governments as well as academia, and the general public. The Library of Commerce collection includes over 5.2 million maps, as well as atlases, geospatial datasets, reference works, etc. (Library of Congress, Geography and Map Division, 2015). The online collection is much smaller and focuses on Americana. Maps can be downloaded from the website as jpeg2000 files.

The National Oceanic and Atmospheric Administration (NOAA) was established in 1970 as a scientific arm of the United States government. One arm of NOAA is the National Ocean Service (NOS), which hosts the Office of the Coast Survey (OCS). OCS has gone through many name changes. It was established in 1807 as the Survey of the Coast. In 1837 it was renamed as the Coast Survey. Then in 1878 it was named the U.S. Coast and Geodetic Survey. Finally in 1970, with the establishment of NOAA, the name was changed to the Office of the Coast Survey. The original mission of the OCS was to provide accurate nautical charts. Today, its responsibilities include the monitoring and study of hydrography, geodesy, astronomy, topography, oceanography, tide, and current measurement (NOAA Coastal Services Center, 2015). OCS provides many products that deal with coastline surveys, bathymetry, and navigation. These include nautical charts, T-sheets, H-sheets, and vector shorelines.

Nautical Charts: Coast Survey has been making nautical charts since 1807. They are NOAA's signature product, charting the waters of the Great Lakes and United States coastal waters. They are used to plot courses for navigation and provide an accurate representation of the coastline and, as such, need to be updated regularly. The shoreline delineation is usually at mean sea level. The T, TP, and H are survey series used to construct nautical charts for navigation.

T-sheets: These have had many monikers including shoreline surveys, coastal surveys, TP-sheets, and shoreline manuscripts. T-sheets were created from surveys conducted between 1834 and 1980. They were renamed TP-sheets after 1968. Both T-sheets and TP-sheets are topographic surveys.

H-sheets: The OCS began surveying and producing H-sheets in 1837. Also known as smooth sheets they include bathymetry data from hydrographic surveys based on boat soundings. They can also include information about bottom types which are obtained from bottom grabs during surveys. Other alongshore features and roads can be depicted. Digitized bathymetric data was made from smooth sheet surveys between 1837 and the mid-1970s.

Vector Shorelines: The OCS created vector shoreline files from NOAA raster charts. They are in ESRI's shapefile format. The vector shorelines were made from 88 T-sheets made between 1873 and 1999. The purpose of the Vector Shoreline Project is to provide public access to charted coastline data.

The New York Statewide Digital Orthoimagery Program provides NAPP 1 Meter Resolution Imagery from 1994 – 1999. The National Aerial Photography Program (NAPP), is a multi-agency project of the federal government coordinated by the USGS. The New York Statewide Digital Orthoimagery Program (NYSDOP) has produced high resolution imagery from 2000 – the present day. The program's goal is to obtain imagery for New York State on a 4-to-5 year cycle. This program does not include New York City.

The **United States Geological Society** (USGS) provides information on ecosystems, environments, natural hazards, natural resources, climate, land use, and core science systems. The products produced by the USG that are used in this thesis are topographic quadrangle maps.

Topo Quads: The USGS library contains over 54,000 topographic maps that cover the entire United States. Both historical and contemporary topographical maps are used in this thesis. The USGS Historical Topographic Map Collection contains maps of the Jamaica Bay region from as early as 1897. Maps from 1900 and earlier are at a scale of 1:62,500. Later maps are at a scale of 1:24,000. (Figure V.B.-2) Three 1:62,500 maps (Staten Island, Brooklyn and Hempstead) were combined to cover the full extent of the study area. Eight maps at a scale of 1:24,000 (Jersey City, Brooklyn, Coney Island, Far Rockaway, Jamaica, Lawrence, Lynbrook, and the Narrows) were combined to cover the study area. The topographic quadrangle maps from the USGS are available as geo.pdf files. Later maps have metadata within the geo.pdf. For earlier maps, legends are sometimes located on the map frame or in the Directory of Quads provided by the USGS.

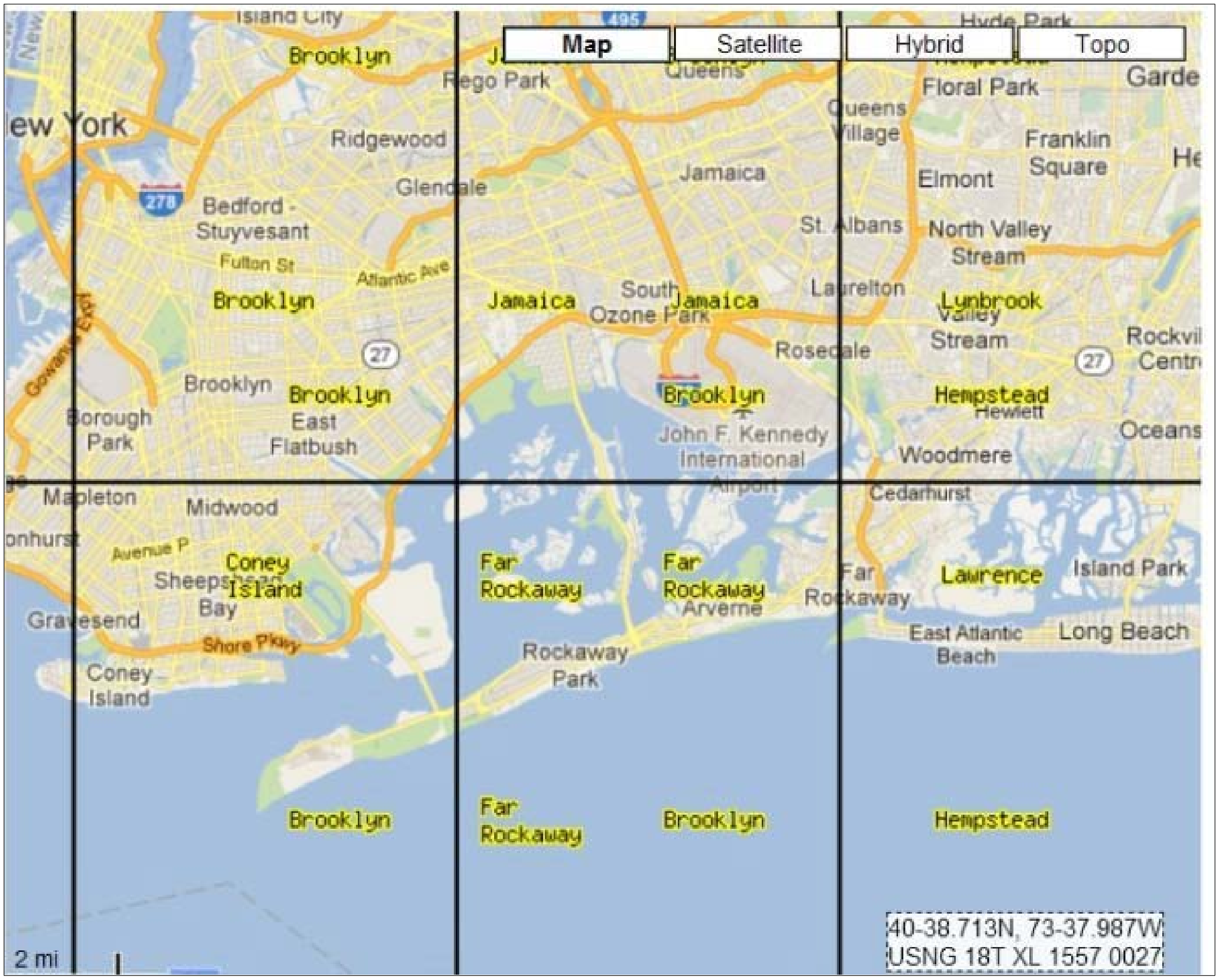


Figure V.B.-2 USGS Index Map for Jamaica Bay

“The **National Agriculture Imagery Program** (NAIP) is administered by the USDA's Farm Service Agency (FSA) through the Aerial Photography Field Office (APFO) in Salt Lake City, Utah. NAIP acquires orthorectified imagery at a resolution of 1-meter ground sample distance (GSD) for the United States during the agricultural growing season, or "leaf on" conditions. Orthorectified images combine the image characteristics of an aerial photograph with the georeferenced qualities of a map"(U.S. Geological Survey, 2015).

The APFO is a repository for more than 22 governmental programs. It contains imagery from as early as 1947. Of the collection 87% is negative, 12% is positive, and the balance halftone and internegative (a specialized type of negative film). Only 22% of the imagery is in color, 63% is in black and white, and 14% is color infrared imagery (CIR) (Mathews, 2005).

Nationwide Environmental Title Research, LLC (NETR) gathers data from a variety of government sources including local, state, and federal environmental records. The site charges for property data and historical aerials. Unfortunately, metadata is limited. When it is available, the data source and a date range for the data will be identified; for example as USGS (09/05/55 - 10/23/55). Some of the data used from this source does not have any information available other than date. The company was contacted but they were unable to identify the source. Since these maps were used for observation and not quantifiable machinations, yearly data seemed adequate (NETR Online, 2015).

Raster File Types: Imagery is available as a raster. A raster consists of a matrix of cells organized into rows and columns. Each cell contains a value representing information. Rasters are digital aerial photographs, imagery from satellites, digital pictures, and scanned maps. This thesis utilizes rasters of satellite imagery, and scanned maps. Downloaded maps and satellite imagery are available in a number of different file types. These include: jpg/jpeg, jp2/jpg2000, tif/tiff, pdf, geo.pdf, and sid. These can all be imported into a GIS. Some formats (.sid and geo.pdf) have spatial information. Raster formats that do not contain spatial information can be georeferenced.

Raster Formats Without Spatial Data

JPG/JPEG – was developed by the Joint Photographic Experts Group in 1992. They are image file formats that are supported on the Web. JPG format has a compression technique designed to compress color and grayscale continuous-tone images. Data that cannot be perceived visually is discarded in the compression. JPG images support 16 million colors. JPG is best suited for photographs and complex graphics. Compression results in a loss of clarity and sharpness and as such does not work well on line drawings, lettering, or simple graphics. They are the most common image format used by digital cameras and other photographic image capture devices and one of the most common formats for storing and transmitting photographic images on the internet.

Jp2/JPEG 2000 was developed by the Joint Photographic Experts Group committee in 2000. JPEG2000 files can be compressed to a smaller file size with less deterioration of image quality that .jpg.

Pdf – Portable Document Format was developed in the early 1990s as a way to share documents, including text formatting and online images, among computer users of disparate platforms who may not have access to mutually compatible application software. Each .pdf file has a complete description of a document, including the text, fonts, graphics, and other information needed to display it.

Tif/tiff – Tagged Image File Format is a file format for storing raster images that is popular among graphic artists and the publishing industry. It is widely supported by image-manipulation applications, publishing and page layout applications, scanning, faxing, word processing, optical character recognition, and other applications.

Raster Formats with Spatial Data

Geo.pdf - Geospatial PDFs are pdf files with geospatial extensions. They relate a region on a pdf document page to a region in physical space by the process of geoferencing. Certain features specific to both pdf and geospatial pdf: their ability to graphically represent vector and raster information; their ability to separate graphic content into separate layers; and their ability to integrate table information with graphic information allowing for the integration of metadata.

Sid – MrSID – Multi-Resolution Seamless Image Database. The file format was developed by LizardTech. It allows for the encoding of georeferenced raster graphics to be used in GIS.

The result is a collection of 67 maps that were used to create the basemaps. (Figure V.B.-3) (see Appendices A – H for complete sets of basemaps). A number of the maps are composites. They combine several maps in order to cover the full extent of the research area. The composites are grouped and identified by color coding. Each basemap is assigned a reference number that identifies the maps that were used as its foundation. Throughout the thesis additional maps were used to aid in visualizing particular discussion.

Ref.	**Year**	**Name**
1		Historical Wetlands
2		Current Wetlands
3		PLUTO 'Year Built'
4	1811	Map of the Country Thirty Miles Round the City of New York (David Rumsey Historical Map Collection, 1811)
5	1845	New York Bay and Harbor (David Rumsey Historical Map Collection, 1845b)
6	1852	Map of Kings and part of Queens Counties, Long Island N.Y. / surveyed by R.F.O. Conner (Lionel Pincus and Princess Firyal Map Division NYPL, 1852)
7	1860	Map of the City of New-York and its Environs (David Rumsey Historical Map Collection, 1860)
8	1873	Map Showing the Route & Connections of the Central Rail Road Extension Company of Long Island (Library of Congress, Geography and Map Division, 1873)
9	1888	Colton's New Map of Long Island (David Rumsey Historical Map Collection, 1888)

Ref.	Year	Name
10	1891	The Narrows to Jamaica Bay-Coney Island, North to Brooklyn (David Rumsey Historical Map Collection, 1891b; David Rumsey Historical Map Collection, 1895)
11	1895	New York, Kings, Queens, Richmond, Rockland, Westchester and Putnam Counties (David Rumsey Historical Map Collection, 1895)
12	1897-1903	USGS Topographic Composite
	1898	Staten Island, NY, NJ, file name: NJ_Staten Island_255388_1898_62500_geo.pdf (U.S. Geological Survey, 1898)
	1900	Brooklyn, NY, file name: NY_Brooklyn_139313_1900_62500_geo.pdf (U.S. Geological Survey, 1900b)
	1903	Hempstead, NY, file name: NY_Hempstead_139678_1903_62500_geo.pdf (U.S. Geological Survey, 1903)
13	1922	Jamaica Bay and Rockaway Inlet Nautical Chart (U.S. Coast and Geodetic Survey, 1922)
14	1923-1925	USGS Topographic Composite
	1897-1923	Hempstead, NY, file name: NY_Hempstead_129886_1897_62500_geo.pdf edited in 1923 (U.S. Geological Survey, 1897)

Ref.	Year	Name
	1900-1924	Brooklyn, NY, file name: NY_Brooklyn_123126_1900_62500_geo.pdf edited in 1924 (U.S. Geological Survey, 1900a)
	1900-1925	Staten Island, NY, NJ, file name: NJ_Staten Island_255397_1900_62500_geo.pdf edited in 1925 (U.S. Geological Survey, 1900c)
15	1924	Aerial Map of New York City (Fairchild, 1924a)
16	1926	Jamaica Bay and Rockaway Inlet Nautical Chart (U.S. Coast and Geodetic Survey, 1926)
17	1933	Jamaica Bay and Rockaway Inlet Nautical Chart (U.S. Coast and Geodetic Survey, 1933)
18	1937	Jamaica Bay and Rockaway Inlet Nautical Chart (U.S. Coast and Geodetic Survey, 1937)
19	1940	Jamaica Bay and Rockaway Inlet Nautical Chart (U.S. Coast and Geodetic Survey, 1940)
20	1947	USGS Topographic Composite
	1947	Jersey City, NJ, file name: NJ_Jersey City_254499_1947_24000_geo.pdf (U.S. Geological Survey, 1947d)

Ref.	Year	Name
	1947	Brooklyn, NY, file name: NY_Brooklyn_123124_1947_24000_geo.pdf (U.S. Geological Survey, 1900a)
	1947	Coney Island, NY, file name: NY_Coney Island_137694_1947_24000_geo.pdf (U.S. Geological Survey, 1947a)
	1947	Far Rockaway, NY, file name: NY_Far Rockaway_138136_1947_24000_geo.pdf (U.S. Geological Survey, 1947b)
	1947	Jamaica NY, file name: NY_Jamaica_129963_1947_24000_geo.pdf (U.S. Geological Survey, 1947c)
	1947	Lawrence NY, file name: NY_Lawrence_130229_1947_24000_geo.pdf (U.S. Geological Survey, 1947e)
	1947	Lynbrook, NY, file name: NY_Lynbrook_130380_1947_24000_geo.pdf (U.S. Geological Survey, 1947f)
	1947	The Narrows, NY, file name: NY_The Narrows_139983_1947_24000_geo.pdf (U.S. Geological Survey, 1947g)
21	1954-1957	USGS Topographic Composite

Ref.	Year	Name
	1954	Far Rockaway, NY, file name: NY_Far Rockaway_138137_1954_24000_geo.pdf (U.S. Geological Survey, 1954a)
	1954	Lawrence, NY, file name: NY_Lawrence_130230_1954_24000_geo.pdf (U.S. Geological Survey, 1954b)
	1954	Lynbrook, NY, file name: NY_Lynbrook_130382_1954_24000_geo.pdf (U.S. Geological Survey, 1954c)
	1955	Jersey City, NJ, file name: NJ_Jersey City_254500_1955_24000_geo.pdf (U.S. Geological Survey, 1955a)
	1955	Coney Island, NY, file name: NY_Coney Island_137695_1955_24000_geo.pdf (U.S. Geological Survey, 1956)
	1955	The Narrows, NY, file name: NY_The Narrows_139984_1955_24000_geo.pdf (U.S. Geological Survey, 1955b)
	1956	Brooklyn, NY, file name: NY_Brooklyn_123128_1956_24000_geo.pdf (U.S. Geological Survey, 1956)

Ref.	Year	Name
	1957	Jamaica, NY, file name: NY_Jamaica_129966_1957_24000_geo.pdf (U.S. Geological Survey, 1957)
22	1954	Historical Aerial Imagery(NETR Online, 1954)
23	1966-1969	USGS Topographic Composite
	1966	Coney Island, NY, file name: NY_Coney Island_137696_1966_24000_geo.pdf (U.S. Geological Survey, 1966a)
	1966	Jamaica, NY, file name: NY_Jamaica_129967_1966_24000_geo.pdf (U.S. Geological Survey, 1966c)
	1966	Lawrence, NY, file name: NY_Lawrence_130231_1966_24000_geo.pdf (U.S. Geological Survey, 1966f)
	1967	Jersey City, NJ, file name: NJ_Jersey City_254502_1967_24000_geo.pdf (U.S. Geological Survey, 1967c)
	1967	Brooklyn, NY, file name: NY_Brooklyn_123129_1967_24000_geo.pdf (U.S. Geological Survey, 1967a)

Ref.	Year	Name
	1969	Far Rockaway, NY, file name: NY_Far Rockaway_138139_1969_24000_geo.pdf (U.S. Geological Survey, 1969a)
	1969	Lynbrook, NY, file name: NY_Lynbrook_130383_1969_24000_geo.pdf (U.S. Geological Survey, 1969b)
24	1966	Historical Aerial Imagery (NETR Online, 1966)
25	1979-1981	USGS Topographic Composite
	1966-1979	Coney Island, NY, file name: NY_Coney Island_137182_1966_24000_geo.pdf edited in 1979 (U.S. Geological Survey, 1966b)
	1966-1979	Jamaica, NY, file name: NY_Jamaica_137279_1966_24000_geo.pdf edited in 1979 (U.S. Geological Survey, 1966d)
	1966-1979	Lawrence, NY, file name: NY_Lawrence_130233_1966_24000_geo.pdf edited in 1979 (U.S. Geological Survey, 1966e)
	1967-1979	Brooklyn, NY, file name: NY_Brooklyn_123131_1967_24000_geo.pdf edited in 1979 (U.S. Geological Survey, 1967b)

Ref.	Year	Name
	1966-1981	The Narrows, NY, file name: NY_The Narrows_139988_1966_24000_geo.pdf edited in 1981 (U.S. Geological Survey, 1966g)
	1967-1981	Jersey City, NJ, file name: NJ_Jersey City_254504_1967_24000_geo.pdf edited in 1981 (U.S. Geological Survey, 1967d)
26	1980	Historical Aerial Imagery (NETR Online, 1980)
27	1994-1998	USGS Topographic Composite
	1994	Jamaica, NY, file name: NY_Jamaica_137282_1994_24000_geo.pdf (U.S. Geological Survey, 1994; U.S. Geological Survey, 1995a)
	1995	Brooklyn, NY, file name: NY_Brooklyn_137132_1995_24000_geo.pdf (U.S. Geological Survey, 1995a)
	1995	Coney Island, NY, file name: NY_Coney Island_137185_1995_24000_geo.pdf (U.S. Geological Survey, 1995b)
	1998	The Narrows, NY, file name: NY_The Narrows_136951_1998_24000_geo.pdf (U.S. Geological Survey, 1998)

Ref.	Year	Name
28	1994	Orthoimagery DOQQ (1994-02-22 - 1994-06-03) (NYS Department of State, Division of Coastal Resources, 1999 (date represented 1994-1998))
29	2004	Historical Aerial Imagery (NETR Online, 2004)
30	2006	USDA Orthoimagery Composite
	2006	USDA Brooklyn (USDA-FSA, 2006a)
	2006	USDA Nassau (USDA-FSA, 2006b)
	2006	USDA Queens (USDA-FSA, 2006c)
31	2009	USDA Orthoimagery Composite
	2009	USDA Brooklyn (USDA-FSA, 2009a)
	2009	UDSA Nassau (USDA-FSA, 2009b)
	2009	USDA Queens (USDA-FSA, 2009c)
32	2013	USDA Orthoimagery Composite
	2013	USDA Brooklyn (USDA-FSA, 2013a)

Ref.	Year	Name
	2013	USDA Nassau (USDA-FSA, 2013b)
	2013	USDA Queens (USDA-FSA, 2006c)
33	2006	New York City Reconnaissance Soil Survey

Figure V.B.-3 List of Maps Used to Create Basemaps (If a map has two dates it means that revisions were made after the date of publication.)

V. APPLICATION OF METHODS

C. GIS

Using maps allows the integration of diverse information. They enable the visualization of the relationship of history-to-place by providing a spatial reference to the narrative. "Maps can provide a common ground for landscape level thinking," (Grossinger et al., 2007). Using GIS and documentation make the understanding of information more transparent and relationships easier to see. GIS is efficient in depicting transportation. Using vector data it can display right-of-way (ROW) information. Right-of-way, is an easement/thoroughfare – for transportation purposes, including roads, railways, canals, and others. In Jamaica Bay, ROW is persistent in staying the same as technology changes.

Software

Two GIS software programs and one photo editing software program were used in preparing this thesis. The first is Blue Marble Geographic's Global Mapper, version 15.2.5. The second is the GIS software program, ESRI's ArcGIS for Desktop, version 10.2.

Global Mapper software facilitates viewing, cropping, and joining raster images. There were numerous versions of USGS topographic maps for the same extent and date. With Global Mapper, comparing multiple images is a simple task. If necessary, rasters are first prepared with Global Mapper before they are imported into ArcGIS. Global Mapper is used to remove collars, crop rasters, and to join multiple rasters into a single raster file. Importing images with or without spatial data is extremely easy with Global Mapper. It can also handle very large files. Global Mapper was the "go to" software for viewing and evaluating maps.

ArcGIS was used for all other GIS processes; georeferencing (Figure V.C.-1), creating maps, digitizing features, creating feature classes, and shapefile. Using ArcGIS, basemaps were produced using digitally available maps/rasters from the previously mentioned sources and a neighborhood shapefile. Each map required some if not all of the following processes. All maps and data sets were set to the same projection and datum, WGS1984 UTM 19N. Maps with existing projections were transformed to the desired projections. Maps without spatial information were georeferenced using numerous control points. A second or third order polynomial was used transform the map. The process was repeated until a residual error of 35 or less was achieved (ESRI, 2014). Data from the USGS and the US Census was used to aid in the georeferenceing process. (Figure V.C.-1) A complete list of maps created for this thesis is at the end of this section. (Figure. V.C.-6)

TIGER/Line Files	Shapefile	U.S. Census
USGS Topographic Maps	Raster	USGS Historical Map Collection

Figure V.C.-1 Datasets Used for Georeferenceing

Some older maps without spatial information were composed of several sheets and were poorly aligned. These images were imported into Photoshop, separated, realigned, and rejoined before being imported into ArcGIS.

Shapefiles

The shapefiles that were created for this thesis are: Historical Wetlands, Contemporary Wetlands, 20ft Contours, Neighborhood Boundaries, Bays of Long Island, and Barrier Islands of Long Island. (Figure V.C.-5)

Neighborhood Boundaries*:* A digital shapefile of neighborhoods was created using a number of sources. In New York City, neighborhoods are not delineated by the government. They are often defined by those who live in the area, or by historical precedent. The names of neighborhoods are often fluid and can change over time (Schutzberg, 2008). A number of different sources were used to create this shapefile. (Figure V.C.-2)

Book	The Neighborhoods of Brooklyn	(Jackson & Manbeck, 2004)
Book	The Neighborhoods of Queens	(Copquin, 2007)
Map	New York City: A City of Neighborhoods	NYC Department of City Planning
Map	Google Maps	Google Maps
Data	New York City Community Districts, ESRI shapefile	New York City Department of City Planning
Data	NYS Counties shapefile	New York State Office of Cyber Security and Critical Infrastructure Coordination
Data	Pediacities Neighborhood shapefile	http://nyc.pediacities.com/
Data	DOITT Open Space	Department of Information Technology and Telecommunication
Data	Selected Facilities and Program Sites	NYC Department of City Planning
Data	New York City Department of Parks and Recreation Data	NYC Department of Parks and Recreation
Data	NYC_Waterfront_Parks	NYC Department of City Planning

Figure V.C.-2 Data Used to Create the Neighborhood Shapefile

Historical Wetlands Shapefile*:* Identifying historical wetlands is problematic. Mapping wetlands is a more fluid process relying more heavily on the interpretation of the cartographer than the mapping of roads and buildings. For example, instructions for mapping wetlands are not consistent from map to map, many maps do not differentiate between types of wetlands, and subtidal wetlands like tidal flats are often not included.

NOAA charts were used extensively in this thesis. They are selective and inconsistent in their portrayal of land cover. Wetlands' extents were digitized from historical maps and were also extrapolated backward. An assumption was made that wetlands that were present in a particular data set should also be present in the previous data set. This helped to mitigate some of the information missing from NOAA Charts (Gimmi et al., 2011). Data sets of historical land cover provided by the Wildlife Conservation Society were used in conjunction with historical maps to digitize historical wetlands.

Contemporary Wetlands Shapefile: The wetlands of Jamaica Bay are in constant flux through the process of erosion and efforts in restoration. A contemporary wetlands shapefile was constructed using several data sets. However, due to their dynamic condition, they can only be approximated. . (Figure V.C.-3)

data	FWS_wetlands	U.S. Fish and Wildlife Service/National Wetlands Inventory
data	USFW_Wetlands	U.S. Fish and Wildlife Service/National Wetlands Inventory
data	NYS Counties shapefile	New York State Office of Cyber Security and Critical Infrastructure Coordination
data	Shoreline_outline	GNRA
data	Gateway_Legislative_Boundary_2008	GNRA

Figure V.C.-3 Data Used to Create a Contemporary Wetlands Dataset

During the GIS processing and the creation of other shapefiles, some additional data sets were used. (Figure V.C.-4) One in particular, the Primary Land Use Tax Lot Output (also known as PLUTO) produced by the New York City Department of City Planning, was used to create a basemap. This map identified buildings by the year they were built. This information was categorized by decade and compared to historical wetlands cover. It provides an approximate visualization of the chronology of land cover change.

Data	Jamaica_sewershed	NYC Department of City Planning
Data	Jamaica_watershed	GNRA
Data	USDA NRCS Watershed Boundary dataset	http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset/
Maps	Landfill	(Walsh, 1991b; Walsh & LaFleur, 1995)
Data	PLUTO	NYC Department of City Planning Bytes of the Big Apple

Figure V.C.-4 Addition Datasets

Digitized 20 ft contours from USGS (DATE)
Neighborhoods
Historical Wetlands
Current wetlands
Bays of Long Island
Barrier Islands of Long Island

Figure V.C.-5 Shapefiles Created for This Thesis

Maps: Approximately 200 maps were created to supplement and illustrate this thesis. There are up to 34 basemaps (not every basemap is relevant for every region) for each of the 5 regions Flatbush, Flatlands, Gravesend, Jamaica and Hempstead and a set for the entire Jamaica Bay estuary. (Figure V.C.-6) As mentioned previously basemap are assigned a reference number.

Ref.	Year	Name
1		Historical Wetlands
2		Contemporary Wetlands
3		Pluto 'Year Built'
4	1811	Map of the Country Thirty Miles Round the City of New York
5	1845	New York Bay and Harbor
6	1852	Map of Kings and Part of Queens Counties, Long Island N.Y.
7	1860	Map of the City of New-York and its Environs
8	1873	Map Showing the Route & Connections of the Central Rail Road Extension Company of Long Island
9	1888	Colton's New Map of Long Island

Ref.	Year	Name
10	1891	The Narrows to Jamaica Bay-Coney Island, North to Brooklyn
11	1895	New York, Kings, Queens, Richmond, Rockland...
12	1897	USGS Topographic Composite
13	1922	Jamaica Bay and Rockaway Inlet Nautical Chart
14	1922	Jamaica Bay and Rockaway Inlet Nautical Chart
15	1923	USGS Topographic Composite
16	1924	Historical Aerial Imagery
17	1926	Jamaica Bay and Rockaway Inlet Nautical Chart
18	1933	Jamaica Bay and Rockaway Inlet Nautical Chart
19	1937	Jamaica Bay and Rockaway Inlet Nautical Chart
20	1940	Jamaica Bay and Rockaway Inlet Nautical Chart
21	1947	USGS Topographic Composite
22	1954	USGS Topographic Composite

Ref.	Year	Name
23	1954	Historical Aerial Imagery
24	1966	USGS Topographic Composite
25	1966	Historical Aerial Imagery
26	1979	USGS Topographic Composite
27	1980	Historical Aerial Imagery
28	1994	USGS Topographic Composite
29	1994	Orthoimagery DOQQ
30	2004	Historical Aerial Imagery
31	2006	USDA Orthoimagery Composite
32	2009	USDA Orthoimagery Composite
33	2013	USDA Orthoimagery Composite
34		Soil Map

Figure V.C.-6 Maps that Were Made for this Thesis

V. APPLICATION OF METHODS

D. TRIANGULATION

As mentioned previously, Grossinger et al. (2007) used a method called triangulation in there work to construct an historical ecological profile of the Santa Clara Valley of Southern California (Grossinger et al. 2007).

In geography, triangulation is the process by which the location of an unknown point is calculated through the location of two known points at a known distance apart. Triangulation is a research method that gained popularity in the social sciences. In 1959 the idea of triangulation was proposed by Campbell and Fiske as "multiple operationism", an argument that more than one method should be used in the validation process (Jick 1979). As a method, it calls for the combination of two or more aspects of research in the study of the same phenomenon (Jick 1979). The understanding is that researchers can improve the accuracy of their findings by collecting different types of data for the same study (Jick 1979). Triangulation is often used as a way to integrate qualitative and quantitative data. The goal of triangulation is to strengthen the design of the research and to assist in the interpretation of the findings (Thurmond 2001).

Basic designs of triangulations include: data sources triangulation, investigator triangulation, methodological triangulation, theoretical triangulation, and data analysis triangulation. The use of more than one triangulation method is called multiple triangulation (Thurmond 2001).

Data source triangulation examines the consistency of different data sources from within the same method. It identifies the differences in data based on time, space, and persons: when the data was collected, from where the data was collected, and from whom the data was collected (for example public versus private sources). It often results in collecting larger amounts of data from multiple sources. An example is combining qualitative records with field work or integrating interviews and surveys (Thurmond 2001).

Investigator triangulation uses multiple researchers to gather, interpret, or analyze the data to minimize bias (Cohen and Crabtree 2006).

Methodological triangulation is more commonly known as mixed methods, or multi-methods research. It looks at the consistency of findings produced by different data collection methods. It can include the use of both qualitative and quantitative studies comparing the results made by different collection methods (Cohen and Crabtree 2006; Thurmond 2001).

Theoretical Triangulation is the use of multiple theories or hypotheses (Thurmond 2001)

Data analysis triangulation uses more than one method to analyze the data, such as different statistical techniques.

There are difficulties and disadvantages to triangulations. In the most general of terms, the Robert Wood Johnson Foundation cautions users of triangulation as follows:

> "Some see triangulation as a method for corroborating findings and as a test for validity. This, however, is controversial. This assumes that a weakness in one method will be compensated for by another method, and that it is always possible to make sense between different accounts. This is unlikely. Rather than seeing triangulation as a method for validation or verification, qualitative researchers generally use this technique to ensure that an

account is rich, robust, comprehensive, and well-developed." (Cohen and Crabtree 2006)

Grossinger et al. (2007) used the triangulation method of collecting historical data from a large number of sources over a long period of time, a combination of overlapping independent data sources (Grossinger et al. 2007). Multiple types of documentation allowed the information to be cross referenced. Quantification of historical sightings of a particular landscape by type and time was used to assess the reliability of the information. The extent of a land cover type was labeled as of high, medium, or low certainty. A caveat to Grossinger's research was that the result of triangulation, such as using the number of sources as a measure of reliability did not necessarily improve map accuracy.

A simpler method of triangulation than that of Grossinger et al. (2007) is used in this research. Over 780 data resources were collected, about half of which were specifically related to the history of the Bay. This included maps, histories, encyclopedias, websites, reports, research, newspaper articles, and GIS data. Certainty and quantification were not included in the process. Basic data types were narratives from written histories, historical maps, and GIS data.

Histories were specific or general such as Miller's "Fat of the Land" a history of New York City's garbage; or Belloit's 1918 History of the Rockaways and Gotham: A History of New York to 1898". Over 150 maps from 1776 to 2014 were collected. Surprisingly it was easier to find maps from before the 1960s. A possible reason for this is that historical map collections are focusing on older maps. Maps from the more recent past are not of as much interest. Looking at the collection of maps included in this research, we see relatively larger gaps between subsequent maps from 1960 and 2000. Newspaper archives were searched, as instances that appeared to be of significant importance were identified in the historical literature. GIS databases of the historical wetlands extent from the Wildlife Conservation Society and the National Wetlands Inventory, were compared with historical maps and Walsh's study on historical landfills of New York City. PLUTO's 'Year Built' data was categorized by decade to visualize a progression of land cover change.

The summation of all of this is a brief review of the historical events of land use/land cover change in the historical Jamaica Bay estuary, the identification of the agents of change, and a perspective on the potential drivers of land use/land cover change.

VI. HISTORICAL ANALYSIS

(see Appendix A for a complete set of Jamaica Bay Estuary Basemaps)

There were two over-arching and conflicting concepts for the future of Jamaica Bay that existed side by side until the late 1930s. Broadly speaking, they can be identified as *natural* versus *industrial*.

The wetlands surrounding the Bay disappeared to development. However, a decision regarding a significant portion of the Bay was reached in 1954, when the Parks Department and the New York State Department of Conservation made an agreement that the area would be established as the Jamaica Bay Wildlife Refuge (Jamaica Bay Environmental Study Group and Environmental Studies Board 1971). "Natural" won out, eventually evolving into the Gateway National Recreation Area. An understanding of the influences and options that existed in the past will help to identify and understand the decisions the land managers made at that time (Konvitz 1989). It is through these two frameworks that decisions regarding land cover change due to the change of the perceived value of the all-encompassing Jamaica Bay area can be understood.

VI. HISTORICAL ANALYSIS

A. JAMAICA BAY PARK

(see Appendix A for a complete set of Jamaica Bay Estuary Basemaps)

Native Americans and early colonists had a reciprocal relationship with the Bay and their actions had little effect on the terrain (Black 1981). Things changed over the years when the Bay was no longer seen as a source of food and fodder but instead as a wasteland. This began to change once again as the urban centers in Manhattan and northern Brooklyn became more and more populated. The rapid growth of these two cities and their lack of municipal services for the disposal of garbage and sewage created urban environments filled with filth, disease, and noxious odors (Miller 2000). It was in the shadow of this situation that, in the 1830s, the shores of the Bay started gaining popularity as places of refuge and respite from the city (Black 1981).

In 1930, Robert Moses presented his plans for creating a park that would encompass Jamaica Bay, the parkways, and the bridges that would connect them with the other parks in and around New York City (Black 1981). In 1938, Sanitation Commissioner William F. Carey proposed locating a city dump and incinerator in Jamaica Bay. The ash and garbage dumps would be used to landfill the North and South Islands of the Jamaica Bay Harbor plan (Kroessler 1989). In response, Moses published "The Future of Jamaica Bay" which outlined his plans for Jamaica Bay Park (Kroessler 1989; Anonymous1910b). In that same year, 1938, Mayor Fiorello LaGuardia placed most of Jamaica Bay under the Parks Department's jurisdiction, ending the debate between *natural* vs. *industrial* (NYC

Department of Parks & Recreation 2015b; U.S. Department of the Interior and U.S. Geological Survey 2015).

The following is a partial list of New York City parks in Jamaica Bay. (Figure VI.A.-1) It highlights the holdings on or before 1938 that were assigned to the Parks Department in 1938:

Park Name	**Acres**	**Acquisition History**
Barren Island		**1938 Jurisdiction of most of Barren Island awarded to the Parks Department (Black 1981)** 1942 Federal Government purchased remaining 51 acres (Black 1981)
Bayswater Park	40	**1931 City purchased 15.4 acres** 1960 Second parcel was added
Beach Channel Park	12	**1912 First parcel acquired through dispute** **1913 Second parcel acquired from another city agency** **1930 Third parcel acquired through condemnation**
Beach Channel West	1	**1938 Title was vested to the City of New York**
Brant Point Wildlife Sanctuary	20	1980 First parcel established as a protected area 1992 Second parcel acquired from another city agency 1990 Third parcel acquired by condemnation
Brookville Park	90	

Canarsie Park	132	**1895 City of Brooklyn purchased land for Canarsie Park** **1934 Second parcel acquired from another city agency** 1949Third parcel acquired from another city agency 1950 Fourth parcel acquired from another city agency 1958 Fifth parcel added 1974 Land south of Shore Road transferred to Nat'l Park
Coney Island Beach & Boardwalk	399	**1921 City secured property along the beachfront** **1938 Jurisdiction awarded to the Parks Department**
Four Sparrow Marsh	64	1994 Acquired from another city agency.
Fresh Creek Nature Preserve	77	
Hook Creek Park & Hook Creek Wildlife Sanctuary	111	
Idlewild Park	181	1956 First parcel assigned by an agreement with the Port Authority 1958 Second parcel acquired from another city agency 1964 Third parcel acquired through purchase of private property total acreage was 224 acres 1965 Parks department ceded 66.1 acres to Port Authority
Jamaica Bay Park	150	**1938 Parks Department took jurisdiction of 151.8 acres** 1951 Established as the Jamaica Bay Wildlife refuge 1974 Transferred 9,000 acres to National Parks 1993 Acquired an additional 2 acres

Joseph T. Mcguire Park	77	
Leif Ericson Park	17	**1925 Parcel acquired by the city**
Marine Park	798	**1917 Private donation of 150 acres** **1937s Landfill and purchases increased the park's area to 1822 acres** 1974 Transferred 1024 acres to the National Parks
Paerdegat Basin Park	119	1998 Acquired from another city agency
Rockaway Beach & Boardwalk		**1938 Parks Department took jurisdiction**
Rockaway Community Park (Edgemere Park)	255	1948 Assignment of city land 1955 Purchase of privately owned land
Rockaway Freeway Parks	9	1950 Purchased from the Long Island Railroad intermittent parcels of land along the original Long Island Railroad route
Seagirt Avenue Wetlands	5	1995 Assigned from another city agency
Spring Creek Park Addition	58	

Spring Creek Park	54	**1938 Parcel acquired by condemnation** 1992 Parcel assigned from another city agency 1994 & 1995 Two additional parcels added
Vernam Barbadoes Preserve (Terrapeninsula Preserve)	27	1996 to 1999 Acquired from another city agency in three parcels

Figure VI.A.-1 In 1938 The New York City Corporation gives jurisdiction of 9,151.8 acres including: Coney Island's beaches and boardwalks, Rockaway in Queens and South Beach on Staten Island to the Parks Department. The parcels in bold are the properties that were transferred to the Parks Department (NYC Department of Parks & Recreation 2015a). The above information is from the New York City Parks Department website unless otherwise indicated. (NYC Department of Parks & Recreation 2015a)

Concurrently, Robert Moses was interested in developing Coney Island and the Rockaways in the image of Jones Beach. Robert Moses gained power through his ability to promote and finance massive public works from the federally funded New Deal. The Great Depression public works programs gave $44 million dollars of federal loans and grants to New York City in 1933. This money was used for, among other things, LaGuardia Airport, the Rockaway Beach Improvement, Jacob Riis Park, and the Marine Parkway Bridge. The master plan of the Rockaway Improvement Commission called for connecting the Rockaways with the Shore Parkway. This gave Robert Moses the funds for the reconstruction of the Cross Bay Boulevard, the construction of the Marine Parkway Bridge and the development of Rockaway Park, and Jacob Riis Park (Kroessler 1989). (Figure VI.A.-2)

Figure VI.A.-2 Parks and Roads Built by Robert Moses (Caro 1974)

VI. HISTORICAL ANALYSIS

B. JAMAICA BAY HARBOR

(see Appendix A for a complete set of Jamaica Bay Estuary Basemaps)

Early industrial activity in Jamaica Bay took place on Mill Island and Barren Island. In 1878 the official recognition of a plan to convert Jamaica Bay into an international harbor took place with a petition presented by the Secretary of War and the City of New York (NYC Department of Parks & Recreation 2015b). The industrial plan was further spearheaded by the New York State Department of Docks which had jurisdiction over Jamaica Bay from 1897-1936 (Black 1981). In 1906 The Jamaica Bay Improvement Commission was established by New York State, whose main assignment was to study the prospect for the development of an international harbor in Jamaica Bay (Jamaica Bay Improvement Commission 1907). While the plan never came to fruition, some parts of the project were completed and the project had an impact that existed beyond its demise and which still affect the Bay today. (Figure VI.B.-1) (Figure VI.B.-2)

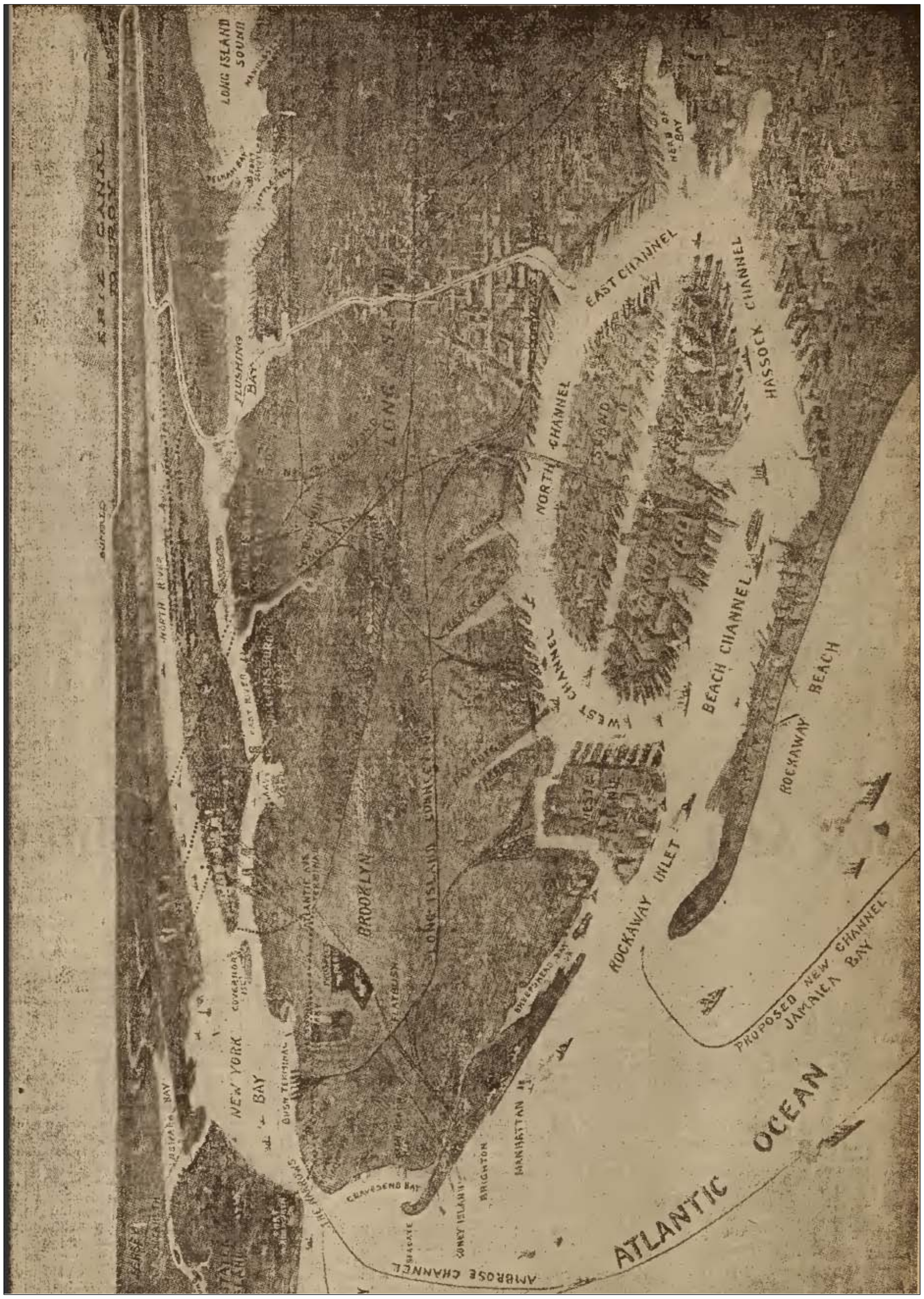


Figure VI.B.-1 Proposed Jamaica Bay Harbor (Anonymous1910b) pg 17 (Note the canal running between Long Island Sound and Jamaica Bay)

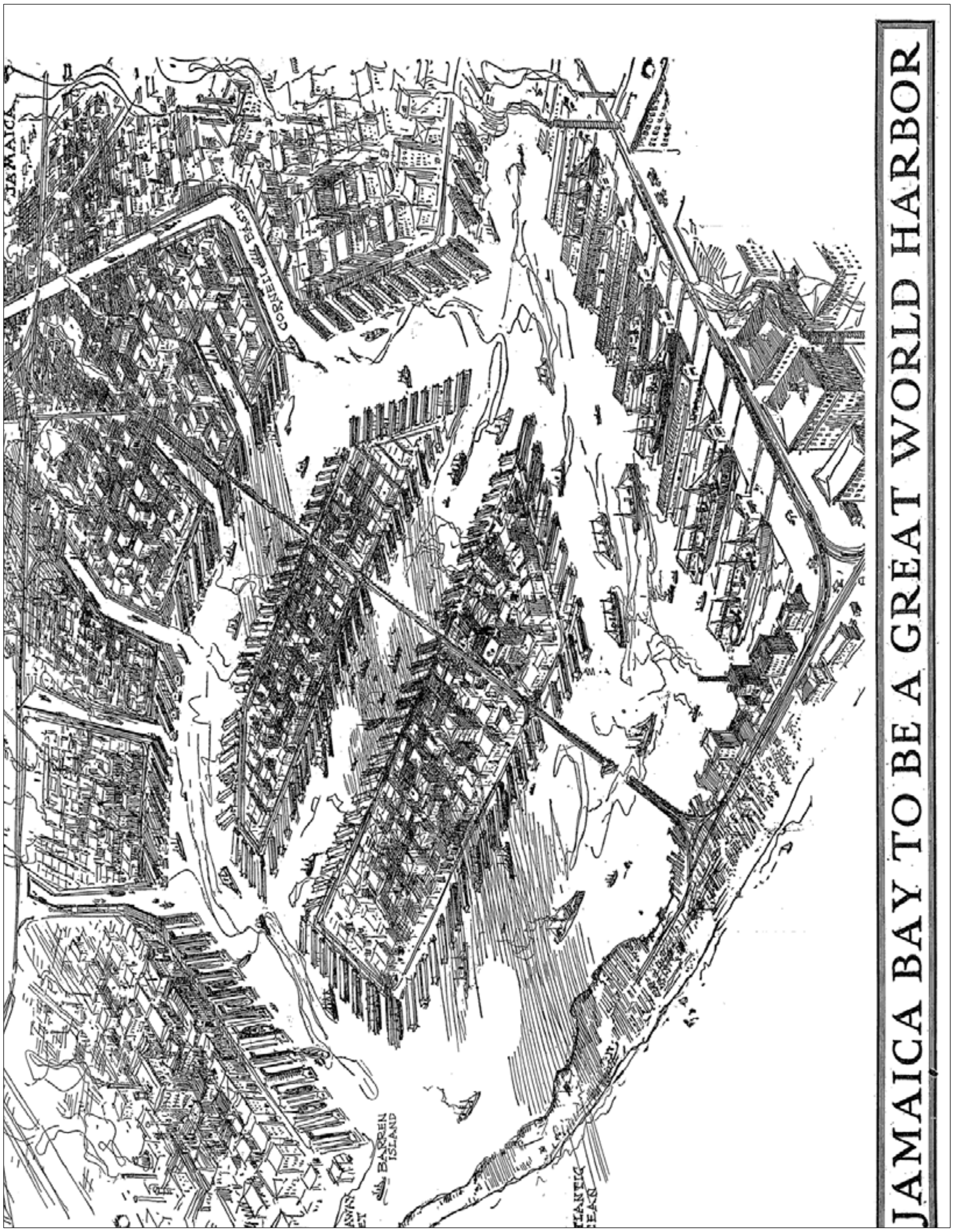


Figure VI.B.-2 Proposed Jamaica Bay Harbor (Anonymous1910c)

Barren Island (Figure VI.B.-3)

One of the largest islands in Jamaica Bay, Barren Island, included thirty acres of upland and was accessible overland during low tide. It also had shallow water access to the north shore and deeper water access to the south, making it one of the few deepwater access locations within the Bay (Black 1981; Cody, Auwaerter, and Curry 2009). This gave Barren Island an attractiveness that was unique in the Bay, and as early as the 1740s the island's deepwater access enabled it to be sourced for sand destined for Manhattan by boat (Black 1981)

In the 1830s, New York was considered to be the filthiest city in the United States. Piles of manure, mud and garbage filled the streets. As the city grew, noxious industries, including slaughterhouses, tanneries dyers, distillers, glue works, bone boilers, and stables that were originally established outside the city, were now within it. Pigs roamed the streets to help remove some of the garbage but they became a nuisance (Burrows and Wallace 1998).

The sanitary problems of Manhattan had a significant effect on Barren Island. In 1848 a cholera outbreak in New York resulted in 5,000 deaths (Miller 2000). Sanitation reform soon followed with the beginning of a sewer system and the ousting of 26,000 hogs from the streets of the city. In 1851, the city banished the bone boiling works and the renderers from the southern half of Manhattan (Miller 2000; Burrows and Wallace 1998). Subsequent legislations removed these factories from the rest of Manhattan (Anonymous1859a; Anonymous1859b; Anonymous1957). As a result, some of the bone boiling factories were relocated to Barren Island (Black 1981). (Figure VI.B.-4)

The year 1881 saw the founding of the Department of Street Cleaning in Manhattan. At that time much of the city's refuse was dumped in the ocean. The 1888 Marine Protection Act forbade ocean dumping, so the city turned Rikers Island into a city dump. Increasing the size of the island fourfold, it rose to an elevation of 140 feet. In 1895, George Waring was made commissioner of the Street Cleaning Department. For the first time, trash collecting and street cleaning were performed regularly. The city looked at various forms of trash management including incineration, reduction, and burning at sea. The New York Sanitary Utilization Company won the city contract and built the world's largest reduction plant on Barren Island (Miller 2000; Olen 2015; Schneider 1999). The growing industry and the development of a residential community to serve it saw the population of Barren Island reach a high of 1500 by 1910 (Cody, Auwaerter, and Curry 2009).

From 1897 to 1935, the Department of Docks had jurisdiction over Jamaica Bay. They promoted industrial development in the area (Black 1981). The initial plan called for extending Flatbush Avenue to the Bay, connecting Barren Island to the rest of Brooklyn, dredging the Rockaway Inlet and the channels to Mill Basin and Canarsie, and converting Mill Island into an industrial site (Black 1981). (Figure VI.B.-5

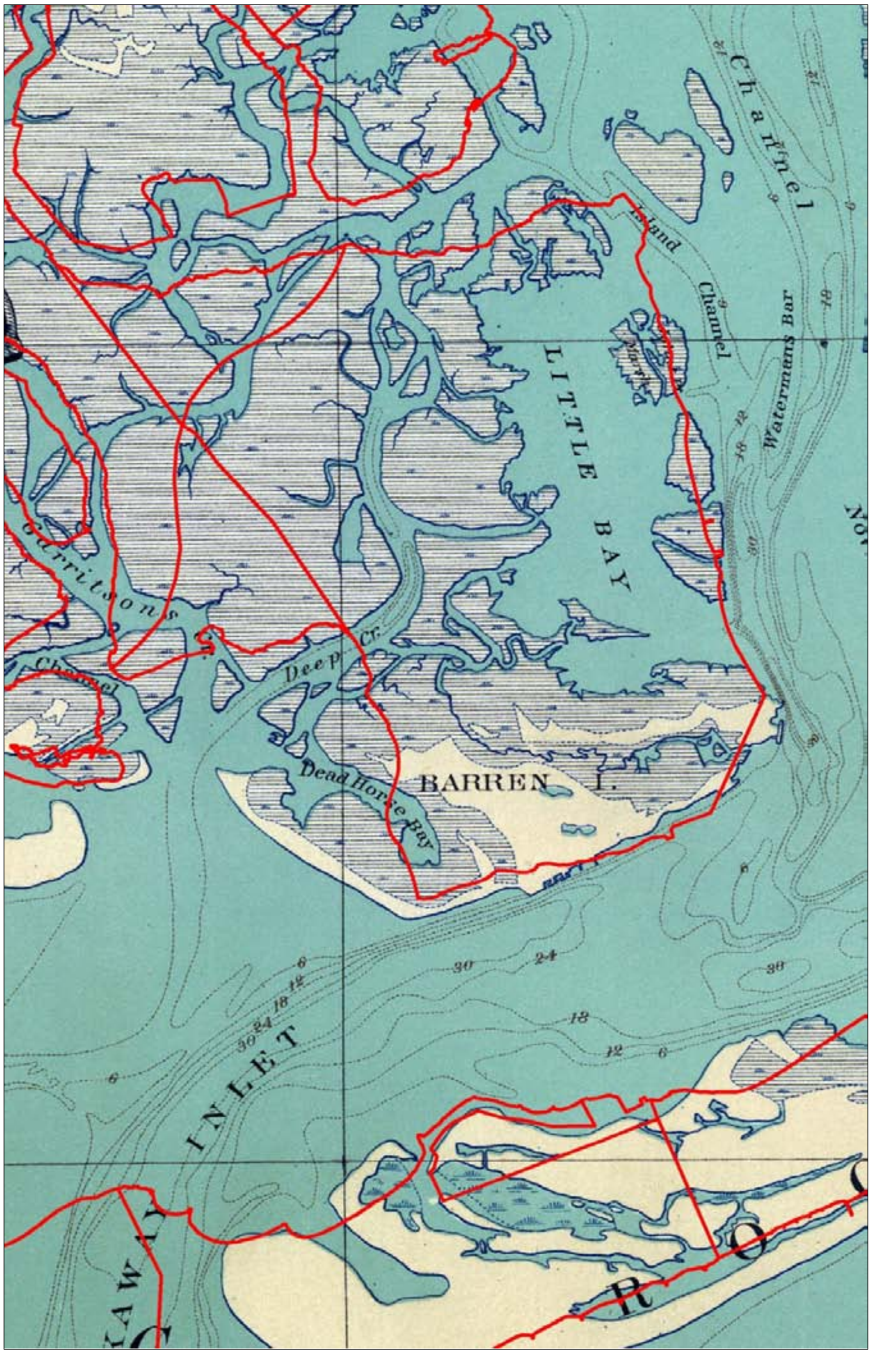


Figure VI.B.-3 Barren Island

(David Rumsey Historical Map Collection 1891)

NAME	ACTIVITY	DATE
Cornell East	Fertilizer	1859
West Factory	Fertilizer	1859-60
Smith & Company	Menhaden	1868-71
Steinfield & Company	Unknown	1869-73
Simpson	Unknown	1869
Goodkind Brothers	Menhaden	1872-77
Swift & White	Fertilizer	1870-81
Hawkins Brothers	Menhaden	1872-88
Jones & Company	Menhaden	1872-81
Valentine Koon	Menhaden	1872-74
Barren Island Manufacturing	Fertilizer	1875-88
Thomas A. Shae	Fertilizer	1875-81
E. F. Coe	Fertilizer	1878-95
Read & Company	Unknown	1879-83
Menhaden Company	Menhaden	1881-?
Barren Island Bone	Fertilizer	1884-93
P. White & Sons	Fertilizer	1884-?
Robinson	Unknown	1886-87
Barren Island Fertilizer & Oil	Fertilizer	1890-95
Andrew Wessel	Unknown	1895
Wimpfeimer	Fertilizer	?-1890
R. Recknagle	Unknown	unknown
Louis C. DeHomage	Unknown	unknown
Barren Island Oil and Bone	Fertilizer	1889-?
NY Sanitary Utilization Co.	Disposal	1905-19
Products Manufacturing	Disposal	?-1934
Vaniderstine & Sons	Hides	1910
Cove Chemical	Unknown	1911

Figure VI.B.-4 Companies Located on Barren Island from 1859 to 1934

(West-Valle, Decker, and Swanson 1992; Black 1981)

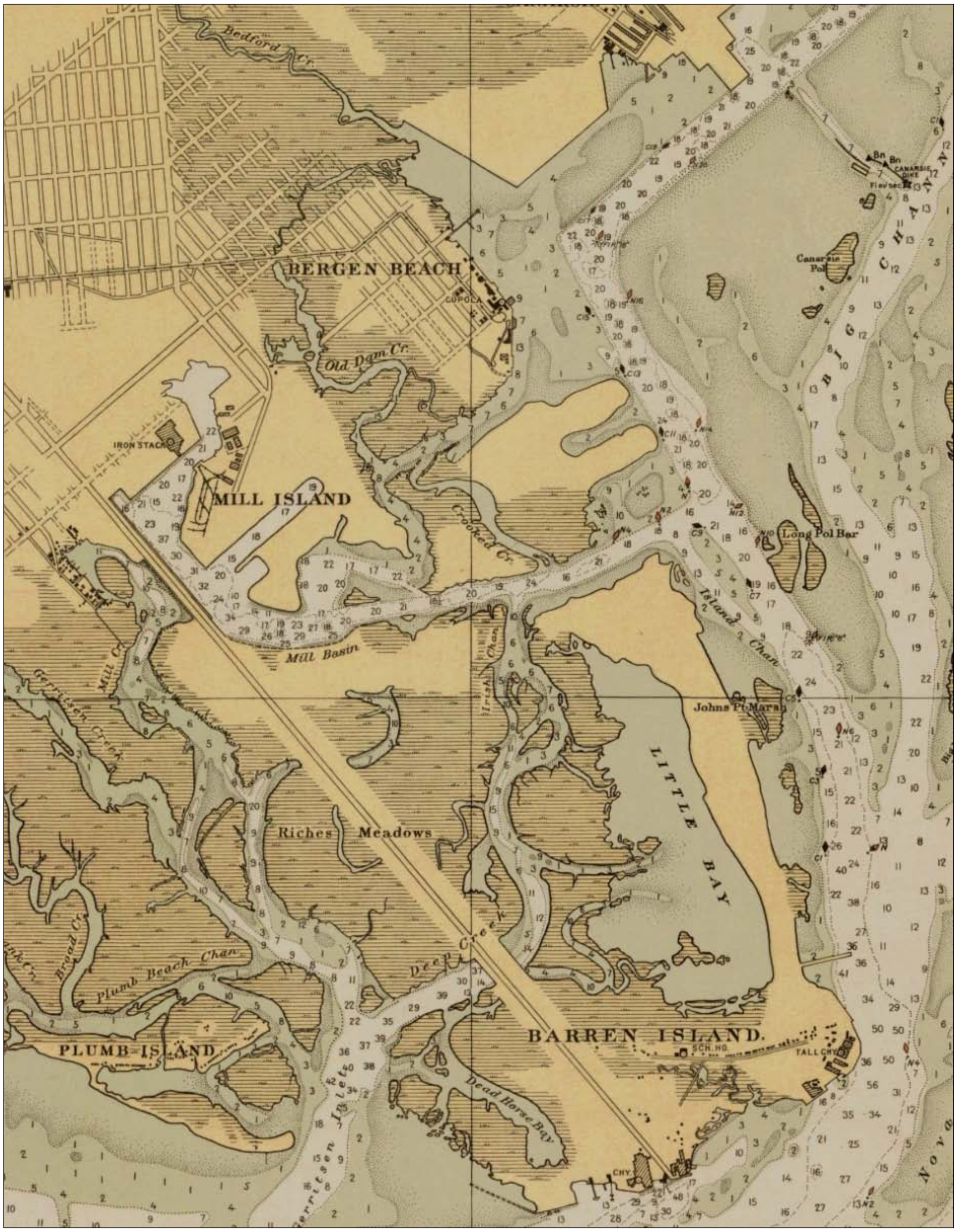


Figure VI.B.-5 Barren Island: Completed Flatbush Avenue Extension, Mill Island, and the Area North of Barren Island Land Filled (U.S. Coast and Geodetic Survey 1926)

Surprisingly, the completion of Flatbush Avenue did not result in the further industrial development of Barren Island. Industry on the Island, as well as the population, began to decline as a result of changes in "regional development, political opposition to waste processing within the city, changes in transportation, and continued planning for redevelopment of Jamaica Bay" (Cody, Auwaerter, and Curry 2009). The odors from the factories on Barren Island became a nuisance to the developing communities in the Rockaways and the other surrounding areas. The city and state tried to close the factories in 1899 but failed. In the decade that followed the city often closed the factories in the summer, only having to later reopen them. Eventually, the industries on Barren Island started to close. The schools of fish used for making fertilizer dried up, the number of horses used in the city drastically declined, and in 1919 the city started redirecting some of its trash to other waste disposal sites. By 1930 the population was reduced 400 people. When the Parks Department first took jurisdiction of Barren Island in 1938, most of the residents were evicted. In 1942 the Federal Government took title to the last remaining tract of land, forcing the last of the residents to leave the island (Black 1981).

Canals

Over the years, proposals to commercially develop Jamaica Bay demanded significant changes to its topography. Recommendations included plans for dredging channels, filling marshland, and digging canals (Anonymous 1877). While none of the canals were ever completed, their proposals still had an influence on the development of the Bay. The success of the Bay as a seaport was seen as dependent on its having access to the rest of New York Harbor and the freight traffic from the Erie Canal (Whitford 1922).

As early as 1810 a proposal was made to the New York Legislature for the Erie Canal to be built from the Hudson River to the Great Lakes. The success of the Erie Canal, completed in 1825, spurred interest in building additional canals. While the initial expectation was that the Erie Canal would improve the economy of New York State, the canal was more successful than anticipated. It was a boon not only to the New York State economy but to the national economy as well. The Canal, its continued modifications, and the establishment of railroad-canal routes was responsible for stimulating the agricultural growth of all the states bordering the Great Lakes by allowing agricultural production to reach much larger markets (Whitford 1922).

Proposals for canals abounded upon the successful completion of the Erie Canal. Within 14 years a total of 10 additional canals were authorized within the state of New York (Whitford and Beal 1906). Plans for the various waterways and the port at Jamaica Bay were often talked of collectively (Whitford and Beal 1906; Whitford 1922).

The success of the Erie Canal and the other canals along the eastern seaboard led to the idea of an Atlantic intra-coastal waterway and the establishment of the Atlantic Deeper Waterways Association in 1907. The Association's goal was to connect the bays and sounds along the eastern seaboard to provide a protected waterway from Florida to Boston (Schoff 1914; Atlantic Deeper Waterways Association 1915). As part of the overall plan, many proposals were made for canals running east/ west from Gravesend Bay to the Peconic Bay, and north/ south from Jamaica Bay to Flushing Bay.

Gravesend Bay to the Peconic Bay Canals (Figure VI.B.-6)

Proposals for canals running east/west along the south shore of Long Island were of interest to private enterprise as well as city, state, and federal agencies. Proponents of the canals spoke of savings in freight costs and the economic development of the communities along the route. In 1826, Holmes Hutchinson, who became chief engineer of the Erie Canal from 1835 to 1841, proposed a waterway from Gravesend Bay to Peconic Bay (Whitford 1922). It would open 250 miles of ocean front real estate for both residential and agricultural development that was spurred on by greater market access. It was also suggested that in time of war the canals would provide protection and harbor for U.S. fleets.

With the proposal to make Jamaica Bay into a seaport, the Gravesend Bay/Jamaica Bay canal grew in importance. It was thought that if the port in Jamaica Bay ever come to fruition, the canal would be a necessity. There would be the need for unimpeded access for freight between the various components of the New York Harbor, the Barge Canal, and the proposed Jamaica Bay Port. The existing land and rail access were limited and the external passage around Coney Island was not always safe. Therefore, an internal waterway was considered to be the best option (Whitford 1922). The value of this canal was dependent on the establishment of the Jamaica Bay Harbor, without which the cost of the construction would be excessive (Whitford 1922).

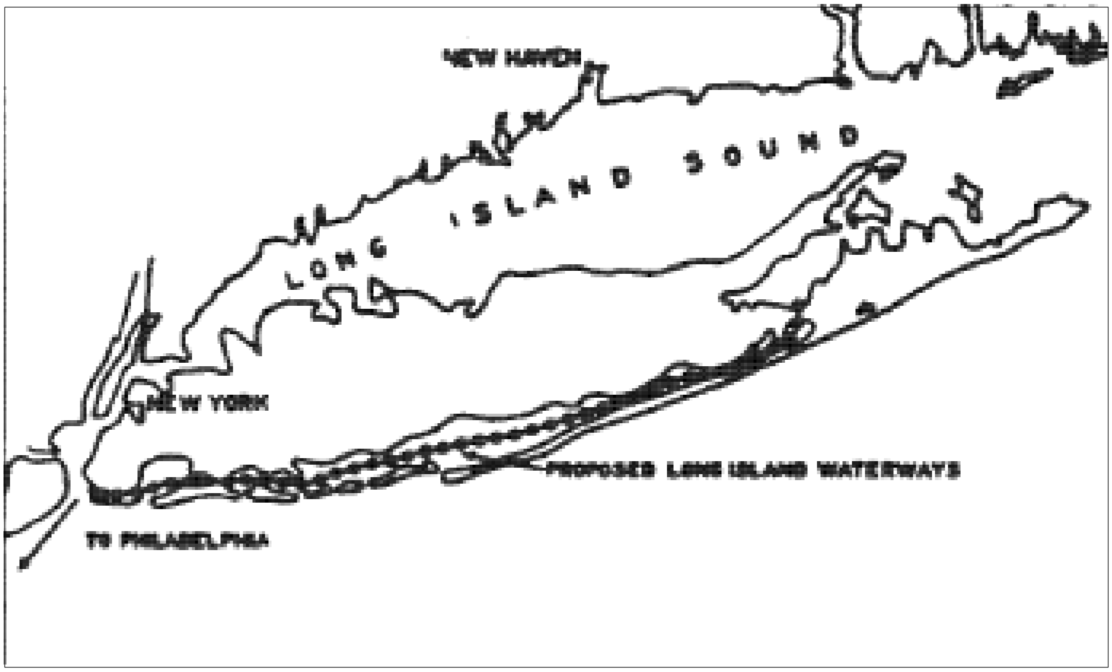


Figure VI.B.-6 Proposed Long Island Waterway from Gravesend Bay to the Great South Bay (Schoff 1914; Whitford and Beal 1906)

Jamaica Bay/Flushing Bay Canal and the Newtown Creek/Flushing Bay Canal

There were also two proposed canals that would run north/south on Long Island connecting Jamaica Bay with Long Island Sound. They included the Jamaica Bay/Flushing Bay Canal and the Newtown Creek/Flushing Bay Canal. The Newtown Creek/Flushing Bay Canal would connect Newtown Creek with the Jamaica Bay/Flushing Bay Canal. The disadvantages of these two canals were (1) they were not connected to the state canal system, and, (2) they were saltwater canals and needed to include locks to accommodate the differing tides at each end (Whitford 1922).

These canals were of interest only to New York State and not the Federal government. Proposals for a survey of the canals were set before the New York State legislature in 1909, 1910, 1911 and 1912 and were finally approved in the Law of 1913. Legislation for the construction of the Jamaica Bay/Flushing Bay Canal was presented to the State legislature twice, once in 1914 and then again in 1920, but it failed to pass both times (Whitford 1922).

The Newtown Creek/Flushing Bay Canal proponents cited the following points in favor of the canal: it would increase wharfage, promote commercial development, would be an aid in sewage disposal, and it would provide a bypass of the difficult Hells Gate/East River junction. The engineers' report from the law of 1913 estimated that the cost of the Jamaica Bay/Flushing Bay Canal would be $20,000,000 and the Newtown Creek/Flushing Bay Canal $6,000,000. He did not recommend building the canals, saying that the cost was excessive for the benefits they provided (Whitford 1922).

Jamaica Bay Improvement Plan

The argument for the development of the Jamaica Bay harbor was outlined in a 1913 article written by Henry Meyer, President of the Jamaica Bay Improvement Association.

> "There are nine reasons why Jamaica Bay should be improved:
> First. Jamaica Bay is the ideal location for an ocean terminal, offering, as it does, a safe harbor with a good inlet and outlet to the ocean.
> Second. Jamaica Bay will amply provide railroad facilities for railroads to all parts of our country.
> Third. Jamaica Bay will enable shippers and manufacturers to obtain transportation at the lowest possible cost.

Fourth. Jamaica Bay would enable the State of New York to regain the commerce which rightly belongs to it. Ocean liners and canal barges would be brought in direct contact, thus saving great cost of loading and unloading.

Fifth. Jamaica Bay will furnish 163 miles of additional dockage to New York City's dock system, which is more than all the combined shore, line of all the boroughs of the City of New York.

Sixth. Jamaica Bay offers exceptional opportunities for warehouses and factories.

Seventh. Jamaica Bay can be connected at comparatively small cost with the Harlem River by a waterway to Flushing Bay, and with the Hudson River by the proposed Coney Island canal.

Eighth. Jamaica Bay stands out as a central location for a seaboard terminal for railroads. This is evident from the terminal planned by the Pennsylvania Railroad and Harriman railroads.

Ninth. Jamaica Bay will bring together water and railroad transportation at a central location that will accommodate them all.

Without question, the Improved Jamaica Bay forever spells the destiny of the City of New York as being the greatest metropolis on earth. Because, of natural location, the Jamaica Bay will be a new door to the nation, which will have such an effect on the growth of the surrounding country as to increase its population a hundred fold." (Meyer 1910)

Federal interest in the plan was noted in an article in the New York Times with mention of a 1910 Rivers and Harbors Appropriation Bill presented to the House. It would authorize the government to spend up to $7,000,000 toward the construction of the harbor conditional upon the city spending $1,000,000 (Anonymous1910a). That same year the Jamaica Bay Improvement Commission was created to explore the development of a Jamaica Bay International Harbor (Cody, Auwaerter, and Curry 2009).

The 1910 report from the New York City Department of Docks' commission contained both a majority and minority report. Both reports recommended the building of the harbor with New York State and the Federal government as willing participants in the project. The report recommended the creation of bulkheads and channels along the northern and western shores of the Bay. (Figure VI.B.-7)

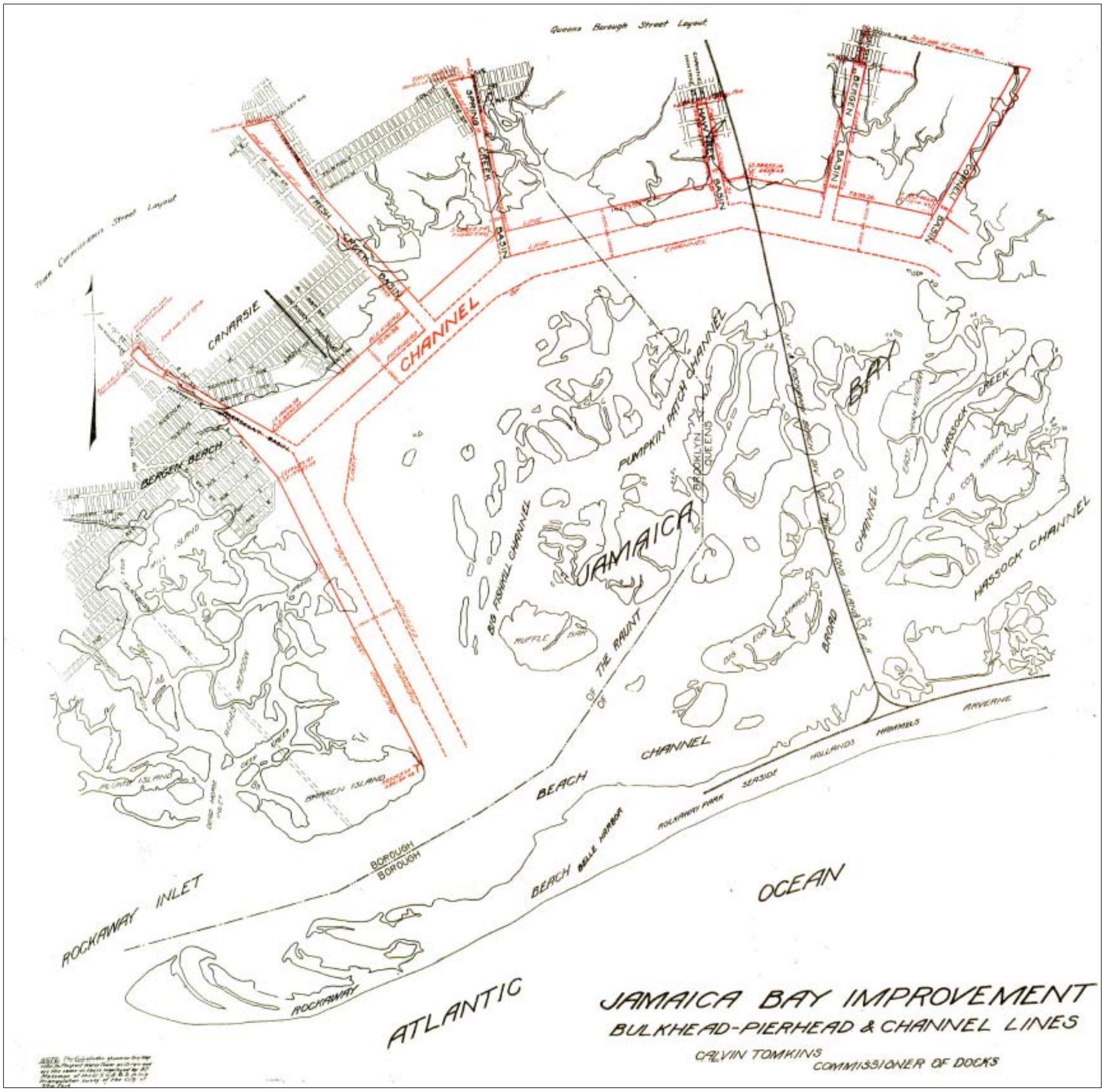


Figure VI.B.-7 Recommendations for Bulkheads, Pierheads, and Channel Lines

(Tomkins 1910)

The state-appointed Barge Canal Terminal Commission was exploring several sites for a terminal in New York City. The locations being considered were Newtown Creek, Wallabout Bay, Gowanas Bay, Staten Island, the Bronx, and Jamaica Bay. The total area being considered for the Jamaica Bay terminal was 45½ square miles. This includes all the lands in and around Jamaica Bay that were covered by water at high high tide. One of the concerns about locating the terminal in Jamaica Bay was the exposure of cargo to foul weather as it rounded Coney Island. The Terminal Commission's report recommended the Flushing Bay/Jamaica Bay Canal since it would provide an inland waterway using the Harlem River and avoiding the trip around Coney Island. The cooperation and responsibilities of the city, state, and federal government were clearly outlined. The plan called for New York City to construct the bulkheads on the shore of the Bay and along an island in the middle of the Bay. The federal government would dredge the Rockaway Inlet and maintain it yearly with an initial coast of approximately $7,000,000. The state would yield title to all of its land and land under water holdings to the city. The commitment of the federal and state governments was dependent on the city allotting $1,000,000 to the project (New York (State) Barge Canal Terminal Commission 1911).

According to the 1919 Port of New York Annual report, little progress had been made on the harbor project (Smith 1919). Private companies, such as Howard Estates, began modifications of their properties in accordance with the Department of Docks' proposal (Anonymous1912; Anonymous1915). Private interests, with the help of the City dredged the Mill Basin channel in 1917. Business had already started to locate to Mill Basin (Stickle 1917; Cody, Auwaerter, and Curry 2009). (Figure VI.B.-8)

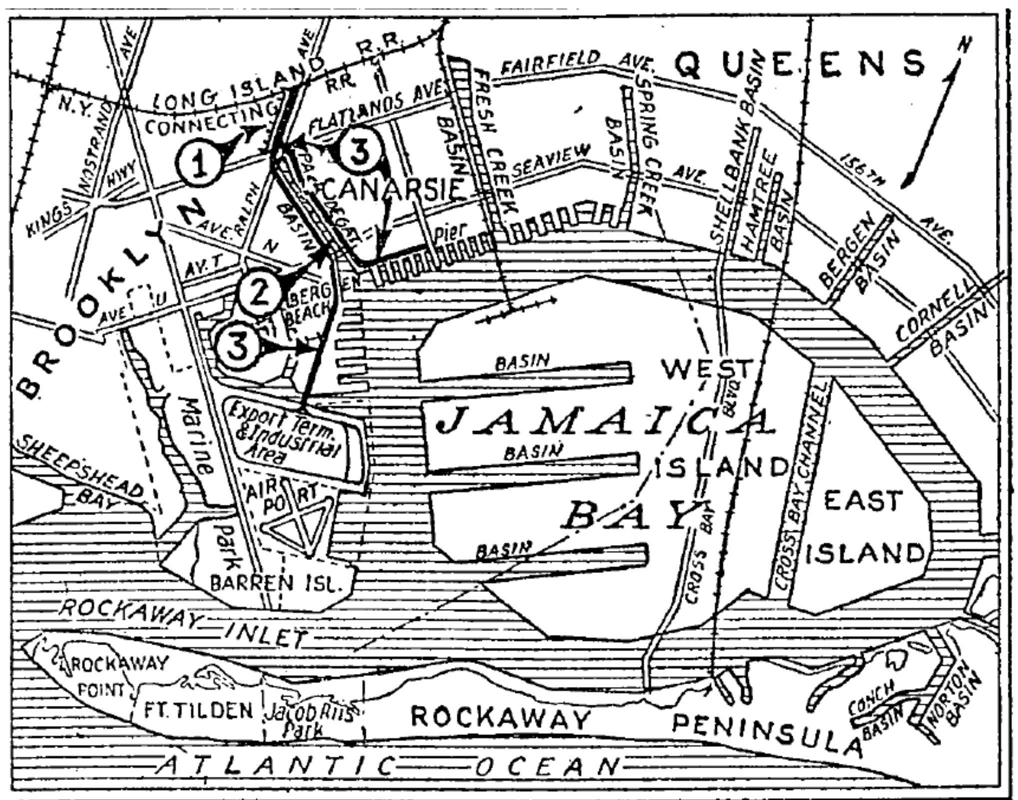
In 1921, authorization was made by the Department of Docks to build six 1000-by-200-foot piers between Mill Basin and Barren Island. Only one was built and it was used for land filling the area north of Barren Island with the dredged materials (Anonymous1921a).

The inadequacy of the existing New York Harbor spurred the promotion of the harbor project. The port was run by private enterprise which charged high rates. Railroads were in competition with maritime transit and charged high rates to transport cargo to and from the ports. This provided additional support for the idea of canal access to the Jamaica Bay Harbor. The railroads had control of a significant amount of waterfront property for which they refused the building of wharfage. Waterfront property in Manhattan was limited and prohibited further expansion of terminals and docking facilities (Jamaica Bay Improvement Commission 1907; Whitford 1922). There was no cooperation between the harbors of New York and New Jersey. New York became concerned over the loss of commerce to New Jersey (Jamaica Bay Improvement Commission 1907; Whitford 1922).

The realization of this threat began in 1914 as New Jersey began the development of the municipal Port of Newark and later on, in 1927, Newark Airport. This also reduced the pressure that was pushing the Jamaica Bay proposal.

In 1926 a contract for a commercial pier to be built in Canarsie was issued by the Department of Docks. Canarsie was selected because it was already commercially successful and a channel to Canarsie had already been dredged (Wrenn 1975).

The Great Depression had begun in 1929, making money for the Jamaica Bay project scarce. What monies were available were funneled into Floyd Bennett Field. What appears to be the last push for the Jamaica Bay Harbor was an article written in the New York Times in 1930. (Figure VI.B.-8) The plans had, over the years, gone through a number of modifications. The illustration in the New York Times identifies additional manmade features that had been completed, including Floyd Bennett Field and basins along the northern shore of the Rockaway Peninsula. (Anonymous1930). It was at this point that Robert Moses first presented his plan for his version of Jamaica Bay, which was settled in his favor in 1938.



MAP SHOWING JAMAICA BAY PROJECT.

Figure 1 indicates the line of the proposed spur track from the Long Island Railroad connecting its present line with the head of Paerdegat Basin. Figure 2 shows Paerdegat Basin which is to be dredged to provide a deeper channel into Jamaica Bay. Figure 3 shows the proposed branch of the Long Island Railroad connecting the east and west sides of the bay, the route of which has been approved by the Board of Estimate.

Figure VI.B.-8 A 1930 Proposal for Jamaica Bay Harbor

(Anonymous1930).

VI. HISTORICAL ANALYSIS

C. FLATBUSH

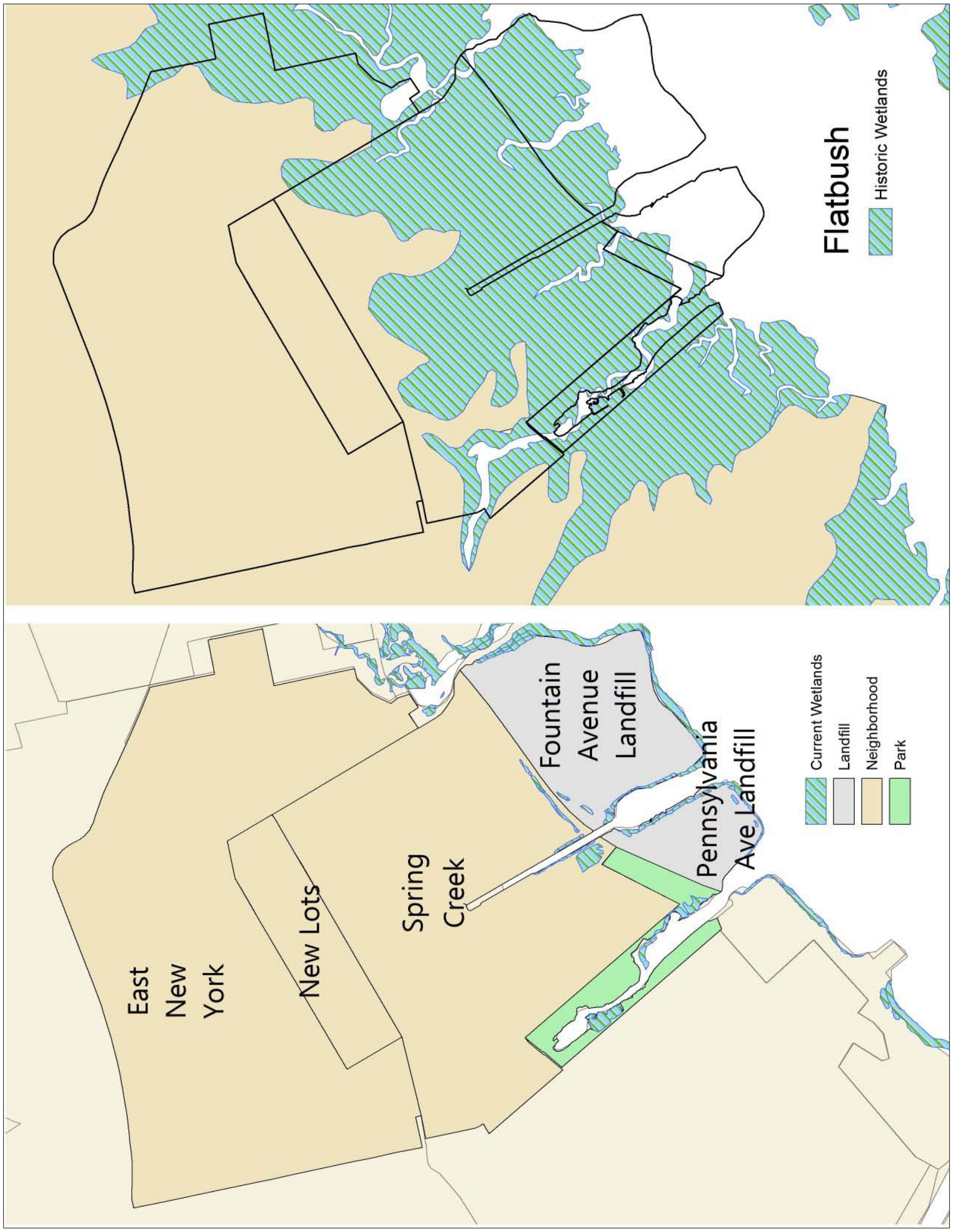
(see Appendix C for a complete set of Flatbush Basemaps)

Flatbush Boundaries:

- North: Atlantic Avenue (Cypress Hills)
- South: Jamaica Bay
- East: Conduit Avenue (Queens)
- West: Van Sinderen Avenue, Fresh Creek (Canarsie) (Jackson, Manbeck, and Citizens Committee for New York City 2004)

Flatbush Neighborhoods: (VI.C.-1 Flatbush)

- Spring Creek
- Fountain Avenue and Pennsylvania Avenue Landfills



VI.C.-1 Flatbush: Contemporary and Historical Wetlands

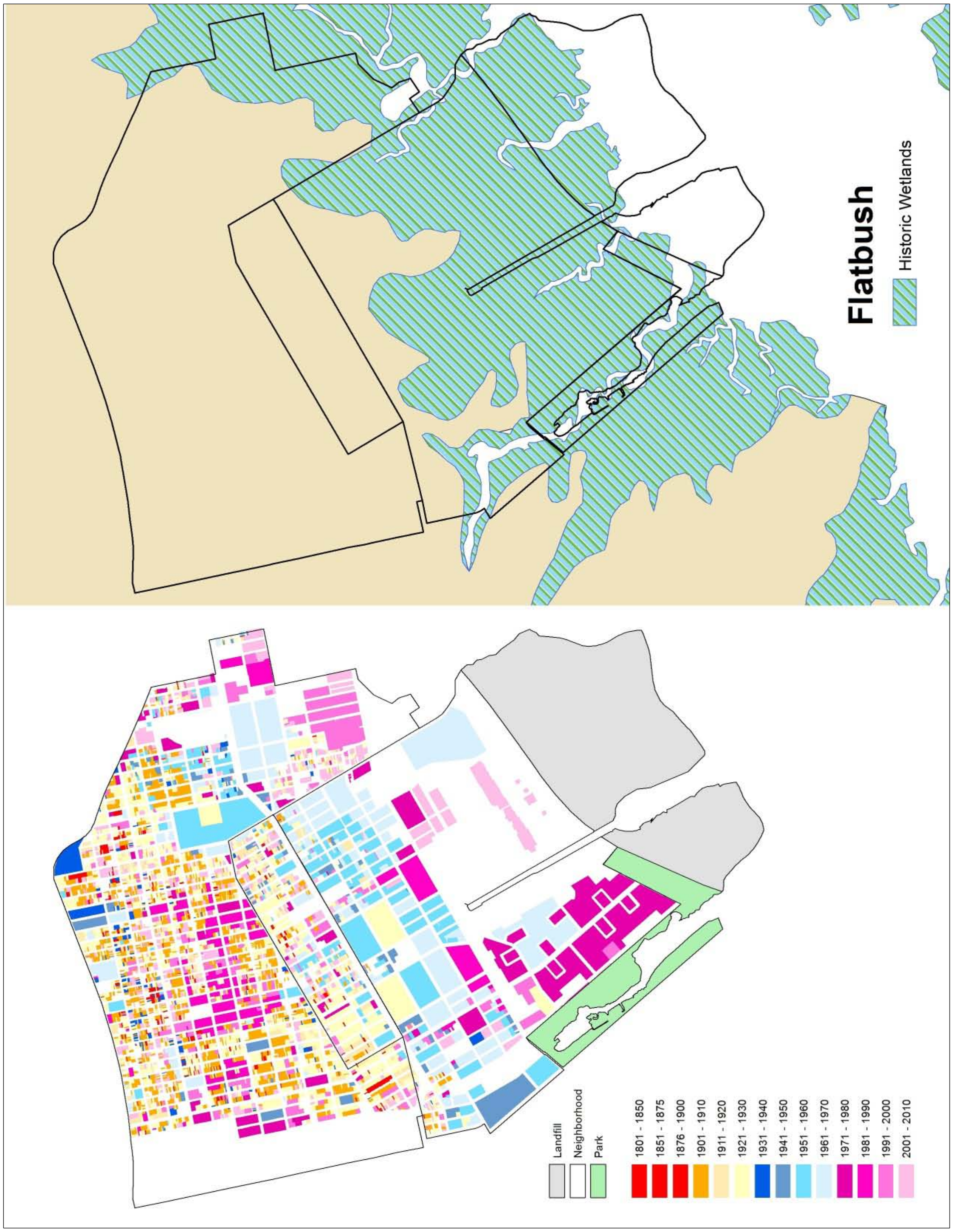


Figure VI.C.-2 Flatbush Pluto Year Built Data Compared with Historical Wetlands

This thesis will follow the convention in "The Neighborhoods of Brooklyn" (Jackson, Manbeck, and Citizens Committee for New York City 2004). East New York begins at Atlantic Avenue and includes the neighborhoods of New Lots and Spring Creek. The neighborhoods of City Line, Highland Park, and Cypress Hills are not part of this discussion.

Flatbush can be divided into four discrete areas: East New York, the area north of New Lots Avenue (New Lots Avenue to Atlantic Avenue), New Lots (New Lots Avenue to Linden Boulevard), Spring Creek (Linden Boulevard to the Shore Parkway GNRA), and GNRA (south of the Shore Parkway) comprising the Pennsylvania and the Fountain Avenue Landfills. (Figure VI.C.-1)

Approximately one half of Flatbush was wetlands, with Linden Boulevard generally marking the boundary between upland and marsh. (Figure VI.C.-2) Development began in the 1670s in the area known as New Lots. The growing population of the City of Brooklyn increased the need for more arable land. Approximately thirty farmers settled along New Lots Avenue, 1½ miles north of Jamaica Bay. Further growth was gradual and agricultural until the mid 1800s. Change began in 1835 when John R. Pitkin, Esq., purchased farmland northwest of New Lots Avenue (Williams 2012; Black 1981; Thompson 1843). (Figure VI.C.-3) He envisioned a diverse community of commerce, industry, and housing that would compete with other developing urban centers of the era. He named it East New York, reflecting its position and anticipated growth in comparison to the existing New York City (Black 1981; Olsen 2008). Pitkin proposed a canal from East New York to Jamaica Bay as a way to give a competitive advantage with the addition of a transportation route. The financial panic of 1837 undermined his efforts, the canal was never dug, and he had to sell off most of his property (Williams 2012). By 1844, the Long Island Railroad ran from the Fulton Ferry Landing to Greenport along Atlantic Avenue in East New York. Yet by 1845, the population in East New York was still less than one thousand people. The community was still undeveloped in 1886 when it was annexed to Brooklyn (Sterngass 1993). The population began to explode, spurred by the 1885 completion of the Lexington Avenue El, the elevated extension of the Lexington Avenue subway, that ran from the Fulton Ferry landing to Fulton Street (just north of Atlantic Avenue). By 1890 the population reached 30,000 (Black 1981; Williams 2012). Additional public transportation reached New Lots in 1922 with the arrival of the privately owned Interborough Rapid Transit Company's elevated New Lots Line (Williams 2012).

Most of this growth was north of New Lots Avenue. The area south of Linden Boulevard, being primarily marshland, remained undeveloped for a considerable amount of time (Black 1981). There are a number of assumptions that have been made as to why the southern half of Flatbush took so long to be developed: Black (2001) postulated that the marsh, which in some places was more than a mile wide, hindered "the development of a relationship" between the inhabitants of Flatbush and Jamaica Bay. The shore there was unsuitable for piers due to its lack of upland (Black 1981), and public transportation was underdeveloped. Even today, public transit is limited to buses, and the NYC subway reaches only a far as the intersection of New Lots and Livonia Avenue.

Figure VI.C.-3 Flatbush 1860 (David Rumsey Historical Map Collection 1860)

In contrast to the early development of the Rockaways, Spring Creek's development was extremely slow. The Rockaways' development was spurred on by private investors trying to make a profit on their investments. They focused on the development of transportation and marketing to increase the visibility, accessibility, and marketability of their investment. For this reason, landfill and development were synonymous in the Rockaways.

In Spring Creek, "development" was by public agency rather than by private investment. As such it wasn't driven by profit; therefore development did not have the same financial urgency that private development demonstrated. Recounting land use/land cover change in Spring Creek, the narrative is predominantly one of landfill rather than development.

Examining historical maps of the area illustrates the slow development of the southern half of Spring Creek. A map from 1860 clearly shows the results of John Pitkin's efforts, the development of East New York along Atlantic Avenue. It isn't until 1922 that a NOAA chart displays a street plan south of New Lots Avenue. By 1947, the development between New Lots Avenue and Linden Boulevard was still not completely realized.

The 1937 NOAA chart (Figure VI.C.-4) shows the first major changes in the wetlands of Spring Creek. Much of the area between Linden Boulevard and Flatlands Avenue had been filled in but was still undeveloped. A canal that was originally dug sometime between 1923 and 1926 was widened and named Hendrix Creek. The city filled the land along the creek's west bank for the construction of a waste treatment plant.

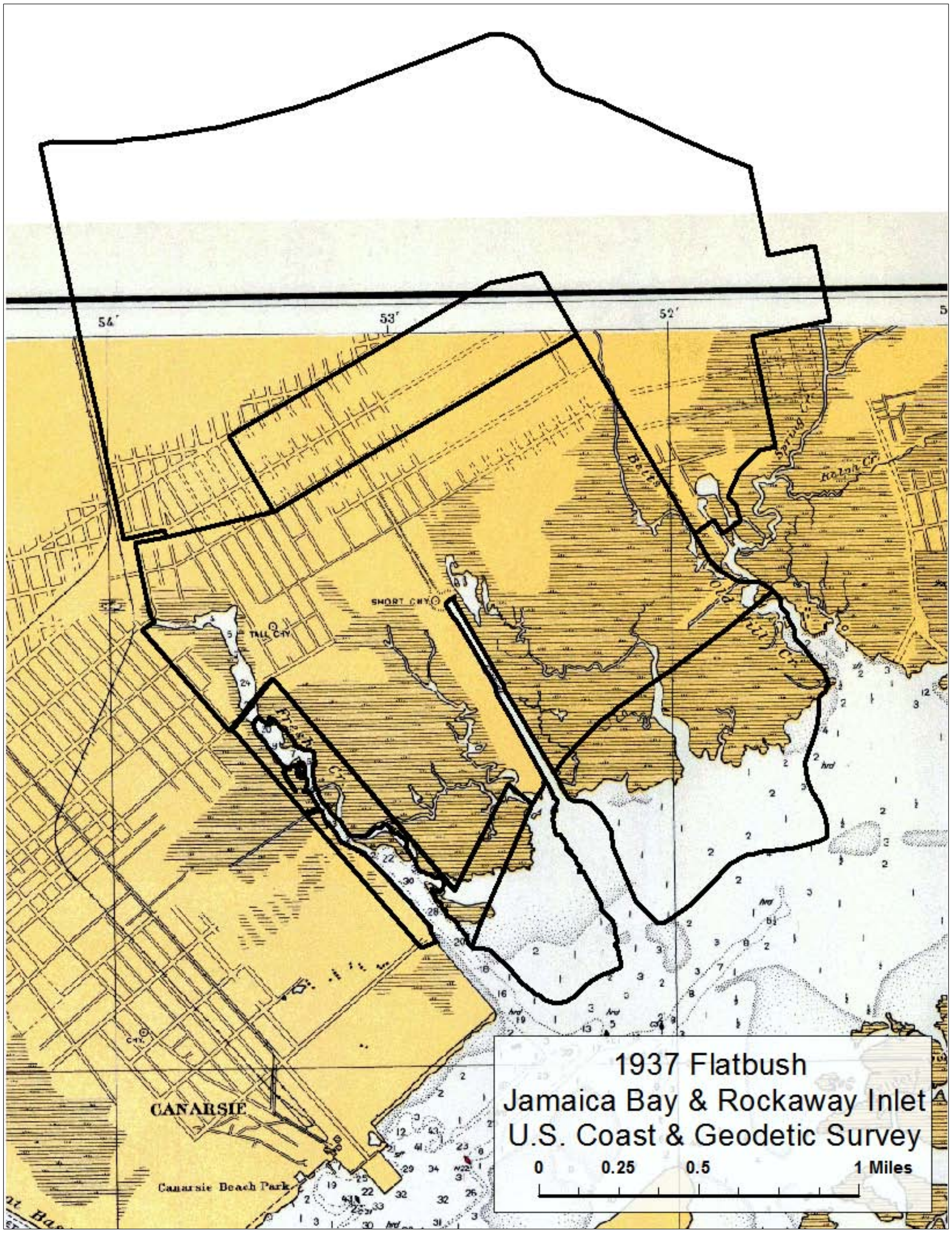


Figure VI.C.-4 Flatbush 1937 (U.S. Coast and Geodetic Survey 1937)

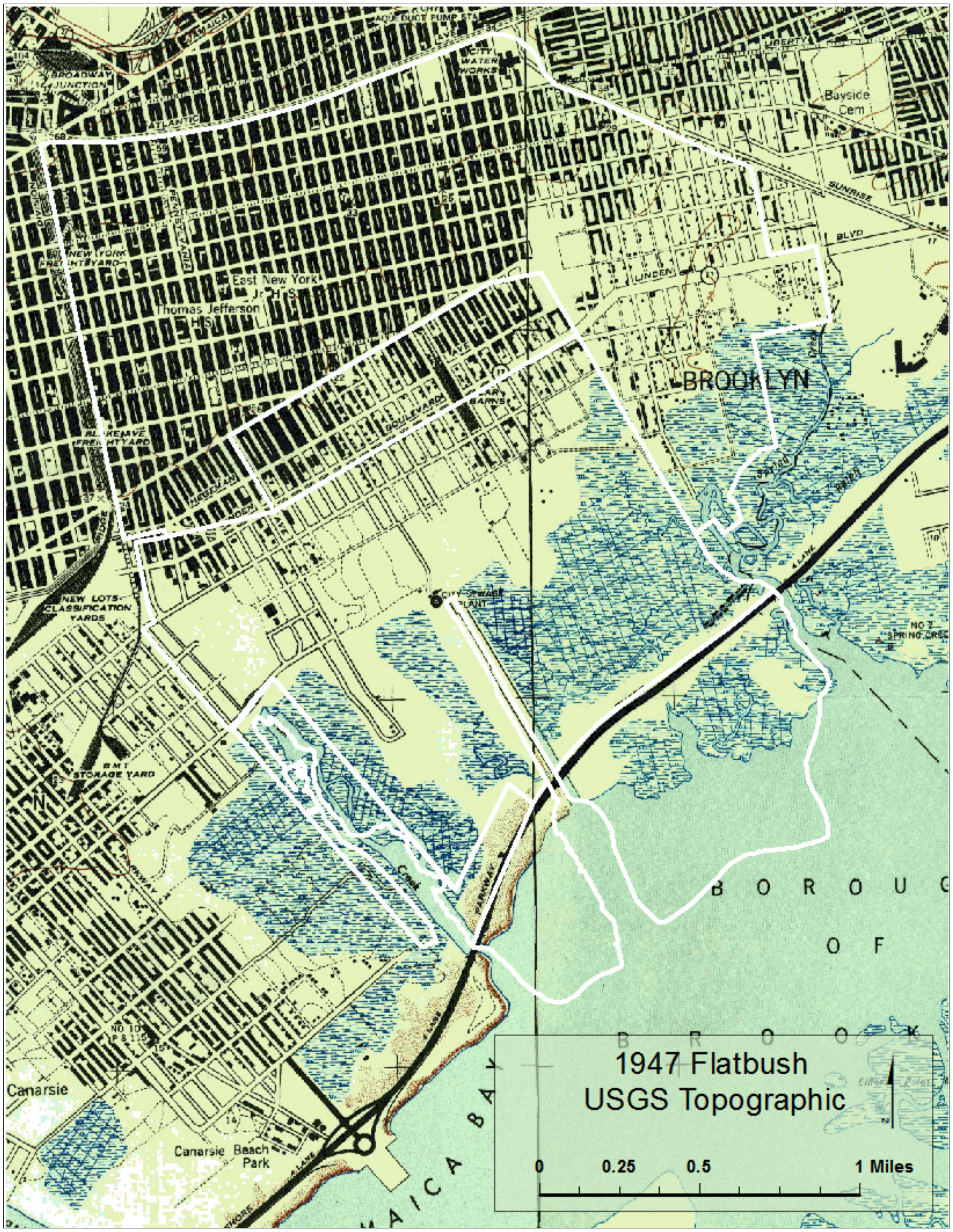


Figure V.I.C.-5 Flatbush 1947

The next big change, the completion of the new Shore Parkway, can be seen in the 1947 USGS topographic map. (Figure V.I.C.-5) There is also the southern extension of Pennsylvania Avenue connecting the Shore Parkway to Linden Boulevard (in red). Large expanses of wetlands are still present.

The rate of progress is clearly illustrated by comparing the "Year Built" Map with the historic wetlands. By examining maps in chronological order and by using the "year built" data from PLUTO, the progress of development of Spring Creek and East New York can be followed.

It wasn't until 1974, with the building of Starrett City along Spring Creek, that there was any construction south of Flatlands Avenue. Starrett City, located just north of the Fountain Avenue Landfill, was the largest federally-subsidized housing project in the country (Guiffo 2005). Shortly thereafter, in 1978, the city built the Brooklyn Disabilities Development Services Offices, a facility that provided housing for the mentally disabled. The area continued to languish until 2002, when the city built the Gateway Mall, hoping to attract people to the area.

The Pennsylvania Avenue Landfill and the Fountain Avenue Landfill

The shoreline of Jamaica Bay was modified more between 1951 and 1974 than after (Boger, Connolly, and Christiano 2012). The last major area along the Bay to be affected by manmade topographical changes was Flatbush. Dredged shipping channels did not extend beyond Fresh Creek, and transportation infrastructure was nonexistent south of New Lots.

The first significant modification in the area was in 1940 when a band of land along the shore was land filled for the construction of the Shore Parkway.

It was the post World War II establishment of the Pennsylvania Avenue and the Fountain Avenue Landfills that caused the greatest change (Black 1981). The Pennsylvania Avenue and Fountain Avenue landfills are located along the northwestern shore of Jamaica Bay between Canarsie on the west and Howard Beach on the east. Both landfill sites were classified as Class 2 Inactive Hazardous Waste Sites. In 1974 they were turned over to Gateway National Park with the provision that the city could continue using them as landfills until 1985 (Philips 2013; Boger, Connolly, and Christiano 2012). Large bulkheads were placed around the landfills between 1974 and 2006 (Boger, Connolly, and Christiano 2012).

The Fountain Avenue Landfill, the larger of the two, opened in 1961. It reached its current extent of 287 acres in 1980 and eventually was built up to 80 feet in height (Olsen 2008; Philips 2013). A 1973 report said that at that time it was receiving 40,000 tons of garbage a day that consisted of sludge, bulk waste, dead animals, asbestos, incinerator ash and other municipal solid waste (Philips 2013; Olsen 2008). The landfill was closed by the New York State Department of Environmental Conservation (NYSDEC) in 1983. During its last year of operation, the Fountain Avenue Landfill received 8,200 tons of debris per day (Olsen 2008).

The Pennsylvania Avenue Landfill opened in 1956. It reached its current extent of 110 acres in 1980 and was land filled to an elevation of 110 feet. Land filling activities were temporarily suspended from 1962 to 1968. In 1980 the New York State Department of Environmental Conservation closed the site (Philips 2013). The year it closed it was receiving between 2,500 and 4,500 tons of debris a day (Olsen 2008).

VI. HISTORICAL ANALYSIS

D. FLATLANDS

(see Appendix D for a complete set of Flatland Basemaps)

Flatland Boundaries:

- Northeast: 108th Street
- Northwest: Avenue D, Ditmas Avenue
- South: Jamaica Bay
- Southwest: Gerritsen Avenue

Flatland Neighborhoods: (Figure VI.D.-1)

- Canarsie
- Mill Basin
- Georgetown
- Bergen Beach

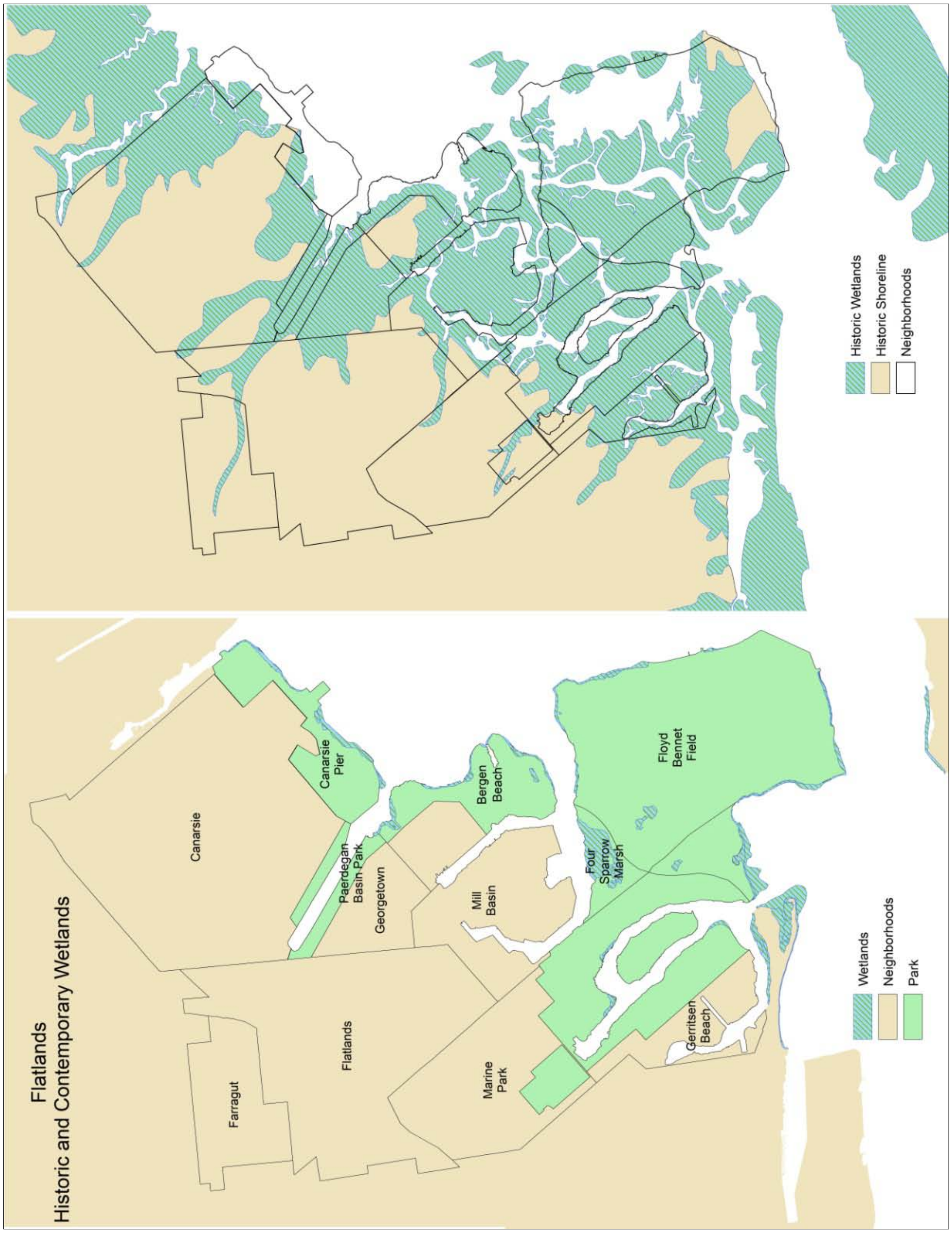


Figure VI.D.-1 Flatlands: Current and Historical Wetlands

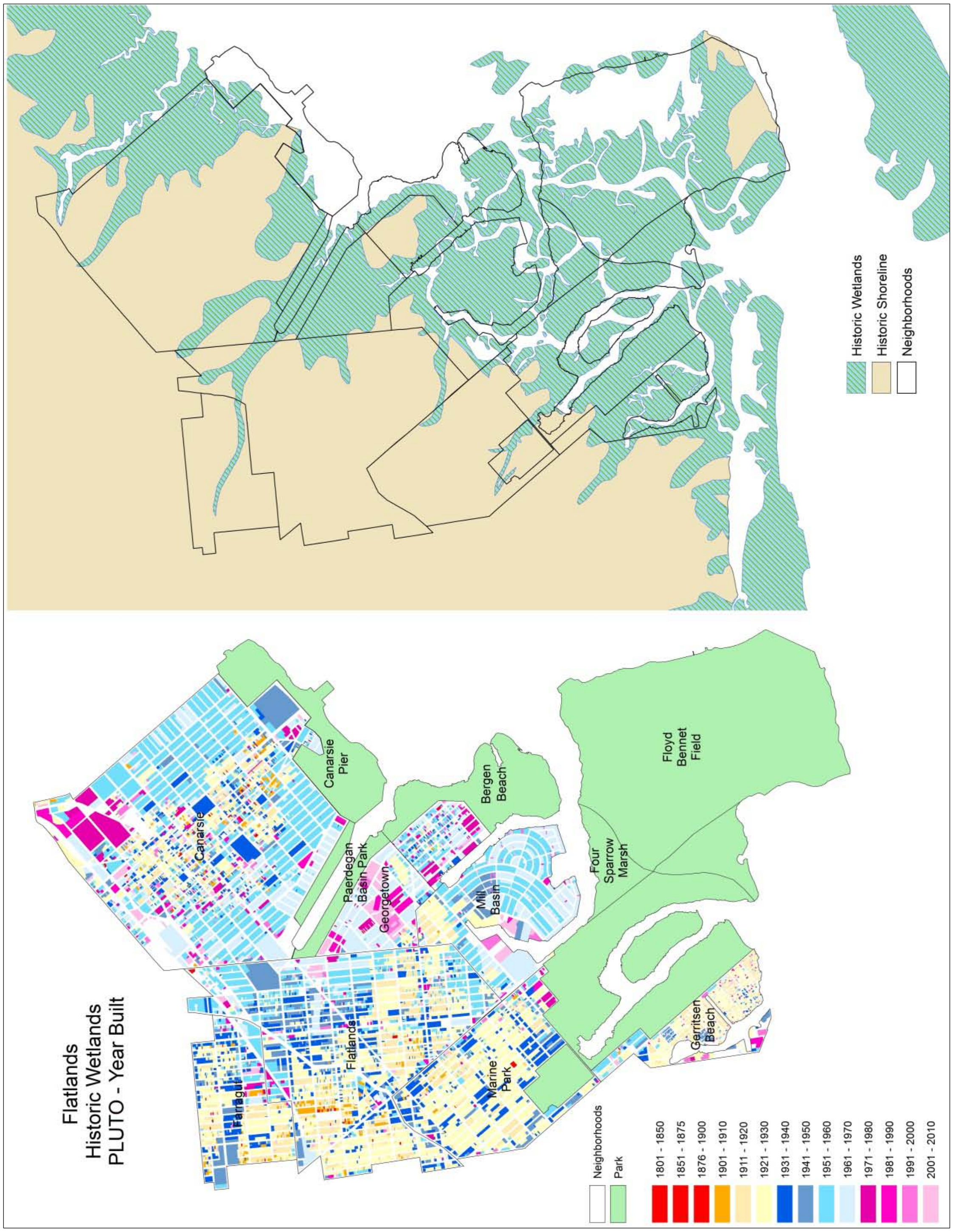


Figure VI.D.-2 Flatlands: PLUTO "Year Built" Data and Historical Wetlands

Along the shore of Brooklyn there were only a few places where uplands were within close access to the Bay. Uplands were found in Canarsie and on Barren, Bergen, and Mill Islands (Black 2001). (Figure VI.D.-1) Without the need for landfill, these areas attracted development earlier than the wetlands. However, early interest did not guarantee successful or continuous growth.

Initial interests in the Flatlands were recreational and industrial, yet both failed and were replaced by residential development. A main factor in their development, or lack thereof, was transportation. Canarsie gained importance as a transportation hub to the Rockaways (Black 1981). Canarsie and Bergen Beach also became recreational destinations. Yet both Canarsie and Bergen Beach faded in importance as competition in transportation services grew. Mill Island's industrial development was spurred by the promise of rail and port service. When neither materialized, industry left the area (Black 1981). Recreational and industrial development lagged in the Flatlands then essentially disappeared (Bellot 1918; Black 1981). The historical wetlands of the area later attracted interest for residential development, but progress was slow (Jackson and Manbeck 2004).

Canarsie, located between Bedford Creek (now Paerdegat Basin) and Fresh Creek, was one of the earliest settlements around the Bay (Black 1981). Running though the center of Canarsie were uplands suitable for farming that attracted settlers as early as the 1620s. The southern point of the triangularly shaped uplands met the Bay at Canarsie Landing, making it an excellent location for fishing. The fishing industry reached its heyday in the 1850s. In the early 1900s people began to get sick from eating local seafood and in the 1920s the shellfishing industry was closed due to the increased pollution of Jamaica Bay's waters (Jackson and Manbeck 2004; Bellot 1918; Black 1981).

Significant interest in Canarsie for its access to the Bay began in the 1860s, driven by the allure of the Rockaways. Prior to the mid-1800s, transportation to the Rockaways was predominantly overland. The first leg of the trip was by ferry from Manhattan to Brooklyn, then by road to Jamaica or Hempstead, then on to Far Rockaway by stage coach or horseback over poor roads (Black 1981).

Canarsie benefitted from the importance of the Rockaways as a recreational destination. It became a point of embarkation to the Rockaways, providing a shorter and easier trip for vacationers. Rail access to the Rockaways began in 1866 with the construction of the Brooklyn & Rockaway Beach line to Canarsie. Trains traveled from East New York to Canarsie where passengers would transfer to a ferry. In the summer of 1867, 122,567 people passed through Canarsie on their way to the Rockaways. The railroad ran 10 round trips a day. However, there were only 3 ferries per day. This created a demand to accommodate the travelers' needs between the legs of their journeys (Black 1981). (Figure VI.D.-4)

Canarsie and Bergen Island were also recreational destinations in their own right, but on more modest scales than Coney Island or the Rockaways. They provided calmer waters, were closer, and were less expensive (Black 1981).

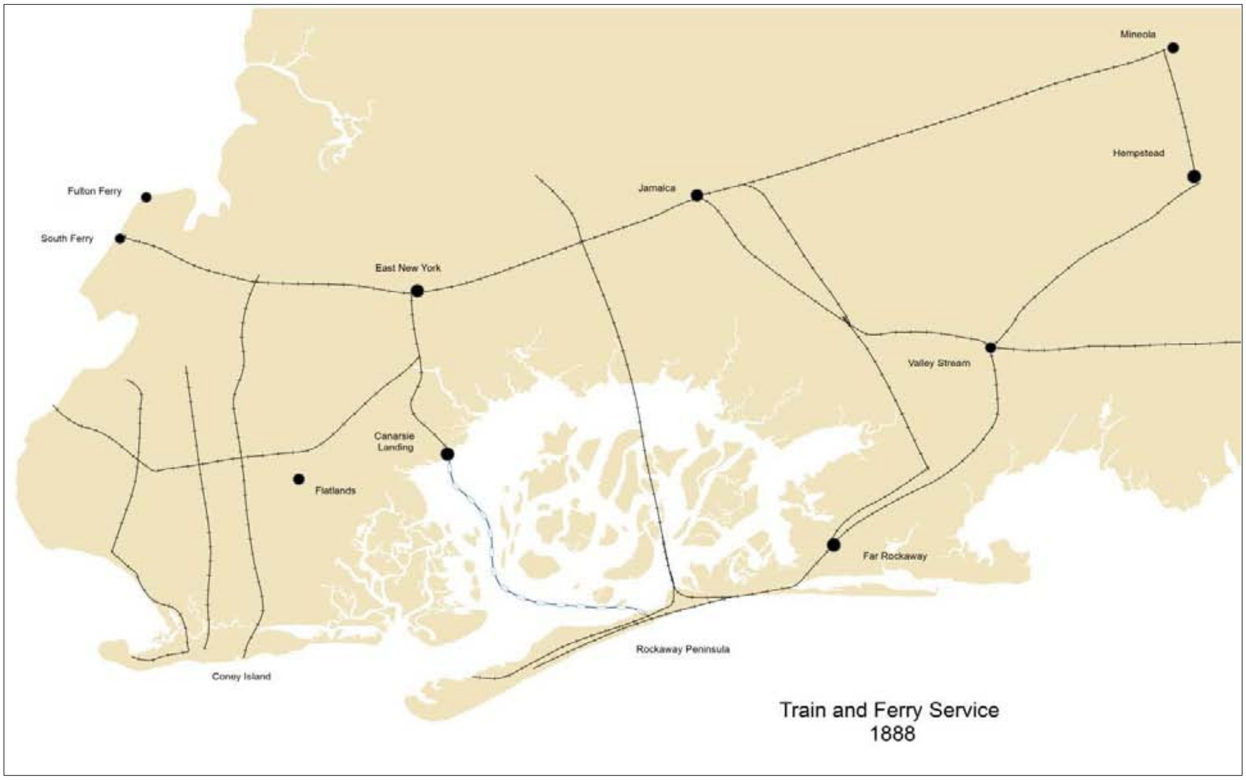


Figure VI.D.-3 Train and Ferry Service in 1888 (data from the 1888 Colton's New Map of Long Island, David Rumsey Historical Map Collection)

Transportation to the beaches of Jamaica Bay was a lucrative business that resulted in increasing competition, constant improvements, shorter routes, and newer modes of transportation. (Figure VI.D.-3)

1. 1868: The Southside Railroad offered service from Valley Stream to Far Rockaway.
2. 1872: The Southside Railroad reached Rockaway Beach.
3. 1873: The Long Island Railroad built a route from Hillside, Jamaica to the Rockaways via Cedarhurst. The LIRR route was much shorter than the route of the Southside Railroad.

4. 1880: The New York, Woodhaven and Rockaway Railroad began service from Brooklyn to Hammels along a 4.8 mile long trestle across Jamaica Bay.
5. 1882: The White Iron Steamboat Company began steamboat service from New York to Coney Island and the Rockaways (Black 2001).

In 1895 the competition from inexpensive trolley service to Coney Island became too great, Bergen Island and Canarsie faded in importance.

While the boom in Canarsie did not translate into continued development and modification of the wetlands, Canarsie Landing continued to be a location of modification. The earliest significant modifications to Canarsie took place there. In 1910, the pier was enlarged to a width of 700 feet. A municipal dock was built by the city in 1926 extending an additional 600 feet into the Bay. (Figure VI.D.-5) At the same time the area from Bedford Creek to Spring Creek was bulk-headed and the area behind the bulkhead was filled using dredge, creating an additional 100 acres of upland. In 1940, the construction of the Shore Parkway caused the filling of an isolated swath of landfill just north of the Bay. The 1966 aerial map of the area is the first to show all the wetlands land filled and developed. (Figure VI.D.-5)

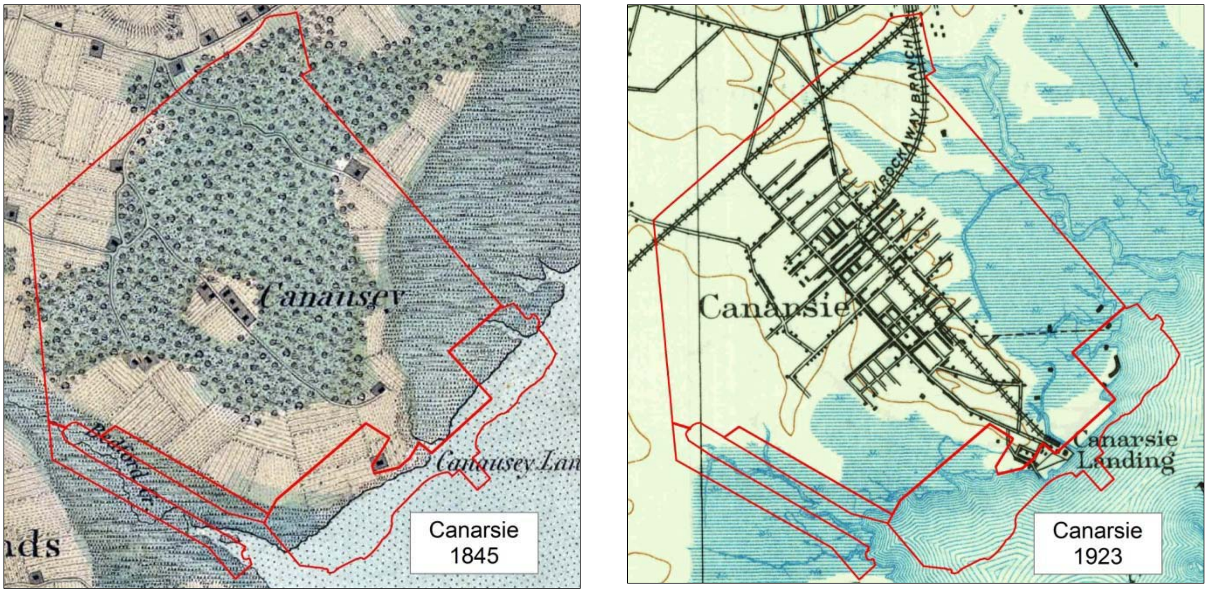


Figure VI.D.-4 Canarsie 1845 and 1923

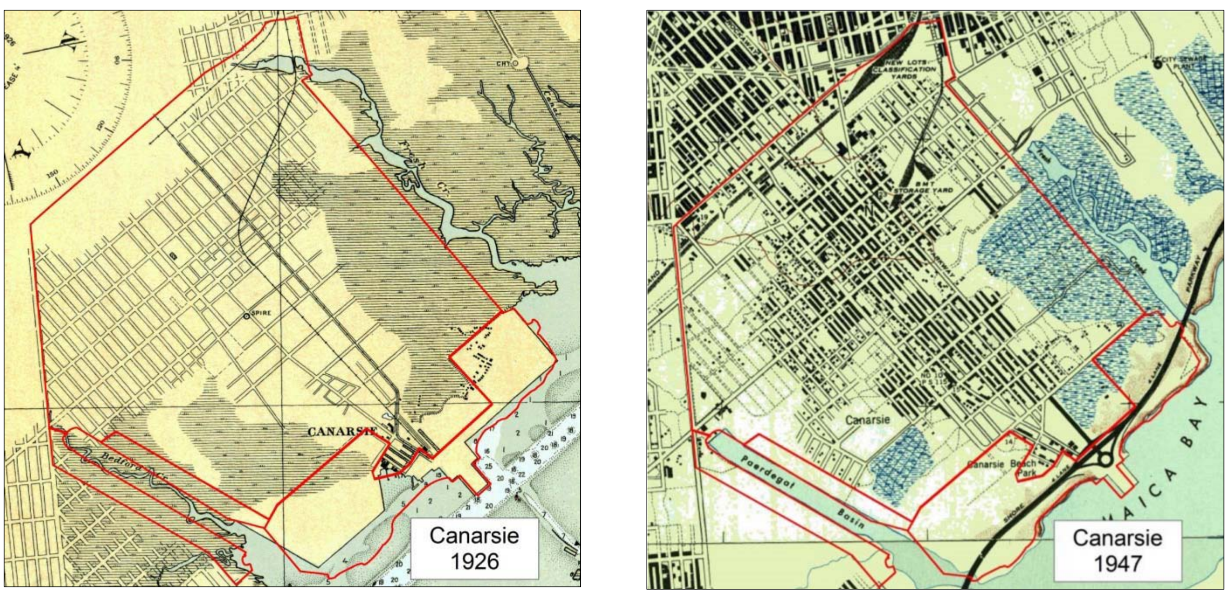


Figure VI.D.-5 Canarsie 1926 and 1947

Bergen Island also contained one of the few uplands near Jamaica Bay. In the 1890s entrepreneurs Percy Williams and Thomas Adams Jr. developed an amusement park on the uplands. As a recreational destination it competed with Coney Island and the Rockaways. Like Canarsie, it lost its importance as other modes and routes of transportation to Coney Island and the Rockaways were developed. It also lost its attractiveness with the establishment of inexpensive trolley access to Coney Island. The property was sold in 1925 for $2 million to developers Max Natanson and Mandlebaum & Levine, who hoped to, but never did, build a residential community. Between 1926 and 1933 the area was filled and laid out. (Figure VI.D.-6) The area was not served by any form of public transportation – bus, train or subway. Bergen Island and Georgetown were two of the largest undeveloped parcels of land in Brooklyn. In 1939 part of Bergen Beach Park was filled for the Shore Parkway, yet it still remained largely undeveloped through the mid-1950s (Jackson and Manbeck 2004).

As late as 1954, most of Georgetown was marsh (Figure VI.D.-6). In 1960 a proposal was made to build 400 two story colonial homes. At the same time the city filled the wetlands and embarked on plans to build subsidized housing in Georgetown. Developers, concerned that subsidized housing would negatively affect real estate values, cancelled the project (Jackson and Manbeck 2004). City housing was never built, and so residential development started. By 1980, half of Georgetown was covered in housing, but it wasn't completed until 2006.

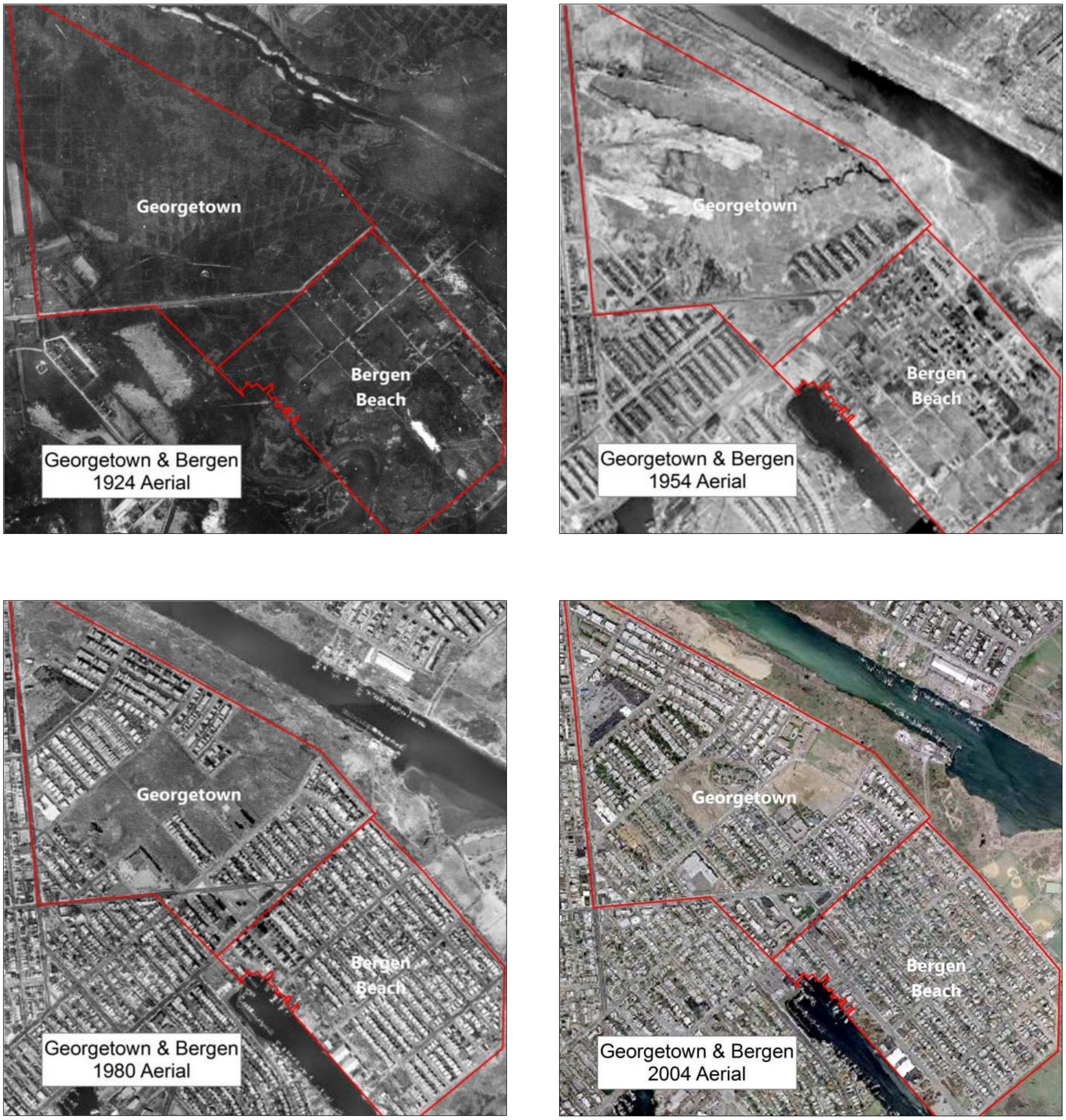


Figure VI.D.-6 Georgetown and Bergen Beach 1924, 1954, 1980, and 2004

(Fairchild 1924a; NETR Online 1954; NETR Online 1980; NETR Online 2004)

Mill Island's development was prompted by industry rather than recreation. (Figure VI.D.-7) Talk of establishing a Jamaica Bay port and rail service to the island enticed a lead smelting company to build a factory there in 1890. Ten years later the land was sold, and by 1906 it was bulk-headed and land filled, creating a 300 acre industrial park that existed until the 1940s. Neither the port nor train service ever materialized. The land was sold to real estate developers who continued to land fill and build housing. Residential development began in the mid1950s and was completed by 1966 (Jackson and Manbeck 2004).

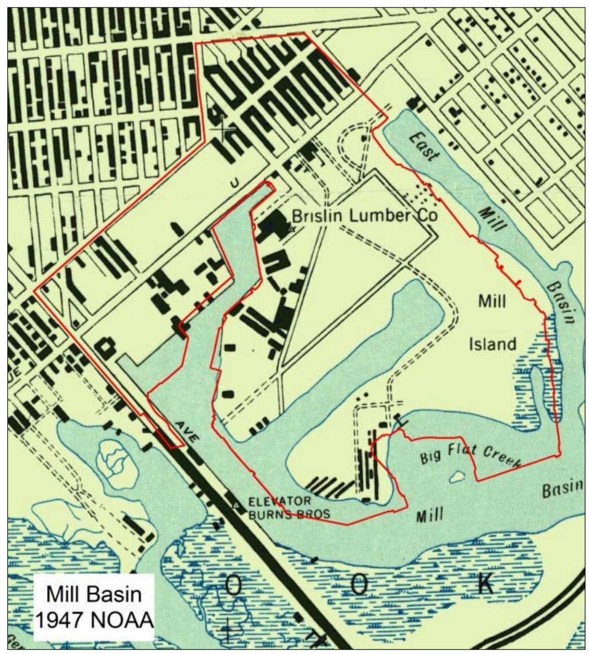


Figure VI.D.-7 Mill Basin 1924 and 1947

Figure VI.D.-8 Mill Basin 1954 and 1966

VI. HISTORICAL ANALYSIS

E. GRAVESEND

(see Appendix E for a complete set of Gravesend Basemaps)

Gravesend Boundaries:

- North: Flatland Avenue, Avenue P
- South: Atlantic Ocean
- East: Gerritsen Avenue, Marine Park
- West: Gravesend Bay Atlantic Ocean

Gravesend Neighborhoods: (Figure VI.E.-1)

- West Brighton
- Sea Gate
- Brighton Beach
- Manhattan Beach

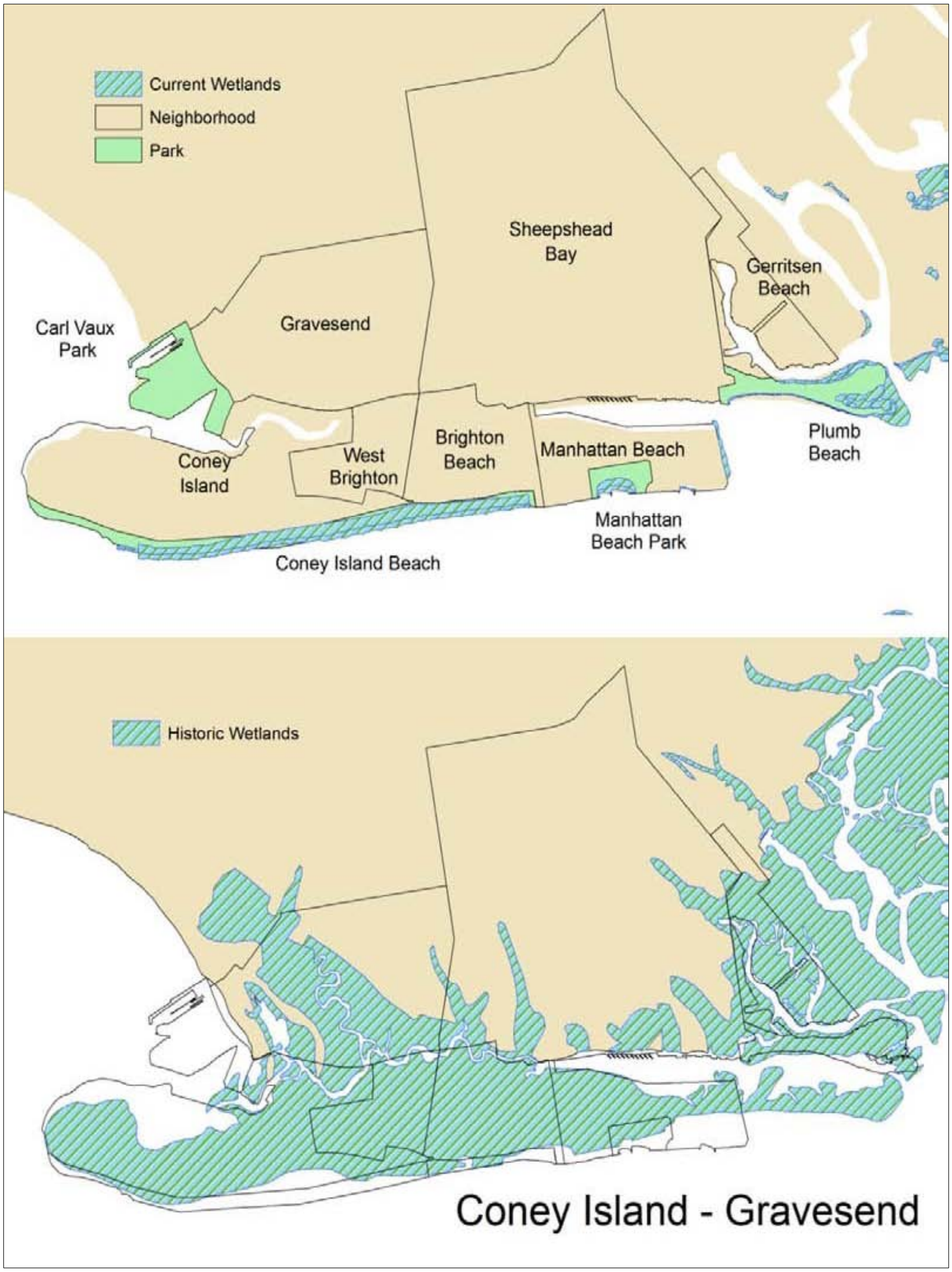


Figure VI.E.-1 Gravesend: Current and Historical Wetlands

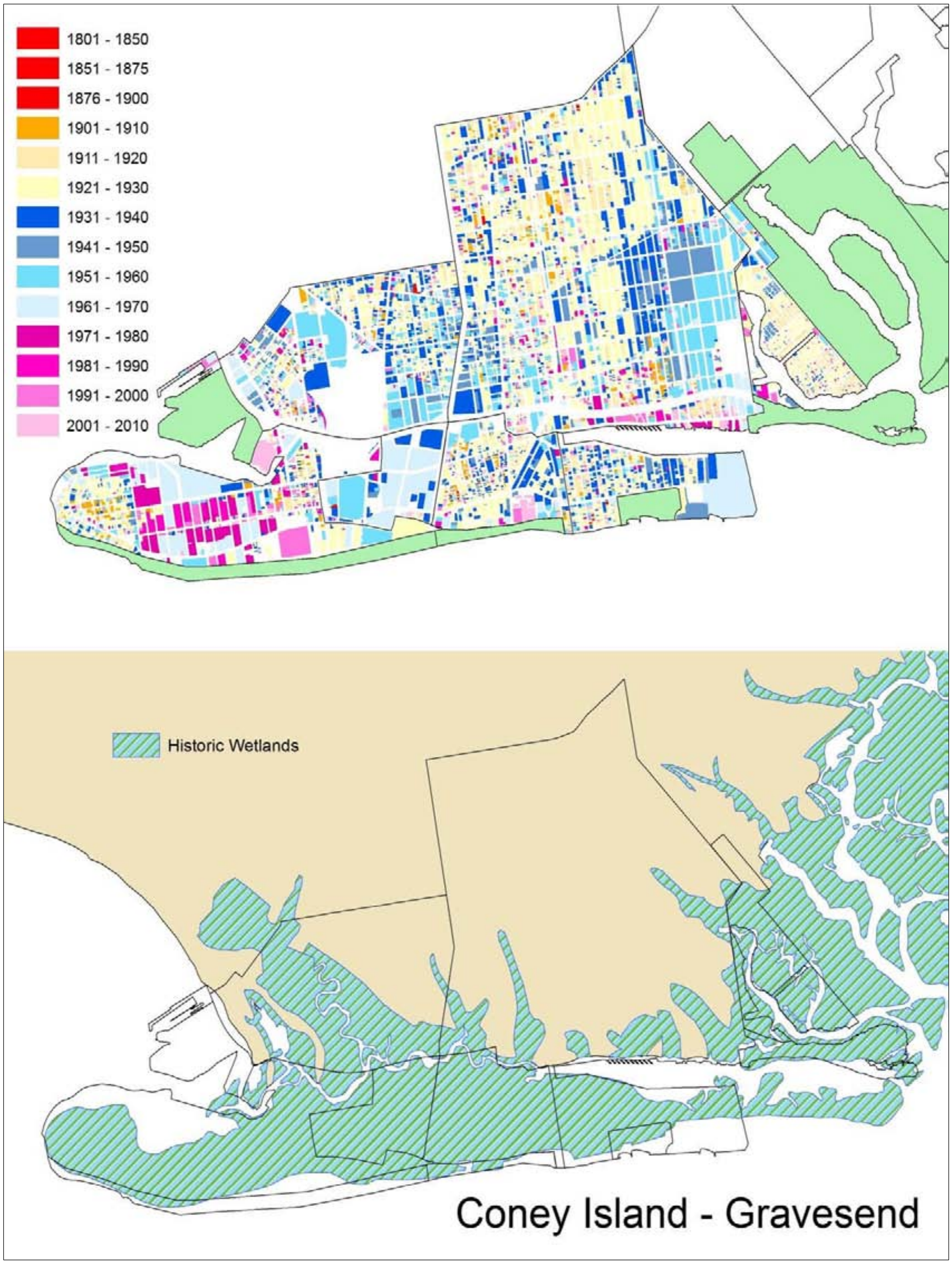


Figure VI.E.-2 Gravesend PLUTO "Year Built" Data and Historical Wetlands

Gravesend, one of the original six towns of Brooklyn, was established in 1643. It was centered on a 16-acre fortress at the intersection of McDonald Avenue and Gravesend Neck Road. The original patent extended to the southern shore and included all of Coney Island. About half of Gravesend was wetlands.

Before the 1860s, Gravesend was a community of small farms. After the 1860s, the shoreline was broken up and sold in large tracts to developers. Competition began between the neighborhoods of Coney Island (West Brighton), Manhattan Beach, Seagate, and Brighton Beach to attract vacationers (Stanton 1998; Bellot 1918; Jackson and Manbeck 2004). With the electrification of the railroad to Sea Beach and the Culver Line in the late 1890s, the area finally began to experience true growth.

Manhattan's wetlands had already been filled in by the Dutch. However, the extensive wetlands in the outer boroughs of the city were thought to be an inexhaustible solution to waste disposal. Most of the waste was transported by barge. Where the wetlands were inaccessible by water, horse carts were used (Walsh 1991a).

The most significant anthropogenic change in Gravesend was not from real estate development but from waste disposal. (Figure VI.E.-2) The town of Gravesend, which included Coney Island, contained over 15,000 acres of wetlands. They existed between Coney Island and the mainland. However using them for waste disposal posed a problem. They were not accessible by barge and the overland route was long and costly. In 1905, an agreement was made to use the same railroad that had been built to take vacationers to the beaches of Coney Island to transport waste to the wetlands. It only took 8 years to completely eradicate the extensive wetlands (Walsh 1991a).

Up until the late 1800s, New York City dumped 80% of its waste into the waters off Manhattan. Refuse was taken by horse cart to the shore, where wooden scows would take it offshore and dump it. Unfortunately, it would often wash up on shore causing much distress. In response, the city instituted its first solid waste management plan. Ocean dumping was replaced with land disposal and a comprehensive recycling program (Walsh 1991a).

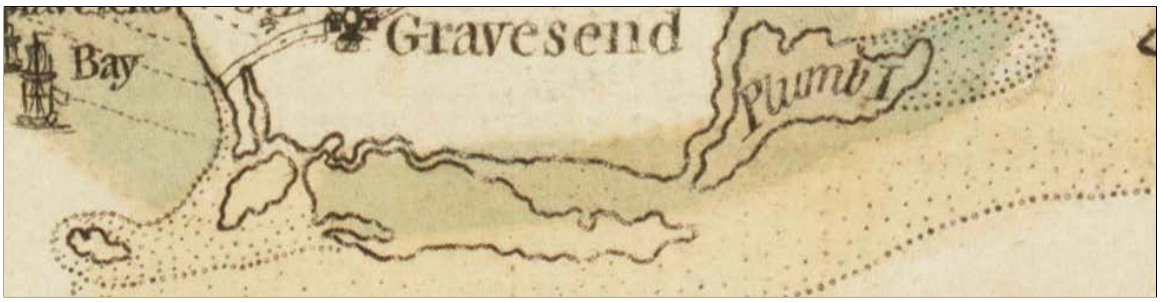


Figure VI.E.-3 Coney Island 1776 (Holland 1776)

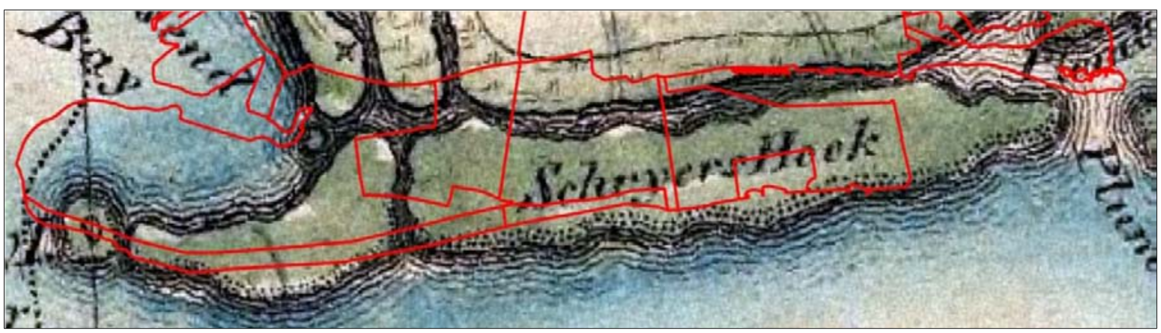


Figure VI.E.-4 Coney Island 1811 (David Rumsey Historical Map Collection 1811)

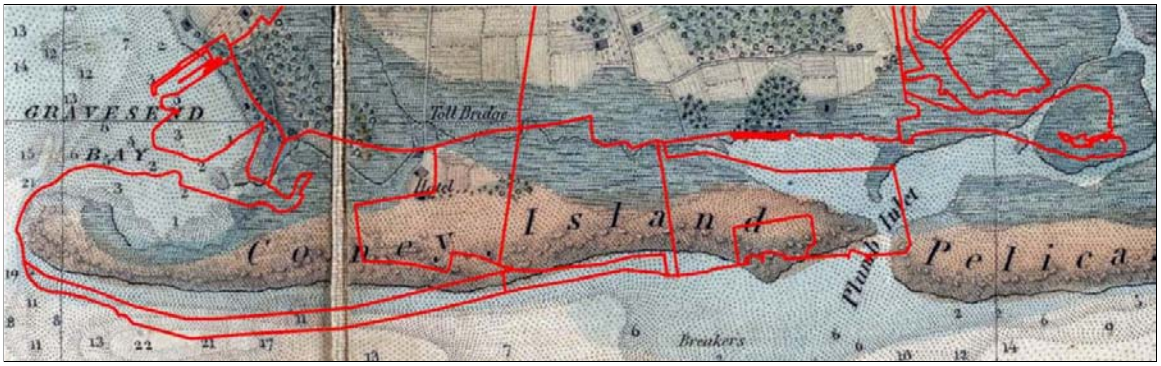


Figure VI.E.-5 Coney Island 1845 (David Rumsey Historical Map Collection 1845a)

Coney Island, like the Rockaway Peninsula, was and is greatly affected by environmental forces. Recorded history shows extraordinary changes in the area with periods of significant accretion and erosion. Until recently, natural forces were the predominant factors affecting the shoreline.

Maps from 1776 depict Coney Island as being comprised of three separate islands. The growth of Coney Island was rapid as accretion deposited sand, filling in the islands and eventually forming one whole island separated from the mainland by a creek. (Figure VI.E.-3) (Figure VI.E.-4) (Figure VI.E.-5)

Yet in 1939 a description of Coney Island spoke of severe erosion on Coney Island and concerns that the island would disappear. “The effect of severe ocean storms has long been visible here, and much of what was once Coney Island has disappeared… The exposed situation of this island subjects it to the encroachments of the sea, and to be entirely destroyed at some future period.” (Thompson 1839) (pg. 445). Manmade changes to the island have proved the concern of its loss to be unfounded at present.

The Coney Island shoreline continued to be unstable. From 1845 to 1860 Coney Island had a familiar profile. However, maps from 1888 show a very elongated island. (Figure VI.E.-6) A Category 4 hurricane made landfall at Jamaica Bay in August of 1893. That hurricane might have been responsible for the dramatic reconfiguration of the shoreline. (see Appendix K for a list of Historical Hurricanes that Impacted New York Cities Coast)

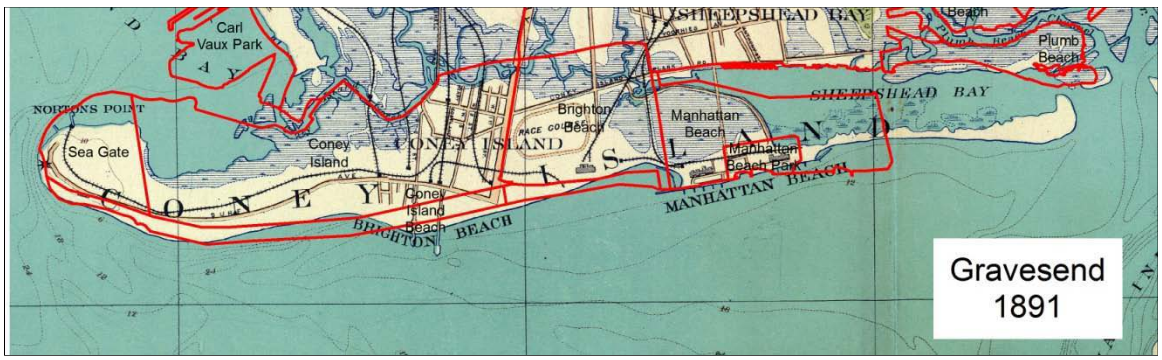


Figure VI.E.-6 Coney Island 1891 (David Rumsey Historical Map Collection 1891b)

Prior to the demise of the wetlands, the sandy shore of Coney Island was developed as a resort. On Coney Island, real estate and transportation were closely intertwined (Stanton 1998). Coney Island's investment catered largely to day trippers and their amusement. Its promise of great profits depended on facilitated access to the shore. Competition was fierce, with offerings to vacationers of greater accessibly, shorter commutes, and affordable fares.

In the mid-1800s, three major roads were built between Brooklyn and Coney Island, all of which still exist today. Two were toll roads, the Shell Road built in 1823, and Coney Island Avenue built in 1850. The third, Ocean Parkway, which was completed in 1876, was first proposed by Frederick Law Olmsted and Calvert Vaux in the 1860s (Stanton 1998).

Prior to 1880, most people traveled to Coney Island by steamboat, the water route being shorter than the land route. By steamboat the trip was slightly less than an hour, but by land it took more than two hours (Cudahy 2009). Ferries mainly plied two routes that impacted travel to Coney Island. On the northern route, one left Manhattan to meet the excursion rails to Coney Island. The second route went directly from Manhattan to Coney Island.

Ferries played an important role. Not only was the direct ferry route shorter and faster, but it didn't require transfers along the way. Ferry service started as early as the mid-1840s, with scheduled service starting in the 1850s. The first pier on Coney Island was at Coney Island Point and extended into Gravesend Bay. Thomas Bielby, the owner of the Fort Hamilton and Coney Island Ferry Company, also built a pavilion in the area in the mid 1840s.

In 1871 Charles Feldman, who invented the hotdog, started the Ocean Navigation and Pier Company. In 1879 they built an Iron Pier on the Atlantic side of Coney Island in West Brighton. It was 1,400 feet long, had a "1000-foot promenade, and could accommodate 30,000 patrons." (Cudahy 2009).

The Iron Steamboat Company began service to Coney Island. It provided service between Manhattan and the Iron Pier in West Brighton and between New York and Long

Branch, New Jersey. A second Iron Pier was built in 1882 by a subsidiary of the Prospect Park and Coney Island Railroad. The Iron Steamboat Company negotiated exclusive contracts with both the first and second Iron Piers. Another company called Whites Regular Line also serviced Coney Island on its way to and from the Rockaways (Cudahy 2009).

During the late 1800s, five excursion railroads and one street railway were built connecting Coney Island to Manhattan and Brooklyn (Jackson and Manbeck 2004). The first railroad to Coney Island was horse drawn and began in the early 1850s. By 1864, the first steam powered railroad came to Coney Island (Cudahy 2009; Stanton 1998). The five railroads were: (Figure VI.E.-7)

1. 1862 Coney Island and Brooklyn Railroad, James A. Van Brunt.
2. 1867 Brooklyn, Bath, and Coney Island Railroad: West End Line, New Utrecht Avenue Line, Godfrey Gunther
3. 1875 Prospect Park and Coney Island Railroad: Culver Line: Gravesend Avenue Line, McDonald Avenue Line, Andrew N. Culver
4. 1877 Brooklyn, Flatbush, and Coney Island Railway: Coney Island Railway
5. 1878 New York and Manhattan Beach Railway: Manhattan Beach Branch, August Corbin
6. 1879 New York and Sea Beach Railroad (Cudahy 2009; Stanton 1998)

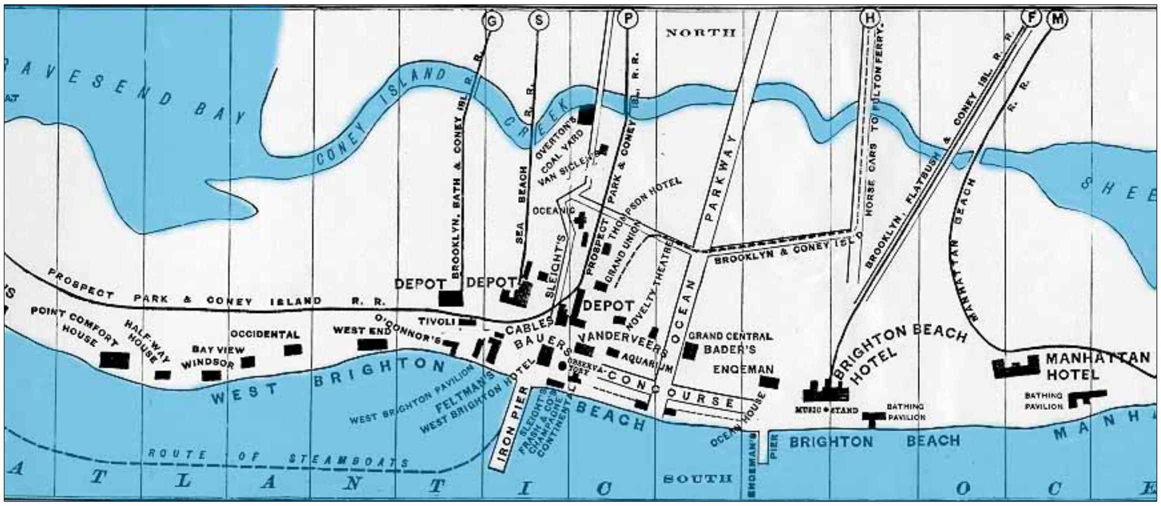


Figure VI.E.-7 Transportation Routes to Coney Island in 1879

(Stanton 1998; Pritskett 1879) (see Appendix J for more information)

Transportation to Coney Island is notable in that many of the historical routes have survived. The majority of historical mass transit routes to the shores of Jamaica Bay were in the Rockaways and Coney Island. They were driven by the lure of the beaches and the subsequent real estate development. Even though competition was fierce, resulting in hundreds of companies, mergers, and bankruptcies, in Coney Island four of the five original steam railroads' rights of way still exist today (Cudahy 2009). What also stands out is the tie between land use/land cover change with real estate and transportation.

The large number of railroads, their mergers and foreclosures, makes naming and describing the history of railroads on Coney Island beyond the purview of this thesis.

The neighborhoods of Coney Island, like those of the Rockaways, were championed by individuals. Some of the more note-worthy individuals were: August Corbin of

Manhattan Beach, Andrew R. Culver of West Brighton, and William Engelman of Brighton Beach. Railroad companies saw profits in providing services to vacationers and subsequently invested in hotels, amusement parks, racetracks, and a multitude of other facilities as well as transportation (Stanton 1998).

VI. HISTORICAL ANALYSIS

F. JAMAICA

(see Appendix F for a complete set of Jamaica Basemaps)

Jamaica, one of the six original towns in Queens, borders the Bay along the northeast shore. Extensive wetlands were to be found in Howard Beach, Rosedale, and at John F. Kennedy International Airport. Much of Rosedale's wetlands still exist today as the Hook Creek Wildlife Sanctuary. The rest was land filled and is part of Idlewild Park. (Figure VI.F.-1) The John F. Kennedy International Airport will be discussed separately along with other airports in the vicinity.

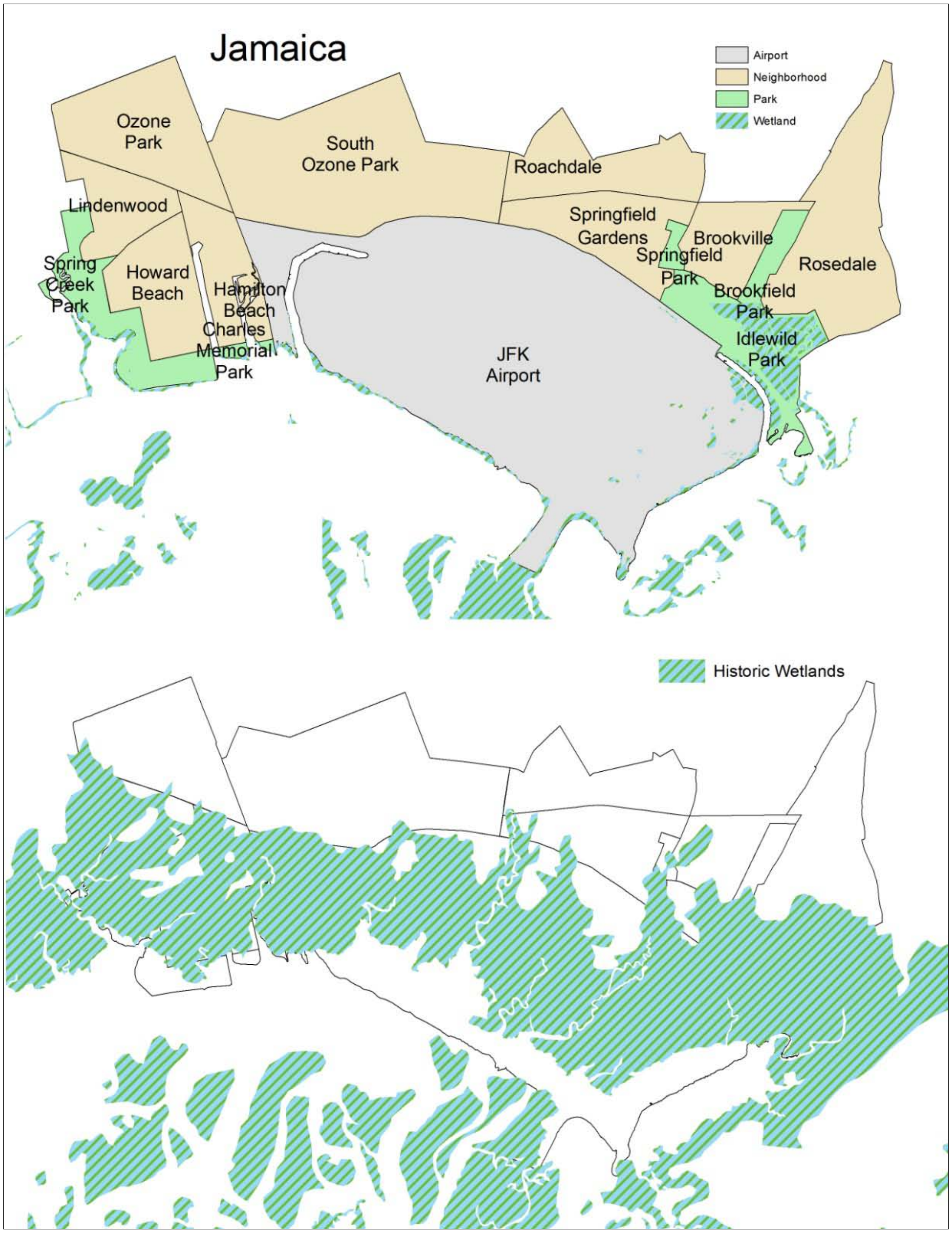


Figure VI.F.-1 Jamaica, Queens Current and Historical Wetlands.

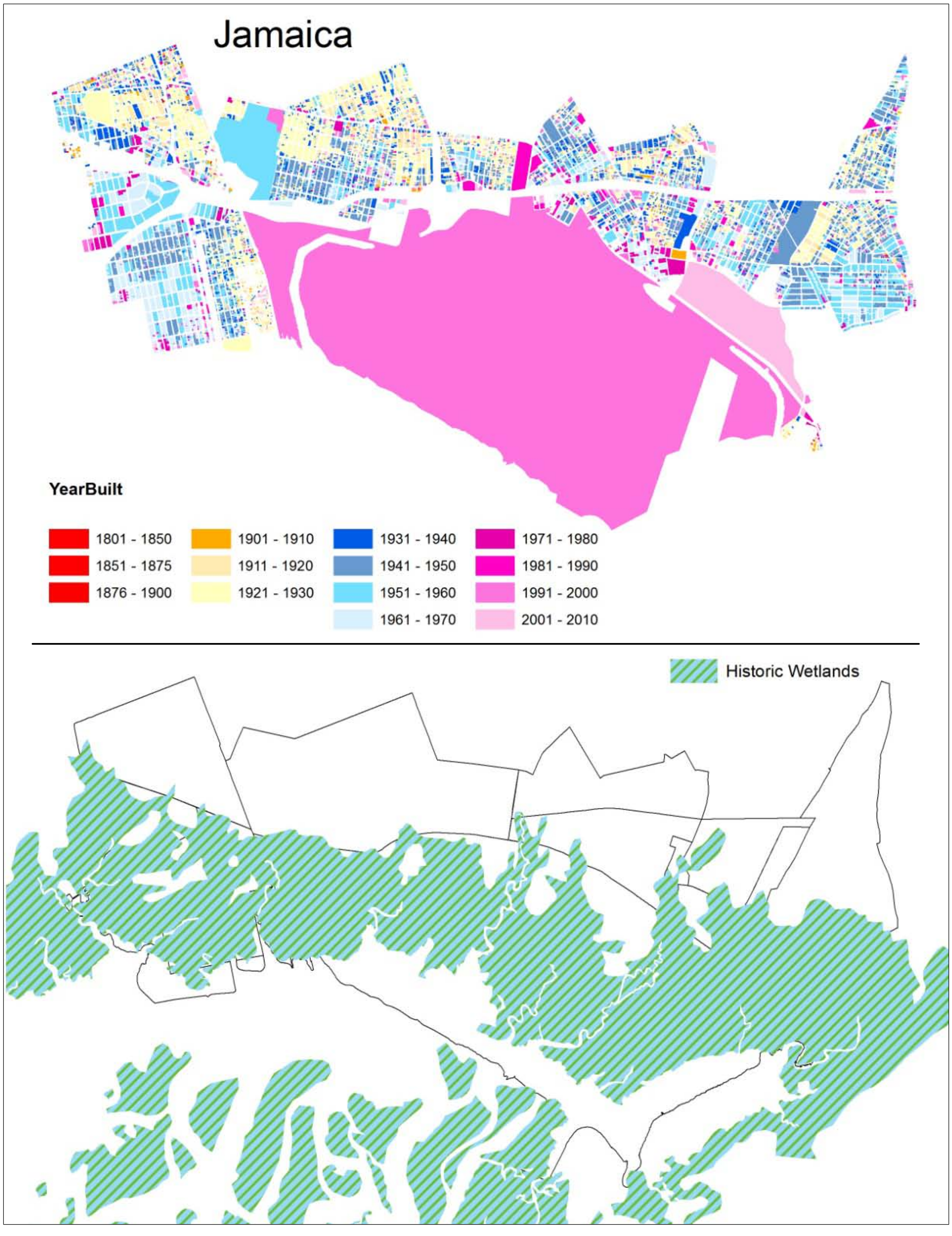


Figure VI.F.-2 Jamaica, Queens PLUTO "Year Built" Data and Historical Wetlands

Howard Beach Boundaries:

- North: North Conduit Road
- South: Jamaica Bay
- East: 104th Street and Kennedy Airport
- West: Old Mill Creek, 78th Street, Ralf Creek, and Betts Creek

Howard Beach Neighborhoods: (Figure VI.F.-1)

- Hamilton Beach
- Lindenwood
- New Howard Beach
- Old Howard Beach
- Ramblersville (approximately 25 acres)

Howard Beach is the location of three trans-Bay transportation projects: the first is the MTA's A train, the second is a toll road built in the late 1900s by Patrick Flynn that was never completed, and the third is Cross Bay Boulevard (Black 1981). (Figure VI.F.-6)

The foundation for the first project, the MTA, was laid in 1877 with a 99-year grant of a 30-foot right-of-way for the New York, Woodhaven, and Rockaway Beach Railroad. The route was from Glendale, Jamaica to Hammels, Far Rockaway along a 4.8 mile long trestle across Jamaica Bay (Bellot 1918).

In 1880, the New York, Woodhaven, and Rockaway Beach Railroad purchased a 150-foot wide right-of-way over a similar route originating from Hunters Point rather than Glendale.

Regular service began the same year (Black 1981). The increasing popularity of the Rockaway shore motivated the construction. Its popularity also resulted in the development of marine transportation. In 1882, R. Cornell White's Iron Steamboat Company started providing direct service from Manhattan to the Rockaways, offering stiff competition to the railroad (Black 1981). Railroad travel across the Bay also resulted in the creation of small fishing communities along its route, including Goose Creek, The Raunt, Broad Channel, and Beach Channel. These small fishing communities were severely affected by the 1916 closing of the Bay to fishing and shellfishing. The only one that still exists is Broad Channel. In 1888, the railroad was reorganized as the New York and Rockaway Beach Railway. Then, in 1921, ownership passed to the Long Island Rail Road. New York City purchased the right-of-way from the LIRR in 1955 and opened the IND line in 1956.

Most of the land along Jamaica's shore was owned by Frederick W. Dunton, a real estate developer. He formed the Cooperative Society of New Jersey which subleased a 150-foot wide right-of-way from Long Point, Howard Beach to Seaside, Rockaway. In 1897 the Brooklyn and Jamaica Turnpike Company was incorporated to build a road across Jamaica Bay (Anonymous 1897). The lessee, Patrick Flynn, began construction of the Jamaica Bay Turnpike, a toll road 500 feet west of the railroad. It was to also accommodate horse drawn trolleys and bicycles (Black 1981; Ranft 1997; Anonymous1901). Like so many other transportation/development projects, both would benefit from the construction. The project would provide the realtor with needed landfill and improved access (Black 1981).

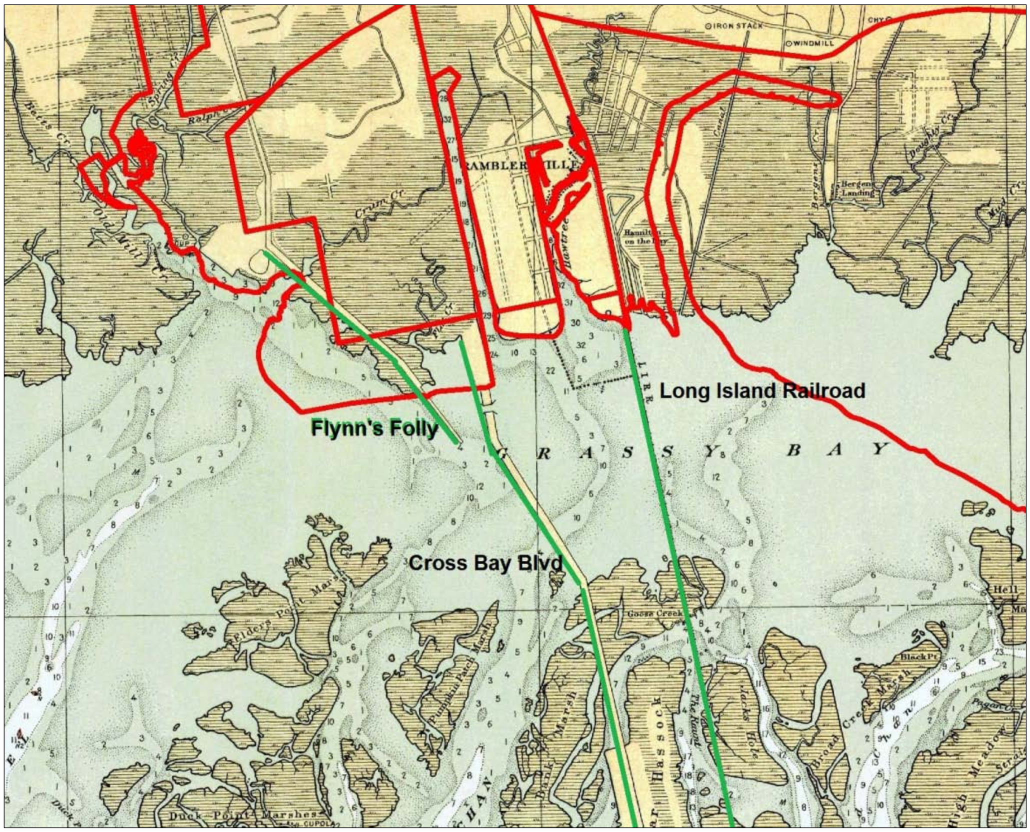


Figure VI.F.-3 Three Trans-Bay Projects in Howard Beach and land filled Hamilton Beach (Ramblersville)

By 1902, Flynn's road reached half way across the Bay. Concerned about the competition the railroad had Flynn's project shut down (Ranft 1997). There are few remnants of Flynn's road today, but some are visible in the 1924 aerial map of Howard Beach.

The Cross Bay Boulevard was completed in 1923 and ran south from Liberty Avenue across Jamaica Bay to Rockaway Beach. The water route of the Cross Bay Boulevard is quite similar to Flynn's road's right-of-way, but the boulevard connects to the mainland east of

Flynn's road, just east of the railroad. Understanding the economic advantages of a more direct route to the city residents, businesses, and towns of the Rockaways offered a number of easements to the railroads in a 1917 proposal. William Howard's Howard Estates contributed one mile on the north shore of the Bay to the railroad, and a realtor in the Rockaways did the same with land along Beach 95th Street (Anonymous1917).

Howard Beach, while a relatively small area, is divided into a number of distinct communities, each with their own history and timeline. The names have changed over time as well as the area that they encompass. Today they are known as Hamilton Beach, Lindenwood, New Howard Beach, Old Howard Beach, and Ramblersville.

Howard Beach, originally known as Remsen Landing, was the site of fishing shacks built on stilts along Hawtree Creek. By the 1800s, there were also summer houses built on pilings. Two roads led to Remsen Landing; the Road to Remsen Landing ran from Aqueduct Racetrack to the west of Remsen. On the eastern side of Remsen Hawtree Creek Road led to Jamaica Village. Within 10 years, the neighborhood developed the nickname Little Venice and had the beginnings of a year round community (Copquin 2007; Ranft 1997). Howard Beach was also a mecca for recreational and commercial fishing. When pollution and the threat of disease caused the city to close the Bay to fishing, development of the area slowed (Black 1981). A 1943 profile of Howard Beach still considered the area to be sparsely populated (New York City Market Analysis 1943).

With the building of the New York, Woodhaven, and Rockaway Railroad in 1880, the fledgling neighborhood was cut in half. To the east of the railroad were two communities: north was South Aqueduct, and south along the Bay was East Hamilton Beach. To the northwest of the railway was Remsen Landing, later to be known as Ramblersville, and the southwestern community was West Hamilton Beach (Ranft 1997). On maps from 1853 to 1964, farms, roads, and buildings can be seen east of the railroad. Then on maps from 1966 forward, the two communities of South Aqueduct and East Hamilton no longer exist. Eventually, the area formerly known as South Aqueduct became a parking lot for Kennedy Airport.

In the early 1920s, Shellbank Basin and Hawtree Creek were dug by individual investors including William Howard, and the marshes to the left and right of Hawtree Creek were land filled with the dredged material (Ranft 1997; Williams 2015).

Hamilton Beach Boundaries:

- West: Hawtree Basin
- South: Jamaica Bay
- North Russell Street
- East: 104th Street and John F. Kennedy International Airport (JFK)

Hamilton Beach, west of the railroad, was originally known as Ramblersville and West Hamilton Beach. Landfill from the dredging of Shellbank Basin and Hawtree Creek led to the establishment of Hamilton Beach (Ranft 1997). (Figure VI.F.-6) By 1926 Hamilton Beach consisted of only a dozen streets. Two bridges provided access to the neighborhood, a wooden one for vehicular traffic and a second for pedestrians (Jackson and Manbeck 2004; Jackson, Keller, and Flood 2010).

Lindenwood Boundaries:

- South: Belt Parkway
- North: North Conduit Road
- East: Cross Bay Blvd
- West: 78th Street, Ralf Creek, and Betts Creek

Lindenwood is a relatively new community that was built in the 1950s and 60s. The aerial maps of 1924 and 1954 show it to be a mix of farmland and marsh. By 1966, the area was filled and converted primarily into small apartment buildings. (Figure VI.F.-3) (Figure VI.F.-4) (Figure VI.F.-5)

New Howard Beach Boundaries:

- North: Belt Parkways
- South: Jamaica Bay
- East: Shellbank Creek, Cross Bay Blvd
- West: Old Mill Creek

Figure VI.F.-4 New Howard Beach 1924 (Fairchild 1924b)

Figure VI.F.-5 New Howard Beach 1954 (NETR Online 1954)

Figure VI.F.-6 New Howard Beach 1966 (NETR Online 1966)

Originally, New Howard Beach was predominantly marshland with a small upland running east to west. The area remained relatively undeveloped during the first half of the 1900s. In 1900, Patrick Flynn began the construction of a road across the Bay to the Rockaways. He used dredged material from Old Mill Creek to build the land portion of his road from Crescent Street in Brooklyn to Long Point in New Howard Beach. The 1924 aerial map shows the area as predominantly wetlands, the upland is farmed, and Flynn's Road is to the west. The PLUTO map shows the northern part of New Howard Beach being built between 1941 and 1950. The Rockwood development to the south was built in the early 1950s. By 1966, the majority of New Howard Beach had been land filled and developed. Much of New Howard Beach was built as private homes.

Old Howard Beach Boundaries:

- North: Belt Parkway
- South: Jamaica Bay
- East: Hawtree Basin
- West: Shellbank Basin

Starting in 1897, William Howard amassed 500 acres of marsh along what today are 99th Street and the Bay. He land filled the area, then built the Howard Landing Hotel and a dozen cottages. In 1909, he established the Howard Estates Development Company. The Howard Estates Development Company dredged the Shellbank Basin (also known as Shellbank Canal or Stillwell Basin) and used the dredged material for landfill (Jackson, Keller, and Flood 2010). Initially, the railroad station and post office were named Ramblersville, but in 1916 they were both renamed as Howard Beach.

Ramblersville Boundaries: (approximately 25 acres) (Figure VI.F.-6)

- North: 160th Street
- South: Russell Street
- East: 104th Street and John F. Kennedy International Airport
- West: Hawtree Basin, Old Howard Beach

Ramblersville, formerly Remsen Landing, is the oldest neighborhood in Howard Beach and one of the smallest in New York City. Initially, access to the neighborhood was by the New York, Woodhaven, and Rockaway Beach Railroad Aqueduct Raceway station. It was located just northeast of Ramblersville. Railroad access enabled Oscar Rust to establish a fishing station in the area of Hawtree Creek in the late 1880s. Then in 1899, the railroad (now part of the LIRR) opened a station at Ramblersville, which eventually was renamed Howard Beach (Williams 2015). It developed from a fishing outpost to a recreational community. Over the next fourteen years 300 homes were built on stilts in Ramblersville, giving it the moniker ”Venice on Stilts” (Anonymous1903).

VI. HISTORICAL ANALYSIS

G. HEMPSTEAD (ROCKAWAYS)

(see Appendix G for a complete set of Hempstead – Rockaway Peninsula Basemaps)

(see Appendix H for a complete set of Hempstead – Rockaway Neck Basemaps)

Rockaway Boundaries:

- North: Jamaica Bay
- South: Atlantic Ocean
- East: The towns of Hewlett, Hewlett Bay Park (In this discussion)
- West: Rockaway Inlet

All of the Rockaways were part of the town of Hempstead until 1898 when they became part of the newly created City of New York. As part of Hempstead, the histories of the Rockaways also included the towns of Rockaway Neck, Woodmere, Lawrence, Inwood, Cedarhurst and Hewlett. Four of the five towns, Woodmere, Lawrence, Cedarhurst, and Inwood, front Jamaica Bay. Since they were the point of egress and access to the Rockaways and share much history, they are briefly discussed in this section (Bellot 1918).

(Figure VI.G.-3)

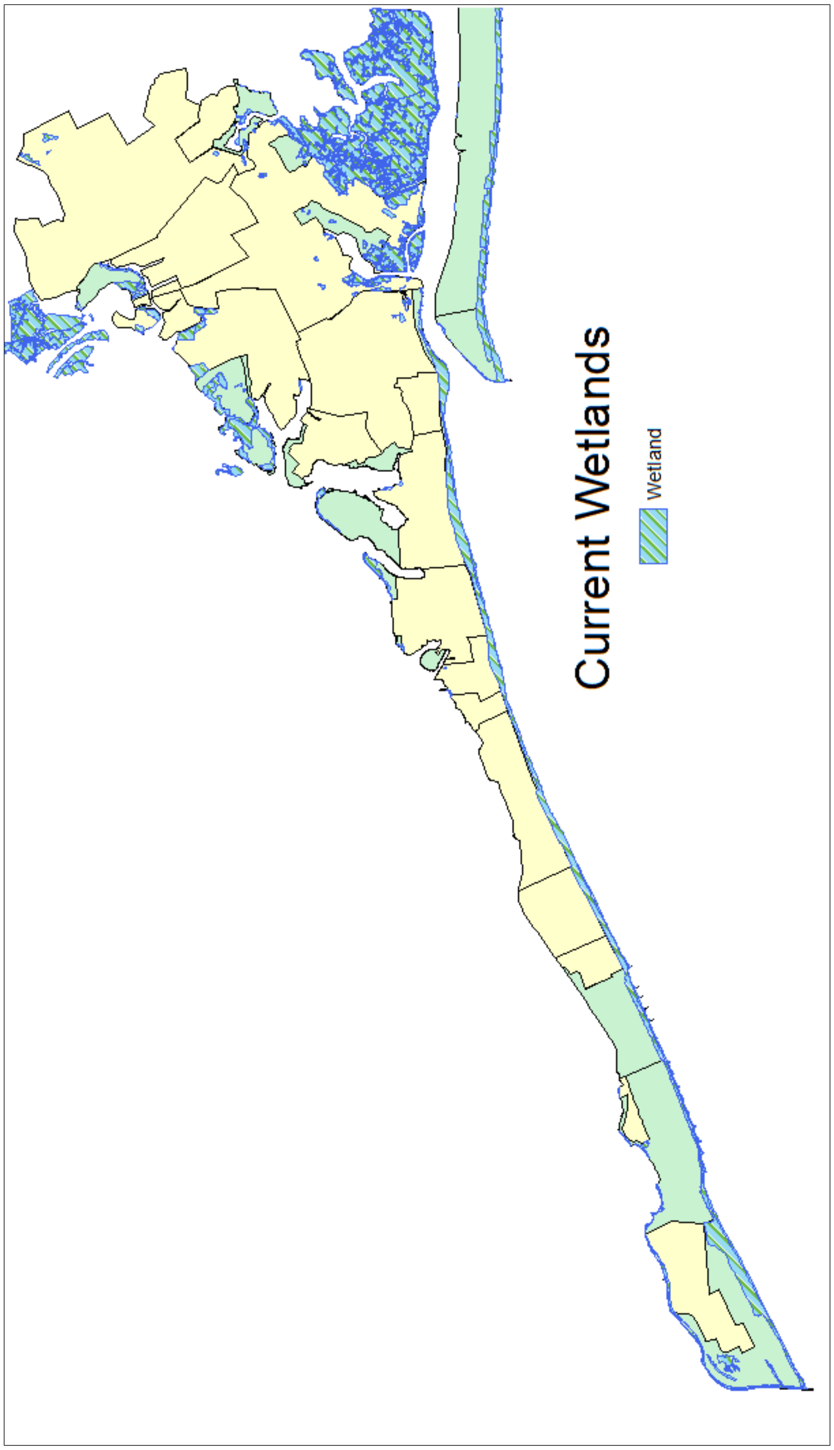


Figure VI.G.-1 Hempstead Current Wetlands

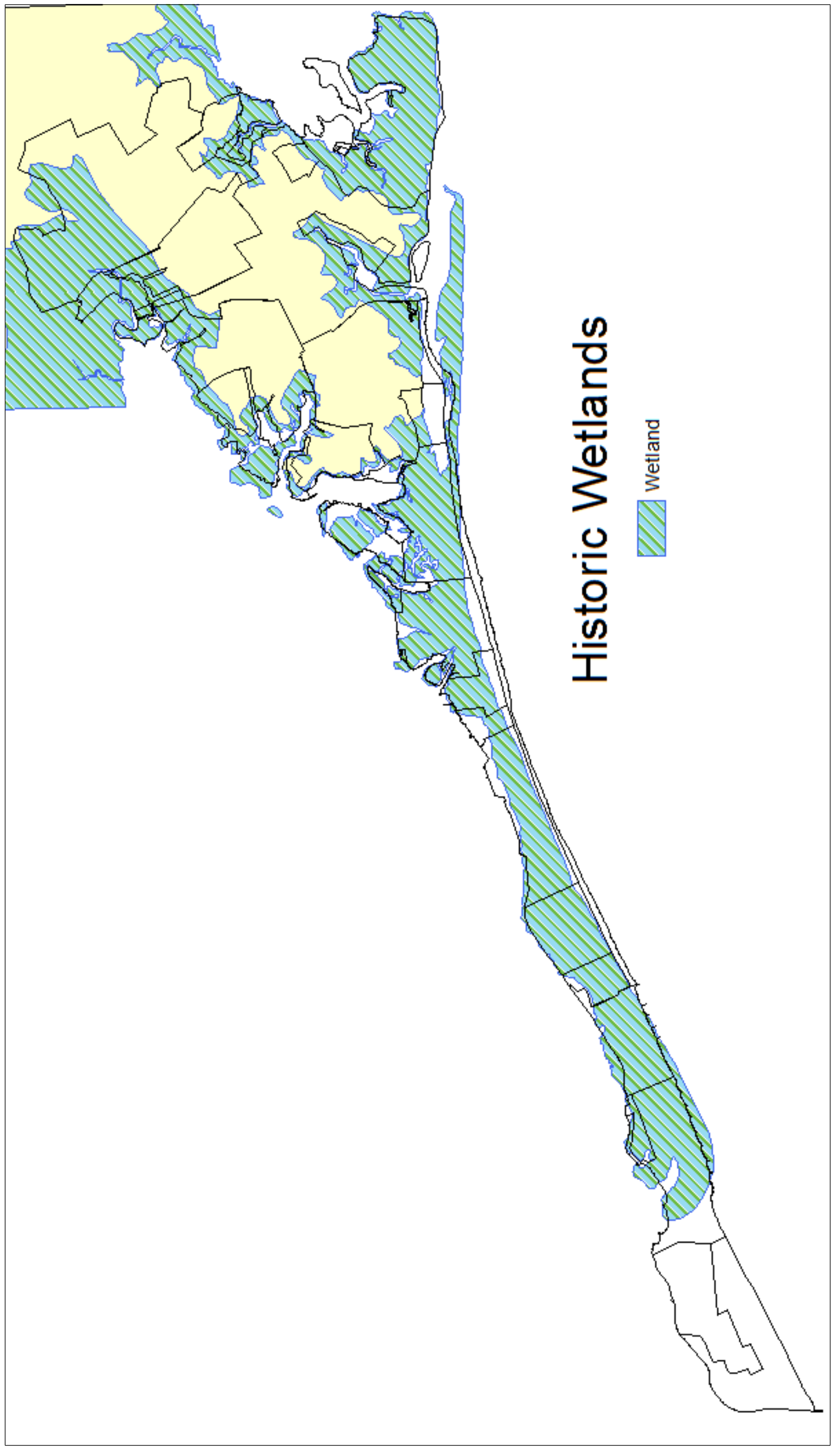


Figure VI.G.-2 Hempstead Historical Wetlands

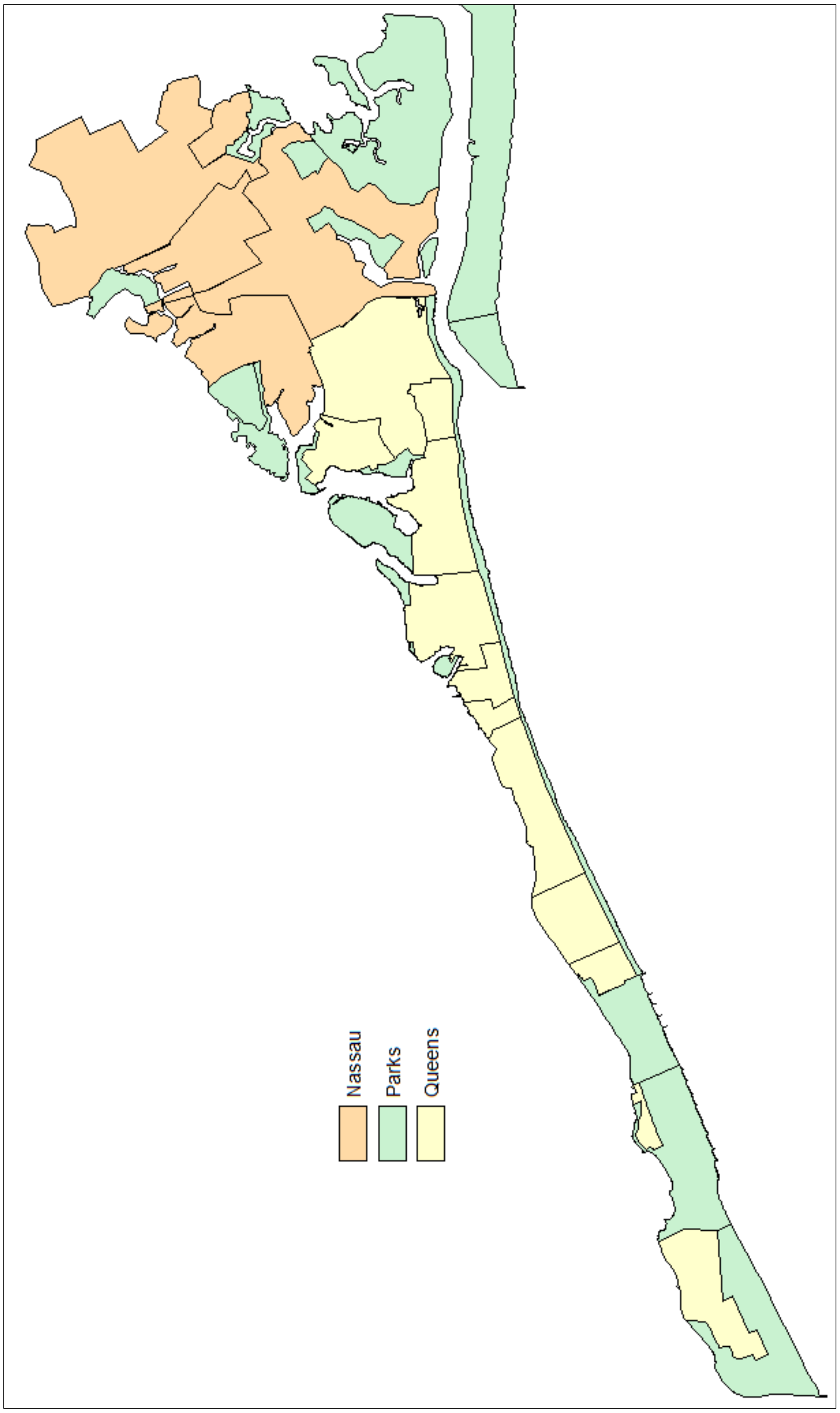


Figure VI.G.-3 Neighborhoods of the Borough of Queens and Nassau County

Rockaway Comminutes: (Figure VI.G.-4)

- Rockaway Neck
    - Cedarhurst
    - Hewlett
    - Inwood
    - Lawrence
    - Woodmere

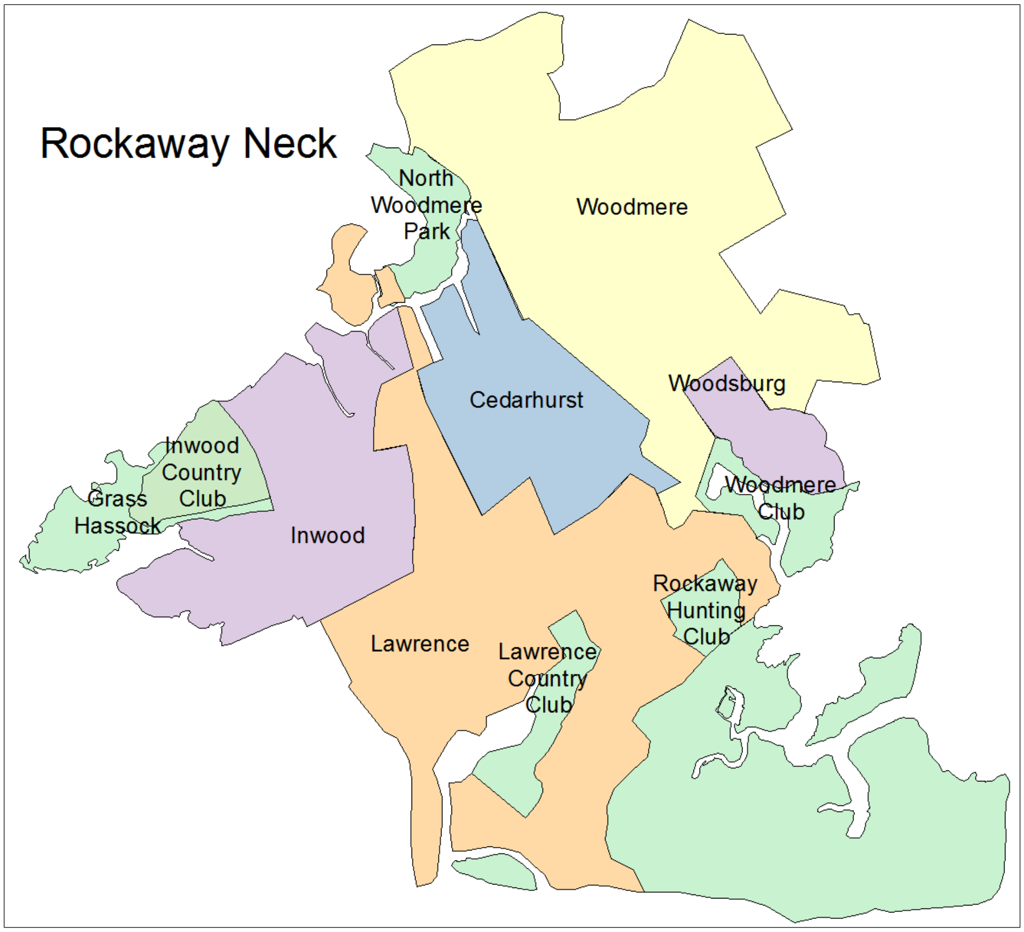


Figure VI.G.-4 Rockaway Neck Neighborhoods

Rockaway Comminutes: (Figures VI.G.-5)

- Rockaway Peninsula
    - Arverne
    - Bayswater
    - Belle Harbor
    - Breezy Point
    - Edgemere
    - Far Rockaway
    - Fort Tilden
    - Hammels/Rockaway Beach
    - Jacob Riis Park
    - Neponsit
    - Seaside/Rockaway Park
    - Roxbury

Figures VI.G.-5 Rockaway Peninsula Neighborhoods

The Rockaways include both the uplands of Rockaway Neck and the wetlands of the Peninsula. The south shore of the Peninsula was composed of sandy beaches and dunes, while the north shore was marsh.

Rockaway Neck is one of the two major uplands (the other being Canarsie) found close to the shore of the Bay (Mather 1847). The Peninsula is a barrier island composed of unconsolidated sediment that forms the south shore of Jamaica Bay. Its dynamic existence is due to the processes of long shore drift and weather. Long shore drift causes accretion and erosion, a continuous process whose consequences can appear in a year or over centuries. Hurricanes and Nor'easters can make dramatic changes in the coastline in just days. Storms can create inlets or sandy islands overnight which can be filled or just as easily eroded over time. The overarching result is the continuing modification and elongation of the Peninsula. (Figure VI.G.-6)

In Hassler's map of 1844 the Peninsula was 6.9 miles long. By 1930, when a jetty was installed at the western tip of Rockaway Point, it was 11.3 miles long. (Figure VI.G.-7) The placement of the jetty prevented further westward expansion, but the accretion of sediment has caused the western end of the Peninsula to increase in size, elevation and stabilization. If not for a jetty, the Peninsula might have grown an additional half mile in the past eleven years (assuming an average growth of 270 ft per year). These strong forces keep the Peninsula constantly in flux, changing its size, shape and ecology along its entire length.

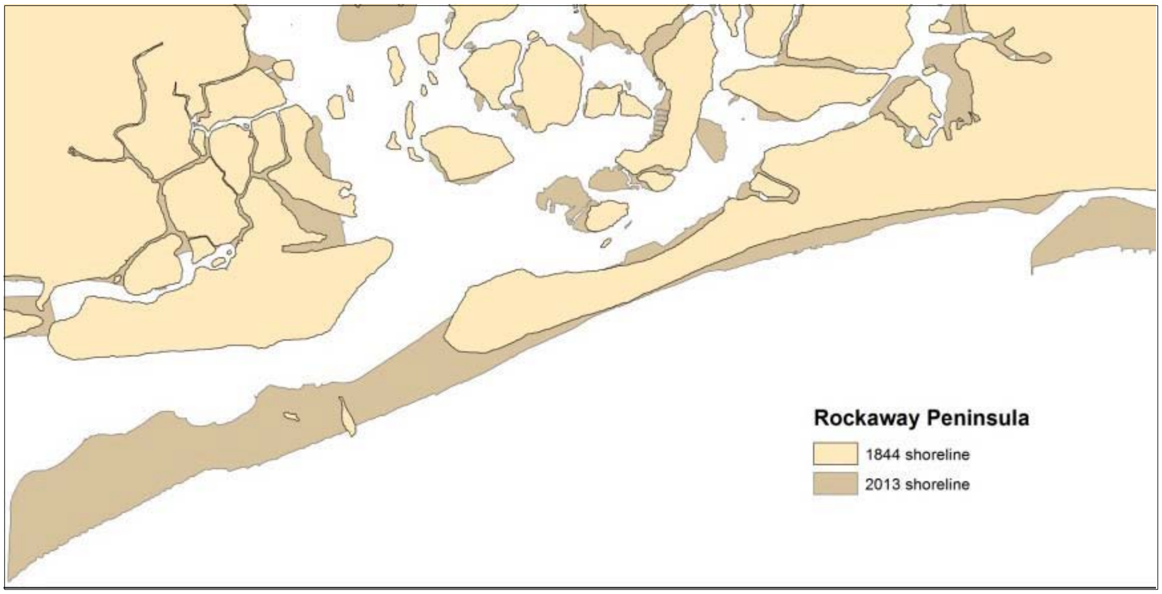


Figure VI.G.-6 Rockaway Peninsula from 1844 to 2013

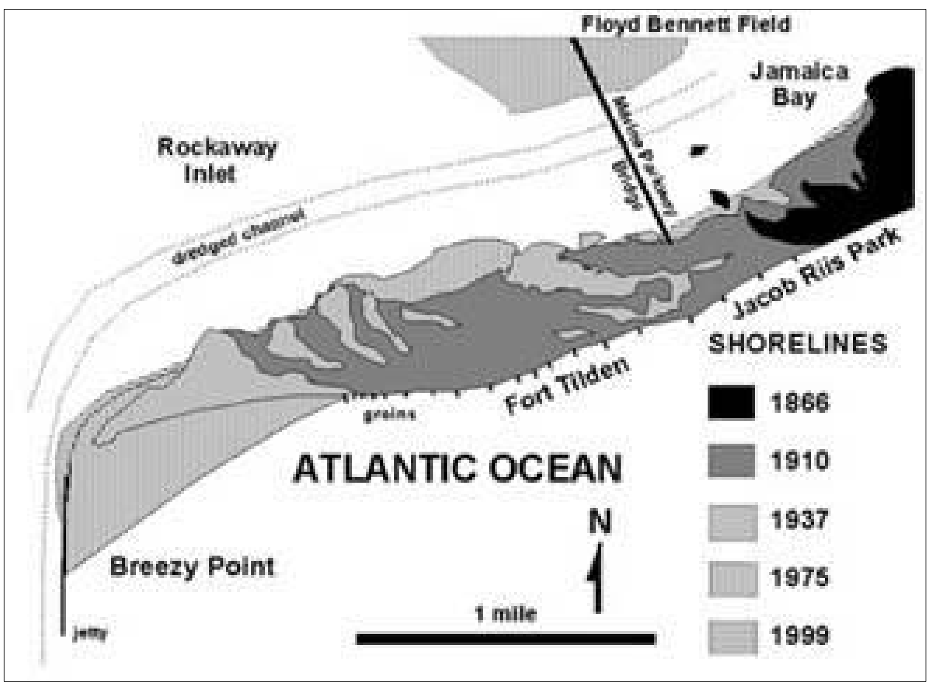


Figure VI.G.-7 Rockaway Peninsula 1844, 1866, 1910, 1937, 1975 and 1999

(Tanguay 2010)

The heel of the Rockaway Peninsula has also been an area of dramatic change. Looking at maps from 1776 onward, barrier spits attached to the heel of Rockaway Neck have appeared and disappeared over the last few centuries. In Hassler's map of 1844, the barrier island disappeared only to reappear in the 1860s. Over the next decade the island became more substantial. At its peak it was 1/4 mile wide, a mile long, and appeared to be substantial and stable enough to be developed as a summer resort. The spit was joined to the Peninsula at Beach 37th Street, further west than previous formations. It created a Bay directly under the heel of Rockaway Neck. This barrier island (spit) had two names, Hog Island and Far Rockaway Beach. The newly formed Bay was called the Bay of Far Rockaway. (Figure VI.G-8) (Figure VI.G.-10) The barrier island's existence was dynamic. It was severely eroded in 1893, by an unnamed hurricane. In 1905, Hog Island re-stabilized. It was even more attractive than before, being closer to the mainland, and foot bridges were built across the narrow Bay. Over time the reincarnated Hog Island became unstable and slowly eroded away, disappearing completely by the 1920s. In spite of the capricious nature of the Rockaways, its attractiveness was too great to prevent development (Norcross 2014; New York Historical Society 2011; Onishi 1997).

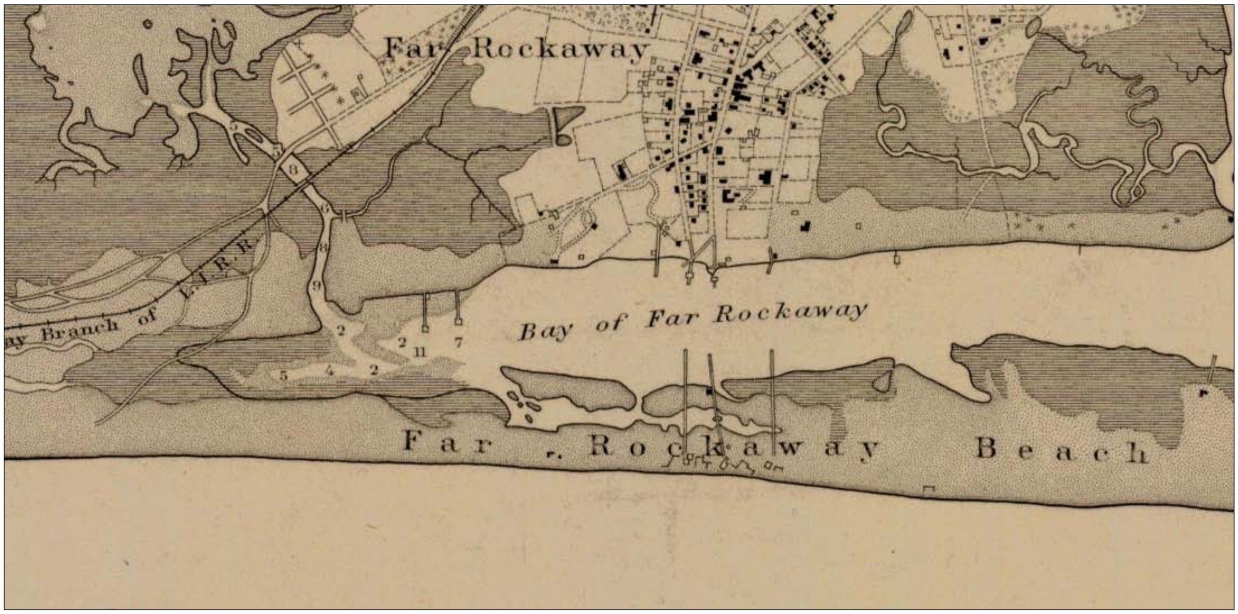


Figure VI.G-8 Bay of Far Rockaway (Pritchett 1899)

note: Norton's Creek canal connecting Jamaica Bay to Bay of Far Rockaway.

Until the 1830s, the primary value of the Rockaways was the salt hay that grew in the wetlands as feed for livestock. In the early 1830s, investors started buying properties along the Atlantic shore (Beach 15^{th} to Beach 25^{th} Street). The Marine Pavilion Hotel and Resort was the first major hotel to open on the Peninsula. The hotel can be found in the 1844 and 1852 maps of the Rockaways. (Figure VI.G.-9) The hotel gave the area a national reputation as a summer resort. It existed for only 20 years, burning down in 1864.

Figure VI.G.-9 Marine Pavilion Hotel in 1852

(Lionel Pincus and Princess Firyal Map Division NYPL 1852)

Until the arrival of the Marine Pavilion, there were only two roads to the Rockaways. (Figure VI.G.-11) The first was a path made by Native Americans that was traversable only by foot and horseback. It traveled northwest across Hook Creek, behind what is today the John F. Kennedy International Airport, to Jamaica. Today's Rockaway Turnpike and Rockaway Boulevard follow a similar route. The second and better road ran northeast connecting Far Rockaway with Hempstead. Today this route is known as Broadway (Bellot 1918).

Figure VI.G.-10 Where the Marine Pavilion Hotel would have been in 1870

At the same time that the Marine Pavilion Hotel opened, the same investors formed the Jamaica and Rockaway Turnpike Company. They completed a shell road over the path that travelled northwest behind what is now John F. Kennedy International Airport. This road ran directly from Jamaica to the Marine Pavilion Hotel. It was a shorter route and made travel from Brooklyn to the Rockaways easier (Bellot 1918). With improved access and a new reputation as a summer resort, the Rockaways were poised for development.

The attractiveness of the Rockaways prompted much speculation. As early as 1833, ideas were explored to extend public transportation to the Rockaways. By 1868, rail lines had been built only as far as Valley Stream. Then, in 1869 the South Side Railroad extended the route to Far Rockaway. The South Side Railroad extended the line again in 1872, constructing the "Rockaway Railway" running 4 miles along the ocean front from Wavecrest to Rockaway Beach. (Figure VI.G.12)

Figure VI.G.-11 Two Main Roads to Far Rockaway

(David Rumsey Historical Map Collection 1811)

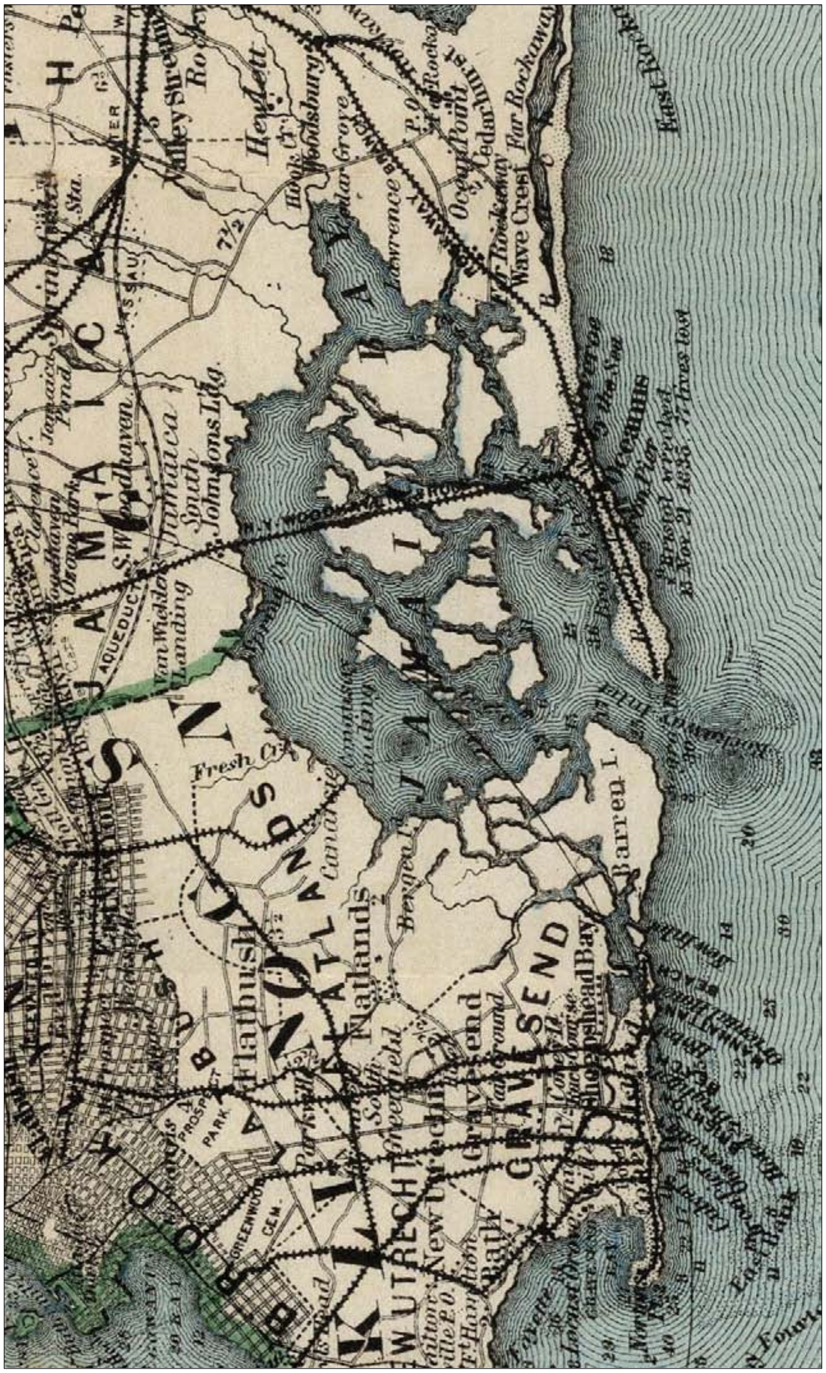


Figure VI.G.12 Railroad lines to Far Rockaway, Canarsie, and Coney Island

(David Rumsey Historical Map Collection 1891a)

In the Rockaways, transportation and development were tied tightly together. Developers were aware of the importance of access to the value and marketability of their endeavors. Often developers gave land to the railroads as incentives to attract transportation services to their communities.

In 1873, the Long Island Railroad Company built the Springfield "cut-off" from Jamaica to the Rockaways. The first station in the Rockaways was Cedarhurst. When the tracks reached the Peninsula they ran parallel with those of the South Side Railroad. The Long Island Rail Road trip from Jamaica was seven miles shorter than the South Side route. The Long Island Rail Road Company acquired the South Side Railroad and discontinued operation over the shorter route.

New Yorkers weren't just looking for a place by the beach. Another impetus to the development of the Rockaways was the exodus of Manhattanites from the city's deplorable sanitary conditions and disease (New York Parks Department 2001). Disease was rampant in New York City and there were numerous epidemics including; the Yellow Fever epidemic from 1795 to 1804, the Cholera epidemic of 1832, the Cholera outbreak of 1849, and the Cholera epidemic of 1854 (The Weissman Center for International Business 2014).

VI. HISTORICAL ANALYSIS

H. AIRPORTS

(see Addendum I for a list of airports in Greater New York)

After the invention of the airplane in 1903 aviation grew at an extraordinary rate. By the end of World War I there were 115 permanent airfields in the United States (Blakemore and Linck 1981). There were approximately 700 airports in 1928, and in 1929 construction was started on an additional 900 new airports across the country, more than the number of airports that had already been in existence (Pilat 1929). (Figure VI.H.-1)

The development of aviation in New York had five primary locations; the Hempstead Plains, Jamaica Bay, southern Brooklyn, northern Queens, and northeastern New Jersey (Masefield 1972). Chronologically, the center of aviation in New York began in the Hempstead Plains in the 1910s, then the Rockaways and Floyd Bennett Field in the 1920s, LaGuardia in the 1930s, and John F. Kennedy International Airport in the 1940s. New Jersey had a parallel and intertwined airport history (Masefield 1972).

The Hempstead Plains was the original hub, being the most geographically suitable location. It was the only prairie east of the Alleghany Mountains and offered a perfect field for take-offs and landings. World War I saw seaplanes landing in Port Washington and the Rockaways. Greater New York (latitudes 40.10' to 41.00, longitudes 73.00' to 74.30W) had been home to 105 airfields on 70 sites by 1972 (Masefield 1972).

VI. HISTORICAL ANALYSIS

H. AIRPORTS

1. Floyd Bennett Field

In 1927, the Department of Commerce appointed a 'Fact-Finding Committee on Suitable Airport Facilities for the New York District' (Blakemore and Linck 1981). It was established by the Federal government over its concerns that New York City had yet to establish its own municipal airport (Blakemore and Linck 1981; Cody, Auwaerter, and Curry 2009).

The commission's report, filed on November 29, 1927 listed 17 airports already in existence in the greater New York area: 3 governmental, 4 commercial, and an additional 9 intermediate airports. The government fields included Mitchel Field in Nassau County, Rockaway Naval Air Station in Queens, and Miller Field on Staten Island. The four commercial fields were Roosevelt and Curtiss Fields in Nassau County, and Hadley Field and Teterboro Airport in New Jersey. The existence of so many airports could have explained New York's lack of urgency to build its own municipal airport (Blakemore and Linck 1981; Cody, Auwaerter, and Curry 2009).

The Fact Finding Committee recommended six primary sites: two in New Jersey and four in New York, as well as four secondary sites (Cody, Auwaerter, and Curry 2009). The first choice of the Committee was Juniper Valley in Middle Village, Queens. It was selected because it had an elevation of 100 feet and had comparatively little fog. New York City chose Barren Island, one of the secondary sites on which to build its municipal airport. There were three reasons why New York chose Barren Island.

1. City, state, and federal funds to the tune of $100,000,000 had already been spent by the Department of Docks toward the creation of an international harbor at the same site. It was thought to be beneficial to the project to locate the airport in the anticipated commercial zone (Blakemore and Linck 1981).
2. The city already owned the land. All the other sites would have required the City to purchase the land (Blakemore and Linck 1981; Cody, Auwaerter, and Curry 2009)
3. A consultant named Clarence Chamberlain, an American aviator, recommended Barren Island. Because of its location; fog was not a problem, and being far from the city there were not any obstructions to take-offs and landings (Blakemore and Linck 1981).

Before New York thought to act on the committee's recommendations, New Jersey began construction on Newark Airport. Newark was completed on October 1, 1928 (Cody, Auwaerter, and Curry 2009). It was Newark Airport that ignited New York City's efforts to build Floyd Bennett Field. Without competition, Newark Airport served as the municipal airport for greater New York City. Flights booked to New York City would arrive at Newark Airport. In addition, Newark supplanted Hadley airport for a lucrative airmail contract with the United States Post Office (Cody, Auwaerter, and Curry 2009; Blakemore and Linck 1981; Pilat 1929).

The Air Mail Act of February 2, 1925 allowed nongovernmental carriers to provide airmail service. This made it the driving force behind the development of public aviation in the United States. Passenger flight was not lucrative, as the prices charged to encourage people to choose air travel over land travel did not cover costs. Like most airports, Newark could only cover operating costs by securing airmail contracts with the United States Post Office (Cody, Auwaerter, and Curry 2009). To win the contract, Newark adhered to the Post Office's requirements. It also built the Pulaski Skyway. The Skyway linked up with the newly built Holland Tunnel, giving the airport fast access to New York City.

New York City and its mayors, first Walker and then LaGuardia, were incensed over Newark Airport positioning itself as New York's airport and over the loss of revenues from the airmail contract (Cody, Auwaerter, and Curry 2009; Blakemore and Linck 1981). The Department of Docks started the construction of Floyd Bennett Field in 1928, and in May of 1931 the first stage was completed. The airport, which over time covered 380 acres, was built in four stages costing the city a total of $10,500,000. Efforts were made to satisfy the requirements of the Postal Service, and access to the airport was improved with the widening of Flatbush Avenue and the installation of bus service. Since passenger traffic did not cover their operating expenses, the airlines refused to use Floyd Bennett Field if it did not get the Postal Department contract (Cody, Auwaerter, and Curry 2009).

The battle for Floyd Bennett Field as the airmail terminus continued until 1936. The decision was made in favor of Newark Airport on March 21, 1936. New York City had not shown that its services would be better than those of Newark nor would it be less expensive. In spite of the City's efforts, Floyd Bennett Field was never designated the airmail terminal by the Post Office. Without the commercial airlines opening service in Floyd Bennett Field, the airport became a commercial failure (Blakemore and Linck 1981). With the loss of the contract, New York City leased the airfield to the United States Coast

Guard for 50 years (Masefield 1972). It was sold to the United States Navy in 1941, and after World War II it again became a municipal airport until it was given to the National Parks Service in 1974 (Blakemore and Linck 1981). Originally only 387, acres the airport eventually grew to become 1,288 acres (Masefield 1972) (see Appendix I for a this of Airports in greater New York)

Aerodrome Name	**Year**	**Location**	**Lat_W**	**Long_ N**
Aviation Country Club	1929	Nassau	40.47	73.33
Barren Island	**1927**	**Jamaica Bay**	**40.36**	**73.53**
Belmont Park Race Track	1910	Nassau	40.43	73.43
Brighton Beach	**1908**	**Coney Island**	**40.34**	**73.57**
Brindley Field	1918	Nassau	40.45	73.36
Brooklyn Coast Guard Air Station	**1936**	**Jamaica Bay**	**40.36**	**73.54**
Brooklyn Seaplane Base		**Mill Island**	**40.37**	**73.55**
Central Park Flying Field		Nassau	40.45	73.40
College Point	1919	Queens	40.47	73.52
Curtiss Airport Valley Stream	1929	Nassau	40.41	73.43

Aerodrome Name	**Year**	**Location**	**Lat_W**	**Long_ N**
Curtiss Field, Mineola	1920	Nassau	40.44	73.37
Edo Seaplane Base		Queens	40.47	73.52
Fitzmaurice Field	1928	Nassau	40.41	73.28
Floyd Bennett Field	**1928**	**Jamaica Bay**	**40.36**	**73.53**
Flushing Airport		Queens	40.47	73.50
Garden City Aerodrome		Nassau	40.44	73.37
Glenn H. Curtiss Airport	1927	Queens	40.47	73.53
Grumman Airport	1936	Nassau	40.45	73.30
Hazelhurst Field	1917	Nassau	40.44	73.37
Hazelhurst Field 2	1917	Nassau	40.44	73.37
Hempstead Plains Aerodrome	1914	Nassau	40.44	73.37
Hicksville Air Park		Nassau	40.47	73.33
Holmes Airport		Queens	40.46	73.54

Aerodrome Name	**Year**	**Location**	**Lat_W**	**Long_ N**
Idlewild Int. Airport	**1948**	**Jamaica Bay**	**40.38**	**73.47**
Jamaica Bay Airport	**1936**	**Jamaica Bay**	**40.38**	**73.47**
John F. Kennedy International Airport		**Jamaica Bay**	**40.38**	**73.47**
La Guardia Airport	1939	Queens	40.47	73.53
MacArthur Municipal Airport		Nassau	40.48	73.06
Mineola 1 Aviation Ground	1909	Nassau	40.44	73.37
Mineola 2 Aviation Ground	1914	Nassau	40.44	73.37
Mitchel Field		Nassau	40.44	73.37
Mitchel Field Air force Base	1918	Nassau	40.44	73.37
Naval Air Station (Floyd Bennett Field)	**1931**	**Jamaica Bay**	**40.36**	**73.53**
North Beach	1925	Queens	40.47	73.53
Port Washington Marine Base	1919	Nassau	40.50	73.42

Aerodrome Name	**Year**	**Location**	**Lat_W**	**Long_ N**
Queens County Airport		**Jamaica Bay**	**40.39**	**73.48**
Rockaway Beach Airport		**Jamaica Bay**	**40.33**	**73.52**
Rockaway Point N.A.S.		**Jamaica Bay**	**40.33**	**73.54**
Roosevelt Field		Nassau	40.44	73.37
Roosevelt Field Heliport		Nassau	40.44	73.37
Roosevelt Field Unit 1	1920	Nassau	40.44	73.36
Roosevelt Field Unit 2	1930	Nassau	40.44	73.37
Sands Point Seaplane Base	1963	Nassau	40.50	73.42
Sheepshead Bay Race Track	**1910**	**Jamaica Bay**	**40.35**	**73.57**
Sunrise Airport		**Jamaica Bay**	**40.38**	**73.47**
Wright Flying Field	1916	Nassau	40.45	73.36

Figure VI.H.-1 Airports of Brooklyn, Queens and Nassau County

(Airports in bold type are located in the study area)

VI. HISTORICAL ANALYSIS

H. AIRPORTS

2. John F. Kennedy International Airport

With the failure of Floyd Bennett Field, Mayor LaGuardia tried a second time to acquire the Post Office contract with the construction of the New York City Municipal Airport #2 at North Beach, now known as LaGuardia Airport. The airport was built on the site of the 105-acre Glenn H. Curtis Airport in North Beach which was established in 1929. It was renamed in 1937 when it was purchased by the City. The new airport covered 550 acres and cost the City $46,000,000. One of the main reasons that Floyd Bennett Field lost out to Newark was because the trip between Newark and the City was faster that the trip from Floyd Bennett to the City. North Beach was closer to the City and the newly constructed Queens-Midtown Tunnel made the trip much faster. Commercial airlines committed to use the airport even before it opened, and within one month of its opening the postal service decided to split the contract between Newark and North Beach (Cody, Auwaerter, and Curry 2009).

In spite of its early success, LaGuardia Airport had some problems. Much of the airport had been built on landfill which had been done improperly. The airport began sinking six inches a year, in some places as much as 5 to 6 feet. But an even greater problem was that there was no room for further development. With the exponential growth of air travel, Mayor LaGuardia wanted to build a new airport for New York City by 1940. LaGuardia Airport could handle 42 operations per hour; however, New York was looking for an airport that could handle 360 operations per hour (Meyers and Young 2011).

Construction began on that new airport in 1942. The initial 1,000-acre airport was located on the eastern shore of Jamaica Bay, part of which had previously been the Idlewild Golf Course, and the rest was marsh. The airport eventually grew to encompass 4,930 acres--one-sixth the area of the Bay (Lefkowitz 1972). It cost $71,000,000 to landfill another $100,000,000 was needed to prepare the land (Meyers and Young 2011). Hydraulic fill was pumped from Jamaica Bay's Grassy Bay. The site was chosen because takeoffs and landings could take place over water.

During construction the airport was unofficially named Idlewild. It was dedicated on July 1, 1948 as the New York International Airport. It was renamed the John F. Kennedy International Airport in December of 1963. In the 1960s, Runway 4L was extended into the Bay. It blocked the northwest area of the Bay known as Grassy Bay seriously affecting the Bay's ability to recycle its waters with the ocean greatly increasing residence time. Currents in Jamaica Bay run clockwise and this impediment causes stagnation and a reduction of the water's oxygen content (Lefkowitz 1972; Olsen 2008). Residence is an indicator of how long a pollutant or a biological organism will reside in a bay/estuary before being forced out of its mouth due either to river discharge or tidal flow. Residence time in Jamaica Bay has increased from 7 days to more than 30 (Gordon et al., 2001).

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VII. SUMMARY OF FINDINGS

This observed analysis focused on the effect of transportation and sanitation on land use/land cover change and identified the decision makers of land use land/cover change and how they responded to the drivers of change. The summary is structured as follows:

First: a chronological discussion of land use/land cover change across the Jamaica Bay estuary.

Second: a discussion of the decision makers and how they responded to the drivers.

Third: a discussion of sanitation as a driver of change in Jamaica Bay.

Fourth: a discussion of transportation as a driver of change in Jamaica Bay.

Fifth: a discussion of other drivers of change in Jamaica Bay.

Chronology

Most of the development along the shore of Jamaica Bay was by private enterprise rather than by public entities. This was most certainly true for the southern shore of the Bay in both the Rockaways and Coney Island. Driven by the horrendous sanitation conditions within the cities of Brooklyn and New York, anyone who could afford to spent time away from the cities--especially in the summer (Miller 2000).

Development in the Rockaways began in Far Rockaway. In the 1830s the same company that built the Marine Pavilion Hotel on the Atlantic side of the Peninsula also built Rockaway Turnpike, a road that connected the Peninsula to the rest of the world (Bellot 1918). The model of a partnership between transportation and real estate development in Jamaica Bay began.

Over the next several decades Far Rockaway grew and filled with hotels that catered to people escaping from the city. Growth continued as the communities along the peninsula established rights-of-way (ROW). Rail transportation spread across the peninsula to Holland in the 1850s and the Hammels/Rockaway Beach shortly thereafter (Bellot 1918).

The Rockaways were also responsible for the early 1860's emergence of the north shore fishing communities of Canarsie and Hamilton Beach in the 1880s. In exchange for real estate, a promise was made and kept by fellow developers to establish rail service to Canarsie and, from there, ferry service to Rockaway Park (Bellot 1918). Canarsie began to bloom as 1) a transportation hub, offering ferry service to Rockaway Beach and 2) as a recreational destination in its own right (Black 1981).

The Rockaways were being developed as elite summer communities with strict regulations to dissuade undesirable elements (Bellot 1918). The development of Coney Island was quite different. There was very little regulation, which allowed it to develop more as an amusement center. Competition on Coney Island was fierce between the neighborhoods of Brighton Beach, Coney Island, West Brighton, and Manhattan Beach as each neighborhood developed its own transportation network. The trip to Coney Island was short and inexpensive compared to the trip via Canarsie. Eventually, Coney Island attracted hundreds of thousands of day trippers while interest in Canarsie declined (Cudahy 2009).

In the late 1860s, rail service came to Far Rockaway, traveling south from Valley Stream through the towns along Rockaway Neck, including Bayswater, Cedarhurst, Hewlett, Inwood, Lawrence, and Woodmere. With it came the real estate development of upscale year round communities in these towns (Bellot 1918).

In 1880, a railroad was built on trestles across the Bay to the Rockaway Park. The shorter and easier trip continued the push of development. The train access spurred Rockaway Park to greater heights, reaching Arverne in1880, then Edgemere in 1890. Arverne and Edgemere were both stops on the rail line between Far Rockaway and Rockaway Beach (Bellot 1918). On the north shore the railroad passed between Howard Beach and Aqueduct Race Track. Initially, it provided limited rail service to Howard Beach (at that time known as Ramblersville). However, as William Howard began his development of Howard Beach, a permanent station was established (Anonymous1914).

In 1900 Belle Harbor, benefitting from the railroad service to neighboring Rockaway Park, was laid out and sold in plots. The following decades saw the western end of the Rockaway Peninsula (Neponsit, Roxbury, Breezy Point) developed as inexpensive bungalow communities. Compared to the more expensive neighborhoods to the east, investment in transportation was not as worthwhile an investment.

In the 1860s along the north shore of the Bay, Bergen Beach and Howard Beach also enjoyed growth as a place for summer recreation. Bergen Beach was, like Canarsie, an alternative to Coney Island. It, too, began to decline with the introduction of inexpensive fares to Coney Island's beaches. In 1918, land fill connected Bergen Beach to the mainland (Black 1981). However, it did not provide enough incentive for real estate development so it closed in 1920. The construction of the Shore Parkway in the 1940s did not attract investment either. It was not until the 1960s that real estate development in the area took hold.

Howard Beach was the location of three cross-bay transportation projects to the Rockaways: the Long Island Rail Road (1880), Flynn's Folly (1902), and the Cross Bay Boulevard (1923) (Black 1981; Anderson 2003). Rail service continues today, as the New York City Metropolitan Transit Authority took over the ROW, and so does the Cross Bay Boulevard. Flynn's Folly was a failed attempt to build a toll road across the Bay. The original community built in 1899 by William Howard is today Hamilton Beach. Like the Rockaways, it was first developed with a large hotel and eventually became a residential community . The area west of the Shellbank Basin, like most of the Bays' north shore, was much slower to develop and, as late as 1954, half of it was still undeveloped and 1/3 of it was still wetlands.

Other than Howard Beach, Canarsie, and Mill Island, the north shore of the Bay was of much less interest to developers. It lacked the fresh breezes off the Atlantic Ocean, and without them the likelihood of profits was dimmer. A certain level of profit was needed to warrant an investment in transportation. There was approximately a 30-year gap between the residential development of the south shore and the rest of the north shore of Jamaica Bay: New Howard Beach (1940), Lindenwood (1950), Bergen Beach (1960), Georgetown (1960), and Spring Creek (1970-2010). All of the above, with the exception of Spring Creek, was by private investment.

Private/Public Decision Makers

Private Decision Makers

Private land owners/managers were driven by profit. In all situations, both recreational and commercial, they made significant investments in transportation. The model was set early on with the builders of the Marine Pavilion Hotel; the same also built the Rockaway Turnpike. Later on, land was donated for the establishment of rail stations all along the Rockaways. The industries on Mill Island took it upon themselves to land fill and dredge Mill Channel. William Howard dredged canals in Howard Beach (Anonymous1915).

Private commercial development along the Bay was limited. It took place at only two locations: Barren Island and Mill Island. Barren Island's first factories opened in the 1850s and started to decline in the 1920s. On Mill Island industry arrived in 1910 with the expectation of the commercialization of the Bay with transportation facilities to match. The commercial inhabitants of Mill Island had taken on the responsibility to landfill the island and dredge the channel, but the promise of rail transportation and the development of the Jamaica Bay seaport was never fulfilled, so industry left shortly thereafter.

Public Decision Makers

The earliest public investment of the Bay began with the Rockaway Peninsula. In 1910 with the City's purchase of Jacob Riis Park. The city wanted to save some of the area's wonderful beaches for the public. Later in the decade, during World War I, the federal government built Fort Tilden alongside an existing Coast Guard Station. In 1920, the City built Floyd Bennett Field, the Shore Parkway in the late 1930s, and John F. Kennedy

International Airport in the 1940s. The Bay was also seen as a solution to the City's tremendous refuse problem. The City opened the Edgemere Landfill in 1938, the Pennsylvania Avenue Landfill in 1956, and the Fountain Avenue Landfill in 1961.

A swath along the entire north shore of the Bay was land filled by the city in the 1940s for the construction of the Shore Parkway, but it had little effect on the development of the north shore. The Parkway, built by Robert Moses, was not intended to help with community development. It was built to connect the string of parks he had built along the south shore of Long Island and to make them accessible only by automobile. Spring Creek was/is the last parcel along the Bay to be developed. Land filled by the city, profit was not a driver in its development. As late as 1954 the land was relatively untouched.

Sometime between 1934 and 1937, Hendrix Creek was widened. Some changes started to take place on the western third of Spring Creek, the area north of the Pennsylvania Avenue Landfill. At the same time, the city filled the land along the west bank of Hendrix Creek, probably using the dredge material from Hendrix Creek, for a waste treatment plant. It took the city another 15 years to make additional changes in the area. By 1954 it was land filled and Pennsylvania Avenue was extended to the Shore Parkway. Another 20 years passed and in 1974, Starrett City, a subsidized housing project, was built. The eastern portion of Spring Creek is still partially undeveloped.

Sanitation

Sanitation was immensely important as an underlying and proximate driver of land cover change and responsible for land use modification. The sanitation problems of the cities of New York and Brooklyn were an underlying factor in the development of the Rockaway Peninsula, Coney Island, Canarsie and, to a lesser extent, Howard Beach. Disease and foul conditions were a strong motivator for people to seek refuge outside of the cities. Efforts to improve conditions inside the City forced the relocation of rendering factroies, fertilizer production, and other noxious industries to Barren Island.

The creation of the three large landfills, Edgemere, Fountain Avenue, and Pennsylvania, and the filling of the 15,000 acres of wetlands between Coney Island and Brooklyn, made sanitation an important proximate driver. Land cover and land use change around the Bay caused a change in the type and amount of containment that affect the waters of the Jamaica Bay estuary and the ground water. The pollution of the Bay's waters caused significant modification of the Bay's land use, including cessation of fishing and shellfishing, and use of the bay for bathing.

It is possible that one of the reasons the City was able to tolerate the wetlands on the north shore for so long was due to the ditch digging program that the City initiated in 1916. Experiments in New Jersey had found that mosquito control was possible by ditching the swamps, making the more costly land filling unnecessary (Steinberg 2014).

Transportation

Accessibility was one of the most important factors in the development of the communities around the Bay. Transportation and its infrastructure shaped the relationship between the urban centers of Brooklyn and Manhattan and the surrounding countryside. The mode of transportation was determinate of the movement of people and the accessibility of the land. Changes in transportation technology, with its increases in speed and frequency, were strong motivators of land use/land cover change. While horse-powered street rail lines were used in Brooklyn and Manhattan, it was the use of steam and electricity in rail and maritime modes of transportation that were the real beginnings of mass transit. Rail was the determinate of the countryside around Jamaica Bay in that the communities that received a rail station developed rapidly, leaving the un-serviced communities behind. The communities that were left without rail and maritime access became dependent on the development of the internal combustion engine (automobiles and busses) (Antrop 2004).

Transportation had a far-ranging effect on land use/land cover change in Jamaica Bay as an underlying driver of recreational, residential, and commercial development. The cooperation between private investors of real estate and transportation facilitated the development and growth of the Rockaways, Coney Island, Canarsie, Howard Beach, and Mill Island. Profit was to be made transporting people to and from their recreational activities and properties on Mill and Barren Islands-- not to mention the transportation of goods.

The transportation infrastructure that was put into place by local developers and private transportation companies for the most part survived and became part of the current municipal system. Public municipal infrastructure followed existing right-of-ways (ROW). This was true for the cross bay transit facilities, the railroad from Valley Stream to Far Rockaway, and the subways to Coney Island. An exception to the rule was rail service to Canarsie Pier which was discontinued.

On the north shore of the Bay, among the communities that were slow to develop, the lack of transportation most likely hindered neighborhood development. Had there been a transportation structure in place it might have encouraged development of the areas. Rail transit was never established on the north shore in the communities that developed later. Today there is still a dearth of public transit infrastructure. These communities are still served by bus, a slower and less efficient mode of urban transit.

The construction of the transportation infrastructure was a proximate driver of land use/land cover change. Infrastructure includes airports, ferry terminals, train yards, sewage treatment facilities, and power plants. John F. Kennedy International Airport and LaGuardia airports alone occupy almost half the land the City devoted to these uses. (NYC Department of Environmental Protection (DEP) 2015)

VIII. CONCLUSION

Historical ecology and land use land/cover change were overarching concepts in the design and execution of this thesis. Historical ecology focuses on the interaction between humans and their environment over long periods of time. It provides insight into historical patterns and landscape composition, including geological, biological, and physical properties of past landscapes. These histories can then be used to help with ecological restoration by guiding restoration, management priorities, and design.

Similarly, land use/land cover change looks at the interaction between humans and their environment over long periods of time. It focuses on the factors that influence decision makers and their choices of land use. Past information is used to project future land use land cover scenarios. This information is used in global change studies and sustainability.

This thesis chooses a third path. It looks at the historical landscape of Jamaica Bay and studies the choices of decision makers that led to irrevocable land cover change and the loss of the wetlands that surrounded the Bay. An urban economic model that appears to have relevance to the development of most of Jamaica Bay's shore postulates that urban spatial structure is an endogenous process. These models hypothesize that there is interdependence among local decision makers. The local decisions of one individual affect the location decisions of others. "Such interdependence can arise due to a variety of factors, e.g. demand and supply, linkages between customers and firms, knowledge spillovers among firms, or congestion effects among residential land uses." (Irwin and Geoghegan 2001)

Clearly, transportation decisions made by one individual affects another. It can hardly be otherwise. Most sanitation decisions, with the exception of landfill, tend to be exogenous. Both transportation and sanitation are integral in land use/land cover changes. However, it is the influence of these drivers on the initial land use change decisions that led to irrevocable changes to the Jamaica Bay wetlands. Understanding the process may aid in urban planning decisions in the future.

Jamaica Bay Parks

While there is a great deal of green space in Jamaica Bay, most of the shoreline is land filled. Robert Moses kept the interior of the Bay as wetlands by creating the Jamaica Bay Wildlife Refuge. But he land filled the parks that he created along the shore. Other areas namely Edgemere, Fountain Avenue, and Pennsylvania Avenue, have been used as landfills.

One of the major problems facing the wetlands in Jamaica Bay is their inability to expand shoreward as the sea level rises. Robert Moses constructed the Shore Parkway close to the shore, basically strangling the bay. In the areas where the parkway is exceedingly close it is often flooded. The park-lands around the bay are compact and do not support wetlands. Modifying some of the parkland around the bay would give the wetlands the ability to expand shoreward. The landfills, as well as Spring Creek Park, Canarsie, Bergen Beach, Floyd Bennett Field, Plumb Beach, Marine Park, and Hamilton Beach, all offer enough land to provide both recreational facilities and wetlands. Where the parkway is extremely close to the shore, a possible solution to both the flooding of the highways and the land inland might be to elevate the parkway along some sections to allow the wetlands to continue underneath. Of course, this could only be accomplished where there is sufficient park land fronting areas that are developed, such as Canarsie, Bergen Beach, and Plumb Island.

While this might seem like a gargantuan task, wetlands are seen as a better solution to coastal flooding than many other projects. In June of 2013, a $20 billion system of flood barriers to protect low-lying areas from storms was presented by Mayor Bloomberg. A recent report by the Army Corp of Engineers reported that wetlands provide a better, more effective solution to flooding.

A significant issue to overcome is convincing the Parks Department to allow for the changes. The Parks Department has a policy of non-intervention, a 180-degree opposite of the ACE. An example of the importance of this to the Parks Department is the long debate as to whether or not to repair the damage from hurricane Sandy to the East and West Ponds of the wildlife refuge since it contradicts this agency's policy. Public access to these parks is extremely limited and much of it is underutilized. Possible leverage would be to provide public access to the parks.

Future research possibilities

Land use/land cover change and the historical ecology of Jamaica Bay are complex and afford many avenues of future research. In this thesis GIS was used as a tool for visualization. The wetlands shapefiles that were developed to support this thesis were created to provide consistency, not accuracy. From a historical ecological perspective Jamaica Bay is difficult to study. Using GIS in a quantifiable manner is also difficult. Inconsistencies and gaps in data are enormous. Data regarding historical wetlands ecosystems are usually defined as wetlands or marsh. Often there is no differentiation between low marsh, high marsh, tidal flats, sea grass beds, or freshwater wetlands. Borde et al. (2003) reconstructed historical wetland types using GIS and resource data similar to that collected for this thesis. Theoretically, it should be possible to reconstruct historical wetlands ecosystems using his model (Borde et al. 2003). However, the commercialization of the Bay for oysters destroyed most of the original habitats leaving us with little information as to its more "natural" state.

Long term spatial analysis of changes in Jamaica Bay's wetlands is also difficult. Jamaica Bay's wetlands have both accreted and eroded overtime. Hurricanes and nor'easters have made dramatic changes overnight. Some storms have significantly changed the profile of the Bay. This makes the establishment of an historical baseline an arbitrary decision. The result of such a study would be would be highly subjective. However, combining it with an analysis like Borde et al. (2003) could produce interesting results.

Economic, demographic, and political factors of land use/land cover change have also had a strong influence on decision makers. Demographics, especially immigration, had a significant effect on the United States. From the mid-1840s to the 1920s the population of the United States increased sixfold, from 17 million to 105 million. Between 1790 and 1910 the urban proportion of the total population grew from 5% to 45% (U.S. Census 1993).

Changes in real estate values and economic downturns would have had significant effects on private investment. Political corruption, notably Tammany Hall was an important factor in the development of Coney Island. In 1898, all the five boroughs of Brooklyn, Queens, Manhattan, the Bronx, and Staten Island were consolidated into a single city. How did the consolidation of the boroughs, its collective governance, affect land use/land cover change decisions? As an institution what role did the City play in the ecological history of Jamaica Bay?

The development of parks and their influence on the ecology of the Bay were not covered in this thesis. Robert Moses was a major influence in the development of the parks surrounding the Bay. He ended the debate between the development of Jamaica Bay as either a "natural" resource or an industrial port with the establishment of the Jamaica Bay Wildlife Refuge and the transfer of lands to the Parks Department. Title of lands underwater is a significant issue in his power play. It gave title, of much of the Jamaica Bay shoreline, to the City. Robert Carro's "The Power Broker" barely mentions Jamaica Bay, which leaves an opportunity to research Robert Moses's involvement.

This thesis focused on the specific decisions made across the Bay that caused irrevocable changes to the wetlands. It is not a long-term study of land use/land cover change. Historical studies of the drivers of land use/land cover change over time would provide insight in the economic rise and fall of many of the neighborhoods around the Bay.

Understanding the interacting mechanisms at play in Jamaica Bay could provide insights in to the functioning of Jamaica Bay as a system. Solecki et at. (1999) provide a good framework for human-environmental interactions specific to their study of the Florida Everglades. Using this framework and adapting it to the Jamaica Bay estuary would enhance the understanding of Jamaica Bay's complex societal–ecological linkages (Solecki et al. 1999).

This thesis provided a broad historical analysis of Jamaica Bay through the lens of land use/land cover change. The above is just a brief idea of possible directions that future research can take. Images in this document are .jpgs. In an effort to make this thesis more useful to other researchers the maps in the appendices are saved in a more detailed format as tif files.

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LIST OF APPENDICES

Appendices are separate documents.