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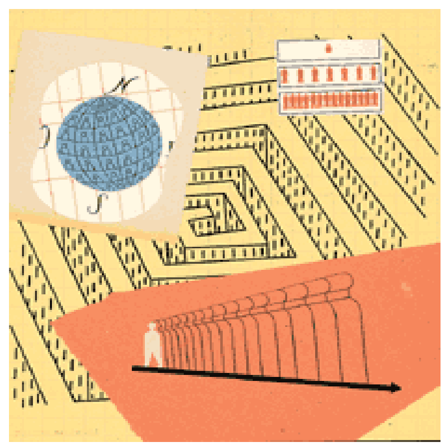

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Water Quality Problems and Solutions in Jamaica Bay: Analyzing the Role of Wastewater

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Executive Summary

The New York/New Jersey Clean Ocean and Shore Trust commissioned our team of Columbia University graduate students to assess and make recommendations concerning environmental impacts associated with the disposal of treated wastewater in Jamaica Bay, a marine system along the coasts of Brooklyn and Queens, New York. The Bay, a 10,000 acre body of water, receives the vast majority of its freshwater flow from treated effluent coming from four Wastewater Pollution Control Plants (WPCPs). The 267 million gallons of wastewater discharged from these plants per day has very high concentrations of nitrogen, which is known to have adverse effects on aquatic ecosystems. This report assesses the viability of a range of policy solutions to deal with nitrogen loading in the bay; including the construction of an outfall pipe which would dispose of the treated wastewater several miles out in the Atlantic Ocean.

In order to understand the complex environmental issues facing Jamaica Bay and the New York Harbor as a whole, the team performed a general review of the primary and secondary literature focusing on the sources, effects, and remedies of nutrient loading in aquatic systems; including the Department of Environmental Protection Nitrogen Control Action Plan Sixth Semi-Annual Report (1998), the Blue Ribbon Panel Report (2001), the New York Harbor Water Quality Report (2003), and the Health of the Harbor Report: The First Comprehensive Look at the State the of the NY/NJ Harbor Estuary (2004).

The scientific literature is clear that high nitrogen levels in aquatic environments are problematic because they can create conditions in which algae thrive and excessively bloom, also known as “eutrophication.” These algal blooms can cause reduced dissolved oxygen (DO) levels to the point of hypoxia, which can cause massive fish kills and a loss of aquatic organisms. Another consequence of algal blooms is reduced water clarity, which may lead to a loss of benthic vegetation.

Studies on the quality and health of Jamaica Bay do suggest that algal blooms and water clarity are problems in Jamaica bay. Moreover, wetlands have declined dramatically in recent years. There is a suspected link between nitrogen in the effluent discharged from the treatment plants and the decline of the bay’s wetland areas. Further, the physical changes in the bay, created by the dredging of borrow pits, retain the nitrogen longer by decreasing the natural flushing rates of water from Jamaica Bay. A major challenge to assessing the solutions to these problems is that a lack of scientific consensus still exists regarding the extent to which nitrogen is harming Jamaica Bay’s ecosystem. Another issue in question is to what degree the physical processes in Jamaica Bay substantially impact the retention of nitrogen, and to what extent they are exacerbating the previously questioned health of the Bay. Finally, there is debate surrounding whether nitrogen loading plays a role in the loss of wetlands in Jamaica Bay.

While the scientific uncertainty suggests that more research is needed to identify the extent of these problems and the relative impact of nitrogen loading in causing these problems, the fact remains that nitrogen loading exists in the bay and is a highly probable source of environmental degradation. Thus, proactive policy solutions are needed to prevent further degradation of the ecosystem. The policy solutions proposed in this report focus on the most prominent source of nitrogen coming into the bay -- “centrate” discharged from WPCPs, which is the water remaining after wastewater sludge is dewatered so that the remaining solids can be disposed on land. Other secondary sources of nitrogen to the bay are atmospheric deposition and combined sewer overflows (CSOs), which occur during rain events.

The client requested that the team analyze the costs and potential effectiveness of an outfall pipe. We examined in depth the Boston Outfall Pipe in Boston Harbor, which has been operational since 2000. The physical pipe was expensive to build ($390 million dollars) and the entire effort to carry out the project was very time consuming and expensive (10 years and approximately $3.9 billion dollars). If such a pipe was built in Jamaica Bay, it would completely remove the freshwater flow from Jamaica Bay which could significantly alter the dynamics of the bay and potentially lead to an increased frequency of algal blooms.

In addition, the environmental impacts of discharging treated wastewater into the Atlantic are largely unknown.

Other options include, rerouting the effluent, recycling the effluent, and filling the borrow pits. Retrofitting the WPCPs may be the most viable option; it will effectively remove nitrogen from the system, it will not restrict freshwater flow into the bay, and it will not shift the problem outside of the bay. It will also be important to implement small-scale wastewater recycling programs with the goal of increasing their efficiency and cost-effectiveness.

Our research highlights the importance of policy makers putting less emphasis on a single solution to protect or restore Jamaica Bay. Both short-term and long-term project goals must be considered to effectively remove nitrogen from the system and maintain freshwater flow into the bay, not simply shifting the problem to a different marine system. We feel continued research into the extent of the problem with nitrogen loading in the Bay is critical. Finally, it is important that an increased collaboration takes place between agencies and environmental organizations; it is necessary that they all participate in public forums to voice their concerns and share knowledge in order to create effective policy solutions that can enhance the water quality of Jamaica Bay.

I. Introduction

For the Spring Semester 2005 Workshop, Team Coast, a group of graduate students from Columbia University's Masters of Public Administration in Environmental Science and Policy program, was assigned to assist the New York/ New Jersey Clean Ocean and Shore Trust (COAST) in analyzing problems and solutions associated with nitrogen loading in New York Harbor, specifically in Jamaica Bay. COAST's mission is as follows: *"to provide for the maximum enhancement, enjoyment and conservation of the marine resources of the Hudson-Raritan Estuary and the New York Bigh.t*"

Over a four-month period, our research team studied the New York area's problems involving treated wastewater effluent flowing into local *estuaries***,** the marine systems where fresh water and salt water meet. Our client, COAST, asked that we create a report on the effects of treated wastewater effluent on Jamaica Bay, a marine system along the coast of Brooklyn and Queens, and to assess the feasibility of an outfall pipe that would reroute the treated wastewater from the Bay out into the Atlantic Ocean. This report's main focus is to contribute to the pool of knowledge, ideas, and potential solutions that work to protect and preserve natural ecosystems in and around the New York/New Jersey area.

Historically, New York City's waterways have endured environmental degradation from numerous sources of pollution. Up until the 1970s, New York City dumped raw sewage directly in the Harbor; currently, treated nitrogen rich wastewater is disposed directly into area waterways. Today, water pollution control plants (WPCPs) no longer dispose of raw sewage into the Harbor; they dispose of dewatered sewage sludge on land and the water that remains from the sludge processing, called *centrate*, is then discharged into the bays and harbors. Centrate is the nitrogen-rich water resulting from the treated sludge dewatering process. Total New York City municipal discharge of treated wastewater is approximately 2 billion gallons daily – water that is extremely high in nitrogen concentrations. The problem is that high levels of nitrogen are known to have detrimental effects on aquatic ecosystems.

This study analyzes the environmental impacts of the disposal of treated wastewater into Jamaica Bay. In addition, we assessed the other sources of nitrogen that may contribute to the deterioration of the bay. These included *atmospheric deposition* and *Combined Sewage Overflows* (CSO), which are sewer pipes that, during storms, discharge untreated wastewater from a sewer system that carries both sanitary wastewater and stormwater. These overflows occur because the system does not have the capacity to transport and treat the increased flow caused by stormwater runoff.

Disposing treated wastewater into Jamaica Bay adds to the *nitrogen loading,* or increased nitrogen concentration, in the Bay. This loading causes *eutrophication*, a process by which a body of water becomes enriched with dissolved nutrients. This is a concern because nitrogen is a limiting nutrient in marine systems and when present, huge *algal bloom* events frequently take place. These algal blooms, sudden massive growths of microscopic and macroscopic algae, thrive under excessive nitrogen loads. When these blooms die off, the process of their decomposition removes dissolved oxygen (DO) from the bottom levels of the marine environment. This loss in DO can induce *hypoxic events*, events of low oxygen concentration in the water. Hypoxic events may create environments unsuitable for fish to live and can suffocate plants living in the water.

This report addresses the status of water quality in Jamaica Bay, including the trends in algal blooms and DO. Additionally, it reviews the possible solutions for addressing wastewater disposal and examines the political and economic feasibility of each solution when making our final recommendations.

II. Water Quality Problems in New York Harbor and Jamaica Bay

A. New York Harbor Water Quality: Physical and Legal Environment

The Port of New York and New Jersey is the largest port on the east coast of the United States. Approximately $110 billion worth of goods were shipped through the harbor in 2004, the highest value ever recorded.[1] In addition, commercial and recreational fishing, boating, and various tourist related activities generate billions of dollars for the regional economies. The dependence of these activities on the ecological health of the Harbor grew increasingly apparent when declines in fish stocks and contamination of shellfish beds caused economic damages.

New York Harbor has experienced environmental degradation from many sources, including the discharge of sewage directly into the water, deposition of contaminants from the atmosphere, run-off of agricultural and industrial contaminants from the surrounding urban areas, and accidental spills from ships using the harbor. Historically, raw, untreated sewage of New York City was discharged into the waterways, which contributed to ecological damage by introducing excessive pathogen contamination and nutrient loading into the system. With the passage by Congress of the Clean Water Act in 1972, massive capital investment into NYC wastewater treatment plants led to the construction of new facilities and upgrades of old ones, thus eliminating the ongoing discharge of raw sewage into NY Harbor. This act required that all WPCPs upgrade to secondary treatment of wastewater, where bacteria consumes the organic content of waste and removes settleable solids. With the passage of the Ocean Dumping Ban in 1988, discharging of untreated sewage into the harbor and disposal of treated sewage sludge off the coast of the U.S. waters was prohibited.

Shortly after raw sewage stopped being discharged into New York Harbor, the importance of the New York/New Jersey Harbor Estuary was officially recognized as a vital and functioning ecosystem when the U.S. Environmental Protection Agency admitted it to the National Estuary Program in 1988 at the request of the New York and New Jersey Governors. The National Estuary Program, authorized by Congress as an amendment to the Clean Water Act of 1972, mandates development of comprehensive management plans to establish and maintain a healthy and productive ecosystem with full beneficial uses. The two state governments created the *Harbor Estuary Program (HEP)* with the primary purpose of restoring and maintaining the Harbor ecosystem, which supports a diversity of living resources on a sustained basis. The program, consisting of a partnership of federal, state and local agencies, community groups, and business organizations, has continuously been working on the development and implementation of a Comprehensive Conservation and Management Plan for the past sixteen years. Additionally, the goals of the HEP includes preserving and restoring ecologically important habitat, attaining water quality that supports bathing and other recreational uses, ensuring that fish and shellfish in the estuary are safe for unrestricted consumption and managing pollutants so that they do not contribute to impairments in and outside the estuary.

New York Harbor has made significant environmental quality improvements since the late 1980s. Most importantly, pathogen contamination has declined by several orders of magnitude due to the upgrades to secondary treatment at the wastewater treatment plants. In addition, significant increases in DO concentrations have occurred, particularly in surface waters. Furthermore, marine and bird species are making a comeback in the area.[2]

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[1] Port Authority of NY & NJ. Press release on March 16, 2005. Accessed on April 28, 2005 from: http://www.panynj.gov/.

[2] NYCDEP, 2003, New York Harbor Report for 2003. p. 5.

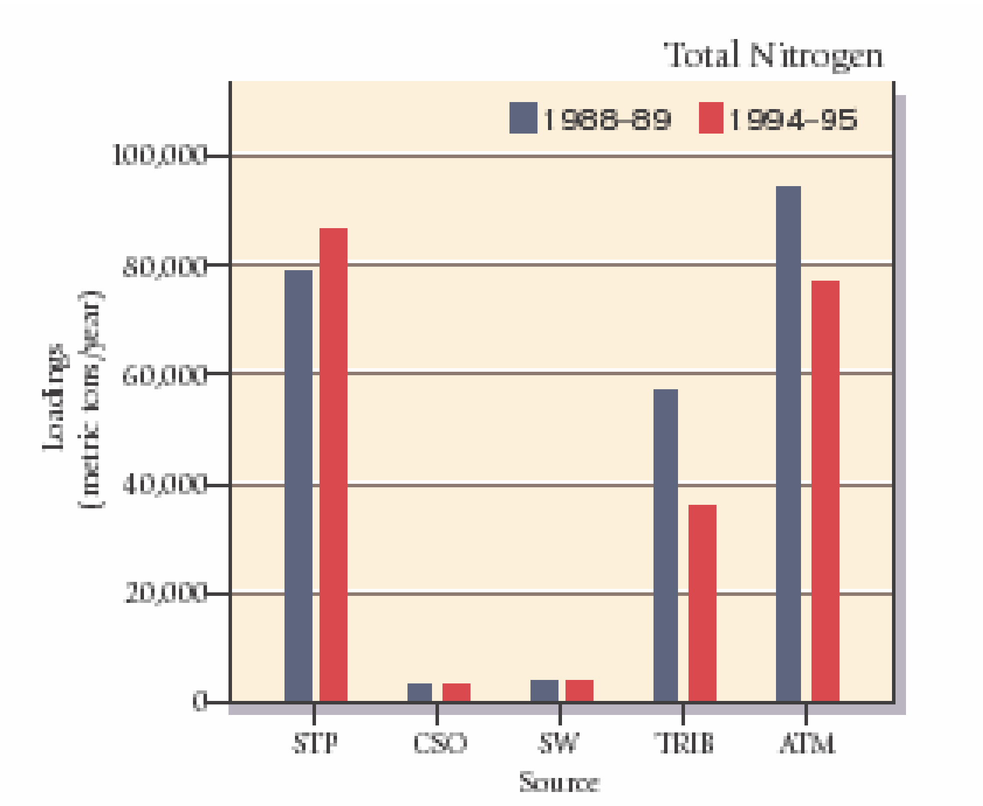
However, major causes of continued impairments to the estuary ecosystem have been identified.[3] These include:

- *Habitat loss and degradation* - Of the original 100 square miles of wetlands that existed in the entire estuary before it was settled by Europeans 300 years ago, only 14 square miles remain. This loss has contributed to the disruption of original hydrology, reduction of fisheries, the destruction of shellfish beds, and the reduction in diversity and abundance of coastal wildlife
- *Toxic contamination* emanating from sources such as wastewater treatment plants, landfill leachate, ocean dumping, vehicle exhaust emissions, and accidental spills, which has contributed to unsafe seafood consumption and concerns about the disposal of dredged sediment.
- *Pathogen contamination* originating from CSOs (the overflow of the storm water into sewage lines during storm events discharged into waterways), sewage treatment malfunctions, and illegal connections to sewers, which lead to beach closures and prohibitions on shellfish harvesting.
- *Floatable debris* - [most small-scale floatables come from CSOs] the deterioration of piers and bulkheads contribute to floatable debris which causes hazards to marine organisms and navigation and significant aesthetic impairment
- *Nutrients and organic loading from treatment plants and the atmosphere* - which have been associated with low DO levels and algal blooms which lead to reductions in fish and shellfish reproduction, reductions in marine organism habitats, noxious odors, and even mass die-offs of fish and shellfish.

The HEP has attempted to address some of the problems listed above through its Management of Nutrients and Organic Enrichment program. This program established methods to eliminate the adverse impacts from municipal discharges, tributary inputs, sediment flux, CSOs and storm water runoff. The goals of the program are to establish a better understanding of the causes of eutrophication and its symptoms, such as hypoxia and algal blooms, and to eliminate its adverse impacts. It recommended upgrading municipal sewage plants to full secondary treatment, developing low cost nitrogen reduction plans, and conducting additional studies to understand the causes of hypoxia and algal blooms. The current plan has a goal to reduce nitrogen loads in the estuary by about 25%. Figure 1 below illustrates the contribution of nitrogen to the entire estuary system from various sources:

[3] NYCDEP, 2003, New York Harbor Report for 2003.p. 5.

Figure 1: Contribution of Nitrogen to Estuary System



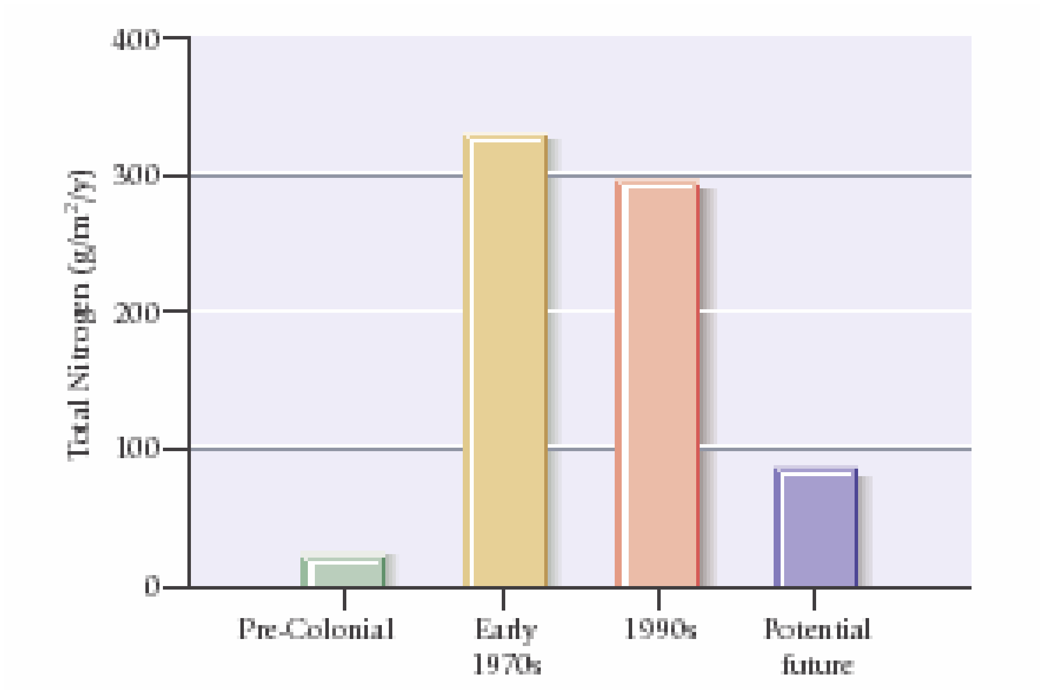
STP: Sewage Treatment Plants
CSO: Combined Sewer Overflows
SW: Storm water
TRIB: Tributaries
ATM: Atmospheric Deposition

Source: Health of the Harbor: The First Comprehensive Look at the State of the NY/NJ Harbor Estuary. Accessed: http://www.harborestuary.org/

Though the data represented in the chart is almost ten years old, the relative significance of nitrogen loading from the different sources is clear; sewage treatment plants and atmospheric deposition contribute the vast majority of nitrogen to the estuary.[4] Figure 2 illustrates where the estuary is in terms of the amount of nitrogen currently being absorbed into the system, and how much reduction may ultimately be necessary before it is restored to the level of health envisioned by the HEP.

[4] Hudson River Foundation. Health of the Harbor: The First Comprehensive Look at the State of the NY/NJ Harbor Estuary. March 2004. Accessed on March 31, 2005 from: http://www.harborestuary.org/mgmt.htm.

Figure 2: Total Nitrogen History and Future



Source: Health of the Harbor: The First Comprehensive Look at the State of the NY/NJ Harbor Estuary. Accessed: http://www.harborestuary.org/

While the sources of nitrogen loading are relatively clear, the impacts of nitrogen on different areas of the harbor as well as the feasibility of policy solutions for reducing nitrogen in NY/NJ Harbor are not yet established.

To help address some of these difficult questions, the remaining sections of this report focuses on nitrogen loading problems in one part of New York Harbor – Jamaica Bay. Nitrogen loading in Jamaica Bay is particularly problematic because of the physical setting of the Bay as described below. The solutions pertaining to the Jamaica Bay problems, discussed later in this report, therefore will likely be unique to the Bay itself.

B. Physical Attributes and Environmental Problems of Jamaica Bay

Jamaica Bay is a 10,000 acre body of water located between Brooklyn, Queens and the Rockaway peninsula, as shown in the map in Appendix A. The Bay is surrounded by a variety of habitats including: grasslands, shrub-lands, salt and freshwater wetlands, meadows, and coastal forests.[5] It is a relatively contained area compared to the other bodies of water that make up New York Harbor. Sources of ocean water and freshwater are well defined for the Bay. Ocean tides come in and go out through the narrow Rockaway inlet, and the only major sources of freshwater to the Bay are WPCP outflows and CSO outlets. Appendix B depicts the four WPCPs in relation to sampling sites. Consequently, the most

[5] NYCDEP, 2002, New York Harbor Report for 2002.

significant volume of fresh water flow into the Bay is the 267 million gallons per day discharged on average by the four treatment plants whose outflows drain into Jamaica Bay.[6]

Over the course of the last century Brooklyn and Queens have been developed to near capacity. Jamaica Bay, once known for its thriving shellfish industry, now receives the majority of the runoff from these highly developed boroughs. These urban pressures, along with over-fishing of the local waters, have caused the deterioration of the watershed, and destroyed the once thriving shellfish industry.[7] Concern over the status and health of the area has led to the creation of the Jamaica Bay Wildlife Refuge in hopes of providing a barrier between human impact and the fragile Bay. However, recreation, dredging, storm water runoff, and the release of treated sewage water are continuously threatening the water quality of the Bay. In addition, human alterations to the channels and borders, mainly due to dredging and filling, have significantly altered the hydrology and natural patterns water flow of the Bay.

Dredging began in the late 1800s in Jamaica Bay in an attempt to establish it as a major seaport, and the dredging continues to this day. Much of the dredged material was used to fill-in wetlands in order to provide more space for development. The Bay in its natural state was relatively shallow; its deepest point was approximately 10 feet.[8] As a result of the dredging of channels for ships and borrow pits for land-fill materials used in the construction of Kennedy International Airport, its deepest point is now approximately 50 feet deep.[9] The large depressions and channels that result from dredging serve as a sink for sediment, and it is possible that this sediment would otherwise be depositing on shallower areas and helping to maintain wetlands.[10]

Dredging may have contributed considerably to changes in the flow and flushing rates of water in Jamaica Bay. If flow rates have dramatically decreased as suggested by Gordon et al., then the flushing of nitrogen out of the system may be occurring at a slower rate. This could mean that nitrogen may be held in the Bay for long enough periods to create concentrated levels high enough to disrupt natural habitats. One model from Lamont-Doughty Earth Observatory estimates that the “average bulk residence time of Jamaica Bay,” or the rate of flushing, is 7 days.[11] However, their report also indicates that certain areas of the bay may have much longer residence times. It has been estimated that different areas of the Bay may have residence times of up to one month or more.[12] Consensus has yet to be reached on the exact residence time of the different regions of the Bay. Determining these facts is essential for understanding how long the nutrients released from the sewage outfall pipes remain in the area. Increasing the residence time of a water body increases the time it takes to flush the water system, which causes an accumulation of nutrients, particles, and chemicals the system is not used to handling. This accumulation, also known as nutrient loading, can alter the biological processes of bay. For instance, it can lead to excessive algal blooms, which will be discussed later of this paper.

Environmental degradation of wetlands and habitat has coincided with the lack of available sediment and high nitrogen levels in Jamaica Bay. However scientists have yet to establish a casual link to the loss of wetlands. It is estimated that the Bay’s wetland areas have been reducing at a rate of an average of 3% per year.[13] Wetland depletion in the Jamaica Bay area is clearly demonstrated in two satellite images in of

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[6] NYCDEP, 2002, New York Harbor Report for 2002.
[7] National Park Service Gateway National Recreation Area, Jamaica Bay Unit. 2003.The Evolving Legacy of Jamaica Bay.
[8] United Status Geological Survey, 2003: http://3dparks.wr.usgs.gov/nyc/parks/loc70.htm
[9] United Status Geological Survey, 2003: http://3dparks.wr.usgs.gov/nyc/parks/loc70.htm
[10] Gordon et al. 2003; and Interview with Beau Ranheim of NYCDEP on March 31, 2005.
[11] Gordon et al. 2003 p. 47.
[12] Ibid.
[13] Hudson River Foundation. Health of the Harbor: The First Comprehensive Look at the State of the NY/NJ Harbor Estuary 2004. Prepared for the NY/NJ

the Bay, which highlight the changes in wetland boundaries and vegetation from 1974 to 1999. If the current rate of deterioration continues, Jamaica Bay's wetlands will completely disappear within a few decades, affecting dramatically the overall health of flora and fauna in the region.[14]

The deterioration of wetlands has become an important public policy issue because of the dramatic losses in recent years and the perceived connection with human alterations and inputs into the ecosystem. Many communities, environmental groups, and local governments are concerned and have supported continued scientific research on the causes of wetland loss. Appendix D provides a list of the current community and local governmental organizations currently researching the issue of nitrogen loading in Jamaica Bay.

One possible cause of the ecosystem degradation in Jamaica Bay, as suggested in the overview of New York Harbor, is the nitrogen-rich wastewater coming from Jamaica Bay's four WPCPs.[15] As will be discussed in later of this report, it is difficult to determine the true impacts of heightened nitrogen levels in the region. The effects of algal blooms and nitrogen loading will also be discussed later in this report. In addition, water clarity has decreased. Dredged borrow pits create sinks where high amounts of sediment and nutrients can collect, and can create pockets of water high in nitrogen. If these pockets are remixed during storm events then they may represent a considerable hazard to the ecosystem.[16] Even without pooling of nitrogen in deeper regions of the Bay, increased algal proliferation could be one of the major factors undermining wetland health. This could mean that high nitrogen levels are significantly negatively impacting the region.

It is clear that the physical attributes of Jamaica Bay have been significantly altered in the past century by human actions and has resulted in environmental problems. It is now important to assess the degree to which this system has been affected and what solutions will be effective and politically feasible for the region.

Harbor Estuary Program. Accessed on March 31, 2005 from:
http://www.seagrant.sunysb.edu/hep/pdf/TargetsGoals.pdf

[14] Ibid

[15] NYCDEP, 2002. New York Harbor Report for 2002.

[16] US Army Corps of Engineers, New York District. 2004. Hudson-Raritan Estuary Environmental Restoration Feasibility Study; Jamaica Bay Study Area Report:
http://www.nan.usace.army.mil/harbor/links/JamaicaBay_SAR_RevSep04.pdf.

III. Study Methodology

In order to understand the complex environmental issues facing Jamaica Bay and the New York Harbor as a whole, we performed a general review of the primary and secondary literature focusing on the sources, effects, and remedies of nutrient loading in aquatic systems for scientific research and analysis. Included in the reviewed literature were the Blue Ribbon Panel Report (2001) and the New York Harbor Water Quality Report (2003), both of which proved to be invaluable resources.

In addition, we evaluated the dataset of water quality indicators collected over the course of 95 years and administered by the New York City Department of Environmental Protection (NYCDEP) in order to detect trends in nitrogen levels in Jamaica Bay. Indicators assessed in the analysis include total nitrogen, chlorophyll-*a*, secchi depth, and DO levels taken from nine sampling sites along the Jamaica Bay coastline. We also examined data from a group of Columbia University scientists, lead by Dr. Arnold Gordon, who have been conducting an intensive investigation on the health of Jamaica Bay and its wetlands, looking specifically at the causes and effects of nitrogen levels. The workshop team also conducted interviews with these scientists and others whose work includes the study of Jamaica Bay.

Additionally, the technologies designed for removing nitrogen from the sewage water that is deposited into the Bay were compiled and evaluated for their applicability in remedying Jamaica Bay's nutrient loading problem. These include: biological nitrogen removal (BNR), separate centrate treatment, modified Ludzak Ettinger process, enhanced nutrient removal (ENR), cyclical nitrogen removal, and microfiltration.

To further support of the scientific data and literature and aid in making recommendations for policy action, the team created a number of Geographic Information System (GIS) images. A preliminary review of the existing maps and data was conducted via Internet searches followed by a meeting with COAST GIS Officer Dr. Yuri Gorokovich at the Lamont-Doherty Earth Observatory to obtain additional GIS data on Jamaica Bay. The GIS data collected was processed and analyzed using ArcGIS 8.3 and 9.0 software. In addition, we included bathymetric information, the location of wastewater control plants, and the direction and location of outfalls into the Bay.

To develop policy recommendations for this report, the team also conducted a literature review of proposed and implemented wastewater treatment and effluent discharge policies; including the established wastewater policies for the New York Harbor, enacted federal, state and local wastewater legislation and alternative methods for wastewater effluent disposal. The team used the internet, journals and databases for the initial literature review. In addition, we conducted detailed informational interviews with the New York State Department of Environmental Conservation (NYSDEC), the NYCDEP, the Nitrogen Work Group (NWG) with the Harbor Estuary Program (HEP), and California's Department of Water Resources. Case study research also provided essential information to assess the possible policy solutions for Jamaica Bay. The case study research focused on the City of Boston's Deep Sea Outfall. We also researched data on wastewater re-use programs in California, New Jersey and Florida.

In comparing and assessing the various technical solutions for reducing nitrogen loading in Jamaica Bay, the team also looked at the costs and benefits associated with each of these possible solutions. Due to the lack of comparable cost data from the case studies, and the difficulty in pricing ecological services, the cost-benefit analysis focuses largely on qualitative assessments and the likely magnitude of the costs and benefits associated with each solution. We created a matrix in order to break down each solution into a set of costs and benefits to allow for comparing and contrasting. This compartmentalization helped identify areas where solutions could be combined in order to offset costs while producing maximum benefits.

Finally, to understand and identify the likely political support and opposition for the solutions proposed in this report, the team compiled a list of stakeholders focusing on who was involved in Jamaica Bay, and specifically, the issue of wastewater treatment. The team then listed questions to ask each agency; this method ensured that each agency or group was asked the same questions so the team would have the same information from all stakeholders. The team attempted to contact several state, city and local agencies as well as individuals within New York and New Jersey Universities. The contact procedure varied between a phone call and a follow up email listing the team's questions and an exploratory email to see if the agency or individual was open to speaking with us. We conducted interviews via phone or email.

IV. Nitrogen's Effect on Jamaica Bay

A. Nitrogen's Effect on Ecosystems

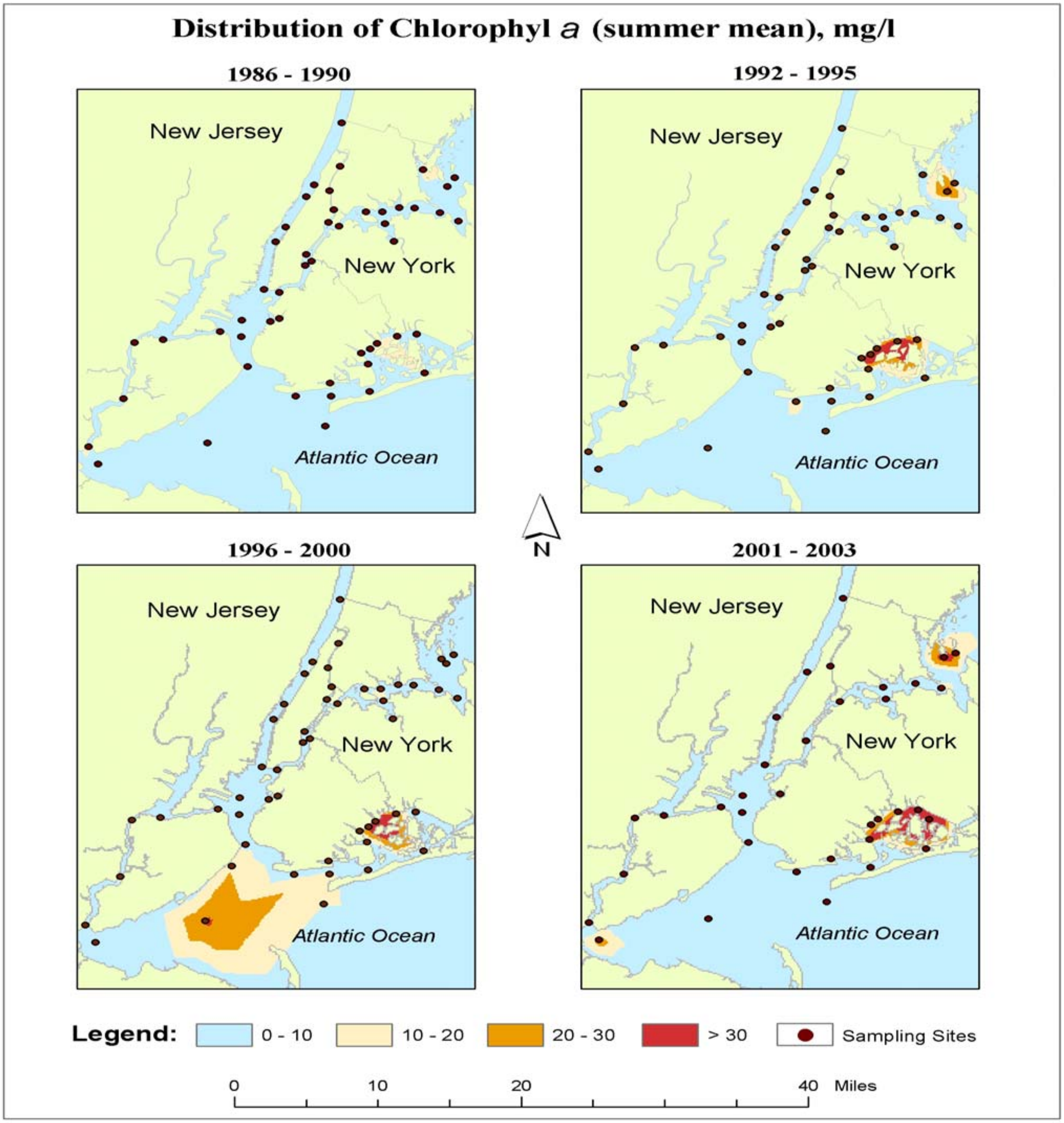
Nitrogen is found in aquatic systems in the form of ammonium (NH_4), nitrate ($N0_2$) and nitrite ($N0_3$). Nitrogen is a limiting nutrient for the growth and proliferation of certain organisms. In aquatic environments, high concentrations of nitrogen have been shown to cause excessive algal (phytoplankton). Nitrogen in the form of ammonium is one of the main nutrients algae consume. Nitrites are a by-product of the consumption and the break down of ammonium by algae; and can be further broken-down into nitrate in the presence of nitrogen fixing bacteria. During extreme eutrophic events, nitrogen concentrations in the water decrease as the algae consume the nitrogen. This can mask increased nitrogen levels, as the increase is no longer in the water column, but held within the biotic structure of the algae.[17]

Algal blooms can cause issues such as shading effects (algal mats that block light from reaching lower depths in the water column), and many scientists have theorized that this contributes to marshland loss. A shading effect occurs when an algal bloom is so excessive it covers the surface of the water, affecting the ability of light to penetrate the water column, thus inhibiting the process of photosynthesis. When these organisms are no longer able to photosynthesize or just die of old age, they settle on the bottom of the bay and decompose. This increase in decomposing material (dead algae, vegetation, aquatic organisms) accumulates on the Bay floor, using the available oxygen and thus destroying benthic habitats of organisms such as the blue crab and summer flounder.[18]

Excessive algal blooms also lead to a condition known as *eutrophication*.[19] Eutrophic conditions are most notable during two distinct algal bloom periods defined by Gordon et al. in 2003, as the winter/spring bloom (February-March) and the summer bloom (June-July) "…interfere with the recreational use of lakes and estuaries, and the health and diversity of indigenous fish, plants, and animal populations."[20] Primarily, algal blooms can decrease the concentrations of dissolved oxygen in aquatic ecosystems (also known as "hypoxia"). The breakdown and consumption of nitrogen requires oxygen, and oxygen is also utilized during the decomposition of aquatic organisms.[21] Dissolved oxygen is a vital nutrient for aquatic organisms, including fish. Periods of high nitrogen levels can limit the availability of this nutrient.

[17] Gordon et. al. 2003.
[18] EPA, 2005, Mid-Atlantic Integrated Assessment: http://epa.gov/maia/html/eutroph.html.
[19] Ibid.
[20] Ibid.
[21] Ibid.

Figure 3. Distribution of Chlorophyll-a over time for all of New York Harbor
(Source: 2003 New York Harbor Water Quality Report, NYCDEP)



Scientists are concerned that Jamaica Bay's wastewater treatment plants and sewage outflows described in the previous section are leading to problems of eutrophication, or excessive algal blooms.[22] Figure 3 depicts the increasing chlorophyll-*a* concentrations (an indicator of the presence of algae) for Jamaica Bay compared to the overall New York Harbor system from 1990 to 2003. The Jamaica Bay graph shows a clear increase in chlorophyll-*a* levels, whereas the overall New York Harbor graph shows more sporadic concentration levels and no clear trend of increase over the 13 year time period. This highlights the distinct eutrophic trend in Jamaica Bay. During this time period, chlorophyll-*a* levels have increased to the point that Jamaica Bay is now considered a hyper-eutrophic ecosystem, damaging the surrounding aquatic life.[23]

Declining water clarity of Jamaica Bay, as measured by its secchi depth, also provides evidence of the problems associated with high nitrogen levels in the Bay.[24] Water must maintain a certain clarity in order for many benthic organisms to survive and in Jamaica Bay water clarity has steadily decreased over time. This decrease is likely a result of increased algal blooms in the Bay, which are associated with increased nitrogen levels. Other possible factors are still being studied. In comparing the secchi depth for Jamaica Bay and all of New York Harbor over a 13 year time period (1990-2003), there is a clear decrease in the average summer mean secchi depth for all Jamaica Bay sampling sites. The visibility depth ranges from 5.97 ft (1.15 Standard Error [SE]) in 1990 to 3.77 ft (0.62 SE) in 2003. In comparison, the rest of New York Harbor shows a relatively small decrease over time of 5.26 ft (0.47 SE) to 4.55ft.(0.59 SE). In Jamaica Bay, site J7, known as Grassy Bay, has the lowest secchi depth and thus the least water clarity. Grassy Bay is one of the most heavily influenced regions of the Bay as it has experienced high levels of dredging. It is also the sampling site located closest to WPCP outflows.

Another factor affecting the ecosystem of Jamaica Bay is the reduction in DO concentrations in certain areas of the Bay. Appropriate levels of DO as dictated by the NYCDEP are outlined in Figure 4 below:[25]

Figure 4. Dissolved Oxygen Concentrations

Concentration (mg/L)	**Condition**
0 - 3	Unsafe, hypoxic conditions for aquatic and human life
3 - 5	Not well oxygenated conditions for aquatic life or recreational use
5 - above	Stable conditions for aquatic life and recreational use

Source: Data for table provided by the NYC Department of Environmental Protection (NYCDEP)

[22] Gordon et. al. 2003 p. 60.
[23] Gordon et. al. 2003.
[24] One method used to determine the clarity of a water body is secchi depth. This involves the use of a black and white round disk called a secchi disk attached to a rope. The disk is released into the water at the sampling site and lowered until no longer visible. The depth of disappearance is then recorded (NYCDEP, 2002, New York Harbor Report for 2002).
[25] NYCDEP, 2002, New York Harbor Report for 2002.

DO levels are measured at the surface and bottom of sampling sites for the New York Harbor Water Quality Reports, where shading effects, decomposition, and nitrogen breakdown affect the DO concentrations the most.

On the one hand, the 2002 New York Harbor Water Quality Report has stated that on average DO concentrations in Jamaica Bay have steadily increased since 1986, showing an improvement in water quality (Average DO concentrations for all Jamaica Bay Sites for the summer 2003, which have a mean value above 5mg/L). On the other hand, many individual site samples have DO levels well below that which is considered stable, indicating regions of hypoxia or hypoxic events. Site J12 had a recorded DO level of 5.78mg/L in June of 2003 that dropped to 1.76mg/L in July. It is important to note that there are very limited numbers and locations of samples in Jamaica Bay. There are ten sample sites, but only data for nine of those sites. Those sites are also only sampled approximately four times in the summer and once in the winter and not consistently at the same time of day or tide level. Thus it is difficult to extrapolate true trends in any of the water quality indicators, especially DO where the levels are very close to the limit of the stability range.

The most important data showing the detrimental effects of nitrogen loading in Jamaica Bay is the increasing difference between surface and bottom concentrations of DO. Looking over a 13 year time period; there is a visible increasing trend in the difference between surface and bottom concentrations. This is thought to be a result of increased algal blooms limiting the availability of DO in the benthic region. This creates a stratified environment in the bay, where surface areas have more light and higher DO concentrations, and benthic regions have limited available nutrients and light.

There are conflicting ideas about what this data states about the ecosystem health of Jamaica Bay. Several scientists feel that the data is inconclusive and that nitrogen levels do not pose a threat to the water quality or ecosystem of Jamaica Bay.[26] However, after examining the research presented in The New York Harbor Quality Report and the work of numerous research scientists studying the area, the evidence does show algal blooms have increased, water clarity has decreased, and dissolved oxygen levels may be extremely low in certain areas of the Bay. All of these variables can affect the health of the Bay. This data along with the rapid loss of wetlands makes these trends visible in Jamaica Bay as compared to the rest of New York Harbor.

B. Sources of Nitrogen in Jamaica Bay and Control of these Sources

In order to find solutions to controlling high nitrogen levels in Jamaica Bay, it is important to isolate the different sources of nitrogen and the relative contribution of nitrogen from these sources. Point sources of nitrogen have direct entry points into the Bay and include outfalls from WPCPs and CSOs. Non-point sources are diffuse and more difficult to isolate and include direct and indirect atmospheric deposition, storm water run-off, and groundwater sources. According to the Health of the Harbor Report issued by the Hudson River Foundation in March 2004, and illustrated in the bar chart presented in the beginning of this paper, almost 200,000 metric tons of nitrogen entered the entire estuary in 1995. Approximately 42% was discharged from treatment plants, 38% originated from atmospheric deposition, 18% entered from tributaries, and the remaining 2% from storm water and CSOs.[27] It is also necessary to understand how these sources of nitrogen are controlled under the current regulatory and policy framework to underscore

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[26]Phone Interview with Dr. John Tanacredi; Professor, Chairman, Department of Earth and Marine Sciences, Dowling College, 9th March, 2005.

[27] Hudson River Foundation. “Health of the Harbor: The First Comprehensive Look at the State of the NY/NJ Harbor Estuary”. March 2004. p. 63. Accessed on April 27, 2005 from: http://www.harborestuary.org/

the feasibility alternative solutions for reducing nitrogen levels in Jamaica Bay. These different origins of nitrogen and the policy framework governing them are explained in greater detail below.

C. Wastewater Pollution Control Plants

A large percentage of all freshwater that feeds into Jamaica Bay comes from the four WPCPs (26th Ward, Coney Island, Jamaica, and Rockaway) that discharge into the Bay. Approximately 267 million gallons per day are discharged from these plants. Included in this discharge is around 50,000 pounds of nitrogen. The Nitrogen Control Action Plan of 1998, designed to address the growing nitrogen problem, has set aggregate total nitrogen effluent limits of 45,300 pounds per day for a 12-month rolling average and 54,600 pounds per day for a maximum monthly average. [28]

The amount of nitrogen released as of 1998 from each WPCP into Jamaica Bay as outlined in the Nitrogen Action Control Plan is as follows:

- 26th Ward discharges 11,190 lbs/day
- Coney Island discharges 15,420 lbs/day
- Jamaica discharges 18,550 lbs/day
- Rockaway discharges 2,130 lbs/day

These discharges result in an approximate total discharge of 47,290 lbs/day of nitrogen into Jamaica Bay from WPCPs.[29] Only one of these WPCPs, 26th Ward, has separate centrate treatment and Biological Nutrient Removal (BNR). BNR is a process that removes excess nitrogen in the form of ammonia from the centrate through the use of bacteria during the last treatment phase of the wastewater.[30] When possible, centrate from the smaller WPCPs is redirected to the 26th Ward plant in order to remove excess nitrogen. However, during large storm events there is not enough capacity to treat centrate from other WPCPs. The NYCDEP was planning to export the sludge from the Owls Head WPCP (a non-Jamaica Bay treatment plant) to a dewatering facility other than 26th Ward, the status of which is uncertain at this time.

D. Wastewater Pollution Control Legislation and Policy

The discharge of pollutants from wastewater control plants is regulated under federal and state laws; thus any assessment of potential policy or technical solutions to control nitrogen must take these policies into account. The primary federal policy that addresses wastewater is the Federal Water Pollution Control Act Amendments of 1972, now known as the Clean Water Act, which establishes guidelines for wastewater treatment and effluent limits. Additionally, the Clean Water Act created a system for permitting discharged wastewater, which is the National Pollution Discharge and Elimination System (NPDES). The NPDES controls pollution by regulating point sources that discharge pollution into U.S. waters [31] through technology requirements and limits on the discharge of specific pollutants. Any municipality that discharges "pollutants" into the United States waterways must apply for and obtain an NPDES permit.[32] Some of these pollutants include: five day biochemical oxygen demand (BOD5), fecal coliform,

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[28] NYCDEP Nitrogen Control Action Plan, 6th Annual Report. http://www.nyc.gov/html/dep/pdf/ncap1.pdf and http://www.nyc.gov/html/dep/pdf/ncap2.pdf
[29] DEP, 1998, Nitrogen Control Action Plan. 6th Semi Annual Report.
[30] Long Island Sound Study. 1990. Nutrient Reduction Action Plan Demonstration Projects. http://www.longislandsoundstudy.net/pubs/facts/fact11.pdf
[31] Environmental Protection Agency, Office of Wastewater Management. (2004).*Water Permitting 101*. Retrieved on March 10, 2005, from: http://www.epa.gov/npdes/pubs/101pape.pdf
[32] Ibid.

manmade organic compounds, nitrogen and phosphorous.[33] Additionally, all permits must contain effluent limits, monitoring requirements, standard conditions and special conditions (e.g., best management practices). The EPA or individual States (upon approval from the EPA) may administer the permitting process. However, for those States that administer the NPDES permit process, the EPA must obtain verification and certifications that the discharge is complying with the effluent limits.[34]

Both New York and New Jersey have an approved state program to administer the federal NPDES policy and an approved general permits program. NYSDEC is responsible for administering the *State Pollution Discharge Elimination System* (SPDES). New Jersey's Department of Environmental protection administers the *New Jersey Pollutant Discharge Elimination system permit program*.

In 1985 the City noticed hypoxic events and poor circulation in western Long Island sound and regions of Jamaica Bay. The city attributed these issues to nitrogen loading into Long Island sound and areas of Jamaica Bay. Because of these events, in 1998 future total nitrogen (TN) limits were incorporated into the SPDES permit system limiting the future TN discharges from wastewater control plants. In 1987, concerned environmental groups, such as the Sierra Club and the Environmental Defense, wanted TN limits to be immediately incorporated into the SPDES permit system as opposed to having the TN limits applied in the future. These environmental groups took the NYSDEC to court and as a result of these legal hearings nitrogen control requirements were incorporated into the SPDES permits. Specifically, TN requirements were imposed on the WPCPs in Jamaica Bay based on 1990 total nitrogen discharge levels. Furthermore the SPDES nitrogen control requirements also required that the Red Hook and Oakwood Beach WPCPs have Basic Step Feed BNR upgrades.[35]

The Jamaica Bay WPCPs total nitrogen effluent limit (aggregate for four plants) of 45,300 pounds per day for a 12-month rolling average and 54, 600 pounds per day for a maximum monthly average. These limits were based on discharges prior to sludge dewatering.[36]

Additionally, the EPA is currently working on new policy guidelines addressing whole effluent toxicity. The policy and guidelines that are currently in development is the National Whole Effluent Toxicity Implementation guidance (WET). Whole effluent toxicity is "the aggregate toxic effect of an aqueous sample measured directly by an aquatic toxicity test."[37] As part of the NPDES permit programs, states control whole effluent toxicity as one method to control the discharge of toxic pollutants into the waterways. During the 1980s the NPDES program focused on technology and pretreatment requirements. However, WET data gather during the 1980s indicated that even with the technology and treatment requirements many toxic pollutants were still being discharged into the water.

In 1984 the EPA developed the "Policy for the Development of Water Quality-based Permit Limitations for Toxic Pollutants,", which aimed to reduce the toxic pollutant discharges by establishing chemical and biological methods for assessing toxicity of the discharge. Then in 1989, the EPA created procedures for determining when effluent limitations are required in the NPDES permits. In 1994, in an attempt to protect aquatic life, the EPA issued a national policy on effluent limitation to control WET as part of the

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[33] Ibid.
[34] Ibid.
[35] Nitrogen Control Action Plan. (1998). *6th Semi-Annual Report: History/Summary of the NYCDEP Nitrogen Control Action Plan.* Retrieved on April 27, 2005, from http://www.nyc.gov/html/dep/pdf/ncap2.pdf
[36] Ibid.
[37] Environmental Protection Agency, Office of Wastewater Management. (2004).*National Whole Effluent (WET) Implementation Guidance Under the NPDES Program*. Retrieved on March 10, 2005 from: http://www.epa.gov/npdes/pubs/wet_draft_guidance.pdf.

NPDES program, which included.[38] The EPA issued a list of approved WET test methods in 1995 to determine the effects of effluent on freshwater, marine and estuary ecosystems to be used in the NPDES program. In 2002 the EPA passed into the Federal Register guidelines for measuring the toxicity of effluent. The EPA is working on establishing guidelines for implementing NPDES WET program, which aims to establish national consistency and reaffirm existing policies. The goal of the new guidelines is to have national consistency for a WET program, to reinforce compliance with existing NPDES regulations by allowing flexibility while also ensuring that the technical and regulatory toxicity requirements are met and to clarify and rephrase the existing WET guidelines.[39] The aim of the new guidelines is to ensure that the WET requirements as part of the NPDES are clear and to promote consistency in WET implementation programs across states.

Furthermore, New York City has adopted policies and legislation that address the specific needs and issues surrounding wastewater treatment in their region. One of the key policies addressing wastewater treatment is the *Nitrogen Control Action Plan*, which is designed to reduce the nitrogen load in New York City's harbors, specifically the western Long Island Sound and Jamaica Bay. The NYCDEP had established a comprehensive program designed to reduce nitrogen discharge, collect data performance and implement nitrogen removal technology. The goal of the plan is to establish low cost nitrogen reductions for the treatment plants that are discharging into Jamaica Bay while complying with the SPDES discharge permit program. The upgrades for the Jamaica and Rockaway plants are not technologically feasible, as the plants were not originally designed for this process. The Coney Island plant would require technical upgrades to nutrify the water (specifically aerator effluent concentrations).[40] The 26th Ward plant is the only plant where the identified nitrogen retrofit upgrades are technically possible and cost effective. Specifically, the upgrades included the Basic Step Feed Biological Nitrogen Reduction retrofit (completed in April 2000) and the Separate Centrate Treatment (completed in March 1998), at a total cost of $3.9million.[41] Given the difficulties with upgrading all the plants in Jamaica Bay, the team has examined other alternative approaches to address the reduction of nitrogen.

E. Atmospheric Deposition

Atmospheric deposition of nitrogen may be a potentially large contributing source of nitrogen to Jamaica Bay.[42] Nitrogen emitted during fossil fuel combustion is directly deposited through precipitation into the water of the Bay as well as deposited elsewhere on land and transported to the Bay as storm water runoff. Nitrogen deposited from the atmosphere can also occur as "dry" deposition. This process involves the "sorption of nitrogen gases by wet surfaces and particle deposition."[43] However, dry deposition measurements are still highly uncertain, and there is no standard method for measuring it.[44] Wet deposition is much easier to quantify since the significance of its impact increases as rainfall increases as a fraction of the total water budget.[45] Along with nitrogen, phosphorus has been shown to contribute

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[38] Ibid.
[39] Ibid.
[40] pg. 38. DEP Nitrogen Control Action Plan 6th Semi Annual Report. http://www.ci.nyc.ny.us/html/dep/pdf/ncap3-2.pdf
[41] pg. 42. DEP Nitrogen Control Action Plan 6th Semi Annual Report. http://www.ci.nyc.ny.us/html/dep/pdf/ncap3-2.pdf
[42] Phone Interview with Dr. Michael Kinnish, Rutgers' Institute of Marine and Coastal Sciences, 14th February, 2005.
[43] Morris, J.T. Effects of Nitrogen Loading on Wetland Ecosystems with Particular Reference to Atmospheric Deposition. Annual Review of Ecology and Systematics. Vol. 22: 259-279. November 1991.
[44] Lovett, Gary M. Atmospheric Deposition of Nutrients and Pollutants in North America: An ecological perspective. Ecological Applications: Vol. 4, No. 4, pp. 629-650. 1994.
[45] Ibid.

significantly to total nutrient loads in estuarine systems; however, it is largely been accepted that nitrogen, and not phosphorus, is the limiting factor for algal growth in coastal waters.[46]

Although atmospheric deposition is difficult to measure, there are clear trends in the concentration and deposition of nitrogen in the United States. Trends indicate that atmospheric deposition may be greater in areas in the Northeast compared to the rest of the country.[47] Therefore, atmospheric deposition of nitrogen may represent a more substantial threat to marine ecosystems in New York Harbor. Studies conducted on Long Island Sound found that atmospheric deposition of nitrogen accounted for approximately 14% of the total human-caused nitrogen input into the Sound.[48] Other studies have indicated that wet atmospheric deposition of nitrogen in the New York Bight contributes to 38% of the total nitrogen load; the same study estimates Narragansett Bay at 12%, Barnegat Bay at 40%, and Chesapeake Bay at 27%.[49]

While data for Jamaica Bay is unavailable, it is reasonable to assume that there is contribution from atmospheric deposition. The Hudson Bay Foundation has suggested that atmospheric deposition of nitrogen into the NY/NJ Harbor Estuary may be as large a source as that coming from WPCPs.[50] However, considering the tremendous quantity of nitrogen-rich centrate being discharged into the Bay, and the slow flushing rate, WPCPs potentially represent a much greater source of nitrogen than atmospheric deposition. Although the New Harbor is significantly impacted by atmospheric deposition of nitrogen, the percentage of atmospheric deposition (as a portion of total nitrogen) in other parts of the harbor may be larger because they are receiving less nitrogen from WPCPs. Also, the hydrodynamic activity in other sections of New York Harbor is much greater than Jamaica Bay; therefore, nitrogen levels will not accumulate to the same degree as evident in Jamaica Bay.

F. Atmospheric Deposition Policy

Recently, scientists and policy makers have begun to assess the importance of nitrogen deposited from the atmosphere. The issuance of the federal Clean Air Interstate Rule on March 10, 2005, aimed at reducing nitrogen oxides from power plants by over 60% from 2003 levels by 2015 across 28 eastern states may have a dramatic impact on the amount of nitrogen entering the estuary from atmospheric deposition. The implementation of the Nitrogen Oxide State Implementation Plans (NO_X SIP) under the Clean Air Act Amendments of 1993, were projected to reduce atmospheric deposition of nitrogen into the Long Island Sound by 18%.[51] It was predicted that a further reduction of nitrogen oxide in the magnitude of the legislation just passed would further reduce atmospheric deposition by approximately 33%.[52] Similar effects can be extrapolated for Jamaica Bay.

These policies taken together can eventually lead to an over 50% reduction in atmospheric deposition into the Bay by 2015.[53] However, much work remains to be done until policy measures can efficiently

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[46] S.V. Smith: Phosphorus versus Nitrogen limitation in marine environments. Limnology Oceanography 29: 1149-1160. 1984.
[47] Lovett, Gary M. Atmospheric Deposition of Nutrients and Pollutants in North America: An ecological perspective. Ecological Applications: Vol. 4, No. 4, pp. 629-650.
[48] Long Island Sound Study, 1997. The Impact of Atmospheric Nitrogen Deposition on Long Island Sound. www.longislandsoundstudy.net/pubs/facts/hypfsat.pdf.
[49] Swackhamer, Deborah L. et al. *Impacts of Atmospheric Pollutants on Aquatic Ecosystems*. Issues in Ecology: No.12. Summer 2004.
[50] Hudson River Foundation, 2004. Health of the Harbor: The First Comprehensive Look at the State of the NY/NJ Harbor Estuary.
[51] New York State Department of Environmental Conservation. A Total Maximum Daily Load Analysis to Achieve Water Quality Standards for Dissolved Oxygen in Long Island Sounds. December 2000. p.33.
[52] Ibid. p.35.
[53] Ibid. p.34.

regulate atmospheric inputs of nitrogen. Increasing regulation may be difficult to implement since "controlling emissions from internal combustion engines and power plants will increase costs for basic commodities like electricity and transportation."[54] Citizens are often adverse to these increased costs; therefore, it will be important for scientists and environmental professionals to work together to convince the public that preserving water quality in estuaries and coastal zones is necessary and a justified cost. In order for more stringent policies regulating nitrogen emission sources to be created, scientists need to address the issue of uncertainty as it pertains to the amount of nitrogen loading contributed by atmospheric deposition. If a standard method is developed which can accurately measure atmospheric deposition, we will have a more clear idea of its impacts.

G. Combined Sewer Overflows (CSOs)

Another minor source of nitrogen loading in Jamaica Bay is the combined sewer system of New York City, where storm water runoff and sewage water are transported together to sewage treatment facilities. The treatment facilities were constructed with the capacity to process twice the normal waste flow during dry weather.[55] However, in order to ensure that sewers do not back up during extreme precipitation events, CSOs redirect excess untreated sewage and storm water runoff so that they bypass the WPCPs and discharge directly into Jamaica Bay. There are approximately 20 CSO outfalls that discharge specifically into Jamaica Bay and several hundred others that discharge throughout New York and New Jersey Harbors when precipitation is so heavy that WPCPs cannot handle the load.[56] Overflow events allow for untreated waste, floatables, and toxic substances to be dumped directly into the Harbor's waterways. The addition of untreated waste could compromise the water quality of Jamaica Bay by increasing the amount of nutrients, especially nitrogen, in the system. While the exact amount of nitrogen emitted from CSOs has not been determined, it is believed that they are minimal in comparison to WPCP discharges and atmospheric deposition.[57] The critical issue involving CSOs is the resulting pathogen contamination to the whole estuary after extreme precipitation events. It poses a significant threat to the health of humans and aquatic organisms.

H. Combined Sewer Overflows Policy

Combined Sewage overflows contribute to the problems in Jamaica Bay and in the entire region. At the federal level, the EPA created a Combined Sewage Overflow Policy in 1994 under its NPDES program in an effort to help municipalities and state permitting agencies meet Clean Water Act Standards. As part of this policy the EPA required communities to implement "minimum technology-based controls" to help reduce the impact of CSOs by 1997. Currently, the EPA is finalizing standards on total maximum daily loads (TMDL) standards, which will restrict permitted capacity of CSOs. It has recommended CSO abatement projects including the elimination of CSO by physically separating combined sewer and wastewater systems, the expansion of waste treatment plants, and the creation of storage facilities for storm events.

In New York City, the NYCDEP is working to reduce the CSOs by implementing Best Management Practices (BMP). Following numerous violations of the 1992 Consent Order between the NYCDEP and

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[54] Lovett, Gary M. Atmospheric Deposition of Nutrients and Pollutants in North America: An ecological perspective. Ecological Applications: Vol. 4, No. 4, pp. 629-650.
[55] Hudson River Foundation. New York/New Jersey Harbor Estuary Program: Fact Sheet No. 3. Science and Environmental Research, Inc.
[56] Hudson River Foundation. New York/New Jersey Harbor Estuary Program: Fact Sheet No. 3. Science and Environmental Research, Inc.
[57] Hudson River Foundation, 2004. Health of the Harbor: The First Comprehensive Look at the State of the NY/NJ Harbor Estuary.

NYSDEC, NYCDEP was fined and agreed in the 2004 Consent Order to address water quality problems in New York Harbor associated with CSOs. The NYSDEC estimates that $2.2 billion will be spent on upgrading outfalls and building storage facilities throughout the Harbor.[58] Further, the NYCDEP has identified 36 CSO projects, which entail capital investments to help with the problem.[59] The five largest projects, one of which includes Jamaica Bay, have a budget of $1.46 billion. These projects range from massive underground storage tanks near Flushing Bay to the development of nets near 23 CSO outfalls. The dates for completing these projects range from 2005-2010.

In Jamaica Bay, the largest CSO management project is the Paerdegat Basin project. The Paerdegat is a channelized and bulk-headed tributary to Jamaica Bay. The plan includes maximizing in-line storage within the channel (totaling 20 million gallons), and constructing off-line 30 million gallon storage facility (including underground channels and a retention tank). Twenty-five percent of the CSO discharge into Jamaica Bay comes from Paerdegat Basin where a 50 million gallon storage facility was constructed in 2001 to alleviate some of the water quality problems stemming from CSOs.[60] In addition, the CSO storage facility on Spring Creek, a tributary into Jamaica Bay, is being updated to meet greater capacity.[61] The CSO projects will help to mitigate the degradation of water quality that results from untreated wastewater discharge into New York City's harbors. It is likely that these updates will provide some relief to the nitrogen loading problem in Jamaica Bay

In addition to the CSO projects, NYCDEP is implementing the Catch Basin Program, which is designed to reduce the amount of floatable material. Through this program, NYC's 130,000 catch basins should have been inspected and electronically mapped in 2001. Additionally, the NYCDEP has installed floatable barriers (a.k.a. booms) at the City's 23 outfall locations to catch floatables during CSOs.[62]

Although CSO events breach the WPCPs capacity to store and treat the volume of water present, they are a minor contributor to nutrient loading in the Bay.[63]

I. Run-off

Non-point source run-off may contribute small amounts to nitrogen to the system. However, most run-off is captured in the combined sewage system.[64] This includes substances like fertilizers and animal feces that can add to nitrogen loading.

Data suggests that the primary sources of nitrogen loading are WPCPs and atmospheric deposition. Our study of nitrogen loading in Jamaica Bay' focuses on WPCPs; the case studies presented below focus on how other regions of the country as well as abroad have developed alternative methods for managing their wastewater disposal.

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[58] DEC Newsletter 2005 Environnent http://www.dec.state.ny.us/website/environmentdec/2004b/nycwater908.html
[59] New York City to Invest $2.2 billion in wastewater system. (2004). *Waste News*, 10.
[60] Jamaica Bay: Preliminary Waterbody/Watershed Characterization Report. 2001.
[61] Ibid.
62 New York City Department of Environmental Protection. (2002). *Floatable Reduction Program*. Retrieved on February 5, 2005, from: http://www.nyc.gov/html/dep/html/float.html
[63] Hudson River Foundation, Health of the Harbor Report. The First Comprehensive Look at the State of the NY/NJ Harbor Estuary. March, 2004. accessed on March 31, 2005 from http://www.harborestuary.org/mgmt.htm
[64] NYCDEP. 2002. New York Harbor Water Quality Report.

V. Potential Solutions for Nitrogen Reduction

Several potential solutions exist to control the amount of nitrogen released into Jamaica Bay, including the case studies presented in Appendix D (special emphasis was placed on the construction of the Boston Outflow Pipe). Some may be used in combination with others in order to achieve an effective and efficient reduction. The options have been grouped according to their potential for immediate, intermediate and long-range implementation, due to the fact that the time horizon, as well as the scale for nitrogen reduction, varies among each possible solution.

A. Immediate Solutions/Options

These solutions build off existing capacity or utilize other relatively low-cost methods. They can have the shortest time frame to implementation. These are:

- Maintain Status Quo
- Operational Modifications: Alternative Treatment Plant Strategies
- Physical Mixing/Aeration of Bottom waters
- Biological reaeration: Commercial Seaweed Farms

However, the amount of nitrogen reduction or mediation is limited compared to the other strategies, and therefore may prove to be temporary or complimentary measures to the long-term solutions.

Maintain the Status Quo

Given the uncertainty surrounding many of the environmental issues affecting the bay, a program of continuous research is needed to further understand the causes and impacts of reduction in nutrients on DO levels, algal blooms and other nutrient related outcomes. The Comprehensive Management Plans for both the New York Harbor and Barnegat Bay in New Jersey lists such a program as one of their main recommendations in order to most effectively address the problems.

As illustrated above, there remains a great deal of contention on whether a problem really exists in the Bay. Delaying action now would provide time to:

- Study the effects of the outfall pipe in Boston in the region and help determine whether such an undertaking is appropriate for the Bay.
- Ascertain what the effects of the curbs in atmospheric deposition of nitrogen recently implemented at the federal level will have on the Bay.
- Determine the effectiveness of the wetland restoration efforts mentioned below. However, a long period may elapse before these effects become apparent and the health of the Bay may deteriorate significantly in the meantime.

Operational Modifications: Alternate Treatment Plant Strategies

The NYCDEP evaluated alternative solutions to reduce the nitrogen discharge into the Bay for the three wastewater treatment plants (Rockaway, Coney Island and Jamaica Bay) where it was determined technically infeasible to implement the step-feed BNR process, as had been done at 26th Ward. These alternatives include:

- Export sludge from Owls Head WPCP (3,000 lbs/day) and/or Rockaway (111 lbs/day) to a dewatering facility other than 26th Ward. Total nitrogen reduction = 3,066 lbs/day.
- Discontinue pumping of Coney Island WPCPs sludge to 26th Ward and send sludge to another dewatering facility via sludge vessels. TN reduction = 3,030 lbs/day.
- Importing sludge from Jamaica WPCP to 26th Ward so the centrate stream could get partial treatment in aeration tank #3. TN reduction = 1,250 lbs/day.
- Chemically enhance separate centrate treatment in aeration tank #3 to enable full nitrification of the centrate stream as opposed to the 30-50% nitrification currently being achieved.
- Export centrate from 26th Ward to other water body than JB via sludge vessels. TN reduction = 8,170 lbs/day.
- Export centrate from Jamaica WPCP to other water body via sludge vessels. TN reduction = 4,200 lbs/day.

An initial pilot attempt to reroute centrate from one facility to another has proven problematic due to failures in the pumps used to transport the centrate through the pipes. Follow up on a larger scale has been delayed as a result. The feasibility of exporting centrate via sludge vessels has yet to be analyzed in depth. Questions remain whether the vessels are equipped for such a cargo, and whether the resulting increase in barge traffic may pose navigational issues for the existing commercial and recreational uses of the Bay.

Mixing/Aeration of Bottom Waters

A technique that has been used widely in lakes and dams consists of locating mechanical aerators in areas where low DO is a localized concern.[65] The aerators inject oxygen from the atmosphere to the bottom of the aquatic system where the deficiency exists. It also helps to break up the stratified water column which is prevalent during the summer months. An analysis performed on the East River and Western Long Island Sound concluded that the boat based aerators were feasible, at a capital cost of $200-250 million.[66] However, a pilot project is needed to determine whether this option can be applied on the scale needed for the Bay. Also, this option does not address the other potential effects nitrogen may inflict on the system.

Biological Reaeration: Seaweed Farms

Raising benthic macro algae (seaweed) may help remove nitrogen from the Bay through the same photosynthetic process that creates algal blooms. The seaweed grows on floating structures and is harvested for sale, as a market already exists for the product. However, the scale of nitrogen removal is most likely small and should only be considered as a complimentary effort. In addition, the floating structures may interfere with navigation.

[65] A Total Maximum Daily Load Analysis in Long Island Sound. December 2000. p.35.
[66] IBID.

B. Intermediate to Long-range Solutions

The intermediate and long-range solutions require greater time for the installation and ramp-up phase and have much greater capital costs. They are:

- Modification of Treatment: Retrofitting the Wastewater Plants for Nitrogen Removal
- Modify the Bathymetry: Fill the Pits
- Discharge outside of Jamaica Bay: Build the Pipe
- Biological Enhancement: Wetlands restoration
- Reduce Discharge: Water Recycling
- Improve Monitoring: Integrated Ocean Observing System (IOOS)

With the exception of improved monitoring, intermediate to long-range solutions may have a significant effect on nitrogen removal and may resolve the nutrient issues affecting the Bay for the foreseeable future.

Retrofitting the Wastewater Plants for Nitrogen Removal

Although installing the step-feed BNR process at three of the treatment plants was deemed technologically infeasible, there are other processes treatment plants can install to remove nitrogen. The step-feed BNR process was analyzed because it has proven to be the most efficient and cost effective process. Other processes include:[67]

- Treatment of centrate water separate from total wastewater
- Microfiltration, the separation of water from solids via membrane
- Enhanced Nutrient Removal (ENR), using methanol to reduce nitrogen loads (potentially most effective technology)
- Cyclical nitrogen removal, using processes such as oxidation ditches (OD) which alternate aerobic and anoxic conditions to reduce nitrogen
- Modified Ludzack Ettinger (MLE) technique, which adds onto the activated sludge system by increasing the rate at which water is cycled through the plant

An independent technical advisory committee, formed at the request of the NYCDEP in 1998, comprised of seven experts in the field of nitrogen removal evaluated several of these technologies and concluded that at least one could be implemented in each of the plants discharging effluent into the Bay.[68] In addition, the Connecticut Department of Environmental Protection instituted a program to reduce nitrogen loads from treatment plants. The first phase of the program required a 25% reduction in nitrogen discharges through low-cost removal methods. At a cost of only $21 million, eleven plants were able to reduce over 5,000 pounds of nitrogen per day (a net reduction of 30%) largely through the use of the modified Ludzack Ettinger process.[69] Similar results may be replicated at the Jamaica Bay treatment plants.

Retrofitting the plants for nitrogen removal provides the greatest promise for addressing the nutrient loading issues. Total nitrogen discharged may be reduced by 30-75%, depending on the process used.

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[67] Nutrient Reduction Technology Cost Estimations for Point Sources in the Chesapeake Bay Watershed. Chesapeake Bay Program. November 2002, 5-28.
[68] NYCDEP. Nitrogen Control Feasibility Plan. p. 3. accessed on March 31, 2005 from: http://www.ci.nyc.ny.us/html/dep/html/nitrogen.html
[69] Johnson, Gary. “A Sound Solution”. Water Environment and Technology. Vol. 11:7. July 1999. p. 48

The nitrogen is not shifted to another location, to create potential problems in another area, and a continuous flow of freshwater is maintained in the Bay. The main drawbacks are the costs and technical feasibility of implementation, as none of the plants were originally designed for these processes. Operational problems were encountered at the 26th Ward plant when it was upgraded for the BNR process.

Fill the Pits

As mentioned earlier, the natural topography of the Bay has been dramatically altered by dredging to provide for shipping channels, the extension of the Rockaway peninsula created by land filling, and the excavation of large pits at the bottom of the Bay to provide fill material in the construction of Kennedy Airport. In order to restore the Bay to some semblance of its natural topography and improve the flushing rate of the water within the Bay, the NYCDEP has initiated the idea of filling the pits created when the airport was built. Correcting the other two alterations is not viable, especially to the residents of Breezy Point. An increase in the flushing rate will quicken the removal of nitrogen from the Bay and thereby eliminate the conditions which cause the algal blooms and the low DO. Furthermore, the bottoms of these pits are the areas experiencing the lowest DO levels. Consequently, little viable habitat for aquatic life will be lost through filling, and more bottom surface habitat may be gained as a result. Similar efforts were undertaken in Texas to correct similar problems.

The major drawback to this potential solution is the current uncertainty in what the flushing rate really is in the Bay. As mentioned previously, one study estimates the residence time for water at 10-35 days, whereas another more recent study estimates it at its estimated natural state of 7 days. If the latter study is correct, then there is no real flushing problem in the Bay and therefore filling the pits will have no discernable effect on the Bay. Other issues include the high costs of filling pits in an aquatic system, as well as what material with which to use to fill the pits. Sand is very expensive and cheap dredged material may be contaminated with other pollutants.

Build the Pipe

As discussed in great detail in Appendix D (the Boston Case Study), building an outflow pipe miles out into the Atlantic Ocean is an option. It would remove all nitrogen discharged by the plants from the Bay. However, as indicated by the total cost of $3.9 billion for the Boston case, the costs are likely to be extremely high and the pipe would remove the only significant flow of freshwater into the Bay, the effects of which remain completely uncertain.

Wetlands restoration

A program currently being administered by HEP has allocated a total of $120 million to the conservation and restoration of wetlands within Jamaica Bay. Approximately half of the funds have been dedicated to wetlands reclamation and the other half to wetlands restoration. The wetlands help remove nitrogen as well as filter out contaminants.

Water Recycling

Wastewater recycling is an innovative process for achieving sustainable wastewater treatment, and therefore holds the possibility of a potential long-term water management solution. For a state like California (discussed in detail in Appendix C), which is threatened by the lack of water resources coupled with the semi-arid climate, wastewater recycling helps to bridge the gap between natural water supplies and increasing demands. In New York City the current situation is very different. The city has an abundant source of pristine water in the Catskill and Delaware watershed and does not need a supplemental source. However, while wastewater recycling may not be an economically feasible option currently, it is something that the city should consider as a long-term source of water for industrial and commercial purposes.

Integrated Ocean Observing System (IOOS)

In conjunction with maintaining the status quo, utilizing this technology would aid the national and global effort to coordinate research on the world's changing ocean and coastal systems. The focus of the system is to maintain a central data collection system that with integrated models could predict possible ecosystem problems, or weather events. In addition the IOOS would help foster communication between research scientists. For NY harbor, it would be an invaluable resource, providing the collection of real time data, and the collaboration of many regional Universities.[70] This IOOS system is not operational in New York State yet, but many research institutes in the New York area are trying to work on this system and begin monitoring to observe changes in coastal and climate systems. The detailed and real-time data provided by this system would be invaluable for a better understanding of the threats facing Jamaica Bay and for developing possible solutions.

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[70] Kennish, Mike. Development of an Integrated Ocean Observing System for the New York Bight: An Overview White Paper Examining the Background Rational, and a Proposed Framework for Development.

VI. Political Feasibility and Political Perceptions of Potential Solutions

In addition to the general public's concerns about the Bay, decisions about feasible solutions will have to consider several institutional actors involved in Jamaica Bay. Currently there are 25 government institutions, ranging from the local to the federal level, with some degree of jurisdiction over Jamaica Bay. Thirty private/public/nonprofit organizations also have projects directed at Bay restoration, resource protection, and recreation within the Bay.[71] Several Jamaica Bay stakeholders and their missions are listed in Appendix D. Communication and coordination among all these agencies and groups, particularly at the government level, is crucial to developing effective strategies that improve the health of the Bay in the most efficient ways possible.

The community outreach team researched and consulted with organizations ranging from public agencies to local environmental and advocacy groups to investigate and gauge public perception and political viability of alternative policy solutions to waste water management. Proposed solutions include updating wastewater treatment plant infrastructure and technology, filling in previously dredged harbor locations, and the construction of a sewage effluent pipe into the Atlantic Ocean. The roles of the agencies listed in Appendix D include everything from policy implementation, to scientific analysis, to local community involvement; many of these roles specifically in relation to waste water management in Jamaica Bay.

While each of these organizations is a stakeholder in the health and activities of Jamaica Bay, it is clear that they voice very individual opinions based on factors such as their organization size, member character and opinion, and agency responsibility level to implement change in the current wastewater treatment and management practices. Several of the organizations targeted by the community outreach team responded to directly to phone calls and emails requesting information about their involvement in New York/New Jersey harbors, specifically in Jamaica Bay. Other organizations directed our questions to their public relations and press offices or have not yet returned our phone calls and email communication; we actively pursued their input.

The short-term and long range proposed solutions to waste water management that were presented above would be likely to solicit a breadth of responses varied by agency or organization; in a limited number of cases the community outreach team was able to explore agency responses. To supplement interview research, the websites and mission statements of many agencies listed in Appendix D were consulted.

A. Short Term Solutions

The temporary and flexible nature of the short term solutions would most likely not warrant drastic opposition from any of the government agencies or local organizations considered in this analysis. For instance, maintaining the status quo or 'doing nothing' to change the current infrastructure of the treatment plants would likely be viewed a sound approach by most agencies, even by groups who are of the opinion that there is a problem in Jamaica Bay.

NYCDEP produced the Harbor Report which found that algal blooms and hypoxic events (low DO) are increasing in Jamaica Bay. Organizations such as Friends of Gateway[72] and the Littoral Society,[73] agree with this and believe there is a problem with nutrient loading in the region. There is still some controversy among allies; Friends of Gateway and the Littoral Society believe that the nutrient loading is from two

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[71] Citizens Advisory Committee and the Science & Technical Advisory Committee of the HEP. Successes and Challenges: Highlights of Program Accomplishments and Challenges for the Future. February 2001. Accessed on April 20, 2005 from: http://www.harborestuary.org/mgmt.htm
[72] Personal communication with representative of Friends of Gateway . February 10, 2005.
[73] Personal communication with Marlene Kennedy of the Littoral Society. February 15, 2005.

separate sources. Friends of Gateway believe that effluent from water treatment plants is the single largest contributor to nitrogen loading while the Littoral Society feels that over development in the area is the primary source of nitrogen loading and that wastewater release is among many secondary causes.

These two groups might be happy to see more research done to better understand the causes and impacts of reduction in nutrients on DO levels, algal blooms and other nutrient related outcomes. However, there are others who might agree with maintaining the status quo for a different reason. Dr. John Tanacredi, a professor and Chairman of the Department of Earth and Marine Sciences at Dowling College and formerly a Supervisory Ecologist at Gateway National Park, spoke to us about Jamaica Bay; he believes that reduced water quality in Jamaica Bay is not a problem[74]. He says "If you took all the sewage treatment plants out of Jamaica Bay, it would still have hypoxic conditions; this is a natural condition that occurs all over the world." He calls situations such as algal blooms myths and says they are perpetuated by groups with political agendas. Dr. Tanacredi not only doubts the claims of politically charged groups but also doubts the methodology of the NYCDEP and warns that information they produce should be looked at "with a jaundiced eye."

Another possible short term solution is exporting the wastewater treatment product, centrate, via sludge vessels. This has not been analyzed in great depth and questions such as, exactly where centrate would be diverted, remain unanswered. Any diversion of centrate would likely create issues of "Not in My Backyard" (NIMBY) that would need to be considered among the communities involved. However, Bernie Blum, president of Friends of Rockaway proposes this centrate diversion from Jamaica Bay as a realistic policy solution[75].

These controversies and disagreements between parties were observed regarding these short term solutions, next we will examine public perception regarding long term alternative solutions to wastewater treatment.

B. Long Term Solutions

There is more potential for contention among stakeholders when proposing long term alternative solutions to waste water management; these solutions include large scale spending on planning, infrastructure and implementation. Four long term solutions are considered below.

Retrofitting the Wastewater Plants for Nitrogen Removal

As previously stated, installing the step-feed BNR process at three of the treatment plants surrounding Jamaica Bay was deemed technologically infeasible, however, alternative processes can be installed at treatment plants to remove nitrogen. As noted above, there is discrepancy among individuals and organizations as to if there is a nitrogen problem in Jamaica Bay. Beyond this very basic contention, the dividing questions on these new technologies include the costs and technical feasibility of implementation. However, as noted earlier, significant reductions were experienced at treatment plants in Connecticut through relatively low cost methods. None of the agencies that the community outreach team interviewed commented directly on retrofitting the plants, but debate over this issue might come down along advocate versus implementing agency lines. While scientists or local groups might endorse retrofitting as a solution, it is the NYCDEP who will eventually be mandated by the EPA and NYSDEC

[74] Personal communication with John Tanacredi on March 9, 2005.
[75] Personal communication with Bernie Blum of Friends of Rockaway on February 23, 2005.

to implement whatever solution is decided upon for wastewater management. Due to the limited budget at the NYCDEP, a cost benefit analysis is an essential tool for decision making[76].

Filling in the Pits in Jamaica Bay

This solution has been proposed to restore the Bay to be closer to its natural topography and to improve the flushing rate of the Bay. These changes would then help remove nitrogen from the Bay and consequently reduce the likelihood of algal blooms and low DO, especially the very low DO levels and the bottom of the pits. Mr. Ranheim from the NYCDEP says that filling in the pits "couldn't hurt" because it would create habitat and flushing. He continues by saying that this filling wouldn't "solve" the problem, but rather just cover it up. Mr. Ranheim says that "hardly ever when you fix something is it the same only better, it's just different.[77]" In an interview with Dr. Tanacredi of Dowling College and formerly of Gateway National Park, he said that "the agenda for the City of New York is to refill Grassy Bay…period![78]" As stated before, Grassy Bay is one of the most heavily dredged locations in Jamaica Bay. Based on these two interviews it is hard to exactly state what the NYCDEP's priority is, but again NYCDEP is an implementing agency who will voice their opinion with careful consideration of cost and the change in the health of the Bay produced. For the filling in the pits solution, the degree of cost is determinant upon what material with which to use to fill the pits. Clean sand is very expensive and the cheaper alternative, dredged materials, may bring contamination into the equation. Several of the local organizations listed in Appendix II are focused on stopping pollution in New York/New Jersey Harbors and could heavily protest potentially or known toxic material being used to fill in the Bay, no matter what containment precautions are taken. For example, NY/NJ Baykeepers, the Hudson river Fisherman's Association of New York, and Jamaica Bay Guardian all include looking for or stopping polluters or enforcing laws against pollution in their mission statements on their websites. In addition, Audubon society looks at harbor health issues in relation to bird habitat and migratory patterns and an accidental release of toxins once used as fill materials might irreversible change the property of the Bay and thus the bird migratory patterns.

Build the Pipe

The construction of this solution would remove all nitrogen discharged by the plants from the Bay and transfer this release into the Atlantic Ocean. "If money could be removed from the equation altogether" this would be the best solution, according to Beau Ranheim at the NYCDEP. However, the infrastructure cost alone for this solution is very high and must be factored in. Of the four long term solutions presented here, building of an outfall pipe into the Atlantic Ocean is one of the solutions that Mike Steffens at Friends of Gateway identified in an interview when asked what Friends of Gateway thought could be done to improve the system of wastewater treatment and management. However, in the Boston case study presented earlier, fisherman argued that the Boston Outfall Pipe has "ruined their livelihoods" since they are began to experience a decline in fish catches. It is possible that the Hudson River Fisherman's Association of New York and other fisherman's groups might make the same claims if an outfall pipe were constructed in New York. The Clean Ocean Action (COA) is a group known for closing eight ocean dumping sites and creating powerful public awareness of the ocean and its improved health after the site closures. While they did not respond to out attempts to contact them, based on this record, it is likely that this group would voice strong opposition to this long term solution. Even if the pipe did not harm the harbor or ocean health directly, controversy might rise from public perception, especially in beach communities, that their natural resource was being degraded. In the case of New Jersey Shore beach

[76] Personal communication with Beau Ranheim of DEP on March 11, 2005.
[77] Ibid.
[78] Personal communication with John Tanacredi on March 9, 2005.

communities, where currents would bring the contents of the outfall pipe, this complaint would be coupled with their outrage that the wastewater was from New York.

Water Recycling

Wastewater recycling is a forward-thinking plan for achieving sustainable wastewater treatment. As noted earlier, this option was implemented successfully in California; wastewater recycling may not be an economically feasible option in New York due to current lack of infrastructure to handle this recycled water and more ominously, due to the severe shortage of open and undeveloped space in our urban area. However, with government and local agency interaction, this solution could become much more feasible. For this is a solution, local organizations could really foster a change in citizen water use practices; several of the agencies listed in Appendix D have education, community outreach and education at the heart of their mission.

VII. Cost/Benefit Analysis

In this section, the costs and benefits of the possible solutions are broken down in order to compare the various courses of action to decrease the amount of nitrogen entering or accumulating in Jamaica Bay. The following are examined for each solution: removal of nitrogen (seen here as the "benefit"), materials/infrastructure needed, costs, time horizon, and possible negative side effects. Unfortunately, exact costs are not available, but the information gained from reviewing case studies brings the magnitude of such costs to light. In addition, the costs and benefits of various courses of action are juxtaposed in Figure 5 below to aid in their comparison.

Figure 5: Matrix of Costs and Benefits of the Possible Solutions

POSSIBLE SOLUTIONS	COSTS					BENEFITS				
	Capital Improvements	Infrastructure	Transportation	Technology	Personnel	Decrease in Total Nitrogen	Marsh Restoration	Improved Flushing	Maintained Freshwater Inputs	Flexibility
Maintaining Status Quo									●	●
Rerouting Effluent			●		●	●				●
Retrofitting Existing WPCPs	●			●	●	●			●	
Filling in Borrow Pits	●					●	●	●	●	
Constructing Ocean Effluent Pipe	●	●		●		●				
Recycling Effluent	●	●	●		●	●				

A. Maintain Status Quo

Nitrogen Removal

The same trends in nitrogen fluxes will occur. The reason that "no action" is an option is because there is still no scientific consensus over the existence of a problem in Jamaica Bay. Some scientists believe the water quality parameters in Jamaica Bay are normal and healthy. Therefore, the implementation of costly technical solutions is seen as an unnecessary expense. The argument can even be made that a proposed engineering improvement, such as an outfall pipe, could do more harm than good by removing freshwater flow from the Bay.

Materials/Infrastructure Needed

No new materials or infrastructure are needed to maintain the status quo. However, it has been suggested that more monitoring may be in order before any solution can be chosen with a high level of confidence that it will provide the desired result. Currently, researchers from various institutions are working to deploy an IOOS to aid in this monitoring effort.

Costs

Maintaining the status quo is a "no cost" solution; however, if further research warrants the need for a technical solution, such as an outfall pipe, the further ramifications of no present action could exacerbate the problem and increase the cost of remediation. In addition, additional monitoring, such as with the IOOS, will involve costs, which may be shared among various partners.

Time Horizon

N/A

Possible Negative Side Effects

A "no action" solution does not address the problem of nutrient loading in Jamaica Bay. However, it leaves time for more research in the actual scientific problem. Proponents of no action believe that the problem of nutrient loading in Jamaica Bay is minimal. If this does not turn out to be the case, then precious time has been wasted with unknown consequences.

B. Rerouting Effluent

Nitrogen Removal

As mentioned above, the Nitrogen Control Action Plan gives a series of alternatives to upgrading Jamaica Bay's WPCPs to tertiary treatment. These include dewatering sludge from the Jamaica WPCP at the 26th Ward WPCP, chemically enhancing the sludge treatment process at the 26th Ward plant so that it removes more nitrogen, and exporting centrate from Jamaica Bay plants to other bodies of water that are not nitrogen limited. Table 2 below outlines the possible solutions and the amount of nitrogen removed with each.

Table 1: Nitrogen Removal via Various Rerouting of Effluent or Centrate

Action	**Total Nitrogen Reduction**
Reroute sludge from Owls Head/Rockaway WPCPs outside JB	3,066 lbs/day
Reroute sludge from Coney Island WPCP outside JB	3,030 lbs/day
Import Jamaica WPCP sludge for partial treatment at 26th Ward	1,250 lbs/day
Enhance chemical process for complete denitrification at 26th Ward	--
Export 26th Ward WPCP's centrate outside JB	8,170 lbs/day
Export Jamaica WPCP's centrate outside JB	4,200 lbs/day

Materials/Infrastructure Needed

Many of these recommendations suggest the usage of sludge vessels in order to transport sludge, effluent, or centrate between plants in and outside of Jamaica Bay. These vessels were used previously in order to transport sludge for open ocean dumping prior to the ban on this activity in 1980s. Some are still in operation as they reroute sludge from Owls Head WPCP to other WPCPs that have capacity. The use of pumping stations has been problematic for the transport of sludge and is not considered here.

Costs

Transportation expenses are the major costs incurred when rerouting sludge, effluent, or centrate. These include fuel and personnel costs for sludge vessels. However, since no additional infrastructure is needed, these costs are believed to be small in comparison with other possible solutions.

Time Horizon

Diverting the stream of centrate and/or effluent from Jamaica Bay can begin in the near future, as sludge vessels become available. This solution allows flexibility in its lack of infrastructure investment and will allow for changes to course of action as new information becomes available.

Possible Negative Side Effects

Transporting sludge, effluent, or centrate outside of Jamaica Bay does not necessarily remove the problem of nitrogen inputs but only moves them to a different location. This strategy may cause unforeseen problems in other areas of the NY Harbor.

C. Upgrading Wastewater Pollution Control Plants

Nitrogen Removal

Upgrading the existing WPCPs in Jamaica Bay to tertiary treatment using Step Feed Biological Nutrient Removal technology can provide various levels of denitrification. These levels are given in the Nitrogen Control Facility Plan (1998) and include maximum total nitrogen removal, effluent with total nitrogen of 9mg/L, or effluent with total nitrogen of 4mg/L. Obtaining an effluent with total nitrogen of 4mg/L requires an addition process of denitrification. By upgrading only the 26th Ward WPCP, the NYCDEP can meet the SPDES discharge permits for Jamaica Bay. However, it is unknown whether meeting the permitted levels will spare Jamaica Bay from future eutrophic events.

Materials/Infrastructure Needed

Materials to upgrade WPCPs for nitrogen removal include baffles, mixers, and froth control systems. As of 1998, the NYCDEP was continuing to work out problem areas with these installations and their proper functioning. In some cases, some of the existing WPCPs, which were not originally design for nitrogen removal, do not have the capacity to hold effluent long enough to complete the denitrification process. This means that in order to upgrade these plants, other tanks will be needed, though space as such facilities is limited.

Costs

The following charts were given in the 1998 Nitrogen Control Facility Plan produced by the NYCDEP in order to manage the nitrogen emissions by WPCP in the New York Harbor area. They provide estimated costs for the three levels of nitrogen removal.

Table 2: Cost Estimates[79]

Costs Estimates* for Retrofit Process to Achieve Maximum TN Removal

WPCP	Capital ($mil)	O & M ($mil/year)	Present Worth ($mil)
26th Ward	48	13	333
Jamaica	26	7	176
Coney Island	30	7	178
Rockaway	12	2	64

Cost Estimates* for Recommended Alternative to Meet Effluent TN of 4mg/L

WPCP	Capital ($mil)	O & M ($mil/year)	Present Worth ($mil)
26th Ward	111	10	327
Jamaica	118	10	334
Coney Island	250	14	533
Rockaway	48	4	128

Cost Estimates* for Recommended Alternatives to Meet Effluent TN of 9mg/L

WPCP	Capital ($mil)	O & M ($mil/year)	Present Worth ($mil)
26th Ward	48	9	239
Jamaica	26	7	179
Coney Island	30	7	178
Rockaway	5	1	20

Time Horizon

Upgrading WPCPs in Jamaica Bay can take a matter of years depending on the level of nitrogen removal chosen and amount of unknown difficulties in implementing new technology. The WPCPs in Jamaica Bay were not constructed for nitrogen removal and each one will have its own issues to resolve for it to run effectively.

Possible Negative Side Effects

Upgrades in other WPCPs in the New York City area suffered from problems due to malfunctioning during periods of overload. In these instances more nitrogen was released into the system than without denitrification process. However, as the upgrades become operational, fewer problems should arise. Unlike other possible solutions, upgrading Jamaica Bay's WPCPs does not move the nitrogen to other places and thus may not cause additional problems.

[79] Cost estimates were presented in the December 31, 1998 HEP report and reflect 1998 dollars

D. Building Outfall Pipe

Because data is not available for an outfall pipe designed specifically for Jamaica Bay, the Boston case study is used as a good example of expected costs and benefits for such a project.

Nitrogen Removal

As indicated in the MWRA analysis of the Boston Outfall, the outfall pipe had an immediate effect of enhancing water quality that was formerly impacted by centrate discharge. By discharging the effluent 9.5 miles into the Massachusetts Bay, the nitrogen concentrated effluent was more evenly diffused as demonstrated by the MWRA tracking of the effluent plume.[80] Based on the same MWRA report, it appears that the construction of the Boston Outfall Pipe has benefited the area by increasing water clarity, decreasing ammonium levels, diluting effluent more effectively, and decreasing bacterial counts at former outfall locations. It is well documented that dynamic ocean systems can efficiently "buffer ecological perturbations over the short-term; "[81] however, the Boston Outfall Pipe has only been in operation for five years. Therefore, the long-term impacts of effluent discharge into the ocean have not been adequately measured.

Materials/Infrastructure Needed

The pipe is 9.5 miles long, 24 feet in diameter, and dispersed through 55 risers. The pipe had to be installed 128 meters below the ocean floor. 240,000 tons of precast concrete rings were needed to line the tunnel. A boring machine was used to create the tunnel, and then buried at the end of the tunnel. One-hundred-and-eighty workers were employed, six days per week, at a cost of 2.5 million man hours. The work crew encountered several unforeseen problems with rock conditions causing delays and cost increases.[82]

Costs

Construction of the Boston Outfall pipe cost $390 million. This sum was part of a $4 billion sewage treatment project in Boston Harbor and does not include interest on capital investment.

Time Horizon

The Boston project began in 1991, and was operational by September 2000.

Possible Negative Side Effects

Recent research off the coast of Cape Cod revealed that plankton type and levels may have been affected near the Boston Outfall diffuser locations. The original 2000 MWRA environmental assessment

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[80] The State of Boston Harbor. "After the Outfall: Massachusetts Bay Monitoring." Retrieved February 17, 2005 from: http://www.mwra.state.ma.us/harbor/html/soh2002_39.htm

[81] Moore, Gregg. "Effects of Boston Outfall on the Marine Community of Cape Cod Bay." Provincetown Center for Coastal Studies. March 7, 2005. Retrieved February 2, 2005 from: http://www.coastalstudies.org/pdf/CCBFinalCCC.pdf

[82] Neilson, James. "Extracts from Panorama: Last Lap in Lesotho." World Tunneling. Vol.9:9. November 1996. Mining Journal, 2001. Retrieved February 20, 2005 from: http://www.mjconstruct.com/tunnel/archive/1997/wt1196.htm

concluded that “no significant adverse effects” would occur on planktonic species;[83] however, in only five years this conclusion has been debated.

The Provincetown Center for Coastal Studies is continuing to express concern over the diffuser locations, and their impact on the endangered right whale. They are suggesting a “precautionary approach” to the potential long-term impacts of the Boston Outfall discharge. Therefore, they believe more research needs to be conducted on the potential adverse impacts of the effluent discharge on aquatic species.[84]

An outfall pipe in Jamaica Bay will divert a major portion of the nutrient levels away from the Bay, but this may simply be shifting the problem from the Bay to the ocean. A location off the coast will more adequately buffer the nutrient levels due to increased dilution and circulation, but this may simply be another diversion of the problem, not a solution.

Another major impact of diverting the centrate from Jamaica Bay to the ocean would be the removal of freshwater flow from the Bay. Before construction of the Boston Outfall pipe, Boston Harbor received only 50% of its freshwater flow from treated effluent wastewater. Jamaica Bay is almost entirely dependent on treated effluent wastewater as its sole source of fresh water. Removing this flow could impact the Bay’s ability to flush out any contamination.

E. Filling Borrow Pits

Nitrogen Removal

For the purpose of this project, the solution of filling in the deeper borrow pits of Jamaica Bay is to increase the flushing rate and circulation of water in the Bay, and, therefore, increase the Bay’s ability to naturally flush out nutrients. The MIT Sea Grant Center for Coastal Resources conducted research on the benefit of filling Norton Basin and Little Bay (two of the deepest locations in Jamaica Bay), and concluded that filling the pits and restoring them to historic depths would “drastically improve hydrodynamic exchange rates, which would improve sediment quality and benthic habitats.”[85]

In addition, filling in the deeper pits of Jamaica Bay may help restore wetlands. The process of dredging in Jamaica Bay has created a “sediment-starved” hydrodynamic condition, in which molecules of water are more prone to erode wetlands. By filling in the pits, more sediment will be available for wetland accretion in the system; therefore, the likelihood of wetland erosion will be decreased. Linking this solution to the preservation of wetlands may present a politically and socially viable approach, since loss of wetlands is the most tangible and noticeable problem to the general public. However, it is important to point out that there remains a lack of evidence to link the solution of filling the pits with wetland restoration.

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[83] Moore, Gregg. “Effects of Boston Outfall on the Marine Community of Cape Cod Bay.” Provincetown Center for Coastal Studies. March 7, 2005. Retrieved February 2, 2005 from: http://www.coastalstudies.org/pdf/CCBFinalCCC.pdf

[84] Provincetown Center for Coastal Studies. “Center Releases Results of Four-Year Cape Cod Bay Monitoring Project.” March 17, 2005. Retrieved March 20, 2005 from: http://www.coastalstudies.org/site-resources/monitor_project.htm

[85] Wenning, R. and D. Woltering. “Use of Ecological Risk Assessment Methods to Evaluate Dredged Material Management Options.” Retrieved February 3, 2005 from: http://massbay.mit.edu/marinecenter/conference/abstracts10.html

Materials/Infrastructure Needed

The procurement of a massive quantity of fill material will be needed to fill the borrow pits of Jamaica Bay. Clean fill material may be extremely expensive, as opposed to contaminated dredged material. However, there is a tremendous amount of fill material available from the dredging of NY Harbor, 4 million cubic meters of sediment per year. It is well documented that these dredged sediments have been contaminated with toxic chemicals, such as PCBs and pesticides.[86] The use of contaminated dredge material to fill the deep borrow pits of Jamaica Bay would be inexpensive, but will potentially impact aquatic organisms and benthic habitat. Not all sediments in New York Harbor are contaminated. For example, sandy materials from Ambrose Channel are likely suitable, both ecologically and toxicologically, for Jamaica Bay. Only those materials that are suitable for ocean disposal at the Historic Area Remediation Site (HARS) would be suitable for remediation in Jamaica Bay.

Costs

A similar project at the Port of Houston Authority that involved the filling of a 200-acre bay bottom to mitigate the effects of wetland loss had an estimated cost of $4 million. In the same study, the creation of the Spillman Islands Terminal needed 7.0 million cubic yards of new site fill with an estimated cost of $40,250,000.[87]

The cost of filling will greatly vary depending on the amount of fill needed, and the quality of the fill. The use of contaminated sediment would greatly reduce the total cost. One estimate put the cost of fill at $\$10/m_3$[88], while the Army Corps of Engineers report quoted a fill price at $10 per cubic yard,[89] with $10 per cubic yard seeming to be a standard for the Army Corps of Engineers.[90] Besides the cost of fill, there could be legal expenses for regulatory approval to fill the area, and those for environmental monitoring after filling is complete.

Clean fill from excavation of clay layers during the deepening of navigation channels in NY harbor could provide a low cost source of fill as well.

Time Horizon

The amount of time for filling the borrow pits will depend on permits and approval as the actual process of filling is not time intensive.

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[86] Neuhausler et al. "X-Ray Microscopy on Contaminated NY Harbor Sediment." Retrieved February 10, 2005 from: http://www.nsls.bnl.gov/newsroom/publications/activityreport/1998/NE1640.PDF
[87] Lockwood et al. "A Comparative Analysis Between the Spilmans Island and Bayport Sites." February, 2003. Retrieved February 17, 2005 from: http://www.portofhouston.com/pdf/genifo/POHA-Comparative-Analysis.pdf
[88] Northwest Hydraulic Consultants. "Impact of Climate Change on Annual Extreme Discharges in the Fraser Valley." Retrieved February 17, 2005 from: http://64.233.161.104/search?q=cache:lXqjoN0eb8wJ:victoria.tc.ca/~yk810/FraserRiver.doc+%22cost+of+fill%22,+water,+circulation&hl=en
[89] Burrus, et al. "The Economics of Hurricane Floyd: Minimization of Storm Surge Costs." May 24, 2000. Retrieved March 2, 2005 from: http://www.ecu.edu/coas/floyd/papers/floyd003.pdf
[90] U.S. Army Corps of Engineers. "Appendix A-How To Perform A Detailed Evaluation Of Flood Proofing Options." Retrieved February 19, 2005 from: http://www.usace.army.mil/civilworks/cecwp/NFPC/fphow/ace8-09.htm

Possible Negative Side Effects

There is concern that filling will increase turbidity and disruption of aquatic habitats. In addition, filling in the borrow pits may impact aquatic life and benthic organisms. There is currently no scientific consensus concerning the aquatic vitality of Jamaica Bay's deeper borrow pits. According to the NYSDEC, the habitats of Norton Basin and Little Bay "are no longer reaching their full ecological potential" as habitats available to support aquatic species.[91] Both the US Army Corps of Engineers, New York District (USACE-NYD) and NYSDEC have proposed the filling of Norton Basin and Little Bay as a means to "restore ecological functions to a highly impacted aquatic environment."[92] However, other research conducted by the National Park Service (NPS) and the American Littoral Society (ALS) conflicts with the declaration of these areas as dead zones. Therefore, filling the borrow pits will potentially be contested by environmental groups.

In addition, the origin of fill material is a point of contention. Since sections of the NY Harbor must be dredged 50 feet deep to create adequate port access, there will be a tremendous amount of potentially contaminated dredge material that needs to be relocated. The USACE and NYSDEC have declared that the formerly dredged dead zones of Jamaica Bay represent admissible areas to deposit this material.[93] However, questions remain concerning the underlying motive for filling these deep borrow pits: is it a potential solution for restoring ecological functions and increasing the Bay's flushing rate or just a way to unload contaminated dredged material. The solution to fill in the borrow pits materialized after USACE released the details of a federally mandated plan to further dredge and deepen the waterways to the Port of New York and New Jersey to 50 feet.[94] Hence, the dilemma lies in where to deposit the tremendous quantity of dredged material. Norton Basin and Little Bay have become recipients of the potentially contaminated dredged material.

Some community groups believe USACE is interested strictly in dumping the dredge material, not necessarily for the ecological benefit of Jamaica Bay.[95] Independent research conducted by the National Park Service and the ALS has determined that aquatic organisms are thriving in Norton Basin and Little Bay. Therefore, the filling of borrow pits would adversely impact and alter the existing benthic habitats of these regions.[96]

Another issue with this solution partially lies in the conflicting scientific consensus over the flushing rate in Jamaica Bay. Some reports claim that Jamaica Bay has an approximate 30 day flushing time, as opposed to other reports which report a "bulk residence time of Jamaica Bay" is seven days.[97] If the residence time is in fact seven days, then flushing does not necessarily represent a major concern, and filling in the pits may not have an extremely beneficial impact on the removal of nutrients from Jamaica Bay.

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[91] Rhoads et al. "Norton Basin/Little Bay Restoration Project: Historical and Environmental Background Report." November, 2001. Retrieved February 10, 2005 from: http://www.dec.state.ny.us/website/reg2/jbborrow/pdf/vittor01.pdf

[92] Ibid.

[93] Magooglaghan, Brian. "Borrow Pit Due Out In March." The Wave, Rockaway Community Newspaper. February 27, 2004. Retrieved February 10, 2005 from: http://www.rockawave.com/news/2004/0227/Community/025.html

[94] Ibid.

[95] Ibid.

[96] Magooglaghan, Brian. "Borrow Pit Due Out In March." The Wave, Rockaway Community Newspaper. February 27, 2004. Retrieved February 10, 2005 from: http://www.rockawave.com/news/2004/0227/Community/025.html

[97] Gordon et al, 2003 p. 47

F. Recycling Effluent

Nitrogen Removal

The recycling of wastewater effluent can divert nitrogen-rich waters from aquatic systems, such as Jamaica Bay, to be used in some other capacity, either on agricultural fields or for industrial purposes. The amount of nitrogen removed via recycling is equivalent to rerouting effluent or centrate to other WPCPs or piping it out to the open ocean.

Materials/Infrastructure Needed

The materials needed to recycle wastewater depend on the proximity of the WPCP to the facility where the water will be used. In some cases this involves extensive new piping systems or vehicles for transporting wastewater to agricultural fields or other non-potable water uses like landscape irrigation.

Costs

As described in the case studies above, the State of California is implementing a vast wastewater recycling program that will cost approximately $11 billion over 25 years.

Time Line

Implementing programs for wastewater recycling take time. The costs, organization, and planning for the needed infrastructure make this solution one with along time horizon involving high upfront costs and long term future benefits.

Possible Negative Side Effects

Recycling effluent will divert the current stream of freshwater from Jamaica Bay with unknown ecological consequences.

VIII. Conclusions and Recommendations

The scientific debate as to whether or not the nitrogen introduced into the Bay by discharged effluent is the direct cause of hypoxia and algal blooms, as well as playing a role in the extensive loss of wetlands in Jamaica Bay, creates a climate of uncertainty in developing policy recommendations. As stated by Larry Swanson, "the idea that nitrogen is causing this problem (of wetland loss) is a hypothesis." Similarly, the Nutrients Work Group (NWG) established by the HEP, which has focused its research on the causes of eutrophication, hypoxia, and algal blooms, has not yet accumulated the research necessary to formulate sound policy solutions to address these problems. In fact, the NWG has determined that at least another year is needed for running simulations of its System-Wide Eutrophication Model, which is designed to predict how different levels of nitrogen concentrations into the New York Harbor may affect the incidences of algal blooms and hypoxia.[98] Thus, although the science is currently not available to make the clear affirmation that nitrogen is the primary cause of algal blooms, hypoxic conditions, or wetland loss, strong evidence suggests points to these links and that nitrogen loading contributes to the synergistic effect of wetland loss in addition to sediment starvation and rising sea levels.[99]

Despite this conflicting scientific evidence over the severity of nitrogen loading in Jamaica Bay, Harbor Reports from the NYCDEP have indicated a steady increase in nitrogen levels, low DO, and an increase in the frequency of algal blooms. A local environmental coalition, the Jamaica Bay Ecowatchers, has made the observation that fish kills have been extensive throughout the Bay due to nutrient loading from sewage treatment plants causing low DO levels.[100] These findings have sparked a dedicated public movement to take action in protecting Jamaica Bay from further environmental damage. In fact, New York City Council Member James Gennaro has made this issue a priority and is currently supporting several bills aimed at protecting the vanishing wetlands.

Wetland loss is the galvanizing issue that has brought scrutiny to the problem of wastewater discharge into Jamaica Bay. While a causal relationship has not been established between nitrogen loading and wetland loss in the bay, probable connections have been made. In addressing the potential problems of nitrogen loading, it is important to keep in mind that the sources of nitrogen deposition are numerous. The issues of non-point source runoff and atmospheric deposition of nitrogen into the Bay have largely been unrecognized for their contributions to total nutrient loads. While acknowledging that the nitrogen contributions from WPCPs represent the most direct source of regulating nitrogen influx, it is also prudent to invest in continued research to establish more precise percentages of each source's relative contribution. However, the political demands of stakeholders cannot be ignored, as several environmental groups are demanding immediate action. Their belief is that excessive time spent on scientific data collection and debates over the cause and effect relationships can overshadow the fact that the Bay is continuing to deteriorate. Therefore, pressure exists on policy makers to develop meaningful solutions in the absence of scientific certainty.

A. Construction of a Sewage Outfall Pipe

There are several reasons why the construction of a Sewage Outfall Pipe as a potential option to help restore Jamaica Bay to a healthy state is currently not a viable solution. Although an outfall pipe will divert the entire quantity of nitrogen in treated wastewater away from Jamaica Bay, it will cut off most of the freshwater flow into the system. This may further impact the Bay's ability to flush out nitrogen contamination from other sources, creating the potential for eutrophication and nutrient loading in the long-run. In addition, the environmental impacts of discharging the effluent from an outfall pipe into the

[98] *Nutrient Work Group. Meeting Minutes, February 2004. Accessed from: http://www.harborestuary.org/mgmt.htm*
[99] Eugenia Flatow, City Council meeting, 3-31-05
[100] Dan Mundy, City Council meeting, 3-31-05

Atlantic have not been fully measured. Recent research examining the impacts of plankton build-up around the Boston Outfall Pipe diffusers has raised concern over the potential disruption of habitat for certain species such as the Right Whale.[101] Finally, the overall effort to build the Outfall Pipe cost the city of Boston $3.9 billion, which is an expense that NYC greatly prefer to avoid.

B. Retrofitting the wastewater plants

Retrofitting the wastewater plants in Jamaica Bay represents the most viable long-term solution for addressing nutrient loading issues. However, one of the main drawbacks is technical feasibility of implementation, since many of the WPCPs were not designed to handle technology improvements. In addition, the costs of retrofitting WPCPs are very large. The capital costs of upgrading the 26th Ward facility to meet total nitrogen in the effluent of 4 micrograms per liter were estimated at $111 million.[102] However, as identified by the successes achieved in Connecticut, significant reductions in nitrogen are possible at relatively low costs. Retrofitting the WPCPs is the soundest long-term solution to nutrient loading in Jamaica Bay because it will effectively decrease centrate nitrogen levels and ensure that an adequate flow of freshwater is entering into the Bay.

C. Recontouring deeper sections of Jamaica Bay by filling in the borrow pits

Recontouring deeper sections of Jamaica Bay by filling in the borrow pits also presents a viable solution. The historical dredging of Jamaica Bay has altered the natural flow of water. The NYCDEP estimates that dredging activities have increased the flushing rate of the Bay to 35 days; however, other research performed by The Earth Institute estimates that the average flushing rate is 7 days. Arriving at a scientific consensus concerning these differing conclusions may help warrant the implementation of filling activities to improve hydrodynamic exchange rates in the Bay.[103] If the flushing rate has expanded to 35 days, this will fortify the argument for filling the borrow pits. However, this option has been strongly criticized by environmental groups who believe this is a politically motivated action designed to dispose of the excess of contaminated dredge material cleared out of NY Harbor navigation channels. Leonard Houston of the NY US Army Corps of Engineers has insisted that the USACE "would not propose filling the pits with contaminated dredge material if they thought it would harm the Bay." On the other hand, utilizing a suitable, clean dredge material is a more responsible option that will decrease the likelihood of contaminating ecological habitat, but will drastically increase the project cost.

In order for this option to be considered, it will be important for the conduction of more research which illustrates the impact that filling borrow pits will have on aquatic organisms that exist in the deeper sections of the Bay. The option of recontouring Jamaica Bay may increase in popularity if the link between filling the borrow pits and restoring wetlands is established. Since the Bay is "sediment-starved", an increased sediment load will act to decrease the rate of wetland erosion, and filling the borrow pits will effectively remove the sediment sinks that they have created. One possible option to reduce the risk of ecological perturbation is to use potentially contaminated NY Harbor dredge material to fill the deeper sections of the borrow pits, then cap the area with clean dredge material. A reasonable

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[101] Moore, Gregg. "Effects of Boston Outfall on the Marine Community of Cape Cod Bay." Provincetown Center for Coastal Studies. March 7, 2005. Retrieved February 2, 2005 from: http://www.coastalstudies.org/pdf/CCBFinalCCC.pdf

[102] December 31, 1998 HEP

[103] Wenning, R. and D. Woltering. "Use of Ecological Risk Assessment Methods to Evaluate Dredged Material Management Options." Retrieved February 3, 2005 from: http://massbay.mit.edu/marinecenter/conference/abstracts10.html

approach would be to fill the deep borrow pits of Norton Basin and Little Bay, then conduct additional research to assess the effectiveness of filling those pits. If the flushing time is decreased, and ecological habitats are not adversely impacted, then the recontouring of the larger Grassy Bay area to a depth of 8 feet should also be considered.[104]

D. Recycling the effluent

Recycling the effluent may be an important option to implement in conjunction with other policy recommendations. However, there are potentially prohibitive costs and inefficiencies associated with wastewater recycling. At current costs, it would be infeasible to recycle the entire quantity of wastewater that is processed daily in Jamaica Bay.

E. Maintaining the status quo

Maintaining the status quo is an option some scientists, such as Dr. John Tanacredi of Dowling University, believe is the best option for Jamaica Bay. This is a potential option because it allows more time for research to be conducted to illustrate the extent of the problem. However, maintaining the status quo is unacceptable to the environmental groups concerned with the declining health of Jamaica Bay. A "no action" recommendation is politically unpopular and infeasible.

This is a critical time for solutions in Jamaica Bay which address the impending wetland loss and potential implications of decreasing water quality. A continued reliance on increased scientific research to understand the scope of the problem is undeniably needed. In the meantime, wetland areas are degrading at an alarming rate. With the backing of a tenacious community effort to restore the health of Jamaica Bay and reclaim its diminishing wetlands, it may be appropriate for scientists and policy makers to adopt a precautionary principle. Environmental legislation designed to promote the preservation of water quality in Jamaica Bay has not sufficiently addressed the complex natural interactions occurring in the Bay. The Ocean Dumping Ban passed in 1988 was intended to maintain healthy water quality parameters in the harbor and off the coast; but since the ban, Jamaica Bay has experienced a "significant increase in nitrogen levels."[105] Population pressures and manmade changes to the physical characteristics of Jamaica Bay have created a system that is largely incapable of effectively buffering ecological perturbation from nutrient loading. Regardless of the uncertainties surrounding the problem, it may be important to adopt an incremental, but precautionary, approach to reduce nitrogen levels in the Bay due to the political instability of the issue. This approach should focus on the more financially and politically feasible solutions while research continues, as presented below.

F. Recommendations

- Consider policy measures that put less emphasis on a single solution to cure Jamaica Bay, and place more emphasis on incrementally restoring the natural ecological dynamics to the Bay.
    - Recontour smaller sections of the Bay in Norton Basin and Little Bay as a means to improve the flushing rate and help to restore the rapidly diminishing wetlands.

- Secure funding for the long-term retrofitting of Wastewater Pollution Control Plants. This will effectively reduce total nitrogen levels and maintain freshwater inflow to Jamaica Bay while not shifting the problem to other locations.

[104] David Tweedy, City council meeting
[105] Larry Swanson, City Council meeting, 3-31-05

- Implement small-scale wastewater recycling programs with a goal of increasing their efficiency and cost-effectiveness.

- Avoid devoting a major capital effort to the construction of an outfall pipe because it will restrict freshwater flow into Jamaica Bay and may have unforeseen adverse environmental impacts at outfall diffuser locations in the Atlantic.

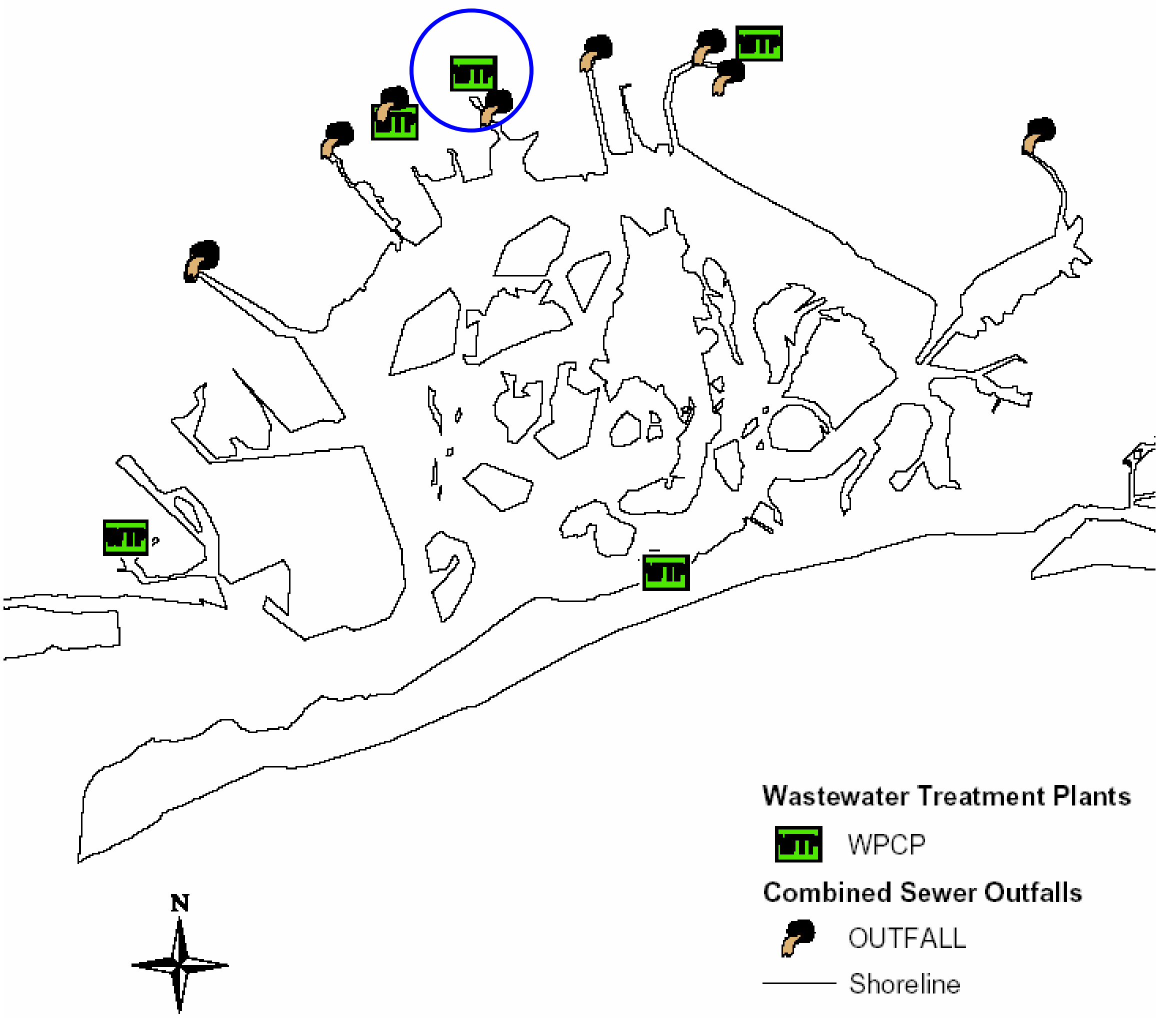
- Support continued research and a more substantive understanding of the scientific problem, with attention to how different policy solutions and engineering improvements can mitigate environmental contamination and help restore the Bay to its original ecological dynamics.

- Identify avenues for the multitude of agencies, organizations, and environmental groups with an interest in the health of Jamaica Bay to coordinate their efforts to sufficiently understand the complex natural systems that are occurring in the Bay. Focus should be put on active participation in public forums to voice concerns, share research, and expand knowledge about Jamaica Bay in order to create scientifically-sound policy solutions that incorporate the concerns of environmental groups.

Appendix A: Map of Hew York Harbor, Jamaica Bay Circled in Blue

Appendix B: Map of Jamaica Bay including WPCP Outfalls and Sampling Sites

Below is a GIS map outlining the Jamaica Bay coastline denoting where the Waste Water Treatment Control Plants, their outfalls, and CSOs outfalls are located in relation to the coastline. The plant circled in blue is Spring Creek Auxiliary, and is a compost plant not a water treatment plant, however, there is an outfall pipe located near it.



Appendix C: Case Studies

A. Implementation of the Boston Outfall Pipe

Background

The Boston outfall pipe is the world's longest offshore sewage tunnel (9.5 miles) transporting treated waste water outside of Boston Harbor and discharging it into Massachusetts Bay in a water depth of about 97.5 ft. The construction of this concrete-line tunnel (25-foot diameter pipes) began in 1991 and was operational by September 2000. The outfall pipe is part of a $4 billion cleanup effort that involved construction of a sewage treatment plant, tunnels for transporting sewage, and the drilling of the tunnel.[106] The effluent discharge is approximately 85 percent pure water after receiving primary and secondary treatment at the Deer Island plant. According to the Massachusetts Water Resources Authority (MWRA) 2002 Monitoring Results, the pipe has a 12 million gallon per day capacity.[107]

Massachusetts Water Resources Authority: Initial Findings

In order to track the location and dilution of effluent from the new outfall pipe, dilution measurements were taken after the pipe was operational and compared to previous years effluent dilution concentrations within the harbor. The results below illustrate that the new bay outfall creates a more evenly spread plume of effluent around a central location. This demonstrates a more rapid rate of effluent diffusion away from the outfall. Previous effluent discharge within the harbor created a large area of highly concentrated effluent spreading into Massachusetts Bay and south of Boston.[108] Scientists also observed the availability of aquatic life near the diffuser heads, and documented "densely growing sea anemones, sea squirts, starfish, founder, cod, sponges, and other animals."[109]

[106] Duckworth, I.J. and K.G. Wallace, Jr. Design of a Recovery Ventilation System for the Deer Island Outfall Tunnel. Mine Ventilation Services, Inc. 2000.
[107] Massachusetts Water Resources Authority 2002 Report : *The State of Boston Harbor.*
[108] Ibid.
[109] Ibid.

Figure 6.A1: Model Prediction of Effluent Dilution

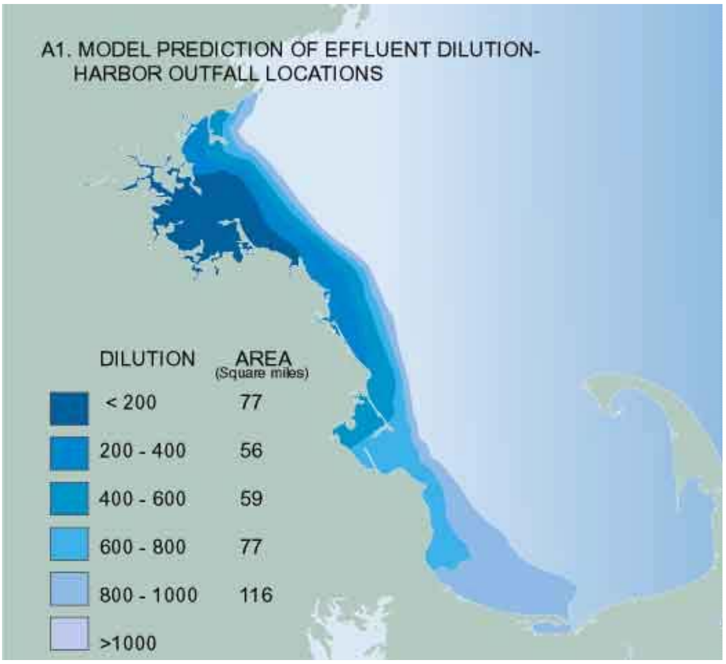
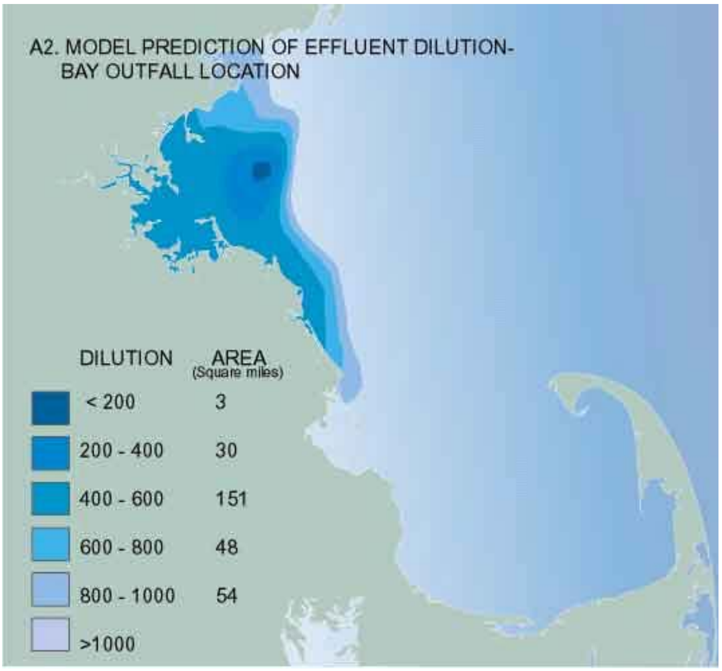


Figure 6.A2: Model Prediction of Effluent Dilution-Bay Outfall Location



Figures 6.A1 and 6.A2: Units represent the effluent dilution factor. The dark blue (labeled < 200) represents an area with a dilution factor of less than 200 parts water to 1 part effluent.
Source: Massachusetts Water Resources Authority 2002 Report : The State of Boston Harbor.

According to the MWRA, there appears to be various beneficial changes in harbor water quality as a result of relocating the outfall pipe. In general, water quality has significantly improved near the former harbor outfalls. The most notable improvements are apparent in the decreasing concentrations of bacteria, ammonium, and fecal coliform as well as increased water clarity.[110]

Benefits and Concerns

The transfer of effluent from Boston Harbor to 9.5 miles out into Massachusetts Bay has provided environmental benefits and raised some concerns. Boston Harbor has experienced an overall improvement in water quality as a result of the relocation of sewage effluent discharge to a location 9.5 miles outside of Boston. However, fresh water flow into Boston Harbor has decreased by 50% as a result of this relocation. This resulting change in the harbor's hydrologic dynamics creates both a benefit and a unique challenge. The harbor will no doubt benefit from the removal of sewage effluent by enhancing water quality and creating a healthier environment for aquatic life. However, the Mystic, Charles, and Neponset rivers now represent the only major freshwater inflows into Boston Harbor.[111] These rivers carry various point and non-point pollutants from upstream watersheds, and with a decrease in fresh water flow as a result of the outfall relocation, these pollutants will experience less mixing and circulation. Therefore, MWRA implemented a comprehensive monitoring program to report on the health of the bay's "water, plankton, sediment, fish, and shellfish", in order to establish a better understanding of the environmental impacts associated with the new outfall.[112]

Based on the MWRA analysis of water quality parameters in Boston Harbor and Massachusetts Bay, it appears that the construction of the Boston Outfall Pipe has benefited the area by increasing water clarity, decreasing ammonium levels, diluting effluent more effectively, and decreasing bacterial counts at former outfall locations. The MWRA analysis also demonstrated no significant impact on aquatic species. However, there is no conclusive evidence that the outfall pipe decreased chlorophyll or algae concentrations. There is evidence that indicates that a region-wide trend of increases in excessive algal blooms may be the cause of this occurrence. Also, bacterial counts at the new outfall location have slightly increased. The increases appear to be negligible, but this may present a concern in the future.

An important development has occurred recently in which the Provincetown Center for Coastal Studies and WMRA released (March 7th 2005) a report about the effects of the Boston Outfall Pipe on the Marine Community of Cape Cod. The report examines changes in planktonic species since the effluent discharge began. The report states that the WMRA's original conclusion that there were "no statistically significant adverse effects on the composition or distribution of planktonic species identified over a broad range of sampling locations" may in fact be incorrect. There have been a variety of small-scale findings that indicate that further work may be needed to fully asses the environmental impacts of the pipe.[113] The research done was conducted by the Cape Cod Monitoring Project (CCBMP), which started testing in 1999. It is well documented that dynamic ocean systems can effectively buffer ecological perturbations over the short-term. However, there is concern over the long-term impact of changing plankton type and levels around the outfall location. In particular, the potential impacts on the Right Whale which depends on a seasonal stock of planktonic species which have historically been available around Cape Cod.[114]

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[110] Massachusetts Water Resources Authority 2002 Report : *The State of Boston Harbor.*
[111] Ibid.
[112] Massachusetts Water Resources Authority 2002 Report : *The State of Boston Harbor.*
[113] Moore, Greg et al. Effects of Boston Outfall on the Marine Community of Cape Cod Bay. The Provincetown Center for Coastal Studies. March 7, 2005.
[114] Ibid.

Another novel finding occurred in 2003 when Woods Hole Oceanographic Institution released its report concerning the prevalence of ulcers on White Flounder in Boston Harbor. The report demonstrated that 24% of the White Flounder caught near the outfall diffusers were infected with ulcers. Other regions of the harbor further away from the diffusers exhibited a very low prevalence of ulcers on White Flounder populations.[115] It is not possible to directly link the causation of ulcers on White Flounder to the outfall pipe discharge of treated wastewater; however, if more research indicates unusual changes and impacts on aquatic species, there may be more substantive evidence that ties these impacts to the outfall pipe.

Table 1. Prevalence of external ulcers in the blind surface of Winter Flounder

Table 1. Prevalence of external ulcers on the blind surface of winter flounder sampled in April 2003.

Station	Ulcer Prevalence Percent (sample size)
Outfall Site	24% (70)
Broad Sound	16% (50)
Nantasket Beach	6% (50)
Eastern Cape Cod Bay	0% (50)
Deer Island	20-27% (15)*

Figure 7. ULCERS ON BLIND SIDE OF WINTER FLOUNDER COLLECTED AT THE OUTFALL SITE, 04/29/03

Source: Moore, Michael J. *White Flounder Ulcer Final Report for Fish and Shellfish Monitoring.* Woods Hole Oceanographic Institution. July 25, 2003.

Figure 7. Ulcers on blind side of Winter Flounder collected at the outfall site

The construction of the Boston Outfall Pipe presents an interesting solution to the problem of nutrient loading in an estuarine environment. The city of Boston has experienced a 36% growth in population over the past 20 years coupled with stricter treatment regulations.[116] The pressing demands of a heavily populated coastal city facing stringent environmental regulations created the need for a sewage outfall pipe, which seems to be a viable political solution. However, this solution has not gone without controversy. Many fisherman have presented the argument that the Boston Outfall Pipe has “ruined their livelihoods” since they are now experiencing a decline in fish catches.[117] Nonetheless, there is still no confirmed scientific evidence that the outfall pipe has created any substantial adverse impacts. In fact, based on the MWRA analysis, it appears that the outfall pipe has improved the harbor’s condition. The controversy may lie more in community and political perception than in scientific fact. An application of

[115] Moore, Michael J. *White Flounder Ulcer Final Report for Fish and Shellfish Monitoring*. Woods Hole Oceanographic Institution. July 25, 2003.
[116] http://wirenh.com/stories/1841
[117] Ibid.

the Boston Outfall Pipe solution to the problem of nutrient loading in Jamaica Bay may also yield a similar political controversy.

Potential Suitability to Jamaica Bay

A solution such as the Boston Outfall Pipe could present a viable solution for Jamaica Bay; however, there are variations in the physical conditions of Jamaica Bay and the Boston Harbor which make such a comparison difficult. One primary distinction is the amount of natural freshwater flow into the two water bodies. Jamaica Bay is almost entirely dependent on treated effluent wastewater as its sole source of fresh water. Removing this flow could impact the Bay's ability to flush out any contamination. Before the implementation of the Boston Outfall Pipe, Boston Harbor received 50% of its fresh water from treated effluent wastewater. Therefore, other natural sources of fresh water continue to influence the circulation and flushing of water within Boston Harbor.

B. Wastewater Recycling-California

Wastewater recycling is defined as "the treating and managing of municipal, industrial or agricultural wastewater to produce water that can be productively reused." [118] Wastewater recycling is an initiative aimed at trying to development sustainable and long-term solutions for the disposal and treatment of wastewater effluent. Recycling wastewater can be used for non-potable purposes, such as agricultural and landscape irrigation, industrial use, groundwater recharge and wildlife enhancement. Wastewater recycling is still a fairly new initiative for the treatment of effluent. However, many states have started to implement this technology with California, having one of the most extensive policies and programs.

California has been using recycled water for non-portable uses for decade, dating back to the late 1890's. The semi-arid climate and the scarcity of water has made wastewater recycling a very attractive option for the state. Starting in 1991, the California Water Recycling Act set statewide policies and goals for wastewater recycling.[119] Then in 2001, with the passage of Assembly Bill 331 the Department of Water Resources was required to establish the 2002 Recycled Water Task Force. The Task Force's primary purpose was to provide recommendations, identify key opportunity areas and determine the constraints of increasing wastewater recycling for industrial and commercial use. The 2002 Recycled Water Task Force report established volumetric wastewater recycling goals and identified 26 issues with conjunctive recommendations for recycling programs and projects.[120] The main volumetric goal for was to increase wastewater recycling to 1.5 million acre feet per year (equivalent to 1.8 billion m3 or 488.7billion gallons-liquid) by 2030, which is estimated to require an investment of $11 billion.[121] Currently the state recycles 500,000 acre feet (equivalent to 616.7 million m3 or 162.9 billion gallons). [122]

Wastewater is recycled through primary, secondary and tertiary (advanced) treatments. The greater the level of treatment the increased quality of the recycled water and in instances where the water may come into contact with humans more treatment is necessary. In 2002, California used 46% of its recycled water for agricultural purposes, such as crop irrigation. The next largest usage was for landscape irrigation, which accounted for 21% of the water used.[123] Groundwater recharge used 10% of the recycled water for

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[118] California Department of Water Resources. (2004). *Water Recycling Facts*. Retrieved March 30, 2005, from: http://www.owue.water.ca.gov/recycle/
[119] Ibid.
[120] Ibid.
[121] Ibid.
[122] Ibid.
[123] Ibid.

replenishment and restoration of the groundwater aquifers. Some of the other uses included industrial use (5%), wildlife habitat enhancement (4%) and recreational impoundment (6%).

California is currently recycling 500,000 acre-ft of water annually with the potential to recycle 1.5million acre-ft/year.[124] The potential uses for the recycled water include, landscape irrigation, industrial uses, such as power cooling towers, oil refineries, recycled newspaper processing and laundries, agricultural uses and office building for toilet flushing.

During an interview with a manager at the Department of Water Resources, some issues with wastewater recycling were addressed. Issues associated with the large costs of constructing the treatment facility and building the pipe infrastructure to carry the recycled water has been an obstacle in the implementation of these programs. Some cities have worked to overcome the cost and infrastructure issue by working with agencies to develop small, recycling plants. By developing these localized plants the agencies can tap into the sewer systems, treat the wastewater, distributing it locally and then send the byproducts to the main treatment facilities.[125]

San Diego is a good example of a successful city wastewater recycling program. San Diego currently recycles 13,000 acre-feet annually (equivalent to 16million m3 and 4,236million gallons). San Diego has three primary uses of recycled water, which include agricultural irrigation, municipal and industrial use and groundwater recharge. Agricultural irrigation along with municipal and industrial use comprises 69% of the recycled wastewater and groundwater recharge uses the remaining 31%.[126]. The San Diego county water authority is responsible for overseeing the wastewater recycling programs for the region and is also part of a larger organization, the Water Reuse authority. An example of a large-scale wastewater recycle program is in San Diego City at the North City Water Reclamation Plant. The plant has the capacity to treat up to 30million gallons of water daily, which would be distributed through the 45 miles of distribution pipeline. The primary benefit of wastewater recycling for San Diego, as well as many other California cities, is that it supports sustainable water management because of the region's high dependence on imported water. San Diego City alone imports 90% of its water. [127]

[124] Ibid.
[125] F. Karajeh, Department of Water Resources, personal communication, March 29,2005.

[126] San Diego County Water Authority. *Recycled Water*. Retrieved March 30, 2005, from http://www.sdcwa.org/manage/sources-recycling.phtml
[127] The City of San Diego Metropolitan Wastewater Department. (2005). *North City Water Reclamation Plant*. Retrieved on March 30, 2005, from http://www.sandiego.gov/mwwd/facilities/northcity.shtml

Appendix D: Community Outreach Agency List

Public Agency Involvement in New York/New Jersey Harbors

The New York City Department of Environmental Protection (NYCDEP) is responsible for protecting and preserving the environment of New York City and its upstate watersheds…NYCDEP also operates the City's wastewater treatment facilities, operates and maintains the City's water mains and sewers (http://www.ci.nyc.ny.us/html/dep/html/commis.html) NYCDEP has been involved in several investigations such as the "New York Harbor Water Quality Report".

The New York State Department of Environmental Conservation (NYSDEC) protects New York State's environment and manages its natural resources. The NYSDEC has been involved in conducting ecological investigations of subaqueous borrow pits in Norton Basin and Little Bay of Jamaica Bay between 2002 and 2003. These investigations produced data on the physical, chemical and biological features of the pits (http://www.dec.state.ny.us/website/reg2/jbborrow/pdflist.html).

Gateway National Recreation Center/ National Park Service is a 26,000 acre recreation area that extends through three New York City boroughs and into northern New Jersey. The National Park Service is the steward of Jamaica Bay and has written a report on it's condition. Management of Jamaica Bay occurs within the larger context of New York City and of the actions of many agencies, organizations, and individuals (http://www.nps.gov/gate/index.htm).

University Research Initiatives

The Rutgers University Institute of Marine Coastal Science provides national and international leadership in marine science and is New Jersey's focal point for education, research, and service efforts in estuarine, coastal, and ocean environments. They are dedicated to developing, communicating, and understanding processes governing change and sustainability in marine and coastal ecosystems, and to shaping future directions for the use and protections of our vital marine and coastal resources (http://marine.rutgers.edu/index.html).

The Center for International Earth Science Information Network (CIESIN) is part of the Earth Institute at Columbia University; they study social, natural, and information sciences, and specialize in interdisciplinary research related to human interactions in the environment (http://www.ciesin.org/). Scientists at CIESIN have conducted studies on Jamaica Bay health and have provided data and expertise to the COAST student consultants from SIPA.

Local Organization Missions

Barnegat Bay National Estuary Program (BBNEP) is one of the 28 estuaries of "national significance" in the U.S. and it is funded by the USEPA. BBNEP is housed and sponsored locally by Ocean Country College. It is a partnership of federal, state, municipal, academic, business and private organizations that work together with Ocean County and its communities to help restore, maintain, protect and enhance the natural resources of the Barnegat Bay Estuary and it watershed (http://www.bbep.org/).

Clean Ocean Action (COA) is a coalition of over 170 conservation, environmental, fishing, boating, diving, student, surfing, business, service, and community groups. COA aims to improve the degraded water quality of the marine waters of the New Jersey/ New York coast. COA uses research, public education, and citizen action to convince public officials to enact and enforce measures to clean up and protect our ocean. A few accomplishments of this group are the closing of eight ocean dumpsites, enabling of powerful clean water laws, and creation of greater public awareness of the ocean and its improved health (http://www.cleanoceanaction.org).

NY/NJ Baykeeper's mission is to protect, preserve, and restore the ecological integrity and productivity of the Hudson-Raritan Estuary. It is a citizen advocacy group for the Estuary's bays, streams and shores of NY and NJ. Baykeeper works to stop polluters, influence land use decisions, and restore habitat that will benefit the natural and human communities (http://www.nynjbaykeeper.org/).

NY/NJ Sea Grant is a partnership and bridge between government, academia, industry, scientists, and private citizens to help Americans sustainably use lakes and ocean waters for long-term economic growth. Sea Grant fosters scientific discovery, technology transfer, economic growth, and public education through research grants to academic institutions, government agencies, and nonprofits (http://www.seagrantnews.org/about/).

Hudson River Fisherman's Association of New York (HRFA) was formed by fishermen from Garrison, New York who were concerned about industrial abuse of the Hudson River. This small group pressured the government to enforce laws against polluting the waters of the Hudson that were for years in place but never followed. HRFA is concerned with fishing and pollution in the River (http://www.hrfanj.org/).

Jacques Cousteau National Estuarine Research Program (NERRS) is a system reserves around the country developed to protect the biologically, ecologically, economically, and aesthetically important areas known as estuaries. The reserve promotes the responsible use and management of the nation's estuaries through scientific research, education, and stewardship (http://marine.rutgers.edu/cousteau/jcnerr/aboutjcnerr.htm).

Jamaica Bay Guardian has been active for two years; their mission is to be stewards of the Bay, striving to work with others toward improving water quality and protecting natural resources of the Jamaica Bay ecosystem. They are involved in routine patrols of the bay to look for pollution, presenting educational programs about the Bay's resources to schools and civic groups, conducting wildlife censuses for the National Park Service, attending Port Authority Bird Hazard and Jamaica Bay Task Force meetings, and testifying before NYC Council Hearing on the disappearing marshes of Jamaica Bay (http://www.alsnyc.org/guardian.htm).

The Audubon Society is working on the Buffer the Bay program to address wetland disappearance and create a proposal to enhance wetland protection. They look at harbor issues as it relates to bird habitat and migratory patterns.

The Trust for Public Land (TPL) is a national, nonprofit, land conservation organization that conserves land for people to enjoy as parks, community gardens, historic sites, rural lands, and other natural places. TPL has a program in the New York/New Jersey Harbor that works to protect and repair the harbor's health and diverse ecosystem. They have protected 382 acres in New York that are linked to the harbor (http://www.tpl.org/tier2_sa.cfm?folder_id=170).

The Eastern Queens Alliance (EQA) is an activist group from eastern Queens involved in wetlands restoration; they lead an effort to protect Idlewild and the rest of Jamaica Bay. Some of their efforts include cleanups and fundraising walks in Idlewild and lobbying to block big developments such as the Triangle Equities' Brookville Center, a mall that would pave over 23 acres of wetlands. Recently (2004), the EQA won a grant from the EPA to plan and implement a two day Idlewild park Wetland Restoration Workshop for community and adults in Southeast Queens.

The Jamaica Bay Ecowatchers is an ecological advocacy and compliance group that works with five other community groups to preserve Jamaica Bay. These groups are the American Littoral Society (ALS), the Bay Improvement Group, the Friends of Gateway, the Jamaica Bay Guardian, and the NY/NJ

Baykeeper. Jamaica Bay Ecowatchers consists of local fishermen and was instrumental in discovering that the marsh islands in the Bay were disappearing. They are dedicated to the preservation, protection, enhancement, and restoration of the Bay's Ecosystem (http://nin.nbii.org/jamaicabay/stakeholder/ngo_jbe.html).

United Community Centers (UCC)was organized by residents of local housing projects in East New York to struggle for a better community and higher quality of life. The UCC includes many services, including youth groups that go camping and sailing on Jamaica Bay (http://www.volunteernyc.org/org/952618.html).

The American Littoral Society (ALS) acts to inform the community about ecological issues within the Bay and educate children on the ecosystem of the Bay (osprey club). They also patrol the Bay. A Littoral Society Representative told us that the current treatment system is good on one hand, but bad on the other. The interviewee believes that the development in the area is one of the primary causes. She didn't believe that wastewater is more or less damaging than other issues with development. However, there is a problem with nitrogen loading.

Hackensack Riverkeeper's mission is to provide representation for the natural living resources of the Hackensack River. This representation is manifested in the Hackensack environmental advocacy, education, and conservation programs. The focus of Hackensack Riverkeeper, Inc. is to protect and defend the environmental quality of the eco-system of the estuary, river, and watershed and the quality of life for the people and other creatures that inhabit the Hackensack River Watershed (http://www.hackensackriverkeeper.org/).

Friends of Gateway (FoG) is an urban outdoors program that was created by the Regional Plan Association as the successor to the Gateway Citizens Committee in 1987. FoG is dedicated to protecting, improving and enhancing public awareness of, and access to the New York Metropolitan area's unique National Recreation Area. Jamaica Bay is one of the areas of interest for this group (http://www.treebranch.com/friends_of_gateway.htm).

The Brooklyn Bird Club was founded in 1909 and currently has over 150 active members. The club promotes bird watching and conservation in Brooklyn and beyond. Jamaica Bay is listed as a hot spot for bird watching, even though their bird watching trips do not go to the Jamaica Bay area. The bay is said to be nationally and internationally renowned as a prime birding spot where thousands of water, land, and shorebirds stop during migration (http://www.brooklynbirdclub.org/).

Metropolitan Waterfront Alliance (MWA) advocate for aquatic habitats. They are a network of organizations that work to ensure the right choices are made in regards to private development and the leasing of waterfront parcels. MWA is concerned with helping to reclaim and reconnect to "the greatest natural resource", which is the harbor, rivers, and estuaries of the New York/New Jersey waterfront. They are active through education, grassroots organizing and media advocacy to include the public's voice and values in the decision-making that will determine the future of this region's waterfront and waterways (http://www.waterwire.net/AboutMWA/WhatIs.cfm).

The Jamaica Bay Task Force (JBTF) strives to be a vehicle for public participation in the local planning process. JBFT expects to have an influence on public decisions even though it is not a decision making body. This group has been meeting for years regarding environmental issues that influence the Bay and observe them as "over-zealous and their contentions against development in the Jamaica Bay area border on what the normal observer would consider foolish," says Jonathan Gaska, the district manager for Community Board 14 (http://www.treebranch.com/jamaica_bay_task_force.htm).

List of Acronyms

ALS	American Littoral Society
BBNEP	Barnegat Bay National Estuary Program
BMP	Best Management Practices
BNR	Biological Nitrogen Removal
BOD5	Five Day Biochemical Oxygen Demand
CCBMP	Cape Cod Monitoring Project
CIESIN	Center for International Earth Science Information Network
COA	Clean Ocean Action
CSO	Combined Sewage Overflows
DO	Dissolved Oxygen
ENR	Enhanced Nutrient Removal
EQA	Eastern Queens Alliance
FoG	Friends of Gateway
FPCAA	Federal Pollution Control Act Amendments
GIS	Geographic Information System
HEP	Harbor Estuary Program
HRFA	Hudson River Fisherman's Association of New York
IOOS	Integrated Ocean Observing System
IRIS	Integrated Risk Information System
JBTF	Jamaica Bay Task Force
MLE	Modified Ludzack Ettinger
MWA	Metropolitan Waterfront Alliance
MWRA	Massachusetts Water Resources Authority
NERRS	Jacques Cousteau National Estuarine Research Program
NIMBY	"Not In My Backyard"
NO_xSIP	Nitrogen Oxide State Implementation Plans
NPDES	National Pollutant Discharge Elimination System
NWG	Nutrients Work Group
NYCDEP	New York City Department of Environmental Protection
NYSDEC	New York State Department of Environmental Conservation
OD	Oxidation Ditches
OWM	Office of Waste Water Management
RfD	Reference Dose
SPDES	State Pollution Discharge Elimination System
TMDL	Total Maximum Daily Loads
TPL	Trust for Public Land
UCC	United Community Centers
USACE-NYD	US Army Corps of Engineers, New York District
WET	National Whole Effluent Toxicity Implementation
WPCP	Waste Water Pollution Control Plants

Appendix E: Glossary of Terms

algal bloom: A sudden spurt of algal growth, which can affect water quality adversely and indicate potentially hazardous changes in local water chemistry.[128]

atmospheric deposition : The process by which particles suspended in the air are deposited by precipitation or wind in the ocean, rivers, or on land.[129]

benthic: Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.[130]

Biological Nutrient Removal (BNR) The removal of nutrients, such as nitrogen and/or phosphorous during wastewater treatment.[131]

Biological Oxygen Demand (BOD): A measurement of the oxygen demand of organic material which, when breaking down in water, consumes oxygen in the water column.[132]

biomass: All of the living material in a given area; often refers to vegetation.[133]

boom: A floating device used to contain oil on a body of water.[134]

borrow pit: An excavated area where material has been dug for use as fill at another location.[135]

centrate: The nitrogen-rich water resulting from the treated sludge dewatering process that can increase total nitrogen loadings.[136]

coliform: Microorganisms found in the intestinal tract of humans and animals. Their presence in water indicates fecal pollution and potentially adverse contamination by pathogens.[137]

Combined Sewer Overflow (CSO) : An event where the discharge of untreated human and industrial sewage and stormwater into local waterways occurs when the capacity of a combined storm/sanitary sewer system is exceeded by local runoff.[138]

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[128] United States Environmental Protection Agency, "Terms of the Environment." Last updated on Friday, July 16th, 2004. Accessed on Saturday, April 30, 2005. URL: http://www.epa.gov/OCEPAterms/dterms.html
[129] New York City Department of Environmental Protection (NYCDEP). *New York Harbor Survey Water Quality Report 2003*. Retrieved April 30, 2005, from http://www.nynjcoast.org/NYCDEPHarbor_survey/docs/summ.htm
[130] Ibid.
[131] Ibid.
[132] Ibid.
[133] United States Environmental Protection Agency, "Terms of the Environment." Last updated on Friday, July 16th, 2004. Accessed on Saturday, April 30, 2005. URL: http://www.epa.gov/OCEPAterms/dterms.html
[134] Ibid.
[135] MERRIAM-WEBSTER ONLINE. Merriam-Webster, Incorporated. 2005. Accessed on Saturday, April 30, 2005 at: www.Merriam-Webster.com
[136] New York City Department of Environmental Protection (NYCDEP). *New York Harbor Survey Water Quality Report 2003*. Retrieved April 30, 2005, from http://www.nynjcoast.org/NYCDEPHarbor_survey/docs/summ.htm
[137] United States Environmental Protection Agency, "Terms of the Environment." Last updated on Friday, July 16th, 2004. Accessed on Saturday, April 30, 2005. URL: http://www.epa.gov/OCEPAterms/dterms.html
[138] New York City Department of Environmental Protection (NYCDEP). *New York Harbor Survey Water Quality Report 2003*. Retrieved April 30, 2005, from http://www.nynjcoast.org/NYCDEPHarbor_survey/docs/summ.htm

Dissolved Oxygen (DO): Amount of oxygen gas dissolved in a given volume of water at a particular temperature and pressure. This term also refers to a measure of the amount of oxygen available for biochemical activity in a waterbody, an indicator of the quality fo that water.[139]

dredging: Removal of mud from the bottom of water bodies. This can disturb the ecosystem and cause silting that kills aquatic life. Dredging of contaminated muds can expose biota to heavy metals and other toxics.[140]

effluent: Wastewater (treated or untreated) that flows out of a treatment plant, sewer, or industrial outfall. Generally refers to wastes discharged into surface waters.[141]

enterococcus: A common bacterial species found in the intestines of humans and animals; recently took the place of fecal coliform as the new federal standard for water quality at public beaches.[142]

estuary: Region of interaction between rivers and near-shore ocean waters, where tidal action and river flow mix fresh and salt water. Such areas include bays, mouths of rivers, salt marshes, and lagoons. These brackish water ecosystems shelter and feed marine life, birds, and wildlife.[143]

eutrophic: Having waters rich in mineral and organic nutrients that promote a proliferation of plant life, especially algae, which reduces the dissolved oxygen content and often causes the extinction of other organisms.[144]

eutrophication: Biological phenomenon of excessive nutrient load, heightened vegetative growth and subsequent low dissolved oxygen levels in water ecosystems.[145]

floatable: Primarily manmade debris, they contribute to beach closures, interfere with navigation, entangle wildlife and impair aesthetics.[146]

hydrology: The science dealing with the properties, distribution, and circulation of water.[147]

hypoxia: The state of a water body with dissolved oxygen concentrations of less than 2 ppm, the level generally accepted as the minimum required for most marine life to survive and reproduce.[148]

inlet: a bay or recess in the shore of a sea, lake, or river; a narrow water passage between peninsulas or through a barrier island leading to a bay or lagoon.[149]

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139 Ibid.
140 United States Environmental Protection Agency, “Terms of the Environment.” Last updated on Friday, July 16th, 2004. Accessed on Saturday, April 30, 2005. URL: http://www.epa.gov/OCEPAterms/dterms.html
141 Ibid.
142 New York City Department of Environmental Protection (NYCDEP). *New York Harbor Survey Water Quality Report 2003.* Retrieved April 30, 2005, from http://www.nynjcoast.org/NYCDEPHarbor_survey/docs/summ.htm
143 Ibid.
144 MERRIAM-WEBSTER ONLINE. Merriam-Webster, Incorporated. 2005. Accessed on Saturday, April 30, 2005 at: www.Merriam-Webster.com
145 New York City Department of Environmental Protection (NYCDEP). *New York Harbor Survey Water Quality Report 2003.* Retrieved April 30, 2005, from http://www.nynjcoast.org/NYCDEPHarbor_survey/docs/summ.htm
146 Ibid.
147 United States Environmental Protection Agency, “Terms of the Environment.” Last updated on Friday, July 16th, 2004. Accessed on Saturday, April 30, 2005. URL: http://www.epa.gov/OCEPAterms/dterms.html
148 Ibid.

leach: To remove soluble or other constituents from by the action of a percolating liquid.[150]

leach·ate: A product or solution formed by leaching, especially a solution containing contaminants picked up through the leaching of soil.[151]

methemoglobin: A brownish-red crystalline organic compound formed in the blood when hemoglobin is oxidated either by decomposition of the blood or by the action of various oxidizing drugs or toxic agents. It contains iron in the ferric state and cannot function as an oxygen carrier.[152]

methemoglobinemia: The presence of methemoglobin in the blood due to conversion of part of the hemoglobin to this inactive form.[153]

nitrification: The process by which ammonia is changed to nitrite, then nitrate, and finally nitrogen gas.[154]

nitrate: A compound containing nitrogen that can exist in the atmosphere or as a dissolved gas in water and which can have harmful effects on humans and animals. Nitrates in water can cause severe illness in infants and domestic animals. A plant nutrient and inorganic fertilizer, nitrate is found in septic systems, animal feed lots, agricultural fertilizers, manure, industrial waste waters, sanitary landfills, and garbage dumps.[155]

nitrite: An intermediate in the process of nitrification.[156]

pathogen: An agent that causes disease, especially a living microorganism such as a bacterium or fungus.[157]

primary waste treatment : First steps in wastewater treatment; screens and sedimentation tanks are used to remove most materials that float or will settle. Primary treatment removes about 30 percent of carbonaceous biochemical oxygen demand from domestic sewage.[158]

Reference Dose (RfD): The RfD is a numerical estimate of a daily oral exposure to the human population, including sensitive subgroups such as children, that is not likely to cause harmful effects during a lifetime.

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[149] MERRIAM-WEBSTER ONLINE.   Merriam-Webster, Incorporated. 2005. Accessed on Saturday, April 30, 2005 at: www.Merriam-Webster.com

[150] Ibid.

[151] MERRIAM-WEBSTER ONLINE.   Merriam-Webster, Incorporated. 2005. Accessed on Saturday, April 30, 2005 at: www.Merriam-Webster.com

[152] The American Heritage Dictionary of the English Language, Fourth Edition. Houghton Mifflin Company. 2003. Accessed on Saturday, April 30, 2005 at: http://www.thefreedictionary.com

[153] Ibid.

[154] New York City Department of Environmental Protection (NYCDEP). *New York Harbor Survey Water Quality Report 2003*. Retrieved April 30, 2005, from http://www.nynjcoast.org/NYCDEPHarbor_survey/docs/summ.htm

[155] United States Environmental Protection Agency, “Terms of the Environment.” Last updated on Friday, July 16th, 2004. Accessed on Saturday, April 30, 2005. URL: http://www.epa.gov/OCEPAterms/dterms.html

[156] Ibid.

[157] MERRIAM-WEBSTER ONLINE.   Merriam-Webster, Incorporated. 2005. Accessed on Saturday, April 30, 2005 at: www.Merriam-Webster.com

[158] United States Environmental Protection Agency, “Terms of the Environment.” Last updated on Friday, July 16th, 2004. Accessed on Saturday, April 30, 2005. URL: http://www.epa.gov/OCEPAterms/dterms.html

RfDs are generally used for health effects that are thought to have a threshold or low dose limit for producing effects.[159]

secchi depth: A measure of the cloudiness or turbidity of surface water.[160]

secondary treatment: The second step in most publicly owned waste treatment systems in which bacteria consume the organic parts of the waste. It is accomplished by bringing together waste, bacteria, and oxygen in trickling filters or in the activated sludge process. This treatment removes floating and settleable solids and about 90 percent of the oxygen-demanding substances and suspended solids. Disinfection is the final stage of secondary treatment (See: primary, tertiary treatment).[161]

tertiary treatment: Advanced cleaning of wastewater that goes beyond the secondary or biological stage, removing nutrients such as phosphorus, nitrogen, and most BOD and suspended solids.[162]

whole effluent toxicity: The aggregate toxic effect of an aqueous sample measured directly by an aquatic toxicity test.[163]

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[159] Ibid.
[160] The American Heritage Dictionary of the English Language, Fourth Edition. Houghton Mifflin Company. 2003. Accessed on Saturday, April 30, 2005 at: http://www.thefreedictionary.com
[161] United States Environmental Protection Agency, "Terms of the Environment." Last updated on Friday, July 16th, 2004. Accessed on Saturday, April 30, 2005. URL: http://www.epa.gov/OCEPAterms/dterms.html
[162] Ibid.
[163] Ibid.