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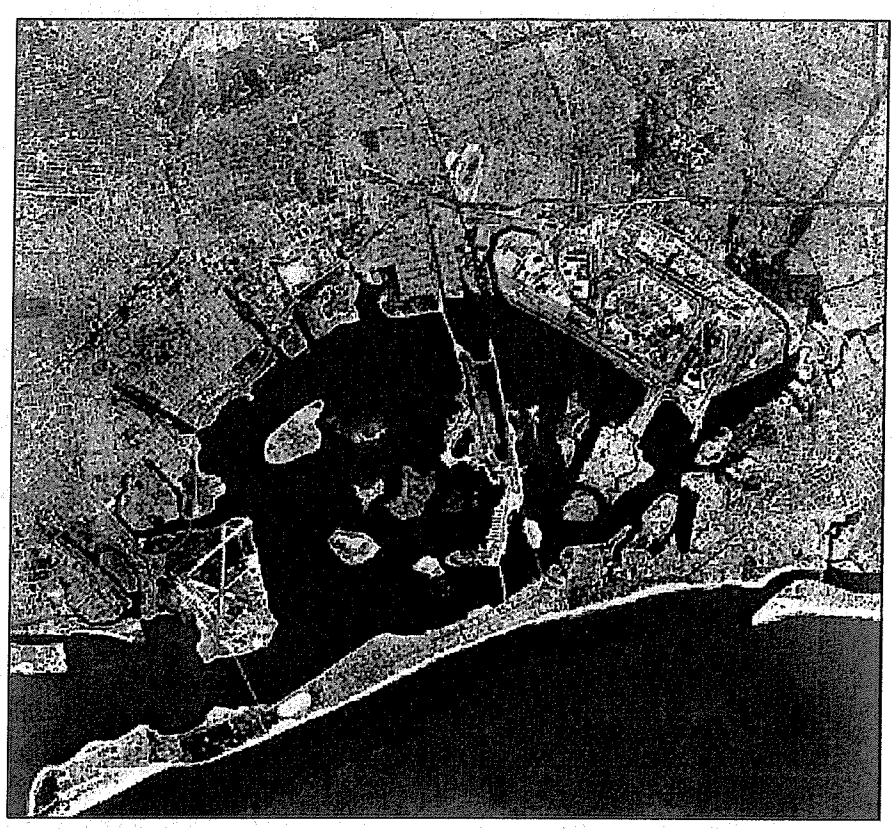

Comprehensive Jamaica Bay Report

New York City Department of Environmental Protection

October 2006

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Executive Summary

As required by the Nitrogen Consent Judgement (#04-402714), to be referred herein as the 2006 Nitrogen Consent Judgement, entered into by the New York State Department of Environmental Conservation (NYSDEC) over the New York City Department of Environmental Protection (the Department), a Comprehensive Jamaica Bay Report is to be prepared and submitted to the NYSDEC by October 31, 2006. As required by the Consent Judgment, this *Report* summarizes work that was undertaken to examine possible alternative methods of meeting applicable water quality standards for the open waters of Jamaica Bay. The *Report* integrates information obtained from the Jamaica Bay Eutrophication Project Study, the Use and Standards Attainment Project, the Citywide Advanced Wastewater Treatment Program and the Long Outfall Relocation Project and provides recommendations and an implementation schedule for improving water quality in the open waters of Jamaica Bay. The content and submission of the *Report* by this date fully satisfy the requirements of the 2006 Nitrogen Consent Judgment.

ES.1 Overview of the Effort

The coordinated engineering and scientific investigations summarized in this report commenced in June 2003. At that time, the Department merged the ongoing water quality planning efforts of the Jamaica Eutrophication Project (commenced 1994), the Use and Standards Attainment Project (commenced 1999), the Citywide Advanced Wastewater Treatment Program (commenced 1998) and the Long Outfall Project (commenced 2002) for purposes of developing a comprehensive report to evaluate and, as necessary, reduce the impacts of nitrogen discharges to the bay and improve dissolved oxygen levels within the open waters of the bay.

Extensive evaluations were undertaken of the open waters of Jamaica Bay to characterize water quality and biological resources. Wastewater and other inputs were monitored and extensive peer-reviewed water quality modeling was performed to establish the causal relationship between Water Pollution Control Plant (WPCP) inputs and resulting water quality. Detailed engineering evaluations were conducted to evaluate a wide variety of treatments including low level, medium level, high level and limit of technology reductions; as well as non-treatment alternatives including outfall relocation, bay recontouring and aeration to improve water quality within the open waters of Jamaica Bay. Rigorous engineering and cost evaluations were performed for all alternatives. Additionally, extensive sampling and monitoring of the pelagic and benthic ecosystems within the open waters of Jamaica Bay were and continue to be performed to characterize current conditions and improvements that might be expected as a result of reducing the total nitrogen load discharged to the open waters of the bay.

Most of the engineering analysis done for the Comprehensive Jamaica Bay Report concluded during the summer of 2005 and the last twelve to eighteen months has been spent conducting agency coordination meetings to review the work effort and implications attaining water quality in Jamaica Bay. These included numerous meetings with the New York State Department of Environmental Conservation (NYSDEC), the US Army Corps of Engineers (USACE), the National Park Service and

the Port Authority of New York and New Jersey. In September 2005, the Department met with NYSDEC's technical staff to review the work effort completed at that time. In October 2005, the NYSDEC and the Department Commissioners also met to review regulatory and policy implication of report results to that time. At each meeting, the ineffectiveness of advanced wastewater treatment in meeting water quality objectives, and the significance of the human alterations of Jamaica Bay in the Grassy Bay and North Channel areas on water quality attainment, were discussed. Additional technical meetings were held in late 2005 and 2006 where these issues were continually highlighted and explored. Also discussed was DEP's concept of cost-effective and phased reductions in wastewater loadings to Jamaica Bay and interagency coordination for bay restoration by recontouring.

In July 2006, DEP participated in a Value Engineering workshop held with the NYC Office of Management and Budget (OMB) where a group of national experts were assembled to review the proposed plan. Alternatives were reviewed and analyzed rigorously for one entire week considering a variety of factors including effectiveness in improving water quality, schedules and cost. This workshop concluded with the VE agreeing with the recommended plan as proposed in this report, as well as some follow-up actions.

The *Comprehensive Jamaica Bay Report,* therefore, represents the culmination of considerable technical analysis and agency coordination to plan for the improvement and protection of this valuable natural resource. On the basis of the efforts described above, the following general and key findings are presented, and recommendations are made to improve water quality in Jamaica Bay:

ES.2 Summary of General Findings

The Jamaica Bay watershed has been extensively developed and urbanized with a population of approximately two million persons residing within its drainage area. The bay's geomorphology and bathymetry have been extensively altered, especially during the development period of the last century. Grassy Bay has been deepened from approximately 2 feet below mean low water (MLW) to 40 feet below MLW during that time.

Jamaica Bay is eutrophic with high levels of algal productivity, particularly in the Grassy Bay and North Channel areas. Water quality measurements show that the phytoplankton activity is a result of over enrichment by the nutrient nitrogen. Bay dissolved oxygen concentrations are subsequently seasonally depressed. The most severe oxygen depression is confined to the lower layers of the Grassy Bay and Grass Hassock borrow pits and the deeper portions of the dredged North Channel during the summer period.

On the basis of ichthyoplankton and benthic infauna sampling to date, Jamaica Bay's ecosystem appears to be productive and resilient, yet seasonally stressed in specific locations. The fishery is productive with larval diversity and density consistent with a coastal region on the north shore of eastern Long Island. Ichthyoplankton taxa numbers appear unrelated to water quality, although taxa shifts appear to be related to seasonal dissolved oxygen depression. Faunal abundance and species numbers are associated with bathymetry, water quality and bottom sediment composition. The characteristics of shallower, and well mixed regions of the bay, were found to be markedly different from those in the deep borrow pit and channel areas.

Modeling and water quality sampling investigations demonstrate that the seasonal water quality depression in Jamaica Bay is related to the discharge of treated wastewater to the bay which is exacerbated by the historical human alterations of the bay's bathymetry, particularly in Grassy Bay and the North Channel. The four WPCPs that discharge to the bay contribute approximately 90 percent of the total nitrogen input. Of these plants, the most important in terms of water quality impact are the 26th Ward and Jamaica WPCPs.

Various engineering alternatives demonstrate differing levels of effectiveness in terms of reducing eutrophication impacts and improving oxygen resources in affected areas, particularly Grassy Bay and the North Channel. Advanced wastewater treatment, and non-treatment alternatives such as outfall load relocation, coarse bubble instream diffuser aeration in Grassy Bay, and bathymetric restoration of Grassy Bay and the North Channel via recontouring were considered. Combinations of these alternatives were also evaluated for cost-effectiveness. The alternatives considered varied in their estimated conceptual capital construction cost of from $65 million to $ 5.5 billion in 2006 dollars.

ES.3 Summary of Alternatives; Key Findings

Advanced wastewater treatment at the 26th Ward and Jamaica WPCPs, is effective in reducing the total nitrogen load discharged to the open waters of the bay and improves the seasonal dissolved oxygen levels in Jamaica Bay.

Limit of Technology nitrogen reduction at all four Jamaica Bay WPCPs discharging to the open waters of Jamaica Bay will not attain the dissolved oxygen water quality standard of 5.0 mg/L at all times and in all locations under current altered bay bathymetry. Similar improvements to dissolved oxygen can be achieved at less stringent levels of nitrogen reduction due to the existing bathymetry of the bay.

Relocation of the four Jamaica Bay WPCP outfalls to the Atlantic Ocean or Rockaway Inlet would improve eutrophic and water quality conditions within the open waters of Jamaica Bay to a degree greater than that from Limit of Technology nitrogen reduction. As with advanced treatment, most improvement would be realized by relocation of the 26th Ward and Jamaica WPCP outfalls. However, load relocation would not attain the current dissolved oxygen standard in the lower water column of Grassy Bay during the summer, due primarily to historical bathymetric alterations. Additionally, the outfall relocation alternatives will be difficult to implement and permit due in part to strong public opposition to wastewater disposal to, or near, the ocean. Further, the removal of the main source of non-saline water to the bay may have negative impacts to the existing ecosystem that are difficult to predict and quantify at the present time.

A coarse bubble seasonal in-stream diffuser aeration system is cost-effective in attaining the dissolved oxygen standard in Grassy Bay. However, an extensive diffuser field would need to be constructed within Grassy Bay. The National Park Service, which has jurisdiction over the bay and subaqueous land, has informed the Department over several meetings, that a man-made solution of this type to correct a man-made problem would not be acceptable.

Modeling and water quality sampling demonstrates that the dissolved oxygen levels of Jamaica Bay in Grassy Bay and the North Channel are significantly impacted by the historical alterations of the bay's bathymetry for sand mining. It is projected that restoration of the bathymetry in these areas would achieve improvements in bottom dissolved oxygen concentrations, similar to that attained by advanced wastewater treatment. The projected improvements in bottom dissolved oxygen concentration attained by bathymetric restoration, could be further enhanced if implemented in conjunction with cost-effective treatment.

ES.4 Comprehensive Report Recommendations

In view of the complexities of Jamaica Bay's ecosystem and the historical human-caused alterations of the bay's watershed, receiving waters and bathymetry, the Department recommends a phased approach for adaptive management of needed environmental improvements. This approach would consist of cost-effective treatment reductions for nitrogen, and continued ecosystem evaluation and post-construction ecosystem monitoring in order to assess the effectiveness of controls. The Department would also work closely with other stakeholder agencies to monitor progress, and seek interagency cooperation to improve the bay's environment and ecosystem, as appropriate.

Of the various treatment and non-treatment alternatives that have been evaluated, the most readily implementable option from a Department control and regulatory approval standpoint, is nitrogen reduction by advanced wastewater treatment. Modeling and engineering analysis show that nitrogen reduction at the 26th Ward and Jamaica WPCPs are most water quality effective of the four Jamaica Bay WPCPs. It is recommended that the Department complete implementation of Contract 12 nitrogen load reduction at the 26th Ward WPCP as currently planned and being implemented, and obtain approval for design and construction of Level 2 Biological Nitrogen Removal (BNR) with modified flow split, partially oxic nitrification at the Jamaica WPCP.

It is projected that this level of nitrogen load reduction will achieve 85 percent annual attainment (days) of the current dissolved oxygen standard in the most severely impacted lower water column of Grassy Bay area on a time basis. On a more representative and complete ecosystem-based volume and time weighted basis, dissolved oxygen standards attainment of 83 percent (volume basis) is projected for Grassy Bay, even during the more critical summer period. This level of attainment would increase to 90 percent with the recontouring of Grassy Bay and North Channel to a depth of 8 feet below mean low water.

The Department proposes to extend its current water quality and ecosystem monitoring program, with NYSDEC oversight, for an additional two years, to further establish existing ecosystem impacts and establish baseline conditions. The Department will provide a detailed report on this program to NYSDEC upon its completion. The Department will also cooperate with NYSDEC to develop and implement a post-construction water quality and ecosystem monitoring program which would be implemented after proposed 26th Ward and Jamaica WPCPs upgrades are constructed and placed into operation.

The Department will also be completing, under the Citywide Long Term Control Plan (CSO) Project, the development of the Jamaica Bay Watershed/Sewershed Protection Plan, which is now in progress. This plan will evaluate and recommend additional steps that the Department and possibly other City agencies can consider to reduce runoff and inflows into the sewer systems to further reduce loadings to the open waters of Jamaica Bay and its tributary waterways.

The engineering and scientific work conducted during this project demonstrates the significant adverse impacts produced by the human alterations of Jamaica Bay's geomorphology and bathymetry. The deepening of the Grassy Bay area in particular, as well as the North Channel, reduces dissolved oxygen resources and otherwise adversely impacts demersal and benthic aquatic life. It is therefore recommended that NYSDEC continue and extend its leadership role in Jamaica Bay restoration projects to seek interagency cooperation for the bathymetric restoration of Grassy Bay and the North Channel.

Given the technical, engineering and regulatory obstacles which exist for full attainment of the current dissolved oxygen standard, DEP would like to suggest that it may be beneficial for both the City and the DEC to jointly assemble another third party review of this proposed plan be conducted. In the meantime, DEP will gladly share information from the week long Value Engineering workshop that was held in July 2006, including all recommendations

1. Introduction

1.1. Background

1.1.1. Physical Description

Jamaica Bay is a part of the New York/New Jersey Estuary System. Jamaica Bay is a shallow bar-built estuary located on the south shore of western Long Island, New York, Figure 1-1. The bay is bordered by Brooklyn to the west, Queens to the north, Nassau County to the east and Rockaway to the south. The bay is roughly circular and covers an area of 19 square miles of open water, tidal flats, bordering marshes and a number of interior marshland islands. Navigable channels averaging 27 feet in depth encircle most of the outer ring of the bay. Much of the area in the center of the bay consists of narrow channels and tidal marsh islands, which are exposed during low tides. Interchange of water with the Atlantic Ocean is through the Rockaway Inlet.

Jamaica Bay is one of the largest and most productive coastal ecosystems in the State of New York, as well as within the Northeastern United States, and is an important recreational destination for local, national and international visitors. It contains approximately 9,100 acres of surface waters, including the largest tidal wetland complex in New York State. These wetlands provide benefits such as natural water quality improvement, flood protection and shoreline erosion control for the commercial and residential areas in and around the bay in Brooklyn and Queens. Jamaica Bay is a habitat for marine life and a spawning nursery ground for aquatic species with its nutrient rich waters.

1.1.2. Historical Background

Until the late 1800s, Jamaica Bay was essentially non-developed and served a prosperous shellfish and fishing industry. Originally, Jamaica Bay was a roughly circular marshland comprised of approximately 25,000 acres, which was protected from the ocean by the Rockaway peninsula (Figure 1-2). It remained in this state until the beginning of the twentieth century when a plan was introduced to develop the bay into a major seaport. This plan included widening and deepening of the channel between the inner and outer zones of the existing marshes. To that end, a channel was dredged in the northwestern portion of the bay that was 1,000 to 1,500 feet wide and 30 to 40 feet deep.

The fill from Jamaica Bay dredging activities was used to raise the marshes adjacent to the land in order to build piers and docks, and to create Floyd Bennett Airfield and what is now John F. Kennedy International Airport. As noted in the report Jamaica Bay and Kennedy Airport Volume II, dated January 1971, prepared by the Jamaica Bay Environmental Study Group, an estimated 125 million cubic yards of material had been dredged from the Bay. The report provides a listing of approximate dredge volumes and their uses based upon review of US Army Corps of Engineer dredging permits.

Information provided to the Study Group by the Corps, identified the following dredge permits and permitted volumes:

• JFK International Airport	75.8 million cubic yards
• Sanitary fill along the north shore	10.0 million cubic yards
• Seaplane runways near Floyd Bennett Field	2.5 million cubic yards
• Fill for NYS Mental Hygiene Hospital	3.6 million cubic yards
• Beach Channel High School	2.0 million cubic yards

The report notes that "the actual volume of dredging may be slightly below that authorized by the Corps".

Jamaica Bay has been heavily influenced by man, and currently suffers from degraded water quality conditions. Anthropomorphic changes within, and surrounding Jamaica Bay, have taken place such that overland flow, infiltration and biogeochemical processing of a broadly vegetated watershed has disappeared and been replaced by a sewershed. These physical alterations are shown on Figure 1-3. They included: disruption of natural drainage by piping of flows through sewers; either separate storm or combined sewers, creation of deep channels and borrow pits, and the construction of hardened shoreline structures, such as bulkheads and sea walls

In addition to these physical alterations, sewerage and drainage infrastructure necessary to provide sanitary conditions and flood protection to the approximately 2 million people living within the Jamaica Bay watershed/sewershed were constructed. These include the four Jamaica Bay Water Pollution Control Plants (WPCPs) which treat the wastewater generated within their respective tributary areas. The locations of these WPCPs are shown on Figure 1-4.

In 1948, Mayor La Guardia, and Parks Commissioner Robert Moses, in an attempt to protect Jamaica Bay from development, transferred the lands adjacent to Jamaica Bay and the salt marshes to the New York City Department of Parks. In 1974, Jamaica Bay became part of the Gateway National Recreational Area, which is under the jurisdiction of the National Park Service.

As noted in the legislation creating the Gateway National Recreational Area, the Jamaica Bay Unit includes all islands, marshes, hassocks, submerged lands, and waters in Jamaica Bay, Floyd Bennett Field, the lands generally located between highway Route 27A (Belt Parkway), and Jamaica Bay, and the area of Jamaica Bay up to the shoreline of John F. Kennedy International Airport. The extent of the Jamaica Unit of the Gateway National Recreational Area is shown on Figure 1-5.

1.1.3. Water Pollution Control Plants

The four WPCPs, owned and operated by the New York City Department of Environmental Protection (the Department), discharge treated effluent into the open waters of Jamaica Bay. These include the Coney Island, 26th Ward, Jamaica and Rockaway WPCPs. With the exception of the 26th Ward WPCP which provides biological nutrient removal via separate centrate treatment, these WPCPs currently discharge secondary treated effluent to the bay. The location of these plants is shown on Figure 1-4.

1.1.3.1 Coney Island WPCP

The Coney Island WPCP is permitted by the New York State Department of Environmental Conservation (NYSDEC) under State Pollutant Discharge Elimination System (SPDES) permit

number NY-0026182. The facility is located at 2591 Knapp Street, Brooklyn, NY, in the Sheepshead Bay section of Brooklyn, on a site adjacent to the Rockaway Inlet/Shell Bank Creek.

The Coney Island WPCP serves the communities of Sea Gate, Coney Island, Brighton Beach, Homecrest, Manhattan Beach, Sheepshead Bay, Manhattan Terrace, Midwood, Gerritsen Beach, Plum Beach, Flatlands, Canarsie, Paerdegat Basin, Georgetown, Mill Basin, Marine Park, Bergen Beach, Mill Island, Rugby, Remsen Village, East Flatbush, Ditmas Park, and Wingate.

The plant provides full secondary treatment. Processes include primary screening, raw sewage pumping, grit removal and primary settling, air activated sludge capable of operating in the step aeration mode, final settling, and chlorine disinfection. Chlorinated effluent is discharged via an outfall pipe with diffuser into the Rockaway Inlet. Sludge handling facilities include primary sludge degritting, waste sludge screening, gravity thickeners, anaerobic digesters, sludge storage and gas holding tanks. Digested sludge is pumped via a 12-inch diameter force main to the 26th Ward WPCP for dewatering.

The Coney Island WPCP has a design dry weather flow (DDWF) capacity of 110 million gallons per day (MGD), and is designed to receive a maximum flow of 220 MGD (2 times DDWF) with 165 MGD (1.5 times DDWF) receiving secondary treatment. Flows in excess of 165 MGD receive primary treatment and disinfection prior to discharge to Rockaway Inlet.

1.1.3.2. 26th Ward WPCP

The 26th Ward WPCP is permitted by the NYSDEC under SPDES permit number NY-0026212. The facility is located at 122-66 Flatlands Avenue, Brooklyn, NY, in the Spring Creek section of Brooklyn, on a site adjacent to the Hendrix Street Canal, leading into Jamaica Bay, and is bounded by Flatlands Avenue, Van Siclen Street, and Schroeders Avenue.

The 26th Ward WPCP serves the communities of Ocean Hill, Brownsville, Broadway Junction, Highland Park, Cypress Hills, City Line, East New York, New Lots, Spring Creek, and Starrett City.

The 26th Ward WPCP provides full secondary treatment and tertiary treatment. Processes include primary screening, raw sewage pumping, grit removal and primary settling, basic step feed BNR mode of air activated sludge, final settling, and chlorine disinfection. Chlorinated effluent is discharged into an outfall to the Hendrix Street Canal, a tributary of Jamaica Bay.

The waste activated sludge is combined with the primary sludge and pumped to gravity thickeners. The combined sludge is thickened, and is anaerobically digested in three primary and one secondary digester. The digested sludge is stored within an on-site storage tank and dewatered on-site via centrifuges. The 26th Ward WPCP also accepts digested sludge generated at the Jamaica, Rockaway and Coney Island WPCPs for dewatering.

The 26th Ward WPCP has a DDWF capacity of 85 MGD, and is designed to receive a maximum flow of 170 MGD (2 times DDWF) with 127.5 MGD (1.5 times DDWF) receiving secondary treatment. Flows in excess of 127.5 MGD receive primary treatment and disinfection prior to its discharge to the Hendrix Street Canal.

1.1.3.3. Jamaica WPCP

The Jamaica WPCP is permitted by the NYSDEC under SPDES permit number NY-0026115. The facility is located at 150-20 134th Street, Jamaica, NY, in the Jamaica section of Queens, on a site adjacent to Bergen Basin.

The Jamaica WPCP serves the communities of Howard Beach, Lindenwood, Ozone Park, Woodhaven, Richmond Hill, Kew Gardens, South Ozone Park, Jamaica Center, South Jamaica, Hollis, St. Albans, Rochdale, Springfield Gardens, Brookville, Laurelton, Rosedale, Cambria Heights, Queens Village, Bellaire, Bellerose, Briarwood, Jamaica Hills, Jamaica Estates, Holliswood, Glen Oaks, and Floral Park.

The Jamaica WPCP provides full secondary treatment. Processes include primary screening, raw sewage pumping, grit removal and primary settling, air activated sludge capable of operating in the step aeration mode, final settling, and chlorine disinfection. Chlorinated effluent is discharged into an outfall pipe with splitter box capable of directing treated effluent to both Bergen Basin and Jamaica Bay. The present plan of operation for the plant calls for treated dry weather effluent to be discharged into the open waters of Jamaica Bay only.

In the 1990s, sludge dewatering facilities were constructed at the plant. Five gravity thickeners receive sludge from the sludge distribution box, where degritted primary and waste activated sludge are mixed with diluent water. Thickened sludge is pumped to six fixed covered circular anaerobic digesters providing two-stage digestion, with two units acting as secondary digesters or gas extractors. The digested sludge is then pumped to the sludge dewatering building that contains four centrifuges for dewatering.

The Jamaica WPCP has a DDWF capacity of 100 MGD, and is designed to receive a maximum flow of 200 MGD (2 times DDWF) with 150 MGD (1.5 times DDWF) receiving secondary treatment. Flows in excess of 150 MGD receive primary treatment and disinfection prior to its discharge to Jamaica Bay.

1.1.3.4. Rockaway WPCP

The Rockaway WPCP is permitted by the NYSDEC under SPDES permit number NY-0026221. The facility is located at 106-21 Beach Channel Drive, Rockaway, NY, in the Rockaway Park section of Queens, on a site adjacent to Jamaica Bay located between Beach 108th Street and Beach 104th Street.

The Rockaway WPCP serves the communities of Far Rockaway, Edgemere, Arverne, Somerville, Seaside, Rockaway Park, Broad Channel, Belle Harbor, Neponsit, and Breezy Point.

The Rockaway WPCP provides full secondary treatment. Processes include primary screening, raw sewage pumping, grit removal and primary settling, air activated sludge capable of operating in the step aeration mode, final settling, and chlorine disinfection. Chlorinated effluent is discharged to Jamaica Bay.

Waste sludge is thickened in six gravity thickeners. Following thickening, the sludge is conveyed to seven anaerobic digesters. Three digesters can operate as primaries and four can operate as secondary

digesters. Digested sludge from the Rockaway WPCP is conveyed via barge to the 26th Ward WPCP for dewatering.

The Rockaway WPCP has a design dry weather flow (DDWF) capacity of 45 MGD, and is designed to receive a maximum flow of 90 MGD (2 times DDWF) with 67.5 MGD (1.5 times DDWF) receiving secondary treatment. Flows in excess of 67.5 MGD receive primary treatment and disinfection prior to discharge to Jamaica Bay.

1.1.4. Other Active Programs

The City of New York is committed to its role as an environmental steward of the New York Harbor, and began addressing water quality issues in the 1950's. To date, the Department has spent or committed over $2.1 billion in its Citywide Combined Sewer Overflow (CSO) abatement program. Because of this ongoing program, water quality has improved dramatically over the past 30 years (the Department Harbor Survey Annual Reports).

Additionally, implementation of the Department's current 10-year capital plan will continue that trend, as it continues to address CSO-related water quality issues through its City-Wide CSO Floatables Program, pump station and collection system improvements, and the ongoing analysis and implementation of CSO abatement solutions. The following sections provide a brief description of ongoing Department programs aimed at improving water quality within Jamaica Bay.

1.1.4.1. CSO Programs 1950 to 1992

Early CSO assessment programs began in the 1950's and culminated with the construction, in 1972, of the Spring Creek Auxiliary Water Pollution Control Plant, a 20-million gallon CSO retention tank at the head of Spring Creek, a tributary to Jamaica Bay. This project was one of the first such facilities constructed in the United States.

In 1983, the Department re-invigorated its CSO facility-planning program in accordance with NYSDEC issued State Pollutant Discharge Elimination System (SPDES) Permits for its WPCPs, with a project in Flushing Bay and Creek. In 1985, a Citywide CSO Assessment was undertaken which assessed the existing CSO problem and established the framework for additional facility planning. Three tributary project areas were defined (Flushing Bay, Paerdegat Basin, and the Jamaica Tributaries) as part of this effort. Detailed CSO Facility Planning Projects were conducted in each of these areas in the 1980s and early 1990s, resulting in a series of detailed plans for the Flushing Bay and Paerdegat Basin CSO Retention Facilities now under construction. Construction of the Paerdegat Basin CSO Retention Facility is on schedule and will be placed in service on August 31, 2011 in accordance with the CSO Consent Order Construction Milestone.

1.1.4.2. City-Wide CSO Plan for Floatables Abatement

The Department developed a Floatables Abatement Plan for the CSO areas of New York City in June 1997. The objectives of this plan were to provide substantial reductions in floatables discharges from CSOs throughout the City, and to provide for attainment with appropriate NYSDEC and Interstate Environmental Commission (IEC) requirements pertaining to floatables. As part of the Department's Interim Floatables Containment, Program 25 booms/nets have been installed city-wide to capture

floatables. Five of these booms/nets have been installed in sewer outfalls discharging into Jamaica Bay. The Department regularly cleans and services these facilities.

1.1.4.3. Use and Standards Attainment Study

In recognition that approved levels of CSO abatement would not achieve water quality standards under all circumstances, the Department initiated the Use and Standards Attainment (USA) Project in 1999 to bring the engineering program into compliance with the regulatory requirements of the CSO Control Policy and subsequent 2001 Guidance.

This project was designed to follow the process outlined in the CSO Control Policy for the development of CSO abatement projects that included water quality analysis, facility planning, water quality standards compliance determination, water quality standards review and revision, as appropriate, public outreach, and development of long term control plans. The USA Project used USEPA's Watershed Approach Framework to investigate all causes of water use impairments, in addition to CSOs.

The goals of the USA Project were to examine desired and attainable water uses with stakeholder involvement, reconcile water quality standards with realistically attainable uses given the site-specific constraints, implement the water quality standards review process, and serve as the technical basis for waterbody specific Use Attainability Analysis as appropriate.

The USA Project divided the harbor into several open water and tributary project areas. The project was overseen by a Government Steering Committee, which included the United States Environmental Protection Agency, NYSDEC and other interested federal (US Army Corps of Engineers, National Park Service), Interstate Environmental Commission and local agencies (the Department). In addition, active public outreach was to be achieved by the formation of stakeholder teams for each of the 26 project areas.

The USA Project continued and advanced The Department's CSO water quality modeling capabilities. Landside models of the City's combined and separate sewer systems were updated and advanced in the USA Project to provide an improved presentation of CSO discharges and control alternatives. The Department's System-wide Eutrophication Model (SWEM) developed for nitrogen planning issues in the East River and Long Island Sound in 1997 was applied for water quality impact evaluations in open waters.

The Jamaica Bay Eutrophication Model (JEM), developed as an outgrowth of CSO facility planning work in the 26th Ward WPCP tributary area, was applied for impact evaluation in that waterbody. The NYC Tributary CSO Models, developed during the original CSO facility planning work, in the 1980s and early 1990s, were all significantly updated using the latest technology to improve water quality impact evaluations and the assessment of CSO control structures.

1.1.4.4. Long-Term CSO Control Planning

In 2005, NYCDEP and NYSDEC entered into a Combined Sewer Overflow (CSO) Consent Order which governs the Departments obligations to address CSO discharges throughout the Harbor,

including Jamaica Bay and its tributary waterbodies. The intent of the Order is to bring the City's CSO matters in compliance with newer provisions under the Clean Water Act related to CSO and Environmental Conservation Law. The Order requires DEP to develop Waterbody/Watershed Plans (WB/WS) by June 2007 for Jamaica Bay, Spring Creek, Hendrix Creek, Fresh Creek, Bergen Basin and Thurston Basin. These Waterbody/Watershed Plans are to address the nine elements of the CSO Long Term Control Plan (LTCP) as outlined in EPA's CSO Policy and Water Quality Act of 2000. Specifically, the WB/WS will include the following nine elements:

1. System Characterization, Monitoring, and Modeling
2. Public Participation
3. Consideration of Sensitive Areas
4. Cost/Performance Considerations
5. Operational Plan
6. Maximization at the Treatment Plant
7. Implementation Schedule
8. Post Construction Compliance Monitoring Program

These WB/WS will make recommendations for cost-effective CSO controls to improve water quality and will be basis for the LTCP. The LTCP will include the recommendations from the WB/WS and also include water quality standards review and revisions, as necessary. A LTCP has already been developed for Paerdegat Basin and was publicly noticed in September 2006. The LTCPs for Jamaica Bay, Spring Creek, Hendrix Creek, Fresh Creek, Bergen Basin and Thurston Basin are presently being developed and will be submitted.

1.1.4.5. Jamaica Bay Water Quality Improvement Projects

There are numerous the Department engineering and construction initiatives that address specific issues to improve water quality in Jamaica Bay. These include:

- WPCP Upgrades;
- Paerdegat Basin CSO Facility;
- Spring Creek Auxiliary WPCP Upgrade;
- Upgrades to Various Pumping Stations;
- Landfill Closure;
- Ecosystem Restoration;
- Floatables Control; and ,
- Sewer System Improvements

In addition, there are several projects aimed at improving water quality within the open waters of Jamaica Bay. These include:

- Citywide TRC Management Program;
- 26th Ward and Rockaway WPCP Stabilization Projects;
- Habitat/Marshland (Yellowbar Hassock, Elders Point) Restoration
- Little Bay and Norton Basin Study; and,
- Harbor Estuary Program

1.1.4.6. Jamaica Bay Watershed Protection Plan

On June 30, 2005, the New York City Council passed a local law (Local Law 71), to amend the administrative code to require the development of a Watershed Protection Plan (WPP) for the watershed/sewershed of Jamaica Bay. It is the intent of this legislation to establish "the initial pathway towards restoring and maintaining the water quality and ecological integrity of the Bay by comprehensively assessing threats to the Bay and coordinating environmental remediation and protection in a focused and cost-effective manner."

This legislation requires that the Department create a WPP for the watershed/sewershed of Jamaica Bay. The WPP is currently being developed with completion scheduled on or before September 1, 2007. Local Law 71 requires explicitly in Section 2(b)(1) that the WPP focus on best management practices (BMPs) for stormwater control. The Department is performing a watershed-specific analysis of opportunities to reduce erosion and stormwater runoff to Jamaica Bay.

The development of the WPP integrates opportunity for public input during the development process. Local Law 71 required the formation of an Advisory Committee consisting of members of the public and of governmental agencies that are familiar with the challenges facing Jamaica Bay. The Advisory Committee has met monthly, receiving technical information about the bay, requesting information from the Department and other agencies, and has issued a series of recommendation for consideration by the Department for inclusion in the WPP. Additionally, four public meetings have been held to update the public on the progress of the Plan's development, solicit comments and concepts for consideration, and provide a forum for stakeholder engagement. Two public workshops are planned to obtain further public input on the environmental management strategies under development by the Department.

1.2. Current Water Quality Standards

The NYSDEC assigns classifications to all of the waterbodies within its jurisdiction. These classifications are assigned such that "The discharge of sewage, industrial waste or other wastes shall not cause impairment of the best usages of the receiving water as specified by the water classifications at the location of the discharge and at other locations that may be affected by such discharge." Two of the classifications developed by NYSDEC apply to waters within Jamaica Bay are Class SB and Class I.

Class SB applies to the open waters of Jamaica Bay, Shellbank Creek, Gerritsen Creek and Mill and East Mill Basins. Class I applies to the remaining tributaries of Jamaica Bay. The best usages of Class SB waters are primary and secondary contact recreation and fishing. These waters must also be suitable for fish propagation and survival. Class I waters have best usages of secondary contact, and must be suitable for fish propagation and survival. Associated with each of these classifications are

water quality standards that are assigned such that each waterbody can achieve its best usage. For this Report, the water quality standards of concern is dissolved oxygen in the open waters of Jamaica Bay.

1.2.1. Dissolved Oxygen

The current dissolved oxygen (DO) standard for Class SB waters requires that the DO concentration shall not be less than 5.0 milligrams per liter (mg/L) at any time. Similarly, the current DO standard for Class I waters require that the DO concentration shall not be less than 4.0 mg/L at any time. The waters of Jamaica Bay and its tributaries do not consistently attain these standards, especially during the summer.

1.3. Current Water Quality Conditions

Water quality varies significantly within the bay due to the bay's geometry and bathymetry and the distribution of pollution sources (Figure 1-6). Pollution sources include the four Jamaica Bay WPCPs, several combined sewer overflows (CSOs), numerous storm sewer outfalls, three landfills, groundwater, and atmospheric deposition. In general, water quality in the western and southern portions of the bay is better than water quality in the northern and eastern portions of the bay. Tidal exchange of water between the western bay and the Lower Harbor of New York Harbor, through the Rockaway Inlet, flushes pollutants out of the bay keeping the open waters of western Jamaica Bay cleaner.

The northern portion of the bay is impacted by discharges from the Jamaica and 26th Ward WPCPs, and CSOs that discharge into Paerdegat Basin, Fresh Creek, Hendrix Creek, and Bergen Basin. The eastern portion of the bay, particularly Grassy Bay, has poor water quality due to the effluent discharge from the Jamaica WPCP, and poor tidal flushing due to a deep man-made borrow pit and constricted channels that connect the eastern bay to the western portion of the bay.

The Department conducts water quality surveys of Jamaica Bay as part of the Harbor Survey Program. These data tell the story of the water quality in the bay. The Department currently samples eight open water stations throughout the bay for a number of water quality constituents (Figure 1-7). As noted within the Department's Annual Harbor Survey Reports, water quality within the open waters of Jamaica Bay has improved dramatically over the last thirty years.

1.3.1. Nitrogen

Planktonic algae are aquatic plants that require nutrients, light and the appropriate temperature to grow. The macronutrients that are required for algal growth are nitrogen and phosphorus. If either nitrogen or phosphorus concentrations in the water column are low, algal growth becomes nutrient-limited. In estuarine systems, such as Jamaica Bay, nitrogen is typically the limiting nutrient, which means that algae typically deplete nitrogen in the water before they deplete phosphorus. A concentration of less than 0.04 mg/L of dissolved inorganic nitrogen (DIN) is thought to begin to limit algal growth.

Dissolved inorganic nitrogen consists of ammonia (NH_3), nitrite (NO_2) and nitrate (NO_3). Figure 1-8 presents the year-round DIN data collected in the water column of Jamaica Bay from 2001 through

2005. The data show that except for rare occasions in the western and southern portions of the bay, the DIN concentrations are well above the limiting concentration for algal growth. In some locations the median DIN concentration would have to be reduced by more than a factor of ten to approach nutrient limiting conditions.

1.3.2. Dissolved Oxygen

One of the more important constituents that is monitored within the bay is dissolved oxygen (DO). DO is important for aquatic life propagation and survival. Low dissolved oxygen levels can lead to fish kills as well as odor problems resulting from the creation of hydrogen sulfide (H_2S) gas in the sediment. The NYSDEC has set a minimum DO concentration of 5.0 mg/L for the open waters of Jamaica Bay. Figure 1-9 presents DO data from 2001 through 2005 at eight locations in the bay. The data show that all locations in the bay have DO concentrations less than 5.0 mg/L, at least occasionally. Stations to the north and east have more occurrences of low DO concentrations than other portions of the bay. Deeper areas of the Bay, that are not vertically well mixed, such as station J12 in Grassy Bay, have the lowest DO concentrations. Under current conditions, portions of the bay do not consistently achieve the DO water quality standard set by NYSDEC.

1.4. Order on Consent Nitrogen/Consent Judgement

The NYSDEC and the Department entered into a Nitrogen Control Order on Consent (Index # CO2-20020131-7) on April 22, 2002 that updated SPDES permits of the four Jamaica Bay WPCPs in order to reduce the total nitrogen load discharged into Jamaica Bay. One of the goals of the Nitrogen Order on Consent was to control the occurrence of eutrophic conditions in Jamaica Bay by reducing the total nitrogen load discharged to the open waters of the bay, thereby improving attainment of dissolved oxygen water quality standards.

Presently, the SPDES permits of the four Jamaica Bay WPCPs establish two types of limits on permissible aggregate nitrogen discharges. These include: (a) the "Maximum Monthly Average Limit," defined as the average of the individual samples for that month; and (b) the " 12-month Rolling Average Limit," defined as the average daily total nitrogen load for the current month, averaged with the eleven previous months average level. The aggregate Maximum Monthly Average Limit for the Jamaica Bay WPCPs under the current SPDES permit is 54,600 pounds per day, and the aggregate 12-month Rolling Average Limit for the Jamaica Bay WPCPs is 45,300 pounds per day.

The Consent Order obligated the department to undertake and submit to the NYSDEC, for review and approval, a Comprehensive Jamaica Bay Report which summarizes and integrates the information obtained from the Jamaica Bay Eutrophication Project, Use and Standards Attainability Study, and Outfall Relocation Study. The Report is also to include recommendations and an implementation schedule for improving water quality in Jamaica Bay either through treatment or non-treatment.

The Order on Consent Nitrogen was superseded on January 10, 2006 by a Consent Judgement (Index # 04-402174). The Consent Judgement requires that the Comprehensive Jamaica Bay Report be submitted to the NYSDEC on October 31, 2006. The Consent Judgement also requires that that construction of Phase I Plan Improvements to the 26th Ward WPCP be completed by June 30, 2008 and that said improvements to the 26th Ward WPCP result in a Combined Nitrogen Effluent Limit for the Jamaica Bay WPCPs of 45,300 pounds per day.

1.5. Comprehensive Plan Components and Objectives

In order to satisfy the requirements of the Consent Judgement, and to allow for the preparation of the Comprehensive Jamaica Bay Report, the Department in June of 2003, consolidated the Long Outfall, Jamaica Bay Eutrophication and Use and Standards Attainability Projects under the umbrella of the Comprehensive Jamaica Bay Report Project. The objective of the Comprehensive Jamaica Bay Project is to investigate both treatment and non-treatment alternatives, to improve water quality within the open waters of Jamaica Bay resulting from nitrogen loading to the open waters of the bay.

2. Previous Analysis

2.1. Introduction

The Jamaica Bay CSO Abatement Facility Planning Project, undertaken from 1988 through 1993, was conducted to determine the impact of CSOs on Jamaica Bay and its tributaries, and to analyze abatement alternatives. As part of the Jamaica Bay CSO Abatement Facility Planning Project, a model was developed to assess the impacts of CSOs on dissolved oxygen and coliform bacteria in Jamaica Bay. This project analyzed data collected during July and August of 1988, with some additional data collected outside of this time period to fill data gaps. The parameters that were emphasized in the water quality sampling program included temperature, salinity DO, biochemical oxygen demand (BOD) and total and fecal coliform bacteria. The model showed that CSOs had major impacts on the DO and coliform concentrations in the tributaries to which they discharged. The modeling also showed that CSOs were responsible for the majority of the coliform bacteria found in the open waters of Jamaica Bay. However, CSOs were found to have only small, short-term effects on the DO levels within the open waters of the bay. The findings of this project led to the Jamaica Bay Eutrophication Study.

2.2. Jamaica Bay Eutrophication Model

The findings of the Jamaica Bay CSO Abatement Facility Planning Project indicated that nitrogen loading from the WPCPs might be an important factor influencing dissolved oxygen levels in the open waters of Jamaica Bay. The Jamaica Bay Eutrophication Study was designed to assess if nitrogen loads from the WPCPs were resulting in eutrophication within the bay, and to develop a eutrophication model that could assess remediation alternatives to improve water quality in the open waters of the bay. The sampling program for the study included water quality, sediments, and pollutant sources including WPCPs, CSOs, storm sewers, and atmospheric deposition. Sampling also included biological sampling for phytoplankton, benthic algae, microzooplankton, macrozooplankton, *Ulva lactuca* (sea lettuce), *Spartina alterniflora* (saltmarsh cordgrass) and bivalves, in an effort to determine the important factors to include in the model. A tide gage and current meters were also deployed as part of the program. The majority of the sampling was conducted between July 1995 and July 1996. A more thorough overview of the sampling program and its results are presented in the Jamaica Bay Eutrophication Study Report dated June 2002, prepared by O'Brien and Gere.

A model was developed based on results from the sampling program. A representation of the model grid is presented in Figure 2-1. The model that was developed for this project, the Jamaica Bay Eutrophication Model (JEM), includes four components (Figure 2-2). The first component is a hydrodynamic model called the Estuarine Coastal and Ocean Model (ECOM). This three-dimensional time-variable model calculates tidal elevations, current velocities, horizontal and vertical mixing, salinity and temperature. ECOM provides the output for use in the second component of the water quality model the Row-Column Advanced Ecosystem Modeling Program (RCA). RCA is also a three-dimensional time-variable model. The JEM version of RCA includes state-variables necessary to simulate a eutrophic waterbody. These state-variables include two phytoplankton groups, five forms of phosphorus, six forms of nitrogen, two forms of silica, six forms of carbon, hydrogen sulfide

and dissolved oxygen. A full description of the model kinetics can be found in The Jamaica Bay Eutrophication Study Report dated June 2002, prepared by O'Brien and Gere.

The third component of the model is the sediment nutrient flux model. This model is run dynamically with the water quality model. The water quality model calculates deposition of organic matter to the sediment. The sediment nutrient flux model completes the mass balance around the system by tracking the interactions of the material in the sediment. The sediment model calculates concentrations in the pore water, concentrations in the solid phase and the conversion of organic matter to inorganic matter through diagenesis. The inorganic nutrients that are calculated by the sediment model can then flux back into the water column under proper conditions. The model will also calculate the appropriate sediment oxygen demand based on the amount of organic carbon that settles to the sediment.

The final component of JEM is a suspension feeder, or bivalve model. This model simulates the effects of clams and other suspension feeders on water quality. The sampling program indicated that suspension feeders might be an important influence on water quality, so this submodel was added to JEM. The model computes filter-feeder biomass and the associated filtration rate associated with the calculated biomass.

The affects of the marsh grass are also incorporated into the model; however, the marsh grass is not dynamically modeled. As part of the sampling program, the marsh-grass biomass was sampled and analyzed for its carbon, nitrogen and phosphorus content. Based on this information, a calculation was made to estimate the total biomass of marsh grass in Jamaica Bay. Segments in the model were assigned to have marshes based on aerial photographs. Loss rates for inorganic nitrogen and phosphorus were then assigned to model segments with marshes during the *Spartina* growing season. This attempted to simulate the uptake of nutrients by the marshes. During the die-back period of the marshes, a source of organic carbon, nitrogen, and phosphorus is returned to the water column or incorporated into the sediment.

Based on the results of the sampling program, *Ulva* and other benthic algae were not incorporated into the model. A determination was made that these species did not have a major impact on water quality in the bay.

After the model was developed, JEM was calibrated against the data collected during 1995 and 1996. The process of calibration involves adjusting model coefficients, such as oxidation rates or settling rates, within scientifically acceptable ranges, so that the model calculations satisfactorily reproduce the observed data. Since the model is merely a simple representation of the bay, it cannot be expected to reproduce every data point, or even every parameter.

After model calibration, the model was peer reviewed by a Model Evaluation Group (MEG). The MEG included experts in physical oceanography, water quality modeling, estuarine ecosystems, and biology. The MEG approved the model for use in assessing the relative benefits for various remediation alternatives that could be assessed.

JEM has been used to assess numerous remediation alternatives. These alternatives include relocation of existing WPCP outfalls, various levels of nitrogen removal at WPCPs, bathymetric recontouring of Jamaica Bay, aeration of Grassy Bay, as well as other alternatives including

combinations of outfall relocation, treatment, and recontouring. These results will be discussed further in sections 2.3 and 7.0 of this report.

2.3. Projections

A calibrated model is a useful tool for determining which remediation alternatives will be effective in reaching water quality goals in a cost efficient manner. To this end, a series of screening alternatives were modeled to determine the most promising alternatives to be studied in more depth during facilities planning.

A series of six projection alternatives were run as part of the Eutrophication Study. These projections are presented for informational purposes only. These projections are based on 1995-96 calibration conditions. Hydrodynamic runs were completed for alternatives where the WPCP, CSO or storm sewer flows were modified, and for alternatives where the bay was recontoured. The reflecting boundary conditions required no modifications. Any changes at the boundary were computed internally within the model. No changes were made to the calibrated model constants or parameters.

2.3.1. Projection Description

The six alternatives consisted of two treatment alternatives, two recontouring alternatives, one outfall relocation alternative and one biological alternative. A brief description of each alternative will follow, along with the rationale for its consideration.

JFK Airport Runway Removal

The eastern end of Jamaica Bay, known as Grassy Bay, does not attain the dissolved oxygen standard more than any other section of the main bay. Part of the reason for the poor water quality is the small current velocities. This poor circulation reduces flushing, which allows organic material to settle to the bottom. The poor circulation also allows density stratification to occur, trapping oxygen depleted water for long periods of time.

Removal of the JFK runway, it was argued, would increase current velocities and improve flushing. (The actual remedial alternative would involve placing the runway on a raised platform or installing conduits below to allow water under the runway.) For this projection run, the land segments representing the JFK runway were replaced by water segments. A water depth of five meters, at mean tide, was assigned to these segments. The hydrodynamic model was rerun. No changes were made to the water quality model loadings.

Bay Recontouring

A second attempt to improve dissolved oxygen levels by reducing flushing time involved filling sections of the bay. Grassy Bay, Shellbank Basin, Mill Basin and East Mill Basin were all filled to a constant depth of 15 ft. at mean low water (MLW). The hydrodynamic model was rerun for the new bathymetric conditions. The hydrodynamic model also determined the new depositional and non-depositional segment locations. No loading changes were made for this alternative.

Biological Nitrogen Removal (BNR)

Jamaica Bay is a very eutrophic system. It is believed that nitrogen is the limiting nutrient to phytoplankton growth within the bay. Limit of Technology (LOT) BNR was modeled to determine its ability to reduce eutrophic conditions. In the Jamaica Bay Eutrophication Study, the WPCP effluent TN concentration used for the LOT alternative was set at 4.0 mg N/L during the period April through September. For the remainder of the year, the WPCP effluent total nitrogen concentration was set at 8.0 mg N/L.

Phosphorus Reduction

For the phosphorus reduction alternative, an attempt was made to make phosphorus the limiting nutrient for phytoplankton growth. The WPCP effluent total phosphorus concentrations were set to 0.2 mg P/L for the entire year.

Outfall Relocation plus CSO Capture

In the outfall relocation plus CSO capture alternative, the effluent discharges of the four Jamaica Bay WPCPs were relocated outside of Jamaica Bay to a location that would not affect the concentrations within Jamaica Bay. The Department's planned CSO remediation plan was also included. The CSO remediation plan includes diverting 30 million gallons per storm from Fresh Creek, 50 million gallons per storm from Paerdegat Basin and 50 million gallons per storm from Bergen Basin. For the model simulation, the CSO tanks would hold the volume of water collected for 24 hours. If two storms occurred within 24 hours of one another, the CSO tanks could only capture the volume of water remaining in the tank from the first storm, if there was any capacity left in the tanks. The hydrodynamic model was rerun for this alternative. It should be noted that while these CSO tanks were planned at the time of the 1995-96 analysis, only a 30 MG tank with 20 MG of in-line storage at Paerdegat Basin remains in the Department's current planning.

Bivalve Racks

Suspension feeding bivalves can filter large amounts of water through their systems. In an attempt to reduce the phytoplankton biomass in the water column, a model simulation was run with an increased amount of bivalve biomass. This was accomplished by reducing the mortality rate of the bivalves. Bivalve biomass was increased by approximately five times.

2.3.2. Loading

Figure 2-3 presents the daily average loading of carbon, nitrogen and phosphorus to Jamaica Bay for the calibration as well as the projections. The average daily loading for the carbon, nitrogen and phosphorus for the calibration was approximately 35,700 kg C/day (78,500 lb C/day), 24,700 kg N/day (54,300 lb N/day) and 2,280 kg P/day (5,000 lb P/day). The JFK Runway Removal, Bay

Recontour, and Bivalve Rack projection runs all had the same loading as the calibration. In the BNR run the nitrogen load was reduced by 68.1%. The phosphorus reduction run had phosphorus loadings reduced by 84.2%. Phosphorus, nitrogen and carbon loads in the outfall relocation and CSO capture projection were reduced by 94.6%, 95.0% and 83.2% respectively.

2.3.3. Results

The results of the projections will be presented in two ways. The first is to present results spatially based on water quality sampling stations used during 1995-96. These station locations are presented in Figure 2-4. Six stations have been chosen as representative stations to show the relative changes in minimum DO, the estimated minimum DO and percent attainment for each projection alternatives during the summer period. The stations chosen are J4 and J6 in the North Channel, J8 and J3 in the eastern portion of the bay, and J17 and J20 located in the head ends of Mill Basin and Shellbank Basin respectively. The second method of presentation is a series of color figures displaying the percent attainment, computed by the model, of bottom water DO during the summer period for a few of the projection alternatives. The summer period was chosen because it is during this period that the most degraded water quality conditions are observed.

Figure 2-5 presents the change in the minimum summer bottom water dissolved oxygen concentration for the six selected stations for each projection. Removal of the JFK runway extension results in only small changes in the open waters of Jamaica Bay. The Station J8 minimum DO improves by 0.52 mg/L, however, the minimum DO is reduced at stations J3, J4 and J6. Removing the JFK runway extension simply allows the degraded water in Grassy Bay to spread into other areas of the bay.

Filling Grassy Bay to a depth of 15 ft. at MLW generally reduces the minimum DO. This occurs for three reasons, the dilution volume of Jamaica Bay is reduced, material can settle to the bottom more quickly trapping it in the back end of the bay, and the volume of water over which the sediment oxygen demand (SOD) is exerted is diminished. However, as will be seen, percent compliance of the DO standard increases with the filling of the bay.

Biological nitrogen removal improves the summer minimum bottom DO concentrations in most of the bay. The majority of the bay improves by at least 0.5 mg/L, with the largest increase observed at station J15 (not shown) of 1.02 mg/L. At the Rockaway Inlet, and in the tributaries, virtually no change is observed in the minimum DO.

Phosphorus reduction also improves minimum DO concentrations throughout the bay, but the improvements are smaller than as a result of nitrogen reduction. Improvements in the minimum DO concentrations are generally greater than 0.3 mg/L, with the largest improvement observed at station J9 (not shown) of 0.49 mg/L. These results are expected because Jamaica Bay is more potentially nitrogen limited during the summer period.

The outfall relocation and CSO remediation alternative causes dramatic improvements throughout the bay. This is expected, as more than 90 percent of the non-boundary nutrient loading is removed. The largest increase in the minimum bottom DO occurs at station J8, with an increase of 3.3 mg/L. Some improvement in DO is also observed at the tributary stations.

The bivalve alternative has mixed results for the minimum calculated DO concentration. The bivalves will increase the effective settling rate through filtering, reduce the phytoplankton concentration, and impart a DO deficit through respiration.

When the Eutrophication Study was initiated, it was hoped that BNR would be sufficient to solve the eutrophication problem in the open waters of Jamaica Bay. However, the BNR projection shows that the nitrogen reduction due to BNR is inadequate. The reason for this is presented in Figure 2-6. The figure displays average summer surface DIN concentrations at all 20 stations. The three bar types represent the calibration, the BNR projection and the outfall relocation projection. The solid vertical line represents the Michaelis constant, which is the concentration at which the growth rate of phytoplankton will be cut in half due to nutrient limitation. The dashed line is the concentration at which phytoplankton begin to become nutrient limited (0.04 mg N/L). Also note the log scale. The results from the BNR projection show a dramatic reduction in DIN concentrations from the calibration. However, the concentrations are still generally twice the limiting value. Only with outfall relocation does the DIN concentration approach limiting concentrations.

Figure 2-7 presents the estimated minimum summer bottom water DO at the six stations for the calibration and eight projections. Due to differences between the calibration and the data, the estimated minimums are the difference between the calibration and the projection results added to the DO data at the fifth percentile. The fifth percentile was chosen because the absolute minimum DO measurements tend to be outliers in the probability distribution. Estimated minimum DO concentrations could not be less than zero. The figure shows that under almost any alternative, it will be difficult to meet NYSDEC's water quality standards for DO one hundred percent of the time.

Figure 2-8 presents the model-estimated percent attainment of NYSDEC current water quality standard for DO. In this case, the model's inaccuracies could not be corrected with data. The best interpretation of the results is a comparison between the various alternatives and not the absolute magnitude of the percent attainment. In general, the outfall relocation alternative provides the greatest percent attainment, while the bivalve racks provide the lowest percent attainment. In the North Channel, at stations J4 and J6, most of the alternatives have little impact on the percent attainment. At station J8, in Grassy Bay, removal of the JFK runway extension has the greatest positive impact other than outfall relocation. However, this alternative has detrimental effects on other areas of the bay. In Head of Bay, even outfall relocation does not cause major improvements in DO attainment. This is most likely due to the fact that there are still major CSO and stormwater loadings, as well as the Nassau County WPCPs from Inwood (no longer in service) and Cedarhurst impacting the area. At the head ends of East Mill and Shellbank Basins, filling the basins to a depth of 15 ft provides a greater positive effect than most of the other alternatives.

To give a different perspective on the effect of the various remediation alternatives, spatial color figures of percent attainment with NYSDEC current water quality standards are presented. Figure 2-9 presents a comparison of the percent of time the DO concentration is greater than the standard for the calibration, the bivalve racks, the JFK runway extension removal, and the filling Grassy Bay and tributaries alternatives on an annual basis in the bottom layer of the model. The percent attainment is represented by eight colors, each representing five percent of the scale. Red represents the lowest attainment of less than 70 percent and blue represents the highest attainment, 100 percent of the time.

In Figure 2-9, the calibration shows the lowest attainment of the DO standard occurs in Grassy Bay with less than 70 percent attainment. The model estimates lower attainment when the bivalve racks

are installed. Some improvement in DO attainment occurs to the northwest of the runway due to removal of the runway extension, but DO standard attainment decreases to the southeast of the runway. Recontouring Grassy Bay provides some improvement in DO standard attainment in the bay, mostly in the northwest of Grassy Bay. In general, these alternatives do not provide much improvement in DO standard attainment over the calibration condition.

Figure 2-10 presents the calibration versus the phosphorus reduction alternative, the nitrogen reduction alternative, and the outfall relocation alternative for DO standard attainment on an annual basis. Phosphorus reduction results in small improvements to DO standard attainment in Grassy Bay over the baseline. Greater improvements in DO standard attainment occur as a result of nitrogen BNR, although areas of Grassy Bay still have less than 75 percent attainment of the DO standard on an annual basis. Greater than 90 percent DO standard attainment on an annual basis occurs bay wide due to outfall relocation and CSO removal.

2.3.4. Additional Alternatives

After the completion of the modeling for the Jamaica Bay Eutrophication Study, the Department periodically requested that additional model runs be executed for screening purposes using JEM. Three of these scenarios are presented below. The scenarios include removal of all CSO inputs, and the pumping of ocean water into the bay. All of these scenarios were run using 1995-96 calibration conditions.

CSO Removal

All CSO flows and loads were removed from the model to assess how much of the improvement in the outfall relocation and CSO removal scenario was due to the CSO loadings.

Ocean Pumping – 275 MGD

Pumping ocean water into Grassy Bay would increase mixing and reduce flushing times in the bay. This scenario analyzes the results of pumping ocean water at a rate approximately equivalent to the current discharge of the four WPCPs into a single model segment in Grassy Bay near the JFK runway extension. Ocean water concentrations were obtained from the System Wide Eutrophication Model (SWEM).

Ocean Pumping – 1 BGD

This scenario analyzes the results of pumping 1.0 billion gallons per day (BGD) into several model segments toward the center of Grassy Bay.

Figure 2-11 presents the annual DO standard attainment in the bottom layer of the model for the 1995-96 calibration, the no CSO alternative, and the ocean pumping scenarios. Removal of the CSOs has very little impact on attainment of the DO standard in Jamaica Bay, although improvements can be observed in the CSO tributaries and Grass Hassock Channel. The total nitrogen loading from the CSOs is small when compared to the WPCPs. The 275 MGD ocean pumping scenario shows some improvement in DO standard attainment near the discharge point, but most of Grassy Bay does not experience an increase in the annual DO standard attainment. Pumping 1 BGD of ocean water into

Grassy Bay does increase DO standard attainment in most of Grassy Bay, but some areas still have less than 80 percent DO standard attainment on an annual basis.

2.3.5. Summary of Initial Projections

The initial JEM projections show that improving dissolved oxygen in Jamaica Bay is not a simple task. Based on the results of the initial screening runs, several alternatives were removed from further consideration and the remaining alternatives warranted further analysis under the Comprehensive Jamaica Bay Water Quality Plan.

Removal of the JFK runway extension has very little impact on dissolved oxygen, and is detrimental to water quality in some locations. The actual implementation of this plan would be to build culverts under the runway or to build the runway on stilts to allow water to flow under it. These conditions would allow less flow than complete runway removal and thus would result in less improvement than projected. For these reasons this alternative was removed from further consideration.

Recontouring Grassy Bay to a depth of 15 feet below mean low water provides limited improvement in DO concentrations. However, it is clear that the deepness of Grassy Bay contributes to poor water quality because it acts as a trap for particulate matter, and the poor vertical mixing that exists during the summer results in vertical stratification that also impact water quality. Recontouring Grassy Bay was kept for further analysis to examine additional recontouring depths and to use in combination with other alternatives.

Bivalves also do not appear to be the solution to attaining DO standards in the bay. Model results indicate a decrease in DO standard attainment with the scenario that was examined. This alternative was removed from further consideration.

Phosphorus reduction improves DO standard attainment. However, since nitrogen tends to be the potentially limiting nutrient during the critical summer period it makes more sense to remove nitrogen from bay than phosphorus. This alternative was removed from further consideration.

The nitrogen BNR scenario examined does not remove enough nitrogen to improve DO levels in the bay to the point where 100 percent DO standard attainment is reached. However, more improvement is achieved with 60 to 80 percent of the TN removed than 90 percent of the TP removed. Nitrogen BNR must be considered for any serious analysis to improve water quality in Jamaica Bay.

Removal of CSO does not improve the DO levels in Jamaica Bay very much. This alternative was removed from further consideration under the Comprehensive Jamaica Bay Water Quality Plan, but levels of CSO reduction will be examined under the Long Term Control Plan to address tributary water quality issues.

Pumping 275 MGD to 1 BGD of ocean water into Jamaica Bay does improve DO standard attainment in the bay, but not as much as outfall relocation. Due to concerns over pumping this volume of water into the bay and changing salinity levels, this alternative was eliminated from further consideration.

The outfall relocation to ocean scenario that was examined comes very close to achieving 100 percent attainment with the DO standard. This alternative was included for further consideration.

These modeling results formed the basis of understanding for the modeling conducted as part of the Comprehensive Jamaica Bay Report. Additional modeling analyses were conducted as part of this project to choose the appropriate alternative for nitrogen reduction and improved water quality in the bay. The results of these analyses are presented in section 7.0.

3. Loadings and Baseline for Analysis

3.1. Loading Conditions

Loading conditions have changed over the last twenty years due to population and regulatory changes. For any analysis of future conditions, it is important to define baseline conditions with which to compare to future conditions. This section discusses the determination of the baseline used in the Comprehensive Jamaica Bay Report.

3.1.1. Historic (1995-1996)

The ocean dumping of sludge was banned by the US Environmental Protection Agency in 1991. This resulted in a change in the manner in which the Department handles sludge generated at the WPCPs. Sludge generated at the Jamaica and Coney Island WPCPs is pumped to the 26th Ward WPCP, and sludge generated at the Rockaway WPCP is barged to the 26th Ward WPCP for dewatering. Sludge generated at the Jamaica WPCP can also be dewatered on-site via centrifuges installed at that facility. Sludge dewatering at the 26th Ward WPCP is accomplished via centrifuges that increase the solids concentration of the sludge thereby reducing hauling costs associated with off-site disposal. The dewatering process results in the generation of a liquid stream known as centrate. This centrate contains an additional loading of total nitrogen (TN) that must be treated at the plant.

After the centrate was first generated at the 26th Ward WPCP, there was a substantial increase in the nitrogen loading to the bay (Figure 3-1). The total nitrogen load from WPCPs discharging into Jamaica Bay increased from less than 40,000 pounds per day (lb/day) to greater than 50,000 lb/day for much of the mid- to late-1990s. Since the late 1990s, upgrades to the 26th Ward WPCP, via separate centrate treatment, and modifications to the operation of the plant have, reduced the total nitrogen loading from the WPCPs to below 40,000 lb/day. Jamaica Bay remains eutrophic despite these reductions in the TN load. For the purposes of the Comprehensive Jamaica Bay Report analysis, 'historic' loading conditions will be defined as the high TN loading conditions that occurred during the 1995-96 model calibration period. These loads represent some of the highest historical TN loadings to the bay. The loadings calculated for this condition was based on treatment plant records of monthly TN loads for each of the four WPCPs that discharge into Jamaica Bay.

3.1.2. Existing

The "Existing Conditions" loadings used for this analysis were based on WPCP records from the 2002 calendar year. Estimates of the mean of the measured constituents were calculated to apply as constant annual concentrations. These same concentrations were used for the permit conditions except for the nitrogen constituents. Flows were based on 2002-2003 dry-weather WPCP flows with wet-weather flows, above the normal dry-weather flows, from 1988 added to the 2002-2003 dry-weather flows. Figure 3-1 shows that the 12-month rolling average loading in 2002 did not vary significantly from more recent WPCP records.

3.1.3. Permit

In 2002, the NYSDEC and the Department entered into a Nitrogen Order on Consent, which included a permit limit for the discharge of total nitrogen into Jamaica Bay from its four WPCPs. As previously noted, the permit limit included a 12-month rolling average of 45,300 lb/day to be achieved by January 2009. The permit also included a maximum monthly average limit of 54,600 lb/day for the four Jamaica Bay WPCPs. As noted on Figure 3-1, the Jamaica Bay WPCPs currently achieve these limits.

The distribution of loadings at each of the Jamaica Bay WPCPs was based on BioWin modeling results using conditions for year 2045 flows and WPCP effluent concentration data from 1999 and 2000 except for the 26th Ward WPCP. The development of the loading at the 26th Ward WPCP was based upon biological nitrogen removal, which reduced the effluent nitrogen concentration at this plant. An attempt was made to exactly match the 12-month rolling average loading of 45,300 lb/day. The preliminary BioWin modeling was conducted by the Department and was applied to the model as the best information available to assign to permit conditions.

3.2. Establishment of Baseline

The analyses performed as part of the Comprehensive Jamaica Bay Report were a continuation of the work conducted as part of the Jamaica Bay Eutrophication Study. The previous work was based on the 1995-96 conditions. During this period, nitrogen loadings were at or near historic highs. Since then, improvements at the WPCPs have decreased nitrogen loadings to pre-centrate levels. These levels are below the 12-month rolling average total nitrogen loading of 45,300 lb/day that is specified in NYSDEC SPDES permit for the Jamaica Bay WPCPs.

The establishment of baseline nitrogen loading was necessary for the Comprehensive Jamaica Bay Report analysis. Choices for this baseline included 1995-96 historically high conditions, permit conditions, and existing conditions. A decision was made to use the permit limit as the baseline condition. The reason the permit limit was chosen as the baseline was because this is the highest allowable total nitrogen load that can be discharged to the bay. While the WPCPs are currently operating below this limit, it is possible that future conditions might force the WPCPs to operate at or near the permit limit. Using the 1995-96 conditions as the baseline is unreasonable, as some alternatives that are being considered, such as bay recontouring, do not include treatment, and thus would not meet permit requirements. Using the permit total nitrogen loading was thought to be the highest allowable nitrogen level, and therefore the most conservative baseline.

Table 3-1 presents the concentrations and loads used for the baseline conditions. These loads are constant on an annual basis except for the ammonia, and nitrite plus nitrate loadings at the 26th Ward WPCP that changed seasonally. A comparison between the baseline and existing condition concentrations for nitrogen is presented in Table 3-2. The other constituents had the same concentrations between the two alternatives. The 1995-96 loads were based on monthly treatment plant concentrations and are thus too numerous to present in the table. Table 3-3 presents a comparison between nitrogen loadings for the three potential baseline conditions. In all cases, the ammonia dominates the nitrogen loading on a total basis. Nitrite plus nitrate is the smallest component of the nitrogen loading.

The permit baseline will be used to compare against the projection alternatives. All of the projection alternatives that do not include nitrogen removal at the WPCPs presented in Section 7.0, use 45,300 lb/day as the total nitrogen loading from the WPCPs.

3.3. Meteorological and Tidal Conditions

Meteorological conditions for the modeling analysis were based on rainfall conditions for an "average" year. This was done primarily to be consistent with other projects being conducted for the Department. Rainfall primarily impacts CSOs and storm sewers. The use of an average year is consistent with the USEPA presumption approach as defined in EPA's CSO Control Policy. Projects that involve CSO facility plans are more concerned with rainfall. In Jamaica Bay CSOs and storm sewers discharge less than five percent of the nitrogen loading to the bay on an annual basis.

Based on analyses by HydroQual, 1988 was chosen as the average rainfall year. For consistency, the other meteorological conditions for 1988 as well as the tidal conditions for 1988 were used to force the hydrodynamic model for this analysis.

Figure 3-2 presents some of the input used in the model. August and December were dry months, while May, July and October were wet months. Rainfall for 1988 was 40.7 inches with the thirty-three-year (1970-2002) median being 39.4 inches based on rainfall data from John F. Kennedy International Airport.

3.4. Wastewater Flows

The wastewater influent flows used in the development of the Comprehensive Jamaica Bay Report to determine WPCP Upgrade design requirements, cost estimates and water quality monitoring were projected year 2045 flows. These flows are as follows

26th Ward	71 MGD
Coney Island WPCP	107 MGD
Jamaica WPCP	91 MGD
Rockaway WPCP	27 MGD

The genesis of these flows was the Department's Comprehensive Nitrogen Management Program (CNMP), whose team members determined that Revised High End (HER) wastewater flow projections reflected a realistic change in influent flows to the WPCPs. It was these HER wastewater flows that were used in the preparation of the Department's Comprehensive Jamaica Bay Report. At this time there have been further revisions made to 2045 flows by the Department, however, these revisions do not appreciably affect nitrogen loadings to an extent that would change any of the findings in any way.