HUDSON-RARITAN ESTUARY
ENVIRONMENTAL RESTORATION FEASIBILITY
STUDY

JAMAICA BAY

STUDY AREA REPORT

JUNE 2004

U.S. Army Corps
of Engineers
New York District

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I. INTRODUCTION

Background

1. The New York District of the Corps of Engineers (the District) is conducting a feasibility study for ecosystem restoration in the Hudson-Raritan Estuary (the Estuary) – the Hudson-Raritan Estuary Ecosystem Restoration Study, herein referred to as "HRE". The study area is delineated as the Port District, an area surrounding greater metropolitan New York City within an approximate 25-mile radius of the Statue of Liberty (Figure 1). However, for purposes of ecological continuity the actual study area may include additional portions of this system beyond the man-made Port District boundary.

2. The overall goal of the HRE is to restore ecological function and diversity that have been lost or degraded as a result of human activities. The HRE will rely on both existing and newly obtained natural resource data to identify areas to be restored or conditions that must be addressed to assure successful ecosystem restoration. The two primary components of the study are the preparation of a Comprehensive Restoration Implementation Plan (CRIP) and the implementation of restorations/enhancements at various locations in the Estuary.

3. The purpose of the CRIP is to serve as a master plan that lays out a comprehensive and coordinated strategy that, when implemented, will guide the ecological restoration of the Estuary. The CRIP will establish a framework within which the actions needed for successful restorations can be holistically evaluated and planned. The plan will address actions to enhance, expand, recreate, and diversify natural habitats, and actions to eliminate constraints to ecological functions, such as sediment contamination. The CRIP will describe the strategy for restoration efforts that will include immediate, mid-term, and long-range options. It will also provide a central focus for public input, data collection, restoration efforts, and management actions and policies, regardless of who might have authority, desire and/or funds to undertake any action.

Study Area Delineation of the Estuary

4. To get a more manageable and understandable picture of the Estuary, its history of degradation, local needs and desires, potential restoration opportunities, and current restoration efforts will be documented in eight Study Area Reports (SARs). The study area boundaries are typically delineated by major watersheds and/or major physical features, such as highways or waterways. By and large, each study area can be characterized by its ecological functions, history of degradation, and resulting needs and opportunities. For example, Jamaica Bay, a historically expansive wetlands complex, has been subject to extensive fill and loss of wetlands; the Hudson River system, to hardened shorelines and contaminated sediment; and the Lower Bay contains coastal and offshore environments, experiencing loss of dunes and benthic habitat. Separating the project area into smaller study areas will enable the study team and potential stakeholders to address study area-specific restoration needs as well as individual restoration opportunities within each study area, and to collect and characterize data in a more usable and understandable way, all under the ultimate umbrella of the CRIP, which links the study areas into one major plan.

5. The eight study areas to be included in the CRIP are as follows (see Figure 1):

1) Jamaica Bay,
2) Lower Bay,
3) Lower Raritan River,
4) Arthur Kill/Kill van Kull,
5) Newark Bay/Hackensack River/Passaic River,
6) Lower Hudson River,
7) Harlem River/East River/Western Long Island Sound,
8) Upper Bay.

Purpose of the Study Area Reports

6. The identification of potential restoration opportunities in each study area will be a two-fold process. First, the District will identify potential restoration sites based upon a preliminary needs and opportunities survey of various interested groups/agencies conducted by the Regional Planning

Association (RPA) and presented in their Needs and Opportunities Report. This information will be supplemented by additional analyses of restoration needs and opportunities on a more local level. Study area needs will be determined based upon the causes of ecosystem degradation and the condition of existing natural resources in each study area. This effort is already underway (but far from completed) and potential restoration sites in the Jamaica Bay study area have been identified.

7. Second, the District will hold stakeholder meetings in each study area. The purpose of these meetings will be to incorporate additional comments from environmental organizations, community groups, and other individuals and stakeholders in each study area. This process will ensure the needs and opinions of as wide and diverse a group as possible is incorporated into the CRIP.

Format of the Report

8. This SAR addresses the Jamaica Bay study area (Figure 2). The **Study Area Description** section describes the setting, history of degradation, existing land/water usage, and existing natural resources in the study area. Restoration needs and existing restoration efforts are summarized in the **Ecosystem Restoration** section.

II. STUDY AREA DESCRIPTION

Setting

9. This Study Area Report encompasses the Jamaica Bay study area, which is located at the southwestern tip of Long Island and includes the boroughs of Brooklyn and Queens, New York, and the town of Hempstead, New York (Figure 2). Jamaica Bay connects to Lower New York Bay through Rockaway Inlet. The study area is approximately 10,000 hectares (25,000 acres).

Study Area History

10. Historically, the Jamaica Bay study area consisted of large expanses of salt marshes and pine-dominated forests. European settlement led to the development of the majority of the upland areas for residential, commercial, and industrial land uses.

11. Degradation of the natural systems in the study area continued into the 20th Century. Large expanses of wetlands were lost as a result of the construction of large commercial, industrial, and military facilities such as John F. Kennedy International Airport (JFK) and Floyd Bennett Field. The material used to fill the wetland areas was dredged from the shallow water areas of Jamaica Bay, such as Grassy Bay. These actions created large, deep borrow pits within the Bay.

12. Prior to the inception of the Clean Water Act in 1972, many of the industrial facilities in the region released toxic contaminants into local waterways. Many of the toxic contaminants discharged into the waterways of the study area are persistent chemicals that do not easily breakdown. As a result, these toxins accumulate through the food chain in the tissues of plants, invertebrates, fish, and birds that reside in or move through the area.

13. The contamination of both marine sediments by chemical pollutants and heavy metals, and the resulting spread of those materials through aquatic and terrestrial food chains have been recognized as key environmental problems in the Estuary. Numerous studies of the problems have been undertaken by various organizations and agencies, including the Environmental Protection Agency, the National Oceanic and Atmospheric Administration (NOAA), the USACE, and the States of New York and New Jersey, which have focused on the relationship between sediment contaminant levels and benthic habitat quality. Previous studies have identified areas within the Jamaica Bay study area

containing slightly elevated levels of chromium. More detailed discussions and results of past and current studies of sediment contamination are described in the more detail in the *Summary of Sediment Characterization Studies* (USACE – under development).

Existing Land/Water Usage

14. Predominant land uses within the Jamaica Bay study area are developed commercial, industrial, and residential. Along the waterfront, land and water uses include marinas, marine parks, parkland, vacant disturbed land (wetlands and uplands), tidal wetlands, and residential land. Public parks and open space present in the study area include Gateway National Recreation Area, Floyd Bennet Field, Prospect Park, and Breezy Point. Surface water is used for commercial shipping and non-contact recreation, such as fishing and boating. There are no public bathing beaches within the Jamaica Bay study area.

15. Many of the existing undisturbed wetland, upland, and shallow water habitats within Jamaica Bay are part of the Gateway National Recreation Area, which is managed by the National Park Service (NPS). Several other large tracts of land have also been preserved and fall under the jurisdiction of either New York City or the State of New York. These lands include Dubos Point, Bayswater State Park, Norton Basin, Brant's Point, Vernan Barbados (known to some as Terrapin Point), Four Sparrow Marsh, Spring Creek, most of Fresh Creek, Conch Point, and Paerdegat Basin.

16. The principal water use of Jamaica Bay is for industrial and wastewater discharge, while the Bay itself is used for commercial and recreational navigation. Water is withdrawn from Jamaica Bay and used as cooling water at the Far Rockaway power plant. Five sewage treatment plants (STPs) discharge treated wastewater that is assimilated by the receiving waters: three owned and operated by New York City Department of Environmental Protection (NYCDEP) (26th Ward, Coney Island, and Jamaica Bay plants); one owned and operated by the Village of Cedarhurst, NY (Cedarhurst); and one STP owned and operated by the Nassau County Department of Public Works (Cedar Creek).

Natural Resources Condition

17. Historic changes to the landscape and current land and water usage within the study area have resulted in the degradation of the natural resources within the study area. There are several inter-

related ecological issues that have been the primary cause of ecosystem degradation in the Jamaica Bay study area. Shoreline erosion due to wind and boat generated waves has caused the loss of up to 20% of the Bay's remaining salt marshes since 1975 (RPA 2003). The study area once consisted of 16,000 acres of wetlands, most of which were classified as intertidal low marsh dominated by smooth cordgrass (*Spartina alterniflora*) (USFWS 1997). Current estimates suggest only 4,000 acres of wetlands remain. Fill material, riprap, and concrete and wooden bulkheads have replaced natural shoreline areas and tidal marshes. Dredging in nearshore areas along bulkheads has resulted in deep channels where shallows and submerged vegetation, such as eelgrass once existed.

18. Changes in basin morphology have affected the circulation of sediments in places such as Grassy Bay. Prior to dredge and fill activities for the construction of JFK and the runway extension, sediment flushing time for Jamaica Bay was 10 to 11 days. After constructions of these facilities, flushing time increased to 35 days. As a result of these and other dredge and fill activities, natural tidal circulation patterns in Jamaica Bay have been altered which, in turn has resulted in the extirpation of some submerged beds of aquatic vegetation. Additionally, pits and channels that are the result of dredging activities may play a role in recent wetland losses in Jamaica Bay. These pits and channels may function as sediment sinks thus preventing sediment deposition needed to maintain salt marsh substrate.

19. Many disturbed wetlands and uplands have been overtaken by non-native and/or invasive species such as common reed and common lugworm. Large monotypic stands of these species represent low-quality wildlife habitat.

20. Given the past industrial history and landfill activities in the study area, portions of Jamaica Bay may contain contaminated upland soils, tidal marsh sediments, and marine sediments. CSOs and storm drain outlets have affected water quality within Jamaica Bay watershed. These outflows and outlets have the potential to degrade water quality by releasing excess nutrients or fecal coliform into the surface waters. In addition, discharges from these sources could result in low dissolved oxygen concentrations and increased turbidity within Jamaica Bay.

21. The natural resources within the study area are important to a variety of species that spend all or part of their lives here. The remaining sub tidal shallows and wetland are important habitat for

benthic invertebrates, fish, and birds. A 1983 survey conducted by the United States Fish and Wildlife Service (USFWS) found 121 species, including amphipod crustaceans and small polychaetes. Therefore, the substrate is important foraging habitat for juvenile and adult winter flounder (*Pleuronectes americanus*). Other fish species commonly found in Jamaica Bay include Atlantic silverside (*Menidia menidia*), bay anchovy (*Anchoa mitchilli*), mummichog (*Fundulus heteroclitus*), and striped killifish (*F. majalis*). These species are important forage for predatory fish and birds that breed, migrate through, or winter in the study area. Other common species found in the study area include bluefish (*Pomatomus saltatrix*), weakfish (*Cynoscion regalis*), and sea robin (*Prionotus* spp.). Anadromous species that use Jamaica Bay include Atlantic sturgeon (*Accipenser oxyrhynchos*), alewife (*Alosa pseudoharengus*), American shad (*Alosa sapidissima*), and striped bass (*Morone saxatilis*).

22. Mudflats in the study area, such as those found in the Plumb Beach area, are important habitat for horseshoe crabs (*Limulus polyphemus*) and shorebirds. Each spring, horseshoe crabs congregate on these mudflats to breed. Migratory shorebirds that winter in the Geotropic and breed in the Artic stop here during their migration to rest and replenish their fat reserves by feeding on the horseshoe crab eggs. This phenomenon has been occurring for eons and species such as ruddy turnstones (*Arenaria interpres*) and red knots (*Calidris canutus*) rely on the horseshoe crabs for their survival. Islands characterized by a variety of habitats including salt marshes, intertidal mud flats, and uplands also exist within the study area. These islands provide important habitat for colonial nesting waterbirds such as herons, egrets, gulls, and terns.

23. Wetland complexes in Jamaica Bay consist of freshwater wetlands and tidal wetlands. Low marsh habitats are dominated by smooth cordgrass (*Spartina alterniflora).* Many high marsh areas and wetlands, which have salinity concentrations less than 18 parts per thousand (ppt) are dominated by common reed (*Phragmites communis*). High marsh is also characterized by herbaceous species such as saltmeadow cordgrass (*Spartina patens*) and shrubs species including beach plum (*Prunus maritima*) and groundsel tree (*Baccharis halimifolia*). Species often found along the upper edge of high marsh include seaside goldenrod (*Solidago sempervirens*) and marsh orach (*Atriplex patula*). In disturbed areas, species such as black cherry (*Prunus serotina*), marsh elder (*Iva frutescens*), and bayberry (*Myrica cerifera*) are often found growing together, among stands of common reed.

24. Despite degradation due to human activities and development, the Jamaica Bay study area remains an extremely important habitat complex because of its geographic location. The study area is situated at a turning point along the mid-Atlantic coast and therefore acts as a funnel, concentrating migratory marine and estuarine species moving between the New York Bight portion of the North Atlantic and the Hudson-Raritan Estuary. Migrating shorebirds, raptors, landbirds, waterfowl, and insects often concentrate in the terrestrial and open water habitats of the Jamaica Bay study area because of the Bay's position along the Atlantic Flyway. The USFWS estimates nearly 20% of North America's bird species migrate through or breed in the study area annually. Salt marsh habitat and upland islands provide nesting habitat for waterfowl, wading birds, terns, and gulls. These habitats also provide roosting and foraging habitat for shorebirds and waterbirds as well as nesting and foraging habitat for grassland birds.

III. ECOSYSTEM RESTORATION

Hudson-Raritan Estuary Ecosystem

25. The New York-New Jersey Harbor Estuary Program (HEP 1996) has identified five primary factors that have caused ecosystem impairments or otherwise degraded water or habitat quality in the Estuary. These factors are:

- Habitat Loss and Degradation: Recent wetland inventories estimate at least 80% of the Estuary's wetlands have been lost or significantly altered.

- Toxic Contamination: The presence of toxins in the Estuary's waters, sediments, and biota is the result of historic and residual contamination by industrial and non-point sources. Today, wastewater discharges, combined sewer overflows (CSOs), accidental releases, vehicle exhaust emissions, household chemicals, pesticides, atmospheric deposition, landfill leachate, urban runoff, and other non-point sources are continuing sources of toxic substances (HEP 1996).

- Pathogens: The primary sources of pathogens include CSOs, sewage treatment plant malfunctions, illegal connections to storm sewers, vessel sewage discharge, urban runoff, and other non-point sources.

- Floatable Debris: Floatable debris is made up of two primary components: trash or litter and harbor drift. Trash and litter enters the Estuary via runoff, storm sewer discharges, CSOs, beach and boat litter, and poor solid waste handling operations. Harbor drift composed primarily of material from dilapidated shoreline structures such as piers, bulkheads, and pilings, is a significant of floatable debris in the Estuary.

- Nutrient and Organic Enrichment: Eutrophication due to excessive discharges of nitrogen is a significant problem in the Estuary. Organic matter comprised primarily of carbon is decomposed as DO and used in the biochemical process. Nitrogen and carbon enter the Estuary through point and non-point sources such as sewage

treatment plants, runoff (primarily from over-fertilized lawns), rivers and tributaries and atmospheric deposition.

Primary Restoration Needs of the Hudson-Raritan Estuary

26. The overall goal of the HRE is to restore and enhance aquatic and nearshore terrestrial habitats that have been lost or degraded as a result of human activities. To achieve this goal, primary restoration needs of the Estuary have been established. These categories were identified in the document entitled *Restoration Opportunities in the Hudson-Raritan Estuary* (USACE 2001). These need are:

- Restore and create intertidal wetlands and mudflats,
- Restore benthic habitats and remediate "hot spots" of contaminated sediments,
- Restore and create freshwater/riparian wetlands,
- Restore fish habitat (remove impediments to fish passage; construct artificial reefs),
- Restore shellfish habitat,
- Restore and enhance shoreline/coastal fringe habitat (including upland areas),
- Create, restore, or enhance vegetated and non-vegetated shallow water habitat.

Restoration Needs of the Jamaica Bay Study Area

27. Over 200 years of intense human use and industrialization have caused the natural ecosystems in the Jamaica Bay study area to become degraded and highly fragmented. As a result, a great need for ecosystem restoration efforts exists. The primary restoration needs in the study area are:

- Restore existing wetlands,
- Prevent additional wetland loss,
- Fill borrow pits,
- Create intertidal mudflats and shallow water habitat, and

- Remove invasive species.

28. The primary restoration needs may be met through existing, ongoing, and future ecosystem restoration efforts in the study area, as discussed below.

Restore and Protect Wetlands

29. The primary ecosystem concern in the Jamaica Bay study area is the accelerated loss of wetlands. Up to 45 acres of the existing wetlands in Jamaica Bay are estimated to be lost annually, thus the major restoration efforts in Jamaica Bay is to prevent additional wetland losses, stabilize the systems, and restore the recent losses. Restoration needs in the Jamaica Bay study area offer opportunities to incorporate beneficial uses of dredged materials. These opportunities are discussed in more detail below.

Fill Borrow Pits

30. Dredging in Jamaica Bay has altered the hydrodynamics of the bay, causing the dredged pits to act as sediment sinks, which is believed to be a significant contribution to wetland loss. Sediments are settling in the dredged pits and are not being deposited to replenish sediment lost to erosion in these coastal salt marshes. Bathymetric recontouring (e.g., filling degraded human-created pits or depressions) could help alleviate this problem. This recontouring could be accomplished through the use of dredged material.

Restore Shallow Water Habitat

31. In addition to filling pits, restoration efforts could also include restoring and creating intertidal wetland and mudflats. If the pilot program at Big Egg Marsh is successful, restoration efforts could incorporate the beneficial use of dredged material by applying thin-layers of dredged sediments to marshes where sediments erosion exceeds accretion. Dredged material could also be used to create mudflats, which are important foraging areas for migratory shorebirds that pass through the study area. Estimates from the pilot study underway at Big Egg Marsh suggest approximately 2000 cubic

yards of dredge material are needed restore one acre of marsh substrate where 18 inches is needed to restore wetland elevations.

Remove Invasive Species

32. Secondary restoration needs for the Jamaica Bay region include restoration of wetland habitats that have been invaded by non-native species, shallow water habitats, and shoreline/coastal fringe (upland) habitats. Removal of non-native species from wetland habitats will improve native plant species diversity and the quality of habitat for native wildlife species. In areas with proper water quality and hydrodynamic conditions, eelgrass and widgeon grass (*Rupee maritime*) beds may also be restored. Restoration of shallow water habitat and beds of submerged aquatic vegetation will improve habitat for fish and benthic organisms. These beds will provide important nursery habitat for fish species including winter flounder (*Pseudopleuronectes americanus*), black sea bass (*Centropristis striata*), bluefish (*Pomatomus saltatrix*), and striped bass (*Morone saxatilis*). Restoration of shoreline/coastal fringe upland habitat could improve or expand existing nesting and roosting habitat for wading birds, terns, and gulls. Creation or restoration of native grasslands in areas such as Floyd Bennett Field could provide valuable food and cover to a variety of wildlife species including small mammals and migratory songbirds.

Existing Restoration Efforts

33. Although restoration efforts under the HRE have not been initiated in the region, other stakeholders are studying the feasibility of ecosystem restoration. The National Park Service (NPS) formed a Blue Ribbon Panel, with the goal of identifying the factors contributing to the accelerated loss of wetlands in Jamaica Bay. Once the primary factors were identified, the NPS began feasibility studies on the efficacy of potential approaches to remediating this problem in Jamaica Bay.

Salt Marsh Restoration Pilot Project

34. One such feasibility study involves a pilot salt marsh restoration to evaluate the use of dredged material to restore salt marsh habitat. Specifically, the proposed project, located at Big Egg Marsh in Gateway National Recreation Area, would involve the application of an average of 18-inches of

dredged sediment onto a deteriorating tidal marsh. The purpose of the application of dredged sediment is to restore the elevations of the marsh and reestablish smooth cordgrass in the marsh.

Gerritsen Creek and Spring Creek

35. The District, along with the New York City Parks Department has formed partnerships to restore tidal wetlands, recreate coastal ecosystems, and increase biodiversity at Gerritsen Creek and Spring Creek. The restoration efforts in these locations are very similar and both are authorized under Section 1135 of the Water Resources Development Act. During the past century, dredging and filling resulted in the degradation of the salt marshes at these sites. The ecosystem disturbance at the sites allowed invasive species to become dominant. The restoration efforts at Gerritsen Creek and Spring Creek will involve improving tidal flow to the project area and improving habitat within inter-tidal salt marshes. In addition, both projects include and upland restoration component. The upland components include creating or enhancing upland coastal grassland and maritime shrubland habitat.

Potential Restoration Sites

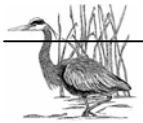
36. In addition to the existing and on-going restoration efforts, 45 potential restoration sites have been identified in the Jamaica Bay study area and are listed in Table 1. Each site not currently under study or construction will be evaluated to determine which of the proposed restoration activities, if any, are feasible from an engineering, ecological, and economic perspective.

Table 1 - Potential Restoration Sites in Jamaica Bay

HRE Site ID	Name	Restoration Opportunities[(1)]
1JB	Binnenwater	*
2JB	Forest Park Twin Ball Fields	3
3JB	Spring Creek	1,6,7
4JB	Shellbank Basin	7
5JB	Bergen Basin	7
6JB	Hawtree Point/Basin	8,10
7JB	Frank Charles Park	1
8JB	Hendrix Creek	1,7
9JB	Pennsylvania Avenue Landfill	1,2,6
10JB	Elders Point Marsh	*
11JB	Pumpkin Patch Marsh	*
12JB	Duck Point Marsh	*

HRE Site ID	Name	Restoration Opportunities[(1)]
13JB	Canarsie Pol	1,6
14JB	Canarsie Beach	*
15JB	Mill Basin	1,2,6,7
16JB	Four Sparrow Marsh	1,10
17JB	Marine Park	*
18JB	White Island	10
19JB	Gerritsen Creek/Inlet	1,6,7
20JB	Sheepshead Bay	6,7
21JB	Plumb Beach	2,6,7
22JB	Breezy Point	6
23JB	Floyd Bennett Field	1,6
24JB	Bergen Beach	1,10
25JB	Rockaway Reef	*
26JB	Stony Creek Marsh	*
27JB	Yellow Bar Marsh	*
28JB	West Pond	1,6,8
29JB	Black Wall Marsh	1
30JB	Big Egg Marsh	*
31JB	Goose Pond Marsh	*
32JB	Grassy Bay	7
33JB	Silver Hole Marsh	*
34JB	Brant Point	1,8
35JB	Vernam Barbadoes Basin/Vernam Barbadoes A&B	1,6,7
36JB	Arverne Urban Renewal Area	6
37JB	Dubos Point	1,8
38JB	Somerville Basin	1,8
39JB	Rockaway Peninsula	5,6,7
40JB	Conch Basin (Little Bay)	1,8
41JB	Healy Avenue	1,8
42JB	Bayswater State Park	11
43JB	Mott Basin	1,10
44JB	Brookville Marshes (Idlewild Marshes)	1,4
45JB	Thurston Basin	1,7
46JB	Hook Creek	1
47JB	Doxey Creek	4
48JB	JFK Shoreline	*

(1) Restoration Opportunities:
1 – Restoration/Creation of Intertidal Wetlands/Mudflats
2 – Benthic Habitat Restoration (Hotspot Removal)
3 – Restoration/Creation of Freshwater/Riparian Wetlands
4 – Restoration of Fishery Habitats (Anadramous Fish Migration, Artificial Reefs)
5 – Shellfish Habitat Restoration
6 – Restoration/Enhancement of Shoreline/Coastal Fringe Habitat (Dunes, Bird Habitat)
7 – Creation/Restoration/Enhancement of Shallow Water Habitat (including Eelgrass)
8 – Shoreline Enhancement/Bank Stabilization
9 – Water Quality Improvement
10 – Riparian Habitat Restoration
11 – Environmental Interpretation
* To be determined



IV. CONCLUSIONS

37. Compared to other study areas in the HRE, Jamaica Bay is losing wetlands at an accelerated rate. Between 1994 and 1999, Jamaica Bay lost an average of 45 acres of wetlands per year. Because the salt marsh system in this study area is unstable, restoration projects must be implemented while marsh recovery is still possible. This is particularly important because Jamaica Bay provides important habitat for a variety of fish and wildlife species. Ongoing pilot studies at Norton Basin and Little Bay need to be brought to completion to determine if filling larger pits in portions of Jamaica Bay (e.g., Grassy Bay) would help alleviate some of the sedimentation problems. In addition, salt marsh restoration should be initiated to mitigate for losses that have already occurred. Projects such as NPS's salt marsh restoration project in Big Egg Marsh may offer opportunities for beneficial use of dredged material through thin-layer application. The feasibility of this beneficial use should be explored on a larger scale to determine if it is an effective method for wetland restoration.

38. Restoration can be accomplished through partnerships between federal, state, and local governments and agencies. For example, the District and other local sponsors may restore wetland and upland areas in the study area. Where degradation is related to issues such as CSOs the responsible parties, facility operators, or other private entities may lead restoration or remediation efforts.

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FIGURES