GOWANUS CANAL AND BAY ECOSYSTEM RESTORATION PROJECT
BROOKLYN, KINGS COUNTY, NEW YORK

WETLAND CREATION GENERAL INVESTIGATION REPORT

July 2004

Prepared by: **U.S. Army Corps of Engineers**
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EXECUTIVE SUMMARY

This Wetland Creation General Investigation Report (Report) was prepared by the United States Army Corps of Engineers (USACE), New York District (District) for the Gowanus Canal and Bay Ecosystem Restoration Project (Project), in Brooklyn, New York (Figure 1). This Project was authorized by the United States House of Representatives Committee on Transportation and Infrastructure Resolution, dated 15 April 1999 (Docket Number 2596), to determine the feasibility of environmental restoration and protection relating to water resources and sediment quality within the New York Port District, including but not limited to creation, enhancement, and restoration of aquatic, wetland, and adjacent upland habitats. The Port District is centered around the New York–New Jersey Harbor, and is located within the Hudson–Raritan Estuary.

The Project area includes the Gowanus Canal, Channel, Bay, and immediate surrounding upland areas (Figure 1). The Gowanus Canal is located in a highly developed section of Brooklyn. The focus area for this Report is the Gowanus Canal proper, and areas immediately surrounding the Canal to the nearest hardened shoreline (Figure 2).

The goal of this Project is ecosystem restoration for the purpose of providing habitat for fish, wildlife, and benthic invertebrates, increasing biodiversity and productivity in the Canal, and removing suspended solids and pollutants/contaminants that are dissolved or transported in water prior to their deposition or infiltration into the Gowanus Canal. The goal of this Report is to present a feasibility level review of the potential for creating wetlands in the Gowanus Canal.

As preparation for this Report, a Literature Search (USACE 2004a, Appendix A) and Conceptual Designs (USACE 2004b, Appendix B) were prepared to identify and schematically display potential wetland creation opportunities, or other management practices, that could be used in an urbanized and heavily polluted waterway such as the Gowanus Canal.

The 15 potential wetland creation sites are identified and described, and information on the conceptual designs described in a previous report (USACE 2004b) are expanded and compared. Also, the sites are linked with specific conceptual designs, and the characteristics of each potential conceptual design are described as it pertains to each site. Additionally, some recommendations for additional work that would be needed as these potential conceptual wetland designs are developed further, and conclusions, are presented.

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This Wetland Creation General Investigation Report (Report) was prepared by the United States Army Corps of Engineers (USACE), New York District (District) for the Gowanus Canal and Bay Ecosystem Restoration Project (Project), in Brooklyn, New York (Figure 1). This Project was authorized by the United States House of Representatives Committee on Transportation and Infrastructure Resolution, dated 15 April 1999 (Docket Number 2596), to determine the feasibility of environmental restoration and protection relating to water resources and sediment quality within the New York Port District, including but not limited to creation, enhancement, and restoration of aquatic, wetland, and adjacent upland habitats. The Port District is centered on the New York–New Jersey Harbor, and is located within the Hudson–Raritan Estuary.

The USACE entered into a Feasibility Cost Sharing Agreement on 8 January 2002 with the New York City Department of Environmental Protection (NYCDEP), the non-Federal sponsor for the Project. The Feasibility Phase began 1 February 2002.

1.1 PROJECT DESCRIPTION

The Project area includes the Gowanus Canal, Channel, Bay, and immediately adjacent upland areas (Figure 1). The Gowanus Bay extends from the Bay Ridge Channel in Upper Bay, New York Harbor, to the beginning of the Gowanus Creek Channel. The Gowanus Creek Channel is a Federally maintained waterway that extends from the Gowanus Bay, 0.8 miles northeast, to the Hamilton Avenue Bridge. The Gowanus Canal is not a Federally maintained waterway, and extends from the Hamilton Avenue Bridge, north approximately 1 mile to its terminus at the mouth of the Flushing Tunnel, located south of Butler Street. The Gowanus Canal and Channel are located in a highly developed section of Brooklyn. The focus area for this Report is the Gowanus Canal proper, and areas immediately surrounding the Canal to the nearest hardened shoreline (Figure 2).

The Gowanus Canal was constructed in 1881 to accommodate industrial users and commercial shippers to the Brooklyn waterfront. As a result, the canal has been subject to over a century of heavy industrial use and is now characterized by poor water quality, contaminated sediments, deteriorating bulkheads, a poor benthic community structure, extensive filling, hardened shorelines, and unpleasant odors. Despite dramatic improvements in water quality over the last several decades, there continues to be episodic discharges of untreated sewage associated with periods of heavy precipitation beyond the capacity of the combined storm and sanitary sewer outfalls (CSOs). CSOs convey human pathogens, a variety of industrial wastes, and floatable materials into the waterways. Non-point source pollution from lawns, roads, broken septic tanks, construction sites, and other disturbed areas provide additional sources of contaminants to the Canal, including sediment, fertilizers, pesticides, bacteria, viruses, salt, oils, grease, and heavy metals (NYCDEP 2003).

Source: NYSDEC, 1994-1999.

500 0 500 1000 Meters

1500 0 1500 3000 Feet

Figure 1. Project Area for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Prepared By: United States Army Corps of Engineers, New York District

Date: 05/04

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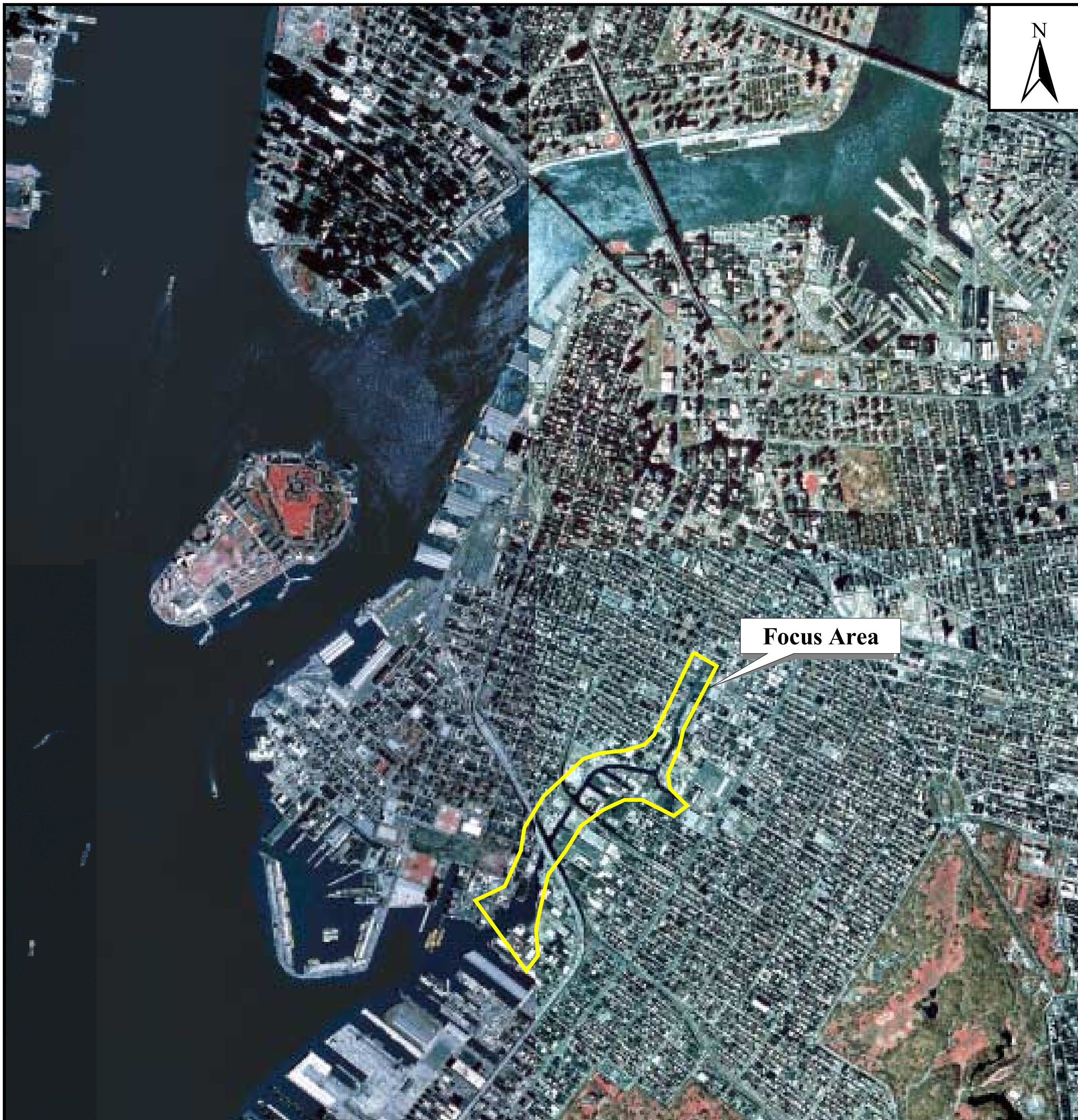

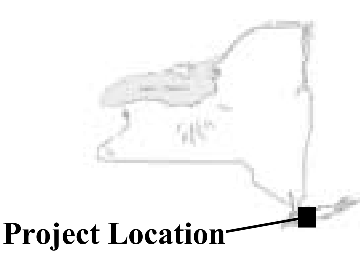

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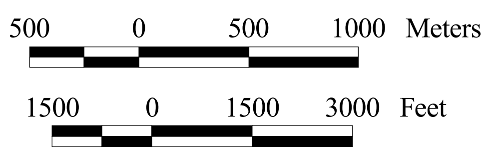


Figure 2. Focus Area for the Wetland Creation General Investigation Report for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Prepared By: **United States Army Corps of Engineers, New York District**

Date: 05/04

z:/projects/cs-300do-33/maps/finalreport/sitelocation.apr

1.2 PROJECT GOALS

The goal of this Project is ecosystem restoration for the purpose of restoring some areas of vegetated wetlands along the banks of the Canal, thereby providing habitat for fish, wildlife, and benthic invertebrates, increasing biodiversity and productivity in the Canal, and removing suspended solids and pollutants/contaminants that are dissolved or transported in water prior to their deposition or infiltration into the Gowanus Canal. The goal of this Report is to present a feasibility level review of the potential for creating wetlands in the Gowanus Canal. Created wetlands and other stormwater management practices, in addition to providing habitat and increasing biodiversity and productivity, can be used for containing, maintaining, and treating a portion of the sources of contamination and sedimentation to the Canal prior to entering the waterway. These constructed wetland systems would be located either at the upper limits of the tidal range, to intercept urban runoff and CSO discharges, or completely within the Canal, handling daily tidal exchange. Area limitations in the Gowanus Canal, due to the need to maintain a travel corridor for boat and/or barge traffic, necessitate that the created wetlands would be small.

1.3 BACKGROUND DATA COLLECTION

A Literature Search (USACE 2004a, Appendix A) was completed to identify wetland creation opportunities, or other management practices, that could be used in an urbanized and heavily polluted waterway such as the Gowanus Canal. This Literature Search includes the following: a brief description of the wetland creation opportunities; information on the size of the area required for treatment, minimum vertical distance required, approximate construction costs, maintenance requirements, advantages and disadvantages, and applicable situations for use of each wetland creation opportunity or management practice; a description of pollutant removal capabilities for each management practice; and, the tolerances, hydrologic condition, wildlife value, and pollutant removal characteristics of tree, shrub, and herbaceous species that may be used in wetland creation.

The wetland creation opportunities that have the potential to meet the Project and Report goals include stormwater wetlands, terraced wetlands, transitional wetlands, and modified submerged gravel filters. These wetland creation opportunities were developed further in the Conceptual Designs (USACE 2004b, Appendix B), and are included in Section 3.0 of this Report. Transitional wetland designs were expanded to include designs for construction within the confines of a turning basin.

This Report incorporates the information collected in the Literature Search (USACE 2004a) and Conceptual Designs (USACE 2004b), and links them with the sites identified for potential action in the Gowanus Canal. Each site is described in Section 2.0 Potential Wetland Creation Sites; conceptual designs are described in Section 3.0 Conceptual Designs; and, the sites are linked with conceptual designs in Section 4.0 Site-Specific Wetland Creation Designs. Recommendations for future data and research needs, and the limiting factors associated with more detailed development of these designs, are included in Section 5.0 Recommendations and Conclusions.

2.0 POTENTIAL WETLAND CREATION SITES

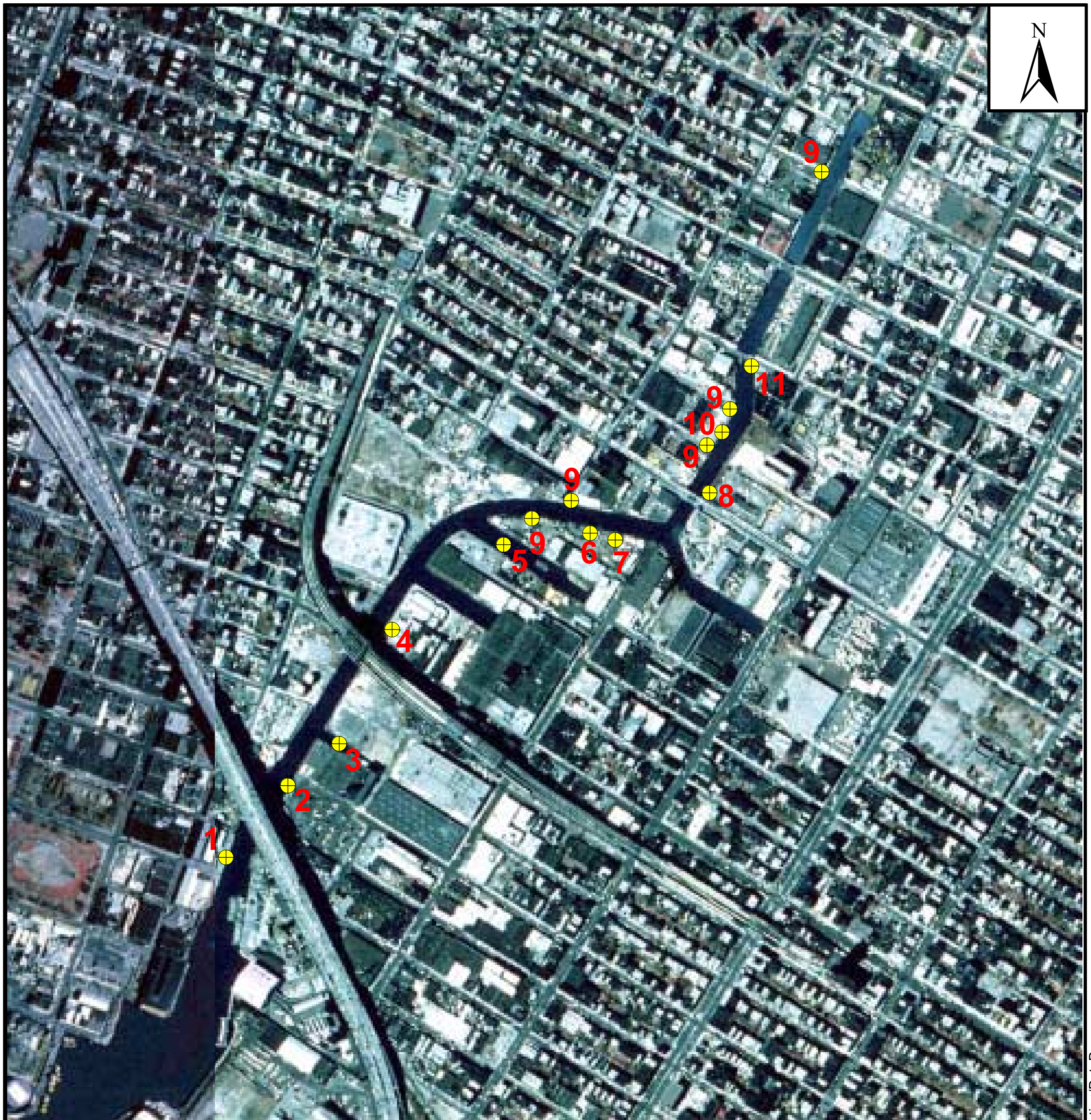
The focus area for this Report includes the Gowanus Canal proper and the uplands immediately adjacent (Figure 2). The Gowanus Canal consists of a maintained open water channel, which has been channelized, is lined by hardened structures (e.g., sheet piling, timber crib bulkhead), and is frequently used by boats and barges for recreation and commercial purposes. The surrounding uplands are heavily developed with a high percentage of impervious ground surfaces.

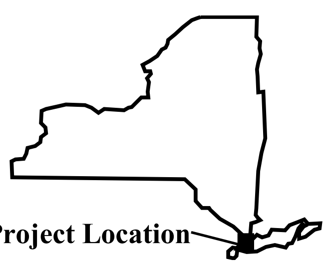
Fifteen areas are identified along the Canal as potential sites for wetland creation, stormwater management practices, upland enhancement, or educational street-end parks; these include 10 unique sites and five street-end parks (Figure 3). Table 1 displays the approximate wetland creation site dimensions for each of the 15 sites. Sites range in size from approximately 1.5 acres to 1/100 acre. The following sections provide a brief summary of the conditions observed at each of the potential sites.

Table 1. Approximate Wetland Creation Site Dimensions for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Site	Description	Length Along Canal (feet)	Width Built Out into Canal (feet)	Overall Width Including Uplands (feet)
1	South of Hamilton Avenue Bridge	200	20	20
2	North of Hamilton Avenue Bridge	100	30	30
3	Turning Basin Adjacent to Lowe's Property[1]	175	50	50
4	North of 9th Street Bridge	300	15	15
5	6th Street Turning Basin[1]	670	50	100
6	Upland Earthen Mound North of 5th Street	112	15	65
7	NYCDEP CSO North of 5th Street	50	15	15
8	North of 3rd Street Bridge	70	30	50
9 (Street End Parks)	DeGraw Street (West)	50	30	50
	First Street (West)	50	30	50
	Second Street (West)	50	30	50
	Bond Street (West)	50	15	35
	Fifth Street (East)	50	15	30
10	2nd Street Community Garden	190	30	110
11	Carroll Street CSO	125	30	30

[1] Turning basin length and width measurements are for the entire turning basin. Size of created wetland can be adjusted according to desired action.





Source: NYSDEC, 1994-1999.

100 0 100 200 300 Meters

300 0 300 600 900 Feet

LEGEND

Potential Site

Figure 3. Potential Sites for Wetland Creation for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Prepared By: **United States Army Corps of Engineers, New York District**

Date: 05/04

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2.1 SITE 1 – SOUTH OF HAMILTON AVENUE BRIDGE

Site 1 is located at the southern portion of the Canal, south of the Hamilton Avenue/Gowanus Expressway Bridge, near its confluence with Gowanus Bay (Figure 3). The topography of the uplands adjacent to Site 1 is relatively flat, and gently sloping towards the Canal. There is no existing bulkhead at this site. The channel banks appear to be comprised of rock, industrial debris, garbage, and fill material. There is almost no herbaceous vegetation to stabilize the banks, and as a result, the banks are sloughing into the channel. Overall, these conditions create prime opportunities for clean up and restoration.

This degraded site presently offers poor quality habitat for vegetation and wildlife. Canada geese (*Branta canadensis*) were observed in the water and on the shoreline at this site. Canada geese are common and are considered almost a nuisance species in some areas, and therefore are typically not preferable target wildlife species for wetland creation. However, the presence of geese provides evidence that other avian species may be attracted to the area with the creation of wetlands and improved wildlife habitat.

The approximate dimensions for potential action at this site are 200 feet along the channel, and 20 feet into the Canal. Construction of structures up to 20 feet into the Canal would not impede barge or boat traffic in the Canal. Wetland creation at this site would require removal of rock, debris, and garbage, installation of sheet piling to isolate the workspace, construction of the specific design features (i.e., retaining wall, bulkhead), and placement of fill material to extend the site into the Canal. Following the completion of construction and stabilization of the site, the sheet piling would be removed to reintroduce hydrology to the site.

2.2 SITE 2 – NORTH OF HAMILTON AVENUE BRIDGE

Site 2 is located just north of the Hamilton Avenue Bridge/Gowanus Expressway along the eastern banks of the Canal (Figure 3). The adjacent upland area is an impervious paved parking area that is associated with nearby infrastructure; a fence and guardrail identify the edge of the Canal. The previous bulkhead has deteriorated and exposed the existing steep Canal wall to erosion by water currents and wind. As a result, the soils underlying the parking lot, fence, and guardrail are eroding and sloughing into the Canal.

The current extent of substrate available for growth of herbaceous vegetation, shrubs, and trees, is limited to the vertical soil surface along the Canal. As a result, no substantial vegetation has become established at this site. Additionally, vegetation cannot permanently establish and stabilize the bank because of the unstable and eroding conditions. There is no existing wildlife habitat at this site.

The approximate dimensions for potential action at this site are 100 feet along the channel, and 30 feet from the existing channel bank into the Canal. Construction of structures extending up to 30 feet into the Canal would not be expected to impede barge or boat traffic in the Canal. The following would need to occur to create wetlands or other management practices at this site: the existing Canal wall would need to be stabilized; sheet piling would need to be installed to isolate the workspace during construction; the specific design features would need to be constructed; fill material would be required to extend the site into the Canal; and, sheet piling would need to be removed following completion of construction to reintroduce hydrology to the site.

2.3 SITE 3 – TURNING BASIN ADJACENT TO LOWE'S PROPERTY

Site 3 encompasses the turning basin located south of/adjacent to Lowe's property (Figure 3). A newly constructed bulkhead lines the Canal on the northern side of the turning basin along Lowe's property. On the southern side of the turning basin, the building is built to the edge of the Canal, providing the southern wall for the turning basin.

A small tree and a patch of low herbaceous vegetation are growing in the southeast corner of the turning basin. This vegetated patch is isolated from any other terrestrial habitat; the only access to this area is by water. There is no substantial existing wildlife habitat at this site.

The approximate dimensions of the turning basin are 175 feet long and 50 feet wide. Wetland creation at this site could encompass either the entire turning basin, or a portion of the basin. If the entire turning basin is used for wetland creation, barge traffic could use another turning basin located 900 feet upstream of this site to turn around. Boat traffic would not be expected to be impacted by wetland creation in this location. Wetland creation at Site 3 would require the installation of sheet piling to isolate the workspace, construction of the specific design features, placement of fill material to create a substrate surface for wetland creation, and removal of sheet piling following construction to reintroduce hydrology to the site. The construction of the adjacent Lowe's property was designed to invite use of the Canal area by the public. Consistent with that idea, educational signs could be erected around Site 3 to inform the public about the functions and values of the wetlands created.

2.4 SITE 4 – NORTH OF 9TH STREET BRIDGE

Site 4 is located just north of the 9th Street Bridge on the eastern banks of the Canal (Figure 3). This site encompasses a very narrow (i.e., approximately 3-foot) buffer strip between the existing infrastructure, an impervious paved parking area, and the Canal. The bulkhead has deteriorated at this site, and cement barriers and industrial debris line the edge of the Canal.

There are a few small trees and other plants growing among the debris at the site. This site currently provides very poor quality habitat for wildlife to rest, nest, or forage.

The approximate dimensions for potential action at this site are 300 feet along the channel, and 15 feet into the Canal. This site is limited in terms of the horizontal extent of potential wetland creation. The openings for many of the small bridges north of the 9th Street Bridge are narrower than the main channel by approximately 15 feet on each side. Based on this information, constructing structures extending up to 15 feet out from the existing channel banks into the Canal would allow continued normal use of the Canal. Wetland creation at this site would require the following: removal of cement barriers, industrial debris, and garbage; installation of sheet piling to isolate the workspace; construction of the specific design features; and, placement of fill material to create suitable substrate for wetland creation.

2.5 SITE 5 – 6TH STREET TURNING BASIN

Site 5 is a large turning basin known as the 6th Street turning basin (Figure 3). There is an old, degraded pier located in the middle of the turning basin, and an additional pier, in unknown condition, located in the northeastern corner of the turning basin. The bulkheads along the edge of the turning basin are deteriorating, with little protection from the erosive forces of wave action in the Canal.

Sparse vegetation exists along the sides of the turning basin because of the lack of available substrate. There may be algae or submergent aquatic vegetation growing on or around the deteriorated pier. Ducks were observed swimming around this pier, and may have been foraging. Overall, this degraded area provides minimal habitat for wildlife, and provides an opportunity for improvement through wetland creation.

The approximate dimensions of the turning basin are 670 feet long by 100 feet wide. Wetland creation could encompass either the entire turning basin, or a portion of the basin. If the entire turning basin is used for wetland creation, barge traffic could use a turning basin located downstream of this site to turn around. Boat traffic would not be expected to be impacted by wetland creation in this location. Wetland creation would potentially require the following: removal of the degraded pier and any debris or garbage that has accumulated in the turning basin; stabilization of the existing bulkhead; installation of sheet piling to isolate the workspace; construction of the specific design features; placement of a large amount of fill material to create a substrate for wetland creation; and, removal of sheet piling following completion of construction to reintroduce hydrology to the site.

2.6 SITE 6 – UPLAND EARTHEN MOUND NORTH OF 5TH STREET

Site 6 is located north of an extension of 5th Street (Figure 3). This site consists of an upland earthen mound that has a large amount of industrial debris and garbage, and is stabilized by upland trees and herbaceous vegetation typically found in disturbed areas and waste places. Currently, there is no existing bulkhead, however there are large chunks of concrete and debris stabilizing the banks along the Canal.

The slope of the adjacent land ranges from gently to steeply sloping into the Canal. There are several small trees growing in this area, and scattered herbaceous vegetation. This site currently provides some wildlife habitat, however the potential for improvement exists. Both upland enhancement and wetland creation could be done at this site.

The approximate dimensions for potential action at this site are 112 feet along the channel, and 15 feet into the Canal. This site is limited in terms of the horizontal extent of potential wetland creation. The potential wetland creation width is based on the approximate minimum channel width at bridges along the Canal. Based on this information, constructing structures up to 15 feet out from the existing channel banks into the Canal would allow continued normal use of the Canal. Wetland creation at this site would require the following: removal of rock, debris, and garbage; installation of sheet piling to isolate the workspace; construction of the specific design features (i.e., retaining wall, bulkhead); placement of fill material to extend the site into the Canal; and, removal of sheet piling following completion of construction to reintroduce hydrology to the site.

2.7 SITE 7 – NYCDEP CSO NORTH OF 5TH STREET

Site 7 includes a NYCDEP regulated CSO, and the degraded buffer zone between the adjacent industrial area and the Canal (Figure 3). The CSO opening was not discernable through the debris and trash that line the bank of the Canal, and it is likely buried under the accumulated debris. The bulkhead along this site has deteriorated, and needs to be replaced.

Vegetation at this site is sparse, growing amidst the garbage and debris along the shoreline. Species present appear to be opportunistic species typically found in disturbed areas and waste places. The existing habitat is of poor quality for vegetation and wildlife. There is an opportunity at Site 7 for improvement of the buffer zone, and creation of adjacent wetlands.

The approximate dimensions for potential action at this site are 50 feet along the channel, and 15 feet into the Canal. This site is limited in terms of the horizontal extent of potential wetland creation. However, constructing structures extending up to 15 feet out from the existing channel banks into the Canal would allow continued normal use of the Canal. Wetland creation at this site would require the following: removal of debris and garbage; location of the CSO outlet; stabilization of the outlet pathway; installation of sheet piling to isolate the workspace;

construction of the specific design features (i.e., retaining wall, bulkhead); placement of fill material to build out the site into the Canal; and, removal of sheet piling following completion of construction to reintroduce hydrology to the site.

2.8 SITE 8 – NORTH OF 3RD STREET BRIDGE

Site 8 is located just north of the 3rd Street Bridge on the eastern banks of the Canal (Figure 3). This site encompasses a vegetated platform, cement bulkhead, and a CSO discharge. The cement bulkhead at this site is intact, and appears stable. A CSO pipe is located under the vegetated platform, and the CSO empties directly into the Canal.

The vegetated platform is approximately 20 feet wide, and supports herbaceous vegetation and some trees typical of urban and disturbed sites. This area provides some habitat for wildlife, however there is potential for improvement.

The approximate dimensions for potential action at this site are 70 feet along the channel, and 30 feet into the Canal. The maximum width of wetland creation is approximately 30 feet, so that the desired channel width necessary for boat traffic in the Canal north of the 3rd Street Bridge is maintained. The vegetated platform could also be incorporated into the restoration, providing 20 feet of adjacent upland area. Wetland creation at this site would require the following: installation of sheet piling to isolate the workspace; construction of the specific design features (i.e., retaining wall, bulkhead); placement of fill material to extend the site into the Canal; and, removal of sheet piling following completion of construction to reintroduce hydrology to the site. Depending on how the upland area is connected to the wetlands, the existing concrete bulkhead may need to be modified or removed.

2.9 SITE 9 – STREET END PARKS

Site 9 includes five street end areas, some of which have existing street end parks (Figure 3). These street end areas, from north to south along the Canal, are located at the end of DeGraw Street on the west side, 1st Street on the west side, 2nd Street on the west side, Bond Street on the west side, and 5th Street on the east side of the Canal. The street end areas have low, concrete bulkheads, in various states of repair.

These street end areas have the potential to allow local residents to have boat access to the Canal. Some of the street end areas have cement brick walkways and cement box planters (approximately 12 ft long by 6 ft wide by 1 ft high) containing herbaceous vegetation. Vegetation and wildlife habitat at these sites is limited to the cement box planters. Improvement of these sites would result in a cleaner, aesthetically pleasing area, and would offer recreational and educational opportunities for the surrounding community.

The approximate dimensions for potential action at these sites are 50 feet along the channel, and between 15 and 30 feet extending out into the Canal. DeGraw, 1st, and 2nd streets could be built out 30 feet into the Canal, and Bond and 5th streets could be built out 15 feet into the Canal, based on the approximate minimum channel width that would need to be maintained in the Gowanus Canal. Also, between 15 and 20 feet of upland enhancement, or street end park improvements could be done. DeGraw, 1st,, 2nd, and Bond streets have approximately 20 feet, and 5th Street has approximately 15 feet of upland enhancement potential. Wetland creation at these sites would require the following: installation of sheet piling to isolate the workspace; construction of the specific design features (i.e., retaining wall, bulkhead); placement of fill material to extend the sites into the Canal; and, removal of sheet piling following completion of construction to reintroduce hydrology to the site. Upland enhancement may include construction or improvement of box planters, and creation of educational signs to inform the public about the site. Depending on how the upland area is connected into the wetlands, the existing concrete bulkhead may need to be modified or removed. Also, it would be important to maintain a boat access point at each of these areas, so that the public can have continued access to the Gowanus Canal.

2.10 SITE 10 – 2ND STREET COMMUNITY GARDEN

Site 10 is known as the 2nd Street Community Garden, and is an existing degraded upland area adjacent to the Gowanus Canal (Figure 3). This site is located on the western banks of the Canal between the 1st and 2nd street end parks (Site 9). The bulkhead at this site has deteriorated, and the edge of the property is sloughing into the Canal.

The site is relatively open, and some trees, shrubs, and herbaceous vegetation have established on the site. The invasive herbaceous species *Phragmites australis* is present on the site, as well as other species typical of disturbed urban sites. The site provides some habitat for wildlife however this habitat can be improved.

The approximate dimensions for potential action at this site are 190 feet along the channel, and 30 feet into the Canal. An additional 180 feet of upland area is available for enhancement.

Wetland creation at this site would require the following: installation of sheet piling to isolate the workspace; construction of the specific design features (i.e., retaining wall, bulkhead); placement of fill material to extend the site into the Canal; and, removal of sheet piling following completion of construction to reintroduce hydrology to the site. Upland enhancement would include the removal of invasive species, such as *Phragmites australis*, and disposal of garbage and debris that has accumulated on the site. Selection of this site would be best if it were done in conjunction with the 1st and 2nd street end parks.

2.11 SITE 11 – CARROLL STREET CSO

Site 11 is located just south of the Carroll Street Bridge on the eastern side of the Gowanus Canal (Figure 3). This site has a NYCDEP regulated CSO pipe that periodically discharges into the Canal. Water exits the CSO from within a large brick and stone bulkhead adjacent to the bridge, and empties directly into the Canal. The bulkhead adjacent to the CSO casing is intact, and does not appear to require any repairs. The mouth of the CSO is partially submerged at high tide.

There is currently no submergent or emergent aquatic vegetation at this site. The adjacent upland area may provide some limited habitat for wildlife, however potential for additional improvement at this site exists.

The approximate dimensions for potential action at this site are 125 feet along the channel, and 30 feet into the Canal, extending out to the pilings adjacent to the opening under the bridge. The upland area adjacent to this site appears to be well maintained, with grass and small evergreen shrubs stabilizing the area. It does not appear that upland improvements are necessary. Wetland creation at this site would require the following: installation of sheet piling to isolate the workspace; construction of the specific design features (i.e., retaining wall, bulkhead); placement of fill material to build out the site into the Canal; and, removal of sheet piling following completion of construction to reintroduce hydrology to the site. In addition to wetland creation, this highly visible site has potential for placement of educational signs to inform the public about the functions and values of the wetlands created and improve public awareness.

3.0 CONCEPTUAL DESIGNS

There are many challenges associated with wetlands creation in areas that are heavily developed and have a high percent of ground surface area that is impervious (i.e., buildings, roads, sidewalks). These areas are considered "ultra-urban", and are characterized by high population densities, high property values, and a high density of paved surfaces and buildings, resulting in highly impervious conditions that accelerate runoff of contaminant- or debris-laden water (USDOT 2004). Also, built-out conditions, or near built-out conditions, often exist in ultra-urban areas, meaning that the maximum development that could occur in an area, based on the zoning regulations for the allowed land uses, building square footages, lot coverages, and parking requirements, has occurred (USDOT 2004). Such is the condition in Brooklyn, New York, along the Gowanus Canal. As a result of these conditions, wetlands creation is limited in terms of the location and space available for wetland creation, economic factors such as real estate and construction costs, maintenance requirements, and sediment and contaminant treatment volumes compared to input volumes. Despite these limitations, wetland creation is feasible in an ultra-urban setting such as the Gowanus Canal.

The tides in the Gowanus Canal range from 4–6 feet above mean lower low water at high tide depending on the point in the tidal cycle (NOAA/NOS 2004). Salinity in the Canal ranges from 19.9–25.3 parts per thousand (ppt) (USACE 2003). Considering the tidal range and salinity in the Canal, wetland creation focuses on creation of intertidal wetlands, or wetlands that contain vegetation that is tolerant of saline conditions resulting from storm tide inundation or incidental salt spray.

The design of wetland creation for the Gowanus Canal accommodates the Project goals (Section 1.2), and accounts for the limitations of wetland creation in an urbanized and heavily polluted waterway, such as the Gowanus Canal. A secondary benefit of wetland creation is improved water quality in the Canal, and an overall improvement in water quality in the watershed.

For these conceptual designs, wetland creation designs are based on a conceptual level understanding of the conditions in the Gowanus Canal following a site assessment, review of existing site data as described in Section 2.0, and a literature review of potential wetland creation management practices (USACE 2004a). Section 3.1 generally describes the conceptual wetland creation designs (USACE 2004b), including effects on biodiversity and productivity, habitat and benthic characteristics, general substrate and vegetation characteristics, and cost considerations. Sections 3.2–3.6 present the specific details of each proposed conceptual design, including a description of the design elements, hydrology source, size, soil/substrate characteristics, plant species recommended, and sedimentation and contaminant treatment capabilities. Section 3.7 provides a relative comparison of the proposed wetland creation designs based on how each conceptual design addresses the Project goals, the approximate cost of constructing, and the amount of maintenance and monitoring required.

3.1 GENERAL CHARACTERISTICS OF CREATED WETLANDS

The conceptual designs proposed can be constructed at a variety of sites within the Project area. With this in mind, the conceptual designs presented below may be modified in various ways depending on site-specific conditions, but are intended to provide similar functions to increase biodiversity and productivity, improve fish, wildlife, and benthic habitat, and remove some suspended solids and contaminants from, or prior to their entry into, the Gowanus Canal. These conceptual designs have comparable structures and characteristics, including the general substrate design, that require similar construction activities. An estimation of the range of associated construction costs also is presented below for wetland creation in general. Variances to the general characteristics described in this section are specified and discussed in further detail within the appropriate wetland creation design section.

The Gowanus Canal, and the New York Harbor system in general, do not have any noteworthy existing wetlands. As a result, creating any wetlands will increase biodiversity, productivity, and habitat for a variety of wildlife, fish, and benthic species. The replacement of low diversity and low productivity open water areas with highly productive intertidal marsh and other wetland habitats would result in a net increase in diversity and productivity in the Canal. Intertidal marsh is one of the most biologically productive types of wetlands (New York State Department of Environmental Conservation [NYSDEC] 2000); diurnal tidal flushing exports the products of photosynthesis and decomposition to adjacent waters, providing the building blocks for growth and development by micro-organisms, on up the food chain to benthic invertebrates, fish, and eventually birds and other wildlife. Diurnal tidal flushing also renews water and nutrient supplies for continued support of chemical and biological processes within the wetland system. High marsh receives less frequent tidal flooding. As a result, high marsh is less productive than intertidal marsh, and produces less marine food. However, high marsh is important for absorption of silt and organic material, and cleansing/water quality improvement, particularly of upland runoff (NYSDEC 2000).

There are also many complex biological and chemical processes that occur in wetlands that function to isolate and remove suspended solids, pollutants, and nutrients. For example, wetland vegetation slows the flow of water, enhancing suspended particulate matter removal via sedimentation, and facilitating the removal of suspended and dissolved pollutants through direct contact with vegetation, biota, and sediments. Changes in soil conditions in wetlands, due to fluctuations between aerobic and anaerobic conditions, result in a variety of chemical transformations that facilitate the processing and removal of nutrients, minerals, and other pollutants.

Created wetland systems also function to improve wildlife habitat and provide species with additional high quality habitat for breeding, nesting, roosting, and foraging. Wildlife species likely to benefit from increased wetland habitat include a variety of reptiles, and avian species including wading birds such as herons (*Ardea* species, *Egretta* species), waterfowl such as ducks (*Anas* species) and cormorants (*Phalacrocorax* species), and seabirds such as gulls (*Larus* species). Created wetlands would also benefit songbirds, both as nesting area for urban residents, and as green "islands" for migratory stopovers in the heavily developed urban landscape. Fish species that may benefit from wetland creation in the Gowanus Canal include bottom feeders such as winter flounder (*Pleuronectes americanus*), windowpane (*Scophthalmus aquosus*), scup (*Stenotomus chrysops*), and possibly summer flounder (*Paralichthys dentatus*) and hogchocker (*Trinectes maculatus*); piscivorous fish such as bluefish (*Pomatomus saltatrix*) and striped bass (*Morone saxatilis*); plankton eaters such as alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), and possibly Atlantic menhaden (*Brevoortia tyrannus*) and American shad (*Alosa sapidissima*); and, mummichog (*Fundulus heteroclitus*), striped killifish (*Fundulus majalis*), and threespine sticklebacks (*Gasterosteus aculeatus*) (USACE 2000a, 2000b).

Wetland systems such as these described also would function to provide conditions that are conducive to the recruitment and establishment of benthic invertebrates. A benthic study of the Gowanus Canal conducted in April 2003 found Nematoda species were the most abundant benthic invertebrates, followed by Polychaeta worms and Oligochaeta worms (USACE 2003). Created wetlands in this area may also provide habitat for horseshoe crab (*Limulus polyphemus*); a variety of true crabs such as mud crab (*Panopeus* species), fiddler crab (*Uca* species), and blue crab (*Callinectes sapidus*); Amphipods such as scud (*Gammarus* species) and related genera; a variety of Pelecypoda such as soft clam (*Mya arenaria*) and ribbed mussel (*Modiolus demissus*); and, clam worm (*Nereis* species), ivory barnacle (*Balanus eburneus*), marsh snail (*Melampus bidentatus*), and shore/grass shrimp (*Palaemonetes* species) (Gosner 1978, USACE 2000b). Benthic organisms are an important element of wetland systems because they serve as major components of the food chain, they process and remove nutrients and pollutants, and they are biological indicators of water quality and environmental health.

The general design for the substrate in these conceptual designs includes an 18-inch topsoil layer overlying a filter medium, such as sand or gravel, of varying depths. The topsoil layer is the site of vegetation establishment, and primary root zone. Preliminary filtration and percolation may occur through the topsoil into the underlying filter medium. Nutrient and pollutant adsorption and uptake may occur in this zone. The underlying porous filtering medium acts to facilitate water movement vertically through the system and provides additional adsorption sites for removal of contaminants. Fluctuating water levels in the topsoil and filter media allow chemical transformations to occur to process and remove contaminants from the water, thereby reducing contact, uptake, or absorption by fauna utilizing the Gowanus Canal and created wetlands.

An important aspect of each conceptual design involves the successful establishment of wetland plants in the created wetlands. Vegetation must be selected according to specific site conditions, including salinity, frequency and duration of inundation (i.e., tidal cycle and CSO inputs), appropriate soil conditions, and exposure to sunlight. Herbaceous vegetation may be preferable in the wetland areas because of the rapid establishment potential and high primary productivity. Shrubs and trees would provide additional diversity and habitat for wildlife at the upper tidal range, or in upland areas. For initial wetland plant establishment, constructed wetlands may incorporate seeds, seedlings, plant plugs, or parts of plants (rootstocks, rhizomes, tubers, or cuttings). Although seeds are generally inexpensive, they are the least reliable planting method for successful establishment in constructed wetlands. To control and prevent erosion, geotextiles and bio-matting should be utilized to stabilize the exposed sediments and shoreline as the vegetation establishes.

It is difficult to estimate costs for constructing conceptual designs because of the uncertainty associated with the space available for construction, the specific design elements selected, and the site-specific features that will need to be incorporated into construction. The United States Environmental Protection Agency (USEPA) (1999) estimates that construction costs for an emergent wetland with a sediment forebay can range from $26,000 to $55,000 per acre of wetland. This cost estimate includes clearing, excavating, grading, erosion and sediment control, staking, and planting. Construction costs at Gerritsen Creek in Brooklyn, New York are estimated to be on the order of $225,000 per acre (Falt 2004). However, due to variations among the conceptual designs, required construction activities are dependent on wetland characteristics and features within the design, and based on site-specific attributes. For instance, wetlands designed for some sites in the Gowanus Canal may not require clearing and excavating activities at the construction site, however they may necessitate debris removal, structural measures such as installation and removal of sheet piling or coffer dams to isolate the workspace, constructing a retaining wall or terraces, and fill transfer and placement. Although the area available for wetland creation in the Gowanus Canal ranges from approximately 1.5 acres to 1/100 acre, the total cost for construction will vary depending on site accessibility and the degree of structural measures that are required to construct a wetland at a particular site. In recognition of these limitations and additional expenses likely to be incurred, the cost of constructing a created wetland in the Gowanus Canal is likely to be significantly higher than the USEPA estimate, on a per site basis.

Monitoring and maintenance of created wetland systems would be critical, particularly in the early stages of development, until wetland vegetation becomes established (USDOT 2004). It is important that vegetation is not overwhelmed by sediment accumulation and that the general topography is maintained so that maximum water quality improvement benefits can be achieved. Maintenance requirements may include removal of accumulated sediments throughout the wetland, especially from within the sediment forebay of CSO-related created wetlands and the water collection chamber of gravel filters, replacement of plants that have died, identification and control of invasive plant species (e.g., common reed [*Phragmites australis*]), or plant harvesting to remove accumulated organic matter (USEPA 1999). Additional maintenance may include trash and debris removal on an annual or biannual basis, depending on the rate of accumulation of trash and debris. Monitoring and maintenance costs would be in addition to construction costs. Monitoring costs are estimated at 1% of construction costs (USACE 2001), and monitoring would need to be done pre-construction, and for 3–5 years following construction. Costs associated with maintenance may be higher during vegetation establishment but are generally moderate thereafter. Maintenance costs are estimated at 2% of construction costs, per year, for the life of the project (USEPA 1999).

3.2 STORMWATER WETLAND

Stormwater wetlands are shallow, constructed wetlands designed to capture CSO discharge and stormwater runoff and allow it to filter through vegetation and soils for the purpose of contaminant and sediment removal and overall improvement in habitat in the Gowanus Canal. In addition to improving wildlife habitat, stormwater wetlands provide cleaner, aesthetically pleasing areas with improved water quality and opportunities for educating the public.

Function

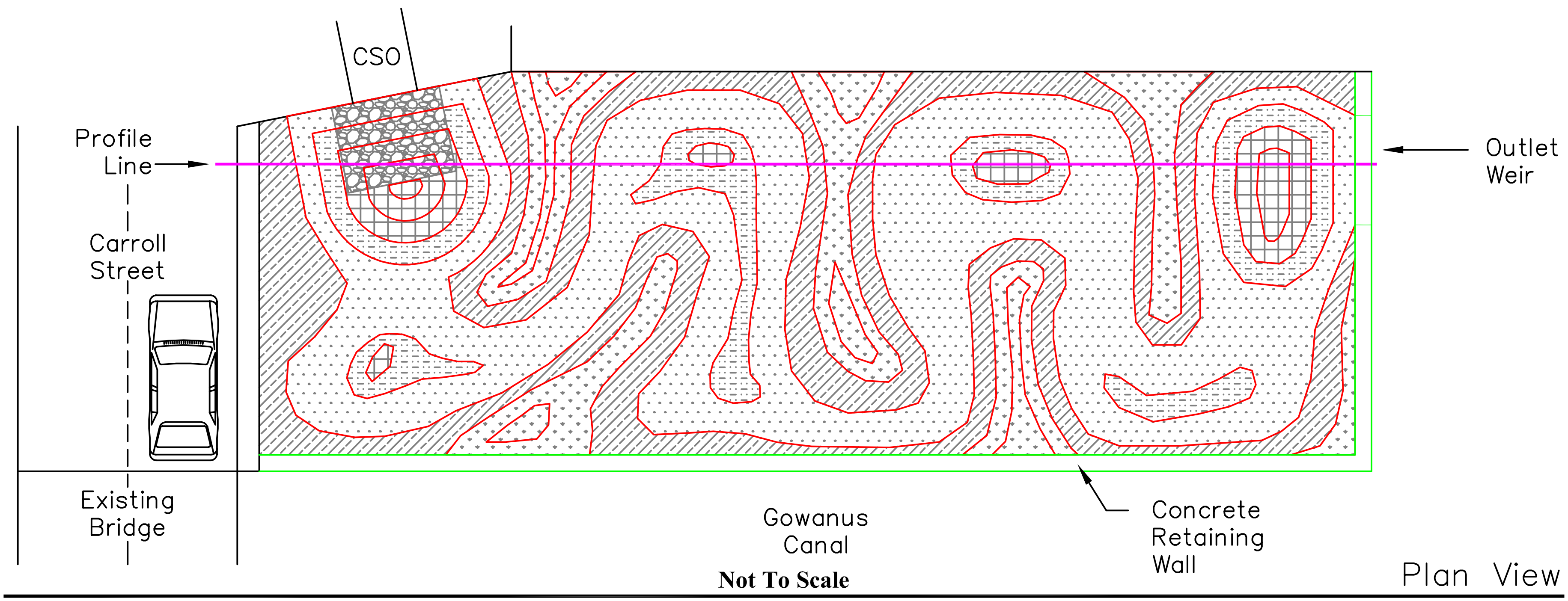
Stormwater wetland systems, as presented in Figure 4, could be utilized to intercept urban runoff and/or CSO discharges. Vegetation within the wetland acts to reduce stormwater runoff velocity and trap sediments and pollutants as the runoff flows through the wetland. Depending on the elevation of the CSO pipe, the stormwater wetland system could be designed to receive predominantly CSO discharge, experiencing tidal exchange only during spring high tide or storm events, or it could be designed to receive intermediate or daily tidal influence. If the stormwater wetland is designed to receive and treat predominantly CSO discharge, the wetland system would be protected from potentially erosive tidal action by a concrete retaining wall that would allow CSO discharge and stormwater to filter through the wetland and drain through an outlet weir into the Canal. Using this wetland design, the retaining wall would be built to just below mean higher high tide level, back-filled with sand filter and topsoil layers to the desired elevation based on the elevation of the CSO outlet pipe. In this configuration, the stormwater wetland would be cut-off from tidal influence, allowing tidal flushing only during spring high tides or storm events. This compartmentalization of the wetland would allow the effective containment and removal of sediment and pollutants, removing them from the source water entering the Gowanus Canal. Sediments and pollutants would be trapped in the stormwater system, allowing processing such as uptake, adsorption, and conversion of contaminants, and minimizing harmful contact with fish and wildlife.

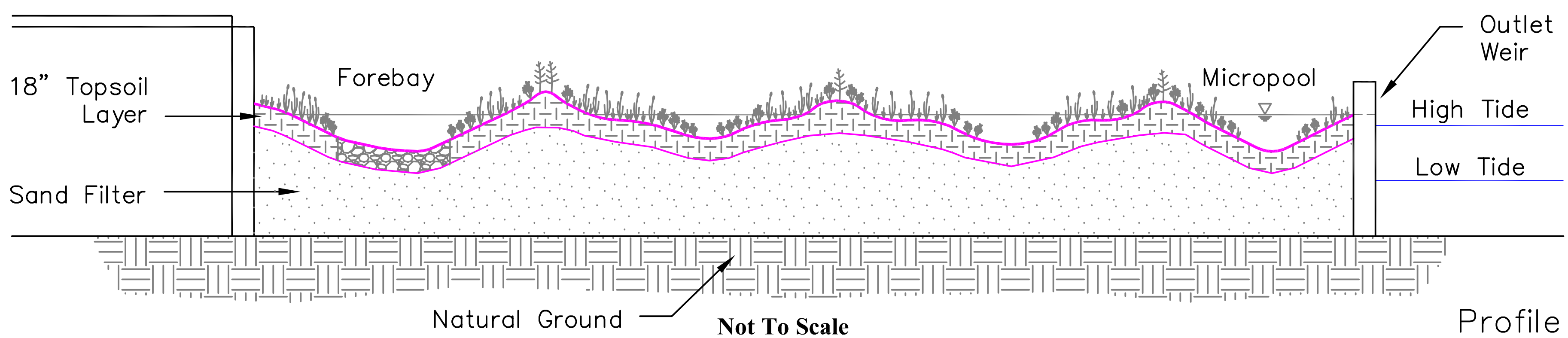
If the elevation of the CSO outlet pipe is at or below mean high tide level, the stormwater wetland can be designed to receive a range of tidal influence from periodic (i.e., during spring high tides) to daily tidal inundation. In this configuration, the retaining wall could be built to mean higher high water, and the system would be separated from the Canal, or to mean lower low water, and the system would function to contain the wetland substrate, minimizing or preventing erosion, but would not prevent regular tidal exchange. In the latter design, the CSO discharge would be treated during low or intermediate tides, but would not be effectively treated during high tide events because the system would be inundated with tidal water.

A retaining wall would be used in the stormwater design to allow the effective containment and treatment of CSO discharge, and to create the maximum area for wetland creation in a limited horizontal space. The retaining wall would eliminate the need for additional horizontal space below mean lower low tide to create stable channel walls.

Pollutant Removal Capabilities

Stormwater wetlands are highly effective at reducing sediment and pollutant levels in stormwater runoff (Hunt and Doll 2000). Stormwater wetlands are capable of removing pollutants by means of sedimentation, filtration, adsorption onto soil particles, microbial activity (e.g., nitrification and denitrification), and plant uptake (Hunt and Doll 2000). Assuming that the amount of water entering a stormwater wetland is appropriate for the design and size, the wetland will have certain removal efficiencies. According to performance monitoring studies conducted by Claytor and Schueler (1996), stormwater wetlands demonstrated removal rates of 80% of suspended sediments, 51–75% of total phosphorous, 26–50% of total nitrogen, 26% or higher for trace





Legend

Plan View

- > 1 foot above designed water Level
- 0 to 1 foot above designed water Level
- 0 to 1 foot below designed water Level
- 1 to 2 feet below designed water Level
- > 2 feet below designed water Level

Profile

- 18" Topsoil Layer
- Sand Filter
- Natural Ground
- Rock Pad
- Vegetation

Figure 4.

Stormwater Wetland Conceptual Design for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

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metals (e.g., copper, lead, zinc), and 26–50% for other soluble nutrients. A study by Hunt (1999) demonstrated a removal rate of 40–45% of the nitrate-nitrogen that enters the stormwater wetland system. According to the NYSDEC Stormwater Design Manual (2001), stormwater wetlands have removal rates of 80% for bacteria (e.g., fecal coliform). Created wetlands may require several years to allow for the development of vegetation, soils, and microbial activity before reaching optimal pollutant removal capabilities.

Design Considerations

In the stormwater wetland design, a sediment forebay is located below the mouth of the CSO pipe to act as a catch basin for stormwater as it enters the wetland. Sediment settles out in the forebay, decreasing sediment accumulation in the wetland and prolonging the life of the wetland system. The wetland topography varies slightly throughout and includes a sediment forebay, micropools, and high and low marsh areas for wetland vegetation to establish. The sediment forebay and sinuous wetland design act to increase retention times and extend the flow path within the wetland system, allowing more time for sedimentation and pollutant removal processes to occur. The lower extent of the wetland is contained by a concrete retaining wall, the height of which depends on the specific design features. Treated water exits the stormwater wetland via a one-way outlet weir, located at the opposite end of the wetland from the CSO pipe. Figure 4 represents a general design of a stormwater wetland; additional modifications can be incorporated depending on site-specific conditions.

Generally, a stormwater wetland system is designed to be a minimum of 3% of the size of the total drainage area in order to adequately accommodate and filter the volume of stormwater runoff received. For the stormwater wetlands in the Gowanus Canal that handle CSO discharge to effectively remove sediment and pollutants, and prevent or minimize contact of fish and wildlife with CSO contaminants, a created wetland should be sized to contain and treat the volume of water released during the first pulse of CSO discharge. This volume may include the first 1-inch of rainfall plus the first triggered release of the CSO. The size of constructed wetland systems within the Gowanus Canal is also dependent on the area available at a site. During periods of high flow, if the CSO discharge volume is higher than the stormwater wetland design specifies, an overflow/bypass pipe could be utilized to divert excess water around the wetland, to prevent scouring out or overwhelming the wetland vegetation. Stormwater wetland systems are designed to promote an environment comparable to naturally occurring wetlands with similar hydrologic characteristics, while providing additional sediment and pollutant removal benefits. The substrate in the stormwater wetland system includes an 18-inch layer of topsoil placed over a sandy substrate. This provides appropriate soil conditions for vegetation establishment, with an underlying porous filtering medium that would function to capture pollutants.

Planting Guidelines

Stormwater wetland systems could be planted with a variety of salt-tolerant herbaceous plants including salt hay grass (*Spartina patens*), salt grass (*Distichlis spicata*), big cordgrass (*Spartina cynosuroides*), common three-square (*Scirpus pungens*), and hardstem bulrush (*Scirpus acutus*). Establishment of a wide variety of native plant species would maximize fish and wildlife habitat and pollutant removal benefits (United States Department of Transportation [USDOT] 2004).

3.3 TERRACED WETLAND

Incorporating terraces, or tiers, into wetland creation design transforms the topography of an existing landscape into a series of flat terraces at varying elevations (Figure 5). This type of terraced wetland system is designed to reduce the velocity of stormwater runoff from upslope areas, provide wetland and wildlife habitat in areas with steeply graded slopes, increase biodiversity and productivity, and remove sediment and pollutants from water entering or in the Canal.

Function

A terraced wetland design could be utilized in areas that are adjacent to impervious areas, such as parking lots or roads. Water that normally would drain directly into the Canal, carrying a variety of contaminants and debris typically associated with paved areas, would filter through the terraced wetlands, providing sediment and pollutant removal benefits prior to entering the water of the Canal. The terraced wetland design could also be modified for treatment of CSO discharge by including a forebay and rock pad at the CSO discharge location, to minimize erosion and allow sediments to settle out.

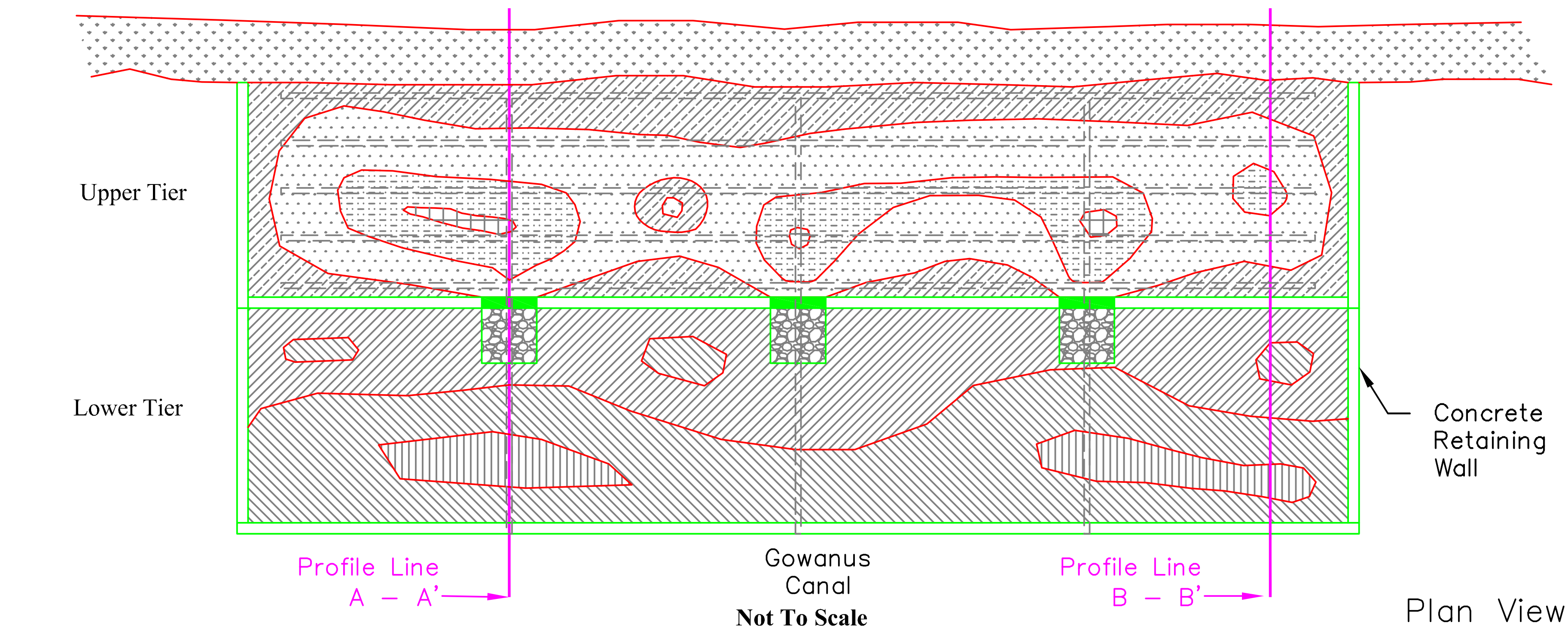
Water enters into this wetland system as stormwater runoff from adjacent upslope areas or as tidal exchange from the Canal. Within the terraced wetland system, the upper tier receives water from stormwater runoff, and may experience a range of tidal flooding. Depending on the elevation of the upper terrace, it may experience tidal flushing only during extreme high tides and storm events, or as frequently as during monthly spring high tides. The lower tier is subjected to tidal flooding during diurnal high tides, and may vary in the amount of stormwater runoff during rain and storm events.

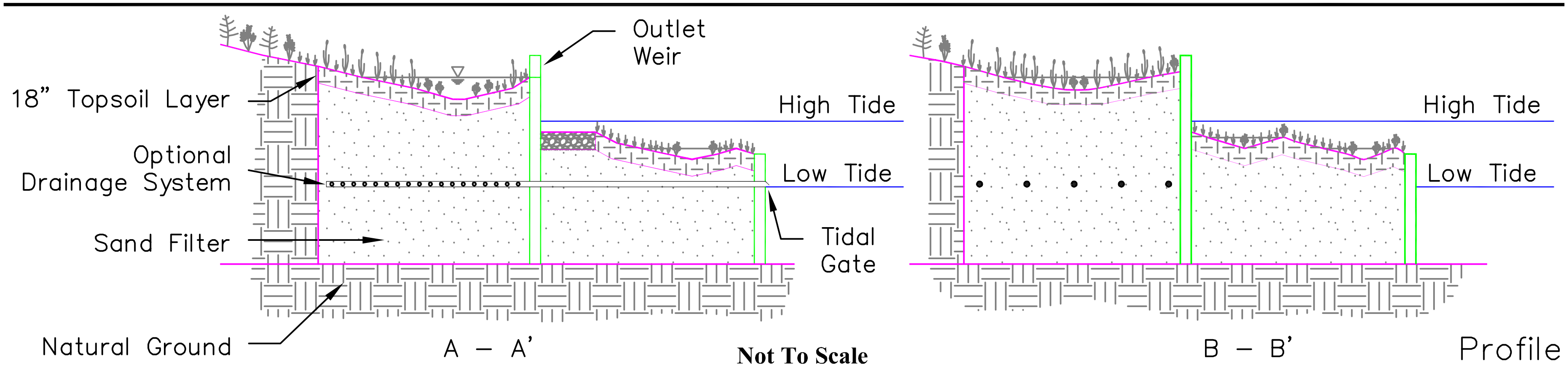
Pollutant Removal Capabilities

Based on wetland structure (i.e., vegetation composition, underlying sandy fill material) and design similarities, pollutant removal capabilities of terraced wetland systems are expected to be similar to those described for stormwater wetlands in Section 3.2.

Design Considerations

In the terraced wetland design, both the upper and lower tiers are surrounded by concrete retaining walls, to contain and treat water and minimize or prevent erosion. This design may be modified to include the transition of habitat in the upper tier into existing upland. The retaining wall for the upper tier rises to just above the mean high tide mark; outlet weirs that allow treated stormwater to drain into the lower terrace. An optional drainage system, in the form of a perforated pipe with a one-way tidal gate, can be utilized to provide additional drainage from the upper tier to the Canal at low tide. With this optional drainage system, treated water that has percolated through the upper tier wetlands drains into the Canal, allowing the water level in the upper tier to drain periodically, creating beneficial soil conditions for a variety of chemical transformations. In addition to stormwater input from the upper tier, the retaining wall of the lower tier is designed to allow water to flood that portion of the wetland during high tide, and drain naturally as the tide recedes. The lower tier includes rock pads located below the outlet weirs from the upper tier to minimize erosion at the point of impact. Figure 5 represents a





Legend

Lower Tier

- 1 to 2 feet below mean high tide
- 2 to 3 feet below mean high tide
- 3 to 4 feet below mean high tide

Profile

- 18" Topsoil Layer
- Sand Filter
- Natural Ground
- Rock Pad
- Drainage Line
- Vegetation

Upper Tier

- > 1 foot above designed water Level
- 0 to 1 foot above designed water Level
- 0 to 1 foot below designed water Level
- 1 to 2 feet below designed water Level
- > 2 feet below designed water Level
- Drainage Line

Figure 5.

Terraced Wetland Conceptual Design for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

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Checked By:	SCW	File#:		Checked:	

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NEAFILE:E:/Projects/CS-330/Terraced Wetland.dwg general design of a terraced wetland; additional modifications are possible depending on site-specific conditions.

As depicted in the Figure 5 profile view, the topography of the wetland system within each tier varies between pool habitats, and high and low marsh areas where wetland vegetation can be established. The tiered design provides increased diversity by having two separate and distinct wetland habitats that occupy less space than a non-tiered system. The substrate within the wetland areas includes an 18-inch layer of topsoil placed over a sandy fill material. This provides appropriate soil conditions for vegetation establishment with an underlying porous filtering medium, which facilitates water movement and functions to capture pollutants.

The size of the terraced wetland system depends on the space available for construction at each site. For terraced wetlands that function to treat CSO discharge, the minimum combined size of the wetlands would need to be large enough to contain and treat the first pulse of discharge from the CSO. As with stormwater wetlands, during periods of high flow, if the CSO discharge volume is higher than the wetland design specifies, an overflow/ bypass pipe could be utilized to divert excess water around the wetland, to prevent scouring out wetland vegetation or overwhelming the system.

Planting Guidelines

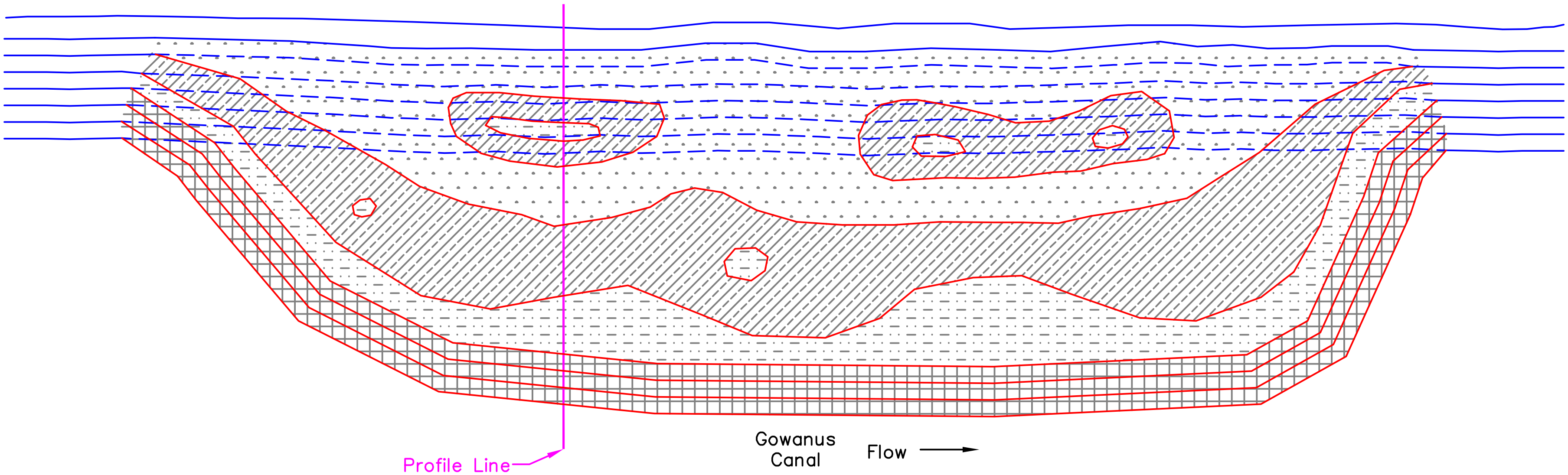
A two-tiered design creates two unique wetland systems, each receiving a mix of stormwater runoff and tidal water. The lower tier of terraced wetland systems could be planted with a mix of native tidal marsh species including smooth cordgrass (*Spartina alterniflora*), seaside arrow grass (*Triglochin maritimum*), creeping bent grass (*Agrostis stolonifera*), *Spartina patens*, and *Distichlis spicata*. The upper tier of terraced wetland systems could be planted with salt-tolerant herbaceous plants including *Spartina patens*, *Distichlis spicata*, sea lavender (*Limonium carolinianum*), *Scirpus pungens*, and prairie cordgrass (*Spartina pectinata*), or salt-tolerant shrubs including groundsel tree (*Baccharis halimifolia*) high-tide bush (*Iva frutescens*), and bayberry (*Myrica pensylvanica*).

3.4 TRANSITIONAL WETLAND

Transitional wetlands can be constructed adjacent to existing upland areas, creating a gently sloping vegetated transitional zone between upland and open water habitats (Figure 6).

Function

Transitional wetlands are designed to flood during regular high tides, and function to provide improvements to fish and wildlife habitat, increase local biodiversity and productivity, and remove sediments and pollutants from water in or entering the Gowanus Canal. Within the Project area, transitional wetlands could be created in areas with little or no existing wetlands, adjacent to upland vegetated or impervious areas.



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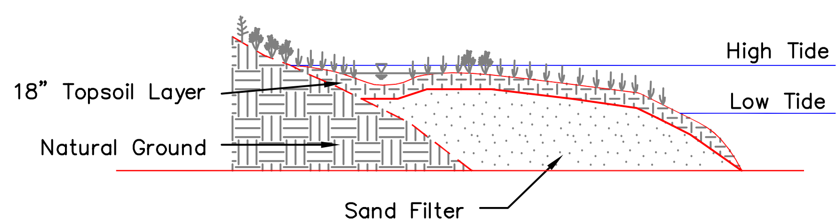
Plan View



Not To Scale

Profile

Legend

Plan View

- Existing Contours
- Proposed Contours
- 0 to 1 foot below mean high tide
- 1 to 2 feet below mean high tide
- 2 to 3 feet below mean high tide
- > 3 feet below mean high tide

Profile

- 18" Topsoil Layer
- Sand Filter
- Natural Ground
- Vegetation

Figure 6.

Transitional Wetland Conceptual Design for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

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NEAFILE:E:/Projects/CS-330/Transitional Wetland.dwg

Pollutant Removal Capabilities

Based on wetland structure (i.e., vegetation composition, underlying sandy fill material) and design similarities, pollutant removal capabilities of transitional wetlands are expected to be similar to those described for stormwater wetlands in Section 3.2.

Design Considerations

The design of transitional wetlands is flexible, and can incorporate topographic variation depending on the area available for construction, the amount of fill material available, the Project goals, and the range of habitats (i.e., frequency and duration of inundation) desired. For example, transitional wetlands can be designed with upland vegetated areas at the upper elevation limit, grading into wetland and open water habitats, or the upper elevation limit can be designed as wetland habitat, transitioning into more emergent vegetation types as the landscape gently slopes into the Canal. Within the transitional wetland, the widths of each contour and the size of micropools can be modified to fit the space available. Figure 6 represents a general design of transitional wetland systems; additional modifications can be incorporated for more accurate site-specific designs.

As depicted in the Figure 6 profile view, the topography transitions from existing upland habitat to high and low marsh areas, sloping gradually into the Canal. Microtopographic changes allow creation of a variety of habitats, including pools, low and high marsh, mudflat, and possibly upland herbaceous or shrub areas. Sand fill material is utilized as an underlying filtering medium that will facilitate water movement and function to capture pollutants. An 18-inch layer of topsoil is placed over the fill material to provide appropriate soil conditions for vegetation establishment.

In general, transitional wetlands can be sized to fit the space available for wetlands creation. However, there must be enough area that side slopes are not steeper than 1:3 to below the mean low tide line. Steeper side slopes are possible below mean low tide, if necessary. Also, the design for transitional wetlands can be modified to include a concrete retaining wall, starting below mean low tide, if space limitations prevent the construction of gently sloping land surface down to the existing substrate, or if excessive wave action is anticipated.

Planting Guidelines

Vegetation in transitional wetlands depends on the habitat conditions specified in the design. The low marsh areas are subjected to diurnal tidal flushing, and could be planted with a mix of native tidal marsh species including *Spartina alterniflora*, *Spartina patens*, and *Distichlis spicata*. Depending on the landscape position and hydrologic conditions, the transition from low marsh to existing grade could be planted with salt-tolerant herbaceous plants including *Spartina patens*, *Distichlis spicata*, *Scirpus pungens*, black grass (*Juncus gerardii*), *Limonium carolinianum*, and salt-tolerant shrubs including *Baccharis halimifolia, Iva frutescens*, and *Myrica pensylvanica*. Establishment of a wide variety of native plant and shrub species would maximize wildlife habitat diversity and contaminant removal capabilities (USDOT 2004).

Transitional wetland sites may face additional environmental stressors resulting from tidal actions and excessive boat traffic in the Canal. These factors may inhibit vegetation establishment, accelerate shoreline erosion, and initiate undercutting of the shoreline in wetlands without a retaining wall. Preventative measures can be taken by identifying high-risk areas and constructing protective retaining walls. It is important to monitor these sites to identify problems and initiate corrective action, as necessary.

3.5 TURNING BASIN WETLAND

Turning basin wetlands are transitional wetlands designed to be constructed wholly within a previously defined space. Turning basin wetlands can be constructed to partially or completely occupy an existing turning basin, depending on the amount of fill/dredged material available and the Project goals.

Function

Turning basin wetlands, as with transitional wetlands, are designed to flood during regular high tides, and function to provide improvements to fish and wildlife habitat, increase local biodiversity and productivity, and remove sediments and pollutants from water in or entering the Gowanus Canal. The habitats desired will determine the flooding frequency and duration (i.e., tidal signal) across the wetland.

Pollutant Removal Capabilities

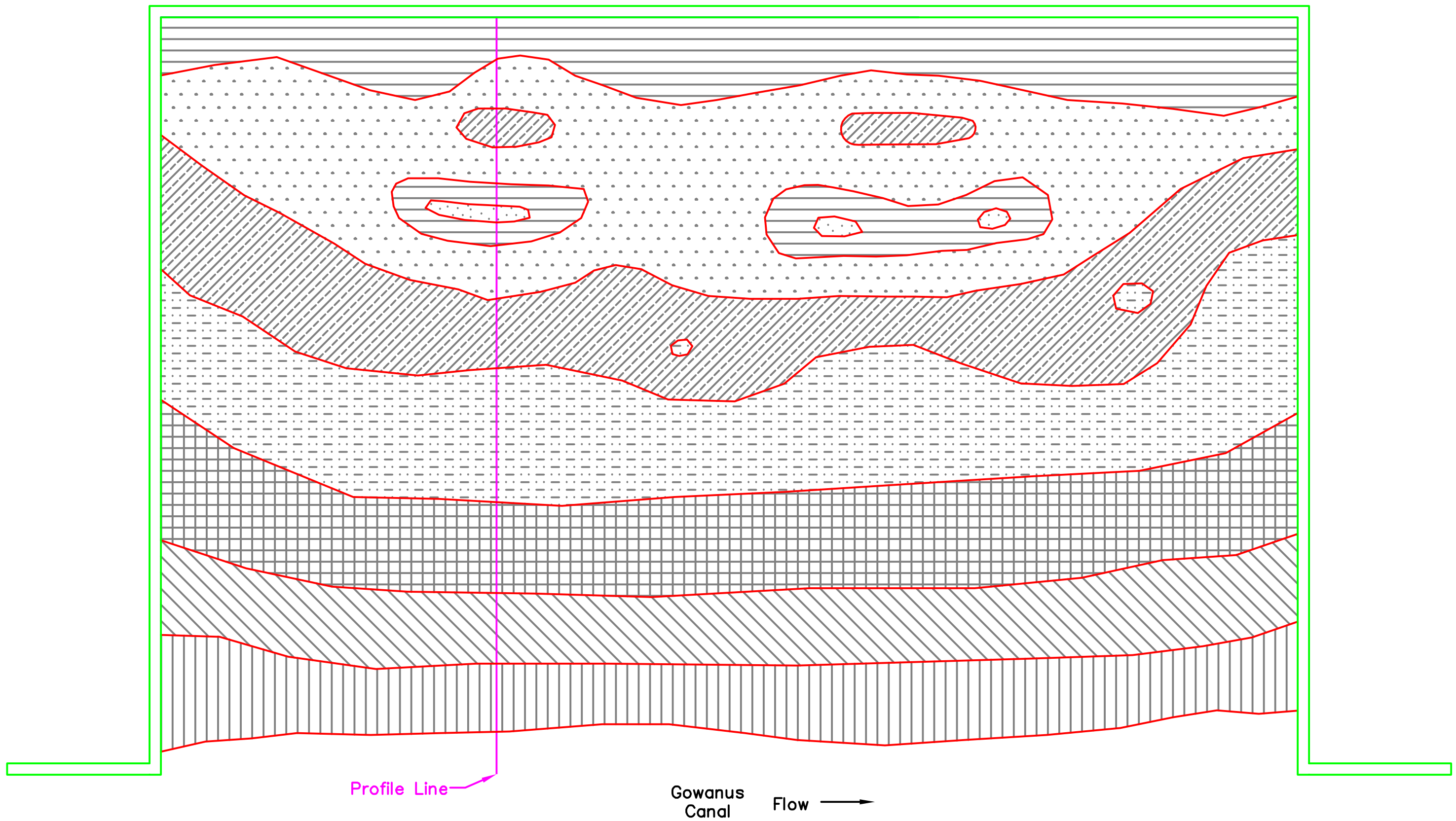
Because turning basin wetlands are transitional wetlands that are designed specifically for construction within a turning basin, pollutant removal capabilities are expected to be similar to those described for transitional wetlands and stormwater wetlands in Section 3.2.

Design Considerations

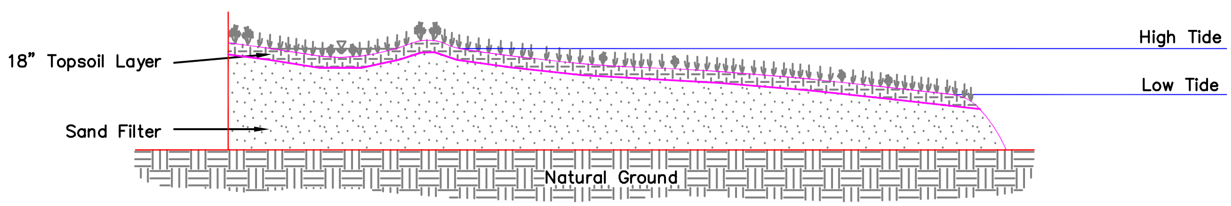
The wide and open layout of turning basins in the Project area provides flexibility in wetland and/or upland creation designs (Figure 7). Depending on the area available, the amount of fill/dredged material available, and the type of habitat creation desired, this design can be modified in various ways to incorporate wetland herbaceous and shrub communities, and wetland to upland transitional communities. The conversion of open water habitats within these turning basins to vegetated wetland and/or upland habitats would increase wildlife habitat, increase biodiversity and productivity, and provide contaminant and sediment removal in the watershed. Figure 7 represents a generalized design for wetland creation within a turning basin; additional modifications can be incorporated depending on site-specific goals and conditions.

Wetland creation designs for turning basins will be sized appropriately based on the space available per site. Within the turning basin wetland, the widths of each contour and the size of micropools can be modified to fit the area available.

An 18-inch layer of topsoil overlies the sandy fill material to provide appropriate conditions for vegetation establishment. As depicted in the Figure 7 profile view, the wetland system transitions from the upper elevation limit into more emergent vegetation types as the landscape gently slopes into the Canal.



Not To Scale — Plan View



Not To Scale — Profile

Legend

Plan View

- 1 to 2 feet above mean high tide
- 0 to 1 foot above mean high tide
- 0 to 1 foot below mean high tide
- 1 to 2 feet below mean high tide
- 2 to 3 foot below mean high tide
- 3 to 4 feet below mean high tide
- 4 to 5 feet below mean high tide
- 5 to 6 feet below mean high tide

Profile

- 18" Topsoil Layer
- Sand Filter
- Natural Ground
- Vegetation

Figure 7.

Turning Basin Wetland Conceptual Design for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

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Planting Guidelines

Based on the wetland design, the type of vegetation and the layout of species in the planting plan will depend on desired topographic variations and hydrologic conditions planned for the site. Low marsh areas subjected to regular tidal fluctuations could be planted with a mix of native tidal marsh species including *Spartina alterniflora*, *Spartina patens*, and *Distichlis spicata*. Depending on the landscape position and hydrologic conditions, the transition from low marsh to existing grade could be planted with salt-tolerant herbaceous plants including *Spartina patens*, *Distichlis spicata*, *Juncus gerardii*, *Limonium carolinianum*, *Scirpus pungens*, and salt-tolerant shrubs including *Baccharis halimifolia, Iva frutescens*, and *Myrica pensylvanica*. Additionally, the wetland system could be designed with wetland herbaceous vegetation in high marsh areas grading into upland vegetated areas at the upper elevation limit.

Additional Considerations

Construction activities utilized for wetland creation within turning basins would be similar to those required for transitional wetland creation sites on gradually sloping landscapes. Due to the considerable amount of fill needed to create emergent wetland sites within turning basins in the Canal, the cost of transporting and placement of fill material may exceed that of transitional wetland creation sites. However, the environmental benefits associated with the wetland habitat created may justify the additional cost.

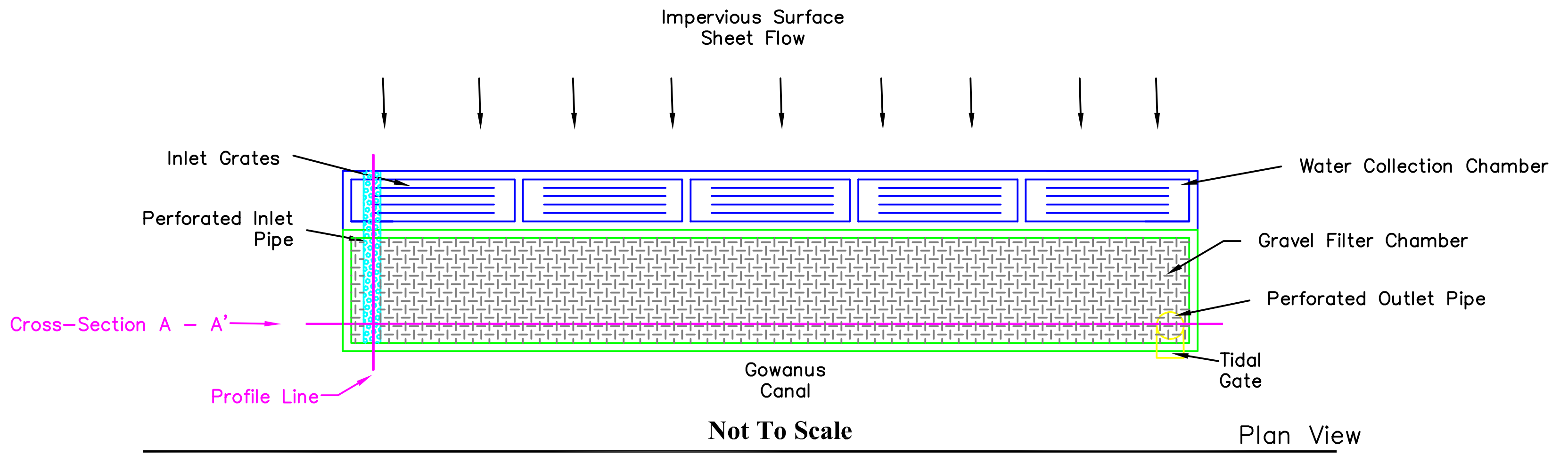
3.6 MODIFIED SUBMERGED GRAVEL FILTER

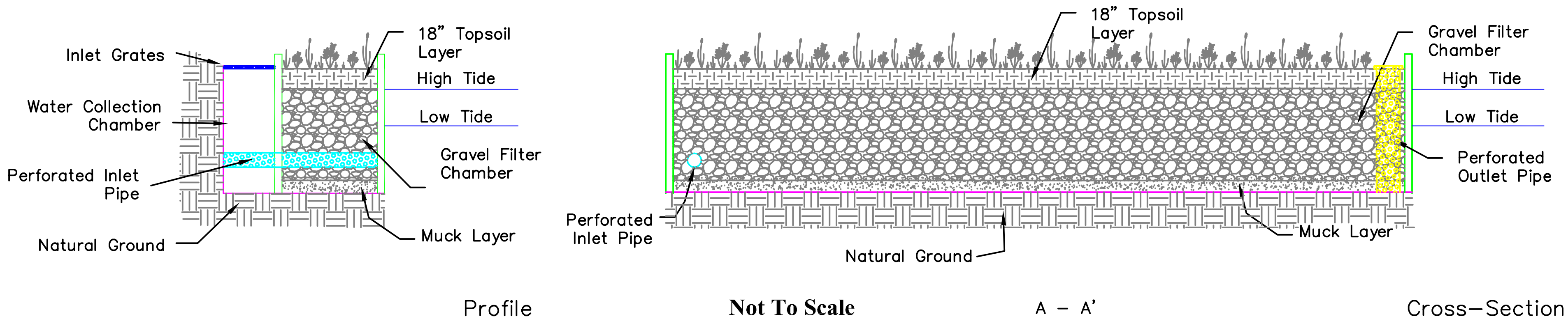
This modified submerged gravel strip, or filter, is designed to contain and treat runoff from adjacent impervious areas, such as roads, parking lots, or other similar types of impervious surfaces. Submerged gravel filters are most suited for use in areas that distribute a significant volume of stormwater runoff.

Function

Submerged gravel filters such as this function to remove sediments and pollutants from water, reduce runoff velocity, and provide some habitat for wildlife. Water is directed from impervious areas through the inlet grates into the water collection chamber, where solids and sediments are allowed to settle out. Water then flows via a perforated inlet pipe into the gravel filter chamber for continued sediment and pollutant removal and treatment. Water levels in this system would fluctuate between the surface of the wetland and the surface of the muck layer, depending on the volume of water at a given time. The water inputs to this system would be predominantly fresh water overland runoff, with tidal inundation occurring only during extreme high tide events.

The submerged gravel filter design could also be modified for treatment of CSO discharge. Instead of collecting water through inlet grates, the CSO pipe would discharge directly into a water collection chamber, and water would funnel through the perforated inlet pipe into the submerged gravel filter. During this flow path, sediments and solids would drop out in the water collection chamber, and additional removal and treatment of sediments and pollutants would occur in the gravel filter chamber prior to discharging into the Canal. Figure 8 represents a general design of a gravel filter; additional modifications can be incorporated depending on site-specific conditions.





Legend

- 18" Topsoil Layer
- Natural Ground
- Gravel Filter
- Muck Layer
- Vegetation
- Perforated Inlet Pipe
- Perforated Outlet Pipe

Modified from Claytor and Schueler 1996.

Figure 8.

Modified Submerged Gravel Filter Conceptual Design for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Drawn By: JCL	Date: 03–24–04	Received:
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NEAFILE:E:/Projects/CS-330/Terraced Wetland.dwg

Pollutant Removal Capabilities

Gravel filters are highly effective at reducing the amount of suspended sediments, total phosphorus, total nitrogen, and nitrate-nitrogen in stormwater runoff (Schueler and Holland 2000). According to performance monitoring studies conducted by Claytor and Schueler (1996), submerged gravel filters demonstrated removal rates of 80% of suspended sediments, 80% of total phosphorus, 65% of total nitrogen, and 75% of nitrate-nitrogen. Few documented studies have analyzed the capacity of submerged gravel filters to remove bacteria. However, a study by Schueler and Holland (2000) demonstrated a removal rate of 78%. Removal of trace metals (e.g. copper, lead, zinc), which often attach to binding sites on suspended particles and filter media (NYSDEC 2001), can be inferred based on the removal rate for suspended solids. The removal rate for trace metals could be up to 80%.

Design Considerations

This modified submerged gravel filter is designed with two primary parallel compartments, the water collection chamber and the gravel filter chamber (Figure 8). This system is designed such that the inlet grates and top of the gravel filter chamber are at or just below the existing grade of adjacent impervious surfaces. The gravel filter chamber is filled with crushed rock or gravel, and supports a wetland vegetation cover crop. The water collection chamber provides pretreatment of stormwater runoff, allowing sediments and solids to settle out. Water is then diverted via a perforated inlet pipe into the gravel filter chamber. The gravel substrate acts to provide initial filtration, as wetland plants rooted in the surface layers take up pollutants through their roots. The bottom of the wetland is sealed with an impermeable liner, which is covered with a layer of muck, preferably extracted from an adjacent wetland to introduce denitrifying bacteria into the system (Schueler and Holland 2000). Treated water exits the wetland system at low tide through a perforated standpipe that outlets via a one-way tidal gate into the Gowanus Canal.

A submerged gravel filter should be 3–5% of the size of the total drainage area (Claytor and Schueler 1996), or sized large enough to handle the first pulse of CSO discharge, to adequately accommodate and filter the volume of stormwater runoff or CSO discharge received. Additionally, the recommended vertical distance is 2–4 feet, including the gravel bed, muck layer, and topsoil. For a CSO-fed system, during periods of high flow, if the CSO discharge volume is higher than the submerged gravel filter design specifies, an overflow/bypass pipe could be utilized to divert excess water around the system, to prevent overwhelming the filter.

As depicted in the Figure 8 profile view, an 18-inch layer of topsoil above the gravel filter chamber provides appropriate soil conditions for wetland vegetation to establish. The gravel filter layer is underlain by a muck layer, which provides additional pollutant removal and nutrient transformation capabilities.

Planting Guidelines

A submerged gravel filter system is designed to have minimal topographic variation, and is planted with a herbaceous cover crop. The modified submerged gravel filter system could be planted with a variety of salt-tolerant herbaceous plants including *Scirpus pungens*, *Spartina alterniflora*, *Agrostis stolonifera*, soft-stem bulrush (*Scirpus validus*), and red fescue (*Festuca rubra*).

Additional Considerations
In addition to construction activities generally described for created wetlands in Section 3.1, construction of submerged gravel filters would also involve placement of an impermeable liner underneath the wetland and gravel bed, transfer and placement of crushed rock or gravel, addition of inlet grates, and construction of the water collection chamber and gravel filter chamber. These additional structural features may result in higher construction costs than systems requiring fewer structural features.

The submerged gravel filter system would require careful attention during the development of plans and specifications to ensure that the volume of water to be treated would be appropriate for the size of the system designed. Water volumes must be sufficient to support the wetland cover crop, but not so much that they overwhelm the capabilities of the submerged gravel filter.

Maintenance and monitoring are particularly important factors in the submerged gravel filter. The water level would need to be monitored quarterly, and after large storms, during the first year of service. If volume and dewatering rates meet expectations, monitoring could be reduced to semiannually. In terms of maintenance, the water collection chamber may fill with sediment, depending on the source and condition of the input water. Once the sediment depth reaches 12 inches, sediment would need to be removed and disposed of at an approved location (Claytor and Schueler 1996).

3.7 COMPARISON OF CONCEPTUAL DESIGNS

The conceptual wetland creation designs can be compared relative to each other based on how each conceptual design addresses the Project goals, the approximate cost of constructing, and the amount of maintenance and monitoring required. The goals of this Project include increasing the value of habitat created for fish, wildlife, and benthic invertebrates, increasing biodiversity and productivity, and removing pollutants from water entering, or in the Canal. A relative comparison of various characteristics of the conceptual designs is provided in Table 2.

In general for the same size area, stormwater wetlands, terraced wetlands, transitional wetlands, and turning basin wetlands will have similar value of habitat created, and similar increase in biodiversity and productivity, which would likely be higher than for the modified submerged gravel filter wetland design. The stormwater wetlands may have slightly lower productivity than the terraced wetlands, transitional wetlands, and turning basin wetlands, however, because of the separation between the system and the diurnal tidal flushing of the Gowanus Canal. The submerged gravel filter is likely to have the lowest value of habitat, diversity, and productivity, because of the homogenous nature of the system. Pollutant removal capabilities would likely be highest in the submerged gravel filter, followed by the compartmentalized version of the stormwater wetland design. The terraced wetlands, transitional wetlands, and turning basin wetlands would likely have slightly lower pollutant removal capabilities because of the decreased retention times for settling of sediments and removal of contaminants.

Table 2. Relative Comparison of Conceptual Wetland Creation Designs for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Conceptual Design	Project Goals			Approximate Cost	Maintenance and Monitoring Required
	Value of Habitat	Increase in Biodiversity and Productivity	Pollutant Removal Capability		
Stormwater Wetland	Moderate	Moderate	Moderate	Moderate	Moderate
Terraced Wetland	Moderate	High	Low	High	Low
Transitional Wetland	Moderate	High	Low	Low	Low
Turning Basin Wetland	Moderate	High	Low	Lowest	Low
Modified Submerged Gravel Filter	Low	Low	High	Highest	High

The relative cost is likely to be highest for the modified submerged gravel filter, due to the complexities and structural nature of the design. Terraced wetlands would be likely to be the next highest cost, followed by stormwater wetlands. The cost for transitional wetlands would depend on whether a retaining wall was constructed. The cost with a retaining wall would be higher, however the benefits in terms of increased area and therefore increased habitat, biodiversity, productivity, and pollutant removal capability may outweigh the increased cost. The turning basin wetland is likely to be the least expensive, given construction in the same size area.

In terms of maintenance, the submerged gravel filter is likely to require the most maintenance, followed by the stormwater wetland. The other systems may require some maintenance, depending on the source water to the sites. A CSO fed system would likely require more maintenance than a tidally fed system because of the extra load of sediments, nutrients, and contaminants contained in CSO water. Monitoring would be necessary at all sites, however the submerged gravel design would require substantial monitoring during the first year after construction to ensure that the system is operating correctly.

4.0 SITE-SPECIFIC WETLAND CREATION DESIGNS

Site-specific wetland creation designs, described below and listed in Table 3, are based on a conceptual level understanding of the conditions in the Gowanus Canal following a site assessment, review of existing site data, and a literature review of potential wetland creation management practices (USACE 2004a).

The conceptual designs presented in this Report are intended to provide benefits to the Gowanus Canal and to achieve Project goals by increasing and improving available fish, wildlife and benthic habitat, increasing local and regional biodiversity and productivity, and removing suspended solids and pollutants/contaminant that are dissolved or transported in source water to the Canal. Additional benefits of the suggested conceptual designs include improved water quality in the Canal, improved recreational opportunities, and increased public education and awareness. These designs were created with general characteristics and optional components so that they may be modified to accommodate a variety of sites based on accessibility, size/space available, landscape position, topography, and elevation.

Several of the wetland creation sites selected for potential action along the Canal pose construction constraints or varied topography that necessitate the need for creative wetland design solutions. In these instances it was necessary to propose various combinations of the designs described in Section 3.0 to accommodate site-specific obstacles to the construction of viable wetlands.

Table 3. Wetland Creation Designs Recommended for Proposed Site Locations for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Site	Stormwater Wetland	Terraced Wetland	Transitional Wetland	Turning Basin Wetland	Submerged Gravel Filter	Adjacent Upland Restoration
1		√	√			
2		√			√	
3				√		
4		√	√		√	
5				√		√
6		√	√			√
7	√	√	√			
8	√	√				√
9		√	√			
10		√	√			√
11	√				√	

4.1 SITE 1 – SOUTH OF HAMILTON AVENUE BRIDGE

Site 1 consists of a substantial strip of usable shoreline, relatively flat throughout and gently sloping towards the Canal, with a substantially degraded channel bank. This site provides opportunities for construction of terraced or transitional wetland creation designs by removing the existing rock, debris, and garbage, and constructing terraced or gently sloping transitional wetland habitat out into the Canal, grading from upland herbaceous into emergent vegetation and mudflat in the Canal. In addition, the bank elevation along the channel bank at Site 1 is more conducive to terraced and transitional wetland designs.

Terraced Wetland

At Site 1, a two-tiered, terraced wetland system (see Section 3.3, Figure 5) could be constructed along a portion, or for the entire length, of the 200-foot long shoreline that is potentially available for wetland creation. Terraced wetland creation would include construction of microtopographic features throughout the wetland system, which would create a variety of habitats, including pools, low and high marsh, mudflat, and possibly upland herbaceous or shrub areas at the upper margin of the constructed area, or on the existing shoreline. This design would significantly increase habitat diversity and productivity compared to the existing landscape.

With the terraced wetland design, the shoreline of Site 1 would transition from existing upland habitat into wetland scrub-shrub or high marsh vegetation within the upper terrace. Vegetation in the upper terrace would include *Spartina patens*, *Distichlis spicata*, *Limonium carolinianum*, *Scirpus pungens*, *Spartina pectinata*, *Juncus gerardii*, *Baccharis halimifolia*, *Iva frutescens*, and *Myrica pensylvanica*. A retaining wall would enclose the upper terrace, preventing erosion of the substrate, but allowing flushing of the high marsh areas during spring and seasonal high tides. Runoff from the upslope areas (i.e., adjacent parking lots) would filter through upland, scrub-shrub, and high marsh areas prior to draining into the lower terrace via outlet weirs.

The lower terrace would contain low marsh and mudflat areas, planted with native salt marsh species such as *Spartina alterniflora*, *Triglochin maritimum*, *Agrostis stolonifera*, *Spartina patens*, and *Distichlis spicata*. The lower terrace would be subjected to tidal flooding during regular high tides. The retaining wall of the lower terrace would be at or below mean low water, and would prevent erosion, while allowing water to flood the low marsh areas during high tide, and drain naturally as the tide recedes. Rock pads would be constructed in the lower terrace, below the outlet weirs that drain the upper terrace, to minimize erosion at the point of impact.

Construction of the terraced system would require the transport and placement of sand and topsoil material to fill in the terraces to the desired elevations. The site would require planting with the desired vegetation, and placement of erosion control matting would be necessary to stabilize the new topsoil and minimize erosion during vegetation establishment.

Transitional Wetland

Within the proposed wetland creation area, a transitional wetland system (see Section 3.4, Figure 6) could be constructed along a portion or for the entire length of the 200-foot long shoreline. Transitional wetland creation along the shoreline of Site 1 would convert the existing degraded, unvegetated channel bank to a gradual sloping vegetated wetland. Vegetation would transition from existing upland habitat at the upper elevation limit, into wetland herbaceous vegetation, such as typical high and low marsh species, and mudflat along the canal. Vegetation planted along the gradient would include salt tolerant herbaceous plants and salt-tolerant shrubs. Topographic variation would provide a variety of habitats, including pools, low and high marsh, mudflat, and possibly upland herbaceous or shrub areas. This design provides additional benefits to the site by providing habitat variety and increasing biodiversity within the wetland area.

Transitional wetland creation at this site would require transport and placement of fill material to construct the gradient out into the Canal. Also, construction of a concrete retaining wall may be necessary if space limitations prevent the construction of a gently sloping land surface down to the existing substrate, or if excessive wave action is anticipated. As was the case with terraced wetlands, erosion control matting would be necessary to reduce erosion while the wetland is revegetating.

4.2 SITE 2 – NORTH OF HAMILTON AVENUE BRIDGE

Site 2 is a deteriorated bulkhead that is devoid of vegetation and is subject to erosion from water and wind. Deterioration of the previous bulkhead at Site 2 has created a steep, cut bank that is adjacent to an impervious parking lot. As a result, the existing topography makes this site a candidate for terraced wetlands and modified submerged gravel filters. In addition, Site 2 is in an easily accessible and visible area and has potential for public relations and educational opportunities.

Terraced Wetland

The terraced wetland (see Section 3.3, Figure 5) proposed for this site would be similar in description to Site 1 (see Section 4.1). However, the terraces would extend up to 30 feet into the Canal and would occupy up to 100 feet of shoreline and may include an additional terrace due to the elevation of the previous bulkhead and existing parking area. In addition, the concrete retaining walls associated with each tier will protect the wetlands and shoreline in this location from the erosive forces that deteriorated the previous bulkhead.

Combined Modified Submerged Gravel Filter/Terraced Wetland

Creation of a modified submerged gravel filter (see Section 3.6, Figure 8) at Site 2 would provide a design that would contain and treat runoff from the adjacent impervious parking area, thereby removing pollutants and sediment from overland flow prior to infiltrating the Canal. Because the wetland is constructed on top of a gravel filter, in a box shaped design, there is little topographic variation and vegetation consists solely of a herbaceous layer. In addition, the inlet grates for the runoff collection chamber would be just below the existing grade of the deteriorated bulkhead and adjacent parking lot. The wetland would be planted with salt tolerant herbaceous plants including *Scirpus pungens*, *Spartina alterniflora*, *Agrostis stolonifera*, *Scirpus validus*, and *Festuca rubra*.

The success or failure of wetlands created by a modified submerged gravel filter design is dependent on the volume of water (hydrology) received from adjacent impervious areas. This is because the modified submerged gravel filter is a one-way design and would not allow tidal influence to provide the water necessary to sustain the hydrology for the wetland. Therefore, the applicability of a submerged gravel filter wetland at this site will only be realized following site-specific calculations of runoff volumes. Additionally, measurements of the drainage area and the vertical distance from the toe of bank and top of bank along the canal will also determine the size and dimensions of a modified submerged gravel filter wetland that could adequately accommodate and filter the volume of stormwater runoff received at this site.

Because the area for potential action at the site is approximately 30 feet wide and would occupy 100 feet of shoreline, it would likely be cost-prohibitive to build a wetland system entirely composed of a modified submerged gravel filter. Furthermore, it is likely that there would not be enough stormwater runoff to sustain the wetland vegetation at that scale. Therefore, a smaller version of a modified submerged gravel filter combined with one or more terraces would be a more cost-effective and efficient approach at reaching the project goals and would allow for stormwater to be adequately filtered, providing hydrology to the modified submerged gravel filter component of the wetland. Additionally, diverse wetland vegetation and wildlife habitat would extend across the entire site with the addition of terraces, which would be provided hydrology through tidal flow.

4.3 SITE 3 – TURNING BASIN ADJACENT TO LOWE'S PROPERTY

Site 3 is a turning basin located adjacent to the new bulkhead associated with the Lowe's property (see Section 2.3) and therefore, is a candidate for either partial or complete conversion of the turning basin into a transitional wetland (see Section 3.5, Figure 7). Additionally, due to its location adjacent to the Lowe's property, Site 3 is in an easily accessible and visible area and has potential for public relations and educational opportunities, including installation of educational signs.

Turning Basin Wetland

Because turning basin wetlands are transitional wetlands, habitat variation at this site could be designed as a function of the frequency and duration of tidal inundation along the gradient as it gently slopes into the canal. Habitat could be modified to transition from upland habitat to high and low marsh wetland and mudflat areas. In addition, topographic variation could be implemented to create micropools within each grade contour, thereby increasing wildlife habitat and diversity.

Planting with salt tolerant wetland vegetation (see Section 3.5) and creating wildlife habitat at this site would complement the efforts on the Lowe's property, offering educational opportunities for the community, people working in the area, and other visitors to the area to learn about the importance of wetlands and associated wildlife.

4.4 SITE 4 – NORTH OF 9TH STREET BRIDGE

Site 4 is a 300-foot-long section of deteriorated bulkhead located north of the 9th Street Bridge along the eastern bank of the Canal. This site provides opportunities for construction of terraced, transitional, or modified submerged gravel filter wetland creation designs. In addition, Site 2 is in an easily accessible and visible area and has potential for public relations and educational opportunities.

Terraced Wetland

The terraced wetland design (see Section 3.3, Figure 5) proposed for this site would be similar in description and vegetative composition to Sites 1 and 2. However, the terraces would only extend 15 feet into the canal and would occupy up to 300 feet of shoreline. A retaining wall would enclose the upper terrace, preventing erosion of the substrate, but allowing flushing of the high marsh areas during spring and seasonal high tides.

Transitional Wetland

The transitional wetland design (see Section 3.4, Figure 6) proposed for this site would be similar in description and vegetative composition to Site 1. However, due to the limited horizontal width of the site, it is likely that the low marsh area would be much smaller than the high marsh portion of the constructed wetland in order to create a gradient that is stable and resistant to erosion. Additionally, a retaining wall would be required to maximize wetland area created and reduce the potential for erosion.

Modified Submerged Gravel Filter Wetland

The modified submerged gravel filter wetland (see Section 3.6, Figure 8) at this site would be constructed in a similar manner as described for Site 2. However, construction of this design would be limited to areas with the highest potential of overland flow due to the prohibitive costs associated with constructing a 300-foot-long modified submerged gravel filter. The remaining areas along the channel bank could then be converted to terraced or transitional wetlands as described above.

The modified submerged gravel filter wetland was chosen as a potential design for this site due to the limited horizontal width of the site and the presence of an adjacent impervious area with the potential for a large volume of runoff. In addition, the channel height at this location appears to be appropriate for construction of the modified submerged gravel filter within the recommended vertical distance of 2–4 feet.

As was the case at Site 2, the applicability of a modified submerged gravel filter wetland at this site will only be realized following site-specific calculations of runoff volumes. Additionally, measurements of the drainage area and the vertical distance from the toe of bank and top of bank along the canal will also determine the size and dimensions of a modified submerged gravel filter wetland that could adequately accommodate and filter the volume of stormwater runoff received at this site.

4.5 SITE 5 – 6TH STREET TURNING BASIN

Site 5 is a large turning basin known as the 6th Street turning basin that contains a degraded pier, an additional pier in unknown condition, and deteriorating bulkheads (see Section 2.3) and therefore, is a candidate for either partial or complete conversion into a turning basin wetland.

Turning Basin Wetland
Turning basin wetland creation at Site 5 would be similar in design, construction, and vegetative composition to Site 3 (see Section 4.3). Restoration of upland areas within the immediate vicinity of the turning basin could be performed in conjunction with wetland creation, thereby enhancing the environmental and aesthetic quality of this site, increasing habitat diversity, and provide wildlife habitat that would offer educational opportunities for the community, people working in the area, and other visitors to the area.

4.6 SITE 6 – UPLAND EARTHEN MOUND NORTH OF 5TH STREET

Site 6 is an upland earthen mound located north of the 5th Street extension. Restoration of the upland area along the interface with newly constructed wetlands at this site would enhance the environmental and aesthetic quality of this site and provide a more diverse and balanced wildlife habitat that would offer educational opportunities for the community, people working in the area, and other visitors to the area.

Terraced/Transitional Wetland
Terraced and transitional wetland creation are the preferred designs at this location due to the site's gentle to steep sloping topography and the absence of adjacent impervious areas or CSO outlets. Wetland creation at this site would require removal of rock, industrial debris, and garbage, installation of sheet piling to isolate the workspace, construction of specific design features (i.e., retaining wall, bulkhead) and placement of fill material to build out the site into the Canal.

The terraced and transitional wetland proposed for this site would be similar in description and vegetative composition to Site 1 (see Section 4.1). A combination of terraced and transitional wetlands may be more appropriate at this site due to the wide-ranging topography of steep to gently sloping portions of channel bank along the Canal. A terraced wetland could be constructed in areas with steeper banks and would allow its retaining walls to provide a level of protection against wave action and erosion. Transitional wetlands would tie-in to the existing gently sloping uplands and would extend from high marsh to low marsh and mudflat out into the Canal.

4.7 SITE 7 – NYCDEP CSO NORTH OF 5TH STREET

Site 7 is a degraded area located between industrial facilities and the Canal that contains a NYCDEP regulated CSO. The presence of a deteriorated bulkhead, industrial debris, and a CSO at this site provides opportunities for construction of stormwater, terraced, or transitional wetland creation designs that could be used separately or in conjunction with each other.

Stormwater Wetland
Creation of a stormwater wetland (see Section 3.2, Figure 4) at Site 7 would provide a design that would contain and treat overland runoff and stormwater discharged from the CSO located on site, thereby removing pollutants and sediment from stormwater prior to infiltrating the Canal.

Construction of a sediment forebay would reduce runoff velocity and reduce scour and erosion of the created wetland. The wetland would contain topographic variation such as micropools, and high and low marsh areas planted with salt tolerant wetland species, and would include a sinuous flow path. In addition, the flow path of the sinuous stormwater wetland design could be modified, depending on site-specific conditions (i.e., location of the CSO), to flow along the 50-foot-long channel bank or to split and flow in two directions, entering the Canal in multiple locations.

Stormwater wetlands must be sized appropriately to contain and treat the volume of water released during the first pulse of CSO discharge, to adequately contain and filter the volume of stormwater runoff received. Therefore, the applicability of a stormwater wetland at this site will only be realized by comparing site-specific calculations of runoff and CSO discharge volumes to the measurements of the space available to create a stormwater wetland that would adequately accommodate and filter the volume of water received at this site. In addition, an overflow pipe could be utilized to divert excess water and attenuate for periods of high flow when discharge rates are higher than design specifications.

Terraced and Transitional Wetlands

The terraced and transitional wetland design proposed for this site would be similar in description and vegetative composition to Site 1 (see Section 4.1). Both wetland types could be used as stand alone features or could be combined with the proposed stormwater wetland to provide an additional level of vegetative and habitat diversity that would include salt tolerant herbaceous and shrubby plants along a gradient that would include mud flat, low marsh, high marsh, and the upland interface.

4.8 SITE 8 – NORTH OF 3RD STREET BRIDGE

Potential wetland creation at Site 8 includes stormwater and terraced designs. Removal of the existing bulkhead is not recommended due to the positioning of the CSO discharge pipe in the middle of the bulkhead and the substantial cost associated with removal and relocation of the CSO discharge pipe to accommodate the newly created wetland. Due to its location next to the 3rd Street Bridge, Site 8 is in a highly visible area and has potential for public relations and educational opportunities.

Combined Stormwater/Terraced Wetland

Both stormwater and terrace wetland designs (see Sections 3.2 and 3.3) would be appropriate as stand alone structures at this location. However, because the CSO discharge pipe is located in the middle of the bulkhead, a combination of the wetland creation designs recommended may be utilized to provide maximum benefits to this site. For instance, the sediment forebay and sinuous flow components of stormwater wetland design could be coupled with a terraced design that would extend into the canal. This approach would be particularly useful in reducing runoff velocity attributable to the steep grade present at this site and the distance between the outfall and the surface of the Canal. By using the two designs in conjunction with each other, hydrology would be provided in the upper terraces by overland flow and stormwater/CSO discharge, and within the lower terrace by tidal inundation. This combined approach would also allow for an increase in vegetative diversity and habitat. In addition, enhancement to the upland section of this site would provide a cleaner, aesthetically pleasing area, with improved habitat for wildlife.

4.9 Site 9 – Street End Parks

Site 9 comprises the five street-end areas located on DeGraw Street, 1st Street, 2nd Street, Bond Street, and 5th Street. Several restoration opportunities exist at this site, including enhancement of the existing site features, improvement of the bulkhead, and wetland creation. Improving the site and installing informational signs in these parks would provide a cleaner, aesthetically pleasing area and would foster educational opportunities for the community to learn the importance of wetland habitat and associated wildlife.

The dimensions of the wetland creation site, located at each street end park, are horizontally limited (see Section 2.9) because of the need to maintain normal use of the Canal. Stormwater and modified submerged gravel filter wetlands are not likely to be supported in these locations due to the smaller surface area and smaller runoff quantities associated with each site. The design for this site would include enhancement of a 20-foot-wide section of upland that would grade into terraced or transitional wetlands.

Terraced/Transitional Wetlands

Terraced and transitional wetlands (see Sections 3.3 and 3.4) would be appropriate designs for each of the street end parks. Restored and revegetated upland areas adjacent to the canal would filter sediment from stormwater prior to entering each wetland system. Additionally, terraced and transitional wetlands in these locations would create a more natural appearance and would blend in with and accommodate passage to the existing small boat access points located at each site.

4.10 Site 10 – 2nd Street Community Garden

Site 10, the 2nd Street Community Garden, is an ideal candidate for terraced or transitional wetland creation due to the degraded condition of the bulkhead and the gently sloping topography of the site. Enhancement to this site would improve the existing conditions by providing a cleaner, aesthetically pleasing area, with improved habitat for wildlife. Specialized designs such as the stormwater wetland and the modified submerged gravel filter wetland would be unnecessary at this location due to the existing expanse of well vegetated upland area. Sediment transport via overland flow into the canal is not likely due to the existing herbaceous layer on site. Also, due to its location between the 1st and 2nd street end parks, Site 10 is a prime location for upland enhancement and wetland creation, in conjunction with activities at the adjacent street end parks. This site is easily accessibly and highly visible, and has potential for public relations and educational opportunities.

Terraced/Transitional Wetland

Construction of the terraced or transitional wetland designs at this location is similarly described in Section 4.1 and is not expected to impair the normal use of the Canal. Terraced and/or transitional wetlands at this site would function to provide substantial benefits to wetland and wildlife habitat due to the large area available and the gently sloping character of the surrounding landscape. A transitional wetland would be less expensive than a terraced wetland due to the existing topography and the smaller amount of retaining wall that would be required.

4.11 SITE 11 – CARROLL STREET CSO

Site 11, is located on the east side of the Canal and contains a CSO regulated by the NYCDEP. Because the CSO is located within the intact bulkhead on the site and is partially submerged during high tide, wetland creation at this site may require reconstruction of the bulkhead and relocation of the CSO outlet. Terraced and transitional wetlands are not recommended at this site because vertical space limitations would not allow construction of these wetlands to be interfaced with the CSO without impeding the flow of the CSO. In addition, the runoff discharged by the CSO would flow directly into the Canal at high tide, without significant sediment and pollutant removal. A modified submerged gravel filter or stormwater wetland design would be more appropriate for this site. Additionally, Site 11 is easily accessible and highly visible, and has potential for public relations and educational opportunities.

Modified Submerged Gravel Filter Wetland

The creation of a modified submerged gravel filter wetland at this location would also require reconstruction of the existing bulkhead and relocation of the CSO. The construction of this type of wetland, as described previously in Section 4.2, would be cost-prohibitive unless a smaller version was constructed and combined with a terraced or transitional wetland design to optimize the wetland creation area within the dimensions of the site. However, surveys of water volume, velocity, and frequency would need to be conducted at this site to determine whether a smaller design would be able to contain the amount of stormwater discharged at this CSO, or if the modified submerged gravel filter design would be overwhelmed by the CSO output. If the water data indicate that the CSO volume, velocity, or frequency is not appropriate for the system design, a bypass/overflow could be added into the design.

Stormwater Wetland

Stormwater wetland creation design (see Section 3.2, Figure 4) would be appropriate for Site 11, because it is functional and adaptable to a situation where high tide partially submerges the existing outfall. Creation of a stormwater wetland at Site 11 would likely still require renovation and relocation of the existing bulkhead and CSO discharge pipe, respectively. A retaining wall with outlet weirs could then be built around the site to an elevation above normal high tide. This would allow a design that would contain and treat stormwater discharged from the CSO, thereby removing pollutants and sediment from stormwater prior to entering the Canal, and would reduce the potential for the CSO to directly discharge to the Canal when storm events coincide with high tide. Construction of a sediment forebay would reduce runoff velocity and reduce scour and erosion of the created wetland. The wetland would contain topographic variation such as micropools, and high and low marsh areas planted with salt tolerant wetland species, and would include a sinuous flow path.

As stated previously, stormwater wetlands must be sized to contain and treat the volume of water released during the first pulse of CSO discharge, to adequately accommodate and filter the volume of stormwater runoff received. Therefore, the applicability of a stormwater wetland at this site will only be realized by comparing site-specific calculations of runoff and CSO discharge volumes to the measurements of the space available to create a stormwater wetland that would adequately accommodate and filter the volume of water received at this site. In addition, an overflow pipe could be utilized to divert excess water and attenuate for periods of high flow when discharge rates are higher than design specifications.

5.0 RECOMMENDATIONS & CONCLUSIONS

The site-specific wetland creation designs presented in this Report are intended to provide benefits to the Gowanus Canal and to achieve Project goals by increasing available habitat, increasing biodiversity and productivity, and removing sediments and pollutants from source water in the Gowanus Canal. Where appropriate, multiple wetland creation designs are described for each potential wetland creation site, for further consideration and development in later planning and design phases of this Project.

As part of the Project, the USACE plans to work with local community groups to prepare educational signage to inform the public about the special features and important ecological role the created wetlands play in the Gowanus Canal. This could include information about the role of wetlands in terms of habitat, biodiversity, productivity, and pollutant removal, and the importance of water resources. The USACE also plans to involve local community groups in the development of public greenways and nature trails around the Canal, in addition to other educational materials, informational talks, and walking tours of the area.

Although wetland creation is feasible within the Gowanus Canal, additional studies are necessary to determine topographic and hydrologic conditions of the anticipated wetland creation sites in order to proceed with more detailed, site-specific wetland designs. It is important to determine the volume, velocity, and frequency of water inputs, whether via tidal inundation, stormwater runoff overland flow, or CSO discharge, so that each system is designed appropriately. It may be necessary to bypass some of the flow if the volume is too high, slow the flow if the velocity is too fast, and adjust the elevation/water inputs depending on the frequency of inputs. Additional information may also be necessary regarding the specific contaminants and concentrations in input water, the length-width-height specifications for each site, the fill volumes, and the site-specific bathymetry.

Pervious pavements were not explored in this Report, however the design and use of pervious pavements should be explored further for use in the upland areas, particularly as an option in the street end parks (Site 9). Pervious pavement is best used in low traffic areas. It can sustain the weight of cars, while retaining soil for grass or gravel. By design, pervious pavement allows water to filter through to the ground, reducing stormwater runoff, supplying water to vegetation, and recharging groundwater resources. Pervious pavement also reduces the amount of heat radiated compared to regular pavements or concrete (City of Chicago 2002). Pervious pavement could be used in the street end parks to reduce the amount of stormwater runoff going into the Canal, and recharge the groundwater supply. Educational signage could also be erected to inform the public about the benefits of pervious pavement.

It is also important to stress that in the early stages of development, frequent monitoring and maintenance of constructed wetland systems are critical until wetland vegetation has established (USDOT 2004). Monitoring and maintenance requirements are described in Section 3.1. Wetland creation sites proposed along the Canal may face environmental stressors, including invasion by aggressive, exotic species such as *Phragmites australis*, which could potentially influence wetland creation success. However, such environmental factors may be identified through routine wetland inspection and post-construction monitoring, and maintenance activities can be initiated in response. Monitoring is particularly important during the establishment of vegetation, so that preventative and proactive measures can be taken to ensure the success of the created wetland. At a minimum, monitoring should include a site assessment, and vegetation and benthic surveys. It is also recommended that pollutant removal performance be evaluated periodically for systems associated with CSOs to identify any change in the effectiveness of the system. This monitoring is done by comparing inflow and outflow volumes and contaminant levels during storm events. Maintenance frequency and effort is dependant on the site-specific influences and characteristics. Maintenance may be necessary for the life of the Project, depending on the rate of sediment and pollutant accumulation and the ability of the system to self-regulate or self-scour, to ensure that the wetland system is successful at achieving the Project goals. Routine inspections and maintenance activities are recommended to prolong the life of wetland creation sites for 20 years or longer.

Constructed wetlands may require several years to become established before performance and productivity reaches optimal levels (USEPA 2004). However, when designed, constructed, and maintained properly, created wetlands and other stormwater management practices will function effectively to provide habitat, increase diversity and productivity, remove sediment and pollutants, and provide educational opportunities to the public.

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APPENDIX A

LITERATURE SEARCH
for the
Wetland Creation General Investigation Report,
Gowanus Canal and Bay Ecosystem Restoration Project,
Brooklyn, New York

GOWANUS CANAL AND BAY ECOSYSTEM RESTORATION PROJECT
BROOKLYN, KINGS COUNTY, NEW YORK

LITERATURE SEARCH
FOR THE
WETLAND CREATION GENERAL INVESTIGATION REPORT

July 2004

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1.0 INTRODUCTION

This Literature Search was conducted by the United States Army Corps of Engineers (USACE), New York District (District), as part of the Wetland Creation General Investigation Report (Report) for the Gowanus Canal and Bay Ecosystem Restoration Project (Project), in Brooklyn, New York (Figure 1). This Project was authorized by the United States House of Representatives Committee on Transportation and Infrastructure Resolution, dated 15 April 1999 (Docket Number 2596), to determine the feasibility of environmental restoration and protection relating to water resources and sediment quality within the New York Port District, including but not limited to creation, enhancement, and restoration of aquatic, wetland, and adjacent upland habitats. The Port District is centered on the New York-New Jersey Harbor, and is located within the Hudson-Raritan Estuary.

The USACE entered into a Feasibility Cost Sharing Agreement on 8 January 2002 with the New York City Department of Environmental Protection (NYCDEP), the non-Federal sponsor for the Project. The Feasibility Phase began 1 February 2002.

1.1 PROJECT DESCRIPTION

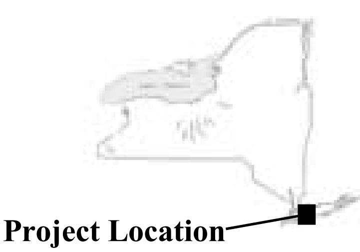
The Project area includes the Gowanus Canal, Channel, Bay, and immediate surrounding upland areas (Figure 1). The Gowanus Bay extends from the Bay Ridge Channel in Upper Bay, New York Harbor, to the beginning of the Gowanus Creek Channel. The Gowanus Creek Channel is a Federally maintained waterway that extends from the Gowanus Bay, 0.8 miles northeast, to the Hamilton Avenue Bridge. The Gowanus Canal is not a Federally maintained waterway, and extends from the Hamilton Avenue Bridge, north approximately 1 mile to its terminus at the mouth of the Flushing Tunnel, located south of Butler Street. The Gowanus Canal and Channel are located in a highly developed section of Brooklyn. The focus area for the Report is the Gowanus Canal proper, and areas immediately surrounding the Canal to the nearest hardened shoreline (Figure 2).

The Gowanus Canal was constructed in 1881 to accommodate industrial users and commercial shippers to the Brooklyn waterfront. As a result, the canal has been subject to over a century of heavy industrial use and is now characterized by poor water quality, contaminated sediments, deteriorating bulkheads, a poor benthic community structure, extensive filling, hardened shorelines, and unpleasant odors. Despite dramatic improvements in water quality over the last several decades, there continue to be episodic discharges of untreated sewage associated with periods of heavy precipitation beyond the capacity of the combined storm and sanitary sewer outfalls (CSOs). CSOs convey human pathogens, a variety of industrial wastes, and floatable materials into the waterways. Non-point source pollution from lawns, roads, broken septic tanks, construction sites, and other disturbed areas provide additional sources of contaminants to the Canal, including sediment, fertilizers, pesticides, bacteria, viruses, salt, oils, grease, and heavy metals (NYCDEP 2003).

1.2 Goals

The goal of this Project is ecosystem restoration for the purpose of providing habitat for fish, wildlife, and benthic invertebrates, increasing biodiversity and productivity in the Canal, and removing suspended solids and pollutants/contaminants that are dissolved or transported in water prior to their deposition or infiltration into the Gowanus Canal. The goal of the Report is to present a feasibility level review of the potential for creating wetlands in the Gowanus Canal. Created wetlands are one type of stormwater management practice, and will hereafter be included under a more general description in Section 2.0 as Management Practices. These management practices, in addition to providing habitat and increasing biodiversity and productivity, could be used for containing, maintaining, and treating sources of contamination and sedimentation to the Canal prior to entering the waterway. These constructed wetland systems would be located either at the upper limits of the tidal range, to intercept urban runoff and CSO discharges, or completely within the Canal, handling daily tidal exchange.

This Literature Search focuses on wetland creation opportunities, and other stormwater management practices that could be used in an urbanized and heavily polluted waterway. The following sections include a description of the management practices and vegetation identified during this Literature Search. The Conceptual Designs will explore in more detail those management practices or wetland creation opportunities identified that could potentially be used in the focus area for the Report. The Report will link potential management practices or wetland creation opportunities with the specific wetland creation sites identified.



Source: NYSDEC, 1994-1999.

500 0 500 1000 Meters

1500 0 1500 3000 Feet

Figure 1. Project Area for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Prepared By: **United States Army Corps of Engineers, New York District**

Date: 05/04

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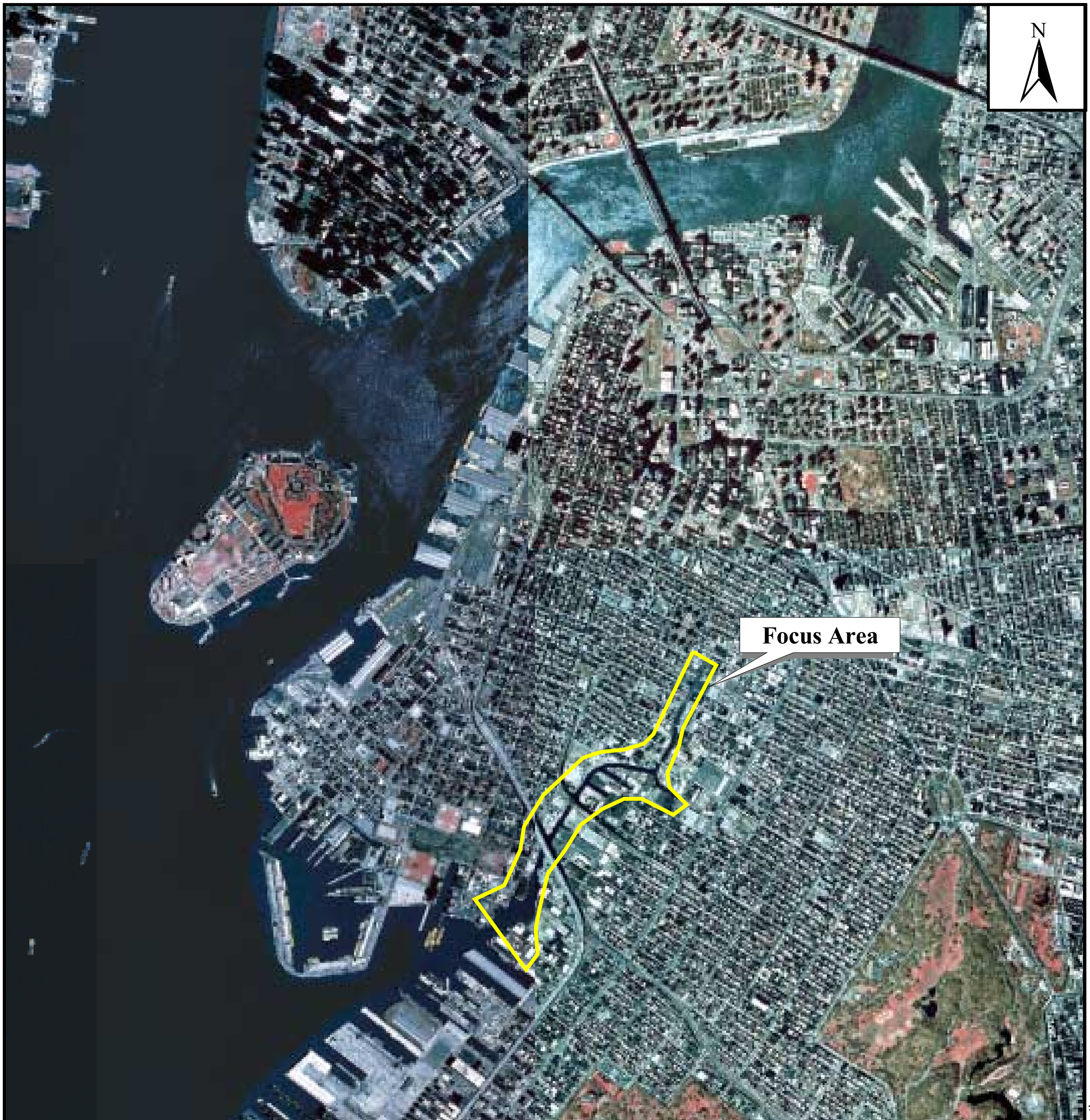

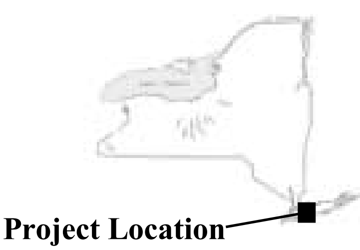

Source: NYSDEC, 1994-1999.

500 0 500 1000 Meters

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Figure 2. Focus Area for the Wetland Creation General Investigation Report for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Prepared By: **United States Army Corps of Engineers, New York District**

Date: 05/04

z:/projects/cs-300do-33/maps/finalreport/sitelocation.apr

2.0 MANAGEMENT PRACTICES

Wetland creation is one of a variety of management practices, techniques, and systems available that are designed to remove suspended solids and pollutants/contaminants that are dissolved or transported in water prior to their deposition or infiltration into the waters down gradient (i.e., Gowanus Canal), while also providing habitat for fish, wildlife, and benthic invertebrates, and increasing local biodiversity and productivity. The following sections briefly describe the management practices identified. In addition, Table 1 provides more detailed information on each management practice, including the size of the area required for treatment, minimum vertical distance required, approximate construction costs, maintenance requirements, advantages and disadvantages, and applicable situations for use of each management practice. Table 2 links each management practice with pollutant removal capabilities, and Table 3 summarizes the articles identified during this Literature Search.

2.1 STORMWATER WETLANDS

Stormwater wetlands are shallow, constructed wetlands designed to capture stormwater runoff and allow it to infiltrate through vegetation and soils. Vegetation within the wetland acts to reduce stormwater runoff velocity and trap sediments and pollutants as the runoff flows through the wetland. Stormwater wetlands also provide habitat for wildlife and add an aesthetically pleasing element to public places. Types of stormwater wetlands include shallow wetlands, extended detention wetlands, pond/wetland system, and pocket wetlands. Determining which type of stormwater wetland would best fit at a particular site is primarily based on site topography, size of site, underlying substrate, depth to water table, and availability of water to feed the wetland. More specific details on stormwater wetlands are presented in Table 1.

Stormwater wetlands are one of the most effective management practices at reducing pollutant levels in stormwater runoff (Hunt and Doll 2000). Stormwater wetlands are capable of removing pollutants by means of sedimentation, filtration, adsorption onto soil particles, microbial activity (i.e., nitrification and denitrification), and plant uptake (Hunt and Doll 2000). These pollutant removal mechanisms effectively reduce levels of suspended sediments, phosphorous, nitrogen, nitrate-nitrogen (N-N), trace metals (zinc, lead, and copper), and bacteria. Pollutant removal capabilities for stormwater wetlands are presented in Table 2.

Thirteen documents were identified that provide information regarding stormwater wetlands as a method of stormwater management. The documents provide general information on creating stormwater wetlands and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.2 STORMWATER PONDS

A stormwater pond is a land depression created for the detention or retention of stormwater runoff, which is maintained as a permanent pool of water to enhance pollutant removal. A vegetative buffer surrounding the pond helps remove pollutants and provides habitat for wildlife. There are several types of stormwater ponds, including micropool extended detention ponds, wet ponds, wet extended detention ponds, dry extended detention ponds, a multiple pond system, and pocket ponds. There are few limitations for the location of stormwater ponds, however the site must be large enough to accommodate heavy volumes of stormwater runoff and contain a permanent pool of water. More specific details on stormwater ponds are presented in Table 1.

Stormwater ponds are considered moderately to highly capable of sediment and pollutant removal when compared with other management practices (Osmond et. al. 1995). Ponds are most effective at reducing suspended sediments and soluble nutrients. Although highly effective at removing lead, stormwater ponds are not as effective at removing other trace metals, such as zinc or copper. Studies have shown variable rates of bacterial uptake (Claytor and Schueler 1996). Pollutant removal capabilities for stormwater ponds are presented in Table 2.

Seven documents were identified that provide information regarding stormwater ponds as a method of stormwater management. The documents provide general information on creating stormwater ponds and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.3 INFILTRATION PRACTICES

There are several types of infiltration practices, including basins, trenches, and wells, that are designed to capture and temporarily store stormwater before allowing it to infiltrate into the soil. Infiltration practices require permeable soils that allow water to leave the storage basin and penetrate the underlying soil (Osmond et. al. 1995). Infiltration devices can be small enough to be implemented in or adjacent to urban areas. One advantage of infiltration devices is that they provide significant groundwater recharge, providing a medium through which surface water can percolate through to ground water (Osmond et. al. 1995). More specific details on infiltration practices are presented in Table 1.

When compared with other management practices, infiltration devices can be highly effective at removing suspended sediments and pollutants. Suspended sediments settle out of stormwater runoff, filling in pore spaces, and pollutants adhere to the sediments, effectively removing them from the water column. However, over time, infiltration devices can become clogged with sediment, making them less effective. Maintenance may be required to restore sediment and pollutant removal efficiencies. Infiltration devices are highly effective at reducing soluble nutrients phosphorus and nitrogen, and trace metals, such as lead, zinc, or copper. Pollutant removal capabilities for infiltration practices are presented in Table 2.

Five documents were identified that provide information regarding infiltration practices as a method of stormwater management. The documents provide general information on implementing infiltration practices and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.4 POROUS PAVEMENT

There are two types of porous pavement: modular block porous pavement and porous asphalt. Both are composed of a permeable pavement surface with an underlying stone reservoir designed to remove pollutants, minimize surface runoff, and to reduce imperviousness. This type of management practice is often considered an infiltration practice due to its ability to store surface runoff before it infiltrates into the subsoil. However, it is also considered an alternative to conventional pavement and is recommended for low traffic parking lots or roadways because of its ability to reduce imperviousness (Osmond et. al. 1995). More specific details on porous pavement are presented in Table 1.

Porous pavement acts as a conveyance layer to the underlying aggregate chamber, which functions as an infiltration device. Similar to other infiltration devices, pollutant removal is achieved through adsorption by soil, filtration, and microbial decomposition. Porous pavement systems have been shown to have high removal rates for suspended sediments, although this often leads to clogging of the subsoil and subsequent failure of the infiltration device. Furthermore, the systems have been shown to have high removal rates of nutrients, organic matter, and trace metals that are largely due to a transfer to groundwater (Osmond et. al. 1995). Pollutant removal capabilities for porous pavement are presented in Table 2.

Three documents were identified that provide information regarding porous pavement as a method of stormwater management. The documents provide general information on limiting factors for using porous pavement and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.5 FILTERING PRACTICES

Filtering practices are designed to capture and temporarily store stormwater and then pass it through a filter bed of sand, organic matter, or another acceptable treatment media (NYSDEC 2001). There are several types of filtering practices, including surface sand filters, underground sand filters, perimeter sand filters, organic filters, and pocket sand filters. Determining which type of filtering practice would best fit at a particular site is primarily based on site topography, size of site, and the underlying substrate. More specific details on filtering practices are presented in Table 1.

Filtering practices are highly effective at reducing the amount of suspended sediments from stormwater runoff (Claytor and Schueler 1996). However, most filtering devices are only moderately effective at reducing soluble nutrients, trace metals, and bacteria. Pollutant removal capabilities for filtering practices are presented in Table 2.

Four documents were identified that provide information regarding filtering practices as methods of stormwater management. The documents provide general information on limiting factors for using the filtering practices, and their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.6 FILTER STRIPS

Filter strips are designed to treat stormwater runoff from adjacent surfaces and remove sediments and pollutants through filtration and infiltration. Filter strips rely on a vegetated surface to reduce runoff velocities and filter sediments and pollutants from stormwater runoff. Filter strips are most suited for use in areas adjacent to roads, parking lots, or other similar types of impervious surfaces, which often distribute runoff in sheet flow across the surface. More specific details on filter strips are presented in Table 1.

Filter strips are highly effective at reducing the amount of suspended sediments from stormwater runoff (Claytor and Schueler 1996). However, filter strips are only moderately effective at reducing levels of trace metals and soluble nutrients. Pollutant removal capabilities for filter strips are presented in Table 2.

Five documents were identified that provide information regarding filter strips as a method of stormwater management. The documents provide general information on limiting factors for using filter strips and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.7 SUBMERGED GRAVEL STRIPS

Submerged gravel strips are designed as a single cell or a series of cells that are filled with crushed rock or gravel, supporting a wetland vegetation cover crop. In this wetland design, stormwater runoff is directed into the underlying gravel layer, rather than entering the system via surface or sheet flow. Wetland plants are rooted in the surface layers of submerged gravel strips (Schueler and Holland 2000). The gravel substrate acts as a filtration device while the plants take up pollutants through their roots. The bottom of the wetland is sealed with a liner which is then covered with a layer of muck, preferably extracted from an adjacent wetland to introduce denitrifying bacteria into the system (Schueler and Holland 2000). Submerged gravel strips are most suited for use in areas adjacent to roads, parking lots, or other similar types of impervious surfaces, which distribute a significant volume of stormwater runoff. More specific details on submerged gravel strips are presented in Table 1.

Submerged gravel strips are highly effective at reducing the amount of suspended sediments, total phosphorus, total nitrogen, and nitrate-nitrogen in stormwater runoff (Schueler and Holland 2000). However, this practice is only moderately effective at removing trace metals. Few documented studies have analyzed the capacity of submerged gravel strips to remove bacteria. However, a study by Schueler and Holland (2000) demonstrated a removal rate of 78 percent. Pollutant removal capabilities for submerged gravel strips are presented in Table 2.

Three documents were identified that provide information regarding submerged gravel strips as a method of stormwater management. The documents provide general information on limiting factors for using submerged gravel strips and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.8 BIO-RETENTION

Bio-retention is a relatively new practice that incorporates soils, vegetation, and landscaping to treat urban stormwater runoff and enhance stormwater quality by collecting it in shallow depressions and allowing it to filter through a combination of soils and vegetation. This practice is designed to capture sheet flow from impervious areas and treat it by using a combination of microbial soil processes, infiltration, evapotranspiration, and plants. Bio-retention areas are best suited for use in commercial parking lots, specifically when implemented as median strips and islands within parking lots. More specific details on bio-retention are presented in Table 1.

There is considerable variation in the effectiveness of pollutant removal from bio-retention areas. However, proper design and maintenance may improve their performance (USEPA 2004). Bio-retention areas are highly effective at reducing the amount of suspended sediments in stormwater runoff; however, this may result in clogging of the filtering medium (Hunt 1999). This method is moderately effective at removing total phosphorus, total nitrogen, and trace metals. Pollutant removal capabilities for bio-retention areas are presented in Table 2.

Five documents were identified that provide information regarding the implementation of bio-retention areas for the purpose of stormwater management. The documents provide general information on limiting factors for using bio-retention areas and on their ability to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

2.9 OPEN VEGETATED CHANNELS

Open vegetated channels are earthen channels vegetated with a dense growth of hardy grass designed to convey stormwater runoff, remove pollutants, and reduce runoff velocity. Determining which type of channel would best fit at a particular site is primarily based on volume of stormwater runoff received in the area. Open vegetated channels can be designed as a drainage channel, grassed channel, dry swale, or wet swale. The drainage channel design is typically used to convey large volumes of water during major flooding events. A grassed channel achieves greater pollutant removal than the drainage channel because it is designed to have a broader bottom, lower slopes, and denser vegetation. A dry swale is an open drainage channel or depression, explicitly designed to detain and promote the filtration of stormwater runoff into an underlying soil media. A wet swale is similar to a dry swale except that it is designed to retain water or intercept groundwater for water quality treatment (Claytor and Schueler 1996). Open vegetated channels are most suited for use in areas within residential communities, adjacent to parking lots, and as highway median strips. More specific details on open vegetated channels are presented in Table 1.

All types of open vegetated channels are considered highly capable at reducing the amount of suspended sediments in stormwater runoff. However, pollutant removal capabilities may vary based on the design of the channel. Pollutant removal capabilities for open vegetated channels are presented in Table 2.

Five documents were identified that provide information regarding the implementation of open vegetated channels for the purpose of stormwater management. The documents provide general information on the design of each type of channel and on the ability of open vegetated channels to improve water quality, reduce runoff velocity, and remove pollutants and sediment. These data are summarized in Table 3.

Table 1. Summary of Management Practices for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Practice	Size (% of Drainage Area)	Minimum Vertical Distance	Construction Costs	Maintenance Requirements	Advantages	Disadvantages	Applicable Situation
Stormwater Wetlands (shallow wetland, extended detention wetland, pond/wetland system, pocket wetland)	3-5%[6]	6-8 inches[8]	Cost per acre is moderate.[7]	Maintenance costs are generally about 2% per year of the construction costs.[5]	Highest pollutant removal option. Ideal site for educational purposes.[1]	Most land-intensive.[1] Potential breeding ground for mosquitos.[3]	Wetlands may be created in almost any area large enough to accommodate the amount of water draining from adjacent surfaces.
Stormwater Ponds (micropool extended detention pond, wet pond, wet extended detention pond, multiple pond system, pocket pond)	2-3%[6]	Maximum of 8 feet, with an average of 4-6 feet.[8]	Construction costs can be somewhat high.[1]	Maintenance consists of mowing, annual inspections, sediment removal.[8] Costs are approx. 3-5% of the construction cost per year.[3]	Traditional, aesthetically pleasing. Also useful for recreational purposes and wildlife habitat.[3]	Relatively land-intensive. Safety issues.[1]	*Not feasible in Project area because ponds typically require a larger area.*
Infiltration Practices (basin, trench, well)	2-3%[6]	N/A	Relatively low design and construction cost.[1]	Must be maintained regularly to prevent clogging.[3]	Introduces surface water to ground water. Not very land-intensive or highly visible, can be used in residential or commercial areas.[3]	Limited application (sandy soils only). High potential for clogging.[1] Water table must be at least two feet under the bottom of the device.[3]	Sites with permeable soils and reasonably deep water tables.[3]
Porous Pavement (porous asphalt, modular block)	N/A	N/A	N/A	Must be maintained frequently to function properly. Quarterly vacuuming and/or jet hosing is needed to maintain porosity.[3]	Diversion of surface runoff to groundwater recharge, providing water quality and quantity benefits.[1]	Asphalt or concrete porous pavement has a high failure rate due to clogging, however, modular block porous pavement tends to remain effective for longer periods.[3] Can only be used on non-sanded surfaces.[8]	Intended for low vehicle traffic areas, i.e., spillover parking.[4] May be most beneficial in watersheds with large areas of impervious surfaces.[3]

Table 1. Summary of Management Practices for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Practice	Size (% of Drainage Area)	Minimum Vertical Distance	Construction Costs	Maintenance Requirements	Advantages	Disadvantages	Applicable Situation
Filtering Practices (surface sand filter, underground sand filter, perimeter sand filter, organic filter, pocket sand filter)	Surface sand: 2-3%; Underground sand: None; Perimeter sand: 2%; Organic: 2-3%; Pocket Sand Filter: 2%[7]	Surface sand: 5-8 feet; Underground sand: 5-6 feet; Perimeter sand: 2-3 feet; Organic: 5-8 feet; Pocket Sand Filter: 5 feet.[6]	Surface sand: Moderate; Underground sand: High; Perimeter sand: Moderate; Organic: High; Pocket Sand Filter: Moderate.[7]	Surface sand: annual cleanout; Underground sand: semi-annual cleanout; Perimeter sand: annual cleanout; Organic: annual cleanout; Pocket Sand Filter: annual cleanout.[6]	Sand filters: Can fit in high land-cost situations. Remove pollutants found in parking areas. Organic: effective sediment and trace metal removal, however, poor pollutant removal capability.	Sand filters: Most expensive per square feet of device. Maintenance can be cumbersome. Organic: annual cleanouts are required for maintenance.[6]	Surface sand: Parking lots, ultra-urban or retrofit; Underground sand: ultra-urban or retrofit, parking lots; Perimeter sand: parking lots, ultra-urban or retrofit; Organic: parking lots; Pocket Sand Filter: ultra-urban or retrofit, parking lots.[6]
Filter Strips	N/A	N/A	Reasonably low construction cost.[1]	Must be maintained regularly or filter strips will fail.[3]	Can provide groundwater recharge.[3]	Large land requirement. Not effective alone, needs other practices to reduce peak discharges or heavy stormwater runoff.[3]	Works best when adjacent to impervious areas where runoff is evenly distributed.
Submerged Gravel Strip	3-5%[6]	2-4 feet[6]	High (based on cost per impervious acre treated).[6]	Wetland cleanouts may be necessary.[6]	Effective pollutant removal. Generally small land requirement.[1]	Construction costs could be high.[1] Tends to clog as sediment accumulates.[2]	Parking lots, ultra-urban or retrofit.
Bio-Retention	5%[6]	4 feet[6]	Relatively expensive[7] Low[6]	Landscaped[6]	Aesthetically pleasing. Can double to meet landscape and water quality objectives.[1] Small land requirement (i.e., 5 acres or less). Larger areas tend to clog.[7]	Very new practice with little data to prove effectiveness.[1] Plants must be removed if soil clogs or becomes polluted.[1]	Urban sites with large areas of impervious surfaces; ideal for treating runoff from parking lots.[6] Generally applied to small sites in a highly urban areas.[7]

Table 1. Summary of Management Practices for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Practice	Size (% of Drainage Area)	Minimum Vertical Distance	Construction Costs	Maintenance Requirements	Advantages	Disadvantages	Applicable Situation
Open Vegetated Channels (drainage channel, grassed channel, dry swale, wet swale)	Drainage or grassed channel 6.5%; dry or wet swale: 10-20%[6]	N/A	Generally inexpensive.[3]	Easy to maintain by mowing and trimming.[3]	Highly effective in preventing erosion and controlling sediment in stormwater runoff and aesthetically pleasing.[3]	Remove only small amounts of pollutants.[3]	Open vegetated channels are designed to rapidly drain stormwater during storm events, typically from residential areas.[6]

Notes:

[1] Hunt III, W.F. 1999.
[2] Australian Wetlands Pty Ltd. 2004.
[3] Osmond, et. al. 1995.
[4] NYSDEC. 2001.
[5] USEPA. 1999.
[6] Claytor and Schueler. 1996.
[7] USEPA. 2004.
[8] Caraco, D., and R. Claytor. 1997.

Table 2. Pollutant Removal Capabilities of Management Practices for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Practice	Total Suspended Solids (TSS)	Total Phosphorus (TP)	Total Nitrogen (TN)	Nitrate-Nitrogen	Trace Metals (copper, lead, zinc)	Bacteria (fecal coliform)	Other Info
Stormwater Wetlands	80%[4]	51-75%[4]	26-50%[4]	40-45%[1]	Variable: 26+%[4]	N/A	Soluble nutrients: 26-50%[4]
Stormwater Ponds	70%[4]	51-75%[4] Phosphorus – mod to high.[2]	26-50%[4]	20%[1]	Metals: lead – high[2], zinc – moderate[2] Variable: 26+%[4]	0-75%[4]	Soluble nutrients: 51-75%[4]
Infiltration Practices (basins, trenches, wells)	Limited data suggests it is initially high – but this causes system to become clogged and thus fail.[1]	76+%[4]	51-75%[4]	Very little is removed.[1]	51-75%[4]	N/A	Soluble nutrients: 51-75%[4]
Porous Pavement (porous, modular block)	High[2]				High[2]		Shown to have high removal rates largely due to transfer to groundwater.[2]
Filtering Practices (Surface sand filter, Underground sand filter, Perimeter sand filter, Organic sand filter, Pocket sand filter)	80-95%[4]	40-65%[4]	35-45%[4]	Negative[4]	35-90%[4]	40-80%[4]	Hydrocarbons – 80%[4]
Filter Strips	70%[4]	10%[4]	30%[4]	Zero[4]	N/A	N/A	Reduce pollutants such as sediment, organic matter, and many trace metals by filtering action of the vegetation. Can remove more than 60% of the particulates and up to 40% of the plant nutrients.[2]

Table 2. Pollutant Removal Capabilities of Management Practices for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Practice	Total Suspended Solids (TSS)	Total Phosphorus (TP)	Total Nitrogen (TN)	Nitrate-Nitrogen	Trace Metals (copper, lead, zinc)	Bacteria (fecal coliform)	Other Info
Submerged Gravel Strip	80%[4]	80%[4]	65%[4]	75%[4]	N/A	Results from a study in Florida showed a 78% removal rate.[3]	
Bio-Retention	Initially high but will result in clogging.[1]	65-87%[5] 70-83%[3]	52-67%[5]	Total nitrogen appears high, but Nitrate-Nitrogen may be negative.[1]	43-97%[5]	90%[3]	There is considerable variation in the effectiveness. However, proper design and maintenance may improve their performance.[5]
Open Vegetated Channels (Drainage channel, Grass channel, Dry swale, Wet swale)	80-90%[4]	20-65%[4]	40-50%[4]	50-80%[4]	N/A	N/A	There is considerable variation between pollutant removal capabilities for each channel design.[4]

Notes:

1 Hunt III, W.F. 1999.
2 Osmond et. al. 1995.
3 Schueler, T.R. and H.K. Holland. 2000.
4 Claytor and Schueler. 1996.
5 USEPA. 2004.

Table 3. Literature Search Summary for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Author or Agency	Report Title	Analyses	Data Utility
Australian Wetlands Pty Ltd. 2004	Stormwater Wetlands	General descriptions, associated benefits, and limitations of management practices.	Stormwater wetlands, submerged gravel strips.
Caraco, D., and R. Claytor. 1997	Stormwater BMP Design Supplement for Cold Climates	General descriptions and detailed designs, maintenance requirements, associated benefits and limitations of management practices.	Stormwater wetlands, stormwater ponds, infiltration practices, filtering practices, open vegetated channels.
Claytor and Schueler. 1996	Design of Stormwater Filtering Systems	General descriptions and detailed designs, costs, pollutant removal capabilities, associated benefits and limitations of management practices.	Stormwater wetlands, stormwater ponds, filtering practices, filter strips, submerged gravel strips, bio-retention, open vegetated channels.
Hunt III, W.F. 1999	Urban Stormwater Structural Best Management Practices (BMPs)	General descriptions, pollutant removal capabilities, associated benefits, and limitations of management practices.	Stormwater wetlands, stormwater ponds, infiltration practices, filter strips, bio-retention.
Hunt III, W.F., and B.A. Doll. 2000	Designing Stormwater Wetlands for Small Watersheds	General descriptions, pollutant removal capabilities, design criteria, plant selection, costs, and limitations of stormwater wetlands.	Stormwater wetlands.
Mastey, Stephen. 1997	Design Strategies for Stormwater Wetlands to Maximize Plant Diversity	General descriptions, design strategies, and study of effects of plant diversity.	Stormwater wetlands, stormwater ponds.
NYSDEC. 2001	New York State Stormwater Management Design Manual	General descriptions and detailed designs, associated benefits and limitations of management practices.	Stormwater wetlands, stormwater ponds, infiltration practices, porous pavement, filtering practices, filter strips, open vegetated channels.
Ormond et.al. 1995	Wetland Management	General descriptions, associated benefits, and limitations of management practices.	Stormwater wetlands, stormwater ponds, infiltration practices, porous pavement, filter strips, open vegetated channels.
Phillips, Veronika	Anatomy of a Constructed Wastewater Wetland	General descriptions and site requirements, plant considerations, and pollutant removal capabilities.	Stormwater wetlands.

Table 3. Literature Search Summary for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Author or Agency	Report Title	Analyses	Data Utility
Schueler, T.R., and H.K. Holland. 2000	The Practice of Watershed Protection	Over 150 journal articles with varying information regarding wetland creation and other stormwater management practices.	Stormwater wetlands, stormwater ponds, infiltration practices, porous pavement, filtering practices, filter strips, submerged gravel strips, bio-retention, open vegetated channels.
United States Environmental Protection Agency, Office of Water. 1999	Storm Water Technology Fact Sheet: Bioretention	General descriptions, design criteria, operation and maintenance, costs, pollutant removal capabilities, associated benefits and limitations of bio-retention.	Bio-retention.
United States Environmental Protection Agency, Office of Water. 1999	Storm Water Technology Fact Sheet: Storm Water Wetlands	General descriptions, design criteria, operation and maintenance, costs, pollutant removal capabilities, associated benefits and limitations of stormwater wetlands.	Stormwater wetlands.
United States Environmental Protection Agency, Office of Water. 2004	Post-Construction Storm Water Management in New Development and Redevelopment: Bioretention	General descriptions, applicability, costs, siting and design considerations, maintenance and cost considerations, limitations, and effectiveness of bio-retention.	Bio-retention.
United States Environmental Protection Agency, Office of Water. 2004	Post-Construction Storm Water Management in New Development and Redevelopment: Stormwater wetlands	General descriptions, applicability, costs, detailed design criteria and drawings, limitations and effectiveness of stormwater wetlands.	Stormwater wetlands.
United States Environmental Protection Agency, Office of Water. 2004	A Handbook of Constructed Wetlands	General descriptions and designs, hydrology, substrates, vegetation, construction plans, operation and maintenance.	Stormwater wetlands.

3.0 VEGETATION

The role of vegetation in constructed wetland and other stormwater management practices is to physically slow the flow of water, allowing suspended sediments to deposit out of the water column, provide a medium for the breakdown of organic material and assimilation of nutrients, metals, and other contaminants by microbes, and fix or uptake pollutants via the root systems (Claytor and Schueler 1996).

There are several factors that need to be considered in the design of a planting plan and selection of species for created wetlands and other stormwater management practices. In general, native plant species should be used instead of exotic or foreign species, even if contaminant removal efficiencies are lower in native species. Vegetation should be selected that can tolerate the hydrologic condition, inundation, salinity, and sun conditions expected for the created wetland. Also, the layout of species in the planting plan should appear random and natural. In management practices with different cover classes (i.e., tree, shrub, herbaceous), all cover classes should be represented in the planting plan. Additionally, urban stressors, such as wind, sun, exposure, insect and disease infestation, and drought, should be considered in the planting plan layout. Lastly, in highly visible sites, aesthetics and visual characteristics, and traffic and safety issues, should also be considered (NYSDEC 2001). Specific information detailing characteristics of vegetation typically used in stormwater management practices is presented in Table 4.

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York.

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Trees and Shrubs								
Red Maple *(Acer rubrum)*	Deciduous Tree.[1]	Regularly to never inundated.[1]	Yes.[1] 4–6 days.[5]	Tidal fresh water.[3] High.[5]	High. Food (seeds and browse).[1,2,5]		Partial sun.[5]	Rapid growth. Tolerates acidic soils.[1] High metals and oil/grease tolerance. High resistance to insect/disease. Shallow roots.[5]
Speckled Alder *(Alnus rugosa)*	Deciduous Shrub.[1]	Regularly to periodically inundated.[1]	Yes.[1]		High. Cover, browse for deer, seeds for birds.[1]			
Smooth Alder *(Alnus serrulata)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Yes.[1]	Tidal fresh water.[3]	High. Food, cover.[1]			Rapid growth. Stabilizes streambanks.[1]
Shadowbush, Serviceberry *(Amelanchier canadensis)*	Deciduous Shrub.[1]	Periodically to never inundated.[1]	Yes.[1] 2–4 days.[5]	High.[5]	High.[1,5] Nesting, cover, food. Birds and mannals.[1]		Partial shade.[1]	Common in forested wetlands and upland woods.[1] High resistance to insect/disease.[5]
Groundsel Tree *(Baccharis halimifolia)*	Deciduous Shrub.[3]	Infrequently flooded.[3]	Some.[3]	Tidal fresh to salt water.[3]				
River Birch *(Betula nigra)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 4–6 days.[5]		Low. Good for cavity nesters.[1]		Full sun[1] to partial sun.[5]	Bank erosion control.[1] High resistance to insect/disease.[5]
Gray Birch *(Betula populifolia)*	Deciduous Tree.[5]	Xeric to hydric.[5]	4–6 days.[5]	High.[5]	High.[5]		Partial sun.[5]	High oil/grease tolerance.[5]
Hackenberry *(Celtis occidentalis)*	Deciduous Tree.[1]	Infrequently to never inundated.[1]	Some.[1]		High. Food and cover.[1]		Full sun to partial shade.[1]	
Buttonbush *(Cephalanthus occidentalis)*	Deciduous Shrub.[1]	1 ft. deep to never inundated.[1]	Yes.[1]	Tidal fresh water.[3]	High. Ducks and shorebirds. Seeds, nectar and nesting.[1]		Full sun to partial shade.[1]	Will grow in dry areas.[1]

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Sweet Pepperbush *(Clethra alnifolia)*	Deciduous Shrub.[5]	Mesic to wet mesic.[5]	2–4 days.[5]	High.[5]	Medium.[5]		Sun to partial sun.[5]	High resistance to insect/disease.[5]
Silky Dogwood *(Cornus amomium)*	Deciduous Shrub.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 1–2 days.[5]	Tidal fresh water.[3] Low.[5]	High.[1,5] Songbirds, mammals.[1]		Shade tolerant.[1]	Drought tolerant. Good bank stabilizer.[1]
Red Osier Dogwood *(Cornus stolonifera)*	Deciduous Shrub.[5]	Mesic to hydric.[5]	2–4 days.[5]	High.[5]	High.[5]		Sun or shade.[5]	High metals, oil, grease tolerance. Needs consistent moisture levels.[5]
White Ash *(Fraxinus americana)*	Deciduous Tree.[1]	Infrequently to never inundated.[1]	No.[1] 2–4 days.[5]	Moderate.[5]	Low[5] to high.[1] Food.[1]		All conditions.[1]	Well drained soils.[1] High metals and oil/grease tolerance. High resistance to insect/disease.[5]
Black Ash *(Fraxinus nigra)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Irregular-seasonal saturation[1]		High. Food (seeds, sap), cover, nesting for birds and mammals. Fruit persist in winter.[1]		Full sun.[1]	Rapid growth. Susceptible to wind/ice damage and disease.[1]
Green Ash, Red Ash *(Fraxinus pennsylvania)*	Deciduous Tree.[1]	Periodically to infrequently inundated.[1]	Yes.[1] 4–6 days.[5]	Tidal fresh water.[3] Moderate.[5]	Moderate. Songbirds.[1]		Full sun to partial shade.[1]	Rapid growing streambank stabilizer.[1] High metals and oil/grease tolerance. High resistance to insect/disease.
Maidenhair Tree *(Ginko biloba)*	Deciduous Tree.[5]	Mesic.[5]	2–4 days.[5]	High.[5]	Low.[5]		Sun.[5]	Avoid female species – offensive odor from fruit.[5]
Honey Locust *(Gleditsia triacanthos)*	Deciduous Tree.[5]	Mesic.[5]	2–4 days.[5]	High.[5]	Low.[5]		Sun.[5]	Select thornless variety.[5]
Witch Hazel *(Hamamelis virginiana)*	Deciduous Shrub.[1]	Periodically to infrequently inundated.[1]	No.[1] 2–4 days.[5]	Moderate.[5]	Low. Food for squirrels, deer, ruffed grouse.[1]		Prefers shade.[1]	Ornamental.[1]

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Inkberry *(Ilex glabra)*	Deciduous Shrub.[5]	Mesic to wet mesic.[5]	2–4 days.[5]	High.[5]	High.[5]		Sun to partial sun.[5]	High oil/grease tolerance. High resistance to insect/disease.[5]
Winterberry *(Ilex verticillata)*	Deciduous Shrub.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 2–4 days.[5]	Tidal fresh water.[3] Low.[5]	High.[1,5] Cover and food (fruit) for birds. Berries last into winter.[1]		Full sun to partial shade.[1]	Moderate oil/grease tolerance. High resistance to insect/disease.[5]
High-tide Bush *(Iva frutescens)*	Deciduous Shrub.[3]	Infrequently flooded.[3]	Yes.[3]	Tidal fresh to salt water.[3]				Grows on mounds next to ditches; upper border.[3]
Common Juniper *(Juniperus communis)*	Evergreen Shrub.[5]	Dry mesic to mesic.[5]	1–2 days.[5]	Moderate.[5]	High.[5]		Sun.[5]	High metals and oil/grease tolerance.[5]
Eastern Red Cedar *(Juniperus virginiana)*	Coniferous Tree.[1]	Periodically to never inundated.[1]	No.[1] 2–4 days.[5]	High.[5]	High to very high.[1,5] Fruit for some birds.[1]		Full sun to partial shade.[1]	Common in wetlands, shrub and bogs and edge of stream.[1] High oil/grease tolerance. High resistance to insect/disease.[5]
Larch, Tamarack *(Larix latricina)*	Coniferous Tree.[1]	Regularly to periodically inundated.[1]	Yes.[1]		Low. Nest tree and seeds.[1]		Full sun.[1]	Rapid initial growth. Acidic boggy soil.[1]
Common Spice Bush *(Lindera benzoin)*	Deciduous Shrub.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 2–4 days.[5]	Tidal fresh water.[3] High.[5]	Very high. Songbirds.[1]		Shade (rich soils).[1]	Tolerates acidic soils. Good understory species. Deep root system.[1]
Sweetgum *(Liquidambar styraciflua)*	Deciduous Tree.[1]	Periodically to never inundated.[1]	Yes.[1] 4–6 days.[5]	High.[5]	Moderate to high.[1,5] Songbirds.[1]		Sun to partial shade.[1]	Tolerates acid to clay soils.[1] Fruit is a maintenance problem.[5]
Tulip Tree *(Liriodendron tulipifera)*	Deciduous Tree.[1]	Infrequently to never inundated.[1]	No.[1]		Moderate. Seeds and nest sites.[1]		Full sun to partial shade.[1]	Rapid growth. Well drained soils.[1]

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Bayberry *(Myrica pensylvanica)*	Deciduous Shrub.[1]	Periodically to never inundated.[1]	Yes.[1] 2–4 days.[5]	Tidal fresh to slightly brackish water.[3] High.[5]	High.[1,5] Nesting, food, cover. Berries last into winter.[1]		Sun to partial sun.[5]	Roots fix nitrogen. Tolerates slightly acidic soils.[1] High resistance to insect/disease.[5]
Blackgum or Sourgum *(Nyssa sylvatica)*	Deciduous Tree.[1]	Periodically to never inundated.[1]	Yes.[1] 4–6 days.[5]	Tidal fresh water.[3] High.[5]	High.[1,5] Songbirds, egrets, herons, raccoons, owls.[1]		Sun to partial shade.[1]	Can be difficult to transplant.[1]
Tupelo *(Nyssa sylvatica vari biflora)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Yes.[1]	Tidal fresh water.[3]	High. Seeds and nest sites.[1]			Ornamental.[1]
Sycamore *(Platanus occidentalis)*	Deciduous Tree.[1]	Periodically to never inundated.[1]	Yes.[1] 4–6 days.[5]	Moderate.[5]	Low to medium.[1,5] Food, cavities for nesting.[1]		Sun.[5]	Rapid growth.[1] Shallow rooted, subject to windthrow. Fruit is a maintenance problem.[5]
Black Cherry *(Prunus serotina)*	Deciduous Tree.[1]	Infrequently to never inundated.[1]	No.[1]		High. Food.[1]			Moist soils or wet bottomland areas.[1]
Eastern Cottonwood *(Populus deltoids)*	Deciduous Tree.[1]	Periodically to infrequently inundated.[1]	Yes.[1] 4–6 days.[5]	Yes.[2] High.[5]	Moderate to high.[1,5] Cover, food.[1]		Sun.[5]	Shallow rooted, subject to windthrow. Invasive roots. Rapid growth.[1] High metals and oil/grease tolerance.[5]
Red Choke Berry *(Pyrus arbutifolia)*	Deciduous Shrub.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 1–2 days.[5]	High.[5]	Moderate to high.[1,5] Songbirds.[1]		Partial sun.[1]	Bank stabilizer.[1] High metals and drought tolerance.[5]
Swamp White Oak *(Quercus bicolor)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 4–6 days.[5]	High.[5]	High. Mast.[1]		Full sun to partial shade.[1]	One of the fastest growing oaks.[5]
Scarlet Oak *(Quercus coccinea)*	Deciduous Tree.[5]	Mesic.[5]	1–2 days.[5]	High.[5]	High.[5]		Sun.[5]	

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Pin Oak *(Quercus palustris)*	Deciduous Tree.[1]	Regularly to never inundated.[1]	Yes.[1] 4–6 days.[5]	High.[5]	High.[1,2,5]		Sun.[5]	Tolerates acidic soils. Gypsy moth target. Prefers well-drained sandy soils.[1]
Willow Oak *(Quercus phellos)*	Deciduous Tree.[5]	Mesic to wet mesic.[5]	4–6 days.[5]	High.[5]	High.[5]		Sun.[5]	Fast growing oak. High resistance to insect/disease.[5]
Red Oak *(Quercus rubra)*	Deciduous Tree.[5]	Mesic.[5]	2–4 days.[5]	Moderate.[5]	High.[5]		Sun to partial sun.[5]	High oil/grease tolerance.[5]
Black Locust *(Robinia pseudo-acacia)*	Deciduous Tree.[5]	Mesic to xeric.[5]	2–4 days.[5]	High.[5]	Low.[5]		Sun.[5]	Fruit is a maintenance problem. Shallow rooted, subject to windthrow.[5]
Swamp Rose *(Rosa palustrus)*	Deciduous Shrub.[1]	Regularly to periodically inundated.[1]	Irregular, seasonal, or regularly saturated.[1]	Low.[1]	High. Food (hips) for birds and mammals. Cover.[1]		Full sun.[1]	Easy to establish.[1]
Black Willow *(Salix nigra)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Yes.[1]	Tidal fresh water.[3]	High. Browsing and cavity nesters.[1]		Full sun.[1]	Rapid growth, stabilizes streambanks.[1,2]
Elderberry *(Sambucus canadensis)*	Deciduous Shrub.[1]	Regularly to never inundated.[1]	Yes.[1]	Tidal fresh water.[3]	Extremely high. Food and cover, birds and mammals.[1]		Full sun to partial shade.[1]	
Bald Cypress *(Taxodium distichum)*	Deciduous Tree.[1]	Regularly to periodically inundated.[1]	Yes.[1] 4–6 days.[5]		Low.[5] Little food value, good perching site for waterfowl.[1]		Sun to partial sun.[5]	NY is north of normal range. Tolerates drought.[1] Not well documented for planting in urban areas.[5]
Eastern Hemlock *(Tsuga canadensis)*	Coniferous Tree.[1]	Infrequently to never inundated.[1]	Yes.[1]		Moderate. Mostly cover and some food.[1]		All conditions.[1]	Tolerates acidic soils.[1]

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
American Elm *(Ulmus americana)*	Deciduous Tree.[1]	Periodically to never inundated.[1]	Irregular-seasonal saturation[1]		High. Food (seeds, browsing), cover, nesting for birds and mammals.[1]		Sun to full shade.[1]	Susceptible to disease (short-lived). Tolerates drought and wind/ice damage.[1]
Slippery Elm *(Ulnus rubra)*	Deciduous Tree.[1]	Regularly to infrequently inundated.[1]	Yes.[1]	No.[1]	High. Food (seeds, buds) for birds and mammals (browse). Nesting.[1]		Shade tolerant.[1]	Rapid growth. Drought tolerant.[1]
Northern Wild Raisin *(Viburnum cassinoides)*	Deciduous Shrub.[5]	Mesic.[5]	2–4 days.[5]	High.[5]	High.[5]		Sun to partial sun.[5]	High metals, oil/grease tolerance. High resistance to insect/disease.[5]
Arrowwood Viburnum *(Viburnum dentatum)*	Deciduous Shrub.[1]	Regularly to periodically inundated.[1]	Yes.[1] 2–4 days.[5]	Tidal fresh water.[3] High.[5]	High.[1,5] Songbirds and mammals.[1]		Sun to partial shade.[1]	High metals and oil/grease tolerance. High resistance to insect/disease.[5]
Nannyberry *(Viburnum lentago)*	Deciduous Shrub.[5]	Mesic.[5]	2–4 days.[5]	High.[5]	High.[5]		Sun to partial sun.[5]	High metals and oil/grease tolerance. High resistance to insect/disease.[5]
Herbaceous Plants								
Sweet Flag *(Acorus calamus)*	Herbaceous.[1]	1 ft. deep to regularly inundated.[1]	Up to 3 in.[1]	Tidal fresh water.[3]	Low.[1]			Tolerates dry periods. Not a rapid colonizer. Tolerates acid conditions.[1]
Redtop *(Agrostis alba)*	Perimeter.[1]	Regularly to infrequently inundated.[1]	Up to 25% of season.[1] 1-2 days.[5]	High.[5]	Moderate to high.[5] Rabbits and some birds.[1]		Shade.[5]	Establishes quickly but not highly competitive.[1]
Creeping Bentgrass *(Agrostis palustris)*	Emergent.[2]	Infrequently inundated.[3]	Yes.[5]	Tidal fresh to brackish water.[3]			Full sun.[3]	Well-drained soils.[2]
Creeping Bentgrass *(Agrostis stolonifera)*	Perimeter.[3]	Infrequently inundated.[3]	Yes.[3]	Tidal fresh to brackish water.[3]				

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Big Bluestem *(Andropogon gerardi)*	Perimeter.[1]	Periodically to infrequently inundated.[1]	Irregular or seasonal inundation.[1]		High. Seeds for songbirds, food for deer.[1]		Full sun.[1]	
Bushy Beardgrass *(Andropogon glomeratus)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 1 ft.[1]				Full sun.[1]	
Broomsedge *(Andropogon virginicus)*	Perimeter.[1]	1 ft. deep to regularly inundated.[1]	Up to 3 in.[1] 1–2 days.[5]	Low.[5]	High.[1,5] Songbirds and browsers. Winter food and cover.[1]		Full sun[5] to partial shade.[1]	Tolerates fluctuating water level.[1] Tolerates drought.[5]
Smooth Brome *(Bromus inermis)*	Emergent.[5]		Fair.[5]	Fair.[5]			Partial shade.[5]	
Blue Joint *(Calamagrotis canadensis)*	Emergent.[1]	1 ft. deep to periodically inundated.[1]	Regular or permanent inundation up to ½ ft.[1]	Tidal fresh water.[4]	Moderate. Food for game birds and moose.[1]		Partial shade.[1]	Well-drained soils.[2]
Sedges *(Carex spp.)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 3 in.[1]	Varies.	High. Waterfowl and songbirds.[1,2]			Many wetland and upland species.
Coontail *(Ceratophyllum demersum)*	Sub-mergent.[1]	Permanent pool 1-6 ft. deep.[1]	Yes.[1]	Tidal fresh water.[3]	Low food value. Good habitat and shelter for fish and invertebrates.[1]		Shade tolerant.[1]	Free floating submerged aquatic vegetation (SAV).[1]
Crownvetch *(Coronilla varia)*	Emergent.[5]		Low.[5]	Fair.[5]				Rapid growth. Requires liming.[5]
Tufted Hairgrass *(Deschampsia caespitosa)*	Perimeter.[1]	Regularly to infrequently inundated.[1]	Yes.[1] 2–4 days.[5]	High.[5]	High.[1]		Full sun.[1]	May become invasive.[1] High metals, insect, and disease tolerance.[5]

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Salt Grass *(Distichlis spicata)*	Perimeter.[3]	Infrequently inundated.[3]	Yes.[3]	Salt to brackish marshes.[3]				Spread from rhizomes.[3]
Waterweed *(Elodea canadensis)*	Sub-mergent.[1]	Permanent pool 1-6 ft. deep.[1]	Yes.[1]	Tidal fresh water.[3]	Low.[1]	High nutrient, copper, manganese and chromium removal.[1]		Good water oxygenator. [1]
Tall Fescue *(Festuca arundinacea)*	Emergent.[5]		High.[5]	Good.[5]				Fast establishment, good growth rate.[5]
Red Fescue *(Festuca rubra)*	Perimeter.[5]	Infrequently inundated.[5]	Fair.[5]	Salt to brackish marshes.[3]				Fair heat and cold tolerance.[5]
Fowl mannagrass *(Glyceria striata)*	Perimeter.[1]	Periodically to infrequently inundated.[1]	Irregular or seasonal inundation.[1] 1–2 days.[5]	Low.[5]	High.[1,5] Food for waterfowl, muskrat, and deer.[1]		Partial to full shade.[1,5]	
Marsh Hibiscus *(Hibiscus moscheutos)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 3 in.[1]	Tidal fresh to salt water.[3]	Low. Nectar.[1]		Full sun.[1]	Tolerates periodic dryness.[1]
Blue Flag Iris *(Iris versicolor)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Regular or permanently up to ½ ft. or saturated.[1]	Fresh to moderately brackish water.[1]	Moderate. Food for muskrat and waterfowl. Cover for marshbirds.[1]		Full sun to partial shade.[1]	Tolerates clay. Slow growth.[1]
Soft Rush *(Juncus effusus)*	Emergent.[1]	1 ft. deep to periodically inundated.[1]	Up to 3 in.[1]	Tidal fresh water.[3]	Moderate[1] to high.[2]			Tolerates wet or dry conditions.[1]
Black Grass *(Juncus gerardii)*	Perimeter.[3]	Infrequently inundated.[5]	Yes.[3]	Salt to brackish marshes.[3]				

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Rice Cutgrass *(Leersia oryzoides)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 3 in.[1]	Tidal fresh to slightly brackish water.[3]	High. Food and cover.[1]		Full sun; tolerant of shade.[1]	Shoreline stabilization.[1]
Duckweed *(Lemna* spp.)	Submergent /Emergent.[1]	Permanent pool 6 in. to 6 ft. deep.[1]	Yes.[1]	Tidal fresh water.[3]	High. Food for waterfowl and fish.[1]	High metals removal.[1]		
Sea Lavender (*Limonium carolinianum*)	Perimeter.[3]	Infrequently inundated.[3]		Salt marsh.[4]				
Cardinal flower *(Lobelia cardinali*s)	Perimeter.[1]	Periodically to never inundated.[1]	Some. Tolerates saturation up to 100% of season.[1]	Tidal fresh water.[3]	High. Nectar for hummingbird, oriole, butterflies.[1]		Partial shade.[1]	
Ryegrass *(Lolium spp.)*	Emergent.[2]			No.[2]	Moderate.[2]			Establishes easily.[2]
Annual Rye *(Lolium multiflorum)*	Emergent.[5]		Good.[5]	Fair.[5]			Fair to good shade tolerance.[5]	
Birdfoot deervetch *(Lotus corniculatu*s)	Perimeter.[1]	Periodically to never inundated.[1]	Infrequent inundation.[1] 1–2 days.[5]	High.[5]	High.[1,5] Food for birds.[1]		Full sun.[1]	Nitrogen fixer.[1] High metals tolerance; low oil/grease tolerance.[5]
Spatterdock *(Nuphar luteum)*	Emergent.[1]	6 in. to 1 ft. deep.[1]	Up to 3 ft.[1]	Tidal fresh water.[3]	Moderate for food but high for cover.[1]			Fast colonizer. Tolerant of fluctuating water levels.[1]
Switchgrass *(Panicum virgatum)*	Perimeter.[1]	1 ft. deep to never inundated.[1]	Up to 3 in.[1] 2–4 days.[5]	Yes.[2] High.[5]	High.[1,5] Food (seeds), cover for waterfowl and songbirds.[1]		Sun or shade.[5]	Tolerant wet/dry conditions.[1] Can spread fast and reach 6 ft high.[5]
Arrow arum *(Peltandra virginica)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 1 ft.[1]	Tidal fresh to slightly brackish water.[3]	High. Food for wood ducks.[1]		Full sun to partial shade.[1]	

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Reed Canarygrass *(Phalaris arundinacea)*	Emergent.[5]		Yes.[5]	Poor.[5]	High.[5]		Poor shade tolerance.[5]	Shallow roots, rhizomatous.[5]
Common Reed *(Phragmites australis)*	Emergent.[2]	Regularly to infrequently inundated.[3]	Yes.[4]	Tidal fresh to brackish water.[3]	Moderate. Cover for wetland wildlife species.[4]		Full sun.[4]	Rapid spread by rhizomes. Exotic that can become invasive.[2]
Timothy *(Phleum pratense)*	Emergent.[2]		Poor.[5]	No.[2]	Moderate. Food (seeds) and cover for songbirds.[4]			Establishes easily. Tolerates wet or dry conditions.[2]
Kentucky Bluegrass *(Poa pratensis)*	Emergent.[5]		Fair.[5]	Low.[5]			Fair shade tolerance.[5]	Moist, well drained soils.[5]
Smartweed *(Polygonum spp.)*	Emergent.[1]	1 ft. deep to periodically inundated.[1]	Up to 1 ft.[1]	Varies.	High. Food (seeds), cover for waterfowl, songbirds.[1,2]			Fast colonizer. Avoid weedy aliens such as *P. perfoliatum*.[1]
Pickerelweed *(Pontederia cordata)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 1 ft.[1]	Tidal fresh to slightly brackish water.[3]	Moderate. Ducks. Nectar for butterflies.[1]		Full sun to partial shade.[1]	
Long-leaved Pond Weed *(Potamogeton nodosus)*	Rooted submerged aquatic.[1]	Permanent pool 6 in. to 6 ft. deep.[1]	Up to 1–6 ft. depending on turbidity.[1]	<0.5 ppt[1]	High. Food (seeds, roots) for waterfowl, aquatic furbearers, deer and moose. Habitat for fish.[1]			Rapid spread. Flowers float on surface (August – September).[1]
Pond Weed, Sago *(Potamogeton pectinatus)*	Sub-mergent.[1]	Permanent pool 1-6 ft. deep.[1]	Yes.[1]	Tidal fresh to brackish water.[3]	Extremely high. Waterfowl, marsh and shorebirds.[1]	Removes heavy metals.[1]		
Arrowhead, Duck Potato *(Saggitaria latifolia)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 1 ft.[1]	Yes.[2]	Moderate. Tubers and seeds eaten by ducks.[1]	High.[2]		Aggressive colonizer.[1]

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Perennial Glasswort *(Salicornia virginica)*	Emergent.[2]	Infrequently inundated.[3]		High.[3]			Full sun.[3]	Native to many cold climates, particularly in salt marshes.[2]
Lizard's Tail *(Saururus cernuus)*	Emergent.[1]	6 in. to 1 ft. deep.[1]	Up to 1 ft.[1]	Tidal fresh water.[3]	Low, except wood ducks.[1]		Shade tolerant.[1]	Rapid growth.[1]
Hardstem Bulrush *(Scirpus acutus)*	Emergent.[1]	6 in. to 1 ft. deep.[1]	Up to 3 ft.[1]	Fresh to brackish water.[1]	High. Cover, food (achenes, rhizomes) for ducks, geese, muskrat, fish. Nesting for bluegill and bass.[1]			Quick to establish. Good for sediment stabilization and erosion control.[1]
Wool Grass *(Scirpus cyperinus)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Irregularly to seasonally inundated.[1]	Tidal fresh water.[3]	Moderate. Cover, food.[1]		Requires full sun.[1]	Can tolerate acidic soils, drought. Colonizes disturbed areas, moderate growth.[1]
Common Three-Square *(Scirpus pungens)*	Emergent.[1]	6 in. to 1 ft. deep.[1]	Up to 6 in.[1]	Tidal fresh to brackish water.[2]	High. Food, cover for waterfowl and fish.[1]	High metals removal.[1]		
Soft-stem Bulrush *(Scirpus validus)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 1 ft.[1]	Tidal fresh to brackish water.[3]	Moderate. Good cover and food.[1]	High.[1,2]	Full sun.[1]	Aggressive colonizer.[1,2]
Giant Burreed *(Sparganium eurycarpum)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Yes.[1]	<0.5 ppt[1]	High. Food (seeds, plant) waterfowl, beaver and other mammals. Cover for marshbirds, waterfowl.[1]		Partial sun.[1]	Rapid spread. Good for shoreline stabilization.[1]
Smooth Cordgrass *(Spartina alterniflora)*	Perimeter.[3]	Regularly to infrequently inundated.[3]	Yes.[3]	Salt and brackish marshes.[3]			Full sun.[3]	
Big Cordgrass *(Spartina cynosuroides)*	Perimeter.[3]	Infrequently inundated.[3]	Yes.[3]	Tidal fresh to salt water.[3]				

Table 4. Vegetation Characteristics for the Gowanus Canal and Bay Ecosystem Restoration Project, Brooklyn, New York (continued).

Plant Name	Form	Hydrologic Condition	Inundation Tolerance	Salinity Tolerance	Wildlife Value	Pollutant Removal	Sun Tolerance	Other Considerations
Salt Hay Grass (also Saltmeadow Cordgrass) *(Spartina patens)*	Perimeter.[3]	Regularly to infrequently inundated.[3]	Yes.[3]	Salt and brackish marshes.[3]	Moderate: Food source for livestock.[4]			Spread by rhizomes.[3]
Prairie Cordgrass *(Spartina pectinata)*	Perimeter.[3]	Infrequently inundated.[3]		Tidal fresh to brackish water.[3]			Full sun.[4]	Rapid spread by rhizomes. Best suited to large areas. Can become invasive.[4]
Seaside Arrow Grass *(Triglochin maritimum)*	Perimeter.[3]	Infrequently inundated.[3]	Yes.[3]	Tidal fresh to salt water.[3]				
Cattail *(Typha sp.)*	Emergent.[1]	1 ft. deep to regularly inundated.[1]	Up to 1 ft.[1]	Tidal fresh to brackish water.[3]	Low. Except as cover.[1]	High.[1,2]		Aggressive species; may out-compete other species.[1,2]
Wild Celery *(Valisneria americana)*	Sub-mergent.[1]	Permanent pool 1-6 ft. deep.[1]	Yes.[1]	Tidal fresh to slightly brackish water.[3]	High. Food for waterfowl. Habitat for fish and invertebrates.[1]			Tolerant of turbid water and high nutrient loads.[1]
Wild Rice *(Zizania aquatica)*	Emergent.[1]	6 in. to 1 ft. deep.[1]	Up to 1 ft.[1]	Tidal fresh to slightly brackish water.[3]	High. Food for birds.[1]		Prefers full sun.[1]	

Notes:

ft. = foot (feet)
in. = inches
ppt = parts per thousand

[1] NYSDEC 2001
[2] Caraco, D., and R. Claytor. 1997.
[3] Tiner, R.W. 1987.
[4] eNature.com. 2004.
[5] Claytor, R.A., and T.R. Schueler. 1996.

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