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Beneficial Uses of Dredged Material for Habitat Creation, Enhancement, and Restoration in NY/NJ Harbor

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ACRONYMS USED IN THIS REPORT

ACPF - Aquatic Confined Placement Facility
BOD - Biological Oxygen Demand
CAA - Clean Air Act
CAC - Construction Aggregate Corporation
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
CPF - Confined Placement Facility
CSO - Combined Sewer Overflow
CWA - Clean Waters Act
CY - Cubic Yards
DMMP - Dredged Material Management Program
DMRP - Dredged Material Research Program
DO - Dissolved Oxygen
EIS - Environmental Impact Statement
GIS - Geographic Information System
HEP - Harbor Estuary Program
HGM - Hydrogeomorphic (The Hydrogeomorphic Approach)
HMDC - Hackensack Meadowlands Development Commission
HRHR - Hudson River Habitat Restoration
MCY - Million Cubic Yards
MHW - Mean High Water
MLW - Mean Low Water
MPRSA - Marine Protection, Research, and Sanctuaries Act
MSL - Mean Sea Level
NEPA - National Environmental Protection Act
NFEA - National Fishing Enhancement Act
NJDCED - New Jersey Department of Commerce and Economic Development
NJDEP - New Jersey Department of Environmental Protection
NJMR - New Jersey Office of Marine Resources
NJMRC - New Jersey Marine Resources Commission
NMFS - National Marine Fisheries Service
NOAA - National Oceanic and Atmospheric Administration
NRC - National Research Council
NYCDEP - New York City Department of Environmental Protection
NYCDOH - New York City Department of Health
NYCDOS - New York City Department of Sanitation
NYCDPR - New York City Department of Parks and Recreation
NYSDEC - New York State Department of Environmental Conservation
NYSDOS - New York State Department of State
NY/NJ - New York/New Jersey
OENJ - Orion Elizabeth New Jersey (Corp.)
PADEP - Pennsylvania Department of Environmental Protection

PAH's - Polynuclear aromatic hydrocarbons
PCB's - Polychlorinated biphenyls
PPT - Parts Per Thousand
RCRA - Resource Conservation and Recovery Act
RHA - Rivers and Harbors Act
RRP - Regional Restoration Plan
SAV - Submerged Aquatic Vegetation
SCUBA - Self Contained Underwater Breathing Aparatus
T & E - Threatened and Endangered
TSCA - Toxic Substances Control Act
USACE - U.S. Army Corps of Engineers
USCG - U.S. Coast Guard
USEPA - U.S. Environmental Protection Agency
USFWS - U.S. Fish and Wildlife Service
VIMS - Virginia Institute of Marine Science
WES - Waterways Experiment Station
WPCP - Water Pollution Control Plant
WRDA - Water Resources Development Act
WRI - Water Resources Institute
YOY - Young-of-the-Year

PREFACE

The work reported herein was conducted in support of the Dredged Material Management Plan (DMMP) for the Port of New York and New Jersey. The DMMP is sponsored by the U.S. Army Corps of Engineers, New York District.

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EXECUTIVE SUMMARY

The purpose of this report is to describe the various potential beneficial use applications of dredged material for habitat creation, enhancement and restoration in NY/NJ Harbor. It also generally describes the potential benefits and impacts of each application along with relative costs (where available) and preliminary anticipated volumes of placement capacity. This report is not intended to be an exhaustive review of all aspects of the beneficial use of dredged material in New York Harbor, but is limited to describing the potential implementation of the most likely habitat development applications.

Habitat creation, enhancement, and restoration with dredged material MUST result in net environmental improvement, or it cannot be considered a “beneficial” use. In some cases, this will involve a “habitat tradeoff”, that is, the elimination of an existing habitat to replace it with a restored habitat that has suffered greater losses and/or is more valuable to the local ecosystem. This loss of degraded or relatively low value habitat would be justified only if the replacement habitat provides a greater ecological function (e.g., provide more fish and wildlife habitat, provide greater sediment/toxic retention, provide enhanced water quality or water circulation, etc.).

Several types of beneficial use applications for New York/New Jersey Harbor are described in this report. The applications being considered for the Harbor are:

1. Upland habitat.
2. Borrow pit restoration.
3. Treatment wetlands.
4. Habitat wetlands.
5. Recontouring for shallow water habitat.
6. Filling dead-end basins.
7. Artificial reefs.
8. Bird habitat.
9. Shellfish habitat.
10. Mud flats.
11. Oyster reefs.
12. SAV habitat.

Upland habitat creation and borrow pit restoration are the applications that potentially provide the greatest volume capacity. Applications # 3 through #9 provide intermediate volumes and vary considerably on a case-specific basis. The last three applications provide limited potential volume.

Each of these applications involves certain assumptions, and the level of detail of study conducted thus far for each application differs considerably. Thus, comparisons between applications, particularly those associated with their relative assets or liabilities, should be made cautiously.

Although some applications are already being implemented (e.g., fish reef creation); for several applications research and development is still required (e.g., shellfish habitat creation); for others demonstrations are necessary (e.g., borrow pit restoration); and still for others, surveys need to be conducted to determine how much volume is indeed actually available (e.g., upland habitat). In some cases, specific candidate sites are described (e.g., Jamaica and Lower Bay borrow pit restoration) with planning-level estimates of available volume. Potential sites were also identified for treatment wetlands (e.g., Bergen and Thurston Basins), bird habitat (e.g., Hoffman-Swinburne Islands, Floyd Bennett Field) and filling highly degraded dead-end basins (e.g., headwaters/tributaries of Newtown and Gowanus Creeks). The building of ocean reefs with dredged rock has been ongoing for many years in the New York Bight and will continue as long as there is a need for this type of material.

The cost/cy varies considerably among applications and will vary among actual sites within an application. Costs range from $5-15/cy for borrow pit restoration to over $40/cy for filling dead-end basins and constructing treatment wetlands. In beneficial use applications, the cost must be balanced against the expected environmental benefits (albeit qualitative or semi-quantitative), either in terms of the whole harbor for large volume applications (e.g., borrow pits) or local areas for small volume applications (e.g., filling highly degraded dead-end areas of Newtown Creek).

Several steps must be accomplished in order to implement these applications. Some are application-sensitive; most are generally applicable. For example, almost all of these applications would require a demonstration project before a full-scale implementation plan could be accomplished. A few, such as shellfish habitat creation, would require upfront research and development. All would require a site impact evaluation for an individual project, which would either be USACE funded if it were part of a USACE project (navigation and/or restoration) or funded by an applicant as part of a Section 404 application.

In summary, the beneficial use of dredged material for habitat creation, enhancement and restoration is a integral part of the solution for the dredging crisis in New York/New Jersey Harbor and if managed properly and funded adequately, offers possibly the best hope for environmentally beneficial consumptive uses for dredged material among the various alternatives proposed under the DMMP.

1: INTRODUCTION

It has long been known that dredged material can be used as a resource rather than managed as a waste product. The U.S. Army Corps of Engineers (USACE) estimates that they have productively used 2.6 billion cubic yards of dredged material over the past 25 years, accounting for 30% of the material dredged by the Federal Government over that time period (Landin 1997). These productive uses include creating oyster reefs, seagrass beds, intertidal mudflats, salt marshes, upland and wetland nesting areas for birds, artificial reefs and wave dissipaters; nourishing beaches and stabilizing shorelines; and construction material/landfill cover. This report examines the potential for using dredged material to restore habitats within New York/New Jersey (NY/NJ) Harbor and is an essential element of a comprehensive management plan for dredged material (USACE 1993, 1998). These productive uses are not expected to consume a majority of the harbor's dredged material over the next 50 years or eliminate the need for other management options. Although small channel and inlet dredging projects often achieve such goals, no major U.S. port has yet been able to use the majority of its dredged material for environmental purposes. Instead, beneficial uses is another management option that can be less expensive than transporting material to ocean placement sites, while providing opportunities for environmental benefits to augment the economic benefits that are derived from dredging the port.

Beneficial Uses: Definition and History

Beneficial uses of dredged material ("beneficial uses") include "all productive and positive uses of dredged material, which covers broad use categories ranging from fish and wildlife habitat development, to human recreation, to industrial/commercial uses" (USACE 1986). Although the term is relatively recent, the concept has existed for decades. Historically, technology and economics limited how far dredged material could be transported before placement, so the USACE often placed dredged material in open waters and marshes near federal channels, provided the material would not become a navigation hazard or readily slump back into the channel. Some of the earliest examples of using dredged material productively involved filling tidelands for port and industrial development (**Figure 1-1**). The ecological functions attributed to open water and marsh habitats have been emphasized in recent years. In response to this emphasis, the USACE initiated the Dredged Material Research Program (DMRP), authorized by the Rivers and Harbors Act (RHA) of 1970. This program included a comprehensive examination of the effects of dredging and dredged material placement on fish and wildlife habitats and recommendations for how those habitats could be enhanced or created with dredged material. The contemporary meaning of the term “beneficial uses” derives from this program and includes using dredged material for: 1) habitat development, 2) beach nourishment, 3) aquaculture, 4) strip-mine and land reclamation, 5) erosion control, 6) road construction, and 7) landfill cover.

Although the USACE has conducted many beneficial use projects, funding these projects can be problematic. Under most circumstances, beneficial use projects must not increase the cost option or maintenance of existing federal dredging projects for "the purposes of improving the quality of the environments in the public interest" if local sponsors pay 25% of the increased costs. Federal costs of any single modification cannot exceed $5 million under Section 1135 unless there is specific authorization by Congress. Section 204 of WRDA 1992 authorizes projects for "the protection, restoration, and creation of aquatic and ecologically related habitats, including wetlands, in connection with dtion or maintenance of existing federal dredging projects for "the purposes of improving the quality of the environments in the public interest" if local sponsors pay 25% of the increased costs. Federal costs of any single modification cannot exceed $5 million under Section 1135 unless there is specific authorization by Congress. Section 204 of WRDA 1992 authorizes projects for "the protection, restoration, and creation of aquatic and ecologically related habitats, including wetlands, in connection with dredging for construction, operation or maintenance of . . . an authorized navigation project" provided local interests pay 25% of construction costs and 100% of maintenance costs. Section 206 of WRDA 1996 authorizes restoration of aquatic ecosystems provided projects are cost effective, in the public interest, and improve the quality of the environment. Local sponsors must pay 35% of construction costs and all maintenance costs and provide all necessary lands for the work. Section 216 of the Rivers and Harbors Act of 1970 authorizes the USACE to review navigation projects and recommend modifications that would involve habitat creation/restoration using dredged material. No more than $5 million in Federal funds can be used for beneficial use projects, unless specifically authorized by Congress, and those special authorizations would set their own funding limits and responsibilities for local sponsors.

Beneficial Uses and Regional Restoration Plans

Our nation's natural resource management policies, and specifically the role of habitat restoration in that management, has recently received considerable scrutiny (e.g., NRC 1992, 1994, U.S. General Accounting Office 1994, Interagency Ecosystem Management Task Force 1995). One of the consensus recommendations from these reviews is for habitat restoration to be pursued in a watershed/ecosystem context. As with many general recommendations, it is still unclear exactly how this recommendation translates into daily actions, but regional restoration plans (RRPs) appear to be the vehicle. RRPs are more than a conglomeration of site-specific restoration plans. They are families of site-specific recommendations based on assessments of resource conditions and trends on a large watershed or ecosystem basis. The basic premise of regional restoration planning is that the relative combinations of habitats as well as their individual amounts determine the ecological viability of an area. Habitat protection and restoration efforts should target re-establishment of the habitat ratios present when the area’s ecosystem was considered healthy. Changes in the abundance of key species (or species guilds) are often used to focus these assessments. RRPs should ensure an approach to restoration that balances the needs of all living resources, with coordination among the various groups pursuing restoration opportunities, and consideration of less obtrusive means of accomplishing projects (e.g., hydrologic restoration of degraded intertidal marshes as compared to creating new marshes from uplands or shallow waters).

Beneficial uses, and particularly the habitat development aspects, should be pursued in an RRP framework. Unfortunately, assembly of such a framework for NY/NJ Harbor is only beginning and is not available to guide this report. Public and agency participation in the planning , construction, and monitoring of beneficial use projects is essential to addressing this information gap. For example, current dredging technology can build many types of estuarine habitat. However, placement of dredged material in estuaries always involves tradeoffs in natural resource values. Creation of nesting islands for birds may eliminate benthic foraging habitat for fish. In some cases this tradeoff makes good ecological sense for an area, in others it does not. Inclusion of the public and natural resource agencies in the examination of the many habitat tradeoffs involved is necessary to ensure support for these projects.

Adaptive Management is another of the consensus recommendations from the recent reviews of natural resource management. Adaptive management recognizes that unpredictable environmental factors influence the outcome of habitat restoration and often lead to unintended results (Thom 1997). These unplanned results are a major contributor to debates about the functional capacity of created habitats. Under adaptive management, projects are pursued incrementally, observed closely while they respond to nature, and subsequent phases and expectations modified based on results. For example, marsh restoration involving tidal creeks is often phased. The initial earthwork omits tidal creeks or only includes rudimentary drainage systems. As nature modifies the site, drainage patterns are established that could not be predicted or easily controlled. Subsequent construction phases establish the tidal creeks in locations guided by drainage patterns that are emerging from the site, and planting follows. The adaptive management approach can be difficult to implement in restoration projects because of institutional pressures to have a discrete, predictable termination for a project. Many beneficial use projects, however, would work well under this management paradigm. Maintenance dredging is an ongoing activity that is fairly predictable in terms of the amounts and quality of the material produced. This regularity in occurrence might allow beneficial use projects to be pursued incrementally, which would facilitate tailoring the project to the site and greatly increase environmental benefits.

Beneficial Uses and Mitigation

It is important to note that a beneficial use plan is <u>not</u> a mitigation plan. Beneficial use plans explore productive ways to use dredged material and are a required consideration of dredged material management plans (USACE 1993, 1998). All USACE projects are in the public interest when criteria set forth in applicable environmental laws and regulations are examined and balanced. For some projects, after impact avoidance and minimization has occurred to the maximum extent practical, mitigation is needed to replace habitat or resources lost. If implemented, some placement options considered by the USACE New York District for the long-term maintenance of the harbor will damage estuarine or coastal habitat. For example, aquatic confined placement facilities (ACPFs) will permanently usurp bottom habitat from the system. Judicious site selection and engineering will reduce the amount of productive habitat impacted to the least amount practical, but a considerable amount of habitat may nonetheless be impacted. The environmental significance of this loss will depend on where the impacts occur and will be viewed within the context of the overall system. In the event that the District and others determine mitigation is needed to implement some placement options, it is natural that projects discussed in this beneficial use plan will be examined to see if they can be used to offset damage from the placement options. However, under a mitigation umbrella, a wide range of projects will be considered, and this range will not be limited to projects that consume dredged material.

Regional Restoration Planning within NY/NJ Harbor

There are many efforts to restore estuarine habitat within NY/NJ Harbor, ranging from efforts by watershed associations to restore marsh habitat along the shore of small embayments, to efforts by governmental agencies to address the entire harbor complex. Beneficial use opportunities should be coordinated with these efforts, partly because they may require dredged material. More importantly, the habitats restored by beneficial use projects should complement those restored under other auspices to ensure a proper habitat balance. The regional habitat restoration efforts currently underway in NY/NJ Harbor were examined for projects that could consume dredged material.

Hudson River Habitat Restoration (HRHR): The USACE New York District, in cooperation with the NY State Department of Environmental Conservation (NYSDEC) and the New York Department of State (NYSDOS), proposes to include restoration of intertidal freshwater and oligohaline wetlands within the Hudson River Estuary as part of a comprehensive habitat restoration program. A recently completed reconnaissance study identified several potential demonstration sites that will serve as models for future restoration activities. Selection of reference wetlands and collection of baseline data was initiated at both restoration and reference sites in 1997. Restoration objectives focus on creation of intertidal wetland habitat and enhancement of existing habitat, primarily for use by fish and wildlife. Specific restoration tasks may include regrading of adjacent uplands (including dredged material islands) to intertidal elevations, removal of invasive plant species (e.g., *Phragmites australis*), and increasing tidal exchange in areas that have experienced hydrologic restriction (e.g., railroad culverts). Data collection efforts in 1997-98 included characterization of fish, invertebrates, wildlife, plant communities, and sediment chemistry at project sites and reference wetlands, along with detailed topographic surveys and continuous measurement of tidal flooding, depth, and duration. These data will be used in restoration design and in the calibration of hydrogeomorphic (HGM) functional assessment models under development by NYSDEC. Presently, it is unlikely that these projects would consume dredged material from the Harbor.

East River and Western Long Island Sound: Save the Sound, a non-profit membership organization dedicated to the restoration, protection, and appreciation of Long Island Sound and its watershed, was recently awarded a two-year grant from The Pew Charitable Trusts to conduct the Long Island Sound Habitat Preservation and Restoration Project. The overall goal is to protect and restore as much of Long Island Sound's degraded habitats as possible. This project will prioritize habitat restoration needs and minimize habitat loss. Working with U.S. Environmental Protection Agency's (USEPA) Long Island Sound Office and others, Save the Sound has begun to identify potential habitat restoration sites throughout the Sound, including the East River.

Jamaica Bay: The Jamaica Bay Ecosystem Restoration Project is examining the feasibility of several engineering measures to improve habitat. These include: dredging to increase flushing at the mouths of silted-in creeks; recontouring of the bottom to promote better water circulation [including the use of dredged material to fill deep man-made pits that are potentially increasing the residence time and the biological oxygen demand (BOD) of the bay]; wetland creation in poorly flushed basins (in some cases using dredged material); the excavation of shoreline fill to restore wetlands and shallow aquatic habitat; the restoration of tidal flow between artificially blocked areas; and use of dredged material to restore upland meadows and eroded areas. All options are being considered, and implementation will depend on feasibility, cost and public acceptance.

Flushing Bay: The Flushing Bay and Creek Ecosystem Restoration project was authorized by Congress in WRDA 1996. The Feasibility Phase of the project will examine the following options for potential implementation: removal of a dike at the southern end of LaGuardia Airport which is partially responsible for deteriorated water quality and siltation in the western part of the bay; creation and improvement of 100-200 acres of tidal and non-tidal wetlands for habitat and water quality improvement; creation of wetlands behind breakwaters for shoreline erosion control and waterfowl habitat; construction of wetlands in artificial drainage areas between fill emplacements to improve water quality; dredging to improve water circulation and to alleviate noxious odors. All or any of these options could be implemented depending on their feasibility and cost. Several of these options, particularly those involving creation of wetlands, could be implemented using dredged material from the local area.

Harbor-Wide 1: The NY/NJ Harbor Spill Restoration Committee (1996) focused on habitat restoration projects that would enhance, restore, replace, or protect natural resources injured from releases of petroleum or other hazardous substances into the Hudson/Raritan Estuary. The impetus for developing the plan was a series of large spills that occurred in the harbor during 1990, most notably 560,000 gallons of No. 2 fuel oil discharged into the Arthur Kill from the *Exxon Bayway*. The Committee's goals for the plan were to coordinate restoration activities from the various spills and to provide a framework for assessing future habitat restoration opportunities. Projects recommended in the plan focus on resource and land acquisition, habitat enhancement, public education, and environmental and technological studies the Committee felt would be needed to improve future decisions. Of the 73 projects recommended for further study, only one, restoration of avian rookeries within the Saw Mill Creek Wildlife Management Area, would clearly consume dredged material. The Committee proposed using dredged material to build small islands in the creek and to manage the vegetation on those islands to maximize their value to shorebirds. The amount of dredged material needed for this project is unknown, but is presumed to be relatively small.

Harbor-Wide 2: Growing public concern for the health of the NY/NJ Harbor and New York Bight ecosystem led the USEPA to establish the NY/NJ Harbor Estuary Program (HEP) in 1988. The Program brings together representatives from the private and public sectors, including government, industry, business, and environmental interest groups, as well as elected officials from counties in the area. Although the Program has spent much effort examining chemical contamination from urban and industrial sources, (i.e. habitat loss and degradation, toxic materials, dredged material management, pathogens, nutrient and organic enrichment, and floatable debris) it also has a workgroup that has identified priority restoration projects in the Harbor, and habitat restoration is a direct goal of the Program. However, to date, most of these projects would not require dredged material. A recent report produced by the U.S Fish and Wildlife Service (USFWS 1997), entitled "Significant Habitats and Habitat Complexes in the New York Bight Watershed," is the most comprehensive and recent inventory of habitats and living resources in the NY/NJ Harbor area and serves as an excellent base for development of a regional habitat restoration plan.

Report Organization

Chapter 2 of this report provides a general description of the estuarine resources within NY/NJ Harbor. Chapter 3 describes opportunities to build artificial reefs in the Harbor and nearby waters. Chapter 4 describes opportunities to restore shellfish habitat using dredged materials. Chapter 5 characterizes the potential to fill borrow pits in the Harbor using dredged materials. Chapter 6 describes opportunities to create intertidal and subtidal habitats in the Harbor. Chapter 7 discusses opportunities to improve water and sediment quality in the Harbor using dredged materials. Chapter 8 discusses the potential for creation and enhancement of bird/wildlife habitat in the Harbor using dredged materials. Chapter 9 describes opportunities near the Harbor to use dredged materials for upland habitat remediation.

Beneficial Uses of Dredged Material

Common Coastal Applications

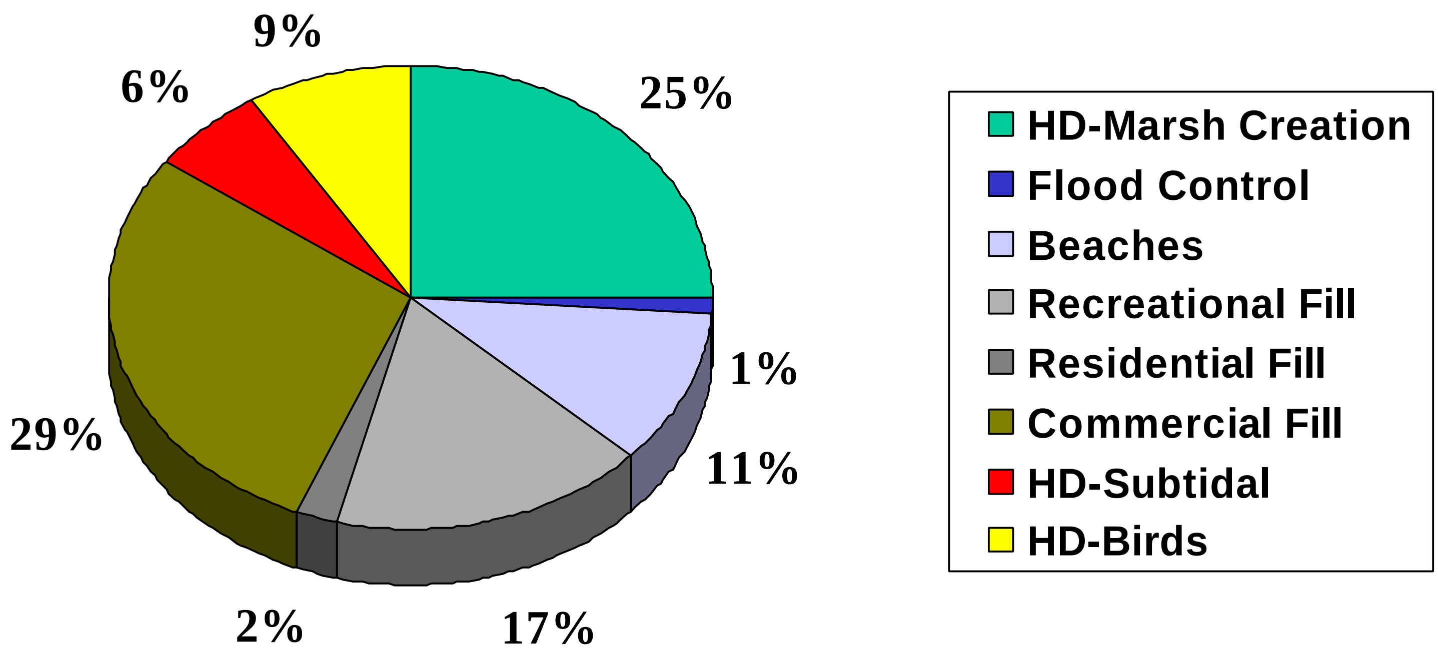

Figure 1-1. Distribution of beneficial use projects by project type according to EM 110-2-5026 (USACE 1986), which is the most recent, comprehensive inventory of beneficial use projects. USACE estimates that 30% of the material dredged in the last 25 years has been used for beneficial use projects. HD = Habitat Development

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2: OVERVIEW OF NATURAL RESOURCES AND ENVIRONMENTAL CONDITION

Natural Resources

The wide range of habitats in the NY/NJ Harbor estuary support diverse biological assemblages which include many species of phytoplankton and zooplankton, polychaetes, molluscs, crustaceans, and other species which comprise the benthic fauna; and well over a hundred species of finfish (Studholme 1988). Most (ca. 70%) of the finfish community consists of marine species [e.g. bay anchovy (*Anchoa mitchilli*), weakfish (*Cynoscion regalis*), winter flounder (*Pleuronectes americanus*)]. Migratory species [e.g. alewife, herring, and shad (*Alosa spp*.), American eel (*Anguilla rostrata*), striped bass (*Morone saxatilis*), Atlantic sturgeon (*Acipenser oxyrhynchus*) and shortnose sturgeon (*Acipenser brevirostrum*)], estuarine species [e.g. hogchoker (*Trinectes maculatus*), white perch (*Morone americana*), mummichog (*Fundulus heteroclitus*)] and freshwater species [e.g. bluegill (*Lepomis macrochirus*), gizzard shad (*Dorosoma cepedianum*)] constitute the remainder in roughly equal proportions. Important recreational species include winter flounder, summer flounder (*Paralichthys dentatus*), tautog (*Tautoga onitis*), American eel, bluefish (*Pomatomus saltatrix*), striped bass, Atlantic mackerel (*Scomber scombrus*), and weakfish. The more important commercially harvested finfish and macroinvertebrate species are: 1) Atlantic menhaden (*Brevoortia tyrannus*), 2) bluefish, 3) northern quahog (*Mercenaria mercenaria*), and 4) blue crab (*Callinectes sapidus*). Over 250 species of birds occur in the estuary including several which are federally listed as threatened or endangered [e.g. bald eagle (*Haliaeetus leucocephalus*), roseate tern (*Sterna dougallii*), peregrine falcon (*Falco peregrinus*), and piping plover (*Charadrius melodus*)],

Lower Hudson River: The Lower Hudson River complex extends from the Battery at the southern tip of Manhattan, north to Stony Point at the northern end of Haverstraw Bay (**Figure 2-1**). The Hudson is one of only a few major tidal rivers on the North Atlantic coast (USFWS 1997). Over 140 species of fish have been reported in the estuary (Beebe and Savage 1988), which is ranked as one of the most productive fisheries areas on the northern Atlantic coast. The Hudson River is a nursery ground for anadromous species such as striped bass, American shad (*Alosa sapidissima*), alewife (*A. pseudoharengus*), blueback herring (*A. aestivalis*), white perch, Atlantic tomcod (*Microgadus tomcod*), bay anchovy, Atlantic sturgeon and shortnose sturgeon, which is listed as endangered under the Federal Endangered Species Act. The Hudson River is a major East Coast spawning areas for striped bass, contributing significantly to the adult population during the summers along coastal New England (USFWS 1997). Marine fish species common in the lower Hudson River include Atlantic menhaden, fourbeard rockling (*Enchelyopus cimbrius*), bluefish, weakfish, northern pipefish (*Syngnathus fuscus*), and longhorn sculpin (*Myoxocephalus octodecimspinosus*). Winter flounder, bay anchovy, hogchoker, and mummichog are common estuarine fish species in the Lower Hudson River. The predominant shellfish species in the Hudson are northern quahog, softshell clam (*Mya arenaria*), and blue mussels (*Mytilus edulis*). Common species of large crustaceans in the lower Hudson River include grass shrimp (*Palaemonetes spp*.), sand shrimp (*Crangon septemspinosa*), lady crab (*Ovalipes sp.), rock crab (*Cancer irroratus*) and blue crab. A consumption advisory is currently in effect for the latter (USFWS 1997).

The Hudson River supports diverse biological communities despite years of physical alterations and contaminant inputs to the river (NY/NJ Spill Restoration Committee 1996). Extensive commercial and residential development has destroyed much of the natural shoreline habitat (USFWS 1997). Polychlorinated biphenyls (PCBs) continue to be a problem in the Hudson; among the more notable releases was the discharge of some 500,000 pounds from two General Electric plants in the upper Hudson between 1946 and 1977 (NY/NJ Spill Restoration Committee 1996). Closure of the commercial striped bass fishery in 1976, and warnings placed on white perch, American eel, rainbow smelt (*Osmerus mordax*), bluefish, blue crab, and other species was a result of PCB contamination in the Hudson River.

Raritan/Sandy Hook Bay Complex: Raritan and Sandy Hook Bays form the southeastern portion of NY/NJ Harbor between the southern shoreline of Staten Island, New York, and the northern shoreline of Monmouth County, NJ. Compared to other parts of the NY/NJ Harbor, the shorelines of Raritan and Sandy Hook Bays have more remaining natural shoreline and open space than any other area (USFWS 1997). A variety of habitats exist here, including open waters, sandy beach, maritime forest, salt marsh, mud flats, and riparian forest. Thirty-two species of fish have been reported in the bay; the most abundant estuarine species include mummichog, white perch, and hogchoker (USFWS 1997). Weakfish, bluefish, winter flounder, summer flounder, striped bass, black sea bass (*Centropristis striata*), tautog, scup (*Stenotomus chrysops*), and spot (*Leiostomus xanthurus*) support recreational fisheries. Commercially valuable yields of northern quahog and softshell clam are obtained by depurating the shellfish, however, the majority of the Bay's shellfish resource remains closed to direct marketing due to pollution. American oyster, surf clam (*Spisula solidissima*) and blue mussel beds are also present. This area is important for migratory and mid-winter concentrations of waterfowl with 20-year midwinter averages of over 60,000 birds.

Temperature, salinity, and dissolved oxygen (DO) vary in this area, both from natural and anthropogenic activities such as industrial waste, sewage, and storm water runoff (USFWS 1997). Industrial, commercial, and residential uses have degraded much of the shoreline of Raritan Bay and its watershed. Heavy metals, PCBs, and polynuclear aromatic hydrocarbons (PAHs) continue to be discharged from industrial uses in the watershed. Sewage treatment plants continue to release organic matter and nutrients. Undeveloped marsh and coastline along Raritan Bay's south shore are currently threatened by proposals to construct residential areas and marinas.

Arthur Kill Complex: The Arthur Kill Complex includes the Arthur Kill, Kill van Kull, and tributaries and wetlands feeding into the Arthur Kill from Union and Middlesex Counties (New Jersey) and Staten Island (Richmond County, New York). Over 60 species of fish have been reported from the Arthur Kill, and there appears to be an increase in species diversity in the last 20 years in association with increased DO levels (USFWS 1997). Mummichog and grubby sculpin (*Myoxocephalus aenaeus*) are present year round; migratory species include bay anchovy, Atlantic silverside (*Menidia menidia*), and alewife; predatory species include bluefish, striped bass, weakfish, and hake (*Urophycis spp*.). Consumption bans and/or advisories exist for many species in these waters (USEPA 1993). Benthic invertebrate distribution and abundance is low as a consequence of the stresses created from human activity (USFWS 1997). Blue crabs remain an important part of the benthic community, however pollution has led to a decrease in oyster abundance over the last century (MacKenzie 1992).

The Arthur Kill and Kill van Kull waterways have 28 petroleum refineries and 22 other industries that process non-petroleum chemicals along their shorelines (Gunster et al. 1993). Over 17.5 million gallons of petroleum products were discharged into the Arthur Kill between 1986 and 1991 (Gunster et al. 1993). Leachate from four area landfills enters the waters of the Arthur Kill along with the effluent of three sewage treatment plants (HydroQual 1991). Pier construction and bulkheading have destroyed critical habitat for many marine and estuarine fishery species (Berg and Levington 1985).

Newark Bay: Newark Bay separates Newark and Bayonne, New Jersey, leads to the Kill van Kull and Arthur Kill, and is fed by the Passaic and Hackensack Rivers. The bay supports some 50 species of finfish including bay anchovy, red hake (*Urophycis chuss*), weakfish, alewife, striped bass, and blueback herring (Woodhead 1992; Berg and Levington 1985). There are consumption advisories on fish from Newark Bay because of high levels of PCB’s and dioxin (USEPA 1993); this contamination is among the highest ever documented in marine sediments (Bopp et al. 1991). Pollution in this area is derived from Newark Airport, Port Newark, and various industries and landfills (NY/NJ Spill Restoration Committee 1996).

Hackensack Meadowlands: The Hackensack Meadowlands are located in northeastern New Jersey, in the Hackensack River drainage basin, which flows into the northern end of Newark Bay. This 8,400 acre wetland is the largest remaining brackish wetland complex in the NY/NJ Harbor Estuary. Over 30 species of fish are found in this area including mummichog, Atlantic silverside, inland silverside (*Menidia beryllina*), striped killifish (*Fundulus majalis*), white perch, brown bullhead (*Ameiurus nebulosus*), white catfish (*Ameiurus catus*), common carp (*Cyprinus carpio*), pumpkinseed (*Lepomis gibbosus*), bay anchovy, and American eel (USFWS 1997). Anadromous species include alewife, American shad, Atlantic tomcod, blueback herring, and striped bass. Polychaetes, molluscs and amphipods dominate benthic assemblages of the Hackensack Meadowlands. Tidal mudflats in the Meadowlands are important habitats for thousands of shorebirds and waterfowl during spring and fall migrations.

The Meadowlands are located in the industrial and urban core, where there is pressure to fill more areas; this would have an increasingly detrimental effect on fish and wildlife populations that depend on the area. Development and industry have degraded water quality and reduced habitat. A variety of industrial pollutants are present in the Hackensack River, probably due to the thirteen landfills in the drainage basin (NY/NJ Spill Restoration Committee 1996).

Upper Bay/Lower Bay: Upper New York Bay extends from the Verrazano Narrows north to the Battery, at the southern tip of Manhattan Island. The Upper Bay includes the Bay Ridge flats, and Red Hook Channel, in Brooklyn; and various embayments, flats and channels in New Jersey, west of the Battery. The Lower Bay includes waters landward of a line from Sandy Hook to Rockaway Point, bounded to the west by Raritan Bay and extending north to the Verrazano Narrows. Characteristic fish species of the Upper and Lower Bays include bay anchovy, winter flounder, American shad, Atlantic tomcod, and alewife (NJDEP 1984). Consumption advisories are in effect for bluefish, white perch, and white catfish; striped bass and American eel fisheries have been closed since 1976 (Cali 1988). Blue crabs are present year-round in New York Bay (Letts 1992).

Jamaica Bay: Jamaica Bay is located on the southwestern tip of Long Island in the boroughs of Brooklyn and Queens, New York City, and the town of Hempstead, Nassau County. Eighty-one species of fish were found in Jamaica Bay during a National Park Service survey of the area in 1985 (USFWS 1997). Winter flounder use the bay as a spawning area and are the most important commercial and recreational fish species present. Common fish species include Atlantic silverside, bay anchovy, mummichog, Atlantic menhaden, striped killifish, scup, bluefish, windowpane (*Scopthalmus aquosus*), tautog, weakfish, black sea bass, summer flounder, and American eel. Anadromous species that use the area include blueback herring, Atlantic sturgeon, alewife, American shad, and striped bass. The Bay's water quality precludes authorized harvesting of shellfish. However, because of the extensive abundance of northern quahogs and softshell clams, the Bay is a constant source of enforcement problems. Finfish are highly motile and can accumulate non-pathogenic contaminants throughout their range. Because some species have a tendency to accumulate certain pollutants, health advisories have been issued to ensure that the public understands the nature of any health risks.

Extensive dredging, filling, and development have altered Jamaica Bay and the estuary continues to be threatened by poor water quality, loss of upland and wetland buffers, and habitat disturbance. The bay receives pollutants from three landfills, wastewater discharge from at least three water treatment plants, combined sewer overflows (CSO's), and untreated stormwater runoff (USFWS 1997).

The East River/Narrows Complex: The Narrows constitutes the westernmost section of Long Island Sound between Hell Gate (at the convergence of the Harlem and East Rivers), and the Hempstead Sill, a major shoal area extending north and south across the Sound from Matinecock Point on Long Island to the New York-Connecticut border. Also included is a small area of southwestern coastal Connecticut in the vicinity of Greenwich. These bays are productive areas that provide nursery grounds for many species of fish and shellfish (USFWS 1997). Striped bass, scup, bluefish, Atlantic silverside, menhaden, winter flounder, tautog, and American lobster (*Homarus americanus*) are common in these areas as are northern quahog beds. The islands in this area (e.g. North and South Brothers Islands) provide important avian habitat. Despite intensive development in this area, many significant habitats still remain, but are stressed or threatened. The three north shore bays (Little Neck Bay, Manhasset Bay, and Hempstead Harbor) are among the most important waterfowl wintering areas in the western portion of this region. Heavy metal and PCB contamination, oil pollution, sewage and stormwater discharges, CSO's, bulkheading, waste placement, dredging, seasonal hypoxia, and numerous other activities threaten water quality and habitat integrity in the Narrows.

Environmental Condition

The Hudson/Raritan Estuary, like many estuaries surrounded by urban areas, exhibits many signs of chemical and physical degradation (Pearce 1988). This region is heavily populated and supports many industries, and is therefore subjected to severe ecological impacts from terrestrial runoff, overharvesting of resources, sewage effluent discharges, CSO's, and direct habitat loss. Indicators of the degree of degradation include algal blooms, chronically low DO concentrations, heavy metals and other contaminants in biota, water and sediments, bacterial contamination of shellfish, and closure of fisheries because of PCB contamination.

Changes -1800s to Present: Extensive beds of oysters were once common in the Hudson-Raritan Estuary, extending from the western end of the bay into the Raritan River and Arthur Kill, and also up into the Hudson and Shrewsbury Rivers (Studholme 1988). Beginning in 1825 and lasting nearly 100 years, these oyster beds developed into a major commercial oyster industry producing 20% of the total oyster harvest in the northeastern U.S. (MacKenzie 1984). However, in the early 1920s shellfish populations began to decline because of increased urbanization and contamination by petroleum products and other contaminants (Jacot 1920). By 1925 the oyster industry had closed because of typhoid outbreaks caused by consumption of contaminated shellfish harvested from Jamaica and Raritan Bays (Studholme 1988). The northern quahog industry closed in both NY and NJ waters in the 1930s due to industrial and domestic pollution (Studholme 1988). Numerous finfish harvests also declined from pollution, loss of habitat, and overharvesting. Shad, Atlantic sturgeon, smelt and menhaden comprised the bulk of the commercial fishery in the 1800's (Esser 1982). As the shad fisheries declined, the commercial fishery turned to menhaden, which eventually collapsed due to overfishing (Summers et al. 1986). By 1937, smelt were rare in the lower Hudson River because of overfishing, destruction of spawning grounds by industrial pollution, and the construction of dams. The Atlantic sturgeon was an important source of caviar, and overharvesting has led to the decline of this species (USFWS 1997).

The habitats of NY/NJ Harbor south of the Tappan Zee Bridge have undergone extensive physical alterations since the beginning of European colonization. Squires (1992) and NYCDEP (1997) detail many of these alterations in a study that made extensive use of historical maps and geographic information systems (**Table 2-1** and **Figure 2-2**). Some of the alterations that have occurred are:

- 1348 acres of marsh and shallow water habitats of Manhattan were filled between 1609 and 1978;

Table 2-1: Changes in the NY/NJ Harbor shore zone, resulting from filling of marshes and underwater lands or dredging of marsh or land between the early 19th century and 1980 (from Squires 1992).

Area	New York (acres)	New Jersey (acres)	Totals	
			Acres	km^2
Original marsh	29,500	42,000	71,500	289
Filled marsh	23,900	29,500	52,500	212
Dredged marsh	3000	1000	4000	16
New marsh*		500	500	2
Marsh remaining	3500	12,000	15,500	63
Underwater lands filled	8500	293,000	301,500	1220

*Includes only major new marsh intervals

- Newark Bay is 33% smaller than in 1886, and has increased in depth (Suszkowski 1990). Construction of Newark International Airport, destroyed 2200 acres of marsh by 1970;

- Since 1971, 92.7 million cubic yards has been dredged from Jamaica Bay, including 48.4 million cubic yards taken from Grassy Bay to provide fill for JFK airport (West-Valle et al. 1992). Between 1949 and 1979, 4930 acres of Jamaica Bay were filled in for the construction of JFK Airport;

- Wetlands, stream mouths, and coves were altered, filled, and/or bulkheaded from 1680 to 1850 in the East River, which caused the destruction of littoral zones and created rigid shorelines (NYCDEP 1983). Blasting of reefs and rocks from 1850 to 1920 increased depths to 30-40 feet below mean low water, and reduced currents at Hell Gate (the confluence of the East and Harlem Rivers) from more than 10 knots to about five knots (Neyer 1994);

- Rikers Island grew from 60 acres to over 400 acres between 1895 and 1938 from the dumping of coal, refuse, and ashes;

- Wetland destruction reached a peak in the tri-state area from 1954-1964. In 1900, 27,600 acres of wetlands were reported to exist in the New York City portion of the Harbor, but by 1969, only 3800 acres remained.

The Hudson River was dredged frequently because of the need for shipping channels, and dredged material was placed directly on the riverbanks, often atop fringing intertidal wetlands. In the past two centuries, the Hudson has lost 300 acres of mapped emergent marsh. However, over 2100 acres of new emergent intertidal marsh has been converted from open water within enclosed, shallow coves and bays as a result of railroad construction on the east and west banks beginning in the 1830s (**Table 2-2** and **Figure 2-3**).

River Impediments to Anadromous Fish: Anadromous fish are those species which normally reside in salt water, but migrate into fresh water to spawn. Alewife is the most common anadromous fish species in the Harbor; others include blueback herring, striped bass, and American shad. Declines in the anadromous fish stocks in the NY Bight have been attributed to damming of rivers for uses such as hydropower, water supply and flood control, and other impediments.

An impediment can be anything that prevents migrating fish from being able to reach their spawning habitat, such as a waterfall, poor water quality, pollutants, debris, or siltation. Durkas (1992) identified over fifty impediments to anadromous fish migration and spawning from forty locations within rivers, streams, and creeks that empty into the NJ portion of the Harbor (Newark Bay, Raritan Bay, and Arthur Kill). Dams and spillways were the most common

Table 2-2: Changes in Hudson River shore zone between the Federal Dam at Troy, NY and Piermont Marsh (Tappan Zee), resulting directly from human activity (from Squires 1992).

Present Use of Made Land	Area of Made Land		Percent of Total Made Land
	Acres	km^2	
Dredged material disposal	6700	27	53
Railroad construction	2000	8	16
Industrial development	1800	7	8
Highway construction	500	2	4
Recreational facilities	300	1	2
Dockage and landing facilities	100	0.4	1
Channel control measures	100	0.4	1
Housing	100	0.4	1
Marsh	1900	8	15
Total made land	12,700	51	101

The values given are for new land created. All values have been rounded.

impediment, occurring at 26 of the 40 locations, physically blocking the passage of fish. Poor water quality at 19 sites primarily decreased the suitability of spawning areas, but was also viewed as a potential impediment to fish passage in a few instances. Other impediments identified in her surveys of the Harbor included tide gates that blocked the flow of seawater and passage of fish (10 locations), excessive channelization of streams creating currents difficult for fish to swim against (7 locations), and culverts placed at angles that severely limited upstream passage (4 locations).

Current Conditions: NYCDEP (1997) lists several signs of improving conditions in NY/NJ Harbor water and habitat quality including:

- Decreases of ambient sewage-indicator bacteria and increases in DO (NYCDOH 1990; 1991; 1992b; O'Connor 1990; Brosnan and Stubin 1992);

- Reestablishment of breeding populations of peregrine falcons, herons, egrets, and other wading birds in the Arthur Kill and Kill van Kull, and ospreys in Jamaica Bay (West-Valle et al. 1992);

- Improved benthic communities in the Lower NY Bay (Steimle and Caracciolo-Ward 1989; Cerrato et al. 1989);

- Signs of the reestablishment of shortnose sturgeon populations (Woodhead and McEnroe 1991);

- Increase in blue crab abundance throughout the Hudson possibly due to improvement in water quality (NYSDOS and Nature Conservancy 1990);

- Heavy re-infestation of woodpilings by marine wood-boring isopods (van Allen 1989; Gruson 1993);

- Upgrading of 67,864 acres of shellfish beds in the estuary since 1985, including the removal of restrictions on 30,000 acres off of Rockaway and Raritan Bays in the late 1980s (Gottholm et al. 1993; Pathogens Work Group 1990);

- Reduced beach closings in NY and NJ (Swanson and Bortman 1994); the reopening of Seagate Beach on Coney Island for the first time in 40 years, and the reopening of South Beach and Midland Beach on Staten Island for the first time in 20 years (NYCDOH 1990, 1991, 1992, 1995); and the lifting of New York City Department of Health's (NYCDOH) "wet weather advisory" for seven of 10 NYC public beaches (NYC Mayors Office 1993), and its reduction from 48 hours to 12 hours at the remaining three;

- Recently increased striped bass stocks (McHugh et al. 1990; Hogan 1995), and decreases in the concentrations of PCB's in their tissues (NYSDEC 1988); and the subsequent relaxing of the NYSDEC advisory for human consumption of striped bass taken south of the Rip van Winkle Bridge (from zero to one meal/month);

- Decreases in lead concentrations in the estuary and nationwide due to the federal ban on tetraethyl leaded gasoline (Smith et al. 1987; Bopp and Simpson 1989); sediment decreases of PCB's and the insecticides p,p-DDD and chlordane (Bopp and Simpson 1989); and the dramatic recovery of the 12-mile sludge placement site in the NY Bight since dumping there ended in late 1987 (NOAA 1991);

- 50-90% reduction from peak levels reached in the 1960s-70s of most trace metals and chlorinated organic compounds found in fine grained sediments from the Hudson River (Chillrud 1996).

It is important that these improvements occurred, but more recent data need to be evaluated to see if these observations represent sustained trends and to discern exact causes. Continued improvements in water and habitat quality are still necessary, especially replacement of habitat lost by filling, bulkheading, and dredging. The improving conditions throughout the Harbor suggest the time is right to move forward with restoring physical habitat because water quality conditions may now, or in the near future, be sufficient to support it.

Figure 2-1


New York - New Jersey Harbor Estuary
Fairfield County
Rockland County
Tappan Zee
Bridge
Passaic County
New York
New Jersey
Westchester
County
Bergen County
Hudson River
Long Island
Sound
Morris County
Hackensack
River
Bronx
County
Essex County
Passaic River
Bronx
NY
Cnty
Hudson
Cnty
East
River
Queens
County
Nassau
County
Newark
Manhattan
Newark Bay
Kings
County
Queens
Union County
Upper
Bay
Somerset
County
Rahway River
Kill Van Kull
Brooklyn
Jamaica
Bay
Staten
Island
Arthur Kill
Lower
Bay
Long Island
Raritan
River
Raritan
Bay
New York Bight
Sandy Hook
Bay
Atlantic Ocean
Middlesex
County
Navesink River
Monmouth
County
Shrewsbury
River
N
State boundary
County Boundaries

Figure 2-2
Madeland vs. Marshland 1900 (From Squires 1992)

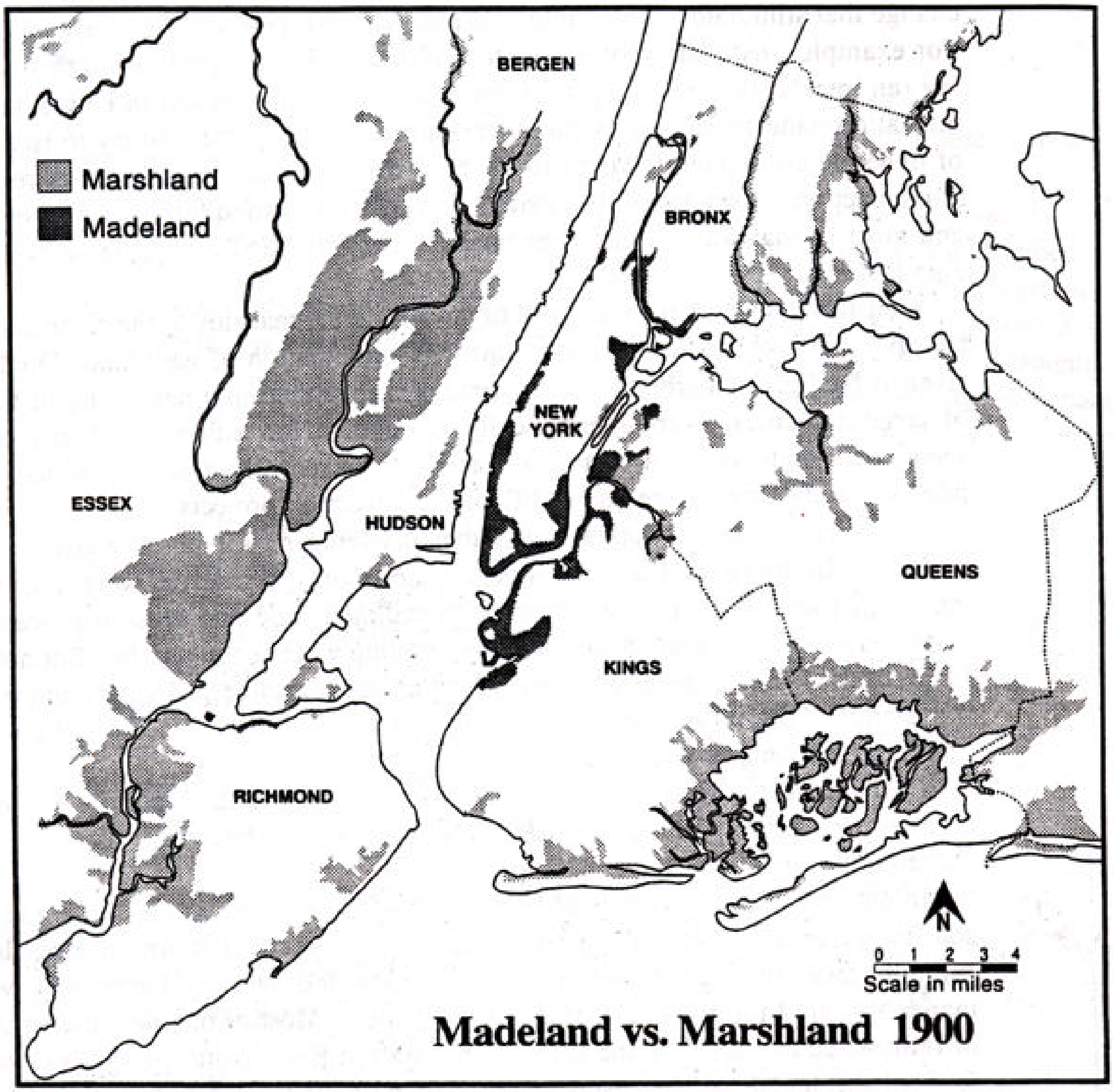
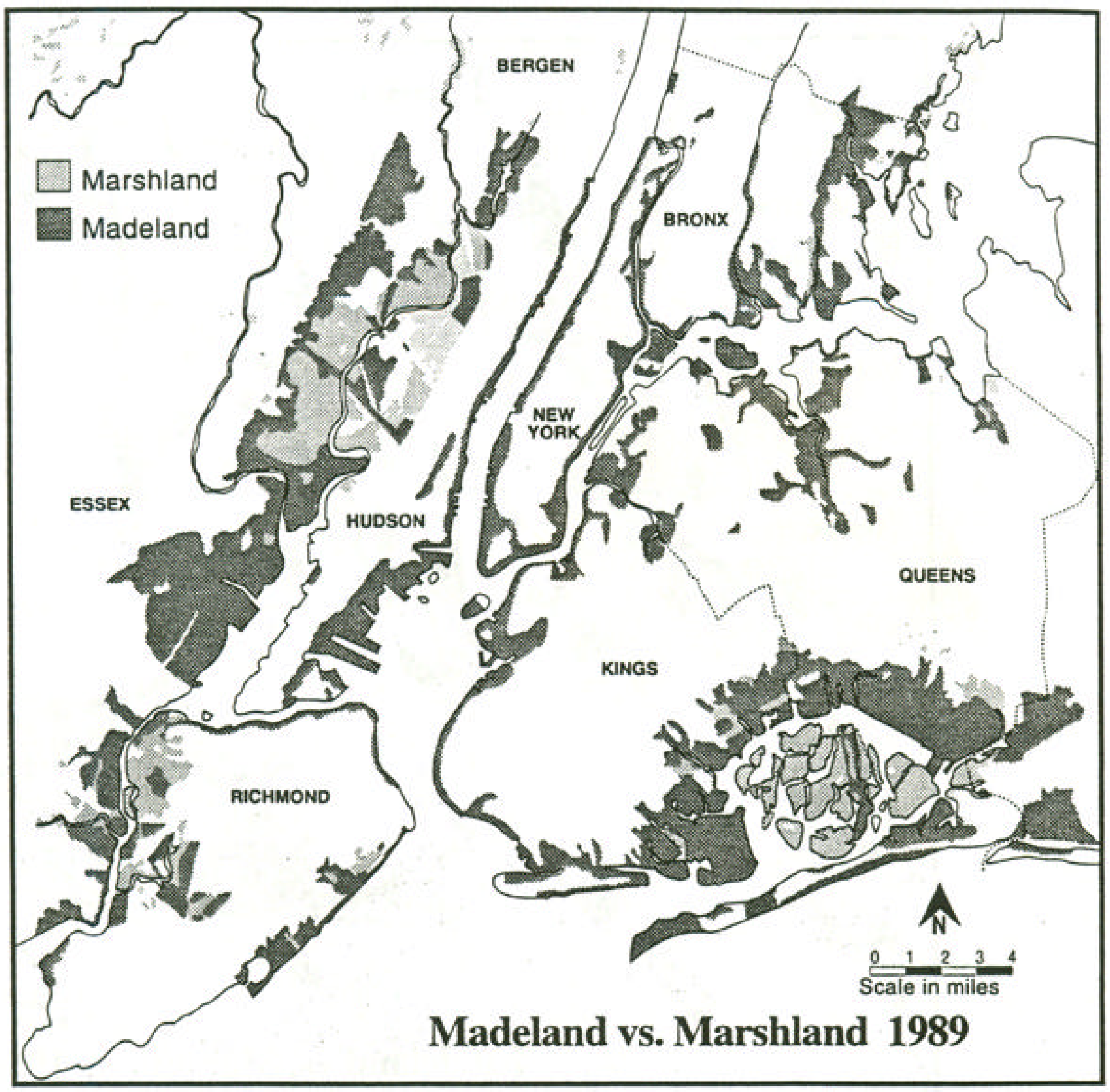


Figure 2-3

Madeland vs. Marshland 1989 (From Squires 1992)



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3: BUILDING ARTIFICIAL REEFS WITH DREDGED MATERIAL IN NY/NJ HARBOR AND THE NEW YORK BIGHT

USACE Efforts to Build Artificial Reefs with Dredged Material

Typically, sunken ships, vehicles, and specially designed habitat modules are used to construct artificial reefs, but the USACE and others have built artificial reefs from rocks and sediment. The sandy borrow areas used in many beach nourishment projects include rocky material unsuitable for the beach. In such cases, rocks are separated from the sand during dredging and used to make reefs in state-approved artificial reef programs. Rock removed while deepening navigation channels has been used to make artificial reefs in many areas, most notably New Jersey, Massachusetts Bay, San Diego Bay, and the Cape Fear River Estuary (North Carolina), with the latter being over 1 million cubic yards in size.

Artificial reefs built with sediments are typically called berms, and they have been built in the U.S., South Africa, the Netherlands, and Australia (Langan 1988). The USACE has developed underwater berms primarily to protect eroding shorelines (Bradley and Hands 1989, Allison and Pollock 1993). *Feeder berms* are constructed in shallow, nearshore waters and provide a source of sand to eroding beaches, which is a beneficial use of dredged material beyond habitat creation. *Stable berms* are constructed in deeper water and reduce the energy in long-period, storm waves that are often the most damaging to a beach. In 1982, the USACE Norfolk District conducted a pilot study of stable berms off Virginia Beach, Virginia, to test whether a stable berm could be built with maintenance material using conventional hopper dredges and positioning equipment (Clarke et al. 1988). Based on the favorable results of this work, Congress authorized a national demonstration project near the entrance to Mobile Bay, Alabama (the demonstration project also included a feeder berm). The Mobile Stable Berm is one of the largest underwater features ever constructed in the U.S. It was made from 17 million cubic yards of new-work material excavated to deepen the entrance channel to Mobile Harbor. Completed in 1990, the berm is in 40 to 45 ft of water and is 20 ft high, 1000 ft wide, and 9000 ft long. After nature reworks the berm to an equilibrium profile, the footprint of the berm is expected to be 1 mile wide and 2.5 miles long (Clarke et al. 1988).

While both feeder and stable berms are built primarily to protect shorelines, the potential for fishery benefits has been acknowledged from the outset for stable berms (Clarke et al. 1988) (Feeder berms may provide habitat benefits, but this possibility has not been examined in the field). The Mobile Stable Berm and the pilot berm off Virginia Beach provide stable refuge and feeding habitats for juvenile and adult life stages of a variety of fish and decapod crustacean species, many of which are of recreational and commercial significance (D. Clarke, USACE-WES, unpublished data). Reports from conventional dredged material placement sites are consistent with these observations. Offshore placement sites are known in many areas, at least anecdotally, to be productive fishing areas, suggesting that topographic features have habitat value. For example, offshore dredged material placement mounds in New England support productive American lobster fisheries (NRC 1994). Factors that affect the habitat value of stable berms include: height and shape of the mound, grain size distribution of the sediments, effect of the mound on local hydrodynamics, and the development of benthic and planktonic invertebrate prey resources in the vicinity of the mound.

Based on the USACE's success in building stable berms, the potential for habitat value to accrue from those berms, and the possibility of such berms consuming several million cubic yards of dredged material, the option of using dredged material to build artificial reefs should be investigated further.

Artificial Reefs: Ecological Considerations

Artificial reefs have been used in the United States for at least 160 years, going back to the deployment of small log huts in South Carolina in the 1830s and clearly provide outstanding fishing opportunities for the public (McGurrin et. al. 1989). Despite the long history of artificial reefs, both in the U.S. and throughout the world, little is known about how artificial reefs function in an ecosystem. Relationships between management goals, reef materials, and siting are poorly understood, primarily because of the lack of controlled scientific studies (Bohnsack et al. 1991). Almost half of the 350+ artificial reefs in the U.S. are in Florida (Grossman et al. 1997). The majority of the experience and research applied to artificial reefs in the U.S. comes from the southeastern U.S., focuses on tropical or subtropical species, and deals with reefs made of hard material (rather than sediments).

Benefits to Biological Resources and Fishermen: Artificial reefs provide habitat and refuge from predators (Bohnsack 1989, Eggleston et al. 1992), foraging areas, (Steimle and Figley 1996), and nurseries (Figley 1994). Artificial reefs can increase the number of species, number of individuals, and average length of finfish both at the reef and in nearby areas (Bortone et al. 1994b, D'Anna et al. 1994).

Artificial reefs can protect from some types of fishing mortality, such as trawling (NYSDEC 1993) and have been used in Sicily to obstruct illegal trawling of inshore fishing grounds, enhance small-scale commercial fisheries, and provide substrate for shellfish aquaculture (Bombace 1989, Bombace et al. 1994, D'Anna et al. 1994). Artificial reefs also benefit recreational fishing. Estuarine reefs are accessible to a larger number of fishermen, particularly those with smaller vessels, and provide an alternative to fishing offshore (**Table 3-1**).

Negative Impacts to Biological Resources: Theoretically, artificial reefs can contribute to overfishing of stocks by aggregating fish, thereby making them easier to catch. Placement of artificial reefs involves a habitat-tradeoff. The benthic habitat beneath the artificial reef and the ecological functions the area provides will be exchanged for the functions provided by the reef.

Table 3-1: Possible functions provided by artificial reefs.

Pros	Cons
A place to avoid predation	Aggregation may lead to over exploitation
A place to feed	Hazard to navigation
Nursery grounds for finfish and crustaceans	Loss of benthic habitat beneath the artificial reef footprint
Enhanced attachment and survival of some bivalve species	Impacts on adjacent communities
Increase in finfish species, number of individuals and average length compared to nearby sand areas	May interrupt migration patterns
Keep fishermen closer to shore (safer)	
Aggregation reduces unproductive searching time and increases catches	
Can be used to keep trawlers out of sensitive areas (restricts the use of some types of gear)	

Effects on Adjacent Areas: Artificial reefs deployed in the Florida Keys resulted in no significant changes in species, total numbers of adult and juvenile fishes, or population densities of the five most abundant species found in adjacent communities (Alevizon and Gorham 1989).

Ambrose and Anderson (1990) investigated the effects of artificial reefs in Southern California on adjacent soft bottom communities. Sediments near the reef had a coarser texture, and several infaunal taxa were either less or more abundant near the reef than in similar bottoms farther away; however, these effects were limited to a small area near the reef modules.

Davis et al. (1982) found that introduced structures alter soft bottom habitats by causing scouring of the sediments, changes in bedforms, and changes to sediment texture. Artificial reefs can entrap drift algae and other organic material which, along with associated reef organisms, can result in organic matter accumulation in the sediments. The size of the impacted area increases with the size of the structure. No impacts were seen beyond the scour areas.

Walton (1982) examined the effects of artificial reefs on resident flatfish populations in Puget Sound, Washington. The addition of hard substrate may discriminate against species preferring soft bottom, such as flounder. However, in Walton's study, even though the resident flatfish were physically displaced from the footprint of the artificial reefs, a four to fivefold increase in flatfish density and biomass was found.

Aggregation vs. Enhancement: Artificial reefs have consistently proven to be effective aggregators of finfish. An examination of studies from artificial reef projects worldwide has shown that artificial reefs have higher fish density (**Figure 3-1**) and higher fish biomass (**Figure 3-2**) than nearby natural reefs (Bohnsack 1989). While aggregation is clearly demonstrated to occur, the impact of artificial reefs on the size of fish populations is poorly understood. This question became framed as the "aggregation vs. enhancement debate," and is an ongoing discussion today.

Bohnsack (1989) reported, in a widely cited paper, that "aggregation vs. enhancement" is a false dichotomy. In fact, there is a continuum from aggregation to fishery enhancement on which artificial reef projects lie (**Figure 3-3**).

Artificial reefs may function either as *sources* or *sinks* in the absence of fishing mortality (Pulliam 1988). As artificial reefs provide shelter and food, they become source habitats for some species. Fishing, which may have increased efficiency due to concentrating individuals in one location, may drive the system towards functioning as a sink. If this is the case, as might be proven by a rigorous monitoring program, then restrictions on fishing may be warranted if the management objective is to increase stock size.

Bohnsack (1989) states that the species most likely to benefit from artificial reefs are those characterized as demersal, philopatric, territorial, and obligatory reef dwellers, strongly suggesting that artificial reefs only benefit habitat limited populations. It may be argued, however, that this is an extreme case. By providing better quality habitat, artificial reefs may allow individuals to channel more energy into reproduction. Sampaola and Relini (1994) and Foster et al. (1995) provide some support for this view; both studies showed increases in epibenthic invertebrates beyond what was expected by the size of the artificial reefs alone. However, increases in epibenthic invertebrates does not necessarily benefit all reef-dwelling fish. Black sea bass at two artificial reefs off of NJ did not consume many of the epibenthic invertebrates associated with the artificial reefs (Steimle and Figley 1996). Stomach contents of tautog collected from sixteen artificial reefs in Delaware Bay indicated that these fish consumed more epibenthic prey from artificial reef structures than from benthic habitats near the reefs (Foster et al. 1995).

Japanese Artificial Reefs - A Large-Scale Effort: NRC (1994) summarizes the evolution and status of Japan's efforts to construct and maintain artificial reefs. In the 1900s, local practices evolved from individual fishermen making their own reefs from rocks to cooperatives building large structures with prefabricated concrete modules with matching funds from federal and local governments. Since 1980, over 1.3 million cubic yards of habitat have been created each year, with nearly 10% of Japan's coastal shelf characterized as having received "improvements" (Nakamura 1985, Yamane 1989). Despite this extensive effort, research conducted on the efforts of the Japanese artificial reef program indicates that artificial reefs can be excellent fish aggregators, but they do not increase standing fish stock for the commercial fisheries (Polovina and Sakai 1989).

Using Dredged Material for Artificial Reefs in the NY Bight or NY/NJ Harbor

Management Objectives: Before artificial reefs are designed, the fishery management goals of the reefs will need to be specified by the USACE and its state and local partners. At a general level, these goals are: 1) enhancing fish stocks 2) increasing access by fishermen to rewarding fishing opportunities. USACE and its partners will also need to decide on the relative importance of habitat and shore protection benefits. The scope of this report was limited to habitat benefits, so the following discussion assumes enhancing fish stocks is the overriding management goal of artificial reefs created with dredged material. This information should be revisited in a broader context at the appropriate time.

Target Species: Resolution of the aggregation vs. enhancement debate is unlikely for species in the NY/NJ area without further study. Nonetheless, it is still likely that the New York District and its partners might want to pursue this avenue given the non-habitat benefits. Based on the life history requirements outlined by Bohnsack (1989), the species most likely to benefit from artificial reefs in the NY Bight and NY/NJ Harbor are black sea bass, tautog, cunner, Atlantic cod (*Gadus morhua*), American lobster, rock crab, and blue mussel (**Table** 3-**2**).

Black sea bass are commonly associated with artificial structures. Artificial reef habitat is used by black sea bass as both a place to feed and, more importantly, as shelter (Steimle and Figley

Table 3-2: Species expected to benefit from artificial reefs in NY/NJ Harbor and the NY Bight.

Common Name	Scientific Name
Black Sea Bass [1,2]	*Centropristis striata*
Tautog [1,2, 3,4]	*Tautoga onitis*
Cunner[1,4]	*Tautogolabrus adspersus*
Atlantic Cod [1,2]	*Gadus morhua*
American Lobster [1,2,5]	*Homarus americanus*
Rock Crab [1,2]	*Cancer irroratus*
Blue Mussel [3]	*Mytilus edulis*

1 NYSDEC (1993).
2 NJDEP (1987).
3 Foster et al. (1995).
4 Olla et al. (1974).

1996). Young-of-the year (YOY) black sea bass are resident in the estuaries from spring through early fall (Able and Hales 1997), and would likely benefit from shallow estuarine artificial reefs. Offshore reefs would serve the adult population year-round, as well as seasonally benefit YOY black sea bass in the winter.

American lobsters can be found from the Atlantic Maritime provinces of Canada to North Carolina. Both inshore and offshore populations occur north of NJ; Raritan Bay being the southernmost estuary where lobsters are abundant. South of NJ, lobsters are typically encountered in offshore waters only (MacKenzie 1990). In Raritan Bay, lobsters inhabit the deeper areas, and have been found on the southern side of the Raritan Bay East Reach in the shipping channel (MacKenzie 1990). Lobsters may benefit from the placement of artificial reefs. Recreational divers have commented anecdotally on increased lobster abundance at nearshore artificial reef sites off Long Island, New York (S. Heins, NYSDEC, pers. comm.). Juvenile and adult lobster, are preyed upon by many bottom fishes (MacKenzie and Moring 1985) and artificial reefs may protect juvenile lobsters from predation. Concrete pumice structures off Point Judith, Rhode Island, have been used to provide shelter for lobster post-larvae and juveniles, increasing predator avoidance and, presumably, increasing the resident lobster population (Dean 1983). The bulk of the lobster diet consists of bottom invertebrates, including blue mussel (MacKenzie and Moring 1985), a species which has been known to cover over 10% of some artificial reefs off NJ (Steimle and Figley 1996).

Two labrid fishes, tautog and cunner, range from Nova Scotia to South Carolina and Cape Cod to the Delaware Capes, respectively (Bigelow and Schroeder 1953). They are active during the day and become quiescent at night, requiring shelter. Juvenile tautogs also require shelter during the day. Shelter sites may become a limiting factor to population size within a particular habitat, such as a rock reef (Olla et al. 1974). Cunners are omnivorous, feeding on a variety of benthic and epibenthic invertebrates including amphipods, shrimps, young lobsters, small crabs, and other crustaceans (Bigelow and Schroeder 1953). Olla et al. (1974) showed that tautog prey predominantly on mussels, while prey preferences of cunner shift seasonally. Cunner shift from mussels in May and June to isopods from July-October. When water temperatures reach between 8 and 5 ^{o}C, tautog and cunner overwinter at perennial sites where they settle into individual shelters (Auster 1989). There they remain torpid until spring when water temperature increases. Overwintering sites for adults are usually in deeper areas (27 to 49 yards) with complex topography (Olla et al.1974).

Rock crabs inhabit the continental shelf and slope waters from Labrador to South Carolina (Bigford 1979). Rock crabs are found on sand and mud substrates as well as artificial and natural hard bottom. Rock crabs do not appear to be habitat dependent, but certain age classes (carapace width less than two inches) may utilize rock structure to avoid predation (F. Steimle, NMFS, pers. comm.).

Atlantic Cod are not habitat-dependent, however they are found in high concentrations on some of the deep water, offshore artificial reefs (F. Steimle, NMFS, pers. comm.). In laboratory tests, juvenile Atlantic cod were shown to prefer cobble substrate to sand or gravel-pebble substrates (Gotceitas and Brown 1993).

Dredged Material Characteristics: Rocks (from the proposed deepening of the Kill van Kull) and sediments ranging from coarse sand to fine silt will be available from dredging efforts within NY/NJ Harbor. While the rocky material is clearly suitable for artificial reefs, it is unclear whether stable berms would provide habitat value in addition to shore protection benefits. First, the target species identified above would require holes for living space or better access to epibenthic prey in order to benefit from the reef. Rock reefs could be designed to address both of these factors, however, additional study is needed to determine whether either factor would be augmented by a stable berm. Second, habitat benefits to a variety of species may accrue through alterations of local currents. Clarke and Kasul (1994) reported dense fish assemblages at the Mobile Stable Berm. Additional modeling and field studies are needed to determine whether similar hydrodynamic alterations caused by a stable berm would improve habitat in NY/NJ Harbor or the New York Bight. If results of these studies are favorable, any sediment that will form large mounds would be acceptable, although contaminated material would require a clean sediment cap.

General Siting: Artificial reefs from rocky material can be constructed in both estuarine and offshore areas. Estuarine artificial reefs may serve as nursery grounds for certain species, while offshore reefs provide habitat for larger, older individuals. Particularly in the estuary, care must be taken in siting reefs to avoid areas with submerged pipelines and cables.

Offshore Reefs: The ocean floor of the New York Bight is characterized by a sand or sand-mud plain interrupted by submarine sand ridges separated by clay bottoms or swales (NYSDEC 1993). The only natural rock bottom in the Bight extends roughly from the Shrewsbury River, NJ, to east Rockaway Inlet, NY. Most of this hard bottom is covered with sand. Placement of dredged rock will increase the availability of this limited habitat type. The USACE should focus on existing sites used in the NY and NJ artificial reef programs when selecting sites for new reefs (**Figure 3-4**).

Estuarine Reefs: Shallow reefs attract smaller fish in greater density and numbers than deeper reefs (Stone 1985). The NY Artificial Reef Program is particularly interested in the use of artificial reefs to enhance production in the estuary (S. Heins, NYSDEC, pers. comm.). In colonial times, NY/NJ Harbor and portions of the Hudson River were covered by large expanses of live hard bottom in the form of oyster reefs. Since the early 1800s, over harvesting, increased sedimentation, decreased water quality, and disease have all but eliminated oysters from the area. Significant areas of hardbottom are no longer present. The use of rock artificial reefs in the estuary may help to restore some of the original functions of the former live bottom reefs. When placing reef material in the estuary, soft bottom, which may not support the weight of the reef, strong currents which may cause the reef to move, and heavy siltation which may bury the reef will all need to be addressed.

Artificial Reef Design: Pickering and Whitmarsh (1997) examined several studies on reef design and noted a marked relationship between reef structure and catch volume. Reef size influences the biomass and number of species and individuals. Increases in species seem to be directly related to reef dimensions in terms of volume of submersed materials and of area covered (Bombace et al. 1994). Bohnsack (1991) found that fish populations at large reefs were larger and had a lower probability of local extinction. However, for twelve artificial reefs placed in Choctawhatchee Bay, a Northern Gulf of Mexico estuary, Bortone et al. (1994a) found that reef size had no significant relationship with fish density. Bohnsack et al. (1994) recommends constructing multiple small reefs, rather than a single large reef, in order to improve overall recruitment.

A one acre rock reef in the estuary with one yard of relief would require 5,000 cubic yards of rock. Deep water offshore reefs, in part due to a lessened concern over vessel groundings, may be created with more vertical relief, providing a vertically varying habitat. Reefs constructed to have an average of 3 yards of relief would require 15,000 cubic yards of dredged rock material per acre.

Regulatory Considerations

Artificial reefs generally require a permit from the USACE under Section 10 of the Rivers and Harbors Act of 1899 for structures and work in navigable waters of the U.S. Section 103 of the Marine Protection, Research and Sanctuaries Act (MPRSA) of 1972, and Section 404 (b)(1) of the Clean Water Act (CWA) of 1972 require permits for placement of dredged or fill material into the waters of the U.S. The states of New York and New Jersey historically have supported artificial reefs made of rock, but may not necessarily support reefs made of sediment.

National Artificial Reef Plan: Through the National Fishing Enhancement Act (NFEA) of 1984 (P.L. 98-623, Title II), Congress established a national policy to promote and facilitate efforts to establish artificial reefs which would facilitate access, enhance public safety for fishermen by siting near ports, minimize user conflicts and enhance fishery resources (Stone 1985). The Act resulted in the National Artificial Reef Plan, issued in 1985. It defines "waters to be covered under this title" to mean the navigable U.S. waters and the waters superjacent to the Outer Continental Shelf to the extent such waters are in or are adjacent to any State," which includes the New York Bight and NY/NJ Harbor.

NFEA does not provide the funding mechanisms for artificial reef development. Most of the federal funding for state artificial reef programs comes from the 1988 USFWS Federal Aid in Sport Fish Restoration Act, 16 U.S.C. sec. 777, which uses funds from a 10% manufacturers' excise tax on sports fishing equipment sales (Murray 1994). The Wallop-Breaux amendments add additional funds from the sale of other types of fishing related gear, import duties on boats, and marine fuel taxes. Although not specific to artificial reefs, the Wallop-Breaux amendments support nearly all U.S. artificial reef development (Murray 1994).

The ties to the recreational fishery have continued at the state level, with the emphasis of nearly all the state artificial reef programs on enhancing fishing opportunities. Historically this has meant aggregating fish to increase catches by the recreational fishing community. Only recently has the focus of a few state artificial reef programs changed to look seriously at the idea of artificial reefs as true habitat enhancement to benefit the fishery as a whole.

New York Artificial Reef Plan: The first artificial reef on record in the waters of New York was built in the mid-1920s when a number of wooden butter tubs, half filled with concrete, were sunk in Great South Bay. Artificial reefs have also been constructed offshore, the first thought to be reefs at McAllister Grounds in 1949 and Shafer Grounds in 1953 (NYSDEC 1993). The New York State Artificial Reef Program began in 1962. Eleven sites are managed under the current reef system (**Figure 3-4**). Existing reefs were created to provide increased recreational fishing opportunities. They also serve as an attractive site for SCUBA divers.

The New York artificial reef plan (NYSDEC 1993) states that every artificial reef in the waters of New York's marine and coastal district should be planned, sited, and built under the auspices of the State alone. The New York coastal and marine district is defined in Section 13-0103 of the New York Environmental Conservation Law as "… the waters of the Atlantic Ocean within three nautical miles from the coast line and all other tidal waters within the state, including the Hudson river up to the Tappan Zee Bridge." No entity, other than NYSDEC, should be issued permits for artificial reef construction by either the USACE or the NYSDEC Division of Regulatory Affairs. Any artificial reef sites within New York's territorial sea will need to be approved by the State's Office of General Services, Division of Land Utilization, Bureau of Underwater Lands.

New Jersey Artificial Reef Plan: There are 14 permitted reef sites that operate under the New Jersey artificial reef program (**Figure 3-4**). New Jersey's program differs slightly from the New York program in that their artificial reefs are established with the goal of "enhancing New Jersey's fishery resources." (NJDEP 1987). The difference is that the New Jersey artificial reef management program seeks to improve catch per unit effort for both commercial and recreational users. In practice, the New Jersey program, like New York's, has focused on improving recreational fishing opportunities. Unlike New York, New Jersey's program has targeted offshore sites specifically.

Theoretically, anyone may apply for a permit to construct artificial reefs in New Jersey waters. However, applicants must show proof of liability insurance. Thus far, no one but the state of New Jersey has addressed the issue of liability; only the New Jersey Department of Environmental Protection (NJDEP) has constructed artificial reefs in state waters.

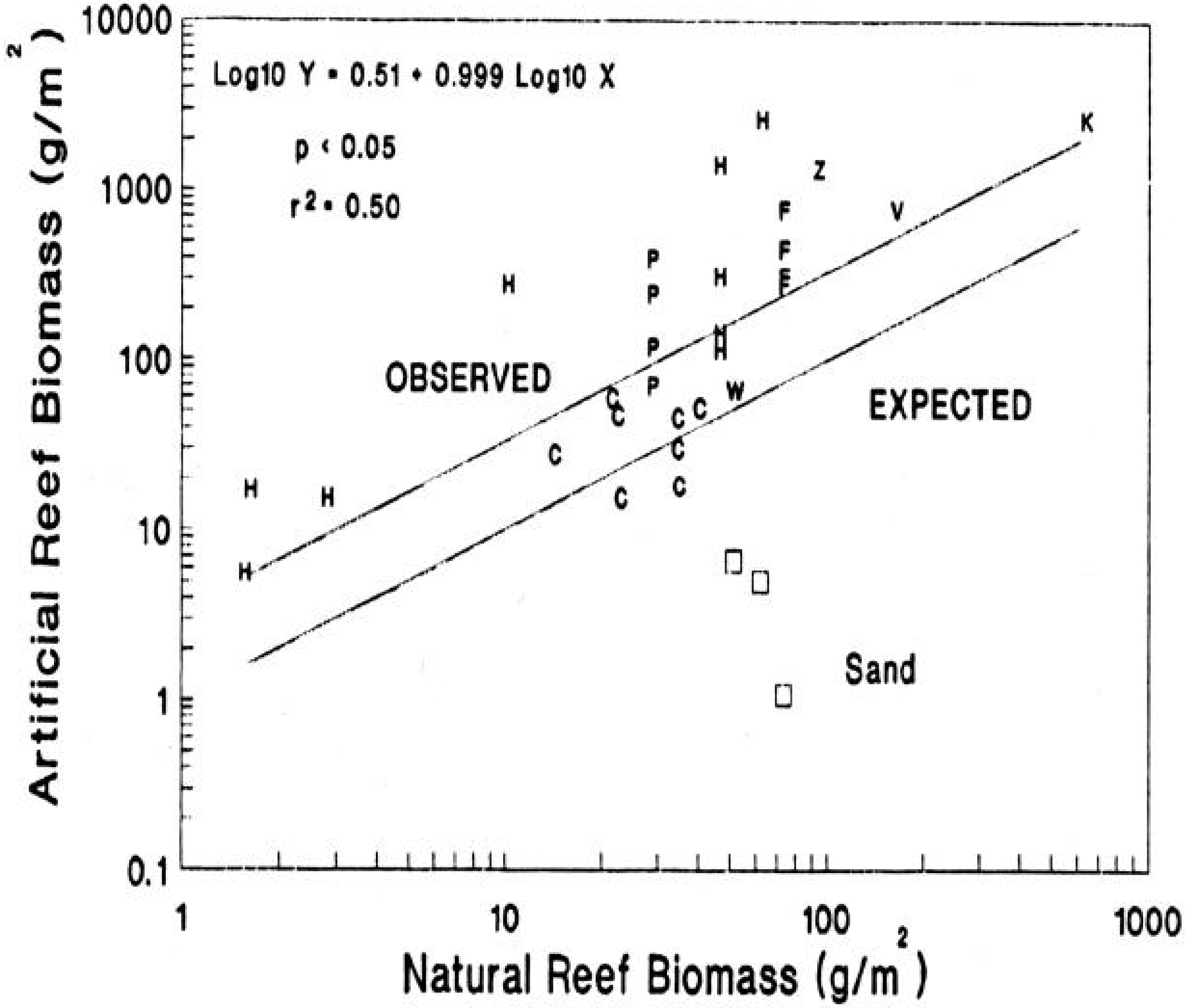
Sanctuaries: The use of sanctuaries or special management areas may reduce fishing pressure on artificial reefs. NYSDEC has authority (Article 13, Title 3 NYCRR) to enact special management zones for artificial reefs. NYSDEC is authorized to "adopt regulations which designate as a special management area any marine or coastal district which contains artificial reefs, natural reefs or wrecks simulating artificial reefs together with the surrounding areas where the biota are dependent upon the physical characteristics of the reef." The department "may adopt regulations restricting the taking of fish, shellfish and crustaceans in any special management area." Although not specified with the same language, NJDEP also has the authority to restrict fishing on artificial reefs. Authorities of both states are limited to their territorial waters (3 miles). The National Marine Fisheries Service (NMFS) and the Mid-Atlantic Fishery Management Council have the authority in federal waters.

Impacts on Navigation and Charting: Vertical relief of artificial reefs, while beneficial to the biotic community, may have negative impacts on navigation and require establishment of navigational aids. The added height of the structure may increase the likelihood of deep-draft vessel groundings. Vessel congestion may also be an issue for shipping traffic as fishermen concentrate near the artificial reefs to take advantage of improved sportfishing.

Artificial reefs affect the accuracy of bathymetry data that is represented on NOAA (National Oceanographic and Atmospheric Administration) navigational charts. Areas where artificial reefs are permitted are "blued out" on the chart. These areas are then labeled as "fish havens" and a note indicating the guaranteed minimum depth for that area is included. All bathymetry soundings for the artificial reef permit area are removed until NOAA has the opportunity to survey the area, following the completion of reef placement. Given the limited funding under which the NOAA bathymetric survey operates, these areas may remain "blued out" on NOAA charts for a considerable length of time. As artificial reef deployments in the United States continue, the increasing prominence of "fish havens" on NOAA charts is met with a good deal of concern from coastal pilots and tugboat operators. This issue is a particular problem in Florida, where the number of artificial reefs permitted, as well as the size of the areas allowed in one permit have increased dramatically. Artificial reef siting should involve all affected parties to ensure that all concerns are voiced and weighed before reef construction begins.

Figure 3-1

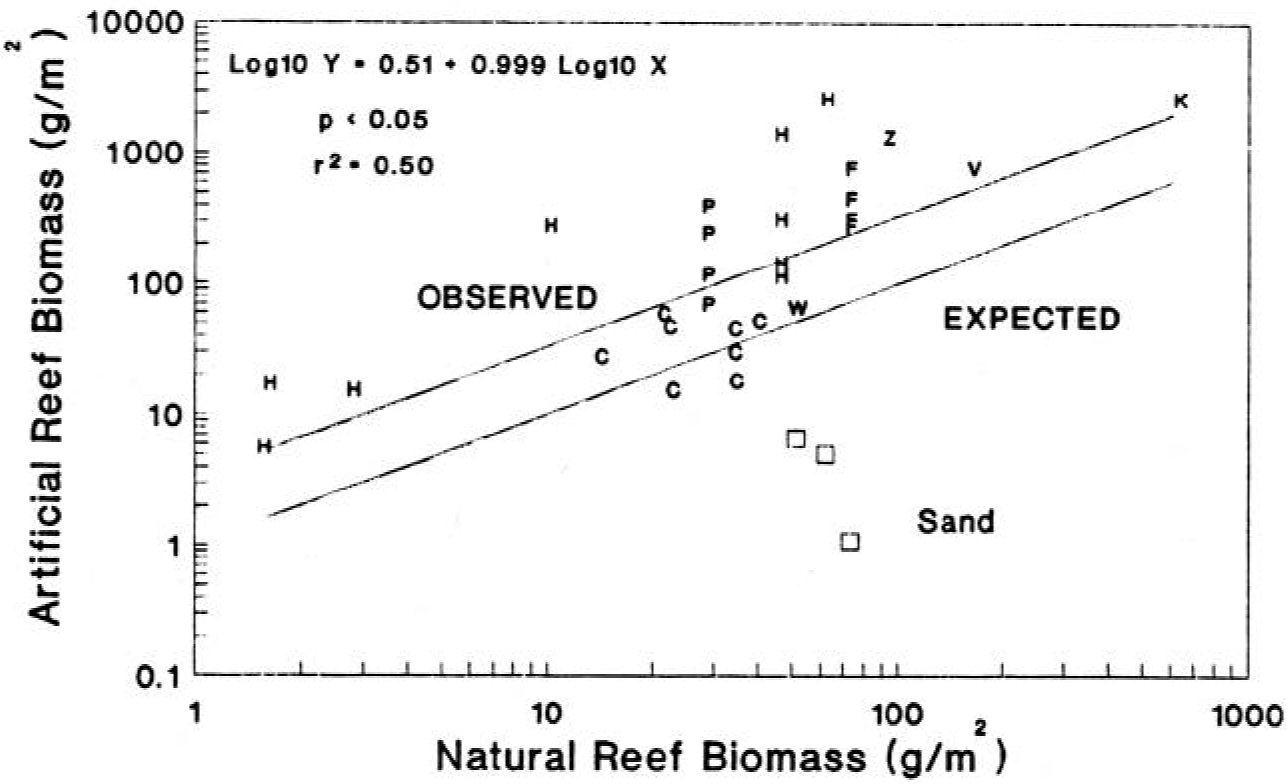
Density of Fishes at Natural and Artificial Reefs



Regression of marine fish density at artificial reefs verses natural control reefs. Squares show sand bottom. Sources: AU, Australia; BC, British Columbia; C, California; E, Enewetak; F, southeast Florida; FW, Florida west coast; G, Guam; H, Hawaii; NC, North Carolina; P, Puerto Rico; V, Virgin Islands; W, Washington. (From Bohnsack et al. 1991)

Figure 3-2

Biomass of Fishes at Natural and Artificial Reefs



Regression of marine fish biomass at artificial reefs verses natural control reefs. Squares show sand bottom. Sources: C, California; E, Enewetak; F, southeast Florida; H, Hawaii; K, Florida Keys; P, Puerto Rico; V, Virgin Islands; W, Washington; Z, New Zealand. (From Bohnsack et al. 1991)

Figure 3-3

Gradients Predicted to be Important for Attraction or Production of Fishes (from Bohnsack et al. 1991)

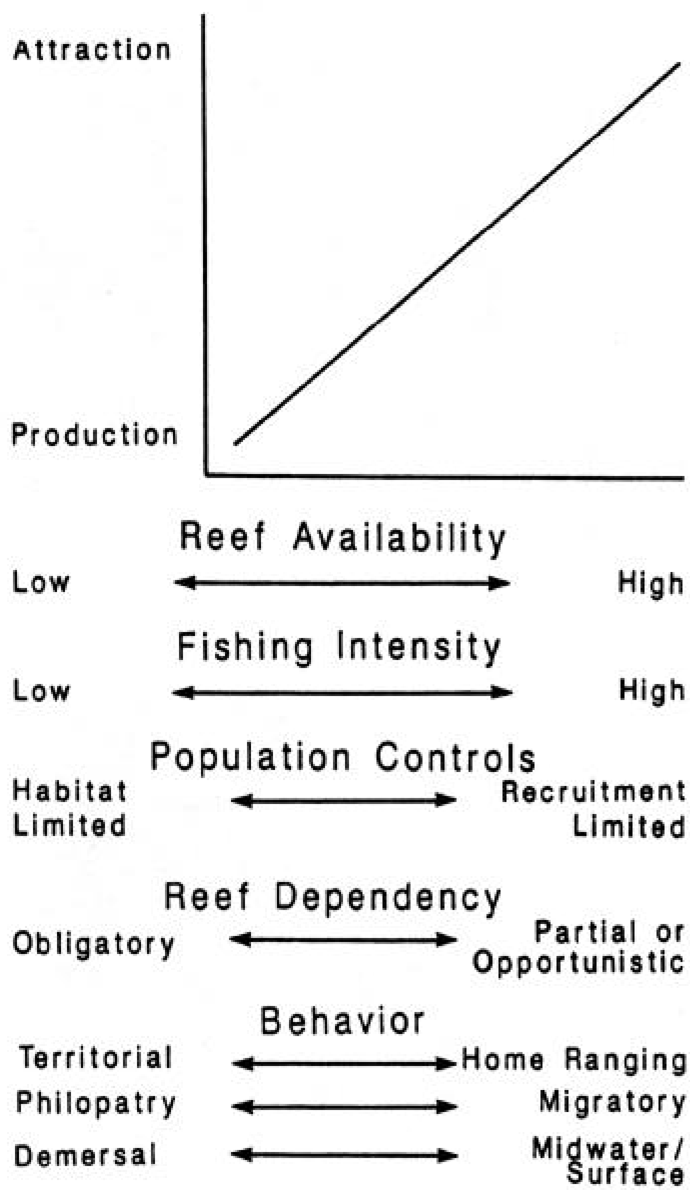
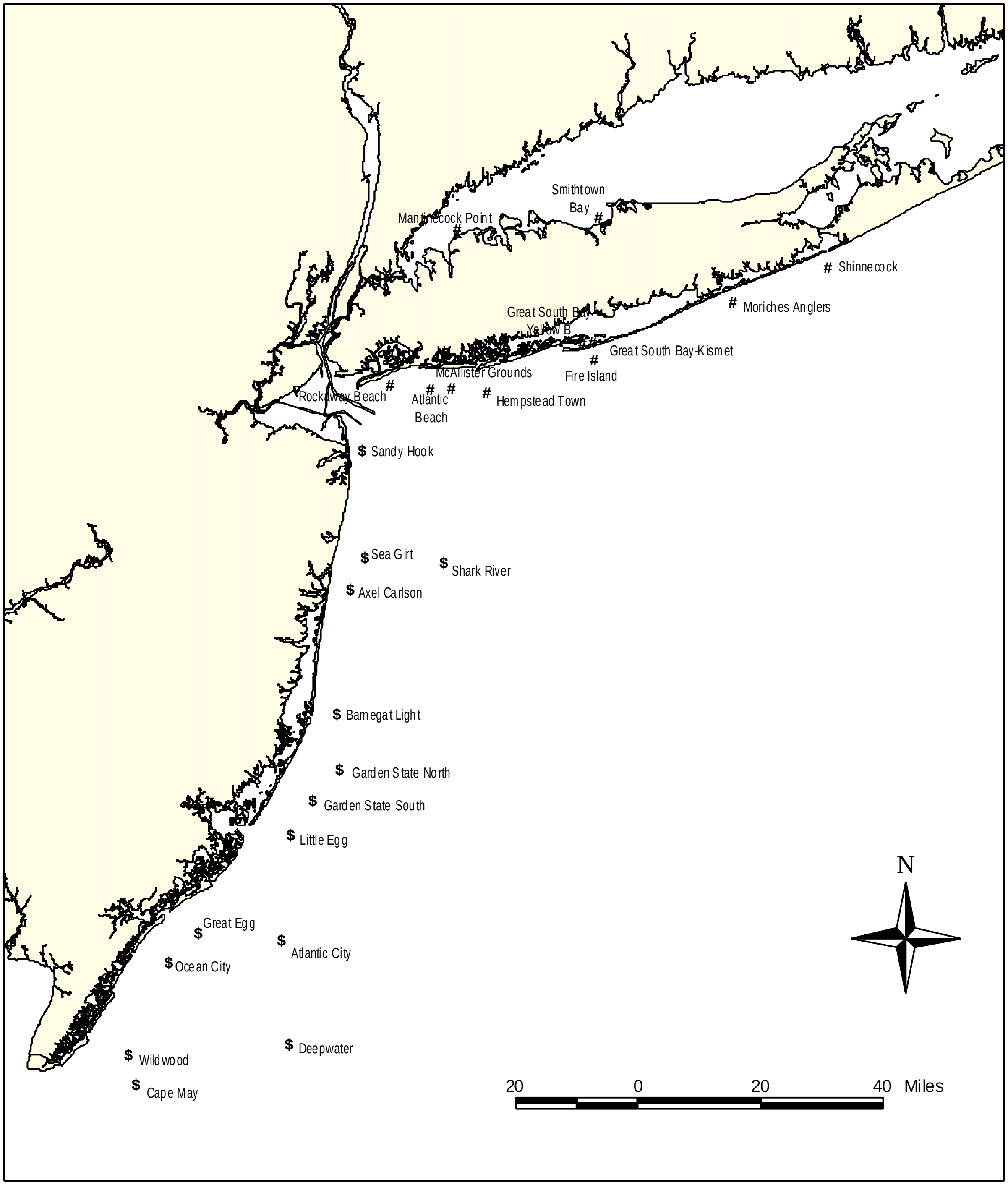


Figure 3-4

Locations of Permitted Artificial Reef Sites



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4: RESTORING SHELLFISH BEDS WITH DREDGED MATERIAL IN NY/NJ HARBOR

USACE Efforts to Build Shellfish Beds

Dredged material deposits in U.S. waters often contain oyster, clam, and mussel shell, particularly along the Intracoastal Waterway. There have been proposals to use dredged material to build shellfish beds, although only a few projects have actually been completed. The USACE's most substantial effort to create a shellfish bed was at Slaughter Creek near Taylors Island, Chesapeake Bay (Earhart et al. 1988). A 2.1 acre mound was formed from 14,000 cubic yards of dredged material (fine sand and silt). Productive oyster bars previously occurred in the immediate area, but the population declined and the reefs eroded, no longer providing a settlement substrate. The dredged material mound was capped in 1987 with a layer of oyster shell about 8-inches thick in the hope that oysters would colonize the reef. Natural processes provided the seed stock for the reef; a nearby healthy reef was probably important in this regard. The Slaughter Creek reef was examined in 1988, 1989, 1990, and 1996 (Daniels et al., submitted). By 1990, the created reef had similar oyster recruitment and size frequencies relative to nearby natural reefs. The Slaughter Creek project cost $90,000 ($43,000 per acre) in 1987 (this figure does not include monitoring). In addition to the Slaughter Creek work, the USACE has built viable, commercially harvestable oyster reefs (ca. 30 acres) in Matagorda Bay, Texas, but these reefs were built with cultch only (i.e., no dredged material was involved). The USACE has not created shell beds for softshell clams, northern quahogs, or blue mussels.

Given the importance of oyster, clam, and mussel beds to the NY/NJ Harbor ecosystem and the limited success the USACE has had in building oyster beds with dredged material, building oyster reefs with dredged material in NY/NJ Harbor warrants further investigation. The next several sections examine the possibilities for the USACE to restore shellfish communities in the Harbor.

Target Species for Shellfish Restoration in NY/NJ Harbor

Northern quahog: Northern quahogs occur over a large portion of NY/NJ Harbor (**Figure 4-1**). Record harvests have recently occurred in Raritan Bay and Sandy Hook Bay. Since northern quahogs are doing well under current conditions, efforts to manipulate the system to increase stocks of northern quahogs would not be a priority. In fact, the state of New York currently manages the Harbor's northern quahogs as a depletion fishery.

Softshell Clam: Softshell clam beds occurred in Sandy Hook and Raritan Bays during 1983-84 (**Figure 4-2**) (Joseph and McCloy 1984). Currently, these beds have dwindled and are now best represented by a small bed on a shoal in the southern portion of Raritan Bay (C. MacKenzie, pers. comm.). The cause of this decline is not known, but may be related to the loss of marsh, seagrass, and shallow water habitat along the NJ shore. Large scale attempts to reestablish softshell clam beds using dredged material should be postponed until the cause of the decline is identified or until small-scale demonstration projects are successful.

Surf Clam: Surf clams are an oceanic species and are not expected to be widely distributed in Sandy Hook or Raritan Bays. Joseph and McCloy (1984) reported a large bed on Flynn's Knoll, a shoal near the mouth of the Harbor (**Figure 4-2**). A 1995 survey found surf clams concentrated, as expected, in the higher salinity waters near the mouth of the Harbor (USACE, unpublished data). There is no evidence that surf clams existed in higher numbers or over a greater geographic range in the Harbor than they do today, and it is unlikely that surf clam populations could be increased in the Harbor via a beneficial use project.

Blue Mussel: Extensive mussel beds occurred in the NJ portion of Raritan Bay and in Sandy Hook Bay during 1983-84 (Joseph and McCloy 1984). **Figure 4-3** only shows the areas that were considered to have commercial potential for northern quahog in NJ waters (NY waters were not surveyed), hence, the extent of mussels, which was an ancillary result from the clam survey, is underrepresented. Unpublished surveys by the USACE from 1994 and 1995 indicate mussel beds throughout the Harbor, with significant numbers present on East Bank Shoal, near Hoffman and Swinburne Islands, Romer Shoal, and Flynn's Knoll. Blue mussels require suitable substrate for attaching their byssal threads. While dredged material can be suitable for attachment, hard materials such as boulders, pebbles, or shells are preferred (Newell 1989). Hence, blue mussels are better viewed as a species likely to benefit from rock reefs than placement of dredged mud, silt, or sand unless those sediments are capped with rock or cultch.

American Oyster: Historically, oysters flourished in NY/NJ Harbor as either self-sustaining or farmed populations. In the colonial period, an oyster bed about 1 mile in diameter and known as the "Great Beds" was present just beyond the mouth of the Arthur Kill and Raritan River (MacKenzie 1990). Exactly how far up the Hudson River and the Kills the oyster population extended is difficult to determine. According to Ingersoll's *The History and Present Condition of the Oyster Industry* (1882), Rev. Samuel Lockwood said that 5 miles above Teller's Point, near Sing Sing, is the uppermost point "where they ever flourished." In the same work, Captain Metzgar mentioned Rockland Lake as the northern limit and "all the way it was almost continuous oyster bottom." Lockwood estimated that, "including the waters inside of Staten Island, not less than 350 square miles of rich oyster banks were open to the people dwelling about New York Bay at the time of its first settlement" (Goode 1887). There was another famous oyster center, near the mouth of the Shrewsbury River, but the populations were declining as early as 1880 (Ingersol 1882). Only scattered oysters (not beds) were present in 1983 (Joseph and McCloy 1984) (**Figure 4-3**) and 1994-95 (USACE, unpublished data).

Summary: Water quality in the harbor has improved significantly in the last 10 years, increasing the likelihood of successful shellfish restoration efforts in the future. The following sections discuss how dredged material might be used in these efforts; however, it should be pointed out that additional studies, such as those being conducted by the Baykeeper, are needed on the current, natural levels of spatfall in the Harbor and the success of small, pilot-scale projects that transplant oysters to the Harbor. While restoring oyster beds in the Harbor would likely yield considerable ecological benefits, it should be noted that such projects would complicate management of northern quahogs and other shellfish resources. Even though the reefs would be established for habitat restoration, rather than restoring the fishery, illegal harvesting might occur and potentially endanger the public if the oysters harbored human pathogens. Further, the public's perception of species that are safe to consume (after depuration) may be significantly damaged by illnesses caused by consuming species illegally harvested from the Harbor.

Oyster Reef Restoration

Ecological Benefits: One adult oyster filters about 1.3 gallons of water each day (Newell 1988). The material filtered reflects the material suspended in the water column (Galtsoff 1964). Oyster reefs act not simply as biological filters, but as processors, taking in some substances, transforming them, and releasing others (Dame et al. 1984). As a result of oyster filter feeding, particulate organic carbon and chlorophyll concentrations decrease and ammonia increases (**Figure 4-4**). Oysters probably induce a shortened cycle of nutrients between the benthos and the phytoplankton, moving large quantities of nutrients to the sediments from the water column (Dame 1993), thus forming an important link between the pelagic and benthic food webs (Newell 1988).

Spatially-complex benthic habitats, such as oyster reefs, support diverse and abundant communities (Bohnsack 1991). Maurer and Watling (1973) associated 154 total species with oyster reefs in Delaware Bay including: 4 sponges, 17 coelenterates, 4 flatworms, 5 nemerteans, 21 annelids, 44 molluscs, 1 sipunculid, 44 crustaceans, 1 pycnogonid, 1 xiphosurid, 8 ectoprocts, 1 urochordate and 3 vertebrates. **Table 4-1** lists resident and transient finfish common to oyster reefs. Oyster reefs also provide attachment sites for the eggs of many small fishes, such as gobies and blennies, as well as the oyster toadfish (*Opsanus tau*) (Hildebrand and Cable 1938, Hildebrand and Schoeder 1927, Murdy et al. 1997). Reefs that support populations of mobile invertebrate infauna and epifauna will provide prey for resident fishes as well as larger, transient bottom feeding fishes.

Importance of Three-Dimensional Reefs: Creation of a three-dimensional oyster reef, (i.e., a reef with vertical relief) will promote a healthy oyster population as well as provide habitat advantages for other species associated with the reef (Lenihan and Peterson 1998). During summer months when the water column is often strongly stratified, bottom waters can become hypoxic and result in mortality of oysters and other species. However, reefs with enough vertical relief to be raised above the benthic boundary layer experience considerably less mortality. Reef height also affects local hydrodynamics, creating down-current, low-flow zones that are attractive to larvae and enhance the survival and growth of juvenile oysters (Lenihan et al. 1996). Finally, there appears to be a correlation between vertical position on a three-dimensional reef and oyster disease (Lenihan et al., in press). Disease prevalence and mortality are higher at the base of the reefs where water flow is the slowest. Lenihan et al. (in press)

Table 4-1:

Fish at Flag Pond oyster reef (Breitburg 1997 and unpubl. data), Fisherman's Island (M. Luckenbach, VIMS, unpubl. data), Piankatank River (J. Harding and R. Mann, VIMS, unpubl. data), and South Carolina (Coen et al. 1997). Species listed as facultative residents are represented by at least some individuals that remain on the oyster reef for several months. Some species listed as transients may actually be facultative residents. However they are highly mobile within the reefs, and duration of residency of individuals has not been studied. Flag Pond data are from dive surveys only; Piankatank data are from trawls along the reef base; Fisherman's Island data are from gill nets, drop nets, and trawling as well as from diver surveys; South Carolina data were collected with lift nets that were fished at low tide (Wenner et al. 1996). Although these species are present in the mid and south Atlantic, they are only provided as an example of finfish communities associated with oyster reefs. Species that occur on oyster reefs in Raritan and Sandy Hook Bays may vary.

	Flag Pond (MD)	Piankatank (VA)	Fisherman's Island (VA)	Inlet Creek & Toler's Cove, (SC)
Oyster Reef resident fishes				
naked goby (*Gobiosoma bosc*)	X	X		X
skilletfish (*Gobiesox strumosus*)	X	X	X	
striped blenny (*Chasmodes bosquianus*)	X	X	X	X
feather blenny (*Hypsoblennius hentzi*)	X			
oyster toadfish (*Opsanus tau*)	X	X	X	X
Facultative residents				
black sea bass (*Centropristis striata*)	X			
northern pipefish (*Syngnathus fuscus*)	X		X	
Atlantic spadefish (*Chaetodipterus faber*)	X	X		
darter goby (*Gobionellus boleosoma)*				X
seaboard goby (*Gobiosoma ginsburgi*)			X	
Transients				
striped bass (*Morone saxatilis*)	X	X	X	
summer flounder (*Paralichthys dentatus*)	X	X	X	X
winter flounder (*Pleuronectes americanus*)	X			
spot (*Leiostomus xanthurus*)	X	X	X	X
pinfish (*Lagodon rhomboides*)	X	X		X
inshore lizardfish (*Synodus foetens*)	X			
American eel (*Anguilla rostrata*)	X			
striped burrfish (*Chilomycterus schoepfi*)	X			
Atlantic silverside (*Menidia menidia*)	X	X		X
Atlantic croaker (*Micropogonias undulatus)*		X		
common carp (*Cyprinus carpio)*		X		
Atlantic Menhaden (*Brevoortia tyrannus)*		X		
pigfish *(Orthopristis chrysoptera)*		X		X
silver perch (*Bairdiella chrysoura*)		X	X	X
spotted hake (*Urophycis regia*)		X		
northern sea robin (*Prionotus carolinus*)		X	X	
butterfish (*Peprilus triacanthus*)		X		
hogchoker (*Trinectes maculatus*)		X		
northern puffer (*Sphoeroides maculatus*)		X		
bay anchovy (*Anchoa mitchilli*)			X	X

Table compiled by Denise Breitburg, The Academy of Natural Sciences, Estuarine Research Center.

hypothesized that oysters in low flow conditions have the greatest susceptibility to Dermo (*Perkinsus marinus*) infection because of their poor physiological condition.

Using Dredged Material to Create Oyster Reefs in NY/NJ Harbor

The primary means of restoring oyster populations is to provide additional hard substrate (cultch) for larvae (veligers) to settle upon (veligers unable to settle upon a suitable hard substrate die). Typically old oyster shells are used, however, in some coastal areas this material is scarce and alternatives such as clamshells, concrete rubble, or fly-ash composites are used. In recent years, the USACE has created oyster reefs in the upper Chesapeake Bay by depositing dredged material in areas historically known to support oyster populations, and capping the dredged material mounds with a layer of oyster cultch (Earhart et al. 1988).

The use of dredged sediments allows for the creation of the 3-dimentional aspects of the oyster reef without the use of a shell core. This practice saves shell, which is becoming a resource in short supply. To seed their beds with clean shell, the Delaware Bay and Long Island Sound oyster fisheries use imported "fossil" oyster shell, which is mined from historic oyster beds in Maryland. Sources of buried ancient shell are clearly in limited supply. The sediment core would replace many layers of shell unavailable for use as habitat or structure by organisms that colonize only the surface of the reef. A one acre oyster reef with one yard of relief would require 5000-7000 cubic yards of sediment for the reef core, depending on compaction. The optimal sediment core composition of a restored reef would be comprised of coarse sand and shell mixture. The sediment mound would be capped with a veneer of clean shell. For sessile marine invertebrates, larval settlement behavior and choice of substrate for attachment is critical for the success of the adult organism (Turner et al. 1994). The oyster shell cap not only provides a hard surface for the larvae to settle, but also provides a chemical cue for the larvae. Oyster larvae appear to choose between substrates, reacting to waterborne chemical clues given off by the oyster shell (Turner et al. 1994, Tamburi et al. 1992).

The amount of clean shell cap required is a function of the sediment core material and major predators of the oyster population. Soft sediments require more shell material because some portions of the shell cap will sink into the sediment and become unavailable for oyster settlement. On firmer coarse sand and shell mixtures, less shell would be required. Shell cap thickness ranges from 6 to 8 inches for restored reefs in the Chesapeake Bay (J. Wessen, pers. comm.) to only a thin veneer 2 or 3 shells thick on the flat, commercial grounds of Long Island Sound. Thicker layers of shell may provide some refuge from oyster predators, especially blue crabs. Ten thousand bushels per acre of clean shell has been successfully used in Virginia, while prosperous Connecticut fisheries often use only 2,000 bushels per acre. Five thousand bushels per acre should provide a three inch thick cap over the sediment mound (J. Wessen, pers. comm.). Experimentally varying the thickness of shell may provide useful information on the role of interstitial space on a healthy oyster reef population. The price of clean shell, purchased by NJDEP for Delaware Bay from a Maryland contractor, was $0.67 per bushel delivered and planted.

Natural levels of spatfall need to be measured, but since resident larval supply would probably be low initially, projects should expect to annually purchase seed oysters, usually in the 2.5 cm (1 inch) size range, from commercial culture facilities for distribution over the shell cap until a self-sustaining population can be established. The price of seed oysters from areas of natural set on the Connecticut side of Long Island Sound ranges from $7 to $25 per bushel, depending on quality (J. Volk, Conn. Dept. of Agriculture, pers. comm.). If the goal is to build a self-sustaining reef, it should be placed in an area where larval supply is high during the settling period (M. Luckenbach, VIMS, pers. comm.). Oyster larvae are meroplanktonic and remain in the water column for two to three weeks after fertilization (Bahr and Lanier 1981). Hydrologic models developed for dredged material management should prove useful in determining what parts of the harbor are likely to retain the larval supply for the required time. Salting the reef with adult oysters may hasten establishment of a self-sustaining population. Female oysters spawn for the first time in their second year when 3.0-4.7 cm (1.2-1.8 inches) long (Galtsoff 1964), and each female produces 23 million to 86 million eggs per spawning (Davis and Chanley 1955). The Connecticut State Aquaculture Program Office reports that adult, brood stock oysters from Oyster Bay, Long Island, sold for approximately $60 per bushel in 1997, with 200 individuals making up an average bushel (John Volk, Conn. Dept. of Agriculture, pers.comm.).

A desirable area for a restored reef will be indicated by the presence of bryozoans or barnacles attached to old shell (J. Wessen, pers. comm.). The presence of clean shell in an area often indicates active, moving sand. Oyster restoration cannot be accomplished in these areas, as the oysters will die from the erosive effects of sand scouring.

In prehistoric and colonial times, most oyster beds were at depths of 2-16 ft and in salinities of about 7-15 ppt (MacKenzie 1997). American oysters in the northeastern United States are limited to subtidal habitats because of ice shear (Dame et al. 1984). Beds covered by less than 6 ft of water, with shells that are 1 inch long and smaller, are a poor substrate because they are in constantly moving water during windy periods and small spat attached to them cannot survive (MacKenzie 1983). Since a vertical relief of at least 3 ft is favorable, and having 3 feet or more of water above the reef will protect it from wave action and ice shear, locations for restored reefs will need to be seaward of the 6 foot contour. A candidate restoration site map was developed by combining this criteria with knowledge of the historic distribution of oysters in the harbor (**Figure 4-5**). This map indicates general areas that meet all of the following characteristics: 1) natural oyster beds or beds maintained through frequent seedings have existed in the past century (MacKenzie 1992, USACE 1996), 2) waters deeper than 6 ft, and 3) areas large enough that at least 50,000 cubic yards of dredged material would be needed to build oyster habitat. All areas would require additional study to verify sediment and water quality suitability, to examine threats from disease and predators, and to examine likely growth and survival rates of young and adult oysters. Results of these studies would likely reduce the areas shown in **Figure 4-5**.

Timing of Restoration: Timing of reef construction and the degree to which reef restoration affects prey for newly settled fish may strongly affect the resident oyster reef fish assemblage. In Flag Pond, a study area in the Chesapeake Bay, peak recruitment of the most abundant resident reef fish occurred within the same brief period during mid-summer. Reef restoration occurring during the summer could impact the recruitment for that year, however it would likely have little or no residual effect on the following years' recruitment.

Threats to Oyster Reef Restoration: In the relatively high salinity areas along the Connecticut coast, fouling organisms [slipper shells (*Crepidula fornicata* and *Crepidula plana)*; barnacles (*Balanus eburneus* and *Chthmalus fragilis)*; bryozoans (*Schizoporella unicornis* and others)] and predators [starfish (*Astererias forbesi)*; oyster drills (*Eupleura caudata* and *Urosalpinx cinerea)*; and crabs (*Cancer irroratus* and xanthids)] are abundant (MacKenzie 1983). In areas where salinities are above 15 ppt, oyster drills and diseases that kill oysters are more prevalent. Fouling occurs less on beds in salinities below 15 ppt. For these reasons, siting the restoration effort in lower salinity waters may result in decreased oyster mortality.

Protozoans are the most common cause of epizootic outbreaks that result in massive bivalve mortalities (Dame 1996). The notable diseases that affect oysters are Dermo, caused by *Perkinsus marinus*, and MSX, caused by *Haplosporidium nelsoni*. While not harmful to humans, these diseases have seriously reduced oyster harvests in Chesapeake Bay and other mid-Atlantic estuaries. In general, the highest incidence of disease occurs in high-salinity waters (>15 ppt). Adult oysters appear to be most susceptible to Dermo after spawning, and mortality increases with age and size (Lauckner 1980).

Susan Ford (pers. comm.) from Rutgers University examined several oyster samples from the Raritan Bay area for diseases in the 1980s. MSX prevalence was found to be up to 50%. Dermo was also present in the area in the early 1990s, and was progressing northward. As both MSX and Dermo are episodically, if not continuously, prevalent to the north and south of the NY/NJ Harbor Area, it would be safe to assume that both diseases occur in the Harbor with equal frequency. Dave Relyea (pers. comm.), with Flowers Brothers Commercial Oyster Culture in Oyster Bay, stated that Dermo is often present in Long Island Sound, resulting in relatively low mortality rates that vary slightly from year to year. MSX prevalence and mortality is more episodic. While a major outbreak of MSX resulted in approximately 60% mortality in 1997, the last significant episode of MSX in Oyster Bay was from 1983 to 1985.

The Baykeeper, an environmental non-governmental organization, is examining the possibility that water quality in the Hudson-Raritan Estuary has improved to the point that viable oyster populations can be supported. As an initial examination of water quality, the Baykeeper has been placing bags of clean oyster shell in a variety of locations to determine if there is sufficient spat settlement to support a restoration effort (**Figure 4-6**). Growth, mortality, and predation of recruited larvae will be measured. Although limited by the number of samples, these early studies may provide valuable information for efforts to restore oyster reefs.

Regulatory Considerations and Projected Agency Support

No areas in the NY/NJ Harbor are open for direct consumption of shellfish. Some portions of the harbor are open for transplanting (NY and NJ) or depuration (NJ) (**Figure 4-7**).

Designations of restricted and closed areas are revised each year as dictated by water quality conditions.

NYSDEC considers shellfish restoration in harbor waters to be the creation of an attractive nuisance (D. Barns, pers. comm.). NYSDEC's position is that adding shellfish to contaminated waters will require increased enforcement and monitoring both on the water and in the markets. NYSDEC is generally opposed to efforts to restore or enhance shellfish resources in NY/NJ Harbor and in fact manages northern quahogs as a depletion fishery. There are similar concerns in NJ, however staff from NJDEP support the concept of shellfish restoration and enhancement, noting that there are already polluted waters containing shellfish and that these resources have been successfully regulated for some time by closely monitoring removal and sale of shellfish from restricted grounds.

Since construction of a three dimensional shellfish reef may pose a threat to navigation, coordination with the U.S. Coast Guard (USCG) and NOAA charting offices, as discussed for artificial reefs in Chapter 3, will be necessary.

Use of dredged material for construction of shellfish reefs in NY/NJ Harbor may be authorized under Section 404 (b)(1)of the Clean Water Act of 1972, Section 1135 of WRDA 1986, and Section 206 of WRDA 1992. Section 216 of the River and Harbors Act of 1970 authorizes the USACE to review navigation projects and recommend modifications that would involve habitat creation/restoration using dredged material. Habitat development projects in the Harbor are also subject to regulation by individual state (NY and NJ) statutes, and permitting authorities.

Figure 4-1

New Jersey Shellfish Inventory, 1983. Distribution of the hard clam, *Mercenaria mercenaria.*

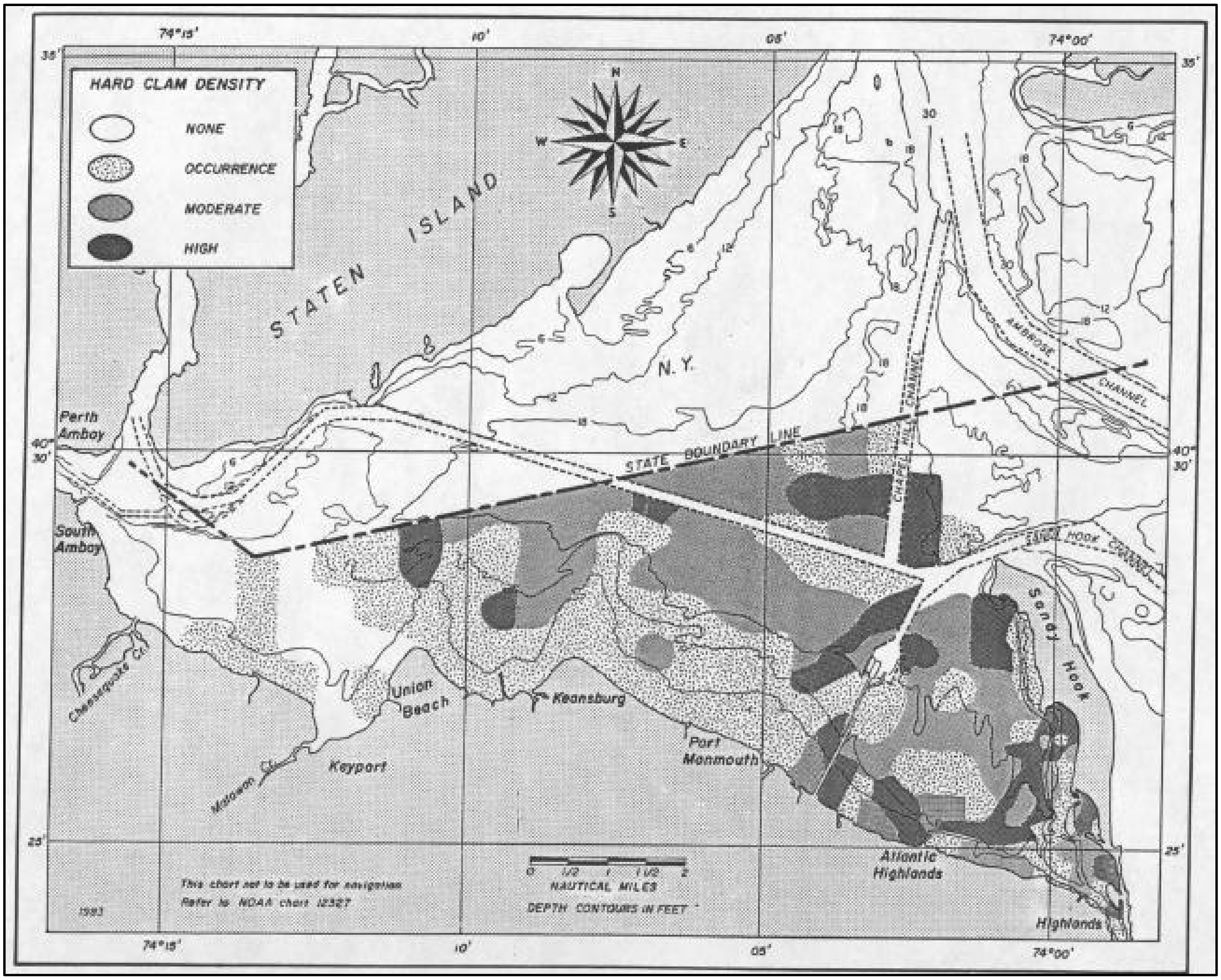

Figure 4-2

New Jersey Shellfish Inventory, 1983. Distribution of the softshell clam, *Mya arenaria*, and the surfclam, *Spisula solidissima.*

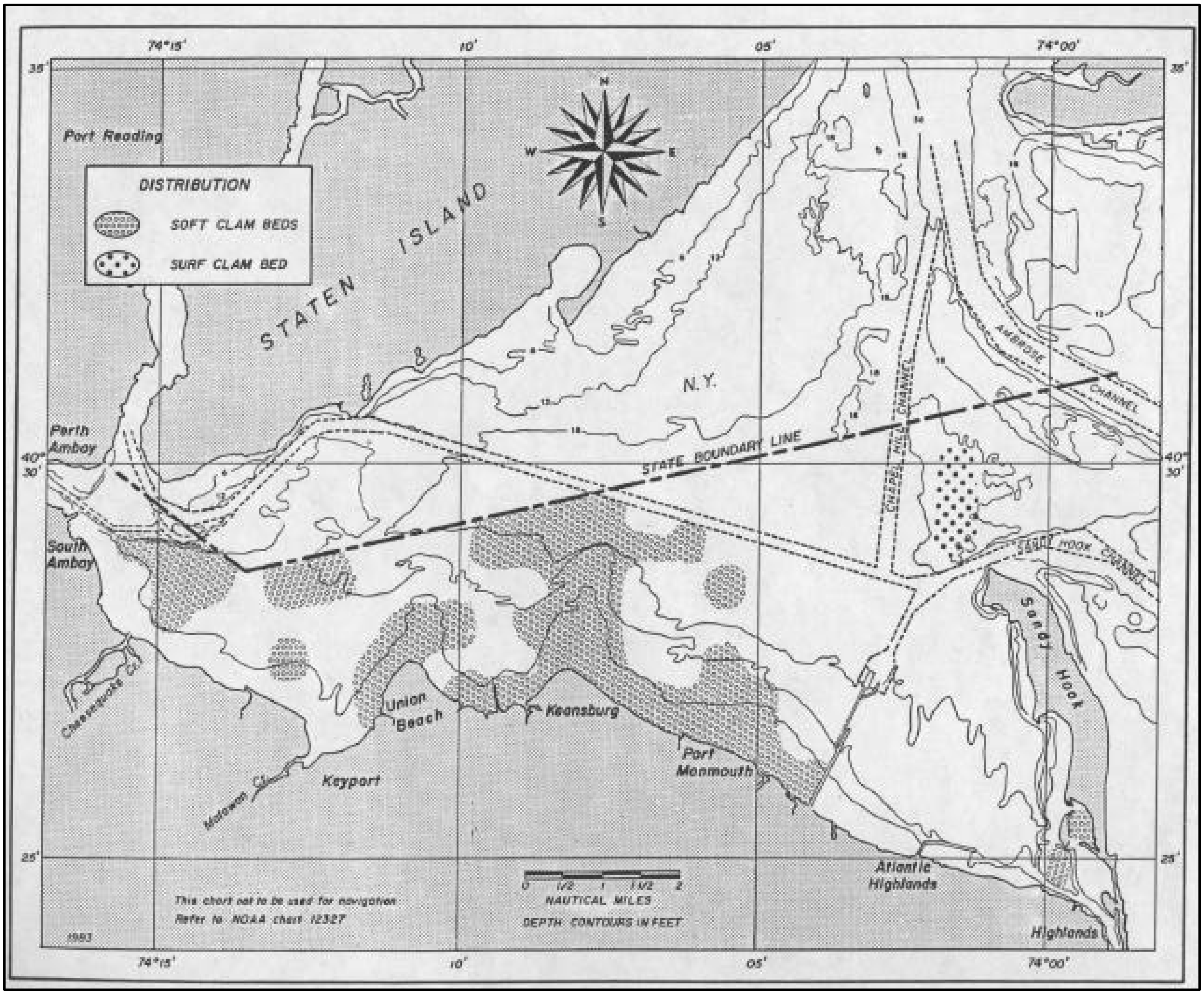

Figure 4-3

New Jersey Shellfish Inventory, 1983. Distribution of the blue mussel, *Mytilus edulis*, and the American oyster, *Crassostrea virginica.*

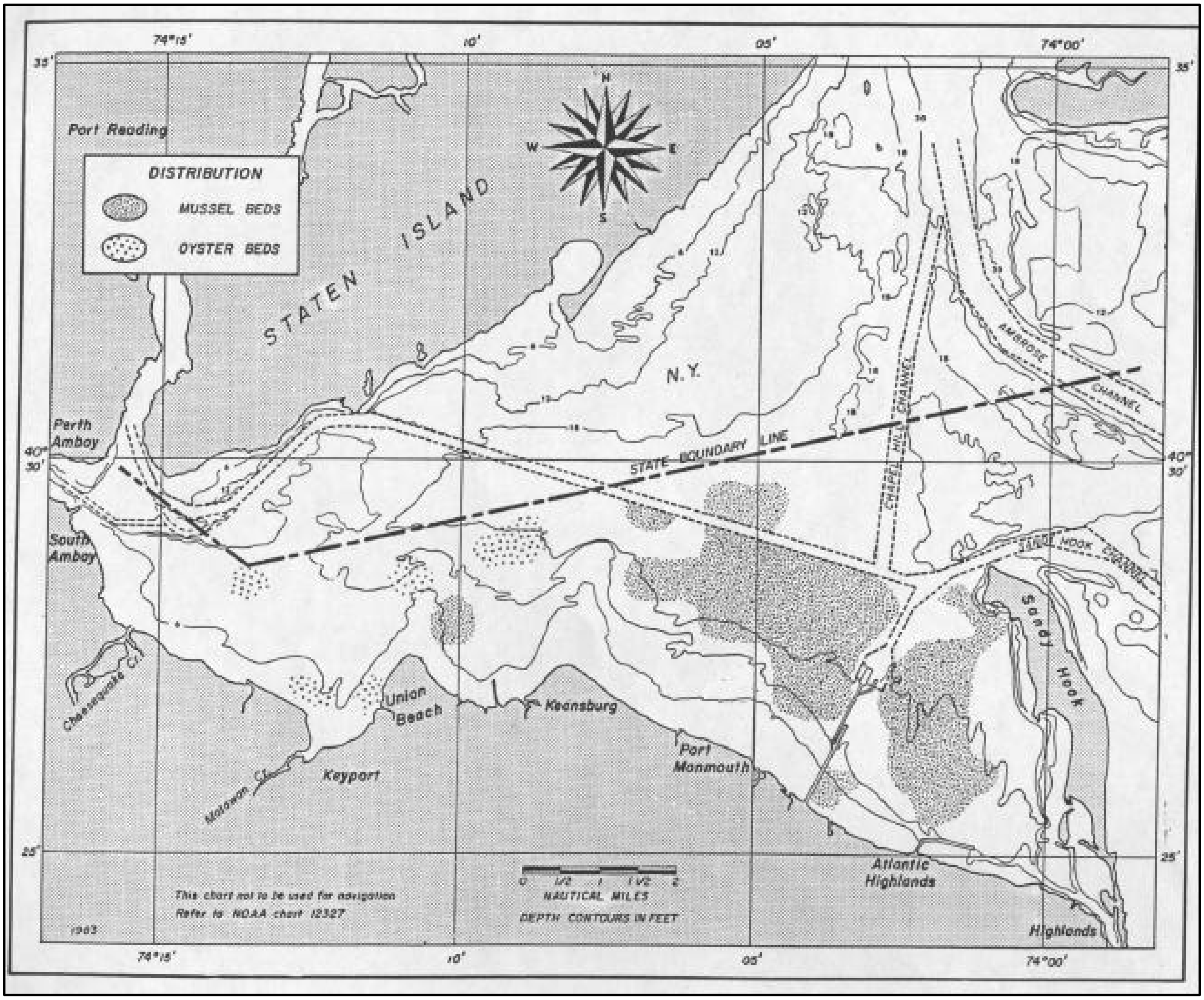

Figure 4-4

A Conceptual summary of the material processing roles played by bivalve filter feeders. (From Dame, 1993)

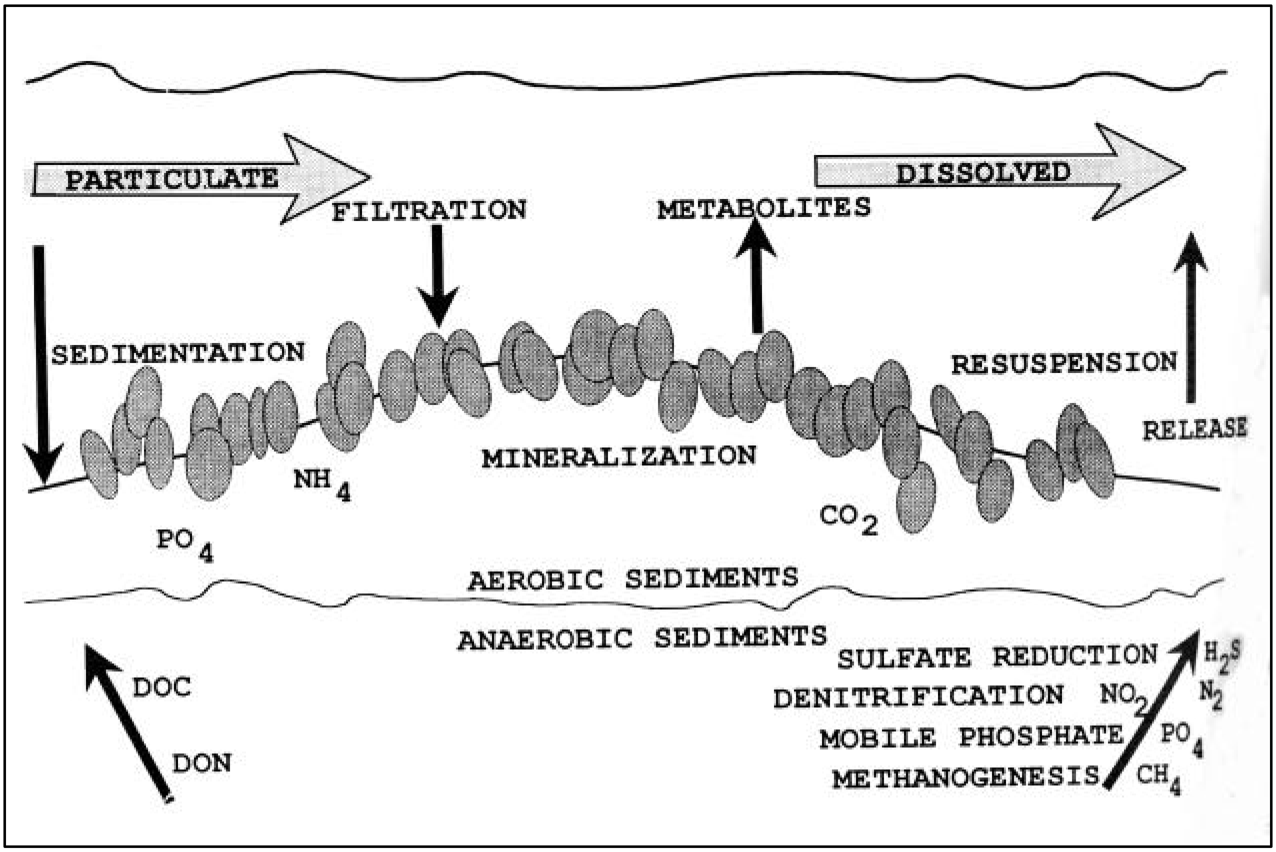

Figure 4-5

Potential areas for oyster restoration based on water depth (> 2m), historic distributions of oysters, and size of area (at least 50 K cubic yards of material needed to build the reef).

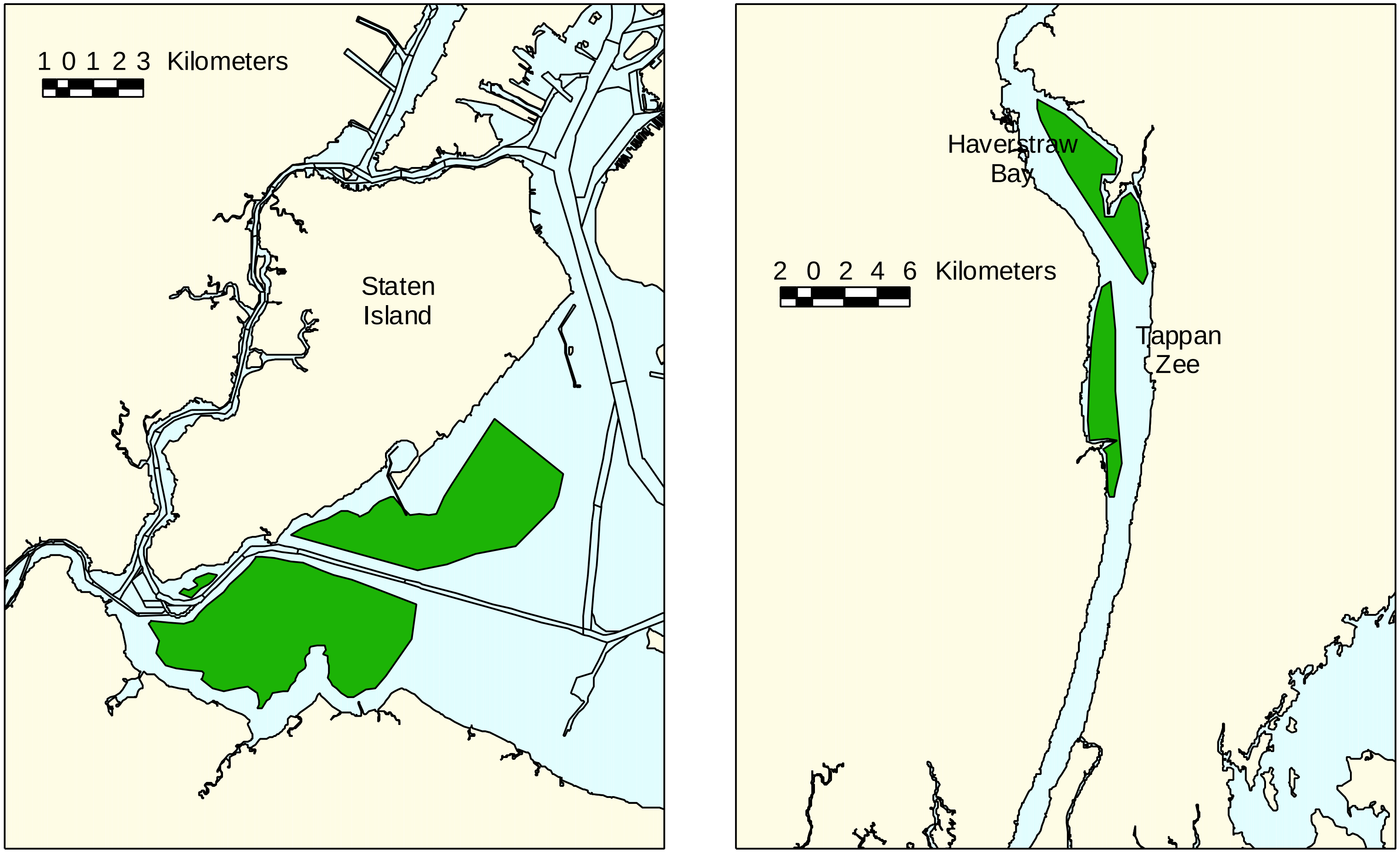

Figure 4-6

Baykeeper Hudson-Raritan oyster restoration feasibility study 1996-97.

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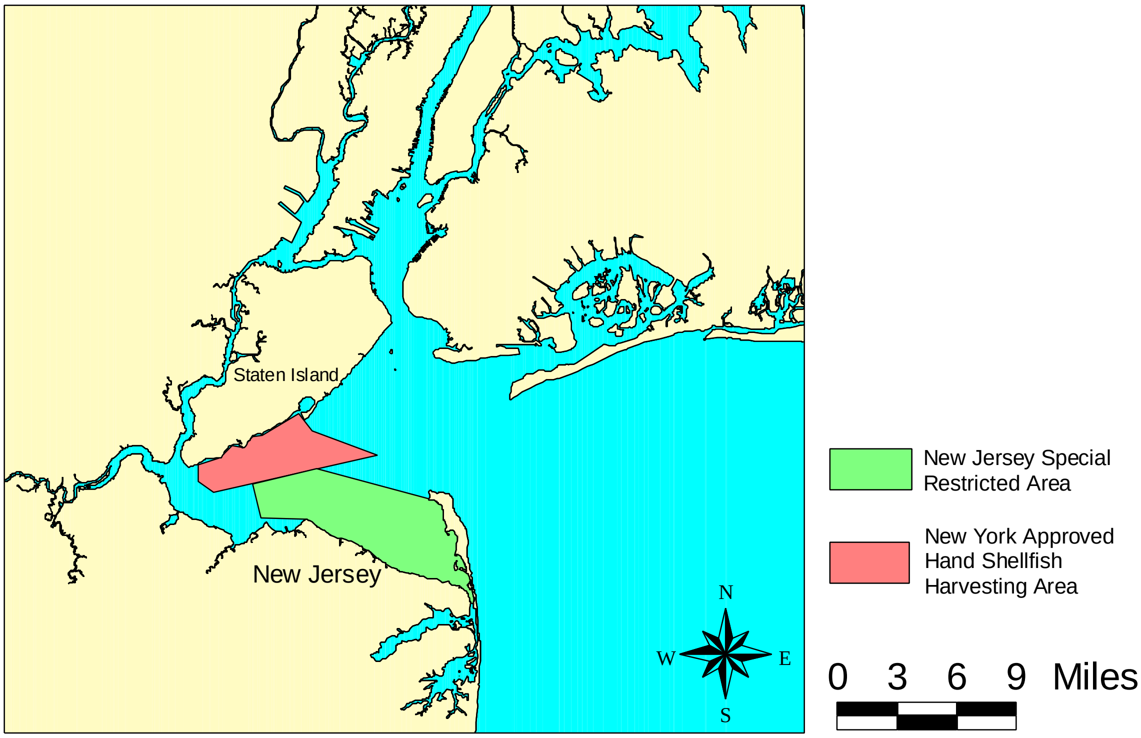
Figure 4-7

Areas open in 1998 to commercial shellfish harvest.



Shellfishing in these areas is open only to commercial harvesters holding transplant permits.
No direct harvest by the public is permitted.
Shellfishing in areas outside these zones is prohibited.

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5: FILLING OF SUBAQUEOUS PITS USING DREDGED MATERIAL IN NY/NJ HARBOR

Commercial demand for construction and fill materials has led to substantial dredging of sand deposits in Lower and Jamaica Bays of NY/NJ Harbor (Broughton 1977, USACE 1991). Removal of sand has significantly altered the bathymetry of the Lower Bay. The depressions in the basin created by sand mining are referred to as *subaqueous borrow pits*. These borrow pits are dredged below the natural bathymetric contours of the Harbor for uses other than navigational purposes.

Borrow pits in NY/NJ Harbor are generally characterized by deep water, reduced hydrodynamic exchange, changes in sedimentation patterns, and altered biological communities relative to adjacent ambient bottom areas (Swartz and Brinkhuis 1978, Bokuniewicz et al. 1986, USACE 1991). The specific characteristics of sediment type, sedimentation rate, DO level, and abundance and diversity of biological communities are largely dependent on the location of each pit. Bokuniewicz et al. (1986) reported silt and mud sedimentation rates between 1.6 and 3.5 in/yr for borrow pits on the West Bank of NY/NJ Harbor. These rates are approximately 100 times greater than surrounding areas where little or no mud accumulates because of tidal currents. These rates also differed from borrow pits on the East Bank of the Harbor which showed little or no accumulation of sediment. Swartz and Brinkuis (1978) found significant differences in oxygen levels between borrow pits on the East Bank compared to borrow pits on the West Bank in NY/NJ Harbor. They attributed the differences in DO to higher sedimentation rates of organic material on the West Bank. Lower flow rates on the West Bank decreased near-bottom DO concentrations compared to East Bank borrow pits. Bokuniewicz et al. (1986) reported significantly lower abundance and diversity of infaunal and epifaunal organisms in borrow pits compared to adjacent control sites. In contrast Cerrato et al. (1989) characterized the East Bank Pits of the Harbor as “preferable benthic habitats” compared to the West Bank borrow pits. The question of whether or not the Harbor system, overall would benefit from filling of borrow pits is dependent on the status of each individual pit and the site-specific benefits, if any, that would be attained by filling each pit.

One option under consideration by the District is to create new subaqueous borrow pits by dredging sediment from specific locations in the Harbor (primarily Lower Bay) and filling the pits with dredged material (USACE 1996). The sediment being removed could be used for several commercial purposes (eg. construction, etc.). This plan, however, is considerably more expensive than simply filling in existing pits and is not a preferred option for the current Dredged Material Management Program (DMMP).

Other concerns brought to the attention of the District are whether the borrow pits are being used as nursery or foraging habitats by migratory and resident fish species (even though they are unnatural features of the Harbor bathymetry) and if filling the pits would eliminate viable habitat for those species (Bokuniewicz et al. 1986, Clarke et al. 1998). These concerns will be addressed later in this section.

Previous USACE Efforts Involving Subaqueous Pits

Previous research on subaqueous borrow pits has addressed concerns of pit stability, whether pits filled with contaminated dredged material and immediately capped with clean dredged material would effectively contain contaminants, the durability of pit caps, and how long a pit could hold contaminated materials. In a “best case” scenario, a borrow pit to be filled with dredged material would be relatively deep compared to the surrounding area, would have steep (approximately 30 degrees) sides, and would be below the wave potential (or effective wave energy) of the given system (Bokuniewicz et al. 1986). The cap for such a pit would consist of clean sediment of greater particle size than the surrounding area and would be 3-6 ft thick. By optimizing these criteria, a borrow pit could be filled with contaminated dredged material, providing a stable, undisturbed containment area where wave action, tidal currents, and bioturbation would not effect the deposited materials.

The ecological characterization of subaqueous borrow pits has been a focus of research for the past two decades (Swartz and Brinkhuis 1978, Kinsman et al. 1979, Brinkhuis 1980, Bokuniewicz et al. 1986). However, information on the function and ecological benefits of borrow pits to an ecosystem is limited. Hydrodynamic effects of borrow pits include an increase in wave energy and tidal range in a basin (Kinsman et al. 1979). Waves and tides traveling across a basin speed up when passing over the deeper water of a borrow pit, enhancing the strength of waves reaching adjacent shorelines. This increase could potentially lead to greater erosion of shorelines. Borrow pits have also been shown to have slower currents compared to surrounding areas; this results in higher sedimentation rates (Clarke et al. 1998). Swartz and Brinkhuis (1978) found that borrow pits with highly organic sediments increased the oxygen consumption rate in the pits. The higher rate of consumption led to lower DO which could limit the abundance and diversity of the benthic fauna. Their results, however, varied based on the location of each borrow pit. The borrow pits they investigated on the West Bank of the NY/NJ Harbor did have an effect on the ecology of the surrounding basin because of a very high organic sedimentation rate. The borrow pits on the East Bank of the Harbor did not have any noticeable ecological effects. Higher rates of water flow and less organic sediment in the East Bank Pits resulted in lower oxygen demand in sediments, decreasing the effects the pit had on DO in adjacent areas. By filling borrow pits that exhibit high oxygen consumption rates, flow rates in he surrounding areas would increase toward historical levels, high organic sedimentation would decrease, DO levels would increase, and benthic invertebrate communities would experience less stressful conditions, potentially increasing in abundance and diversity.

Borrow pits containing organic, fine sediments may also potentially change benthic invertebrate community composition of the surrounding area (Brinkhuis 1980). Bokuniewicz et al. (1986) found that benthic invertebrate abundance and diversity in borrow pits of high silt and clay content were lower compared to control areas of the same basin. They also suggested that the pits have some effect on the abundance and diversity of benthic organisms directly adjacent to the pit itself and that these areas were intermediate in composition compared to control areas and the pit itself. Borrow pits in general do not necessarily have a limiting effect on benthic communities. Cerrato et al. (1989) found that the borrow pits of the East Bank of the Lower Bay were "preferable benthic habitats" because of well oxygenated waters and sediments of high sand content with lower sedimentation rates. Again, borrow pits only appear to limit the ecology of surrounding systems when the basins themselves are characterized by low water flow and high organic sedimentation rates.

The utilization of borrow pits by fishes remains unresolved and highly debated. Bokuniewicz et al. (1986) found a greater abundance and diversity of fishes in deeper water near borrow pits compared to shallow, sandy sites. They felt that filling the borrow pits to ambient depths would decrease the fish populations of the basin. In contrast, Clarke et al. (1998) found no significant difference between fish densities in the Lower Bay CAC (Construction Aggregate Corporation) pit compared to a control site. Other studies investigating the abundance and diversity of fish populations in the borrow pits include Pacheco (1983) and NMFS (1984). Each of these studies found greater abundance and diversity of fish populations in the CAC Pit compared to the Large West Bank Pit, but did not investigate differences in fish distributions in shallow-water control areas. Woodhead and McCafferty (1986) did sample control sites and found no differences in fish distribution between the control areas and the borrow pits of the Lower Bay.

Much of the previous research on the ecology of borrow pits appears to be contradictory. Comprehensive studies, involving multiple borrow pits and adjacent, shallow-water control areas, would more clearly define the ecology of borrow pits. Such studies should include similar techniques for sampling DO, water temperature, species abundance and diversity, pit volumes, sediment grain-size distribution, sediment organic content, contaminant levels, current flow, and sedimentation and erosion rates. Comparison of such detailed seasonal data between control sites and borrow pits would permit greater accuracy in determining if borrow pits offer Harbor-wide detriments or benefits.

Several economic benefits could result from filling subaqueous borrow pits with dredged material. First, and foremost, is the potential to improve water quality in the Harbor by increasing tidal flow and eliminating contaminant sinks (USACE 1991, USACE 1996). Second, the borrow pits address the purpose of the DMMP by offering a large placement volume in which to place dredged material. No other existing options are currently available that would offer comparable volumes. Third, filling the borrow pits with dredged material and then capping them with clean sediment would return portions of the Harbor basin to its historical bathymetric contours. Bathymetric recontouring would likely restore shallow water habitats, improve water flow, improve water quality, and decrease sedimentation rates. If the borrow pits of the Lower Bay and Jamaica Bay were left alone, and not filled with dredged material, they would eventually fill in with fine organic particles and associated contaminants. Filling and capping these pits would create a stable area that would effectively contain contaminants once the pit was filled. Fourth, infaunal and epibenthic communities that were destroyed by dredging the pits, and have since not been able to fully recover, could be restored on the caps of filled borrow pits (Bokuniewicz et al. 1986). Finally, the close proximity of all of the borrow pits to the dredging sites would represent an economically feasible placement option. Because the borrow pits already exist, and do not require additional excavation or construction, the only cost remaining is transporting and depositing contaminated dredged material in the Lower Bay, and costs would be comparable to that of open ocean placement.

There are also several economic drawbacks to the proposed plan of filling subaqueous borrow pits with contaminated dredged material. First, filling and capping the borrow pits is not a permanent solution to the removal of contaminated dredged material. The pit caps could potentially require future maintenance, depending on whether or not the pit was located in a depositional or erosional environment, to prevent loss of dredged material. This maintenance will require time and resources that are difficult to estimate. Second, there is, and will continue to be, public opposition to placing contaminated materials in borrow pits in NY/NJ Harbor. Finally, a controversy exists over whether or not commercially and recreationally significant fish species use the borrow pits as feeding or refuge habitats. Bokuniewicz et al. (1986) and Clarke et al. (1998) found that schools of fish were found in different locations in several of the pits in the Lower Bay. These fish did not appear to be using the pits for any specific reason and were not staying in the pits for an extended duration. At this time the issue remains unresolved. Recreational fishermen claim that the pits attract fish, which they appear to do. It is uncertain whether the schooling of the fish around the pits is most beneficial to the fish or the fishermen (Bokuniewicz et al. 1986). Long-term impacts of filling borrow pits on the fish populations in the NY/NJ Harbor can not be predicted from existing fishery data. While more extensive research is currently becoming available on the utilization of borrow pits by fish populations, determining whether or not fish populations will increase or decrease in abundance if the borrow pits in the Harbor are removed will require long-term research.

Opportunities to Fill Subaqueous Pits in NY/NJ Harbor

The NY/NJ Harbor contains numerous depressions and pits that have been dredged in the past for commercial use of sediments. Many of these pits, however, are not of sufficient size, are in erosional environments, or have well established biological populations and should not be considered for this proposed placement option. Each of the candidate pits is distinctly different from the others and decisions on whether or not a pit has some tangible benefits to the surrounding area, or should be filled, should be made on an individual basis.

The District has characterized each candidate pit by volume, stability, sediment type, hydrodynamics, benthic community, and estimated cost to fill (**Table 5.1**). A summary of hydrodynamic, benthic community, and fish community data for each pit, along with a ranking of which borrow pits have the highest priority for filling is presented (**Table 5.2**).

Table 5.1:
Summary of physical characteristics of candidate borrow pits in NY/NJ Harbor.

Borrow Pit Site	Vol. (mcy)	Fill Depth (MLW) (ft.)	Vol (mcy) with 1 m cap	Vol (mcy) with 2 m cap	Intermediate Fill Vol. (mcy)	Surface Area (my2)	Slope	Avg. / Deepest Depth (ft.)	Dike/no Dike (option to incr. vol.)	Cost ($/cy)
Grassy Bay	29.1	-15	25	16.6	19.2	4	steep	30/46	yes	5-10
Large East Bank	20.1	-30	16.0	12.0	13.3	4.2	~ 6^{o}	50/70	yes	5-10
Large West Bank	11.7	-15	6.9	2.2	7.7	6.3	shallowest	10/38	yes	5-10
Jo-Co	7.4	-10	6.5	4.7	4.9	1.5	mostly steep	30/42	yes (no option)	5-10
CAC	5.1	-20	4.2	3.4	3.3	1.2	~ 4^{o}	40/54	yes	5-10
H/S North	2.8	-15	2.3	1.5	1.8	1	mostly steep	25/37	yes	5
Small East Bank	2.8	-25	2.2	0.2	1.8	1	~ 5^{o}	30/47	no	5-10
H/S South	2.7	-10	1.5	2.0	1.8	0.4	very steep	30/37	no	5
Little Bay/ Norton Bay	2.7	-10	2.3	1.6	1.8	0.3	very steep	50/65	no	5-10

Table 5.2:

Summary of hydrodynamic and biological characteristics of candidate borrow pits in NY/NJ Harbor.

Borrow Pit Site	Hydrodynamics Flow/DO of bottom waters	Priority to Fill	Benthic Communities	Fish Communities
Grassy Bay	low flow / 91.7% below standard[1]	1	• The benthic communtities of the nine pits vary considerably.	• Limited comparative data exists for fish utilization of borrow pits in NY/NJ Harbor.
Large East Bank	moderate flow / above standard	3		
Large West Bank	< East Bank / < East Bank	2	• Current research and existing data suggest that benthic communities in Jamaica Bay and the West Bank of Lower Bay are more impacted than benthic communities of the East Bank of the Lower Bay.	• Recent USACE surveys observed a low concentration of fish in the Jamaica Bay pits. Various concentrations of groundfish have been observed in the CAC pit.
Jo-Co	flow / 74.3% below standard[1]	1		
CAC	moderate flow / above standard[2]	2		
H/S North	unknown / unknown	2	• Differences can be attributed to lower flow rates, low DO levels, & high organic silt/clay content of sediments found in Jamaica Bay & theWest Bank.	• Limited research has been recently completed to better describe fish utilization of borrow pits in NY/NJ Harbor[2]. Preparations for more intensive research are being made for Jamaica Bay.
Small East Bank	moderate flow / above standard	3		
H/S South	unknown / unknown	2		
Little Bay/ Norton Bay	low flow / below standard[3] (0.44 mg/l)	1	• Baseline studies of existing benthic communities would be required at each borrow pit prior to restoration.	• Baseline studies of existing fish communities would be required of each borrow pit prior to restoration.

1 Results of study by Hydroqual, Inc. (1998) for July and Aug. 1995-96. Percentage is number of measurements taken below the NY State DO standard of 5.0 mg/l

2 Results of study by Clarke et al. (1998) for bottom DO levels of CAC pit, April 1997 - March 1998

3 DO level for Little Bay, April 1998 - D. Clarke, pers. comm.

The candidate pits are located either in the Lower Bay of New York Harbor or in Jamaica Bay (**Figure 5.1**). These two areas are distinctly different from one another. The Lower Bay is hydrodynamically more active with elevated wave energy, erosional forces, and higher water quality. Because the Lower Bay is a higher energy system, it is characterized by higher DO levels, increased abundance/diversity of benthic organisms and fish, and more complex erosional patterns. Jamaica Bay is a relatively low energy system. Tidal flow through this area is restricted by many islands and dead-end basins. Because of this and other contributing factors (e.g. pollution), water quality is comparatively poor (HydroQual 1998). The borrow pits in Jamaica Bay, however, are more stable. The pits are not exposed to erosional forces and can be hypoxic for extended periods of time. It is important to remember that when considering each of the borrow pits that those pits located in Jamaica Bay contain higher levels of contaminants (due to past and present pollution sources surrounding the Bay) and much lower abundance and diversity of organisms relative to the Lower Bay pits. The Lower Bay pits have been researched much more extensively than the borrow pits in Jamaica Bay. Very little data exists on abundance and diversity of benthic invertebrates and fish in the borrow pits of Jamaica Bay. Researchers at the USACE Waterways Experiment Station (WES) are currently working on a more comprehensive examination of the borrow pits of Jamaica Bay (D. Clarke, USACE-WES, pers. comm.).

Grassy Bay Pit

The Grassy Bay Pit is located in a deep basin approximately 1.1 miles west of Bayswater, NY and directly to the south of JFK International Airport in Jamaica Bay. It offers one of the greatest opportunities for beneficial uses of dredged material because of its large rectangular size (4000 yds. x 1000 yds.), steep (approximately 30 degrees) sides, low tidal flow through the basin, highly degraded environmental conditions, and low abundance of living organisms (West-Valle et al. 1991). The pit could be used to hold contaminated dredged material or glacial clay from Newark Bay or NY/NJ Harbor deepening projects. The sediments in the Grassy Bay Pit have a high organic content and are composed of mostly fine particles (Ramandetta and Harris 1978, NYCDEP 1997, HydroQual 1998). Ramandetta and Harris (1978) characterized the Grassy Bay basin as being altered from “a shallow, well flushed marsh to a settling pond for fine sediments” once the borrow pit had been dug. Based on limited water samples and model runs, water quality in Jamaica Bay is characterized as generally poor and it can be inferred that the pits experience low DO levels and seasonal hypoxia (NYCDEP 1997, HydroQual 1998). Flushing times for Jamaica Bay have increased from 10 to 11 days to 35 days since the creation of borrow pits (NYCDEP 1997). This change has caused Jamaica Bay to become a fine sediment sink which experiences extended periods of anoxia during summer months. This pit may also be concentrating contaminants associated with fine organic matter. Filling in the Grassy Bay pit would remove the sediment sink from the basin and potentially improve water quality in Jamaica Bay (HydroQual 1998). At this time no studies have been completed characterizing the abundance and diversity of benthic invertebrate and fish communities. Due to low water flow, low DO levels, and high organic sedimentation rates it can be inferred that the biological communities in the Grassy Bay Pit are low in abundance and diversity. This borrow pit, located in a large open channel, offers easy access and maneuverability to dredge barges. At $5-10/cy to fill and a volume of 29.1 mcy, [-15 ft. below Mean Low Water (MLW)] the Grassy Bay Pit offers the single largest option for dredged material placement in the Harbor. Estimated cost to fill the entire pit ranges between $145.5 - 291 million.

Large West Bank Pit

The Large West Bank Pit is located approximately 1.9 miles east of Staten Island and 0.6 miles west of the intersection of Ambrose Channel and Chapel Hill Channel in the Lower Bay. It is a candidate pit because of its large size (2500 yds. x 2500 yds.), moderate tidal flow through the area, relatively poor environmental conditions (Swartz and Brinkhuis 1978), and low abundance of organisms (Bokuniewicz et al. 1986). This pit could also hold contaminated dredged material or glacial clay. The sediments in the Large West Bank Pit are highly organic, mostly fine particles. The benthic communities are low in abundance and diversity (especially compared to the East Bank pits) (Bokuniewicz et al. 1986). However, the Large West Bank Pit has a greater abundance and diversity of benthic organisms than either of the other two West Bank Pits (Cerrato et al. 1989). The composition of the fish community in this borrow pit is uncertain. It is likely, because of low tidal flow and variable benthic communities, that the fish community experiences drastic changes in abundance and diversity throughout the year. Proximity to more open water, however, may enhance abundance/diversity of fish in the Large West Bank Pit relative to the Jamaica Bay pits. Water quality in the Large West Bank pit is degraded due to low flow and high concentrations of organic materials. This pit is susceptible to chronic low DO levels and seasonal hypoxia. One potential problem involved with this pit is that the walls of the pit have either breaches into the adjacent channel or are not strong enough to hold fill material without stabilization at a considerable extra cost. This pit is easily accessible to dredges and has an estimated volume of 11.7 mcy (-15 ft. MLW). The estimated cost to fill this borrow pit, without stabilization, would be between $58.5 - 117 million.

Large East Bank Pit

The Large East Bank Pit is located approximately 0.6 miles south of Coney Island and directly adjacent to the Ambrose Channel in the Lower Bay. It is a candidate borrow pit because of its relatively large size (6000 yds. x 700 yds.), steep sides and moderate tidal flow (SAIC 1996). The pit could be used to hold contaminated dredged material or glacial clay. Sediments in the Large East Bank Pit are primarily sand. This pit is characterized by a greater abundance and diversity of benthic organisms relative to the West Bank Pits because of greater tidal flow and fewer hypoxic events (Cerrato et al. 1989). Little is known of the fish community in the Large East Bank Pit, but because of increased tidal flow, more abundant and diverse benthic communities and fewer hypoxic events, relative to West Bank Pits, fish abundance is assumed to be greater. Water quality in the this pit is better than in the West Bank Pits because of closer proximity to a main channel, better tidal flow, and less organic sedimentation (Cerrato et al. 1989). This borrow pit is easily accessible because of its proximity to the Ambrose Channel. It is, however, less stressed than the West Bank Pits and has a much smaller volume than the Large West Bank Pit. There is also concern regarding the stability of the walls of the Large East Bank Pit; this could increase the cost of filling the pit. At 20.1 mcy (-30 ft. MLW) and an estimated $5-10/cy to fill, the proposed cost to fill the pit would be between $100.5 - 201 million.

Jo-Co Marsh Bay Pit
The Jo-Co Marsh Bay Pit is located approximately 0.3 miles west of Bayswater, NY and directly south of JFK International Airport in Jamaica Bay. It is a candidate to be filled because of its large circular size (1500 yds. x 1000 yds.), steep (approximately 30 degrees) sides, low tidal flow through the area (NYCDEP 1997), and generally degraded environmental conditions. The pit could be used to hold contaminated dredged materials, but would be an excellent candidate for glacial clay due to comparable sizes of clay material being dredged from Newark Bay channels in the area and a greater maneuverability area for barges at the site itself. No studies have been completed at this time on the benthic invertebrate or fish communities of the Jo-Co Marsh Pit. Based on preliminary data from other Jamaica Bay pits, it can be inferred that the low DO levels and high sedimentation rates of the bay make this pit unlikely to support a high abundance and diversity of organisms. One possible disadvantage may be that a sand dike would need to be built at the entrance to the basin to bring the side of the pit up to fill depth. At $5-10/cy to fill and an estimated volume of 7.4 mcy (-10 ft. MLW) the approximate cost to fill the Jo-Co Marsh Bay borrow pit would be between $37 - 74 million.

CAC Pit
The CAC pit is located approximately 3.7 miles to the east of Crookes Point, Staten Island, NY, directly adjacent to the west of the Chapel Hill Channel in the Lower Bay. It is a candidate for fill because of its relatively large size (1500 yds. x 800 yds.), its steep (approximately 30 degrees) sides, generally degraded environmental conditions, and relatively low abundance of organisms (Clarke et al. 1998). The pit could be used to hold contaminated dredged materials or glacial clay. The CAC pit contains primarily silt sediments and seasonally variable benthic and fish communities. Woodhead and McCafferty (1986) found that the CAC pit had the highest abundance of blue crabs and American lobsters of any of the Lower Bay pits. They also found greater abundance and diversity of fish in the CAC pit compared to adjacent shoal areas. Fish distributions in the CAC pit, however, were not significantly different compared to other Lower Bay pits. Dominant fish species in the CAC pit included: Bay anchovy, American shad, blueback herring, alewife, summer flounder, winter flounder, windowpane, butterfish (*Peprilus triacanthus*), red hake, and weakfish (Woodhead and McCafferty 1986). In contrast to these findings, Pacheco et al. (1983), Conover et al. (1985), and NMFS (1984) all reported significantly greater abundance of fish in the CAC pit compared to the Large West Bank Pit. Water quality in the CAC pit is variable and tidal flow is moderate compared to other pits. DO levels fluctuate seasonally, but are not as low as Grassy Bay and the Large West Bank Pit. Swartz and Brinkhuis (1978) recorded a DO range of 3.1-7.16 ml/l for the bottom of the CAC pit between June and August, 1977. Clarke et al. (1998) reported a DO range between 5.06 and 12.77 mg/l for late summer 1997 and early winter 1998. They also reported flood tide data that indicated that the water in the CAC pit is sheltered from the water column flow (< 10 cm/sec or 4 in/sec inside the pit walls). This borrow pit is easily accessible by barges but also has the concern of pit stability and the additional cost of stabilizing areas where breaches could occur. At a volume of approximately 5.1 mcy (-20 ft. MLW) and an estimated cost to fill of $5-10/cy the estimated cost to fill the CAC pit, without stabilization, would be between $25.5 - 51 million.

North Hoffman-Swinburne Pit
The North Hoffman-Swinburne Pit is located approximately 0.6 miles east of Staten Island and approximately 0.6 miles west of the Ambrose Channel in the Lower Bay. It is a placement site candidate because of its size (2000 yds. x 500 yds.), close proximity to the dredging sites, its steep (approximately 30 degrees) sides, and generally poor environmental conditions. The pit could be used to hold contaminated dredged material or glacial clay. Information about the benthic and fish communities are not extensive for either of the Hoffman-Swinburne Pits. Because the North Hoffman-Swinburne Pit is on the West Bank of the Harbor it can be assumed that abundance and diversity of organisms is lower compared to the East Bank Pits (Bokuniewicz et al. 1986). The North Hoffman-Swinburne Pit is dominated by stable blue mussel beds. Moderate tidal flow and relatively high DO levels are characteristic of this site (Swartz and Brinkhuis 1978). The greatest advantage of the Hoffman-Swinburne pits is the close proximity to the areas that will be dredged in NY/NJ Harbor. The location of both pits should allow them to be the least expensive pits to fill compared to any of the other candidate borrow pits. A concern for the North Hoffman-Swinburne Pit would be the need for a stabilizing dike to prevent breaches in the walls of the pit once the pit had been filled. While the cost of placing a dike along the edge of the pit would increase costs, the volume of the pit would also be increased, allowing for a greater volume of dredged material to be placed in the pit. At an estimated volume of 2.8 mcy (-15 ft. MLW) and an estimated cost to fill of $5/cy, the approximate cost fill the North Hoffman-Swinburne Pit is $14 million.

Small East Bank Pit
The Small East Bank Pit is located approximately 2.2 miles south of Coney Island and 1.2 miles north of the Ambrose Channel in the Lower Bay. It is a candidate borrow pit for filling because of its size (2000 yds. x 500 yds.), its steep sides, and poor environmental conditions (SAIC 1996). This pit could be filled with contaminated dredged material or glacial clay. The Small East Bank Pit is similar in physical and biological characteristics to the Large East Bank Pit (USACE 1996). Tidal flow and DO levels in this pit are higher than most of the other candidate borrow pits. Benthic and fish communities are characterized by greater abundance and diversity compared to the West Bank Pit because of the closer proximity to a main channel (Bokuniewicz et al. 1986). This borrow pit has the disadvantage of having an open sill to an adjacent channel and would need to be diked before dredged material could be placed in it. At an estimated volume of 2.8 mcy (-25 ft. MLW) and a proposed cost of $5-10/cy to fill (not including the cost of diking the pit walls), the approximate cost to fill the Small East Bank Pit is $14 - 28 million.

South Hoffman-Swinburne Pit
The South Hoffman-Swinburne Pit is located approximately 0.3 miles east of Staten Island and approximately 1.9 miles west of Ambrose Channel in the Lower Bay. It is a candidate borrow pit because of its size (800 yds. x 500 yds.), its close proximity to dredging locations, its steep sides, and relatively poor environmental conditions. The pit could be used to hold contaminated dredged materials or glacial clay. The benthic communities in the South Hoffman-Swinburne Pit are highly stressed and experience drastic seasonal changes in abundance and diversity of organisms (Bokuniewicz et al. 1986). Very little is known of the fish communities in this pit. The pit is characterized by low tidal flow (less than the North Hoffman-Swinburne Pit), high

rates of sedimentation, and low DO levels. Though it is unknown whether or not this pit experiences seasonal hypoxia, its other conditions make it possibly the most degraded borrow pit in the Lower Bay. Again, the greatest advantages of this pit are its close proximity to the dredging sites and its elliptical size. At an estimated volume of 2.7 mcy (-10 ft. MLW) and a proposed cost to fill of $5/cy, the approximate cost to fill the South Hoffman-Swinburne Pit is $13.5 million.

Little Bay and Norton Basin Pits
Because of the close proximity and similar characteristics of the Little Bay Pit and the Norton Basin Pit they will be considered as one borrow pit candidate that could be filled at a lower cost and with a greater volume than as individual pits. The Norton Basin is a dead-end basin directly north of Edgemere, NY in Jamaica Bay. It is a candidate pit because of its size, steep sides, low abundance and diversity of organisms, and degraded environmental conditions. This pit could be filled with contaminated dredged material or glacial clay. Because the pit is in a dead-end basin it receives very little tidal flow and is characterized by high silt content, low DO, and seasonal hypoxia (NYCDEP 1997, HydroQual 1998). Once again, no studies have been completed of the benthic invertebrate and fish communities for the Norton Basin pits. It could be inferred that because of low DO levels and high organic sedimentation rates that the invertebrate and fish communities of this pit are low in abundance and diversity. This basin is being considered as one of several candidates by the Jamaica Bay Restoration Project for reestablishing a connection with Jamaica Bay and the ocean. Filling this borrow pit could be a significant step toward reaching the goal of restoring habitat quality to the local area. A possible disadvantage with this pit is the potential difficulty of maneuvering barges in the dead-end basin. Dredging an access channel would be required in order to reach the pits. This additional cost could be abated by using the sandy material removed from Norton Basin to form the dike needed at the Jo-Co borrow pit. At an estimated cost of $5-10/cy and an approximate volume of 2.7 mcy (-10 ft. MLW) the proposed cost of filling the Norton Basin borrow pit with dredged material will be between $13.5 - 27 million.

Local Issues Involving Filling of Subaqueous Pits in NY/NJ Harbor

Several issues specifically relevant to NY/NJ Harbor need to be addressed in considering use of dredged materials for restoration of borrow pits. First, is the concern that the borrow pits are being used by fish as refuge and feeding habitats (Bokuniewicz et al. 1986, Clarke et al. 1998, Woodhead and McCafferty 1986). Even though research efforts are currently underway to increase the understanding of the effects of filling existing borrow pits, each pit should be assessed individually on whether or not it has a significant and potentially long-term impact on the fishery populations in the Harbor. If a pit can be demonstrated to have potential long-term beneficial impacts on a species' distribution through the Harbor, the pit should not be filled. It appears that in most cases, however, the borrow pits are not a critical ecological attribute for the Harbor.

Several engineering constraints must be taken into consideration before filling of borrow pits is logistically feasible. The Norton Basin pit would require an access channel before the pits in that basin could be filled. The current channel is too narrow and shallow for barges to effectively maneuver in the basin. All of the Jamaica Bay borrow pits have limited access by barges because of low bridge heights in the area. The cost and time involved with opening and closing the bridges were not factored into the calculations of estimated cost for each borrow pit and should be considered on a site-specific basis. For bridges which cannot be opened, a possible solution would be to either place tug boats on opposite sides of each of the bridges or to use tug boats in Jamaica Bay to transport the barges once they had reached the bridges. The Large East Bank Pit, West Bank Pit, Jo-Co Pit, North Hoffman-Swineburne Pit, and the CAC pit could benefit from the addition of dikes to the lower ends of their basins. Because each of these pits have breaches in the walls of the pit into adjacent channels, adding dikes would both strengthen and stabilize the pits and maximize the volumes of each pit. Finally, the volumes of each pit may be limited by having to place intermediate cap layers into a given pit to prevent the potential escape of contaminated materials (USACE 1996). Because filling a pit with dredged material is not an instantaneous occurrence, layers of clean sediment may have to be placed at varying depths in a pit to prevent erosion of contaminated dredged material before a permanent cap can be put in place. All of the constraints listed above could add time and cost to a proposed filling project.

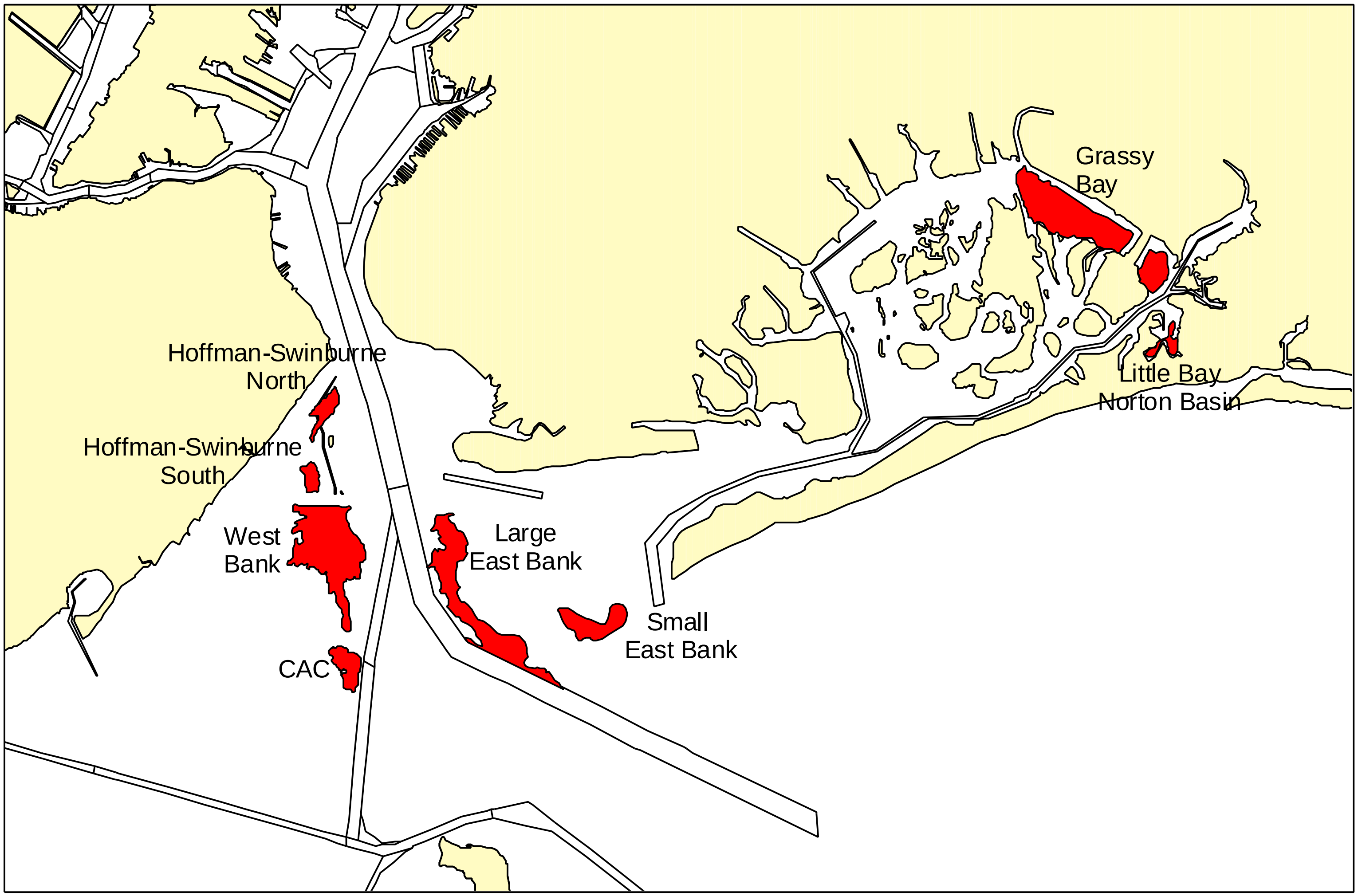
Finally, several of the borrow pits (specifically Norton Basin Pit and Little Bay Pit), located in dead-end basins, could be considered for alternate methods of filling. As with the other borrow pits these pits could be filled to ambient subtidal elevations and then capped with clean sediment. Alternatively the basins in which these pits are located could be more completely filled (an option discussed in greater detail in Chapter 6 of this report). Filling in most of the basin would require sloping the fill up to a specific level and then stabilizing the sediment by planting emergent marsh vegetation or grading to upland elevations. This alternative would allow for a greater volume of dredged material to be used in filling the basin to a higher elevation, also requiring a greater investment of time and money.

Regulatory Authority for Filling of Subaqueous Pits in NY/NJ Harbor

Use of dredged material for the restoration of subaqueous borrow pits in NY/NJ Harbor would be authorized under Section 404 (b) (1) of the Clean Water Act of 1972, Section 1135 of WRDA 1986, and Section 206 of WRDA 1992. Section 216 of the Rivers and HarborsAct of 1970 authorizes the USACE to review navigation projects and recommend modifications that would involve habitat creation/restoration using dredged material. Habitat development projects in the Harbor are also subject to regulation by individual state (NY and NJ) laws, statutes, and permitting authorities.

Figure 5-1

Proposed borrow pits (red) for restoration of shallow water habitat.



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6: RESTORATION, CREATION, AND ENHANCEMENT OF INTERTIDAL MARSHES, MUDFLATS, AND SHALLOW SUBTIDAL HABITATS USING DREDGED MATERIAL IN NY/NJ HARBOR

Intertidal Marsh Creation Using Dredged Material

Intertidal marshes typically occur in low-energy coastal or riverine environments, and span the entire estuarine salinity gradient from tidal freshwater (<0.5 ppt) to polyhaline (>20 ppt) conditions. Ecological functions attributed to intertidal wetlands include shoreline stabilization, storage of floodwaters, maintenance of surface water and groundwater quality, and the provision of nursery habitat for a myriad of estuarine-dependent finfish and shellfish species.

Smooth cordgrass (*Spartina alterniflora*) dominates intertidal salt marsh communities along the Atlantic coast. This species generally occurs between mean high water (MHW) and mean sea level (MSL) and exhibits considerable variation in growth form (i.e., tall, medium, and short), depending on tidal flooding frequency and duration. Above MHW (high marsh) the floral composition of salt marshes increases in diversity and varies with latitude, with several plant species typically present.

Intertidal marshes provide valuable habitat for a variety of organisms, including many commercially important fishery species. Examples of common marsh-dependent fish species along the Atlantic coast include blue crab and summer flounder. Early life stages of these organisms are afforded refuge from predators and benefit from abundant prey resources in shallow tidal marsh habitats. Common prey species include various killifishes (*Fundulus* spp.) and caridean shrimp (*Palaemonetes* spp.) which inhabit the vegetated marsh surface and shallow subtidal creeks and pools. Characteristic marsh invertebrate taxa include fiddler crabs (*Uca* spp.), amphipod and isopod crustaceans, terrestrial insects and arachnids, various bivalve and gastropod mollusks, and annelids. Wading birds, such as egrets and herons, prey upon resident fishes and invertebrates of intertidal marshes. Other birds, both arboreal and aquatic species, feed and nest in upper intertidal marsh habitats. A variety of mammals, including deer, fox, raccoons, and otters make extensive use of intertidal marsh habitats for foraging, breeding and refuge.

Intertidal Marsh Creation/Restoration: The restoration and creation of intertidal marshes has received much attention in coastal engineering. This is likely due to the considerable acreage of tidal marsh that has been lost along U.S. coastlines, recent recognition of the important functions provided by intertidal marshes, and the relative ease in which tidal marsh vegetation can be propagated upon dredged material. It is important to distinguish between “restoration” and “creation” of intertidal marshes, although the two terms are often used interchangeably. *Restoration* generally refers to projects in which an area is returned to a close approximation of some natural or known historical condition. In tidal marsh environments, this may involve removal of dikes, berms, and fill material, or installation of culverts under roadways to re-establish the natural tidal prism.

Marsh *creation* is often a component of the restoration process, especially in projects involving the removal of fill and/or regrading of adjacent uplands to intertidal elevations. However, it is important to recognize that marshes can often be created for habitat development or improvement in upland or shallow subtidal areas, which have not historically supported intertidal vegetation; these projects would not correctly be termed “restoration” in a site-specific context, though they could easily be viewed as restoring lost regional wetland acreage.

Techniques for establishing *Spartina alterniflora* marshes on dredged material deposits along the south Atlantic coast were pioneered by researchers at North Carolina State University in the late 1960s-early 1970s (Broome et al. 1974; Seneca 1974; Seneca et al. 1975, 1976; Woodhouse et al. 1972, 1974). The objective of these early studies was to provide stabilization of shorelines and dredged materials, and to recoup some of the losses to coastal habitats that had occurred as a result of human population growth in coastal areas. Marsh re-establishment techniques were documented and these efforts were replicated at a number of successive sites along the Atlantic, Gulf, and Pacific Coasts. The USACE’s Dredged Material Research Program (DMRP) pioneered large-scale tidal marsh establishment on all three U.S. coastlines in the 1970s (Barko et al. 1977; Garbisch 1977; Garbisch et al. 1975; Lunz et al. 1978; Smith 1978; Landin 1982). Tidal marsh sites established under the DMRP were monitored for various intervals during 1974-1987 (Landin et al. 1989). Parameters studied include plant propagation success, shoreline stabilization properties, and utilization by fish and wildlife species. Successive research has focused on refining the techniques developed by the DMRP, and in recent years, increased attention has focused on replication of ecological function in created or restored intertidal marsh ecosystems.

Opportunities to Create Intertidal Marshes in NY/NJ Harbor: Many potential opportunities exist to create, restore or enhance intertidal marshes in NY/NJ Harbor, and several efforts have recently been completed, or are currently underway (Gaia Institute 1998, Kerlinger 1997b, USACE 1998). However, issues associated with habitat-tradeoffs are conflicting with large-scale tidal marsh development projects harbor-wide (NJDEP 1997). Shallow estuarine habitats are apparently functioning well in many areas of the Harbor, and support diverse and abundant benthic invertebrate and finfish populations. Creation of large parcels of *Spartina* marsh upon areas filled with dredged material will displace existing subtidal habitat. The new intertidal habitat may benefit some shallow water species already present; however, many fishery species in the harbor do not depend on intertidal wetlands, and will likely be displaced. Intertidal marsh creation will provide habitat for species groups which do not use shallow subtidal estuarine habitat, and will support populations for resident “prey species” (e.g. killifish, grass shrimp) which would benefit anadromous and marine predatory species, such as striped bass, bluefish, and flounder. Other ecological functions provided by intertidal marshes, such as shoreline stabilization, surface water and ground water filtration, and provision of nesting/foraging habitat for wildlife should also be considered in an analysis of habitat trade-offs. Proposed intertidal marsh creation projects in the Harbor will need to be evaluated individually, with consideration of the anticipated benefits of the wetland habitat to be created relative to the existing ecological functions of the open-water habitat to be replaced.

The Gaia Institute, of City Island, New York, has developed draft schematic plans to create intertidal salt marsh habitat at various locations in NY/NJ Harbor. These plans call for the beneficial use of 20,000,000 cy of dredged material from the Port of NY/NJ and include locations in the Bronx, the East River, Jamaica Bay and Staten Island. The first of the proposed projects the creation of a 30 acre salt marsh adjacent to the Pelham Bay landfill, in Pelham and Eastchester Bays. The project is designed to partially recoup historic losses of intertidal wetlands, while simultaneously providing natural filtration and decontamination of landfill-derived leachate and urban stormwater inputs. Habitat -tradeoff considerations for this project are addressed in a recent environmental impact statement (EIS) which indicates that this project is intended to restore tidal wetlands in an area of the Harbor where this type of habitat was historically a common and widespread landscape feature (Gaia Institute 1998).

Other tidal marsh restoration/creation projects have been conducted or are planned by various agencies/organizations throughout the Harbor. The New York City Department of Parks and Recreation (NYCDPR) has planted *Spartina alterniflora* marsh at several locations in the Arthur Kill in order to restore foraging/breeding habitat for wading birds and fish (Kerlinger 1997b). Several small-scale tidal marsh creation efforts have been conducted in Jamaica Bay, and additional projects have been proposed under the Jamaica Bay Ecosystem Restoration Project (USACE 1998). An important issue for consideration in Jamaica Bay is the prevalence of cultural resources. Any proposed wetland creation effort in this area should include an archaeological survey to address prehistoric and historic cultural resources, particularly in areas of historic navigational significance (e.g. piers, wharves, bulkheads)

Restoration of tidal marshes in many cases involves re-establishment of historical tidal flow patterns, removal of invasive species (e.g. *Phragmites australis*) and replanting with *Spartina alterniflora*. Projects of this type are ongoing in portions of the Hackensack Meadowlands, New Jersey and are proposed for other areas of the Harbor, including Flushing Bay and Jamaica Bay (USACE 1996, 1998).

Another option for tidal marsh creation in NY/NJ Harbor is to use dredged material in “shoreline softening projects” along heavily industrialized or densely populated residential waterfronts. While this may provide a useful buffer of marsh vegetation, and yield some shoreline stabilization benefits, it is not likely to require significant volumes of dredged material for implementation. It may also be feasible to identify a large upland area in the harbor (either man-made or natural) which can be graded down to intertidal elevation suitable for salt marsh establishment. However, this option, again, would not require large amounts of dredged material (if any), and may require additional placement of upland substrates.

Use of contaminated sediments to create intertidal wetlands in any of these scenarios would require capping with clean sediment in order to prevent release of contaminants (e.g. PCB’s, heavy metals) into surface waters; and potential uptake and sequestration of contaminants by emergent vegetation, infaunal/epifaunal invertebrates, fish and wading birds. Temporary and/or permanent retaining structures may be needed to contain the dredged material, especially in areas characterized by moderate to high wave climate, in order to minimize the potential for dispersal of contaminants (NJDEP 1997).

Serious consideration of intertidal marsh creation using dredged material in NY/NJ Harbor will require detailed reconnaissance and feasibility studies in order to evaluate the habitat-tradeoff issue of salt marsh creation vs. existing subtidal bottom habitat, resolve the logistic and engineering constraints associated with the use of contaminated dredged material, and to select and prioritize candidate sites.

Intertidal Mud Flat Creation Using Dredged Material

Restoration and creation of unvegetated intertidal habitats has not received the level of attention given to restoration/creation of vegetated intertidal habitats, such as salt marshes. However, a variety of fish and invertebrate species, many of commercial and recreational importance, depend on intertidal and shallow subtidal unvegetated marine habitat, particularly during early life stages (Peterson and Peterson 1979). Bivalves which occupy mud and sand flats along the Atlantic coast include northern quahog and softshell clam; both are harvested commercially (Stanley and DeWitt 1983; Stanley and Parsons 1985; Abraham and Dillon 1986; Newell and Hidu 1986). Sandworms (*Nereis virens*) and bloodworms (*Glycera dibranchiata*) are a conspicuous faunal component of tidal flats along the northeastern U.S. coast (Wilson and Ruff 1988). These worms are harvested commercially and sold as bait to sportfisherman. In virtually all estuarine and coastal areas mud and sand flats are important forage sites for wading and migratory birds, which feast on the abundance of invertebrate prey items (worms, small crustaceans, bivalves) available at low tide.

Mudflat Creation: Deposition of fine dredged material in shallow coastal waters may result in the creation of intertidal mud and sandflats. Many such artificial habitats were created prior to the implementation of the National Environmental Protection Act (NEPA) and therefore, are not well documented. A recent study conducted by the USACE New England Division and USACE-WES documented benthic invertebrate community dynamics at a recently constructed mudflat with comparison to a nearby natural mudflat at Jonesport, Maine (Ray et al. 1994). A diverse infaunal assemblage, similar to that of the reference site, was present at the constructed mudflat two years post-construction and included commercially important species such as sandworms and softshell clams.

Tidal mudflats have been created in Japan as compensatory mitigation for loss of natural tidal flats displaced by urban and industrial development; several of these, created within the last decade, have recently been studied in comparison to natural reference sites (Okada et al. 1998). Although soil organic content, soil nitrogen concentration, and microbial biomass of constructed mudflats was lower, microbial respiration and infaunal biomass was similar at both created and natural mudflats.

Opportunities to Create Mudflats in NY/NJ Harbor: Creation of intertidal mudflats in NY harbor requires consideration of the aforementioned habitat-tradeoff issues. If the subtidal habitat in question is functioning well, then mudflat construction offers no tangible benefit; if the subtidal area slated for dredged material placement is degraded, or is not providing the required habitat for target species or biological communities of concern, then mudflat creation could represent a significant ecological benefit. As with salt marsh creation, certain species will benefit, previously uncommon species may prosper, and others may be displaced to deeper habitat elsewhere. A recent recommendation by NMFS to mitigate for shallow-water habitat loss resulting from ongoing and planned Harbor deepening projects entails consideration of creating and restoring intertidal mudflats. The most likely candidate areas for such mitigation would in the Arthur Kill, Kill Van Kull, Newark Bay, and the Raritan River.

Use of contaminated sediments to create intertidal flats in NY/NJ Harbor would require capping with clean sand, or other fine-grained substrate in order to reduce erosion and prevent uptake of contaminants by deposit-feeding invertebrates. This would restrict the suitability of many potential shallow water locations (or decrease the potential amount of dredged material which could be placed at a particular site) where water depths may be insufficient to accommodate placement material *and* a clean sediment cap. Rigorous pre-construction evaluation and post-construction monitoring of cap integrity and project site hydrodynamics will be necessary if contaminated sediments are to be used in creation of intertidal mud/sand flats within the Harbor. Site-specific assessments, demonstration projects and detailed analysis of historic vs. present day distribution of intertidal habitats will be instrumental in site selection and prioritization of future efforts to create or restore unvegetated intertidal habitats in NY/NJ Harbor.

Seagrass Bed Creation Using Dredged Material

Seagrasses are submerged flowering marine angiosperms, of which approximately 35 species are known worldwide. Seagrass beds occur mainly in low-energy shallow subtidal and intertidal habitats along the Atlantic, Gulf, and Pacific Coasts of the U.S., however species composition and areal extent varies considerably along each of these coastlines (Thayer et al. 1984; Zieman and Zieman 1989). Along the Atlantic coast, eelgrass (*Zostera marina*) beds occur from the Canadian Maritime Provinces south to the Albemarle-Pamlico Sound in North Carolina. Generally, eelgrass beds are restricted to protected inshore waters such as the back-barrier lagoons of the NJ barrier islands and in Chesapeake Bay. Seagrass beds along the Atlantic coast are critical nursery areas for many recreational and commercial fishery species, including bay scallop (*Argopecten irradians*), summer flounder, and blue crab. Juveniles of these and other fishery species are afforded refuge from predators and benefit from abundant food resources within the structurally complex seagrass canopy.

Critical environmental parameters for seagrass beds include salinity, temperature, water clarity, and nutrient concentrations. Depth and water clarity exert the primary controls over seagrass zonation and the degree of colonization by epiphytes. Redistribution of sediments by waves and storm surges can severely impact seagrass beds. Diseases can have a catastrophic effect on seagrass communities. During the 1930s, widespread infection by the slime mold *Labryinthula macrocystis* decimated Atlantic coast eelgrass populations, including those along the south shore of Long Island and in Raritan Bay (Short et al. 1987, 1988).

Seagrass beds are susceptible to an array of human-induced degradations. Dredge and fill operations associated with navigation channel maintenance have taken a significant toll. Deterioration of water quality conditions (increased turbidity, increased nutrient concentrations) associated with human population density in coastal areas remains a primary cause of seagrass bed degradation. Physical damage to seagrass beds may result from propeller scar damage in shallow waters.

Restoration/Creation of Seagrass Beds: There has been considerable interest and effort expended to devise effective and logistically feasible methods of restoring seagrass beds, primarily by transplantation. The vast majority of efforts have failed, usually as a result of improper site selection. Salinity, depth, water clarity, substrate type and nutrient concentrations are of utmost importance in selection of a restoration site. The parameters of the transplant site must closely match that of the donor, or reference site, if restoration success is to be realized.

The earliest recorded transplant effort involving eelgrass was documented by Addy (1947a, 1947b) from Massachusetts and several other locations in the mid-Atlantic. Attempts to establish subtropical seagrass beds on dredged material deposits in Port St. Joe, Florida are described by Phillips (1980) and Phillips et al. (1978). Recent efforts to re-establish eelgrass in lower Chesapeake Bay are documented by Moore and Orth (1982) and Orth et al. (1994). Thom (1990) reviewed eelgrass-transplanting projects in the Pacific Northwest.

Planting techniques, along with cost and labor estimates for establishment of eelgrass, shoalgrass (*Halodule* spp.), manatee grass (*Syringodium filiforme*), and turtle grass (*Thalassia testudinum*) on dredged material and other unvegetated substrates are documented by Fonseca et al. (1982a, 1982b, 1984, 1985, 1987a, 1987b). Fonseca (1994) reviews all aspects of seagrass restoration, including planting guidelines and monitoring programs for the Gulf of Mexico; however, this information is applicable to seagrass restoration in general.

A variety of transplant methods have been used to restore seagrasses, including broadcast seeding, seed tapes, stapling of individual plants, and use of "peat pots" or sediment plugs containing whole plants. The latter method appears to be most successful (Fonseca 1994; Fonseca et al. 1990). Fertilizer applications have been tried in some instances, although performance has been inconclusive (Fonseca 1994). Careful attention must be paid to spacing of individual planting units in order to achieve site coalescence. Subtropical seagrass beds in Florida Bay and the eastern Gulf of Mexico have achieved coalescence in as little as 9 months, or as long as 3-4 years, depending on planting distance between individual units. In high-energy areas, coalescence of beds may never fully occur.

Opportunities to Restore/Create Seagrass Beds in NY/NJ Harbor: At the current time, it may not be feasible to implement large-scale efforts to restore or create seagrass beds using dredged material in NY/NJ Harbor or surrounding waters. A recent experimental study conducted by NMFS (Reid et al. 1993) failed to establish viable seagrass beds at five test sites in Raritan Bay. High turbidity and smothering/suffocation of transplant units by macroalgae and epiphytes were the primary factors associated with transplant failure. As described previously for intertidal wetlands and mud/sand flats, use of potentially contaminated dredged material substrate would require use of a clean sand cap in order to prevent release of contaminants into surface waters; and potential uptake of contaminants, including heavy metals, by submersed macrophytes, infaunal/epifaunal organisms, fish and avifauna. Significant changes in wave climate, reduction of Harbor-wide sediment and water-column nutrient concentrations, and an increase in water clarity are needed in order to provide suitable habitat for seagrass re-establishment (on dredged material or otherwise) in NY/NJ Harbor. If ongoing and future contaminant reduction and pollution abatement programs succeed in improving water quality conditions in the Harbor, then seagrass restoration should be re-examined. For now, any attempts to restore seagrasses in NY/NJ Harbor should be limited to small-scale experiments at carefully selected and prepared sites.

Creation of Shallow, Unvegetated Estuarine Habitat Using Dredged Material

Vegetated habitats are most often the focus of estuarine habitat restoration projects; however, shallow *unvegetated* marine and estuarine habitats also constitute a significant resource and provide spawning, refuge and feeding habitat for a variety of fish and decapod crustaceans (Ruiz et al. 1993). Non-vegetated shallow-water habitats have not received as much attention from resource managers as vegetated habitats, and are therefore less likely to be avoided or mitigated for in association with dredging and navigation projects.

Unvegetated estuarine shallows are used extensively along all three U.S. coastlines by a variety of demersal marine fish species. In the Rhode River, a non-vegetated tributary of Chesapeake Bay, mortality rates for several common fish and crustacean species increased significantly with depth (Ruiz et al. 1993). Motile fishes and crustaceans move with tidal ebb and flow, maintaining a relatively constant depth, in order to avoid predators common to deeper waters. The historic loss of submerged aquatic vegetation (SAV) in NY/NJ Harbor and elsewhere along the Atlantic coast has emphasized the relative importance of unvegetated shallows as habitat for demersal and forage species. Many species typically associated with vegetated subtidal habitats will occupy discrete depth zones in unvegetated shallow areas as a predation refuge when vegetated habitats are lost, or otherwise unavailable (Ruiz et al. 1993). Cascading effects of shifts in habitat utilization due to loss of SAV habitat are not well understood, but are regarded as potentially significant in large temperate estuaries.

Creation of shallow, unvegetated estuarine habitat: On the west coast of the U.S., there have been several recent attempts to restore shallow marine habitat by creating “in-bay terraces.” Terracing creates a flat or gently sloping habitat that is shallower than the deeper area it replaces (Rhoads and Lunz 1996). Both hard and soft bottom habitat types have been created, primarily in southern California. While some of these projects have been constructed specifically to provide areas for seagrass restoration, others provide valuable unvegetated shallow foraging habitat for fish and wading birds. Both clean and contaminated sediments have been used in construction of in-bay terraces. Typically, contaminated sediments are placed at the base levels behind containment dikes. Successive, shallower levels are constructed using clean sand or silt. Use of rock substrate to stabilize the terrace perimeter provides an added benefit of complex structure for use a refuge/foraging habitat by fishes and crustaceans. Species which have been reported to benefit from in-bay terracing projects in southern California include grunion (*Leuresthes tenuis*), California halibut (*Paralichthys californicus*), and northern anchovy (*Engraulis mordax*). The California least tern (*Sterna antillarum brownii*) has been reported to forage extensively along shallow sandy terraces at the Port of Los Angeles, California (Rhoads and Lunz 1996).

Examples of species associated with unvegetated shallow-water habitat in NY/NJ Harbor include winter flounder, summer flounder, windowpane, scup, and spot. Forage species, including mummichog, striped killifish, and Atlantic silversides are abundant in shallow subtidal areas. These, in turn, attract predatory species, including bluefish, weakfish, and striped bass. Decapod crustaceans associated with unvegetated shallows in New York Harbor include blue crab, american lobster, and sand shrimp.

Opportunities to Restore/Create Shallow, Unvegetated Estuarine Habitat in NY/NJ Harbor: There currently exists substantial opportunity to restore, create, or enhance unvegetated shallow-water habitat in NY/NJ Harbor. As mentioned previously, re-establishing historical bathymetric contours in areas which have been impacted by sand mining (filling borrow pits) represents restoration of this type of habitat. Dead-end basins, typically characterized by poor circulation, and degraded water quality (see Chapter 7) can be filled to intermediate depths (10-20 ft below MLW). This would raise the bottom into the photic zone, potentially increasing primary productivity by benthic micro-algae, allow for recolonization by benthic invertebrates, increase tidal circulation by eliminating stagnant, deep holes, and isolate severely contaminated, organic sediments typically present in borrow pits or dead-end canals. Naturally deeper areas can be filled to intermediate depths, although it is probably best to focus such efforts on anthropogenically disturbed or dredged areas in the Harbor. This type of habitat restoration can be combined with other restoration efforts in the Harbor (e.g. tidal marsh and mudflat creation, or bird/wildlife island projects). A potential disadvantage to creation of shallow water habitat is that it does not provide as much placement volume relative to upland or intertidal habitat creation on a per unit area basis; however, in many cases, it may represent a preferable alternative to displacement of subtidal habitats, and offers potentially greater placement volume Harbor-wide. As with the other habitat development applications discussed previously, shallow habitat creation must incorporate consideration of the potential for contaminant dispersal via physical or biotic processes. Hydrodynamics and wind/wave energy must be assessed at potential project sites, and capping with clean sediments (silt or sand) will likely be necessary for any application in New York Harbor. Despite these constraints, development of shallow, subtidal habitat may represent a technically feasible and politically acceptable beneficial use option for New York Harbor.

Regulatory Authority for Habitat Development Projects in NY/NJ Harbor

Creation/restoration of intertidal marshes, intertidal mud/sand flats, shallow unvegetated subtidal habitat, and seagrass beds in NY/NJ Harbor using dredged material is authorized by Section 404 (b)(1) of the Clean Water Act of 1972, Section 1135 of WRDA of 1986 and Section 206 of WRDA 1996. In addition, Section 204 of WRDA of 1992 provides funding and authority for the beneficial use of dredged material for creation and restoration of aquatic or related habitats in association with construction, operation or maintenance of authorized navigation projects. Section 216 of the Rivers and Harbors Act of 1970 authorizes the USACE to review navigation projects and recommend modifications that would involve habitat creation/restoration using dredged material. Habitat development projects in the Harbor are also subject to regulation by individual state (NY and NJ) laws, statutes, and permitting authorities.

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7: CONSTRUCTION OF WETLANDS TO IMPROVE WATER AND SEDIMENT QUALITY IN NY/NJ HARBOR

Water and sediment quality issues are among the foremost environmental concerns in NY/NJ Harbor. Centuries of degradation resulting from untreated sewage discharge and industrial activity has severely impacted the Harbor ecosystem. The New York City Department of Environmental Protection (NYCDEP) has conducted an annual water quality survey in New York Harbor since 1909. Recent survey results show that, in general, DO levels throughout the Harbor have increased in the last 20 years (O'Shea and Brosnan 1997). Notable improvements in DO have been documented for the lower Hudson River, the Arthur Kill, Kill Van Kull, the Narrows, the Harlem River, the East River, and Raritan Bay. However, certain locations exhibit severe low DO conditions (e.g. upper Jamaica Bay, Newtown Creek, Gowanus Creek, Flushing Bay, Bowery Bay). Chronic sewage and contaminant loadings associated with CSO's, along with poor circulation, are the primary reasons for the persistence of poor water quality in these areas.

Stormwater runoff is quickly generated in urban areas, the result of flow from impermeable surfaces such as roads and building rooftops. Stormwater is collected in pipes and culverts; the concentrated flow is then diverted into waterbodies, resulting in downstream flooding and pollution. Typical contaminants present in stormwater runoff include fertilizers, pesticides, petroleum products and heavy metals. Construction of new sanitary sewer systems is often impractical due to the magnitude of effort and cost in large urban areas. Thus, efforts to control CSO's are typically aimed at improvement of separation devices and containment facilities which provide flow equalization and gradual release of stormwater effluent (Corbitt 1990).

An opportunity may exist to create wetlands using dredged material as "natural filters" for wastewater in various locations throughout NY/NJ Harbor. Artificial "treatment" wetlands have been used elsewhere in the U.S. and in Europe for stormwater detention and treatment and can provide substantial benefits via removal of solids and contaminant uptake (Kadlec and Knight 1996). Construction of intertidal wetlands in abandoned or disused piers and basins adjacent to CSO's or landfills may function to reduce the severity of wastewater discharges currently entering the Harbor, while simultaneously providing for the beneficial use of a significant volume of dredged material. However, the feasibility of constructing intertidal wetlands to treat urban wastewater is largely untested (Guida and Kugelman 1989).

A research and development effort using a limited number of test sites should precede the implementation of a large-scale treatment wetland program using dredged material in NY/NJ Harbor. These feasibility studies would provide critical information on plant propagation techniques, dredged sediment characteristics and suitability of various sediment types, and the ability of constructed intertidal wetlands to remove suspended solids and contaminants. These demonstration projects will aid in the design of subsequent constructed wetlands by providing improved hydrologic and geomorphologic design criteria. These initial efforts would represent an essential first step towards *quantifying* the benefits of constructed wetlands in degraded urban landscapes and in identifying any engineering and policy constraints inherent to projects of this type.

Status of the CSO Problem in NY/NJ Harbor

Between 70% and 80% of New York City's 6000 miles of sewers are classified as combined sewers, discharging a mixture of rainfall runoff and unprocessed sewage during and immediately following precipitation events. An estimated 730 CSO's presently discharge into NY/NJ Harbor and adjacent waterways, including 460 from New York City, 22 from Westchester, and 248 from NJ. In addition, there are 116 CSO's along the Connecticut shoreline which discharge into Long Island Sound. (O'Shea and Brosnan 1997). NYCDEP conducted studies in the mid-1980's to address persistent water quality degradation associated with CSO's. Notable problem areas were identified in Jamaica Bay and the East River (O'Brien and Gere 1986).

New York City has undertaken recent efforts to reduce CSO discharge in many locations. A water pollution control plant (WPCP) at Newtown Creek is scheduled for upgrade to full secondary treatment in 2007, joining the other 13 WPCP's in New York City at secondary treatment. Abatement of illegal sewer line connections has reduced raw sewage loadings. From 1989-95 NYCDEP instituted operational changes to improve efficiency of WPCP's. Since 1972 a CSO treatment facility has been operating at Spring Creek, Jamaica Bay. An experimental CSO abatement facility was constructed in Fresh Creek in 1988. Both facilities pump CSO flows back to the 26th Ward WPCP for secondary treatment. New York City's comprehensive CSO abatement program includes provisions for retention facilities to be constructed at several locations in the inner and outer harbor, including the East River (including Flushing Bay tributaries), Jamaica Bay (including Paerdegat Basin), and Newtown Creek (WRI 1994). Abatement of CSO's is also an integral part of NYCDEP Jamaica Bay Comprehensive Watershed Management Plan (NYCDEP 1993). An ongoing effort by the New York District, USACE to develop a fish and wildlife habitat restoration plan for Jamaica Bay includes conceptual plans for construction of intertidal wetlands and sub-tidal recontouring for water quality and habitat improvement (USACE 1998).

Use of Constructed Wetlands to Treat Municipal and Industrial Wastewater - Overview

A constructed wetland is a man-made complex of saturated substrates, emergent and submersed vegetation, animal life, and water that simulates natural wetlands for human use and benefits. Synonyms include *man-made*, *artificial* and *engineered* wetlands. These systems are intended to emulate the decontamination functions of natural wetlands. Hundreds of artificial wetlands have been constructed in the U.S. and in Europe to treat municipal and industrial wastewater, as well as stormwater, in rural communities, and large urban areas. Emergent, non-tidal freshwater marshes are most commonly used for wastewater treatment purposes, due to ease of propagation, and fast growth and environmental tolerance of most emergent wetland macrophytes. However, there are a few examples of experimental tidal freshwater wetlands in New Jersey and Louisiana which have been used to treat wastewater. Plants with high uptake and production rates are best suited for use in treatment wetlands. Examples include *Phalaris, Spartina, Carex, Juncus, Scirpus* and *Typha*. Submerged aquatic plants are not as well-suited for treatment of wastewater due to relatively low production rates (in comparison to emergent marsh plants) and intolerance of poor water quality, in general (Guntenspergen et al. 1989).

Nitrogen is the principal nutrient species in wastewater. The principal means for its removal is anaerobic denitrification by soil microorganisms, with subsequent atmospheric release of nitrogen gas. Careful manipulation of water levels is used to optimize denitrification in constructed wetlands. If flooding depth is too great, then nitrogen gas may not effectively escape to the atmosphere. If flooding is too shallow, then proper anaerobic soil development may not occur. Amendment of constructed wetland soils with cellulose has been employed to ensure anaerobic denitrification at a variety of flooding depths (C. R. Lee, USACE-WES, pers. comm.).

Phosphorous occurs in many forms in municipal and industrial wastewater, many of which can be taken up by wetland plants. The primary means of removing phosphorous from treatment wetlands is by biomass harvesting. This can be done as often as every two weeks for certain freshwater marsh species, such as bulrushes. Other species (e.g. *Typha* spp.) require longer recovery times between harvest intervals (Sloey et al. 1978).

Advantages of constructed wetlands for wastewater treatment include:

- low cost to construct and operate
- ease of maintenance
- provision of effective and reliable wastewater treatment
- provision of additional benefits, such as fish and wildlife habitat, green space, etc.

The primary disadvantage of constructed wetlands is the relatively large land area required; this could be a problem in urban applications. Constructed wetlands typically require minimal maintenance; this usually consists of removal of unwanted invasive plant species and vector (mosquito) control using integrated pest management techniques, such as introduction of fish.

Critical design factors for constructed wetlands include:

- Velocity and flow rate
- Water depth and water level fluctuation
- Detention time
- Circulation and distribution patterns
- Soil permeability and groundwater movement
- Turbulence and wave action.

Construction features of treatment wetlands are intended to maximize the residence time of wastewater in the system. The input (outfall) should be designed such that wastewater enters the system as sheet flow, not channel flow, in order to optimize the opportunity for nutrient and contaminant uptake and adsorption.

Early research and experimentation focused on using natural tidal wetlands for processing industrial or municipal wastewater (Mitsch and Gosselink 1993). Recently, however, there has been concern over discharging high volumes of contaminants, nutrients and pathogens into healthy, functioning natural wetlands. The current consensus among wetland ecologists is that natural wetlands should not be impacted via diversion of wastewater. Furthermore, use of tidal wetlands for wastewater treatment can be problematic due to natural hydrologic variation. Discontinuity in flooding depth and duration of tidal systems makes it difficult to quantify assimilation and processing rates. Flow patterns are multi-directional and rapidly changing, and flow boundaries are poorly defined (Guida and Kugelman 1989). These variables can be controlled and adjusted as necessary to optimize performance in constructed non-tidal freshwater wetlands, many of which are quite sophisticated; with impermeable liners, various layers of porous media, pre-treatment ponds, and separate treatment cells with control structures that allow each to be managed independently in order to optimize the assimilative properties of the system. Although tidal wetlands perform the same contaminant uptake and filtration functions of non-tidal wetlands, it is difficult to predict, quantify, or manage nutrient or contaminant assimilation and sequestration, relative to a closed, non-tidal system. Thus, there are very few documented examples of the use of constructed tidal wetlands for treatment of industrial or municipal wastewater. Some worth noting include:

- The use of *Spartina alterniflora* marshes to treat seafood processing plant effluents in New Jersey (Guida and Kugelman 1989).

- Experimental work at Kennedy Space Center on *Spartina alterniflora* and several other brackish and saline wetland species for use in removing metals, especially copper and zinc (Owens et al. 1989).

- Early experimental studies conducted under the USACE - DMRP on the use of tidal wetlands to filter and remove nutrients and heavy metals from dredged material slurry (Lee et al. 1976, Windom 1977). Tidal marsh plants, particularly *Spartina alterniflora* are capable of taking up a variety of metals including copper, manganese, iron, nickel, zinc, and cadmium (Dunstan and Windom 1975).

Opportunities to Construct "Treatment Wetlands" Using Dredged Material in Disused Docks/Basins in NY Harbor

Construction of intertidal marshes from dredged material has been proposed as a beneficial use option for New York Harbor. Many abandoned docks and basins along the New York City waterfront, particularly in the Gowanus Bay area, could potentially serve as sites for the placement of dredged material and subsequent construction of intertidal wetlands (**Figure 7-1**). These intertidal wetlands would not be engineered as "treatment wetlands" as described above;

however, in basins which receive direct input of wastewater via CSO's, some "effluent polishing" benefits attributed to intertidal wetlands would be provided. Because CSO's are subject to highly variable flow rates, maintenance of appropriate tidal water levels within such wetlands would require flow equalization via detention basins or other engineered structures in order to reduce scouring effects and to regulate nutrient and contaminant loads.

Given the large number of candidate sites, the potential for beneficial use of a considerable volume of dredged material is high. Nineteen such basins were surveyed in March 1998 in order to develop approximate estimates of area and volume for constructed marshes using dredged materials. (**Table 7-1**). Eighteen of these were located along the shoreline of Gowanus Bay, in Brooklyn (**Figure 7-2**). Bushwick Inlet, in Greenpoint, Brooklyn, was also surveyed as a candidate site for this alternative.

Throughout the Harbor, there exist many other such sites, notably in upper Jamaica Bay and along the New Jersey waterfront. The New Jersey Department of Commerce and Economic Development (NJDCED) has been developing a plan to construct artificial intertidal wetlands using dredged material and is currently evaluating possible sites along the New Jersey waterfront based on land-use characteristics, using a Geographic Information System (GIS) (J. DiLorenzo, pers. comm.). The Gaia Institute, of City Island, New York, has developed a draft plan to construct intertidal marshes in various locations throughout the Harbor (Paul Mankiewicz, pers. comm). Construction of 30 acre salt marsh has been proposed adjacent to the Pelham Bay landfill, in Eastchester Bay. The goal of this project is to provide a natural filter for stormwater runoff and contaminated leachate from the landfill, as well as restore intertidal wetlands in an area of the Harbor in which this habitat type was historically widespread. Draft wetland construction plans for other areas of the Harbor, estimated to account for some 20,000,000 cy of dredged material from the Port of NY/NJ, are currently being developed by the Gaia Institute and includes project sites on South Brothers Island, Rikers Island, Pugsley Creek, Westchester Creek, East River, various locations in Jamaica Bay, and on Staten Island.

It is estimated that the 19 inter-pier basins surveyed in the Gowanus Bay area could cumulatively provide for placement of over 4.2 million cubic yards of dredged material, resulting in the establishment of 116 acres of intertidal *Spartina alterniflora* marsh (assuming a 5 ft. cap of clean sediment fill in each, graded to intertidal elevation). The cost of placing dredged material in this area is estimated at $37 per cubic yard (USACE 1996). This does not include the cost of capping the dredged material, if necessary, planting of intertidal vegetation, and monitoring/maintenance. Marsh vegetation transplant costs are conservatively estimated at approximately $25,000 per acre (USACE 1996). The total estimated cost of this proposed alternative, assuming that all 117 acres were to be constructed, would exceed $173,000,000. It is very unlikely, however, that all 19 basins would immediately be available for use as placement sites. One or more demonstration wetlands would probably be constructed in the area, at an

Table 7-1:

Potential area (in acres), estimated capacity (cubic yards), and estimated cost of constructing intertidal wetlands using dredged material in disused inter-pier basins; Gowanus Bay and Greenpoint, Brooklyn. Capacity was determined by multiplying basin areas by average depth, determined using an electronic depthfinder aboard the R/V Hudson during site visits, March 1998. Depths were recorded approximately halfway between MHW and MLW, on an outgoing tide. Approximate costs were determined by multiplying estimated capacity by $37 per cy (USACE 1996). The cost of planting intertidal marsh vegetation (*Spartina alterniflora*) was estimated at $25,000 per acre (USACE 1996). The cost of placing a clean sand cap at each site is also estimated at $37 per cy, and is included in the capacity estimate. Thus, actual capacity will depend on the depth of the cap used, in addition to any adjustments to account for compaction and settling of dredged material.

Name	Location	Area	est. capacity	est. cost.
Army Pier 1/2	Gowanus Bay	5.9	238,333	$8,965,821
Army Pier 2/3	Gowanus Bay	6.2	275,000	$10,330,000
Army Pier 3/4	Gowanus Bay	6.2	275,000	$10,330,000
Army Pier 4/57th St.	Gowanus Bay	7.3	316,800	$11,904,100
South of 56th St. Pier	Gowanus Bay	6.0	213,378	$8,044,986
Bush Terminal 1/2	Gowanus Bay	5.7	156,281	$5,924,897
Bush Terminal 2/3	Gowanus Bay	4.1	100,000	$3,802,500
Bush Terminal 3/4	Gowanus Bay	4.5	139,333	$5,267,821
Bush Terminal 4/5	Gowanus Bay	9.1	337,333	$12,708,821
Bush Terminal 5/6	Gowanus Bay	5.5	212,800	$8,011,100
Bush Terminal 6/7	Gowanus Bay	4.8	187,200	$7,046,400
Bush Terminal 7/39th St.	Gowanus Bay	6.1	257,400	$9,676,300
36th - 39th St.	Gowanus Bay	5.7	265,215	$9,955,455
South of 31st St. Pier	Gowanus Bay	9.0	451,050	$16,913,850
South of 23rd St. Pier	Gowanus Bay	7.4	420,000	$15,725,000
North of 23rd St. Pier	Gowanus Bay	7.4	360,000	$13,505,000
North of Isbrantsen Pier	Gowanus Bay	3.4	132,704	$4,995,048
Grain Terminal Basin	Gowanus Bay	5.0	177,100	$6,677,700
Bushwick Inlet	Greenpoint	6.3	102,283	$3,941,971
		115.6	**4,279,877**	**$173,726,770**

average cost of approximately $1,500,000 per acre. Monitoring of the construction and performance of the demonstration wetlands in these inter-pier basins would be invaluable for determination of appropriate design parameters necessary for future large-scale efforts, and for improving the state-of-the-art in constructing intertidal wetlands for improvement of water quality, in general.

Additional benefits of constructing wetlands in this area include the provision of valuable wetland habitat for fish and wildlife, and general aesthetic benefits resulting from the presence of "greenways." Several species of fish and invertebrates present in NY/NJ Harbor are known to directly utilize intertidal wetlands, including summer flounder and blue crab. Important prey species such as killifish, Atlantic silversides, and grass shrimp rely on intertidal wetland habitats; these organisms provide the forage base for migratory and estuarine-dependent predators (striped bass, bluefish, flounder, weakfish, etc.). As with any proposed habitat development project in NY/NJ Harbor involving dredged material, consideration must be given to the potential release of contaminants into surface waters, and the potential uptake of contaminants by wetland biota, including plants, invertebrates, fish and birds. Placement of a clean sediment cap and incorporation of engineering structures to contain contaminated sediments are necessary considerations in projects of this type. Habitat trade-off issues must be considered in wetland creation projects in NY/NJ Harbor, as some important fishery species (e.g. striped bass) benefit from the structurally complex inter-pier and pile field habitat already present in many shoreline areas. Any large scale effort to replace pier/pile field habitats with intertidal wetlands should consider construction of alternative hard structure in deeper waters (e.g. prefabricated artificial reefs) in order to mitigate for the elimination of potential habitat for striped bass and other anadromous or resident fishery species in the immediate area.

The potential for impacts to existing cultural resources must be addressed in consideration of constructing wetlands in this area. Historic navigational structures, such as wharves, piers, and bulkheads are potentially important cultural resources. An archaeological assessment would be required in a feasibility study prior to placement of dredged material and construction of wetlands. The U.S. Military Ocean Terminal and Bush Terminal are located in the proposed study area; both are considered significant cultural resources; the former is currently listed on the National Register of Historic Places.

Filling in Dead-End Canals and Basins

A common environmental problem in urbanized coastal areas involves habitat and water quality degradation in residential and industrial dead-end canals and abandoned dock basins (Hawkins et al. 1992; Maxted et al. 1997). These degraded habitats are abundant in industrialized areas and may date back to colonial times in large U.S. cities (e.g. New York, Boston, Philadelphia); and even earlier in European cities. Typically, dead-end canals are narrow, linear channels with hardened shorelines and a single outlet. In residential areas the primary purpose is to provide private moorage for recreational vessels. Because they are dredged to a depth greater than the surrounding estuary, they often promote poor circulation of water, resulting in stagnation and poor water quality. Chronic water pollution in dead-end canals and basins stems from human and industrial waste discharge, both from vessels and shore facilities nearby. Many dead-end canals and basins in urban areas are severely polluted from decades to centuries of unregulated dumping and discharge. Poor tidal circulation in dead end canals and deep basins, combined with the prevalence of organic matter in sediments, results in near continuous hypoxia or anoxia. Benthic invertebrate communities of dead-end canals and basins are species-poor and dominated by a few opportunistic taxa, mostly annelid worms or insect larvae. Bacterial mats and noxious algal blooms are prevalent. Certain blue-green algae and dinoflagellates associated with these blooms produce toxins known to cause significant mortality in fishes, and may cause sickness in humans. High concentrations of heavy metals and other industrial contaminants may occur in in dead-end canal and basin sediments (Hawkins et al. 1992, Maxted et al. 1997).

The first step to rehabilitating these areas is to identify and curtail/treat discharges of industrial and human wastes. Following cessation of discharge activities, there are several possible means of improving water and habitat quality. Mechanical aeration of anoxic basin sediments has been used to promote mixing and oxygenation. Hydraulic pumps and paddles can be used to promote mixing in enclosed areas. Filter feeding bivalves have been transplanted in dock/pier areas as biological filters to improve water quality. If severely degraded conditions are present, dead-end canals and deep basins can be filled in or recontoured to improve circulation (Hawkins et al. 1992).

Filling in Dead-End Canals and Basins using Dredged Material: Dead-end canals and basins are among the most degraded of aquatic habitats present in New York Harbor and surrounding waters. The location of these areas (either industrial or densely populated residential areas) and the severity of environmental degradation which characterizes them makes them poor candidates for successful habitat restoration. However, if no action is taken, these habitats will continue to contribute to poor water quality and function as a chronic source of pathogens and contaminants to the Harbor ecosystem. Thus, the best option for “improvement” of these areas may be to fill them with dredged material, which would permanently and effectively eliminate a significant detriment to water and sediment quality in adjacent areas. The basins themselves would be transformed into urban terrestrial habitats; and could be covered with a substrate suitable for the development of urban parks or greenways. While this option clearly does not result in restoration of aquatic habitat *in situ*, the long-term benefits of curtailing a source of considerable habitat degradation for the entire NY/NJ Harbor and New York Bight ecosystem may justify this alternative in select cases.

The volume of dredged material that could be beneficially used in this manner is potentially significant. Several sites were surveyed in March 1998 for the purpose of identifying surrounding land-use and other factors that would determine the feasibility of this beneficial use option, and to develop preliminary estimates of dredged material volumes that could be used in this manner. Specific sites examined were:

- Gowanus Canal
- Bowery Bay
- Atlantic Basin
- Wallabout Channel
- Tributaries of Newtown Creek (English Kills, East Branch, Maspeth Creek, and Dutch Kills)

The combined capacity of these 5 sites for dredged material placement is estimated to exceed 2,800,000 cubic yards (**Table 7-2**). Bowery Bay is the single largest potential placement option for this alternative and alone could accommodate over 1,500,000 cy, if filled and graded to upland elevation. The total estimated cost of filling all five sites with dredged material (assuming a placement cost of $37 per cy) is approximately $118,000,000. These costs are preliminary estimates based on initial site visits and their refinement will require analysis of technological and navigational constraints, and detailed hydrographic surveys of each area. These estimates do not include the cost of capping, soil placement, and planting with terrestrial vegetation, if desired.

Filling in of "unrestorable" waterways such as these would require considerable planning and evaluation on a site-specific basis in order to best determine the engineering and environmental constraints associated with this placement option. For example, CSO discharges (outfalls) are present at several of the above sites. During storm events, substantial discharge velocities can occur. These outfalls would have to be either diverted, blocked, or extended through the fill material. Alternatively, a subterranean catchment basin could be installed underneath the fill to temporarily store wastewater for gradual release back to the WPCP. Stormwater runoff which currently enters these waterways via sheet flow across impermeable urban surfaces would no longer be intercepted, requiring the design and incorporation of adequate drainage systems. Several of these sites (e.g. English Kills, Gowanus Canal) are currently designated as "navigable waterways" and would require de-designation prior to filling. Ongoing navigational uses in these waterways, such as transport of fuel oil in Gowanus Canal, will require consideration and development of cost-effective alternatives. Socio-economic, cultural/archaeological, and other non-engineering issues would require detailed consideration in a feasibility study.

A plan to improve habitat and water quality in Long Slip Canal, Hoboken, NJ, involves the construction of a 4.5 acre CPF (Confined Placement Facility) within the canal (Porrovecchio et al. 1997). This site is characterized by limited tidal circulation, stratification of the water column, and chronic seasonal hypoxia/anoxia, resulting in the exclusion of fish from a potentially significant interpier habitat. Two CSO's currently discharge into the basin, further contributing to water quality and habitat degradation. Under the current plan, 100,000 cy of sediment will be dredged from a shoal at the mouth of the basin, and placed in the CPF. The completed CPF will be developed as an expansion of an existing rail yard facility. Improving flow across the entrance channel, and eliminating the stagnant water mass in the basin is expected to result in marked improvements in water quality in the area. The CSO's would be modified and extended to discharge into areas of greater circulation. Finally, it is expected that resident and migratory

Table 7-2:

Potential area (in acres), estimated capacity (cubic yards), and estimated cost of filling dead-end canals and basins with dredged material; Bowery Bay, Atlantic Basin, Wallabout Channel, Gowanus Canal, and Newtown Creek tributaries. Capacity was determined by multiplying basin areas by average depth, determined using an electronic depthfinder aboard the R/V Hudson during site visits, March 1998. Approximate costs for Bowery Bay, Atlantic Basin, and Wallabout Channel were determined by multiplying estimated capacity by $37 per cy (USACE 1996). The cost of placing a clean sand cap at each site is also estimated at $37 per cy, and is included in the capacity estimate. The cost of disposing dredged material in Gowanus Canal and the Newtown Creek tributaries is estimated at $61 per cy (USACE 1996). Actual capacity will depend on the depth of the cap used, in addition to any adjustments to account for compaction and settling of dredged material. Post-disposal site development is not represented in the cost estimates, due to the variety of potential options. Data are unavailable for Dutch Kills at the present time due to navigational constraints.

Name	**Location**	**Area**	**est. capacity**	**est. cost.**
Bowery Bay	Queens	58.2	1,502,832	$55,604,784
Atlantic Basin	Brooklyn	15.3	841,976	$31,153,112
Wallabout Channel	Brooklyn	3.9	37,680	$1,394,160
Gowanus Canal	Brooklyn	10.6	170,417	$10,395,437
English Kills	Newtown Creek	7.0	125,686	$7,666,846
East Branch	Newtown Creek	3.0	81,620	$4,978,820
Maspeth Creek	Newtown Creek	5.8	111,724	$6,815,164
Dutch Kills	Newtown Creek	n/a	n/a	n/a
		103.8	**2,871,935**	**$118,017,323**

juvenile finfish will benefit from refuge and feeding habitat provided by the structurally complex rip-rap armoring along the containment dike.

Another potential alternative involves a variation of the scenario described above in which intertidal wetlands are created in the upper reaches of dead-end basins, as previously outlined for inter-pier basins in Gowanus Bay and other areas. This would probably be most feasible in the several large channels/basins of Upper Jamaica Bay, specifically Paerdegat, Bergen, and Thurston Basins. These waterways are surrounded by residential/industrial areas, and the lower reaches of each are actively used for recreational vessel mooring and industrial/commercial activity, including access by fuel barges for John F. Kennedy International Airport. The upper reaches of these basins, however, appear to be disused or abandoned, and could conceivably function as a repository for a considerable volume of dredged material. Each basin has a CSO outfall at its terminus, and a constructed wetland could provide some water quality improvement benefits at each site. These basins are a chronic source of pathogens, floatables and contaminants via discharge of stormwater and untreated sewage into Jamaica Bay, and as such, would be suitable candidates for habitat development projects which could result in water quality improvement.

The three basins were surveyed in March, 1998 in order to generate preliminary estimates of wetland acreage and dredged material capacity in a constructed wetland scenario (**Table 7-3**). The approximate usable areas of each basin involved were arbitrarily determined via identification of obvious indicators of disuse (e.g. derelict piers, vessels). Areas that were obviously being used for residential or industrial activity were not included. A minimum of 130 acres of intertidal wetland could potentially be constructed within Paerdegat, Thurston, and Bergen Basins. This would accommodate approximately 3.3 million cy of dredged material, assuming a 1.5 m cap of clean sediment fill. Approximate costs of performing this alternative, assuming a placement cost of $37 per cy and $25,000 per acre for planting of intertidal vegetation approach $127,000,000.

Regulatory Authority for Construction of Intertidal "Treatment" Wetlands in NY/NJ Harbor

Construction of intertidal wetlands and filling of disused waterways for water quality enhancement in NY/NJ harbor may be authorized under Section 404 (b)(1) of the Clean Water Act of 1972, Section 1135 of WRDA of 1986 and Section 206 of WRDA 1996. In addition, Section 204 of WRDA 1992 provides funding and authority for the beneficial use of dredged material for creation and restoration of aquatic or related habitats in association with construction, operation or maintenance of authorized navigation projects. Section 216 of the Rivers and Harbors Act of 1970 authorizes the USACE to review navigation projects and recommend modifications that would involve habitat creation/restoration using dredged material. Habitat development projects in the Harbor are also subject to regulation by individual state (NY and NJ) laws, statutes, and permitting authorities.

Table 7-3:

Potential area (in acres), estimated capacity (cubic yards), and estimated cost of constructing intertidal wetlands using dredged material in dead-end canals, upper Jamaica Bay. Capacity was determined by multiplying basin areas by average depth, determined using an electronic depthfinder aboard the R/V Hudson during site visits, March 1998. Approximate costs were determined by multiplying estimated capacity by $37 per cy (USACE 1996). The cost of planting intertidal marsh vegetation (*Spartina alterniflora*) was estimated at $25,000 per acre (USACE 1996). The cost of placing a clean sand cap at each site is also estimated at $37 per cy, and is included in the capacity estimate. Disposal and capping costs may be considerably higher in these basins, due to navigational constraints, however, these locations have not been previously considered for dredged material disposal and additional data are needed. Actual capacity will depend on the depth of the cap used, in addition to any adjustments to account for compaction and settling of dredged material.

Name	Location	Area	est. capacity	est. cost.
Bergen Basin	Queens, W. of JFK	68.1	1,978,080	$74,891,460
Thurston Basin	Queens, E. of JFK	27.7	624,960	$23,816,020
Paerdegat Basin	Canarsie, Brooklyn	34.9	732,333	$27,968,821
		130.7	**3,335,373**	**$126,676,301**

Figure 7-1
Estimated Capacity of Dead-End Basins for Dredged Material

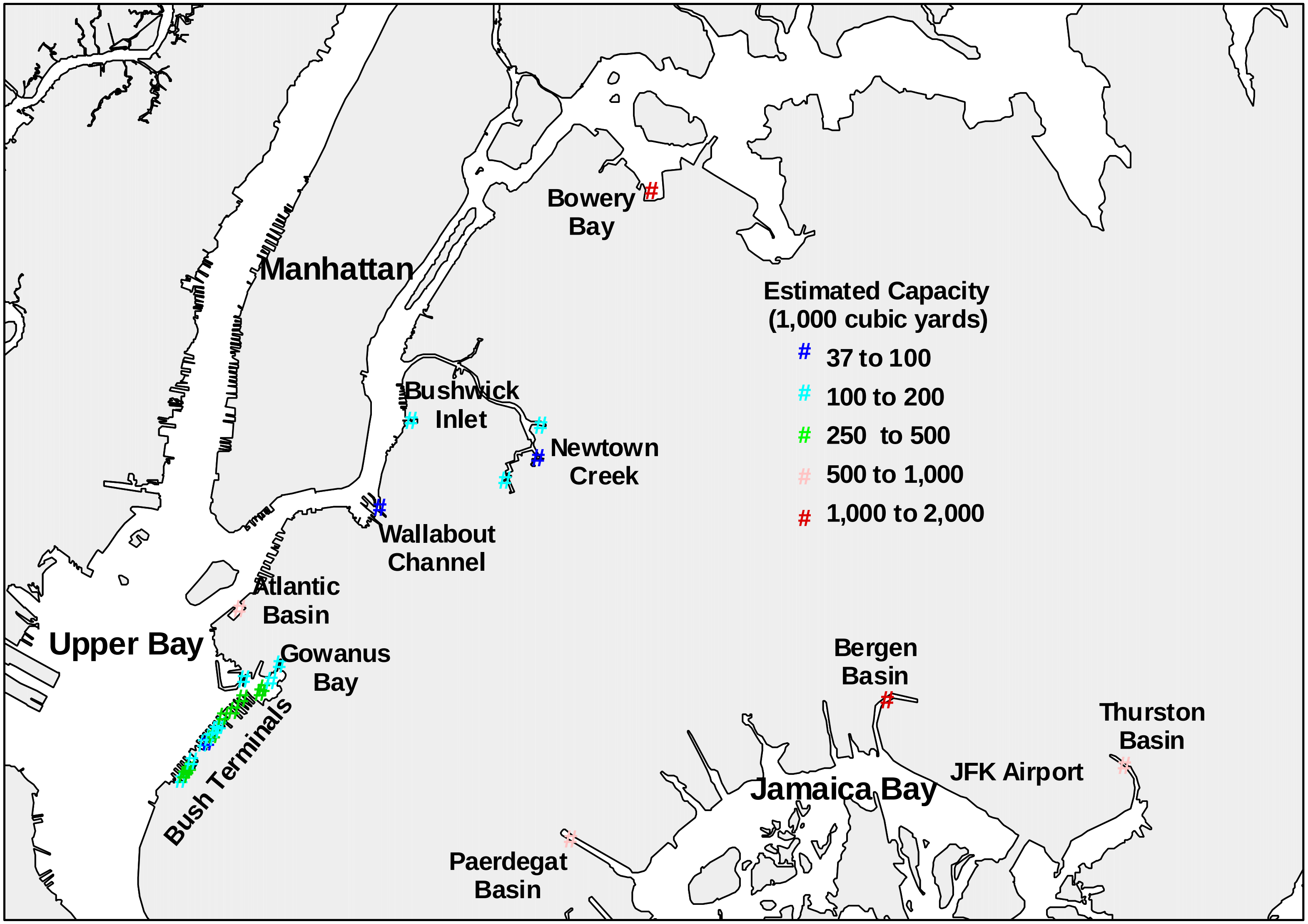

Figure 7-2: Disused basin, Bush Terminal, Gowanus Bay, Brooklyn.

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8. CREATION OF BIRD/WILDLIFE ISLANDS AND UPLAND HABITATS USING DREDGED MATERIAL IN NY/NJ HARBOR

Terrestrial islands and coastal uplands may be created using dredged material to provide nesting and refuge habitats for birds and other wildlife. Historically, in the U.S. and elsewhere, many dredged material islands which were created simply as a convenient placement option for shipping channel maintenance have developed naturally into productive and valuable wildlife habitat. Over 1000 dredged material islands have been constructed in U.S. Atlantic and Gulf coast estuaries; some of the earliest (e.g. Hudson River estuary) date back to the early-mid 19th century. Dredged material islands and upland habitats have also been constructed throughout the Great Lakes region, in Pacific coast estuaries, and in other estuaries worldwide.

Terrestrial habitats created using dredged material range in size from less than one acre to over 200 acres and are typically constructed using sand or silt-sand. Created islands may be confined using riprap, wooden cribs or bulkheads, or stabilized with emergent marsh vegetation (e.g. *Spartina alterniflora*). These habitats may be constructed singly, or in aggregations, or they may be used to increase the area of an existing natural island. In addition to providing habitat for birds and other wildlife, many created islands are used for human recreational activities, such as camping, hunting, fishing, bird watching, etc.

Many of the USACE - DMRP habitat development sites included bird/wildlife islands as part of the overall habitat mosaic created (Buckley and McCaffrey 1978; Chaney et al. 1978; Parnell et al. 1978, 1986; Soots and Landin 1978), and these are generally well-documented with regard to construction techniques, vegetation development, and bird/wildlife utilization. Coastal dredged material islands are used extensively as nesting areas/rookeries by various aquatic avifauna, including terns, gull, pelicans, skimmers, stilts, willets, herons, egrets, ibises, and oystercatchers. Upland meadows and forests created on dredged material provide overwintering habitat and migratory stopovers for waterfowl, songbirds and raptors.

The USACE has undertaken numerous studies on the engineering and ecological attributes of created bird/wildlife islands. Important factors investigated include the effects of topography, slope, elevation, vegetation, stabilization structures, and the role of adjacent aquatic or terrestrial habitats. Population and community-level studies of avifauna and other wildlife have been conducted at dredged material islands in North Carolina, Texas, Louisiana, New Jersey, the Pacific Northwest, the upper Mississippi River, and the Great Lakes region. These studies have resulted in significant improvements to the engineering state-of-the-art for constructing bird/wildlife islands and have provided valuable life-history and population dynamics data for a number of bird and wildlife species which inhabit dredged material islands (Landin 1997).

In general, it appears that islands of no less than 5 acres and no larger than 50 acres in size are optimum, although there are many examples of smaller and larger islands that have proven successful in supporting bird/wildlife populations.

Achieving the proper elevation and slope is critical for nesting success by colonial shorebird species (Landin 1997). Typically, islands should be 6-10 ft above MHW, and a slope of less than 3 ft rise for every 100 ft run is optimum for nesting (eggs roll out of nests built on steeper slopes).

Maximum utilization by a diverse bird and wildlife assemblage is attained when habitat heterogeneity is maximized. Dunes, vegetated swales, ponds, and mud/sandflats are all important components of a well functioning bird/wildlife island. Tree and shrub species rapidly colonize dredged material islands, providing rookeries for species which nest in canopies. Small mammals, such as mice, shrews, and voles will readily colonize these islands, especially if nearby upland habitats are available to provide dispersal corridors. Deer, foxes, raccoons and other species are typical residents of created upland habitats in coastal areas.

Studies along the North Carolina coast (Parnell et al. 1978, 1986) suggest that the presence or absence of retaining dikes is an important determinant of plant colonization rates and subsequent utilization by wildlife species. The earlier constructed wildlife islands in North Carolina (prior to the mid-1970's) were mostly undiked; islands constructed post 1975-76 were diked. Diked islands were not used as extensively as nesting sites by colonial waterbirds compared to the undiked islands. Terrestrial plant species colonize diked islands more rapidly than undiked islands; species which prefer dense vegetative cover (some small mammals, arboreal birds) benefit at these sites; however most colonial waterbirds prefer to nest along sparsely vegetated beachfront, which is available mainly at older, undiked islands. Nest sites located behind dikes are subject to periodic flooding following heavy rain events. Also, many young birds may become trapped and die in rock or riprap structures. Many previously undiked islands have been diked at a later date for stability and longevity; however, this has resulted in a decrease in available nesting habitat for colonial waterbirds.

A recent USACE - Wilmington District effort to re-establish nesting habitat on Wainwright Island, a dredged material placement island in Core Sound, North Carolina has been successful. Approximately 80,000 cy of sandy dredged material was used to restore nine acres of nesting habitat for royal terns (*Sterna maxima*) and sandwich terns (*Sterna sandvicensis*), which had abandoned the rapidly eroding site several years ago (Wilder 1997).

Recent USACE - New Orleans District efforts to construct bird/wildlife islands and wetlands as a beneficial placement option in the lower Mississippi River Delta, Louisiana, have provided over 500 acres of essential habitat, including nesting and roosting areas for white pelicans (*Pelecanus erythrorhynchos*), Caspian terns (*Sterna caspia*) and gull-billed terns (*Sterna nilotica*). An adaptive approach to site construction and maintenance was incorporated in order to achieve the specified development goals, with particular emphasis on island orientation (construction of perpendicular dredged material mounds) and dredged material height requirements (Gunn 1997).

The Detroit District, USACE has beneficially used several million cubic yards of clean and mildly contaminated dredged material from the Great Lakes and nearby waterways in the construction of bird and wildlife habitat, including upland meadow and emergent freshwater wetlands (P.

Horner, pers. comm.). Most of these projects were completed during the 1970's and 1980's and provide critical nesting/forage areas for various aquatic avifauna, including dabbling ducks and the endangered Caspian tern.

Opportunities to Create Bird/Wildlife Islands in NY/NJ Harbor

Creation of bird/wildlife islands or upland habitats is a viable option for the beneficial use of dredged material in NY/NJ Harbor. Natural uplands or island habitats are rare within the heavily urbanized harbor area, and both resident and migratory bird populations would likely benefit from the provision of additional nesting and feeding habitat. As with other beneficial use projects, an important and contentious issue is that of habitat trade-offs. Creation of intertidal or upland habitat in open-water areas is often a controversial topic. It may not be environmentally acceptable to all parties involved to sacrifice shallow water habitat in exchange for bird/wildlife islands. In New York Harbor, this issue can be minimized by carefully identifying and avoiding critical shallow water habitats (e.g. shellfish beds, migratory pathways for anadromous finfish), and perhaps focusing on creation of intertidal and upland habitat along existing shorelines of islands which are undergoing erosion.

The use of contaminated dredged material for creation of bird/wildlife islands or the enhancement of existing terrestrial habitats is a separate issue of concern. Contaminated sediments require capping with clean substrate in order to prevent potential uptake of contaminants by emergent vegetation, insects and other invertebrates, birds, and mammals. Placement of a minimum of two feet of clean substrate on top of dredged material is recommended by NJDEP for upland habitat development projects (NJDEP 1997). Use of estuarine or marine sediments in upland habitat development projects may require desalinization. Soil amendments using lime and organic matter may be needed in order to provide a suitable medium for the growth of upland plant species (NJDEP 1997).

Intertidal marsh and beach/dune restoration benefits various shorebirds such as sandpipers and plovers, gulls, terns, herons, and egrets (**Table 8-1**). Threatened and endangered (T&E) shorebirds, including piping plover (*Charadrius melodus*) roseate tern (*Sterna dougallii*) and least tern (*Sterna antillarum*) have declined in recent years in NY Harbor. Other T&E species, including black skimmer (*Rynchops niger*) and common tern (*Sterna hirundo*) have increased or remained stable. Herons, 9 species of which are known to frequent New York Harbor, appear to be increasing or maintaining stable populations. These birds depend on habitat provided at several existing islands, including Shooter's Island in the Kill van Kull, Prall's Island and Isle of Meadows in the Arthur Kill, and North and South Brothers Islands in the East River, as well as some locations on Staten Island and in Jamaica Bay. Stabilizing and/or expanding available habitat on these islands may ensure continued success and further expansion of these populations (Kerlinger 1997a, 1997b).

Table 8-1:
Species expected to benefit from upland and wetland habitat creation using dredged materials in NY/NJ Harbor* (adapted from Kerlinger 1997a, 1997b).

	Common Name	Scientific Name
Seabirds	Double-crested Cormorant	*Phalacrocorax auritus*
Shorebirds	Least Tern	*Sterna antillarum*
	Common Tern	*Sterna hirundo*
	Roseate Tern	*Sterna dougallii*
	Piping Plover	*Charadrius melodus*
	Black Skimmer	*Rynchops niger*
	Clapper Rail	*Rallus longirostris*
	Upland Sandpiper	*Bartramia longicauda*
Songbirds	Seaside Sparrow	*Ammodramus maritimus*
	Sharp-tailed Sparrow	*Ammodramus caudacutus*
	Grasshopper Sparrow	*Ammodramus savannarum*
	Savannah Sparrow	*Passerculus sandwichensis*
	Eastern Meadowlark	*Sturnella magna*
	Hermit Thrush	*Catharus guttatus*
	warbler species	Parulidae
Raptors	Osprey	*Pandion haliaetus*
	Northern Harrier	*Circus cyaneus*
	Short-eared Owl	*Asio flammeus*
Wading Birds	Great Egret	*Casmerodius albus*
	Snowy Egret	*Egretta thula*
	Cattle Egret	*Bubulcus ibis*
	Little Blue Heron	*Egretta caerulea*
	Tricolored Heron	*Egretta tricolor*
	Green Heron	*Butorides striatus*
	Black-crowned Night Heron	*Nycticorax nycticorax*
	Yellow-crowned Night Heron	*Nycticorax violaceus*
	Glossy Ibis	*Plegadis falcinellus*
Waterfowl	American Black Duck	*Anas rubripes*
	Gadwell	*Anas strepera*
	Mute Swan	*Cygnus olor*

* The species listed in this table were observed in NY/NJ Harbor and do not include a complete listing of all of the possible species that could inhabit or visit New York Harbor over the course of a year or years.

Restoration of upland forests and grasslands primarily benefits migratory and resident songbirds. North American songbirds (those species that do not fly south of the U.S. during winter) are seasonally abundant in the NY/NJ Harbor area and are not in need of special consideration in habitat restoration efforts. Neotropical migrants, however, are in decline due to destruction of overwintering habitat in southern latitudes and fragmentation/loss of breeding habitats in the U.S. Native forest and upland habitats are of particular importance for neotropical migrants, and these species benefit most from restoration projects which include forested uplands. Relatively little is known about neotropical migratory songbird habitat requirements in NY/NJ Harbor, however, it has been suggested that they would benefit most from elimination of invasive or non-native upland plant species and reintroduction of native trees and shrubs (Kerlinger 1997b).

Potential Project Sites: Several locations in the harbor have been specifically identified as potential habitat restoration projects involving beneficial use of dredged material (**Table 8-2, Figure 8-1**). Floyd Bennett Field, part of the Gateway National Recreation Area, in Brooklyn, is one such location (Kerlinger 1997b). A 140 acre grassland restoration was conducted at Floyd Bennett Field during the last decade, and managed for provision of songbird habitat. Unfortunately, the size of this project is insufficient to maintain viable breeding populations of grassland songbirds, and additional acreage is needed. A large volume of fine substrate is needed to cover disused runways at Floyd Bennett Field in order to construct additional grassland habitat. Fine-grained dredged material may potentially be placed at this site. A restored area of at least twice the size of the current grassland would be needed in order to provide suitable nesting habitat for songbird populations (Kerlinger 1997b). As an illustrative example, a 200 acre project at this site could provide for placement of some 970,000 cy of fine-grained dredged material, assuming a fill depth of 3 ft. This material would likely require capping with clean fill and a layer of sand or fertile topsoil, and could then be planted with desired herbaceous or woody vegetation. A management program would be necessary to remove and/or suppress invasive plant species (e.g. *Phragmites*).

Another potential project site is South Brother Island, in the East River. This site is considered to be one of the primary nesting sites for herons and egrets in the Harbor, with approximately 400 nesting pairs present annually (Kerlinger 1997b). Nesting birds must fly several miles to find intertidal wetlands for foraging; creation of several acres of intertidal salt marsh at the east end of South Brother Island would benefit these birds and their fledglings via provision of a nearby forage site, while providing a beneficial use option for dredged material placement. Presently, the area at the east end of the island is shallow water and sandy beach, along with exposed rock outcrops. Strong currents and wave action in the vicinity of this site mandate use of a permanent or semi-permanent protective dike, although this might not be necessary once marsh vegetation became established. Additional studies will be needed to quantify wave climate and erosion potential before any detailed plans for marsh creation could be developed for this site.

The Hoffman-Swinburne Island complex, located along the eastern shore of Staten Island and part of the Gateway National Recreation Area, is another candidate for habitat restoration using dredged material. Swinburne Island is approximately 1.1 acres and is largely covered with

Table 8-2:

Proposed bird/wildlife habitat improvement projects using dredged material in NY/NJ Harbor (from Kerlinger 1997b)

Name	Location	Area (acres)	Proposed Habitat	Target Species	est. capacity (cy)
Floyd Bennett Field	Brooklyn	200-400	upland meadow	songbirds	970,000 - 1,940,000
South Brother Island	East River	5-10	intertidal marsh	herons	100,000 - 200,000
Hoffman-Swinburne Islands	Lower NY Bay	8.4	upland forest	herons/songbirds	40,000
Prall's Island/Isle of Meadows	Arthur Kill	5-15	upland forest	herons/songbirds	24,000 - 73,000

concrete and derelict structures. This site currently supports very little vegetation, native or otherwise. Dredged material substrate could be deposited on the island and planted with native trees and shrubs to create nesting habitat for herons and egrets. Portions of the island could be graded to intertidal elevation and beach created using sandy dredged material to benefit terns and piping plovers. Estimated placement capacity for this option would be 5400 cy, assuming a 3 ft placement depth.

Hoffman Island, the larger of the two at 7.3 acres, is a possible candidate for restoration and creation of early successional stage forest if fine-grained dredged material is used as a surrogate substrate and deposited over existing concrete and rubble. Some 35,000 cy of dredged material could potentially be disposed of here, assuming a 3 ft placement depth. This figure may be an overestimate, however, since some portions of Hoffman Island already support an open canopy *Ailanthus* forest (an undesirable species for songbirds) and would require revegetation, but not substrate deposition.

A possible problem with this scenario is the high density of gulls in the area, which are known predators on tern and plover chicks (Kerlinger 1997b). Additional predators on eggs and chicks at all Harbor sites include barn owls (*Tyto alba*), norway rats (*Rattus norvegicus*) and marsh hawks (*Circus cyaneus*).

Various other potential marsh and upland habitat development sites could be identified in the Harbor, particularly at locations in the Arthur Kill (Prall's Island and Isle of Meadows) and Kill van Kull (Shooter's Island). It was determined in the late 1970's that Prall's and Shooter's Islands were providing breeding habitat for significant populations of colonial waterbirds, including snowy egrets, cattle egrets, great egrets, and black-crowned night herons. The New York Audubon Society documented 866 pairs of wading birds and 500 pairs of gulls nesting on both islands during 1986-1987 (Parsons 1986). Several harbor heron species, including snowy egrets, cattle egrets, great egrets, little blue herons, yellow-crowned night herons, black-crowned night herons, and glossy ibises were found on Isle of Meadows in the late 1980's (The Trust for Public Land and New York Audubon Society 1990). Although these sites currently support intertidal marsh and upland forest habitat, Kerlinger (1997b) estimates that between 5 - 15 acres of new forest could be created on dry sandy portions of the islands currently dominated by common reed (*Phragmites australis*), sumacs, and unvegetated barrens. Forest restoration at this site would require deposition of fine-grained dredged material substrate and could potentially accommodate 24,000 - 73,000 cy of placement volume. The New York City Audubon Society recently conducted test plantings of several tree and shrub species on Prall's Island in order to determine the feasibility of larger-scale restoration efforts. NYCDPR has restored several acres of *Spartina alterniflora* marsh at Prall's Island and several adjacent sites in the Arthur Kill within the last decade

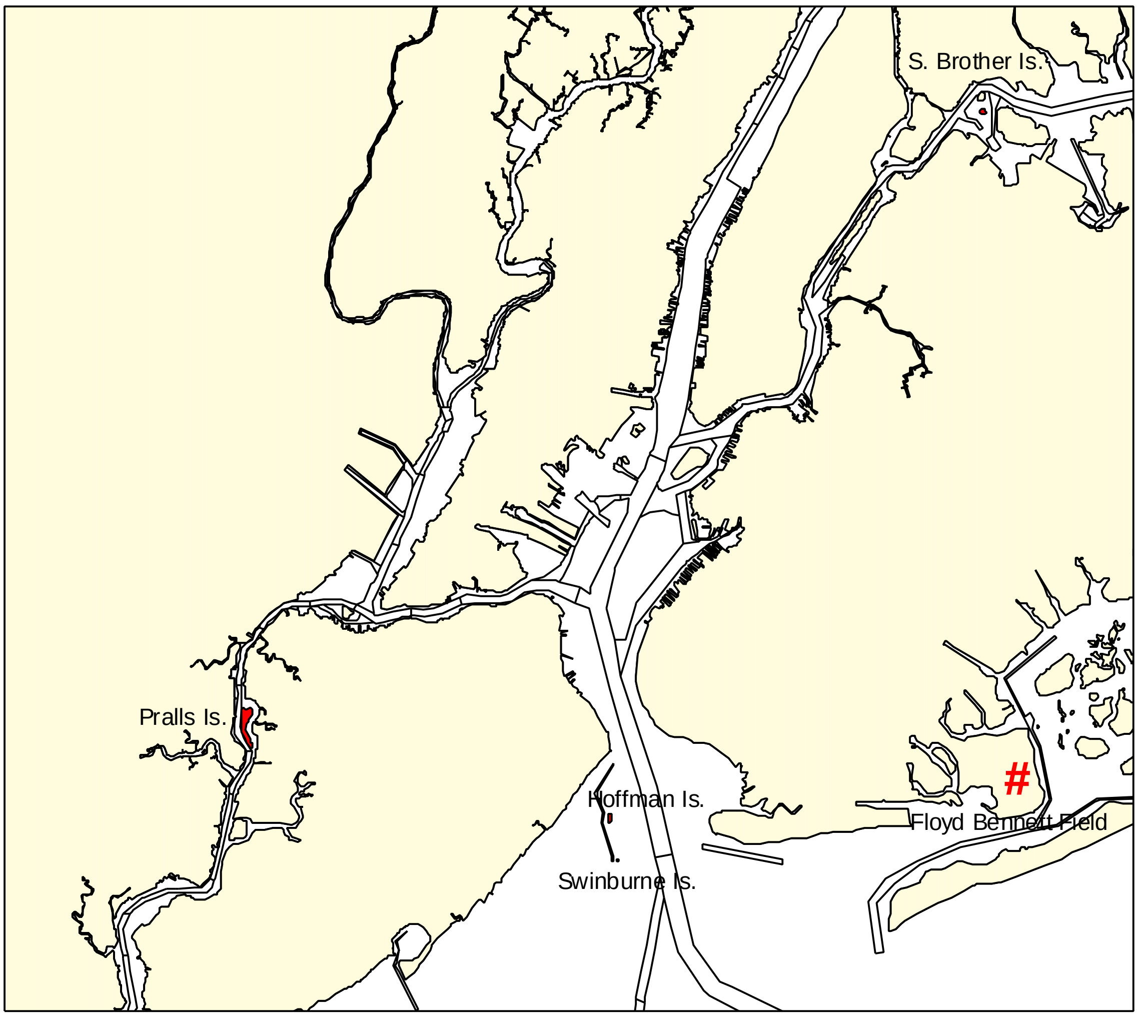
New islands could be created in the Arthur Kill and Kill van Kull waterways, and developed using the upland forest revegetation techniques described above, along with intertidal wetland and beach habitat development. Projects such as these represent a tangible benefit to shorebird and songbird populations in the Harbor, along with the potential for the beneficial use of a significant volume of dredged material.

Regulatory Authority for Construction of Bird/Wildlife Islands in NY/NJ Harbor

Use of dredged material for creation of bird/wildlife islands in NY/NJ Harbor may be authorized under Section 404 (b)(1) of the Clean Water Act of 1972, Section 1135 of WRDA 1986, and Section 206 of WRDA 1996. In addition, Section 204 of WRDA 1992 provides funding and authority for the beneficial use of dredged material for creation and restoration of aquatic or related habitats in association with construction, operation or maintenance of authorized navigation projects. Section 216 of the Rivers and Harbors Act of 1970 authorizes the Corps to review navigation projects and recommend modifications that would involve habitat creation/restoration using dredged material. Construction of bird/wildlife islands and enhancement/restoration of upland habitats in the Harbor area is also subject to regulation by individual state (NY and NJ) laws, statutes, and permitting authorities.

Figure 8-1

Proposed bird/wildlife habitat improvement areas (in red and based on Kerlinger 1997b).



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9: USE OF DREDGED MATERIAL FROM NY/NJ HARBOR FOR UPLAND REMEDIATION AND HABITAT CREATION, ENHANCEMENT, AND RESTORATION

Contaminated dredged material from NY/NJ Harbor may be used beneficially in the remediation of degraded uplands, including landfills, brownfields, and abandoned or disused quarries and mines. These are typically severely degraded upland habitats which, left unremediated, will continue to degrade adjacent terrestrial and aquatic habitats via contaminated runoff and leachate. Filling/capping these sites with dredged material and subsequent on-site development of upland habitats may represent a technologically, economically, and ecologically feasible beneficial use option in the NY/NJ Harbor region (USACE 1997).

Dredged materials intended for use in upland remediation/development projects are typically "stabilized" by blending with binding agents to decrease water content and improve structural properties (shear strength, permeability, etc.). Binding agents include Portland cement, coal fly ash, lime, and cement kiln dust. Selection of a binding agent and the amount of material used is dictated by the intended use of the final product. An additional benefit of the stabilization/solidification process is enhanced immobilization of potential contaminants as they bind to the resulting soil matrix. In many cases, particularly for brownfield remediation, the contaminant levels of dredged material blends are significantly lower than that of the native soils in the area being remediated.

A layer of suitable quality fill is typically used as a final cap over the stabilized dredged material in landfill or brownfield remediation. This cap can then be planted with herbaceous or woody upland vegetation, and may provide refuge, foraging, and breeding habitat for upland migratory and resident songbirds and other wildlife. Landfills adjacent to estuarine or marine habitats can potentially provide nesting and foraging habitat for sea, shore and wading birds, if capped and planted with appropriate vegetation.

Another potential use of contaminated dredged material is the manufacture of fertile topsoil via the addition of cellulose waste, sawdust, compost materials, manure, or biosolids from sewage treatment. Peat, sand or vermiculite can also be used to create soils using a dredged material base. Salt content and grain size are critical variables to be considered in the use of dredged material in production of topsoils. These amended soils have direct potential for use in the reclamation of remote sites, such as abandoned surface mines, where stable vegetative cover and upland bird/wildlife habitat is desired. Manufactured soils can be used in phytoremediation projects designed to sequester contaminants (e.g. heavy metals) into plant tissues or degrade organic contaminants. Researchers at WES and several private industries are leading the development of soil amendment technologies for dredged material (Lee et al. 1998).

Beneficial use of treated/stabilized dredged material for habitat development projects is generally preferable to placement in oceanic or upland confined placement facilities, given comparable costs per cy. USACE, USEPA, NJDEP and NYSDEC are supportive of efforts to utilize treated/stabilized dredged material in a variety of industrial applications, such as landfill remediation, roadbed construction, structural fill, or manufactured soils.

Opportunities for Upland Remediation and Habitat Development Using Dredged Material from NY/NJ Harbor

Brownfield Reclamation: Brownfields are defined as abandoned, idle, or disused industrial or commercial facilities characterized by severe environmental contamination/degradation. Recent federal (USEPA) and state programs in New York and New Jersey are focusing on the remediation and improvement of brownfields. These programs are investigating the use of new and innovative technologies, including potential beneficial applications of dredged material, for the remediation of these areas. Most brownfields that have been remediated to date have been developed as commercial or human recreation projects (e.g. shopping centers, golf courses, etc.). However, it is feasible to consider the development of urban parks, natural areas, and wildlife refuges as potential outcomes of brownfield reclamation projects. Most of the potential brownfield remediation sites in the NY/NJ Harbor region are located in or adjacent to densely populated areas which could benefit from the addition of greenways and open spaces for passive human recreation (e.g. bird-watching). Established populations of both resident and migratory songbirds, sea, shore and wading birds, and other wildlife would benefit from additional acreage of foraging, refuge, and nesting areas.

Several sites in the NY/NJ metropolitan area have already begun to use contaminated dredged material for brownfield reclamation (**Table 9-1**) . The Seaboard Site, a 165 acre industrial brownfield in Kearny, NJ (previously known as Koppers Koke) is accepting dredged material, pending final approval of the site remediation plan by NJDEP. Plans call for 1.3 million cy of stabilized/treated maintenance dredged material from the Port of NY/NJ to be used in capping a 23 acre parcel of the site. The Orion Elizabeth New Jersey (OENJ) site, in Bayonne, NJ includes a landfill and brownfield remediation plan. Over 1 million cy of treated dredged material is being used to cap a 69 acre abandoned landfill and an 87 acre industrial brownfield.

A potential impediment to large-scale remediation of industrial brownfields has been the reluctance of the private sector to assume liability for development of highly contaminated areas. Recently, however, the availability of liability insurance specifically for developers interested in remediating brownfield sites has generated new interest among potential developers, and should result in an increase in the number of proposals to reclaim and redevelop these sites.

Landfill Cover: There currently exist numerous landfills in the NY/NJ metropolitan area that have been abandoned or are currently inactive, and which have never undergone final closure. These sites are a source of considerable environmental degradation resulting from the flow of contaminated leachate into nearby water bodies, including the Hackensack and Passaic Rivers and Newark Bay. Landfill cover material is needed in order to complete the final closure process.

Table 9-1:

Examples of upland remediation and habitat development projects which could potentially use treated/stabilized dredged material from NY/NJ Harbor.

Name	Location	Area (acres)	est. capacity (cy)	est. cost. per cy
Seaboard/Koppers Coke Site	Kearny, NJ	23	1,300,000	$40-50
OENJ-Bayonne Site	Bayonne, NJ	156	1,000,000	$40-50
Jersey Gardens Mall	Elizabeth, NJ	69	1,300,000	$40-50
Pennsylvania/Fountain Ave landfills	Brooklyn, NY	n/a	1,600,000	$33
HMDC landfills	Bergen Cty, NJ	300-400	1,500,000	$33
Fresh Kills landfill	Staten Island, NY	282	1,200,000	$33
Pelham Bay landfill	Bronx, NY	81	350,000	$33
Pennsylvania Mine Reclamation	Statewide	250,000	1,000,000,000	$20-30
Brigham Brickyard*	Kingston, NY	185	1,800,000	$20-25

* This abandoned quarry site is no longer available as a disposal option

Historically, compacted clay has been used for final closure of landfills. The low permeability of clay soils is ideal for reducing infiltration of surface waters, limiting contaminant transport, and maximizing surface runoff. In many cases, dredged material can meet these same engineering criteria, at lower cost. Final capping and closure of NY/NJ Harbor area landfills could provide considerable acreage for the development of upland meadows and forests in areas where greenways and bird/wildlife habitat is lacking.

Another potential use of dredged material in landfill applications would be as daily or intermediate cover. However, at the present time, there is a surplus of alternative materials available for use as daily or intermediate cover in NY/NJ area landfills. Economic incentives may be necessary to encourage private landfill operators to accept stabilized dredged material for use as daily or intermediate cover (USACE 1997).

The suitability of dredged material as a landfill cover material is variable, depending on the physical properties of the sediment being considered (NJDEP 1997). For example, very fine-grained material is generally unacceptable for use as landfill cover due to poor hydraulic conductivity, and susceptibility to erosion and formation of wind-blown dust. Poor drainage characteristics result in formation of leachate seeps on landfill side slopes. Blending of fine-gained dredged material with other soils or materials is necessary to achieve the appropriate structural and drainage characteristics. Excess moisture in dredged material results in poor workability, and the sediments typically must be dewatered prior to application. Salt content and pH must be appropriate to support growth of the desired vegetation species upon final closure.

The New Jersey Office of Maritime Resources (NJMR) has developed plans for closure of several landfills using contaminated dredged material. One such site in New Jersey is the Jersey Gardens Mall, in Elizabeth. An abandoned landfill is being closed by capping with up to 1.3 million cy of stabilized dredged material. This material will be used as structural fill for a parking lot and for construction of road embankments (USACE 1997).

Several landfills in New York City are also potential candidates for capping and final closure using dredged material (**Table 9-1**). The Pennsylvania and Fountain Avenue landfills along Jamaica Bay, in Brooklyn, are scheduled for final closure by 2000. It is estimated that approximately 1.6 million cy of dredged material could be used beneficially as grading fill at these two sites. Costs of dewatering dredged material and using it as an intermediate or final cover at landfills (excluding stabilization or treatment costs) is estimated at approximately $33 per cy (USACE 1996). Both of these landfills represent potential areas for development of upland meadows or forested habitats in order to benefit songbirds, sea, shore, and wading birds, and other wildlife.

Another potential landfill remediation/upland habitat development site in New York City is the Fresh Kills landfill on Staten Island. A 3.5 acre pilot restoration project was conducted at this site several years ago by the New York City Department of Sanitation (NYCDOS) (Kerlinger 1997b). A combination of pine forest, shrubs, and upland meadows was developed over a sand

and topsoil cap adjacent to the Davis Wildlife Refuge. The resulting plant community was intended to simulate the vegetated sand dunes once common to this portion of Staten Island. Although enhancement of bird/wildlife populations was not specifically stated as a project goal, many species common to NY/NJ Harbor would likely benefit from upland habitat creation of this type at Fresh Kills. The landfill is scheduled for final closure in 2001, and several agencies including NYCDOS, NYSDEC, and local environmental organizations are supportive of large-scale restoration of native vegetation communities at Fresh Kills. Two sections of the landfill (Section 6/7 and Section 1/9) currently require grading fill and final cover on 282 acres. Although the exact acreage to be restored has not yet been specified, this proposed project may represent an important opportunity for the beneficial use of a considerable volume of sandy dredged material from the Port of NY/NJ.

Other landfills which might be potential candidates for upland habitat development in the NY/NJ Harbor area include the Pelham Bay landfill, which is currently the site of an ongoing tidal wetland restoration proposal intended to improve water and habitat quality in Eastchester Bay (Pelham Bay) (see Chapters 6 and 7 for additional information on this project), and several large, unclosed landfills encompassing 300-400 acres under the authority of the Hackensack Meadowlands Development Commission (HMDC), located along the Hackensack River, in Lyndhurst and Kearny, NJ.

The Pelham Bay landfill encompasses 81 acres of Pelham Bay Park, in the Bronx. Formerly operated by NYCDOS, responsibility for final closure and remediation was transferred to NYCDEP in 1990 (Gaia Institute 1998). Currently, the impermeable cap placed upon the landfill does not support terrestrial vegetation. Fine-grained dredged sediment/topsoil blends could be used in a beneficial manner at this site by providing a fertile substrate which could be planted with native grassland or forest species. The immediate proximity of this site to Eastchester Bay would provide potential foraging and nesting habitat for sea, shore, and wading bird species, as well as for resident and migratory songbirds, and other wildlife. Currently, there does not appear to be any immediate plan to restore native vegetation communities at the Pelham Bay landfill site. Upland habitat development at this site, using dredged material substrate, would complement ongoing efforts to create/restore intertidal wetlands and other aquatic habitats in this area (Gaia Institute 1998).

Miscellaneous Upland Habitat Development Projects: There currently exist many other sites throughout the NY/NJ Harbor area at which upland habitat restoration, creation, or enhancement would be feasible. Many abandoned woodlots or former residential areas are potential sites for restoration of native dune, grassland, or forest communities. Cumulatively, these may represent a considerable source of placement capacity for dredged material to be used in habitat development projects. To date, only one comprehensive survey of such areas has been conducted, as part of a feasibility study for restoration projects in Jamaica Bay (USACE 1998). This study examined 42 potential upland and wetland restoration sites, and proposed conceptual restoration plans for 34 of these. Future efforts to develop these restoration scenarios for

Jamaica Bay could be integrated into the DMMP via consideration of the potential for using dredged material in aquatic and terrestrial habitat development projects.

Reclamation of Abandoned Mines and Quarries: Abandoned coal mines in the Commonwealth of Pennsylvania may represent the largest potential beneficial use option using dredged material from NY/NJ Harbor proposed thus far, with estimates exceeding 1 billion cy of potential placement volume (USACE 1997). Pennsylvania has approximately 5400 abandoned coal mines in need of reclamation, encompassing over 250,000 acres. Acid mine drainage from these disused coal mines has contributed to the degradation of soils, groundwater, and surface waters, including 2400 miles of streams. Mine fires and subsidence further contribute to the environmental problems associated with abandoned coal mines in Pennsylvania. Treated dredged material from the Port of NY/NJ is currently being tested in this scenario to curtail the chronic degradation of upland and aquatic habitats resulting from acid mine drainage, however, unlike the projects described previously, this activity will not result in habitat creation/restoration/enhancement within the NY/NJ Harbor ecosystem.

The Pennsylvania Department of Environmental Protection (PADEP) has initiated a demonstration project at the Bark Camp Mine Reclamation Center in Houston Township, PA. This site has been permitted to use up to 550,000 cy of contaminated dredged material stabilized with coal fly ash (USACE 1997). The high alkalinity of fly ash should enhance the buffering capacity of the blended fill material. The demonstration project is intended to evaluate the economics and feasibility of using stabilized dredged material in large-scale mine reclamation projects. If deemed successful, this demonstration should lead to issuance of a general permit by PADEP authorizing the use of dredged material in mine reclamation projects statewide.

The primary impediment to widespread use of dredged material for mine reclamation in Pennsylvania is the relatively high cost of overland transport via railcar. Transport costs for dredged material derived from maintenance dredging of the municipal harbor in Perth Amboy, NJ (23,000 cy) to the Bark Mine Cap project are $58.50 cy, excluding dredging costs. Long-term projections of dredged material placement costs for large-scale mine reclamation, contingent upon the development of a regional treatment and transfer facility, range from $20-30 per cy.

Another potential upland beneficial use option is the placement of contaminated dredged material in abandoned quarries and capping with clean fill. Once capped, these areas could then be planted with upland vegetation, and would provide refuge, nesting and foraging habitat for songbirds, and other wildlife. Several potential placement sites were identified along the Hudson River, New York; each was capable of providing in excess of 5 million cy of storage capacity. One site, the Brigham Brickyard in Kingston, NY, had undergone a conceptual design; however, vociferous local opposition to the project resulted in withdrawal of the plans. A potential advantage of quarry sites is that they have the potential to hold considerable volumes of dredged material with minimal site modifications and preparation. This reduces construction and operation/maintenance costs. Based on the Brigham Brickyard proposal, placement of dredged material in disused quarry sites can be expected to cost approximately $20-25 per cy. This figure includes land acquisition, site preparation, design, permitting, operations and maintenance and transport of dredged material upriver by barge (USACE 1996).

Regional Treatment/Transfer Facility

Optimal implementation of land remediation and upland habitat development projects with contaminated dredged material will require the construction of a regional treatment/transfer facility in the NY/NJ Harbor area (USACE 1997). The availability of a large-scale treatment/transfer facility will lower processing and mobilization costs for remediation/habitat development projects. Contaminated dredged material from NY/NJ Harbor would be off-loaded at the facility, stored, processed (dewatering, solidification/stabilization, blended topsoil production), and loaded for truck, rail, or barge transport to project sites.

Selection of an appropriate site for the development of a regional treatment transfer facility for NY/NJ Harbor has met with intense local opposition. A proposed site on the Hudson River in Newburgh, New York is currently in permit review but is being actively opposed.

A privately owned and operated dredged material treatment/transfer facility in Port Newark, New Jersey was used for the Jersey Gardens Mall project. Dredged material processed at this site was stabilized with concrete for use as structural fill.

The New Jersey Marine Resources Commission (NJMRC) is planning construction of a state-owned, privately operated regional treatment/transfer facility. The exact location has not yet been specified, although plans call for construction of the facility as early as Spring 1999. At least initially, this facility will be limited to treatment of sediments from New Jersey waters.

Cost as a Limiting Factor

A significant impediment to the large-scale implementation of land remediation and upland habitat development is the high cost anticipated for this option, relative to other beneficial uses discussed previously. Cost factors include location of the project site, transportation methods, site acquisition, site preparation/planting, and licensing of patent technologies. Cost reduction can be achieved by preferentially selecting sites which do not require truck or railcar transport of dredged material; however, doing so significantly reduces the number of potential placement sites. In addition, many waterfront sites may require construction of offloading facilities in order to receive dredged material.

It is anticipated that the continued development of alternative treatment technologies and implementation of larger-scale decontamination projects will eventually reduce the costs of treating/stabilizing contaminated dredged material, and ultimately result in increased opportunities for upland habitat reclamation and development in NY/NJ Harbor and adjacent areas.

Regulatory Authority for Upland Remediation Projects Using Dredged Material

Remediation of landfills, brownfields, and other upland sites using dredged material may be authorized by a number of Federal statutes, including Section 404 (b)(1) of the Clean Water Act of 1972. Section 226 of WRDA 1996 authorizes the USEPA and the USACE to jointly develop pilot-scale sediment decontamination technologies with capacities exceeding 500,000 cy per year. Under this authority, the USEPA's Section 405 Decontamination Technologies Demonstration Program seeks to develop new sediment decontamination technologies and to identify potential industrial markets for products derived from decontaminated dredged material. Additional Federal authority for the use of dredged material in upland remediation projects may be granted under the Clean Air Act of 1990, the Resource Conservation and Recovery Act (RCRA) of 1976, the Toxic Substances and Control Act (TSCA) of 1976, and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. Upland remediation projects in the NY/NJ Harbor area are also subject to regulation by individual state (NY and NJ) laws, statutes, and permitting authorities.

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