Beneficial Use of Dredge Materials for the Improvement and Enhancement of Eastchester Bay Wetlands and the Water Based Economy of the Eastern Bronx

Draft Environmental Impact Statement

Technical Appendix

Public Notice #97-13010- Y2
Royal Marina Application

July 13, 1998

Submitted to:

- New York State Department of Environmental Conservation
- U.S. Army Corps of Engineers, New York District
- New York State Department of State

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ENVIRONMENTAL IMPACT STATEMENT

Introduction: NEPA: Requirements for an Environmental Assessment/Environmental Impact Statement

The Council on Environmental Quality (CEQ), created pursuant to Section 202 of National Environmental Policy Act Procedures (NEPA), was charged with the responsibility to "develop and recommend to the President national policies to foster and promote the improvement of environmental quality to meet the conservation, social, economic, health, and other requirements and goals of the Nation." This charge resulted in the promulgation of Regulations on Implementing National Environmental Policy Act Procedures (40 CFR 1500-1508, as amended). These regulations and procedures are the basis upon which all Federal environmental documents related to major Federal actions are generated. The CEQ regulations and procedures are supplemented by guidelines, regulations and procedures developed by each Federal agency to comply with the purpose and provisions of NEPA. Federal actions for which environmental documentation is being prepared (EISs and/or EAs) must consider all applicable Federal, State, and local statutes and ordinances affected by the action.

These detailed statements have come to be known as Environmental Impact Statements (EISs) and Environmental Assessments (EAs). This EIS document is a technical appendix to the SEQR Draft EIS. It presents the scientific evidence reviewed to assess potential benefits for the use of dredged materials in wetland construction and habitat restoration.

1.0 Project Identification

Project Name: Beneficial Use of Dredge Materials for the Improvement and Enhancement of Intertidal Salt Marsh in Eastchester Bay along the Pelham Bay Landfill and Pelham Bay Park

Name and Address of Applicant:
Royal Marina
c/o The Gaia Institute
99 Bay Street
City Island, NY 10464

Project Number: Public Notice #97-13010- Y2

Project Location:
Eastchester Bay
Pelham Bay Park
Bronx, NY

1.1 Project Summary

The Applicant proposes to dredge sediments from Royal Marina, then beneficially use the dredged materials to create salt marshes around the Pelham Bay Landfill and the southern tier of Pelham Bay Park. Dredging of Royal Marina, and other marinas in the Eastchester Bay vicinity, is necessary to return water depth to prior navigable levels, restoring capacity to berth boats in existing slips, and again bring in larger vessels, which is no longer feasible at low tide.

This proposed beneficial use plan for dredged materials around Pelham Bay Landfill and the Southern Tier of Pelham Bay Park aims to restore, in total, about 30 acres of intertidal marsh as well as more than ten acres of rocky intertidal and subtidal rocky habitat through the building of a 4,000 foot long stone dike containment facility. The initial phase of this work, beginning with ≈ 1.5 acres of marsh and a 400 foot length of rock armor wall, will create more than a half acre of rocky intertidal and subtidal habitat, providing a prototype, at 1/20 scale, for evaluating the success of benthic macrophyte and faunal recruitment and development, as well as biochemical, geochemical, and geophysical contributions to water quality. This area, with appropriate controls, will be a primary focus of the research and development work of the Pelham Project (see below for a description of the latter).

By using locally dredged materials in local ecological restoration projects, dredging can contribute to the redevelopment of water based industries in the eastern Bronx through the lowering of maintenance dredging costs while enhancing water quality and fisheries production.

This creation of intertidal wetland including saltmarshes, mudflats and rocky subtidal and intertidal ecosystems will remove pollutants and chemicals of concern (COCs) from combined sewer overflow and stormwater discharges, leachate from the adjacent landfill, as well as from the dredged sediments themselves. The creation of a tidal wetland together with rocky subtidal and intertidal habitat of the stone dike containment facility will also contribute to the essential fish habitat of the region.

Dredged materials will be contained beneath the proposed tidal wetland. The contained volume will have less surface area than the present, pre-dredging distribution of sediments. Since contaminants are released through the sediment/water column interface, diminishing the surface area of this interface significantly reduces the scale of the pathway by which contaminants enter the ecosystem. Calculations characterizing the surface to volume ratio of the proposed containment configuration indicate that this structure will reduce the release of COCs contained in the dredged material to the water column by a factor of about three, i.e., a three fold reduction in the ratio of the sediment/water column interface to sediment volume will lead to about a threefold reduction in the movement of COC's through sediment surfaces (see Figure 1.). The biogeochemistry of the marsh microbial communities will provide an additional measure of protection to the water column through documented abilities to destroy and sequester major point and non-point source pollutants, including those found in dredge materials, landfill leachate, surface runoff, storm water, and combined sewer overflow (CSO) discharges. A review of this literature on salt marsh biochemical capacities and estimates on amounts sequestered, is presented in this document.

The proposed project aims to renew an urban waterfront by dredging, increase the intensity of the water-based uses of this and nearby properties, and thus contribute to both state and local waterfront revitalization efforts. By demonstrating how water-based economic activities can be strengthened, at the same time increasing habitat diversity and ecological productivity of the area, the coupling of economic and ecological goals will have the following effects:

1) diminishing contaminant discharge by reducing the surface area of the sediments, and increasing biogeochemical activities which remove or sequester harmful constituents;

2) increasing habitat heterogeneity in northwestern Eastchester Bay by restoring historically prevalent diverse habitat types including intertidal marsh, mudflat, rocky intertidal, rocky subtidal zones, and creeks which were diminished, displaced or destroyed in recent years by landfilling much of the surrounding environment.

3) providing economically attractive dredge disposal options for western Long Island Sound and facilities in and around the eastern Bronx; &

4) intercepting and treating stormwater and CSO discharges from city streets and highway infrastructure as well as any flows of leachate from the landfill.

The redevelopment of marinas can also serve as a catalyst for related private investment in water-based industries in the area, providing economic incentives to refurbish maritime properties generally in nearby deteriorated sites, prevent further deterioration, improve the existing economic base of the local community, restore contiguity between regionally important habitat types, and improve the viability of integrated commercial and recreational uses of the area.

This proposed action is part of the Pelham Project: Developing Wetlands for the Disposal and Treatment of Dredged Material, a project of Columbia University. It is a collaboration of the Earth Engineering Center and the Lamont Doherty Earth Observatory of Columbia University, with the Gaia Institute. The Pelham Project will:

- design the dredge material containment stone dike wave break;
- investigate the development of marsh capacities to remove sediment contaminants;
- oversee dredging, saltmarsh construction and maintenance;
- stage a major interdisciplinary research effort on the marsh for at least three years, including investigations on hydrology and hydrodynamics, geophysics and sedimentology, biology, ecology, and geochemistry.

The project aim is to couple the structural engineering practices of containment facility construction with the ecological engineering of habitat construction and restoration. A primary outcome of the work will be design options which couple dredging project windows with modular containment facility cells. Orientation and arrangement of these cells will be influenced by the structure of existing salt marsh systems, and, where necessary, optimized for pollutant treatment and to make use of freshwater inputs. Details of this proposal of Columbia University are available upon request from Dr. Bud Griffis (Earth Engineering Center, 610 S.W. Mudd Bldg., Columbia University, New York, NY 10027, ph 212 854-8873, FAX 212 854-6267).

2.0 Purpose, Need and Benefits of the Proposed Action

Sediments fall out of suspension in quiescent waters around piers and docks, diminishing the value of these structures for commerce and recreation. This is the case at Royal Marina on City Island, and many of the docking facilities throughout the Borough of the Bronx, the City and the State. At the same time, extensive landfilling has eliminated most of the historic intertidal wetlands and sedimentary shallows in New York and other coastal cities, diminishing pollutant removal and fisheries production in the process. Contaminants in sediments have led to the ban on ocean dumping, effectively eliminating readily available, low cost disposal of dredgings. This regulatory framework requires new approaches to sediment decontamination and disposal which also include marsh creation.

It is fair to say that wetlands can treat the majority of kinds of contaminants in dredged materials (Kaklec & Knight 1996). The historic filling of wetlands in New York City has both removed a major sink for sediments in the area and at the same time a major sink for nutrients and contaminants. Two millimeters of sediments per year over the 45,000 acres of wetlands which have been filled historically in New York would have provided a sink for about a half million cubic yards of sediments ($\approx 4 \times 10^{11}$ grams), about a tenth of the annual dredgings in New York Harbor. It is interesting to note, by way of comparison, that, with a much lower ratio of marsh to open water than the historic New York City region, estimates of sediment removal for Chesapeake marshes are on the same order of magnitude as those provided above, $\approx 10^{11}$ grams per year (Nixon 1981).

2.1 Ecological Enhancement through Habitat Creation and Restoration

Habitat creation through human efforts has been carried on for decades to centuries through the use dams, dikes, structures for the aggregation of fish, and attachment surfaces for macrophytic algae and filter feeders such as oysters and mussels (Grove et. al. 1991). All of these are hydrologic modifications in that flow patterns, rates, or the distribution of velocity gradients are modified. These changes in turn impact on the niches of species and communities, from microbes to macrophytes and macrofauna, leading to changes in ecological structure. More recently, attempts have been made to utilize structural modifications to restore or create functional qualities of aquatic, wetland and other ecosystems for various purposes, including the mitigation of damage caused to other systems (National Research Council 1992; Cairns & Buikema 1982). Dredged materials have been used in the context of wetland and upland habitat creation, and, in all cases, attempts are made to establish the correct hydrological regime for the intended plant communities, and to copy the natural geomorphological features which protect plantings, suppress erosion, and lead to some sediment accretion (Kirby 1995). Much of the work in habitat restoration has focused on a specific effects in a group of organisms such as fin fish (Chipps et. al. 1997), or a specific habitat type, such as tidal flats (Kirby 1995). In a few cases, detailed comparisons have been made between constructed and natural systems (Okada et. al. 1997). A unique environmental enhancement/mitigation project aimed at integrating the construction/restoration of at least five different habitat types, including habitat for an endangered species (Proposed Batiquitos Lagoon Enhancement Project in the City of Carlsbad 1986).

The construction of intertidal salt marsh may be expected to reduce BOD (Hammer et. al. 1993; Kaklec & Knight 1996) and nitrate (Valiela, I. & JM. Teal. 1979a; 1979b; DeLaune et. al. 1989; White & Howes 199) in Eastchester Bay, thus providing a measurable, positive effect in the environment around the Pelham Bay Landfill and Pelham Bay Park. The New York City Department of Environmental Protection has recognized the importance of wetlands to the ecological health and environmental quality of the area. The scope of work for The Pelham Bay Landfill Wetlands Investigation: An Evaluation and Analysis of the Contribution of Wetland Systems to Environmental Quality in Eastchester Bay, by NYC Department of Environmental Protection, states: *"Wetlands enhancement in Eastchester Bay through creation, restoration or augmentation of existing wetlands areas will be an integral part of New York City's remediation of the Pelham Bay Landfill."* Wetlands may here serve both as a remediation technology for landfill leachate, and a means for removing BOD and nitrate from stormwater and other non-point discharges, while creating essential fish habitat. A major thrust and purpose of the more recent Pelham Project is to quantitatively evaluate this constructed marsh and the containment facility rocky habitat communities on water quality, biodiversity, and ecological productivity. Aims of this project are detailed below.

By treating the chemicals of concern (COCs) from the landfill leachate, point and non-point source runoff, and contaminated sediments, the project aims to increase water and sediment quality in Eastchester Bay. While the wetland may be expected to increase the biogeochemical filtration and treatment within several months of planting, it must be recognized that moving, settling, stabilizing, and planting sediments will necessarily precede any enhancement. However, since the historic criticism of dredging has been that sediments are resuspended in the process, and especially through losses of low density materials during deep water disposal (reviewed in Kennish 1992), negative impacts of these prior steps can be minimized by mitigation measures during dredging and by the placement of sediments within a containment facility. Even if such sediment releases are diminished, however, the act of constructing a wetland cannot enhance environmental quality per se. This process must be measured against the plant and microbial uptake and removal of chemicals of concern from the sediments and water column which will follow marsh growth and development. While all the major features of this developmental sequence have not been well characterized to date, prior experience leads to the expectation that the marsh should begin to show environmental quality enhancement effects after six to eight weeks of growth (April to June), when the plant leaves have reached heights of about a half meter (Bergen et. al. 1996). When the plant community approaches this size class, water and sediment quality should increase sufficiently to begin to protect wildlife receptors.

The close proximity of intertidal rocky and marsh habitat with rocky subtidal and soft benthic habitat is expected to increase food availability and feeding habitat, together with protection from predators for fry and juveniles for fin and shell fish, thus increasing fishery productivity and biodiversity of Eastchester Bay. The proximity of diverse habitat types enhances larval, fry, and juvenile survival by allowing fish to minimize predation in structurally complicated habitats which provide cover, while optimizing foraging strategies in environments with high food abundances (Bohnsack et. al. 1991; Irlandi & Crawford 1997). While the archipelago on which the Pelham Bay Landfill is situated probably provided such habitat in historic time (see 1906 historic map of landfill and Royal Marina area on City Island in Figure 2.), the nearest environment with such structural diversity on the scale of acres of habitat is presently more than three miles away.

2.2 Economic Enhancement

In addition to measurable improvements to environmental quality, the proposed action coupling dredging with habitat restoration will serve the local economy. Because of the expense of dredging, many coastal economies have become derelict. A number of previously water oriented properties near the Royal Marina have fallen into disuse over the past several years. Interim uses, including staging areas for construction, are in no way water based.

The areas around the Royal Marina and Pelham Bay Park have high recreational value. Activities around these areas include fishing, boating, and swimming. Improved water and sediment quality will be more protective to human health in a number of ways. Contact with water is a means by which pathogens may be spread to bathers after combined sewer overflow or other sewerage discharges. Physical and chemical processes in tidal wetlands, as well as the activities of intertidal filter feeders can reverse this threat, cleaning water and making it more aesthetically pleasing in the process.

3.0 Site History and Description

3.1 Site Geology

Surficial and Bedrock Geology

Pelham Bay Park is underlain by highly metamorphosed and dissected crystalline bedrock. The eastern side of the Park is underlain by the Hartland schist formation, part of the larger Hutchinson River Group of schists and gneisses underlying much of Westchester County (CA Rich Consultants, Inc., 1985). Bedrock outcrops at the Eastchester Bay shore have been exposed by a combination of glacial erosion from ice advances during the last glaciation nearly 10,000 years ago and from the removal of glacial till (poorly sorted clays, silts, sands and gravels) by wave action.

Beach Sediments

Much of the intertidal zone consists of typical muck soils composed of accumulated upland sediments and organic debris from the decomposition of wetland plants. Sand is limited mostly to the northern areas of the site. These soils range from several inches to two feet deep. They are rich in organic matter and are underlain by loose sand derived from glacial moraine. (Malcolm Pirnie, 1988)

Soils

Upland soils just west of the intertidal zone are classified with the Riverhead Series; relatively deep, very fine sands and course silts with lenses of fine silts and coarse clays derived from glacial outwash. Gneiss and schist minerals such as quartz, orthoclase, and mica increase with depth as does the frequency of coarse sand and fine pebble-sized particles. The soils are well drained with moderate moisture holding capacity and moderately rapid permeability (NYCDPR, 1989).

There are two types of soils in the southern zone. Well-drained loam to sandy loams over deep tills and shallow, excessively well-drained coarse sandy loam to loamy sands on shallow tills.

Shallow soils which are less than 20 inches deep have poorly developed horizons and low moisture-holding capacity. The deeper soils (35-60 inches deep) have high moisture capacity and well developed horizon profiles.

At elevations below 50 feet, upland soils are generally deep and well drained with moderate moisture-holding capacity. Textures are generally fine sand and coarse silt and appear to be uniform. Lenses and layered strata of fine silt and coarse clay exogenous sediment are occasionally encountered in these soils. (NYCDPR, 1989)

3.2 Site Hydrology

Surface and Shoreline Hydrology: Surface drainage in Pelham Bay Park east of New York/New Hartford Railroad bed through the center of the Park is generally to the east toward Eastchester Bay with the exception of more localized drainage from small-scale topographic variations. Lowest surface flow is usually during August and September while higher flows occur during late winter and early spring.

Groundwater flow is toward the east. Near the shoreline, tidal fluctuations and difference in fluid density between fresh and salt waters may locally influence groundwater flow direction velocity. (CA Rich Consultant, Inc., 1985)

The hydrogeologic structures that characterize the subsurface hydrology include unconsolidated sand and gravel glacial deposits, and water-bearing fractured bedrock. The flow volume and direction from the fractured bedrock is highly variable.

Tidal Influence: The area around the Pelham Bay Landfill is tidally influenced, with water levels differing between 0 to 7.2 feet to 8.5 feet from low to hide tide. (Malcolm Pirnie, 1988)

3.3 Site Ecosystems

The New York State Department of Environmental Conservation, Division of Water Resources has classified and set water quality standards for Eastchester Bay as Class SB, suitable for primary and secondary contact recreation and any other use except shell fishing for marketing purposes (NYSDEC, 1985).

A comprehensive environmental characterization report entitled Pelham Bay Park Environmental Characterization Report, was completed by Malcolm Pirnie in 1988 (Malcolm Pirnie, 1988), for the City of New York , Department of Parks and Recreation (NYCDPR, 1989). This report was published as the Pelham Bay Park, Southern Portion, Bronx, NY: Site Analysis (NYCDPR, 1989). This report includes:

- Geology and Soils,
- Ecology/Plant & Animal Communities
- Hydrology, &
- Water Quality.

The Site Analysis concludes with a section of Findings and Discussion that summarizes the various overall health of the surrounding intertidal and subtidal ecosystems. The only significant changes in the subject site area, since this biological inventory was completed, is the re-grading and capping of the Pelham Bay Landfill. Therefore, the data presented, and their conclusions, are likely representative of the current ecosystem conditions at and near the proposed site.

The Pelham Bay Landfill Wetlands Investigation: An Evaluation and Analysis of the Contribution of Wetland Systems to Environmental Quality in Eastchester Bay (Gaia Institute, 1994), includes a detailed assessment of the site wetlands and the potential environmental impacts of wetland enhancement and restoration. This report provides a description of existing intertidal and subtidal structure and diversity, together with an assessment of the present operative scale of biogeochemical activities. Aerial extent of habitat types is used to generate a context in which to compare past, present and potential contributions of different habitat types to water quality in the study region. The PBL Wetlands Investigation also includes a quantitative and qualitative ecological and human health risk analysis of the various chemicals that are currently present at the subject site and the likely effects of wetland restoration on the chemical fate and transport of these chemicals.

Studies of the Eastchester Bay subject site to date, and inspection of historic and present day maps, suggest that intertidal salt marsh and intertidal and subtidal rocky habitat restoration will benefit the local ecological system. These kinds of habitats have been greatly diminished or destroyed by recent human activity, while in the past, they were predominant. The only 'measure' we have of former ecological integrity may be gleaned from the written reports of the productivity of the fishery:

"The Pelham Bridge, over the mouth of the East Chester Creek, has long been famous for the size and quality of fresh fish taken in and around the waters of the Bay and River".

These words of the Reverend Charles E. Lindsley are quoted in Scharf's History of Westchester County (vol. 1, p 706). Conditions from past centuries included many differences from the present, but evidence indicates that at least an order of magnitude of marsh area was lost, and perhaps more rocky intertidal and subtidal habitat in the immediate vicinity of the Pelham Bay Landfill. Since the proposed wetland construction will displace some benthic habitat with a mosaic of intertidal wetlands plus rocky intertidal and benthic habitat, these constructed tidal wetlands will provide structural complexity which supports essential fish habitat. As a case in point, the same source noted above tells us that, although fishing had declined in the area even then:

"Still, within the past twenty years, bass of large size and weighing from 50 to 60 pounds, have been taken with the hook in this vicinity. Black fish are still numerous around the rock and reefs along the shore".

Striped bass have been caught in the 30 to 40 pound range by Turtle Cove and around the City Island Bridge in recent years, but blackfish rarely if ever are taken from the far side of Eastchester Bay, because much of the rock and reef habitat here has been landfilled. Rocky habitat restoration, the colonization of bladder wrack and similar blackfish habitat around the landfill is expected to reverse this trend. The increased biological complexity of a mosaic of different habitat types and ecological communities is expected give rise to a robust, persistent and resilient ecological system - where currently small patches of such systems represent fragments of the previously contiguous community structure.

3.4 Site History

The western tier of Pelham Bay Park is located in the Borough of the Bronx south and west of the Pelham Bay Landfill. The Landfill and this section of the Park mark the western and northern edges of Eastchester Bay. The latter was adjacent to and, according to the 1897 USGS map, tidally connected to Pelham Bay by the impoundment which is now called Turtle Cove. Inspection of the remnants of the original road to City Island of more than a century ago through the middle of the marsh in Turtle Cove indicates that the gravel and rock footings of this road would have blocked the connection between Pelham and Eastchester Bay's to some degree. The present main road to City Island crosses the southern discharge of Turtle Cove into Eastchester Bay, diminishing tidal exchange. Recent work has removed collapsing concrete footings which had impeded tidal exchange, and greatly increased drainage rates and input and output quantities. No work, however, is scheduled to address the northern input into Turtle Cove which had provided tidal throughput from Pelham to Eastchester Bay which is completely blocked by the road to Orchard Beach, constructed in the 1930's.

The geomorphological diversity in aspect and orientation of the archipelago of the Eastern Bronx provided high energy rocky intertidal and benthic habitat, low energy intertidal salt marsh and mud flat environments, soft silty subtidal, and muddy and sandy creek and river bottom habitat. Low lying flats, rock outcroppings, and rocks of the archipelago also provided relatively easy places to span these waterways, as occurred in previous centuries with the building of what is now Shore Road, as well the coastal rail line of the northeast corridor. More recent history brought the Hutchinson River Parkway, I 95, CoOp City, a high school and a hospital which, together with other development, reduced some 2,000 acres of tidal wetland in the northeastern Bronx to about 250.

Decline in the region thus started well before the Pelham Bay Landfill with wetland destruction, together with pollution and over fishing, erosion and runoff compromising the health and diversity of the estuary. Sewage was discharged directly into the Hutchinson River, and Eastchester and Westchester Creeks further degraded the environment. The Hunts Point and Wards Island waste water treatment plants improved the quality of the discharge, and the upgrading of these plants has allowed for a substantial comeback of oyster reefs from Clason's Point to City and Hunter Islands.

While the Pelham Bay Landfill has now been capped, only leachate from the southwest corner of the landfill is pumped to the Hunts Point wastewater treatment facility, potentially leaving other leachate mounded under the cap, to migrate through the eastern and northern reaches of the rock armor wall. A large rock lined stormwater discharge, positioned near where historic maps indicate a former arm of Westchester Creek connected to Eastchester Creek, enters the cove just north of the landfill from the direction of I 95 and the Hutchinson River Parkway. Smaller discharges (5' diameter and less) occur through the adjacent section of Pelham Bay Park, carrying water which supports green films of Enteromorpha, a weedy green algae often indicative of high nitrogen inputs.

The New York City Department of Parks and Recreation has built valuable freshwater wetlands in the Park adjacent to the Landfill, protected from the inflow of leachate by a slurry wall. Only small salt marsh restoration projects have been attempted in this section of Eastchester Bay to date, however, which, because of their scale, cannot have significant impact on water quality or the establishment of essential fish habitat.

3.5 Pelham Bay Landfill-History:

The former New York City Department of Sanitation (DOS) municipal landfill covers approximately 81 acres of the Park. It appears on the New York State Inactive Hazardous Waste Site List because of illegal dumping of hazardous materials such as industrial waste and waste oil. The responsibility for closure and remediation at the Landfill was transferred in 1990 from the DOS to the New York City Department of

Environmental Protection (DEP). Once properly closed, the landfill will be incorporated into Pelham Bay Park. Intermediate cover material was placed on the landfill when solid waste dumping ceased and subsequently was closed and remediated in accordance with the regulations of the New York State Department of Environmental Conservation (DEC) and the U.S. Environmental Protection Agency (EPA). At the time of this writing, the impermeable cap currently covering the landfill is beginning to support a uniform vegetation cover, and thus meet closure specifications. During significant storms, however, large plumes of suspended sediments and solids are still discharged into Eastchester Bay. After the storm of 13 June, 1998, a plume ten meters in width and tens of meters long was discharging for hours from the Landfill stormwater outfall, just East of the Shore Road Bridge (personal observation of PSM).

Formerly, collection and drainage infrastructure directed leachate into Eastchester Bay. Because of this, the City of New York was found to be in violation of Clean Water Act Statutes in a suit filed by the New York Coastal Fisherman's Association. This lawsuit may have served to hasten closure work on this landfill.

In preparation for closure, leachate and sediments were examined by the consulting firm of Woodward and Clyde in 1992 and 1993. Major chemicals of concern (COCs) were found to be lead, benzene, and various polycyclic aromatic hydrocarbons (PAHs) derived from petroleum products (Woodward and Clyde 1993), as well as high concentrations of ammonia and BOD. While sediment samples indicate several 'hot spots' for hydrocarbons and metals, the metal levels in leachate appears relatively low. Even the most problematic metals in the leachate, Fe, Cr, Pb, Ni, and Cu range from 4 to 0.003 mg/l (see discussion of test results in appendix). The most highly concentrated pollutant discharged, from samples to date, is ammonia, ranging from about 10 to 1000 ppm (Woodward and Clyde 1993). While total variability and stability patterns of this signal are not well characterized by sampling to date, the Pelham Project will aims to redress this. These compounds can pose significant threats to the health of humans and/or wildlife when present at significant concentrations.

Human health issues are all the more critical because of the siting of the Pelham Bay Landfill adjacent to several communities, including Throgs Neck, Country Club and City Island. It is also near Orchard Beach, one of the most popular bathing beaches in New York City. Bronx citizens have been concerned about the environmental impacts of the Pelham Bay Landfill from its beginning in 1963. The Talliposa Site, as it is known locally (and was, in former times, by the Native Americans), together with nearly 3,000 adjacent acres in Pelham Bay Park, were marked to be landfilled with New York City garbage for decades following the opening of the dump in the mid-1960's. Public opposition changed the City's plans, and Fresh Kills was eventually chosen to be the large New York City Landfill. While the flow of contaminated water into Eastchester Bay remains an issue for a number of Bronx residents, many continue to fish and swim in the vicinity of the landfill, often on the landfill itself, regardless of official prohibition.

The question remains as to whether the capacity of this environment to protect human health and ecological integrity will be increased or decreased by dredging or the no action plan, and as to whether the water based economy of the region is sustainable.

4.0 Required Components of an EIS

According to regulations (40 CFR 1502), an **EIS/EA must describe the purpose and need for the action that is being proposed, and identify all reasonable and practicable alternatives to the proposed action. The EIS/EA must include a detailed description of the biological, physical, and sociocultural environment that would be affected by the proposed action.** Following this directive, an analysis was produced of the environmental consequences that would result from the implementation of the proposed dredging from Royal Marina and the Western Sound, containment facility and marsh construction around the Pelham Bay Landfill and the Southern Tier of Pelham Bay Park, and possible alternatives to these proposed actions. This description of environmental consequences includes the following:

- any adverse environmental effects that cannot be avoided by the proposed action or no action alternative;
- the effects on short-term uses of the environment and long-term productivity by both action and no action alternatives;
- any irreversible or irretrievable commitments of resources inherent in action or no action alternatives; and,
- the direct, indirect, and cumulative effects of action and their significance.

The purpose and need for dredging of Eastchester Bay and the construction of wetlands within a containment facility around Pelham Bay Landfill and the southern tier of Pelham Bay Park is to minimize the costs of water-based industries and to maximize ecological benefit, or, as stated in the Federal Coastal Zone Management Act of 1972, to "preserve, protect, develop, ...restore or enhance the resources of the Nation's coastal zone". The analysis presented below indicates that the only way to accomplish these multiple ends is to couple ecological with economic enhancement.

Both dredging and wetland construction on dredged sediments within containment facilities are essential to meet the stated purpose of preserving, protecting, developing, restoring and enhancing the resources of the nation's coastal zone. The potential impacts of dredging or not dredging on economic activity and environmental quality may already be described as very large in local, regional, and national terms. Dredging directly affects economic and environmental costs of water access infrastructure and transportation. For this reason, the reply to comments for the dredging of Royal Marina in Eastchester Bay is presented in the form of an Environmental Impact Statement so that positive and negative outcomes of dredging and no action alternatives may be compared directly in economic, environmental and ecological terms.

Provided below is a description of impacts of the proposed action, and of available mitigation measures for minimizing adverse environmental effects, together with a comparison of alternative actions. Effects of the proposed actions and possible alternatives are identified and analyzed in terms of their effects and environmental impacts, as required by the EIS/EA process.

4.1 Environmental impact of the proposed action;

a) Dredging will have the following impacts at the Royal Marina site:

Disturbance of benthic habitat beneath the Royal Marina. While the most quiescent of these environments may be depleted of oxygen during parts of the tidal cycle, especially during warmer months, the higher energy, more oxygenated depositional areas are likely to be habitat for estuarine worms (polychaetes of the genus Nereis, inter alia.), mollusks and arthropods. This habitat, and the organisms which occupy it, will be destroyed during dredging.

The presence of a black organic matrix on top of coherent, gray clays (gleys) suggests that the environment may be too low in oxygen during critical warm weather periods for species of soft shell clam, such as *Mya arenaria*. While sampling (see Sampling Protocols and Results Appendix for a discussion of method)**.** brought up a matrix of blue mussel (Mytilis edulis) shells from a depth of several inches to a foot or more (which appear to be shed from the marina's pilings), no living worms or other invertebrates were found in the sediments. This is far from conclusive evidence, however, since benthic organisms are notoriously difficult to sample. Hand dredging, in fact, has captured periwinkles and tunicates, indicating that the sediment surface supports macrofaunal elements.

Sedimentation Rates and Resuspension of fine grain sediments. The Royal Marina is situated in a quiescent embayment where channel width increases threefold for water moving through the confines of the neck of land and the abutments of the City Island Bridge, with corresponding deceleration in water velocity. In technical terms, the pilings of rows of piers dramatically reduce the Reynolds number, further contributing to decreased water velocity here by breaking up the flow, decreasing turbulence, and increasing sediment deposition.

Some of the organics and clays have sedimentation rates on the order of a meter per day or less. By standard column testing (Montgomery 1978), minimum sedimentation rates were measured and found to be in the half meter per day range. This would place the size classes of the finest sediments at somewhat less than 0.01 mm (interpolated from Table 4.1 Settling velocities of various size particles on p 121 of Environmental Engineering, Peavy et. al. 1985). While algae and some suspended carbon compounds are capable of flocculating these and finer grained sediments in estuaries, such suspended sediments may impact attached filter feeders for a distance of tens to hundreds of linear feet. Estimates of duration of impact are a few days to approximately a week during and after dredging.

b) Constructing salt marsh within a confined containment facility will have the following impacts on the area around the Pelham Bay Landfill and the southern tier of Pelham Bay Park:

Removal of benthic habitat. The four foot diameter rock of the containment facility will displace the majority of the soft sedimentary benthic habitat with rocky benthic habitat. Depending upon the settling pattern of the rock, a few to a maximum of approximately 15 percent of the soft sedimentary benthic habitat may remain exposed in the spaces between where the stone dike of the containment facility rests on the benthic sediments (see Figure 3.). Approximately 1 1/4 to 1 3/4 acres of benthic soft sedimentary habitat within the containment facility will be covered with dredged sediment within the initial containment facility cells. Approximately 30 acres would be covered in the full scale containment facility.

Change in circulation in Eastchester Bay. While the Pelham Project plans to utilize hydrodynamic models to evaluate changes in circulation around the wave wall along the mouth of the Hutchinson River and Eastchester Bay, an initial look using standard analytical tools indicates that the structure will change circulation in Eastchester Bay as measured by Reynolds and Froude numbers.

At the north end of the Pelham Bay Landfill rock armor, where the Hutchinson River moves under the Shore Road Bridge, the ship channel and water flow is constrained to the south west by bedrock outcroppings. While the wave wall in this region will constrain the flow, the Reynolds number, $Re = lU/\mu$ (or discharge width times velocity divided by viscosity), the ratio of inertial to viscous forces, might only change by a factor of two to eight, since the river width would be reduced by half or less, leading to an increase in Re by a factor of 2, and most of the velocity of the river flows down the ship channel at present (because of the resistance of the bedrock at the channels edges), the wave wall might only increase this by a factor of 2, during normal flows. Storm flows may double this estimate. Within a few hundred yards from the mouth of the Hutchinson River, the width of Eastchester Bay increases to 300 and then 500 yards, so the constriction of the wave wall could amount to a velocity increase of about a third to a fifth, with much less effect on turbulence of the moving water mass than nearer to the bridge. This increased rate of river flow and tidal movement would, however, bring more oxygenated water into contact with the rocky intertidal and benthic habitat on the wave wall, increasing growth and development rates, as well as feeding rates by filter feeders which become associated with these structures.

At the southern end of the landfill and along the Southern Tier of Pelham Bay Park, the width of the wave wall falls to a fifth and less of the length and width of Eastchester Bay, contributing little to velocity changes in these areas of the Bay. A different key measure of estuaries is often used at this scale to evaluate changes in water movement, the Froude number, the ratio of inertial to gravitational forces, $F = V^2/gl$. Since l, the length term, is in the denominator here, as opposed to the Reynolds number where it is in the numerator, its increase or decrease has the opposite effect as in the Reynolds number. Since the contribution of the wave wall would be $\leq 1/5$ of the length and width of Eastchester Bay, it appears that circulation, as measured by the Froude number, would be affected by this construction in the range of about 20%. Specific scenarios would have to be evaluated, however, to predict what effects this may have on the flora and fauna of there area, which the Pelham Project aims to do with hydrodynamic modeling.

Scale of benthic habitat removal by the containment facility. The containment facility design calls for a 2:1 base-to-height ratio. Since it is expected that the containment facility will be between 11 and 18 feet tall, each leg of this triangle will be between 22 and 36 feet. The total base length then, including both legs of the triangle will thus be between 44 and 72 feet. Since the landward half of this triangle will be filled with sediments, in this sector, the entire soft sedimentary benthic habitat will be covered. While a few to several percent of the other half of the rock armor structure may remain as soft sedimentary habitat, the use of this habitat by benthic suspension, sediment, and filter feeders will depend on how much oxygenated water moves into the water column above this sediment.

Pathways between the boulders will range from a few to several inches in diameter, with an average diameter of the open passages being around a third of a foot. Water current velocities and wave activity in the surrounding waters of Eastchester Bay should induce flow so that oxygenated water moves into the interstices between the rock armor blocks. While details of flow will partly depend on edge effects and the orientation of the rock armor to circulation and wave activity in Eastchester Bay, the rough surfaces provided by the rock armor should partition flow such that oxygenated water is moved one to several block diameters into the containment structure. Rock armor placement will be modeled, and its effects measured in order to explore how this effect may be maximized in the Pelham Project.

In the case of the eleven foot height structure, there will only be one layer of three to four blocks, on average, stacked one on top of another. In this case, it is expected that the only likely area of depressed oxygen will be next to the central core of the rock armor structure, extending about two to three rock diameters from the center in the case of the 11' X 22' configuration, and some three to five block diameters in the larger, 18' X 36' configuration (see Figure 4.).

The geometry of the rock armor described will displace the majority of soft benthic habitat with benthic rocky habitat. For the 11' high containment facility, total habitat area, however, will actually increase by a factor of four. This follows, since each boulder has a surface area of approximately 50 square feet, and the 4' X 4' sedimentary benthic habitat it rests on has a surface area of 16 square feet. About half of this surface area increase would be subtidal, and half intertidal, thus doubling the area of benthic habitat, while adding two times the benthic habitat area in intertidal rocky habitat. In the case of the 18' height structure, the effective, oxygenated surface area of the benthic subtidal and intertidal community would increase by a factor of 7 following similar assumptions, increasing rocky subtidal habitat by a factor of about 5, and creating about twice the displaced benthic area with rocky intertidal habitat. Actual effects will need to be measured, but a dramatic increase in benthic surface area is expected on geometric grounds.

The Ratio of Restored and Created Benthic Habitat to Benthic Habitat Removed. The planned containment facility/constructed marsh will be approximately 300 feet in width, from the shore to the center of the rock armor containment wall. For the sake of comparison, each four foot strip, comparable to the area under the rock armor blocks, will have an area of 4' X 300' or 1,200 square feet. The 22 foot length of rock armor extending into Eastchester Bay will contain a minimum of about 12 boulders, each with a surface area of 50 square feet, or 600 square feet total, about half of the total surface area removed under the corresponding 300' width. About half of the total area of soft benthic habitat covered under salt marsh would be created by the stone dike containment facility as subtidal rocky benthic habitat, and half as rocky intertidal habitat. In other words, the 11' X 22' configuration would increase habitat surface by about 40% while creating three habitat types: intertidal salt marsh; intertidal rocky habitat, and subtidal/benthic rocky habitat, as noted in the table below.

11’ by 44’		stone dike	benthic area		
Stone dike	existing	containment	covered under	total	
	sedimentary	facility, (12)	4’ wide	habitat displacement	
	benthic	4’ diameter	300 ft. long	habitat displacement	
	habitat	rock	containment	containment	
	4’ by 22’	(4’ by 22’)	facility	facility	
Surface Area					
in square feet	88	603	1,200	1,288	
					percentage of
		created			habitat
	created rocky	rocky	created salt	total habitat	increase
	benthic habitat	intertidal habitat	marsh habitat	created	with the 11’ stone dike
Surface Area	302	302	1,200	1,803	40%
in square feet					

For the 18' high 36' length, about 30 boulders would add a surface area of 1,500 square feet, about 1,000 square feet of which would be subtidal, or about 80% of the benthic habitat displaced. As indicated in the table below, about 500 square feet of rocky intertidal would be added, about 30% of the area of the covered soft benthic habitat. Since the rocky subtidal and intertidal as well as marsh habitat were displaced by landfilling, the overall environmental impact of the proposed project would be to move the surface area and the diversity of the components of the system towards their historic pre disturbance ratios.

			benthic area		
		stone dike	covered under	total	
18' by 72'	existing	containment	4' wide	habitat displacement	
Stone dike	sedimentary	facility, (12)	300 ft. long	under dike &	
	benthic habitat	4' diameter	containment	containment	
	4' by 36'	rock (4' by 22')	facility	facility	
Surface Area					
In square feet	144	1,508	1,200	1,344	
					percentage of
					habitat increase
	created rocky	created rocky	created salty	total habitat	with the 11'
	benthic habitat	intertidal habitat	march habitat	created	stone dike
Surface Area	1,005	503	1,200	2,708	101%
In square feet					

The environmental impact on the biota must also be addressed, since the kinds of habitat which remain today are very different from historic configurations, and also differ significantly from habitat known to support water quality enhancement and fisheries development. From maps of a hundred years ago, it is apparent that the Eastern Bronx was constituted by an archipelago of rocky islands, high energy intertidal and subtidal rocky habitat, and, leeward of these landforms, thousands of acres of depositional and soft sedimentary habitat of salt marsh and mudflat. Most of the rocky and salt marsh intertidal habitat has been removed (see Figure 5.). In addition, the construction of housing, lawns, and roadways has caused accelerated runoff which, with the coastal creeks, has been incorporated into stormwater infrastructure. Most of the tidal creeks have thus been turned into intermittent discharges carrying hydrocarbons, BOD, nitrogen, and suspended solids into Eastchester Bay. One of the aims of the Pelham project is to recreate these creeks by opening up these stormwater structures, allowing storage and treatment to groundwater and stormwater in ponds and creeks, delivering more constant flows of freshwater into Eastchester Bay, and recreating historic and essential fish habitat.

Potential Erosion of Dredged Sediments from the Containment Facility. Placing dredging within the containment facility to a level near the average mid-tide mark is likely to lead to the formation of creek-forms through the marsh. While there is an apparent threat of erosion, the placement of sand, gravels, and shells in these areas will minimize this activity. Creek formation itself, and the ecological and biotic components of this process, provides an opportunity to utilize the structure of the salt marsh and the biota of the creek bottom to increase productivity and thus stabilize these hydrodynamic structures and prevent. By introducing ribbed and black mussels connected to Spartina *alterniflora* wind throws in a few areas along the creek edge, the aim is to provide larval stages of these organisms with maximal access to colonization of creek edges and the bases of emerging *Spartina* stems (Bertness & Ellison 1987; Bertness 1992). Along similar lines, oyster reefs have been found to be stabilizing structures in creek formation and behavior (Keck et. al. 1973; Dame 1987). To attain these structures as early as possible in the development of this system, oysters and shells, which are attractors for spat, oyster larval settlement, will be placed in the creeks as they are developing.

Environmental Impact of Restored Marsh in Terms of Nitrogen, Carbon, Hydrocarbons, Pathogens, & Metals Removal. The thirty acre marsh restoration on fine grained sediments from Royal Marina and other nearby marinas and channels encompassed by this whole plan is expected to have beneficial effects on nitrogen and carbon balance of Eastchester Bay. Although pollutant uptake by salt marshes is partitioned between the sediments and the living plant material, the majority of pollutants, particularly metals, are sequestered by the sediments themselves, and not the plant matter, and hence would not be re-released as vegetation decays during winter, with exceptions noted below. Quantifying the fates of these pollutants throughout the seasons, however, will be a major thrust of research associated with this project.

In brief, established saltmarsh environments can break down, remove or sequester pollutants, nutrients or pathogens in substantial quantities. While a lag in the development of removal capacity is to be expected, the literatures on saltmarsh and constructed fresh water wetlands point towards specific ranges which can be expected in constructed saltmarshes around the Pelham Bay Landfill. Commonly available materials like the simpler carbon sources characterized as BOD should be broken down in the tons to tens of tons per acre per year range. Simple hydrocarbons are expected to be mineralized at rates in the hundreds of pounds per acre per year. More complicated ring compounds are broken down at lower rates, in tens of pounds to parts of a pound per acre per year. Nitrate, which plays the role of a terminal electron acceptor in saltmarsh sediments, can be converted to nitrogen gas and removed from the water column at rates in the tens of pounds per acre per year. Other mechanisms of nitrogen removal can operate at or above this rate, but their variability in published work to date will require further study in the course of the Pelham Project. Metals, specifically cadmium, chromium, zinc, lead, and nickel, in the tens or parts per billion range are reduced by an order of magnitude and sequestered in marsh sediments. Higher loadings are more variable in their behavior. Pathogens in constructed freshwater wetlands are reduced by about two orders of magnitude when influent sources contain hundreds of thousands to tens of millions of bacteria per 100 ml. Evidence from studies on saltmarsh filter feeders suggests that this may be a low estimate for these environments when where mussels, oysters and clams achieve about a 1% coverage of surface marsh area. These estimates are documented below.

Nitrogen
Based on the performance of well developed marsh systems to the north of this region, it is predicted that restored marshes around the Pelham Bay Landfill will remove approximately 40 lbs of nitrate per acre per year (Valiela & Teal 1979a; 1979b; DeLaune et. al. 1989; White & Howes 1994). By extrapolation, this would lead to 1,200 lbs nitrate removal for 30 acres each year. While nitrate reducers are common in well developed salt marshes and in silty sediments, they do not readily develop in more porous media such as sand because of porosity and oxygen inhibition (Thompson, et. al. 1995; Currin et. al. 1996; Zedler et. al.). This was noted by early researches on nitrogen metabolism in marshes (Kaplan, W. I. Valiela, & J.M. Teal. 1979: Valiela, I. & J.M. Teal. 1979), but has not been tested developmentally with a specific focus on nitrate removal. Royal Marina sediments contain little or no sand, and do contain silts and clays, so these should support denitrifying microbial communities.

Carbon: Biochemical Oxygen Demand/Dissolved Organic Carbon.
Dissolved organic carbon, and especially biochemical oxygen demand or BOD have been characterized in many wetlands (Hammer et. al. 1993; Kaklec & Knight 1996), and in salt marsh environments. While removal rates vary, since BOD metabolism largely depends on aerobic microbes, removal rates develop relatively more quickly, and remove much higher qualities per area of marsh, than can occur with nitrate removal. Expected removal capacity would be in the range of tons of BOD per acre per year. Measures of an increasing number of constructed wetlands fall in this range.

	BOD	total landing	treatment area	removal rate	removal rate	removal rate
	(mg/L)	kg BOD/d	in m2	in lbs/acre/d	in tons/acre/yr	tons/30 acres/yr
influent	110.80	90.00	3,600.00	132.63	24.20	726.13
effluent	6.10	36.00				
% removal	90.40					Hammer et. al. 1993

These data indicate what appears in many reports on BOD removal rates. While these can be quite variable, well designed or well structured wetlands often achieve order of magnitude reductions, and these facilities can remove tons per acre per year. While these are freshwater systems, microbial counts suggest that saltmarshes should have equivalent or higher performance values.

The Arcata marsh in Humbolt County, California, was divided into ten cells, with varying hydraulic loadings and detention times. These behavior of these cells indicates an expected range of behavior for constructed marshes generally which are working with lower loadings:

hydraulic	hydraulic	total BOD	total BOD	total BOD	total BOD	BOD removed
loading rate	loading rate	removal rate	removed	removed	removed	tons/30 acres
in m3/m2/d	in ml/m2/d	per m2	in kg/m2/d	in lb/acre/d	in tons/acre/yr	per year
0.24	240,000.00	3,792.00	3.79	33.57	6.13	183.79
0.06	60,000.00	996.00	1.00	8.82	1.61	48.27

The extrapolation for a thirty acre marsh is given to indicate what may be expected in terms of water quality enhancement from the building of the whole Pelham Project. In round numbers, a marsh of this scale could remove between 50 and 200 tons of BOD per year at loading rates of tens of parts per million BOD, which may be expected in Western Long Island Sound. A marsh of this scale behaving at this level would measurably improve water quality in and around Eastchester Bay.

<u>Hydrocarbons</u>

"Microorganisms can degrade any organic compound"(Atlas 1978). This statement is true, in general, as applied to hydrocarbons, although, as the author notes "In reality, there are many complex hydrocarbon structures that are either recalcitrant or at least very resistant to microbial degradation" (Atlas 1978). Under the right biogeochemical conditions of nutrient availability, redox state, and microbial community structure, however, even recalcitrant molecules can be mineralized through a number of steps (DeLaune et. al. 1980; Gambrell et. al. 1981; Evans & Fuchs 1988; Gambrell & Patrick 1988; Heitkamp, MA. & CE Cerniglia 1988; Cerniglia 1992; Wilson & Jones 1992; Lee & Banks 1993; Rielley et. al. 1996).

More hydrocarbons are moved through the Port of New York and New Jersey than any other harbor in the world. This activity, plus the thousands of miles of roadway, and tens of millions of car and truck miles logged daily on City streets and highways inputs substantial quantities of hydrocarbons into the estuaries surrounding New York. Three major sinks for these materials are photooxidation, soils, and sediments. Each of these provide some treatment capacity, and while some work has addressed each of these, the majority of research to date has probably occurred in soils (Dragun 1988;). More than fifty different microbially mediated biochemical transformation and cleavage reactions of hydrocarbons in soils have been identified in categories including methylation, ether formation, N-acylation, nitration, nitrosation, and dimerization (Dragun 1988; Lee & Banks 1993). It is likely that most of these reactions also occur in sediments, and especially in the dynamic, heterogeneous rhizosphere environments afforded by salt marsh development.

With such great quantities of the material being moved, crude oil spills affecting estuaries during loading and unloading and other accidents occur with some frequency. Where concentrations are not too high, breakdown rates in sediments can be substantial. The table below is based on the rates of crude oil mineralization on sand columns. By extrapolation, it suggests that about a tenth of a ton of crude oil can be metabolized on a acre of biogeochemically active sediments.

	Degradation rate	Degradation rate	Degradation	
	In mg of oil	In grams of oil	Rate in lbs of	Rate in tons of
	Per m2 per day	Per m2 per yr	Oil/acre/yr	Oil/30 acres/yr
Kuwait crude oil	90.00	32.85	290.80	4.36

(Johnston 1970, as reported in Atlas 1981).

Lighter fraction petrochemical components of gasoline, other fuels, and solvents also find their way into the estuary. A number of these materials can cause cellular damage in metazoans, and pose potential risk through inhalation or skin contact. This has led researchers to characterize breakdown rates for toluene and xylene under sulfate reducing conditions, which are typical of salt marsh and mudflat systems. Breakdown rates for these potentially problematic compounds where measured in terms of removal per milliliter of sediment. In order to apply these findings to natural systems capacities, it was assumed that only one cubic centimeter per square centimeter behaved with the capacities reported in this mesocosm study. Given these assumptions, a salt marsh would have the capacity remove toluene and xylene in the pounds to hundreds of pounds per acre range, or in the tenth of a ton to ton range for tens of acres, as indicated in the table below.

			degradation	degradation
		degradation	capacity/top	capacity-tons/
toluene & xylene		rates in mg/l	lbs/acre/yr	30 acre/yr
	lowest rate	0.10	8.08	0.12
	highest rate	1.50	121.17	1.82

(Edwards et. al. 1992)

These results indicate that salt marsh microbial communities mineralize certain toxic benzene derivatives. This suggests that actual rates of mineralization on salt marshes is similar to earlier work on sand columns noted above. Thus these systems afford protection to human health and ecological integrity.

Polynuclear aromatic hydrocarbons (PAHs) are ubiquitously distributed molecules in the New York/New Jersey Harbor Estuary. These chemicals of concern are also one of the warning signs vis a vis the disposal of dredgings, since they are relatively refractory, and can be mobilized into food chains and food webs. Nonetheless, PAHs can be mineralized under biogeochemical regimes found in salt marshes. In a case study of an oil spill on a Georgia salt marsh, phenanthrene, chrysene, and fluoranthene were spiked in sediments. Concentrations remained high, around a hundred parts per billion, for about 45 days, followed by a rapid decrease over the next hundred days. Reduction by a factor of three to an order of magnitude occurred with these three compounds, with phenanthrene showing the greatest reduction, and fluoranthene the least in this timeframe, as indicated in the table below (Lee et. al. 1981).

	initial	concentration			
	concentration	on day 150	removal		
	ng/g	ng/g	ng/g	removal rate	removal rate
PAH's	sediment	sediment	sediment	g/ acre/year	g/30 acre/year
phenanthrene	115.00	0.50	114.5	4.60	138.05
chrysene	105.00	15.00	90	3.62	108.51
flouranthene	75.00	20.00	55	2.21	66.31

These inferred removal rates are about two orders of magnitude lower than rates for benzene derivatives given above. It is interesting to note that the initial concentrations in this study are at the same an order of magnitude as the EPA Region 3 screening level (US EPA 1991a; US EPA 1991b; US EPA 1991c), while concentrations after microbial activity are below these screening levels.

The removal rates given may, in fact, be underestimating actual breakdown. The reason for this is that bacteria consume easily metabolized materials first, and thereafter, enzyme induction must occur to metabolize the more refractory materials (Cookson 1995). Much of the literature of bioremediation in fact shows this classic pattern from biochemistry where a lag occurs after introduction of nutrients until simpler metabolites are no longer available, and the induction of specific enzymatic groups is completed by the populations or consortia of microbes involved in the biogeochemical work. This can be seen in the above data, where active metabolic activity was not initiated until day 45. Thereafter, the half life of the PAHs was about 50 days.

Where enzymes are already induced, total PAH metabolism can be much greater. Chrysene was spiked into sediments which had already been contaminated with oil, where enzyme activity had presumably been induced prior to the chrysene addition. As noted in the table below, by extrapolation of these data on metabolism of chrysene, about a pound would be removed by each acre of marsh each year.

	breakdown	removal	removal	removal	removal
	rate	nanograms	g/acre per	lbs/acre/per	lbs/30 acres/
	ng/g sediment	m2 sediment	year in top cm	year in top cm	year in top cm

	per day	per day	of sediment	of sediment	of sediment
chrysene	35.00	350,000.00	513.43	1.13	33.93
control	5.00	50,000.00	73.35	0.16	4.85

While some of the higher molecular weight PAHs may persist in some sediments over time (Herbes & Schwall 1978), breakdown rates of the lighter fractions appear to be high enough to reduce concentrations of hundreds of parts per billion to levels of a third to a hundredth or less of this concentration (Herbes & Schwall 1978; Edwards et. al. 1992).

<u>Pathogens</u>

Stormwater runoff, combined sewer discharges, as well as discharges from water treatment plants all contribute pathogens to the receiving waters. Because these organisms require a host for reproduction, their existence and half life in receiving waters is limited by the biogeochemical filtration rates of these waters. Because wetlands increase the probability of contact between pathogens and biogeochemical surfaces, they increase the removal rate, and decrease the half life of pathogens.

Location		system	performance	
		influence	effluent	% removal
Santee, CA	bulrush			
Winter season (Oct – Mar)				
Total coli no./100 ml.		50,000,000	100,000	99.80%
Bacteriophage, PFU/ml		1,900	15	99.21%
Summer season (Apr- Sept)				
Total coli no./100 ml.		65,000,000	300,00	99.54%
Bacteriophage, PFU/ml		2,300	26	98.87%
Iselin, PA	cattails & grasses			
Winter season (Nov – Apr)				
Total coli no./100 ml.		1,700,000	6,200	99.64%
Summer season (May – Oct)				
Total coli no./100 ml.		1,000,000	723	99.93%
Arcata, CA	bullrush wetland			
Winter season				
Total coli no./100 ml.		4,300	900	79.07%
Summer season				
Total coli no./100 ml.		1,800	80	95.56%
Listowell, ONT	cattails			
Winter season				
Total coli no./100 ml.		556,00	1,400	99.75%
Summer season				
Total coli no./100 ml.		198,000	400	99.80%

(Bastian & Hammer. 1993).

As can be seen from these data, constructed wetlands reduce pathogens by one to three orders of magnitude.

This is likely to be an underestimate of pathogen removal for intertidal wetlands, however, since filter and suspension feeders are often a major component of these communities, and since a strip of mussels 2 feet wide and 250 feet long can completely filter the three acre feet of water (≈ one million gallons) that covers acre of tidal marsh each day. Ribbed and black mussels (*Geukensia demissa* and *Mytilus edulis*), as well as soft shell clams (e.g. *Mya avenaria*), are often major components of the salt marsh fauna in and around Eastchester Bay. Where rocky or piling habitat is available, barnacles are also present in large numbers. Mussel densities can be quite high. A square yard of mussel bed yielded 1612 *Mytilus* individuals (p396 Between Pacific Tides, E.F. Ricketts & J Calvin, Stanford Univ. Press, 4th ed., 1968), which comes to about 180 per square foot, similar to mussel numbers in specific areas of salt marshes in Pelham Bay Park (PS & JA Mankiewicz, unpublished data).

Mussels have been found to filter water at rates of around 250 cm3 (g soft tissue)-1 h-1 or (in some experiments) rather faster". (p311 The Invertebrates R. McNeill Alexander Cambridge 1979). This means it would take roughly 1,300 grams of mussels to filter 2000 gallons in one day, or about 9 grams per square inch, a density found in many mussel beds.

A mussel 70 mm (about 2 1/2 inches) long filters, at some 60% efficiency, the plankton and suspended detritus out of 60 liters of water a day, or 22,000 liters of water a year". (p396 Between Pacific Tides, E.F. Ricketts & J Calvin, Stanford Univ. Press, 4th ed., 1968). This would require some 130 mussels of this size per square foot (about one per square inch in the foot square area) to filter 2000 gallon per day. Pumping water at this rates, it would take about 500 $ft.^2$ of mussel beds to filter the three acre feet of water over a one acre salt marsh.

Metals

Metals are of concern in estuaries, and rates of metal sequestering have been studied under different loading conditions. In Great Sippissiwisset Marsh in Cape Cod, metals were loaded onto quadrats in the marsh, and measurements were taken of metals retained in sediments, taken up by plants and animals, and exported from the marsh. Loadings were generally in the tens to hundreds of milligrams per square meter range, or tens to hundreds of parts per million per square meter, while sediment quantities varied into the hundreds of parts per million. The variability of the sewage sludge applied as a metal source, and the intrinsic variability in marsh components constitute serious methodological defects in the Giblin et. al. 1983 study. Sequestering rates were in the milligrams to tens of milligrams per meter squared per year. Percent sequestered is given below.

Cadmium	Iron	Manganese	Zinc	Chromium	Copper	Leader

15%	24%	27%	28%	45%	49%	60%

More recent work on fully contained mesocosms have shown some similarities to this earlier work. More carefully controlled and measured inputs and output, however, have led to better documentation of system behavior. As the mesocosm work of Sinicrope et. al. 1992 indicates, sequestering rates for most metals may be lower than that reported in earlier work, and, in the case of copper, under some conditions, there may be little sequestering of this metal in estuarine systems.

	Cadmium	Chromium	Zinc	Lead	Nickel	Copper
% sequestered	75%	75%	75%	84%	55%	
loadings mg/m3/d	13.20	18.90	56.70	56.70	56.70	11.3
96 l/day (low)						
Aug – Dec 1990						
loading in mg/l	0.07	0.10	0.30	0.30	0.30	0.06
loadings mg/m3/d	16.00	18.90	572.00	68.70	68.70	275
110 l/day (low)						
Jan – Aug 1991						
loading in mg/l	0.07	0.10	2.50	0.30	0.30	1.2
Aug – Dec ’90 load	2376	3402	10206	10206	10206	2034
Jan – Aug ’91 load	2880	3402	102960	12366	12366	49500
Annual load-mg	5256	6804	113166	22572	22572	51534
Annual sequestering						
Capacity						
In g/m3	4	5	85	19	12	0
In g/m2*	0.57	0.77	12.72	2.84	1.86	0.00