DRAFT

MONITORING AND ADAPTIVE MANAGEMENT PLAN

JAMAICA BAY MARSH ISLANDS ECOSYSTEM RESTORATION
BOROUGH OF BROOKLYN, NEW YORK

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PROJECT BACKGROUND

In the early 1900's, Jamaica Bay was an extensive estuarine ecosystem comprised of many dendritic tidal channels and flats that sustained large expanses of salt marsh. The bay was renowned for the abundance and diversity of its shellfish and its ecological importance as a nursery and feeding ground for countless species of birds and fish (JBERRT, 2002). Over the last century, urban and industrial development has modified the natural environment surrounding the marsh islands through activities such as dredging and filling, construction, pollution from biological and chemical contaminants, and over-harvesting or eradication of native plant and animal species (JBERRT, 2002). During this same timeframe, significant acres of salt marsh have been lost from the bay.

Based on aerial photography interpretation, the NYSDEC estimates that approximately 1,400 acres of tidal salt marsh have been lost from the marsh islands alone since 1924, with the rate of loss rapidly increasing in recent years. Between 1994 and 1999 an estimated 220 acres of salt marsh was lost at an alarming rate of 44 acres per year (USNPS, 2001). Further, it is estimated that if this trend continues, all remaining salt marsh on the islands will be lost over the next three decades. According to the NYSDEC (2001), Elders Point also lost approximately 77 acres of marsh, or 79 percent.

The loss of wetlands has had a cumulative, negative effect on the water quality and wildlife habitat of Jamaica Bay. As wetlands disappear and natural patterns of sedimentation are altered, water quality treatment functions such as nitrogen and phosphorous removal by the wetlands significantly decrease. The decrease in water quality treatment functions is compounded by the intense scale of development and high population density that results in large volumes of treated sewage effluent and storm water discharged to Jamaica Bay. In turn, wildlife habitat functions are lost when habitat is filled and/or fragmented, when invasive species colonize, and when water quality is comprised. These cumulative effects reduce the area's ability to provide habitat for numerous species of migratory and nesting birds, mammals, reptiles, fish, and invertebrates, resulting in a significant disruption to the area's entire interconnected coastal ecology. Consequently, the ecological function and resulting value of the remaining tracts of wetland acreage is significantly reduced.

Elders Point Marsh (EPM), in the north-eastern corner of the Bay, has been targeted by a multi-agency group led by the US Army Corps of Engineers as a high priority site for restoration. This restoration will be accomplished by placing dredge material, which is mostly sand, on the marsh plain. The restoration will be extensively monitored to ensure that this effort, and future efforts accomplish worthwhile ecological goals in providing long term sustainability to Jamaica Bay.

All monitoring conducted on Elders Point Marsh and its reference site will be performed in accordance with the federal and state regulations and standards. The goal of the monitoring and adaptive management program will be to accurately determine the success of the restoration efforts, quickly identify any problems requiring remedial action, and implementation of those remedial actions on a timely basis. A secondary goal is to learn the causes of the success and/or failures of the marsh restoration to aid in a better understanding of the marsh loss issue throughout Jamaica Bay. These efforts are based upon several potential causes presented by the Blue Ribbon Panel's findings(add Info). Both goals, evaluating and learning, although very much interconnected, may need different approaches in monitoring

Full post-construction monitoring and adaptive management will be performed for five years, with additional simplified monitoring in years 7 and 10, beginning with the first full growing season following completion of the restoration at the site.

The extensive monitoring and adaptive management plan covered in this document is warranted for this project due to the level of risk and uncertainty of achieving the projected results. This project is taking place at a site that has accessibility issues, is using uncertain construction methodologies due to the environment, and the site and the surrounding areas are undergoing rapid deterioration with uncertain causes. The parameters that have been chosen to be monitored are based upon both the *New York State Salt Marsh Restoration and Monitoring Guidelines* (NYSDEC, 2000) and the Blue Ribbon Panel Report. (make sure this is cited properly)

RESPONSIBLE PARTIES

The responsible party for the Jamaica Bay Marsh Islands, Elder's Point Marsh five year standard monitoring will be PANYNJ and USACE. Other responsible parties that may be involved include USNPS, NYCDEP and the NYSDEC.

The USACE is the lead designer for the project and as such will be responsible for aspects of the monitoring as a result of adaptive management recommendations. Any standards presented in the adaptive management sections are to be used as guidelines for evaluation. They are not to be used as requirements for actions, only for triggering closer investigation into a parameter. The USACE is not guaranteeing further action after closer investigation.

The regulatory agency responsible for approving the restoration designs, monitoring protocols, and any required permitting for restoration activities is the NYSDEC.

The NYSDEC is responsible for the regulatory permit approval of the environmental impacts associated with the implementation of the restoration design, as well as the monitoring protocols required to demonstrate project compliance.

MONITORING PROTOCOL DESIGN

This work plan for all monitoring activities is being written by USACE, with input from NPS, and shall be approved by the NYSDEC as the regulatory agency. The recommendations outlined below were based on the *New York State Salt Marsh Restoration and Monitoring Guidelines* (NYSDEC, 2000) and on from the entire project team which includes all participating agencies. Where necessary and appropriate, the plan includes site-specific modifications to the recommended monitoring protocol. Monitoring parameters and activities will be clearly articulated and documented in this work plan.

Monitoring at the project site shall be conducted in the restored salt marsh areas and at a minimum of one reference area. Detailed protocols and sampling locations are attached as Appendices to this document.

Reference areas are defined as a site that exhibits the characteristics and functions that are being targeted at the restoration location. The one of the purposes of monitoring reference areas is to discern background environmental effects from the effects attributable to the project. For example, vegetation parameters within the restored salt marsh areas must be compared with the same parameters at the marsh reference areas to determine whether an observed loss of vegetation is a restoration failure or due to a natural event, such as a winter storm that has similarly affected all marsh communities in the area. The reference site is representative of the target condition. The target condition may or may not be achieved at a restoration marsh, but it is important to determine if ecological conditions at the restoration site are progressing in a trajectory toward the reference condition. The reference marsh is always changing, as is the restoration marsh; thus, achieving equivalence of these 2 sites may not be a reasonable goal. The monitored parameters in these two sites, when compared, will indicate how far the restored saltmarsh has evolved into supporting diverse plant and animal communities. The monitoring ultimately should provide

the foundation for evaluating the degree to which ecological function is re-established in the restored intertidal meadow facet of the estuarine landscape.

The reference area chosen for this project is a section of JoCo Marsh in the northeastern section of Jamaica Bay. JoCo Marsh is mainly characterized by a mix of high marsh species with some *Spartina alterniflora.* However, the area known as Grassy Chain has at least 10 acres of habitat that is mainly low marsh which is consistent with the project area. This is the area that will be used for monitoring purposes for the Elder's Point Restoration Project. JoCo appears to have the lowest rate of marsh loss and the highest in plant growth with in the Bay.

This protocol may be used for future Jamaica Bay Islands restorations by USACE with appropriate modifications.

MONITORING PARAMETERS

The purpose of the monitoring is to assess the progress towards, and the success or failure of, the restoration of the salt marsh habitat at Elder's Point Marsh and the achievement of acceptable standards of salt marsh character and function. As a result of the monitoring, the information will provide an enhanced understanding of Jamaica Bay Marsh Island processes. It will help the agencies involved determine the cause of this loss, as well as assess the reasons for the success of the restoration efforts. The following outlines the parameters to be monitored. The specific protocols for each parameter are attached to this document as Appendices A-I.

Vegetation

- Plant species occurring;
- Percent Cover;
- Stem density;
- Plant height and;
- Signs of disease, predation or other disturbance.

Macro Fauna

- Birds
  - Goose Predation
  - Saltwater-fish-feeding birds;
  - Benthic-invertebrate-feeding birds; and
  - Other salt marsh associated bird species.
- Mammals
- Reptiles and Amphibians
- Insects and Spiders
- Horseshoe Crabs
- Ribbed Mussels
- Fiddler Crab Burrows
- Macro-invertebrates in Sediment
- Nekton

Landscape Analysis

- Satellite Imaging
- Topography/Bathymetry Utilizing LIDAR (Baywide)
- Topography/Bathymetry Utilizing Geodetic GPS (Site Specific)
- Sediment Evaluation Tables
- Photo Monitoring

Marsh Sediments

- Soil organic content;

- Grain size;
- Water content; and
- Soil salinity
- Porewater Samples
  - Sulfides, Sulfates;
  - pH, NH4, PO4, NO2, NO3
  - Dissolved Nutrients;

Physical Environment

- Wind Speed/Direction
- Precipitation
- Sealevel
- Dissolved Oxygen
- Tide Gauge
- Water Quality Parameters

PRE-RESTORATION MONITORING ACTIVITIES

For the JoCo Marsh (reference portion), all parameters described shall be monitored at least once prior to commencement of construction. The work plan may call for May and December parameters to be included for these areas in pre-construction monitoring activities during the year prior to construction.

For the Elder's Point Marsh, all appropriate parameters shall be monitored at least once prior to commencement of construction. However, SETs will not be installed Elder's East at this time, except for in any passive restoration areas, if necessary.

POST-CONSTRUCTION MONITORING (IMMEDIATELY FOLLOWING CONSTRUCTION)

Immediately following construction and prior to planting, the project site shall be walked by the NPS, the USACE, and the NYSDEC to assess compliance with submitted work plans. Elevations shall be double checked prior to planting. As Built surveys must be completed to verify elevations. Color photographs shall be taken at all of the permanent fixed-point photo station locations. Based on the monitoring data immediately following construction, the NPS, USACE and NYSDEC shall determine whether any additional work is required to achieve work plan compliance.

POST-CONSTRUCTION MONITORING

The all parameters should be monitored for five years following completion of restoration activities at both the restored and reference site transects as specified in the work plan. All monitoring activities shall occur at the appropriate tide level, which is mostly low tide.

MONITORING REPORTING REQUIREMENTS

Monitoring reports will be written and submitted to all involved agencies by December 1 of each of the five monitoring years and will begin after the first post-construction growing season. Included in each report shall be the monitoring data, photographs, a brief summary of the collected data and a discussion of the data collected.

ADAPTIVE MANAGEMENT

Adaptive management in the context of this project is an approach to resource management in which management goals remain the same, but management objectives and techniques may be modified in response to feedback (such as monitoring results) from the system being managed. Adaptive management recognizes that human knowledge regarding biological and physical systems is limited and that these systems may not always behave as expected. When a management or restoration project is to be implemented but there is some uncertainty regarding the response of the system to particular actions, adaptive management provides a way for management actions to respond to feedback from the system being managed.

Adaptive management will be implemented if specific restoration standards are not met or if it appears that actual conditions will diverge sufficiently far from intended conditions to threaten the achievement of overall project goals. Funding for adaptive management will be included in the project cost estimates so that this option will be available in the future if needed.

Should the development of the site fail to meet quantitative standards action to correct these shortfalls will be undertaken if such action could reasonably be expected to assist in the achievement of these standards. Corrective action could include vegetation management, predator management, topographic modifications (such as creation of or enlargement of channels) and geo textile tube repairs or modifications.

Standard Monitoring within the first five years will be utilized to begin to assess the site for any necessary changes. Additional limited Adaptive management monitoring shall occur for a minimum of five years after the standard monitoring and/or five years after a corrective action is taken.

Adaptive management reporting will be written and submitted, as the Standard Monitoring Reports are, to all involved agencies by December 1 of any year that data is collected for evaluation under adaptive management. Adaptive management reporting will begin after the fifth standard monitoring year has been completed. Included in each report shall be the monitoring data, photographs, a brief summary of the collected data, a discussion of the data collected and any recommendations for corrective action.

The focus of specific parameters for adaptive management will be Vegetation Density, Predation, Elevation and Landscape and Perimeter Changes.

VEGETATION DENSITY

Vegetation monitoring shall continue for cover, height and density during the adaptive management time frames. This will be used to evaluate potential die offs of plant material and/or predation of plant material.

By the third growing season, canopy coverage will be greater than or equal to 50%. Canopy coverage data will be collected through standard monitoring according to the point-intercept method during August-September of each year. This data collection will continue annually post standard monitoring. Canopy coverage less than 50% in year 3 or any subsequent monitoring year, will identify potential adverse conditions impacting progress of restoration, and lead to a determination of whether the adverse conditions can or should be remedied, and if appropriate, implementation of adaptive management action.

PREDATION

Geese are an important parameter to measure, but at the restoration (treatment) site only, for the purpose of protecting marsh vegetation through adaptive management. If the impact of geese on the vegetation or soil exceeds a predetermined threshold, corrective measures should occur to provide increased protection for the restoration site. Sampling for geese impacts should be done approximately weekly during the first three growing seasons during September through May.

The species of concern are Canada Goose (*Branta canadensis*), Brant (*Branta bernicla*), and Snow Goose (*Chen caerulescens*). A total count of the 3 species should be done immediately upon arrival at the edge of the site. Thereafter, during a brief walk-a-round, or while doing other work on the site, make notes of goose signs (grazing, digging, feces, footprints) along with an assessment (quantification or evaluation) of the latest impacts. This will provide information about rooting and grazing intensity as well as elucidate vulnerabilities in the restoration planting. At the restoration site this information is useful feedback for refining the site maintenance activities, to ensure immediate and effective responses to deter digging and grazing of planted grass and volunteer seedlings.

Grazing by geese in the project area shall be determined excessive if the number of recent dig outs exceeds 200 during any monitoring event. Monitoring will be focused to check several vulnerable locations and places where geese were seen at the time of the observer's arrival. Observation of more than 200 recent dig outs during any monitoring event will identify potential adverse conditions impacting progress of restoration which may require immediate attention such as repairing fences, installing additional fence, installing overhead strings, and lead to a determination of whether additional goose deterrence or other adaptive management action can or should be implemented. This action will occur during the first three growing seasons and at the end of these growing seasons removal of the predation fencing shall be evaluated.

ELEVATION AND LANDSCAPE

In order to evaluate the relationship between the marsh plain elevation and the frequency at which it gets flooded, certain parameters will continue to be monitored during adaptive management. Photo monitoring, SET, and topographic mapping will continue on an annual basis in order to ensure proper elevations are maintained to achieve an ideal flooding frequency through out the restoration site. LIDAR and Satellite Imagery will also be used as a tool to evaluate the marsh plain elevation.

Photo-monitoring during years 5 – 10 should occur once annually during the last week of August or the first three weeks of September, and will consist of the same site overview and photographs as described in the above-monitoring tasks at the same permanent transect photo-stations used during the initial monitoring period. When possible, photo monitoring shall also occur immediately following major storm events. The additional 5 years of photo-monitoring periods will be labeled, stored, and distributed in the same manner as occurred during the initial five-year monitoring period.

Post-construction elevation for greater than or equal to 75% (or other percent as determined by analysis of vegetated and nonvegetated areas at JoCo) of the project area shall be within the elevation range at which *Spartina alterniflora* is most productive. (The specified elevation range may be based upon the pre-construction benchmark data of USACE and/or data from the monitoring program.) Elevation data will be collected through project monitoring at seasonal intervals along transects using a geodetic GPS unit to provided elevations accurate to 1 - 2 cm. Elevation in 25% or more of the project area that is greater than or less than the specified

elevation range during any monitoring will identify potential adverse conditions impacting progress of restoration, and lead to a determination of whether the adverse conditions can or should be remedied, and if appropriate, implementation of adaptive management action.

PERIMETER CHANGES

Perimeter changes will continue to be analyzed during the adaptive management period. Geomorphology will be monitored for changes via the use of Satellite imagery, LIDAR and onsite bathymetry to indicate changes in footprints of channels, restored vegetation, and existing site attributes. LIDAR and Satellite imagery shall be made over the entire bay on years zero, one and five under the standard monitoring and year ten within adaptive management. Onsite Satellite imagery and bathymetry data shall be acquired twice yearly during adaptive management.

The perimeter of the project shall be determined to be unstable in areas of the project in which shoreline retreat exceeds 5 m per year. Changes to the perimeter will be measured through project monitoring of shoreline change at the perimeter of the restoration area using a geodetic GPS unit to delineate the perimeter at mean low tide and the sub tidal areas around perimeter to the limits of the survey equipment (1 – 1.5 meters). Perimeter changes will be measured twice annually, late winter/early spring and late summer/early fall. A cumulative shoreline retreat in excess of 5 m per year in any areas of the project will identify potential adverse conditions impacting progress of restoration, and lead to a determination of whether the adverse conditions can or should be remedied, and if appropriate, implementation of adaptive management action.

Appendix A

PROTOCOLS FOR MONITORING VEGETATION, MACRO-INVERTEBRATES, AND BIRDS DURING SALTMARSH RESTORATION IN JAMAICA BAY, NY

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1. Introduction and Monitoring Goals

As part of a long-term program of saltmarsh restoration in Jamaica Bay, NY, the National Park Service is collaborating with the Army Corps of Engineers to implement standardized monitoring protocols for evaluating the success of various restoration techniques and for investigating the fundamental causes of saltmarsh loss.

The goal of these monitoring protocols is to provide an objective assessment of the biological changes resulting from the restoration of saltmarsh islands in Jamaica Bay, Gateway National Recreation Area, New York. In the short term, the monitored parameters will yield information useful as feedback to refine protection and management activities at the site, to ensure the best degree of project success. In the long term, the monitoring will provide the basis for comparing the restoration site with a control site (representative of the pre-treatment condition) and with a reference site (representative of the postulated ideal saltmarsh island condition in the Jamaica Bay environment). The reference site is representative of the target condition. The target condition may or may not be achieved at a restoration marsh, but it is important to determine if ecological conditions at the restoration site are progressing in a trajectory toward the reference condition. The reference marsh is always changing, as is the restoration marsh; thus, achieving equivalence of these 2 sites may not be a reasonable goal. The monitored parameters in these three sites, when compared, will indicate how far the restored saltmarsh has evolved into supporting diverse plant and animal communities. The monitoring

ultimately should provide the foundation for evaluating the degree to which ecological function is re-established in the restored intertidal meadow facet of the estuarine landscape.

2. Proposed Monitoring and Timeframe

The parameters to monitor at each of the 3 sites (restoration, control, and reference) are sampled either at fixed locations according to a prescribed schedule or opportunistically throughout the entire site. They are:

Scheduled sampling at permanent grid locations —

- Vegetation permanent plots (plant species, stem density, height, and cover; also algal mat, ribbed mussels, mud dog whelks, fiddler crab holes, and other macro-invertebrates).
- Macro-invertebrates, terrestrial (mainly insects and spiders by sweep net).
- Macro-invertebrates (in sediment cores).
- Birds (counts at fixed points).

Opportunistic observations throughout the entire site —

- Daily abundance, distribution, and impacts of geese.
- All observations of mammals and reptiles (sightings or signs).
- Different bird species (not seen during the prescribed count).
- Unusual macro-invertebrate species (aquatic and terrestrial, not seen during prescribed sampling).
- Unusual fishes (in pools or at flood tide).

The plant inventory prior to the restoration dredging should include the entire growing season of Smooth Cordgrass (*Spartina alterniflora*), which grows from the last week in March to October, but thereafter declines. Sampling established plants is best done around September. Sampling seedlings should begin at the end of March (to document early germination), and be repeated in mid-April and at the end of April (to document late germination and survival). Birds and other animals that use the marsh generally change as the months progress, so it is useful to begin their baseline inventory early enough to include 6 to 12 months prior to restoration.

3. Location Grid for Sampling

A survey grid is needed in each of the sites (treatment, control, reference), to serve as a framework for locating random sample plots and other sampling points during routine fieldwork. The grid comprises a baseline (oriented approximately north-south) and several perpendicular parallel transects, all laid out to cover the entire site. The alignment of the baseline and perpendicular transects is surveyed using an engineer's transit. Horizontal distances are measured using an 100-meter surveyor's tape.

The baseline should be placed at the higher and more-sheltered end of the site, so that its stakes are likely to survive storms and winter ice. The baseline transect may be staked only at its ends and where the perpendicular sample transects begin. It may prove convenient, however, to stake the entire baseline at regular distance-intervals (e.g. 10 m or 50 m) so that a few stakes survive the winter and make reestablishment of the sample transects easier each spring. The

sample transects are more likely to lose their stakes, because they generally are mostly in lower portions of the catena, compared with the baseline.

Points along the baseline that will serve as starting points for the perpendicular sample transects are chosen as whole meters from a random numbers table. About 3 to 9 sample transects are needed, depending on the shape of the site. Sample points along each sample transect also are selected from a random numbers table. To decide the number of sample points on a transect, divide the total sample size (n = 30, or more) by the desired number of transects.

Alternatively, a random-systematic approach can be used to determine the starting points along the baseline, as well as the plot locations along the sample transects. Choose the starting point of the first sample transect by selecting a random number between 0 and 30 m. The remaining sample transects can be apportioned at equal distances along the baseline, so that the entire site is covered. Locations of the permanent plots along each transect can be at pre-determined regularly-spaced distances, so that the points are spread out over the entire site. Avoid confining the random starting point to such a narrow range of potential numbers that the first transect is forced to fall in the fringe of vegetation at the water edge. All potential points on the site's surface should have an equal chance of being selected.

The time-consuming replacement of missing posts each spring might be avoided by using GPS to relocate the hard-to-find plot markers (1-cm diameter stakes that show only several centimeters above the surface). The disadvantage, however, is that fieldworkers often do not have access to a GPS unit, and even when the unit is available it sometimes is useless because satellites are out of range. Although the GPS unit is sufficiently accurate for some sampling parameters, lost grid posts should be re-measured and re-staked for greater accuracy and convenience in routine activities. Permanent vegetation plots are better for statistical analysis if their precise location can be relocated when plot markers are missing. Since most of the pre-treatment site at Elders Point is submerged, probably few grid posts can be installed prior to filling and few pre-treatment vegetation plots can be sampled. Other sampling can be done by GPS at grid locations without installing stakes.

In each site the baseline is placed toward the side of the site that faces the island interior, whenever possible. Or, on the remnant islands of Elders Point, the baseline may be placed in the middle of the highest island, and the perpendicular transects can be run in east and west directions, denoted by E or W (for example, T-BL022-E137). Although the entire sample grid with permanent plots will be designed on paper before any fieldwork begins, in the pre-restoration sampling only the above-water portion of the grid will be installed at the restoration site.

The grid stakes are pushed or pounded up to 1.5m into the marsh, until solidly seated, so that they serve as permanent marker posts showing 0m, 20m, and so-forth positions along the baseline transect. The starting position of each perpendicular sample transect also is indicated by a baseline grid post. The distance is written on each post by using a permanent black felt marker. The code is T or C or R (treatment or control or reference) – BL000 (the 3-digit distance in meters along the baseline transect). A sample point in the restoration site, for example, that is on sample transect 22, at a distance 60 m west of the baseline, is labeled: T—BL022—W060, written near the top of the grid post.

The baseline grid posts at Big Egg Marsh experimental restoration site are 1/2-inch (1.25 cm) grey pvc pipe (electrical conduit), which are pieces that are 10 feet (3.0 m) long. And the transect grid posts are 1/2-inch (1.25cm) white pvc pipe (cold water pipe), in pieces that are 10 feet (3.0m) long. The permanent vegetation plots are denoted by a 1-inch (2.5 cm) white pvc

pipe. Wooden stakes may be substituted for pvc pipes, although wood is less durable and likely to float off-site when uprooted. Wood, however, has the advantages of being more attractive and biodegradable.

4. Monitoring Methods

This field survey has multiple parts. Some observations are done by boat, but most are by walking. Trampling of the marsh surface is inevitable, but is minimized by walking along established footpaths on the marsh surface. At Big Egg Marsh, footpaths follow the transect lines; when deviations are necessary, they always are north of the transect. All sample plots are established south of the transects, to avoid accidental trampling of the plots.

4.1. Vegetation Permanent Plots

Vegetation monitoring should follow the protocol described in *Monitoring Salt Marsh Vegetation* (Roman et al. 2001). This protocol is being adopted as a standard for all coastal parks in the northeastern US by the National Park Service's Inventory and Monitoring Program. The primary parameters to monitor are plant species, stem density, plant height, and percent plant cover. The same plots also should be used to record the presence of algal mats, and the number of macro-invertebrates such as ribbed mussels, mud dog whelks, fiddler crab holes, and others.

The first priority for the pre-treatment baseline inventory is to establish permanent vegetation plots and to sample them in September-October. The NYSDEC (Niedowski 2000) recommendation that plot locations may be selected anywhere within 2 m on either side of the transect is likely to introduce bias. To meet the statistical assumption of randomness, the exact locations of all plots should be selected from a random numbers table. Or, at least a random-systematic design should be used (see above section on Location Grid for Sampling).

At Elders Point, 30 plots (each 1m x 1m) should be permanently marked in the treatment site. There should be another 30 plots in the control site, and 30 plots in the reference site. Since fieldworkers often walk along the transect lines, the permanent vegetation plots should have a 1-meter offset from the perpendicular transects. At the position of each plot along the transect, the offset from the grid post is a perpendicular 1.00-m distance to the south to create the near corner of the 1-meter-square plot. From there, the plot extends south and east. The position of the northwest corner of the plot should be GPS-recorded using a high-precision unit. At a minimum the northwest corner should be permanently marked with a thin (1-cm-diameter) stake that is driven into the marsh to resistance (about 50 to 100 cm). Only about 3 cm should be left showing above the marsh surface to minimize the chance that ice sheets or wrack rafts will damage the stake. The other three corners of the plot may be staked, too, to make the plot more visible and improve the chance that at least one stake will survive the winter.

Any potential permanent plot that falls within 10m in all directions of an already-selected permanent plot should be discarded and another random point selected. Additional sample transects, and random points along the transect, may be selected as needed to achieve the desired 30 permanent plots in each site.

All walking across the marsh for every study in the baseline inventory and subsequent monitoring should be confined to the baseline and sample transects as much as possible. Sampling points that lie away from the transect should always be approached along the same path from the nearest point on the transect.

Each of the 30 permanent plots in the treatment site, control site, and reference site should be sampled for plant species, for a total count of stems (and mussels, snails, and other macro-invertebrates), and for samples of plant height and cover. Counting is made easier and more accurate by subdividing the plot with 4 sticks placed parallel and evenly-spaced, with another 4 sticks placed at right angles to the first. The result is a plot that has 25 cells. Data are recorded on a standardized data sheet that has a matrix of 25 cells. Data always are recorded starting in the northwest corner of the plot, and writing in the top left corner of the matrix, so that each cell of the data sheet and plot correspond. Plant height is from a sample of 12 plants, 3 in each quarter of the plot, with note of whether the measurement is of seed head, stem, or leaf. The USGS & NPS protocol (cf. Roman et al. 2001) samples 50 points within the plot, rather than making a total count. This works all right for short vegetation, but is not well-suited for the 2-m tall tussocks of *Spartina alterniflora* that exists on the sites in Jamaica Bay. Further discussion is needed.

Plant canopy cover in each plot was recommended by USGS & NPS (Roman et al. 2001) to be sampled by point intercept, 50 pins per plot. To measure the cover, 5 one-meter-long rods are laid out across the plot at 0, 25, 50, 75, and 100 cm. Each rod has 10 points, with the last point being on the perimeter. Standing over the plot and looking down at an offset of 1 cm from the mark, the point-intercept rod is lowered. Whatever the rod touches is counted as cover, so at each point there is a record of the plant leaf contacts and the kinds of contacts (plant litter, mussels, snails, empty shells, debris, bare soil, algae, surface water, soil type, fiddler holes) on the marsh surface. Also, a digital photograph of each plot is made, always from the west side. Sampling details follow Roman et al. (2001). These recommendations work well on firm soils, but in the gelatinous sediments of the control site and in the baseline inventory of the treatment site, both with isolated tussocks up to 2 meters tall by late summer, this sampling method is unworkable—the observer cannot stand over the vegetation and look down. An alternative is to lay down 4 parallel sticks with another 4 parallel sticks at right angles, creating 25 tiny squares. Since each square represents nearly 4 percent of the plot's area, it is relatively easy to make a subjective estimate of canopy cover in each cell by scoring 1, 2, 3, or 4 percent for each cell. Further discussion is needed.

Seed germination and survival can be measured in the 30-plus permanent vegetation plots. The seedlings will have to be counted during the last week in March, and again in mid-April and at the end of April. Most seedlings are eaten, dislodged, or desiccated within days of emergence.

After all the field data are collected from the 30 plots at each site, the data may be analyzed in two ways:

> First, by analyzing all 30 plots together. The sample size is good, but the variability likely will be very large.
>
> Second, by using statistical strata that are defined independently of the data set. Two or 3 strata can be outlined on a photomap to show meaningful habitats. Or the strata can be defined by dividing the range of elevations on the site by 3. For the treatment site, the post-fill target elevations should be used. After the elevation is identified for each plot, the plot is assigned to the appropriate stratum.

The sample size in each stratum will be small, but the variance likely will be small, too.

4.2. Macro-Invertebrates Terrestrial

Insects and spiders are collected with a sweep net while walking along the sample transects and while walking around the periphery of the vegetated marsh. A separate sample may be collected over any wrack-covered areas. One sample consists of 100 sweeps of the net in a wide arc, while walking at a slow steady pace. The net should sweep as close to the ground as possible, depending on the density of the vegetation. Sampling may be done as infrequently as monthly from June through September, by the surveyors of the birds and the mammals & reptiles. One sample of 100 sweeps probably will be adequate for each major vegetation type at a site.

The completed sample is transferred from the net to a large transparent plastic bag, by turning the net inside out while holding the bag closed around the net, so that nothing escapes. The bag is taken back to the laboratory and placed in a cold refrigerator or freezer to immobilize the insects and spiders. They then are gently transferred into a jar containing several centimeters of alcohol. Later, the sample is sorted under a dissecting microscope, and each species of organism is placed into a separate vial with 70% ethanol. Care should be taken to avoid breaking the fragile appendages of the insects. Never shake the jar or vial. Be sure that every jar or vial has a paper label inside, with date, collector, location, and sample number written in pencil.

Investigators also may look under straw and other debris for hidden organisms. These opportunistic observations likely will include amphipods, snails, insects, spiders, and crabs.

4.3. Macro-Invertebrates in Sediments

Paired with every second, or alternate, permanent vegetation plot a soil core will be taken. The core's precise location is 2m west of the northwest corner of the vegetation plot. (A ground-water well will be 1m west of the northwest corner of the vegetation plot.) In subsequent years, the core location will be offset 1 m farther west. Omit any core that falls within 8 m of a SET, or within 2 m of a permanent vegetation plot.

Field collecting follows standard methods (New 1998), except that the coring device is a 33-ounce coffee can that has both ends removed; its volume is about 2940 ml. The can is pressed into the soil by the rocking motion of a foot on top of the can's rim. As soon as the can's top rim is flush with the soil surface, a shovel is used to remove soil from one side of the can, and then the shovel is quickly inserted beneath the can to remove the can and its soil contents. The entire action must be done quickly, to prevent organisms from escaping to deeper depths.

The collected soil is then shaken out of the can, into a plastic bag. Samples are taken to a lab and stored in a refrigerator until they can be processed by sieving. During sieving, any organisms that are visible to the naked eye are removed and placed in a beaker of bay water. The primary sieve sizes will be 2mm (to remove broken shells and plant debris), 1mm, 0.425mm,

0.3mm, and 0.180. The latter two sizes often prove impossible to use within the time constraints; the remaining volume, however, can be estimated by subtraction. Brackish water can be used as needed, to flush the wet sediments through the sieves. Rose Bengal stain and Magnesium Chloride relaxant are used to help separate the organisms from the debris and sediments. Organisms are preserved in 70 % ethanol, and then are sorted by major taxonomic groups. Specimens are saved so that species identifications can be verified at a later time by specialists. In the case of the commonest and most-abundant species (e.g. Mud Dog Whelks and Ribbed Mussels), only representative specimens need be preserved. Additional information on the mussels and snails is collected in the vegetation permanent plots, and those results will be compared with earlier studies, e.g. Franz and Harris (1983; 1988) and Franz (2001).

4.4. Birds

At minimum, a sampling frequency of alternate-month observations of all bird species at all 3 sites (treatment site, control site, and reference site) is recommended, to provide general descriptions of bird use. For a 90% certainty of confirming presence or absence of marsh birds, a minimum of 3 surveys per season is needed (Erwin et al. 2003). These observations at all 3 sites can be done on a calm day, between dawn and 10:00am, to catch seasonal variations in bird occurrence, nesting activity, and feeding. Migratory birds and all other birds will be included in these counts.

The sampling for birds should begin immediately upon arrival at the site, because some species are easily frightened away, and are likely to remain away for hours or the entire day after being disturbed. The fixed-radius point-count technique should be used, because it is a good quantitative method if the statistical assumptions can be satisfied. Spot-mapping is a second useful technique to use, because it records additional species at the site, but it lacks the quantitative rigor of the point count. (Verner 1988, Smith et al. 1998, Nur et al. 1999.)

If the site is more than 5 hectares in size, the point count should be repeated in each 5-ha increment. The observer should walk along a sample transect to the nearest edge of the site, or arrive by boat to a fixed point, and then immediately begin the 10-minute count. The radius of the circle is the distance from the observer to the far edge of the count site, or to the distance that a small bird can be identified, but the total area surveyed will vary depending upon the configuration of the count location, e.g. a semicircle. The sample duration is exactly ten minutes, during which all bird species, numbers, and activities are recorded. The observer then walks through the site to flush and record any birds that were hidden during the observation period. Date, time of day, weather, and tide should be recorded.

Spot mapping is done on each site whenever the observer is not doing a ten-minute count, and can continue opportunistically throughout an entire observation day while doing other tasks. This method is a useful supplement to document bird species that are missed during the 10-minute point count, and is similar in value to checklists (e.g. Droege et al. 1998). Species and numbers are recorded, and note is made of their activity and location (e.g. whether on the marsh surface, on the banks, perched on grid stakes, or in adjacent water). Time of day, weather, and tide will be recorded. Attention also is given to looking for signs such as footprints, feces, fresh grazing, diggings, and food remains. Some opportunistic observations are made at dawn, some at dusk, and others throughout the day and night, somewhat randomly, depending upon other work schedules.

No live birds are to be captured or collected, but any dead evidence may be collected for later reexamination.

4.5. Mammals and Reptiles

While observing birds or doing other work on each of the 3 sites, the observer should record any sightings or signs of mammals and reptiles. Mammal signs to look for in the marsh are predator-killed birds and terrapins, footprints, feces, diggings, scrapings, fur, and regurgitate. At the upland edge look for the lairs or burrows of mammals, and the diggings and scrapes of terrapin nests. These observations will be rare, so fieldworkers should be alert to these signs whenever working on the sites.

5. Geese as a Parameter for Adaptive Management

Geese are an important parameter to measure, but at the restoration (treatment) site only, for the purpose of protecting marsh vegetation through adaptive management. If the impact of geese on the vegetation or soil exceeds a predetermined threshold, prompt intervention should occur to provide increased protection for the restoration site. Sampling for geese impacts should be done approximately weekly (from almost daily in September through May, to as seldom as once each week or two in summer).

The species of concern are Canada Goose (*Branta canadensis*), Brant (*Branta bernicla*), and Snow Goose (*Chen caerulescens*). A total count of the 3 species should be done immediately upon arrival at the edge of the site. Thereafter, during a brief walkaround, or while doing other work on the site, make notes of goose signs (grazing, digging, feces, footprints) along with an assessment (quantification or evaluation) of the latest impacts. This will provide information about rooting and grazing intensity as well as elucidate vulnerabilities in the restoration planting. At the restoration site this information is useful feedback for refining the site maintenance activities, to ensure immediate and effective responses to deter digging and grazing of planted grass and volunteer seedlings.

Fence and overhead strings were used to exclude geese from the planted restored marsh at the Big Egg Marsh Experimental Restoration (treatment) Site. But that was only a 1-hectare site, and the installation and maintenance of more than 1,000 meters of green plastic 1.2-m-tall fence was labor-intensive. Fence probably is impractical to use in much larger areas, such as at Elders Point. The long fetch at Elders Point renders any fencing extremely vulnerable to damage from waves, wind, floating wrack, and winter's floating ice sheets. Scheduling researchers and other workers to be present at the restoration site daily, or almost daily, probably is more cost-effective and more practical. Anyone visiting the site should chase away all geese. At critical times of the year, it might be necessary to station an outboard motor boat with crew at the island for part of each day or night—when to do this would be determined as feedback from the "geese parameter". Inattention to the impacts of geese can result in a decline in vegetation at the restoration site in each successive year. Such a loss would have happened at Big Egg Marsh if there had not been fencing, and similar loss occurs at other restoration sites, e.g. Anacostia estuary near Washington DC (Hammerschlag et al. 2005).

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Appendix B

Nekton Protocol
-- Monitoring Saltmarsh Restoration in Jamaica Bay –

DRAFT (May 4, 2005)

Monitoring Questions

Restoration-Related Questions

- What is the response of saltmarsh nekton, as measured by species composition and abundance, to restoration of habitat from deteriorating to a more stable marsh habitat?
- What is the time-frame for nekton communities in restoring salt marshes to achieve functional equivalency when compared to reference marshes?
- How are changes in nekton related to changes in other ecosystem components such as vegetation, benthos, birds, water quality during the salt marsh restoration process?

Jamaica Bay Ecosystem Related Questions

- How are the species composition and abundance of saltmarsh nekton changing in response to increasing marsh deterioration throughout Jamaica Bay?
- Are invasive species present in the nekton community, are new invasive species being introduced, are they changing in abundance, and are they affecting the structure and function of the estuarine nekton community?

Rationale for Monitoring Nekton

Salt marshes are an important habitat for nekton, including juveniles of economically valuable species in some regions (Deegan 1993; Able *et al.* 1996; Kneib 1997; Minello 1999; Roman *et al.* 2000). Nekton also represent a significant portion of the diets of many piscivorous birds, economically valuable fishes, and, when in estuaries, marine mammals (Friedland *et al.* 1988; Sekiguchi 1995; Smith 1997). Nekton represent an especially valuable factor to include in estuarine monitoring programs because of their well-documented response to human-induced and natural ecosystem changes. For example, fish abundance, species richness, and growth rates of the mummichog (*Fundulus heteroclitus*) increased in response to enhanced nitrogen loading (LaBrecque *et al.* 1996; Tober *et al.* 1996). Several studies have indicated that nekton responds rapidly (*e.g.,* within days to months) to the manipulation of salt marsh hydrology (Rey *et al.* 1990; Taylor *et al.* 1998; Able *et al.* 2000; Roman *et al.* 2002). Long-term monitoring will also document the introduction or expansion of invasive species (*e.g.*, Japanese shore crab, *Hemigrapsus sanguineus*), interactions among invasive and native species and their subsequent impact on nekton community dynamics, and changes in species ranges.

Because nekton responds, often quickly, to environmental change, a program that monitors estuarine nekton will be able to detect changes in species composition and abundance, or shifts in trophic relationships, providing an early warning system to larger ecosystem threats, as well as responses to management actions (e.g., habitat restoration).

History of the Saltmarsh Nekton Monitoring Protocol in the NPS

The saltmarsh nekton protocol described herein was first designed and tested for the Long-term Ecosystem Monitoring Program at Cape Cod National Seashore (Raposa and Roman 2001a) and is based on extensive supporting data (Raposa 2000; Raposa and Roman 2001b; Raposa *et al.* 2003). http://science.nature.nps.gov/im/monitor/protocols/caco_nekton.pdf
This protocol has been implemented at Cape Cod since 2003. In 2003, 2004, and now in 2005, the Cape Cod nekton protocol is being tested for implementation throughout the northeast, from Maine's Acadia NP to Colonial NHP in Virginia. Some minor modifications to the Cape Cod protocol will be made and it is expected that the protocol will be implemented at Northeast coastal parks beginning in 2006 (James-Pirri and Roman 2004 DRAFT). Finally, it is noted that the nekton sampling protocol was successfully implemented at the Jamaica Bay Big Egg Marsh control and restoration sites, beginning in 2003 with pre-restoration monitoring, followed by post-restoration monitoring in 2004.

Protocol Summary (to be followed by detailed procedures)

This protocol describes the methods used to sample nekton (free-swimming fish and crustaceans) in shallow water (<1m) habitats such as salt marsh pools, tidal creeks, and shallow shoreline areas adjacent to salt marshes. Study sites are selected using a stratified random approach. Sampling stations are randomly located within pools and along ditches, creeks, or shoreline areas. Nekton is sampled exclusively with throw traps in shallow water salt marsh habitats (creeks, pools) and ditch nets in narrow mosquito ditches or narrow creeks. There should be two daytime sampling efforts per year; one in early summer (June-July) and another in late summer-early fall (August-October). A minimum of 15 replicate throw trap samples and 10 replicate ditch net samples should be collected from each marsh during each sampling event. Sampling of nekton utilization on the marsh surface is accomplished with bottomless lift-net apparatus.

Nekton composition, and the density and length of individuals from each species are recorded at each sampling station. Environmental parameters are collected concurrent with nekton sampling include temperature, salinity, water depth, dissolved oxygen, and vegetation cover.

Nekton Protocol - Details (portions excepted from James-Pirri and Roman, 2004Draft)

Site Selection

Nekton sampling will be conducted at the Elders Point Marsh (restoration site), Black Bank (control site), and JoCo Marsh (reference). The control site is selected as a marsh that has characteristics similar to the pre-restoration Elders Point Marsh. The reference marsh, JoCo, represents a target condition. The target condition may or may not be achieved at the Elders restoration marsh, but it is important to determine if ecological conditions at the restoration site are progressing in a trajectory toward the reference marsh.

At each site, the boundaries of sampling need to be determined. This could include the entire marsh island at Elders and JoCo, or a randomly selected sub-section of these sites. At Black Bank, a broad fringing marsh, as opposed to an island marsh, the sampling boundaries need to be determined.

Marsh Habitats to be Sampled

Preliminary observations suggest that there are few marsh pools throughout the Jamaica Bay system, but that most nekton habitat associated with marshes includes tidal creeks, ditches, and the shallow intertidal edge of marsh islands and fringing marshes. These habitats (creeks, ditches and edges) will be the focus of the nekton sampling protocol, employing $1m^2$ throw traps and quantitative ditch nets.

The other major nekton habitat associated is the marsh surface (with vegetated or unvegetated) to be sampled with the quantitative bottomless lift net method.

The protocol for the 1m2 throw trap and ditch nets will be explained first, followed by the bottomless lift net method.

Sampling Gear (throw traps and ditch nets)

The recommended sampling gear for monitoring nekton in salt marsh and shallow (<1m) estuarine ecosystems are enclosure traps (throw traps and ditch nets). Enclosure traps are quantitative sampling gear that have a high and consistent capture efficiency in most habitats, tend to better represent benthic nekton, and are small enough (typically 1 m^2) to permit sampling in specific microhabitats (Rozas and Minello 1997). No gear can effectively sample the entire nekton assemblage in all habitats, but the high and consistent capture efficiency is a primary advantage of throw traps over seines. Higher capture efficiencies may also lower sample variance, and thus, sample size during monitoring (Peterson and Rabeni 1995).

Two gear types are used to sample estuarine nekton in pools, creeks, and ditches/narrow creeks (<1m wide). The preferred gear is the $1m^2$ throw trap which can be used to sample salt marsh pools, tidal creeks, and shoreline areas. The second gear is the ditch net which can be used to sample mosquito ditches and smaller tidal creeks. The throw trap is a $1m^2$ box (measuring $1m^2$ wide x 0.5m high) that is open at the top and bottom. The sides of the trap are covered with 3mm mesh hardware cloth. Since the trap samples a known surface area of water ($1m^2$), quantitative and repeatable estimates of nekton density can be obtained. A $1m^2$ throw trap is best used within sand or mud bottomed estuarine habitats.

To adequately describe the nekton community within mosquito ditches and narrow creeks the ditch net is the gear of choice. The $1m^2$ throw trap cannot adequately sample these narrow, but often numerous and important habitats. Density can be calculated for a ditch net by measuring the area of water the net is sampling. The center body of the net lines the sides and bottom of 1 linear meter (approximately) of ditch. There are two doors on the open ends of the net, which when pulled, rise up to close off the ends of the net, enclosing an area of water that is 1m long and as wide as the ditch.

Sample Size (Throw Traps and Ditch Nets)

Densities of estuarine nekton are highly variable, especially over spatial scales (Raposa and Roman 2001a; Raposa *et al.* 2003). One way to address this variability and improve the ability to detect biological differences (*e.g.,* species richness, density) among treatments is to increase sample size. Determining the appropriate sample size depends on a number of factors, such as the desired level of precision, the type of statistical comparisons (if any) that are to be made, and the desired difference among treatments one wishes to detect (Krebs 1989; Sokal and Rohlf 1981). Sample size also varies among different nekton species and depends on different attributes of the nekton community that are under consideration (*e.g.,* density, richness).

A power analysis was conducted for the original Cape Cod protocol to determine the appropriate sample size for sampling estuarine nekton with the $1m^2$ throw trap (Raposa and Roman 2001a;

Raposa *et al.* 2003). The objective of this power analysis was to determine the minimum number of sample replicates that are necessary to detect changes in species composition between nekton communities of salt marshes. Power is a function of the differences between two populations, the sample size, the alpha level of the test (the probability of detecting a difference between two datasets when no difference exists, *i.e.*, Type I Error), and the variability of the measured response. A sample size to 15 dramatically increases the power to differentiate two nekton data sets, even between data sets that are quite similar. With a power above 0.9, there is a >90% chance of detecting a difference between data sets when a difference actually exists. With a low power there is an increased probability of not detecting a difference when the data sets are actually different (*i.e.*, Type II Error). If subtle differences in nekton density are of interest (*e.g.*, comparing nekton density in the same marsh from one year to the next), or if one is interested in detecting differences within individual species between sampling years, then it may be appropriate to have a large number of replicates.

At least 10 ditch net samples should be collected from each site during each sample period. As of this writing an extensive analysis of capture efficiencies and replicate sample sizes for the ditch net has not yet been performed. The replicate size of 10 is a our best estimate based on the power analysis of the throw trap data and the logistics of sampling one marsh with a crew of at least 4 people in one day. However, we present this method as an ancillary method to sample ditches where throw traps cannot be used.

Sampling Frequency (Throw Traps and Ditch Nets)

*Spatial variability in nekton abundance is much higher than temporal variability in freshwater systems due to habitat heterogeneity (Peterson and Rabeni 1995). These authors found that collecting a larger number of samples on fewer dates would optimize sampling efforts, as opposed to taking a smaller number of samples spread out over multiple dates. To our knowledge, a similar detailed analysis of spatio-temporal variability does not exist for estuarine nekton. However, an analysis using nekton densities in tidal creeks from three southern New England salt marshes suggests that variability patterns may be similar for estuarine nekton (Raposa and Roman 2001a). Temporal variability in density among sampling dates was on average 21 times smaller than spatial variability (*i.e., *variability among samples taken on the same sampling date). Because of this, we adopt the sampling strategy suggested by Peterson and Rabeni (1995) and suggest that a larger number of samples be collected on fewer dates to address spatial variability and improve sampling precision.*

Time of Year

- Nekton should be sampled twice per year, once in early summer (after June 15) and once in late summer-early fall (August to late September). Sampling prior to June 15 in the Northeast is not recommended because water temperatures are still cold and few nekton will be collected.
- The same sampling stations should be sampled during the two sampling events for each year.
- Stations should be re-located in subsequent years.

Time of Day

Diurnal Cycle

- Nekton should be sampled during daylight hours, unless specific data concerning nighttime densities are required.

Tidal Cycle

The timing of sampling depends on the tidal regime of the specific marsh and requires field reconnaissance to gather information on the flooding regime of the site, as sites will vary in the duration and amount of tidal flooding.

- Nekton sampled from pools should be sampled when the water has drained off the surface of the marsh (low or ebbing tide or prior to flood tide).
- Nekton sampled from tidal creeks or ditches should be sampled when water has drained off the surface of the marsh, but when there is still enough water in the ditches and creeks to sample (more than 10cm).
- Nekton sampling using a throw trap should occur at the same relative tide stage. To accomplish this, we suggest sampling in seaward habitats first (where the marsh surface drains earliest), and then proceeding to landward areas following the tidal prism. This method ensures that samples are collected at similar water depths throughout the marsh, and is thus one way to control for the effects of tide stage.
- Nekton sampling in ditches should occur at the same relative tide stage. Sampling salt marsh ditches should occur only after the marsh surface is drained of tidal water, but water still remains in the ditches. Sampling should occur on a high slack or ebb tide, when the marsh surface has drained. Timing the sampling for ditch nets is very critical, if the nets are set too late into an ebbing tide, the ditches will be drained before the nets are sampled. A thorough reconnaissance of the study site and its specific tidal regime should be well documented prior to ditch sampling.

Time Frame for Completing a Sampling Event

- All stations for a sampling event should take place within a 5-7 day period.

Establishing Nekton Sampling Stations at each Site (Throw traps and ditch nets)

General Information for Establishing Nekton Sampling Stations

- This SOP describes methods for locating stations in marsh pools, tidal creeks, and nearshore areas.
- All sampling stations should be randomly selected prior to monitoring. There are a variety of ways to randomly select sampling stations and a few methods that could be used are described here. The most important thing to remember when locating sampling stations, regardless of the method used, is that the stations are selected RANDOMLY.
- Several methods are available to randomly select numbers (refer to following sections). Random number tables can be found in statistics textbooks, and random number generators can be found in spreadsheet software packages.
- Nekton sampling stations on ditches, tidal creeks, or shoreline areas should be at least 30m apart.
- Sampling station locations remain permanent for the sampling year, and from year to year are re-located using GPS or maps.

Locating stations on ditches, creeks, or shoreline areas

- To randomly locate sampling stations along ditches, creeks or shoreline areas, the distance of each ditch, creek or shoreline is measured.
- Random numbers between 1 and the total length of the ditch, creek or shoreline are then generated.
- The random numbers indicate the location of sampling stations along the creek or shoreline.

- Stations must be at least 30m apart, if they are not, a new random number should be generated, or one of the stations should be omitted.
- In marshes where there is an extensive creek network (that would prohibit accurate measurement of every single creek) the transect method (Section 1.4.1) or grid method (Section 1.4.2) can also be used to randomly select station locations.
- The grid method (Section 1.4.1) is also acceptable for locating stations along shoreline areas. In this case grids would be located along the shoreline and numbered.
- NOTE: The transect or grid methods (not presented in this document) may be the most appropriate methods for the Jamaica Bay study sites. A preliminary analysis of aerial photographs will be necessary to determine the best method to employ for sample station location.

Marking Sampling Stations

- Sampling stations should be located and marked in the field prior to sampling. If stations are located at the same time as sampling occurs, the nekton in the pool would have been disturbed by the activity associated with establishing the station and thus bias the subsequent sample.
- Stations are numbered sequentially from 1 to the total number of pools sampled.
    - Pools can be labeled "P" followed by the station number (*e.g.*, P1, P2).
    - Ditches can be labeled "D" followed by the station number (*e.g.*, D1, D2).
    - Creeks can be labeled "C" followed by the station number (*e.g.*, C1, C2).
    - This labeling scheme is more useful for keeping track of stations in the field rather than in the database, since the habitat sampled and gear used are always referenced in the database for each sampling station.
- Station locations should be clearly marked so that they can be re-located during sampling events.
- Oak stakes (1m in length) are a good marker, bio-degradable, and readily available from local hardware stores. Station numbers should be indicated on the oak stake with a permanent marker (which will need to be remarked every season) or burned into the wood (branded). Colored flagging can be attached to the stakes to aid in locating the stations.
- UTM coordinates of every station location should be recorded using a GPS. After GPS coordinates are taken, and before sampling begins, a GIS map should be plotted of the station locations to aid when sampling and to verify accuracy of station locations.

Field Crew and Training Procedures

Number of Staff

- One supervisor and at least 2 field technicians are the suggested number of staff to efficiently and accurately collect nekton monitoring data.
- A minimum of 2 people are necessary to physically sample nekton (for efficiency and safety in the field), but it is preferable to have more. A group of 4 people (2 teams of 2) dedicated to nekton sampling were used in the initial protocol testing phase.
- Two people are preferred to sample pools with throw traps. One to count and measure nekton and the other to record data.
- Two people are required to deploy the ditch net samplers.
- Since there are many replicates that must be sampled, it could take 1 team of 2 people 1-3 days to sample one marsh. As sampling must be closely coordinated with tides (sampling

only after the marsh surface has drained during the daylight) a crew of 2 people could have a tight schedule to ensure that the samples are taken in a timely fashion.

- Individuals should be physically fit, be able to work long hours in field conditions, and able to carry the necessary equipment (*e.g.*, throw traps, ditch nets). Conditions in the field can be harsh so it is imperative that individuals conducting the sampling are able to tolerate typical summer conditions on a salt marsh (*e.g.*, extreme heat, mosquitoes, physical labor, extensive walking in hip boots).
- Throwing the throw trap takes practice and good upper body strength, and should be practiced before sampling in the field.

Training Procedures

- It is ideal for new staff to be trained by personnel who have previously sampled nekton using these protocols. Training should take place prior to the sampling season (*i.e.*, 1 to 2 weeks before the first scheduled sampling).
- A trial sampling trip should be conducted so staff can practice nekton identification and field sampling methods (*e.g.*, throwing the throw trap, deploying the ditch net) in the field.
- Staff should know how to use a GPS unit.
- Staff should be able to identify common nekton. They should be familiar with fish anatomy, terminology used in field guides (see Section 2.5.4), and common field identification characteristics of nekton. This can be learned on the job prior to sampling if trained by an expert in nekton identification.
- It is strongly urged that staff involve experts from local Universities or other agencies to assist with nekton identification.
- If voucher specimens are available from previous sampling, they should be studied by new staff.

Staff Qualifications

- A background in the sciences is preferred but not necessary.
- Familiarity with fishes is preferred, but not necessary.
- Individuals should be physically fit, be able to work long hours in field conditions, be able to carry the necessary equipment, and be able to meet travel and sampling constraints.

Bottomless Lift Net Procedure

Bottomless lift nets (Rozas 1992) have many characteristics in common with throw traps and we have found them effective for sampling nekton on the marsh surface, in both vegetated and unvegetated habitats. They are small (6 m^2), easy to use once installed, highly efficient, and relatively inexpensive to build. Their small size allows for sampling in specific marsh surface microhabitats (*e.g., Spartina alterniflora* marsh edge, salt meadow) rather than collecting and integrating a sample from multiple habitat types, and allows a relatively large number of replicates compared to larger gears such as weirs and fyke nets.

The Cape Cod nekton protocol and the revised protocol for the Northeast region of the NPS do not include sampling with the bottomless lift net. It is a time-consuming and labor-intensive technique; however, given the dramatic shift in marsh surface habitat from vegetated to unvegetated in Jamaica and the expected shift from unvegetated to vegetated at the restored Elders and Big Egg restoration sites, marsh surface nekton sampling should be a priority.

Sampling Apparatus (Bottomless Lift Net)

Each bottomless lift net includes a $6m^2$ area of 3-mm mesh nylon net hidden (buried in a shallow trench) within the marsh sediments during low tide. Then at high tide, when the marsh surface floods, the net is pulled up and nekton are captured. At low tide, when the water level recedes, nekton trapped within the enclosure are collected into a small sump (about 20cm x 20cm), identified and enumerated.

Sample Size

It is recommended that the minimum sample size for each site will be n=3 in vegetated habitat and n=3 in unvegetated habitat.

Sample Frequency

Like the throw traps and ditch nets, sampling of each site should occur in early summer and again in late summer/early fall.

Sampling Station Locations

The $6m^2$ should be located in a random manner, with each station from 2m to 5m from a major tidal creek or marsh edge. This consistency in trap location will reduce variability associated with difference in nekton populations from interior vs. fringe areas of the marsh surface. Ideally, both interior and fringe areas should be sampled, but this would be too labor-intensive.

Data Analysis (Throw trap, ditch nets, and bottomless lift nets)

The following information will be derived from the nekton sampling program: Species Density (total nekton density and density of individual species), Species Richness, and Community Composition.

Density

- An Analysis of Variance (AVOVA) can be used to determine if nekton densities (or fish and crustacean densities) are changing over time or are different among marsh sites. Usually density data are log transformed [*e.g.*, log (X+1)] prior to statistical analyses to conform to the assumption of normality. The dependent variable would be density and the independent variable would be either year or site, depending on the hypothesis. If more than two years or sites are compared then a post hoc test (*e.g.*, Least Square Means, Tukey) should be used to determine where significant differences are found.

Species richness

- Species richness is calculated according to Heltshe and Forrester (1983), with pairwise comparisons evaluated by t-test.

Community composition

- The PRIMER software package (http://www.primer-e.com) is recommended and has non-parametric tests to detect differences or changes in community structure (*i.e.*, species composition and abundance). Non-parametric permutation testing procedures can be effectively used to evaluate dissimilarity or similarity in nekton communities between marshes or between sample years. ANOSIM, part of the PRIMER statistical package (Plymouth Routines In Multivariate Research, Carr 1997) is just one example of a non-parametric test, similar to multivariate analysis of variance (MANOVA) but without the generally unattainable assumptions (Clarke and Warwick 1994, Carr 1997). The ANOSIM procedure calculates a similarity measure (such as the Euclidean Distance

measure), and a similarity matrix is created that allows for the objective identification of samples (*e.g.*, nekton sampling stations) that have similar (or dissimilar) communities in terms of species composition and abundance. All pair-wise comparisons are summarized into a test statistic using Clark's R that compares between-group to within-group dissimilarities. Monte Carlo permutation tests are then used to derive p-values.

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Appendix C

Draft Protocol for Habitat Monitoring for the USACE Salt Marsh Restoration Project at Elder's Point Marsh, Jamaica Bay

Kathryn Mellander, GIS Coordinator, Gateway NRA

30 June, 2005 version

This protocol proposes that monitoring of the habitats of the Elder's Point Marsh restoration, control, and reference areas will be done through identification of vegetation groups and non-vegetated areas in and around the salt marshes, as they change over time. The vehicle for this monitoring is automated computer mapping utilizing high resolution satellite imagery, with classification and processing using a combination of image processing and GIS software.

The methodology and technical requirements proposed in this protocol are those of Dr. Y.Q. Wang, of the University of Rhode Island (URI), whose project proposal for development of a salt marsh monitoring protocol through computerized processing of satellite imagery is attached to this document (Wang, 2003). Work on the URI salt marsh monitoring protocols for Gateway NRA (Jamaica Bay was the pilot study for the project) is largely completed, with extremely promising results. The resulting vegetation map, Figure 2, was developed from 2003 QuickBird2^{TM} satellite imagery. The final protocol document from URI will be available shortly.

Monitoring Questions:

1) What is the status (health, spatial distribution and position in the marsh ecosystem, etc.) of habitats in and around Elder's Point Marsh before restoration -- in relation to other neighboring marsh islands? Relative to the control and reference sites?

2) What is the status in the short and long term after treatment? In this most exposed marsh area of Jamaica Bay, how do growth patterns of vegetation, tidal creek, and mud or sand flat areas change from season to season, year to year? Do the original tidal creeks re-establish themselves, and how quickly? What is the relationship between vegetative growth and proximity to the engineered tidal creeks in the initial post-treatment period? Are the tidal creeks allowing tidal flow to all parts of the marsh?

3) What are the spatial patterns of change after restoration in the short and long term? What is the response to physical stresses (wind and wave action, tidal currents)? Are the project's manmade counter-measures to erosion and wave action a significant factor in protecting the new marsh areas? How does this compare to the control and reference sites, and does it give us new insight into the disappearance of this and other marshes?

4) Are the various habitats of the restored area large enough to support the marsh ecosystem as a whole, including the fauna who depend on the marshes? How do the habitat groupings and distribution compare in size and other characteristics to the control and reference site?

Rationale for Habitat Monitoring

Vegetation monitoring at the sample plots for the salt marsh restoration will answer many questions of how successful the treatment for Elder's Point Marsh is. There must also be a comprehensive measure of the status of the marsh ecosystem as a whole, and of the habitats both initially created by the restoration and that evolve in response to natural and manmade processes that affect the restoration area.

Maps of salt marsh features that result from the satellite image classification can be reclassified into habitat groupings such as those recently completed for Gateway NRA under the Inventory and Monitoring Program of the Northeast Coastal and Barrier Network of parks. The vegetation maps of the I&M program use habitat classification terminology that is standard for the National Park Service nationwide.

Computer software capable of automating classification of the imagery into pre-defined groupings, and GIS software with analytical functions to create thematic classifications from the image processing results, have been available for two decades or more. Until recently, the resolution, or pixel size, of the satellite imagery has not been good enough to use in mapping projects at the scale demanded to monitor projects such as this salt marsh restoration. However, a new generation of satellites such as the QuickBird2, with 2.5 meter 4-band multi-spectral imagery enhanced by a 0.6 meter resolution panchromatic band, have made automated mapping feasible for identifying subtle changes in vegetative cover and other marsh features (Wang, 2003).

Protocol Summary

Monitoring status and changes in habitat availability in and around the restoration site, control site, and reference site for the Elder's Point Restoration will be measured through remote sensing and GIS based mapping of vegetation and non-vegetated portions of the marsh systems. This will consist of acquiring satellite imagery with high spectral and spatial resolution, identifying a set of sites whose characteristics are field checked and photographed with GPS-linked digital cameras, and running classification routines using image processing software. Results of the process will be a classified salt marsh map and data quality assessments.

Figure 1a shows a portion of the unclassified satellite image of Elders Point and surrounding marshes. **Figure 1b** is the computer generated map resulting from the image processing methods. The derived salt marsh feature map, although not immediately clear, demonstrates the level of detail in picking out small areas of vegetation and other features, precision which with manual mapping methods would be prohibitively time consuming and labor intensive.



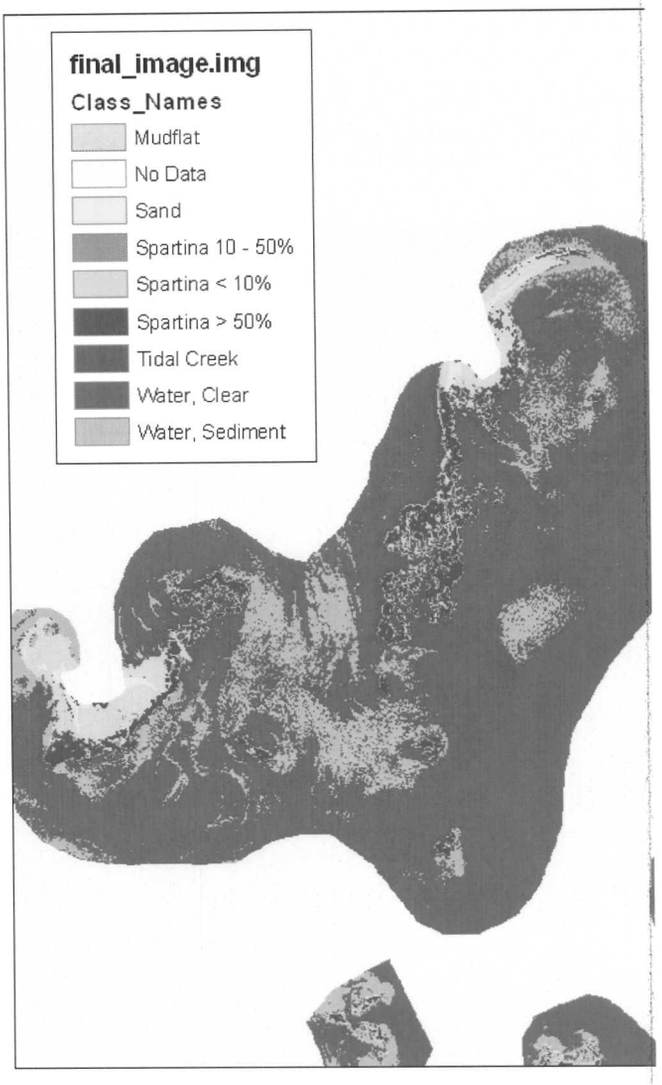


Figure 1a: *Elders Point, 2003 QuickBird2 satellite imagery image*

Figure 1b: *Salt marsh map derived from*

Data Acquisition and Site Selection

Satellite imagery can now be ordered in advance, with specifications of areal coverage, season, tidal level, and percent cloud cover. Site selection must be of the minimum size specified by the satellite operator, and must be large enough to make the image processing statistically valid.

Methodology

Methods for this protocol will be taken directly from that developed at URI. The Y.Q. Wang proposal follows as an excellent summary of the methodology.

DEVELOPMENT OF SALT MARSH CHANGE DETECTION PROTOCOL USING REMOTE SENSING AND GIS

July 2, 2003

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ABSTRACT

The National Park Service has identified that the loss of salt marsh habitat in Jamaica Bay, Gateway National Recreation Area, warrants the development of a cost-effective, long-term salt marsh change detection protocol that can be applied in a broader coastal region of the northeast United States. This proposal addresses the creation of such a working protocol. This project will evaluate the dynamic boundaries of salt marsh areas in the Jamaica Bay delineated by the NPS from historical aerial photographs. Based on the information obtained from the historical aerial photographs, we will conduct both computer-assisted classification and manual delineation of the salt marshes in the Bay area using high spatial resolution QuickBird-2 satellite image. The QuickBird2 satellite image possesses 0.65-meter spatial resolution on its panchromatic band and 2.5-meter spatial resolution on its multispectral bands. The spatial resolution and spectral coverage of the BuickBird-2 data can satisfy the salt marsh mapping requirements. The capability of repeated satellite data acquisition will meet the goal of salt marsh change detection and monitoring. We will first compare and evaluate the salt marsh mapping results between manual interpretation and digital classification of the QuickBird-2 data. We will also compare and evaluate the salt marsh mapping results obtained from manual interpretation of 2003 color infrared aerial photograph and from the QuickBird-2 data. With the comparisons and evaluations, we will be able to develop the change detection protocol using appropriate data. To support the manual and digital classification of salt marshes, we will conduct field works to establish GPS based Virtual Field Reference Database (VFRDB) for the Jamaica Bay area. The VFRDB contains typical GPS transect data that recorded the salt marsh variables such as the vegetation, hydrology, soils and sediments, as well as other observable indicators such as nekton and birds. The VFRDB also contains GPS-photos that recorded landscape specifics of the photo site in at least 4-campass directions (e.g., North, South, East, and West). The VERDB is part of the protocol that will provide benchmark data for long term monitoring and change detection analysis.

INTRODUCTION

Productivity of salt marshes is a primary indicator of ecosystem health (Leibowitz and Brown, 1990). Nationwide, emergent salt marshes declined by an estimated 14,450 acres in ten years from 1986 to 1997 (Dahl, 2000). In November 2000, the New York Department of Environmental Conservation (NYDEC) released a study that shows a sustained trend of significant salt marsh loss in Jamaica Bay over the past 100 years. The Jamaica Bay Wildlife refuge encompasses 2,500 acres within the boroughs of Brooklyn and Queens in New York City (Figure 1). This refuge, the only one in the national park system, provides a variety of habitats for more than 300 kinds of waterfowl and shorebirds. It is a critical stopover area along the Eastern Flyway migration route and is one of the best bird-watching locations in the Western Hemisphere (GARA, 2003). Interpretation of historical aerial photographs shows that 51% of salt marshes in the Bay had been lost between 1924 and 1999. Although the salt marshes have been protected since 1972 as part of the Gateway National Recreation Area, a recent study shows that 38% of salt marshes in Jamaica Bay has been lost since 1974 (Hartig, et al, 2002). The salt marsh decrease in Jamaica Bay has caught the attention of the scientific community (Peteet, 2001) and the media, such as the New York Times (Stewart, 2001), Columbia News (Trimel, 2002), and NASA's Goddard Institute for Space Study (Hartig and Gornitz, 2003). The salt marsh change in Jamaica Bay indicates the same trend of salt marsh change elsewhere in the northeastern United States. Therefore, using Jamaica Bay as the prototype for developing a method for monitoring future extents of salt marshes in the northeastern United States is critically important.

Extensive studies have been conducted for monitoring and quantifying salt marsh dynamics (Boumans et al., 2002; Roman et al., 2002). For example, a recent study reported a monitoring protocol to assess tidal restoration of salt marshes in the Gulf of Maine (Neckles et al., 2002). The protocol was based on a suite of core structural measures that can be applied to any tidal restoration project. Evaluation of the protocol included information content of the variables, cost, skill level required for measurement, and spatial and temporal sampling frequency needed. Baseline habitat map is critically important since it provides a foundation for monitoring activities and a baseline for spatial change analysis. Other monitoring variables include hydrology, soils and sediments, vegetation, nekton, and birds (Neckles et al., 2002).

Methods for examining salt marsh changes vary with project goals, compliance requirements, organization priorities, and financial limitations. In remote sensing and GIS perspectives, timely and repeated data acquisition, quick and easy information extraction, low cost in data acquisition and processing, as well as available baseline referencing data are the key considerations in protocol development.

Remote sensing and GIS have been applied in wetland and salt marsh habitat monitoring in the past years (Zhang, et al., 1997; Ritter and Lanzer, 1997). The U.S. Fish and Wildlife Service has used aerial photography imagery and direct on-the-ground observations to record and monitor wetland changes over time (Hefner et al., 1994; Moulton et al., 1997; Dahl, 1999, Dahl, 2000).
Given that salt marsh monitoring requires repeatable and reliable updates of land cover maps, exploration of new data and approaches that could efficiently update the salt marsh maps is necessary. Recent development of high spatial resolution satellite remote sensing data can be helpful in salt marsh change detection. For example, Space Imaging's IKONOS satellite, featuring data consisting of 1-meter spatial resolution for the panchromatic band and 4-meter spatial resolution for the multispectral bands (visible to near infrared), has been applied in resource mapping (Maeder, et al., 2002). DigitalGlobe's QuickBird-2 satellite, launched in October 2001, possesses 0.61-meter spatial resolution for the panchromatic band and 2.5-meter spatial resolution for the multispectral bands (visible to near infrared). These new satellite data will meet the requirements of salt marsh mapping. The capability of repeated data acquisition by sources high-resolution satellite imagery and relatively low cost will facilitate the practice in salt marsh change detection.

In this proposed project, we will evaluate the changes of salt marsh areas in the Jamaica Bay and develop change detection protocols. Based on the information obtained from historical aerial photographs and provided by the NPS, we will examine both computer-assisted classification and manual delineation of the salt marshes in the Bay area using high spatial resolution

QuickBird-2 satellite image. We will first compare and evaluate the salt marsh mapping results between manual interpretation and digital classification of the QuickBird-2 data. We will then compare and evaluate the salt marsh mapping results obtained from manual interpretation of 2003 color infrared aerial photograph and from the QuickBird-2 data. With the comparisons and evaluations, we will be able to develop the change detection protocol using appropriate remote sensing data sources. To support the manual and digital classification of salt marshes, we will conduct field works to establish GPS based Virtual Field Reference Database (VFRDB) for the Jamaica Bay area. The VFRDB contains typical GPS transect data that recorded the salt marsh variables such as the vegetation, hydrology, soils and sediments, as well as other observable indicators such as nekton and birds. The VFRDB also contains GPS-photos that recorded landscape specifics of the photo site in at least 4-campass directions (e.g., North, South, East, and West). The VERDB is part of the protocol that will provide benchmark data for long term monitoring and change detection analysis.

OBJECTIVES

The overall goal of the project is to develop a remote sensing and GIS salt marsh change detection protocol that is transferable among NPS sites for routine salt marsh mapping and change detection monitoring. The Jamaica Bay will be the test site for protocol development and validation. The specific objectives are to:

1. Establish a GPS-based VFRDB as ground referencing sites and benchmark locations for a long-term use in salt marsh change detection and monitoring
2. Acquire and interpret 2003 QuickBird-2 satellite imagery of the Jamaica Bay area through both manual delineation and digital classification techniques to obtain salt marsh spatial distribution.
3. Compare and validate the agreement between satellite-derived salt marsh data and the delineation result from current and historical aerial photographs
4. Investigate the effectiveness of salt marsh change detection in a regular time frame, with reliable accuracy, and in reasonable cost, using high spatial resolution satellite data.
5. Detailed description of the change detection protocol within a project report.

METHODS

Image and GIS Data Acquisition

We will begin the project by compiling all existing information, such as historical aerial photographs, interpretation of salt marsh areas and the maps, as well as other GIS data. Predominately these data will come from previous projects conducted by the NPS. Besides the above data from NPS, Quickbird-2 satellite remote sensing data, both multispectral and panchromatic for Fall 2003 or Spring 2004 (depending on the quality of data acquisition), will be purchased by the NPS for the project use.

Virtual Field Reference Database (VFRDB)

Ground truthing will take place during the fall of 2003, continuing during the summer of 2004 at Jamaica Bay and throughout the GATE. The NPS professionals will guide the ground truthing. Both a Trimble ProXR and a Kodak Field Imaging System will be employed to document sampling locations throughout the salt marsh. The tentative sampling strategy is to designate several transects. At each sampling point, a GPS location will be recorded and a georeferenced digital photograph will be taken in the direction of each of four compass directions (North, South, East, West). GPS coordinates will be recorded for several prominent ground control

points throughout GATE, and at any first-order USGS survey location that may be in the area. These will help assess the spatial accuracy of the satellite imagery. On return from the field, the differentially corrected GPS data and georeferenced photographs will be compiled to create a Virtual Field Reference Database (VFRDB). The VFRDB will greatly assist in the interpretation of the satellite imagery, and will be a valuable record for future monitoring efforts in its role as the benchmark for continued monitoring of Jamaica Bay.

Image Processing

With permission of NYS DEC, NPS will provide 600 dpi scanned and georeferenced historical aerial photographs with all available metadata. Pre-existing GIS data designating salt marsh boundaries will be examined and characteristics of the salt marsh noted. Using these notes as guidance, we will interpret the QuickBird-2 images. The interpretation results will be reviewed by a NPS salt marsh expert and changes made accordingly until the boundaries match with the interpretation of the expert's. At the meantime, we will digitally classify the high-resolution QuickBird-2 satellite images for salt marsh information extraction. ERDAS Imagine and ESRI ArcGIS will both be used during these processes. The results of both techniques will be assessed against the data derived from the NPS 2003 CIR orthophotographs. Insights gained during this stage promises to be an important factor when developing the working protocol for monitoring salt marsh changes.

Accuracy Assessment

Given the size of the study area, we will conduct the accuracy assessment of the satellite imagery classification using VFRDB information obtained from fieldworks.

Development of Salt Marsh Monitoring Protocol

In consultation with a reference panel designated by the NPS, a working protocol will be developed after considering the functionality and cost-effectiveness of the high-resolution satellite data for demarcating salt marsh boundaries. The report will consist of recommendations for satellite image acquisition, pre-processing, manual interpretation or digital classification, ground truthing, development of the VFRDB, and accuracy assessment. The protocol will be reviewed by the reference panel and changes made accordingly until a protocol is agreed upon. The final report will be accompanied by digital media that contains a digital copy of the report in addition to supporting GIS data, imagery, and the VFRDB.

DELIVERABLES

- GIS vector coverage showing salt marsh boundaries from the 2003 (or 2004) QuickBird-2 image, accompanied by FGDC compliant metadata
- GIS raster result of digital classification of satellite imagery with FGDC compliant metadata
- accuracy assessment tables for both manual interpretation and digital classification techniques of satellite imagery
- satellite imagery used for this project with FGDC compliant metadata
- html-based VFRDB for Jamaica Bay
- report documenting this project, the above deliverables, and finally a recommended working protocol for salt marsh monitoring as developed with the NPS-appointed reference panel

TIMELINE

- July 1, 2003: Project begins
- September 2003: Accomplish the initial site assessment
- May 2004: accomplish the initial delineation of aerial photographs and satellite imagery
- Summer 2004: Conduct ground verification and initial accuracy assessment
- September 2004: Deliver an initial report to reference panel accompanied by GIS data, metadata, accuracy assessment results
- December 2004: Deliver an initial recommendations of protocol to panel, and revise the protocol afterwards
- February 2005: Resubmit revised protocol to reference panel
- June 30, 2005: Final report to the reference panel with all the deliverables.

RESEARCH FACILITIES

This project will be accomplished through a partnership with the Laboratory for Terrestrial Remote Sensing (LTRS) at the University of Rhode Island. The LTRS has accumulated extensive experience in studying land-cover change and impacts on natural communities. Those include projects encompassing the Chicago Wilderness Region (61,000 hectares) (Wang and Moskovits, 2001), State of Rhode Island (275,000 ha) (Novak and Wang, 2003) and the coastal districts of the East African nation of Tanzania (6.6 million ha) (Wang, et al., 2003). The LTRS possesses all necessary computing power and software systems to fulfill the project requirements in remote sensing data processing and GIS analysis. The LTRS is also equipped with traditional photo interpretation facilities including a Digital Transfer Scope, Topcon Mirror Stereoscopes, light tables and the accessories. The lab has a Trimble ProXR 12 Channel GPS receiver and a Kodak 265 Field Imaging System that meet the requirements of ground truthing and verification for remote sensing data processing. The LTRS enjoys a close working relationship with the Environmental Data Center. The Environmental Data Center is the Field Technical Support Center for the New England Cluster of the National Park Service.

Appendix D

Draft Protocols for Land and Sediment Surface Monitoring for the USACE Saltmarsh Restoration Project at Elder's Point Marsh
Kathryn Mellander, GIS Coordinator, Gateway NRA
Version 16 June, 2005

Landscape Monitoring: Topographic and Bathymetric Surveys

Monitoring questions:

Restoration Related Questions

1. What is the pre-treatment geomorphology of the Elders Point marsh and upland surfaces, the supporting sand structures, and the channels and extra-marsh sediments within the zone of influence of the restoration site?
2. How well does the treated site represent that planned for the restoration area? Where and how does it differ?
3. How are the newly deposited treatment sediments (extra-tidal, intertidal, and subtidal) moving? How are these movements related to tidal, climatic, or other influences?

Jamaica Bay Ecosystem Related Questions

1. How can we relate vegetative growth/regrowth with elevation changes?
2. What is happening to the sediments in and around Jamaica Bay? Can we learn anything by this newly deposited sediment?
3. What is the relationship between wind and/or wave processes, elevation change, and vegetative growth?
4. How does vegetation status at the plot elevations relate to other salt marshes in Jamaica Bay?

Rationale for landscape monitoring

The physical form of the restoration site after treatment is one of the basic measures for evaluation of the treatment design and prediction of its success. Pre-treatment topographic and bathymetric surveys of Elders Point Marsh are important for engineering design of the sediment distribution particularly at this site, where sand understructures of the original marsh area are in close proximity to deep and busy navigation channels, and are exposed to the longest fetch of any of the salt marsh islands in Jamaica Bay. Comprehensive surveys, while expensive, are also critical to post-restoration evaluations of the immediate project and as it relates to overall questions of salt marsh losses within the ecosystem of the bay. Intensive elevation/depth surveys along transects related to other monitoring parameters, particularly at vegetation plot locations, the perimeter of the treatment site within the intertidal area, and at sampling transects over the new marsh surface, are critical base measures of what is happening at the restoration, reference, and control sites, relationships to process acting on these sites, and in comparison with marsh status throughout the bay.

Because of the shallowness of the sediments around Elders Point Marsh in particular, topographic and/or bathymetric surveys for the marsh at its present extent, which includes large areas of sand base where there has historically been extensive areas of salt marsh vegetation, is very sparse. There have been bathymetric studies of Jamaica Bay within the last ten years, but at a very sparse sampling distance, and only in areas deeper than 3 feet (NOAA Chart #12350, Jamaica Bay, various). Aside from the initial design studies by the U.S. Army

Corps of Engineers (one foot contours, to a depth of 6 feet around Elders Point Marsh), there is little topographic or bathymetric data for part or all of Jamaica Bay.

High resolution surveys are now feasible and available on a much shorter schedule through technologies such as airborne LIDAR (Light Detection and Ranging) that allows collection of point locations to 10-15 centimeter accuracy for horizontal and vertical position (Duffy, 2004). Likewise, a combination of multi-beam echo soundings and side scan sonar such as that used by researchers at SUNY- Stonybrook, achieve sampling accuracies of approximately 1 meter depth/location (ref here). Although not proposed as feasible for this monitoring protocol, this should be incorporated in the future when possible. Ground-based or boat-mounted intertidal mapping with geodetic GPS units are recommended, extending a seamless topographic survey into and past the intertidal zone to the depths allowed by instrumentation (*i.e.*, pole heights).

Protocol summary

Two levels of topographic surveying for the Elders Point restoration are proposed. The first, a general topographic survey to sub-foot vertical accuracy is recommended for an assessment of the Elders Point area's topographic status in Jamaica Bay, and for comparison to that of the control and reference sites, and other marsh islands. Airborne LIDAR's (see detailed description, below) technological advances make this eminently feasible from both a data quality and efficiency perspectives.

In addition, a more detailed survey, with vertical and horizontal accuracies to within 1-3 centimeters, should also be done before and after the treatment, and at seasonal intervals from then on. The recommended method, use of a geodetic GPS unit, is also extremely efficient and accurate to 1-2 centimeters (USACE, 2003). This unit would also efficiently map intertidal and subtidal areas to depths of approximately 2-3 feet below low tide, depending on the feasibility of movement in these areas (NPS and USDA NRCS field experience, summer, 2004).

Products and results of topographic/bathymetric mapping (summary), frequency of sampling, evaluation

Site selection

At the time of this writing, the final project area, reference, and control sites have yet to be determined, due to changes in funding structures and the regulations pertaining to them, and ongoing discussions of reference and control possibilities. However, the selection of monitoring area that would be most useful for the objectives listed above can be summarized.

Monitoring area – for restoration, reference, and control sites: all land surfaces above mean low tide

Scale and accuracy requirements – elevation (z) to ½ meter or 1 foot, horizontal (x,y) to 1 meter or 3 feet (or less, depending on method of acquisition). Use of a land based (or small boat based) geodetic GPS collection would be limited by the rod length and footing in the area.

Sampling methods –

A. **LIDAR surveys** with ground truth sampling points (NOT viable as marsh elevation status measure), 10-15 centimeter horizontal and vertical accuracy. Three returns: bare earth, top of vegetation, shallow water/understory.
   1. Sampling frequency: Once pre-treatment, once shortly after. Subsequently once every 5 years. All surveys at low tide.
   2. Sampling area: All of Jamaica Bay
   3. Sampling platform: Airborne survey
   4. Data format: 3 returns in text/ASCII xyz format, QA/QC checked via accuracy assessment by contractor, and set of ESRI format output shapefiles and point coverages, as well as contour map

B. **Partial area transects with survey grade GPS**, repeated seasonally for representative topographic transects and measure of shoreline at neap low tide or extreme low tide.
   1. Sampling frequency: late winter/early spring, again later summer/early fall, for 5 years
   2. Sampling area:
      a) Follow vegetative monitoring transects, restoration, control, and reference sites, with point elevation at each vegetation plot, and extending into the sub-tidal area to the limits of the equipment used (hopefully to 2 meter depths)
      b) Perimeter of treated area at low tide
      c) Intertidal zone and subtidal areas around treatment site, to limits of survey equipment (1 – 1.5 meters?)
   3. Data format and map products: Original GPS data point files (text x,y,z), differentially corrected text files, and export shapefiles or coverages, ESRI format.
   4. Sampling methodology: GPS along transects and at perimeter of restoration area on foot where possible, from pontoon or other boat able to navigate over and around marsh at high tide if necessary, depending on footing in mucky areas and time/tide constraints. A combination of these two methods should allow full day data collection.

Survey products and results related to monitoring objectives

The LIDAR surveys and ground based geodetic GPS surveys will produce the same information, at different scales and by different methodologies. Each will produce point elevations with which topographic/bathymetric profiles and three-dimensional topographic surfaces can be produced in a GIS. Since all data will be tied to specific spatial locations, subsequent data collections can be overlaid, statistically analyzed for change over time and for comparisons among restoration, reference, and control sites.

Data specifications and processing – who, how, what

Accuracy assessments, data processing (including differential correction, translation to GIS ready formats, and creation of contour maps) should be completed by the contractor for the LIDAR surveys. Field technicians who collect the geodetic GPS data should also post-process the data, provide metatadata and deliver point text files with xyz coordinates to the GIS specialists of both the NPS and COE.

Data must adhere to both the federal spatial data standards, and to the U.S. Army Corps of Engineers established standards. This will include using the specified datum and coordinate system, and full metadata for any data collection product.

It is strongly recommended that the raw, xyz text files be included as a deliverable with any post-processed data. There are software-independent analytical functions that require this format.

How results/products will be used – applications of surveys

LIDAR surveys will result in a whole-bay elevation and/or contour map, including some bathymetric data, the extents of which will be limited by the turbidity of the water (usefulness of LIDAR in shallow sediment elevation data collection is still somewhat experimental – Duffy et al, 2004).

The pre-treatment topographic and bathymetric survey will identify the relationship as it exists now between elevations and vegetation patterns, as well as draw a three-dimensional picture of the areas around the marsh.

After the post-treatment survey is delivered, immediate evaluation of the planned and actual treatment site status will begin using GIS functionality, as well as identification of areas where the results of sediment depostion diverge significantly. Depths of sediment will be calculated over the entire treatment site by overlay and subtraction of pre- and post-treatment elevations at any point within the treatment area. Before and after orthogonal views of the treatment area can be constructed for visual analysis.

Tracking of vegetative and elevation changes and conditions within the vegetation plots and along the monitoring transects will be tied together by spatial location in the GIS database, able to be seen in combination with any other geo-referenced data layers (aerial photography, thematic maps such as historic salt marsh maps and vegetation data from the monitoring process, and maps of other factors able to be spatially distributed (such as water depth, water quality, and data resulting from marsh sediment monitoring).

References:

Duffy, Mark, 2004 Shoreline Monitoring Protocols for the Northeast Coastal and Barrier Network (get actual ref).

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USACE, Engineering Manual 1110-1-1003, #469, CECW-EE,1 July, 2003, NAVSTAR Global Positioning System Surveying; Chapter 6: GPS Applications in USACE

Appendix E

Sediment Evaluation Tables

Sediment Evaluation Tables (SET) shall be established at the restoration site with a minimum of three tables. Also the appropriate marking layers shall be established at each table. Monitoring should continue at the other existing SET within Jamaica Bay. The tables should be established based on the protocols of D. Cahoon, USGS. The data collected should be compared to the local hydrographic data in the region.

Salt marsh geology should be monitored through the use of sediment-elevation tables (SETs). SETs can be used to understand the relative impacts of both subsidence and deposition on marsh elevation change. They are integral for understanding whether marsh accretion is keeping pace with current rates of sea level change. 3 SETs (along with accompanying marker layers) should be established at Elders Point Marsh. Monitoring will be continued at existing SETs around Jamaica Bay. These should be established following the protocols of D. Cahoon, USGS. These data should be compared to local hydrographic data collected in protocal 5 of basic phase monitoring.

Appendix F

Photo Monitoring

Photo-monitoring shall occur at least four times a year and when possible after storm events.
Photo monitoring shall include documentation with digital color photographs at all fixed-point photo stations utilizing GPS for location, as well as the project site overview location.

Appendix G

Salt Marsh Sediments

Restoration-Related Questions

- What are the sedimentary characteristics of the restored marsh, and how do these characteristics compare to the unrestored setting?
- How do the sedimentary characteristics of the restored marsh change over time?
- Are sedimentary properties (grain size, sediment type) related to the biogeochemical and ecological processes observed in Jamaica Bay?

Jamaica Bay Ecosystem Related Questions

- How has the geological and human history of Jamaica Bay affected the patterns of sediment transport and deposition?
- How does sediment type affect the cycling of chemical species in Jamaica Bay? What role do these chemical species play in marsh loss (see Chemistry section)?

Rationale for Monitoring Salt Marsh Geology

It has been widely suggested that the salt marsh loss in JB is the result of a sediment deficit, which prevents salt marshes from keeping back with sea level rise (Blue Ribbon Panel, Hartig et al. 2002, Turner 1991). This sediment deficit is probably related to the geomorphic changes to the bay over the last century, including the digging of deep channels, borrow pits and the Rockaway inlets. It is hypothesized that these deep channels have become sediment sinks, trapping sediment that would otherwise have been available for marsh sedimentation. These problems have been further antagonized by hydrodynamic changes, which result in the net transport of sediment out of the bay. While these hypotheses are currently under investigation at Stony Brook University, they can be further addressed by the monitoring scheme.

Sediment samples should be collected and analyzed to determine the type of sediment on the marshes before, during and after the restoration. These measurements are critical because 1) they will help determine whether the marshes are capable of accreting in absence of restoration efforts 2) grain size is often as useful proxy for the energetics of the environment, such measurements are useful proxies for environmental conditions in Jamaica Bay (Dyer, 1986) 3) sedimentology affects the cycling of chemical species which may play a role in salt marsh loss (King, 1988; Nyman et al., 1990; Raiswell and Canfield, 1998).

Appendix H

Salt Marsh Chemistry

Restoration-Related Questions

- How do chemical environmental indicators of salt marsh ecosystem health (e.g. H_2S, NH_4, NO_3^-, pH) differ between the restorated, unrestored and control sites?
- Does sulfide (H_2S) reach toxic levels in the restored, unrestored and control sites?

Jamaica Bay Ecosystem Related Questions

- Do local inputs (e.g. sewage) affect the concentation and cycles of sulfide and nutrients in in Jamaica Bay?
- Does enhanced denitrification lead to increased microbial degradation of salt marsh peat?
- Do enhanced nutrient regimes affect *Spartina alterniflora* physiology in a manner which affects marsh loss- by altering the distribution of energy from roots to shoots.

Rationale for Monitoring Salt Marsh Chemistry

Sulfide toxicity has been suggested as a mechanism for salt marsh loss because it is toxic to the dominant marsh plant, *Spartina alterniflora*, at high concentrations. (Nyman et al 1993, Turner et al. 1997). When sulfide concentrations lead to plant stress and mortality, the results is loss of the root matrix which is a major control on peat structure (DeLaune et al., 1994). Enhanced water-logging, caused by increased inundation has been cited as a cause of marsh loss in Louisiana salt marshes (DeLaune et al., 1994). There are two non-mutually exclusive causes of increased sulfide concentrations in Jamaica Bay salt marshes. 1) Increased waterlogging, resulting from an elevation deficiency may yield flushing regimes that do not remove dissolved sulfides. 2) Sulfides may be rapidly produced as labile organic material from sewage is deposited on these marshes (Howes et al. 1986, Mendelssohn et al. 1981). For example, Kolker (unpublished data) has shown a rapid spike in sulfides in Big Egg Marsh during the summer of 2004. This event occurred following a period of heavy rains, which resulted in the overflow of raw sewage from the combined sewage/storm sewers (M. Hayes, NYC DEP). While sulfur cycling in salt marshes is a complex process involving both liquid and solid phases of S, for practical purposes, this study should concentrate on porewater studies and measurements of redox potential (King et al. 1986, Howes et al. 1981).

The sulfide hypothesis will be addressed by generating a series of porewater profiles of dissolved sulfides, to see if sulfides regularly reach toxic values (~4mM) in degrading marshes. These profiles will extract porewater at depths of ~2, 5, 7, 12, and 20cm. A known volume of porewater will be extracted, fixed in ZnAcetate and sent away for HS analysis. Porewater profiles of sulfide and dissolved nutrients will be generated. Profiles of redox potential will also be conducted along side these porewater profiles. Profiles will be measured along one transect in each of the three sites. They will be sampled twice per season, and for three additional days following a large summer storm.

It has been suggested that salt marsh loss is related to nutrient enrichment because 1) Nutrient-enrichent causes *S. alterniflora* to alter its allocation of energy from roots to shoots. This decreased biomass in the peat decreases the structural integrity of the peat, resulting in peat breakdown. 2) The bacteria in the peat are nitrogen limited (esp. denitrifying bacteria), and increased fertilization results in increased microbial activity. These microbes consume sedimentary organic matter leading to the breakdown of peat. 3) Enrichment leads to increased organic matter production in the estuary, contributing of anoxic conditions where sulfides increase (see above).

Nutrients need to be monitored to understand how nutrients affect Spartina alterniflora physiology, if enhanced NO3 concentrations are associated with areas areas of degrading peat and if nutrient inputs do indeed lead to peaks in sulfide concentrations. Nutrient sampling should follow pore water sampling. Dissolve nutrients should be measured with dissolved sulfides. Additionally, cores should be taken along the transects and nutrients (NO_2, NO_3, NH_4, and PO_4^{2-}) should be analyzed at ~ 5cm increments. Finally, surface waters from near the marsh should be sampled for nutrients. It is recommended that future work in Jamaica Bay investigate nutrient dynamics in greater detail.

Appendix I

Physical and Hydrographic

Monitoring Related Questions.

- Are changes in the salt marsh geomorphology controlled by physical, hydrodynamic and meteorological forcings?
- Is salt marsh deposition keeping pace with short and long term rates of sea level rise?
- How are biological and chemical processes related to patterns of temperature, precipition, tidal cycles and long term sea level change.

Jamaica Bay Ecosystem Related Questions?

- How do changes in sea level, winds, temperature and precipitation in Jamaica Bay compare with regional patterns in these processes?
- On what scale are the physical, hydrodynamic, and meterological processes that affect sedimentation, chemistry and biology in Jamaica Bay controlled?

Rationale for Monitoring the Physical Environment

The physical environment exerts a large scale control on almost all of the processes which could affect the success of the salt marsh restoration effort. Examples of these impacts can include impacts of temperature and sunlight on the growth of *Spartina alterniflora*, the role of winds and waves in redistributing sediments and the impacts of sea level change on salt marsh hydrology. It is important to know at the spatial scales the physical factors that govern salt marsh processes exist. For example, if salt marsh erosion is caused boat traffic generating large waves, then this problem can be remedied on the local scale (perhaps through law enforcement.) If, on the other hand, marsh loss is driven by a global rise in sea level, then local efforts to remedy marsh loss may be futile. Either way, it is crucial that this type of contextual information should be compiled for Jamaica Bay.

Monitoring physical and hydrographic data for Jamaica Bay can be done with relative ease because local agencies are already collecting most of the important information and distributing it freely over the internet. Two sets of time series for each hydrographic parameter should be established. The first time series should be a compilation of annual means. The second time series should show intra-annual variability. This should construct both monthly mean and highlight particularly important events (i.e. passage of hurricanes, major summer thunderstorms, CSO discharges). This data should be compared to all of the data collected elsewhere in the monitoring program to develop a comprehensive understanding of the hydrological, climatological and oceanographic factors which contribute to salt marsh processes in Jamaica Bay. Need to cite websites etc where information to be downloaded so it is consistently collected from the same source as possible

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