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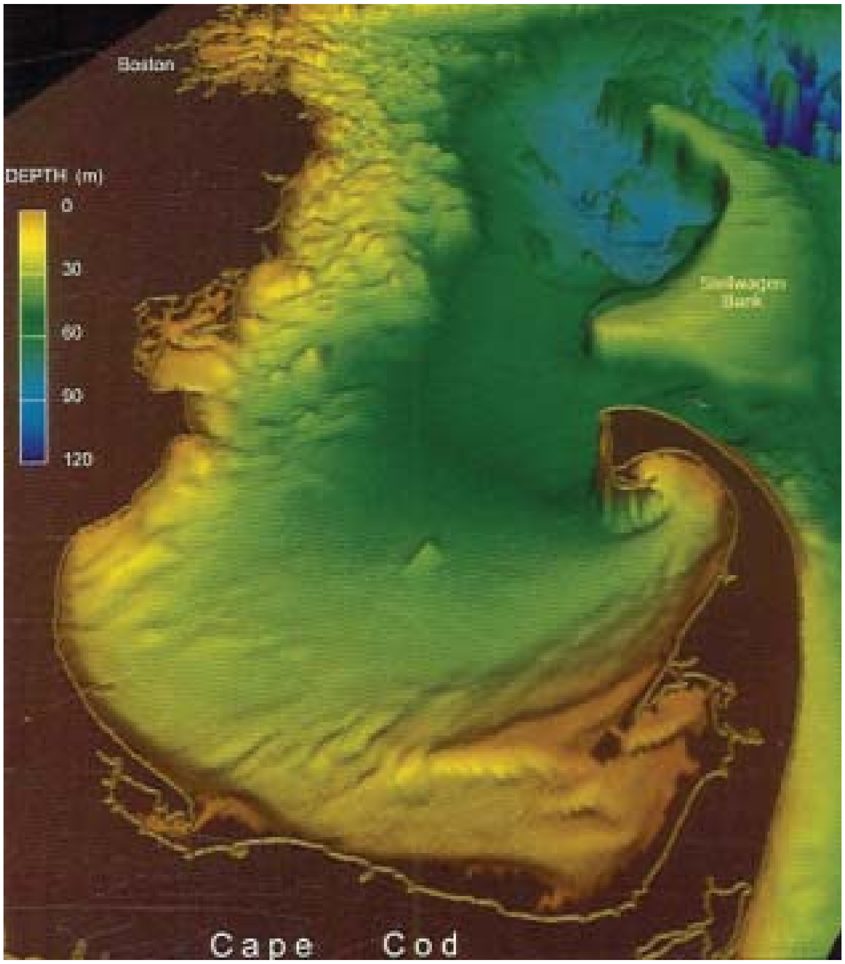
ASSESSING POTENTIAL ENVIRONMENTAL IMPACTS OF OFFSHORE SAND AND GRAVEL MINING



Prepared for

Commonwealth of Massachusetts
Executive Office of Environmental Affairs
Coastal Zone Management

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DRAFT FINAL REPORT

Assessing Potential Environmental Impacts of Offshore Sand and Gravel Mining

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Cover Image: Bathymetry of Massachusetts and Cape Cod Bays; produced by the U.S. Geological Survey, Woods Hole

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ASSESSING POTENTIAL ENVIRONMENTAL IMPACTS OF OFFSHORE SAND AND GRAVEL MINING

INTRODUCTION

Historically, most Massachusetts beach nourishment projects have been relatively small-scale, with sand obtained from local dredging projects or land-based deposits. In recent years, however, a regulatory environment that encourages non-structural methods of shore protection, the costs and impacts of transporting sand from land-based sources, and increasing demand for larger nourishment projects have all led to a rising interest in offshore sand sources. As a result of an increased demand for beach nourishment material, the Executive Office of Environmental Affairs (EOEA), through the Massachusetts Coastal Zone Management Office (MCZM), identified a need to explore the potential environmental impacts of offshore sand and gravel mining in Massachusetts Bay for the purposes of beach nourishment. Although nearshore sand and gravel deposits exist in water depths 30 ft and shallower, the potential for significant physical environmental impacts (e.g., alteration to shoreline erosion patterns associated with refocusing of wave energy) due to resource extraction increases with decreasing water depth. Significant sand and gravel deposits exist in offshore waters; however, available dredging equipment is limited to depths of about 100 feet. As such, sand and gravel resources in water depths between 30 and 100 feet are considered the most viable resource sites for potential beach replenishment and storm protection projects.

The primary purpose of this document is to provide guidance to applicants seeking to implement beach nourishment projects, including site characterization, impact analyses, and the regulatory process associated with extracting sand and gravel from offshore borrow sites. The document seeks to establish a methodology that successfully integrates the regulatory requirements of Federal, State, and local agencies to facilitate application preparation and subsequent permitting decisions. To this end, the process described in the U.S. Army Corps of Engineers Highway Methodology Workbook for integrating Section 404 permit requirements with project planning and engineering requirements was adapted as a model for evaluating offshore sand and gravel extraction activities. This document assumes that the reader will have some knowledge of permitting in Massachusetts, a general knowledge of coastal processes and oceanography, and familiarity with the use, design, and implementation of beach nourishment projects for shore protection.

The document is divided into four main sections: 1) the **Introduction** provides a description of project purpose and goals, and a scope for the document; 2) the **Regulatory Framework** is discussed using the Corps Highway Methodology for integrating Federal and State permitting requirements; 3) **Sand and Gravel Mining in Massachusetts State Waters** provides a general description of environmental concerns for Massachusetts Bay; and 4) a **Case Study** that illustrates the use of these guidelines to evaluate the environmental impacts of potential sand and gravel mining at the New England Offshore Environmental Study (NOMES) sand sites in Massachusetts Bay.

REGULATORY FRAMEWORK

Understanding the process of evaluating the environmental impacts of offshore sand and gravel mining is critical for ensuring that all environmental factors are addressed so a specific project can be approved. The most important part of this process is permit requirements and regulatory considerations. Because the U.S. Army Corps of Engineers is integral to the permitting and decision-making process, Section 404 (b)(1) guidelines and the Corps' Highway Methodology were used to structure the present guidelines for evaluating potential impacts of offshore sand and gravel mining. The methodology provides a way to systematically review and evaluate alternatives with participation by interested regulatory agencies and the applicant.

Appendix A documents applicable Section 404 guidelines for sand and gravel mining in Massachusetts State waters. This document is meant to provide guidance on environmental permitting considerations for potential applicants seeking to mine beach-quality sand from offshore sites. The following description summarizes many of the most important aspects required for studying the environmental impacts of a specific offshore sand and gravel mining operation under MEPA regulations, such as project scoping, the screening process, a description of the existing environment, an evaluation of potential environmental impacts, mitigation and monitoring, and project permitting.

A. Scoping

The first step in the study of environmental impacts is formulating precise statements of purpose and need for a specific sand and gravel mining project. The purpose and need leads to the scoping process during which a particular sand and gravel mining project is described, reasonable alternatives are determined, important environmental issues for impact analysis are identified, and other environmental review requirements are resolved.

The Section 404 regulations presented in Appendix A control the site selection process, which follows a series of logical steps to identify the most appropriate offshore sand and gravel borrow site for beach-quality sediment. A flowchart of this procedure is shown in Figure 1. These steps include:

1) Beach nourishment selected as a shore protection alternative
2) Characterize the material to be extracted from the borrow site
3) Identify extent of search area for sand resources
4) Identify widest range of possible alternatives (upland sources, nearshore sources, offshore sources)
5) Develop screening criteria (to identify the characteristics a site should have to be a good alternative)
6) Develop site-specific information (to identify the characteristics of the site relative to screening criteria)
7) Compare/contrast alternatives
8) Identify least environmentally damaging, cost-effective sand and gravel resource site.

B. Description of the Screening Process

The primary emphasis of the site selection process is site screening. The goal of the screening process is to identify the most appropriate sites for offshore sand and gravel mining. There are no numerical thresholds that identify the best site; rather, the screening process is designed to assess a wide range of potential sites, and through a comparative analysis, the list of sites is continually narrowed until only the most appropriate site remains.

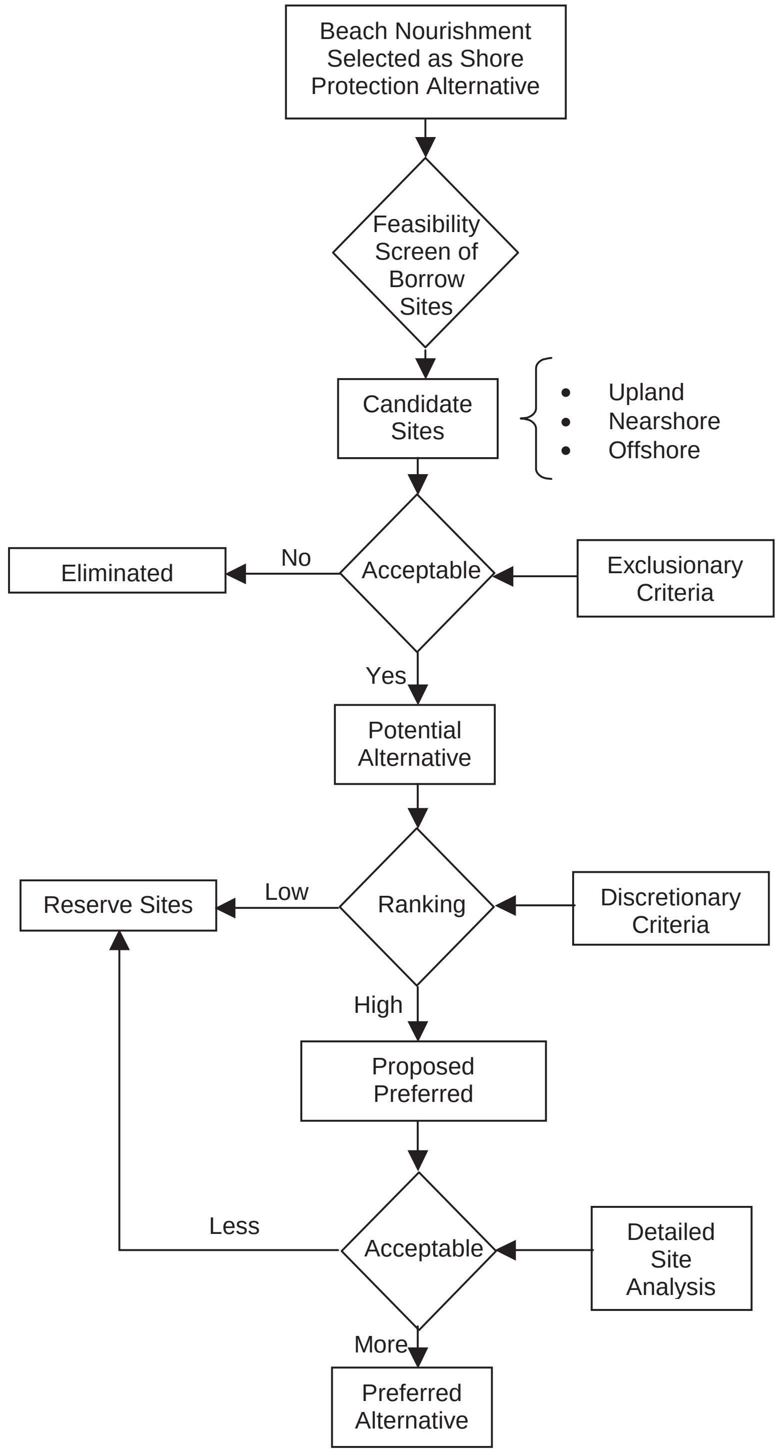

Figure 1. Screening process flowchart for beach nourishment/offshore sand mining projects.

Appropriate is defined as those sites that best meet the Federal Least Environmentally Damaging Practicable Alternative standard, that are permittable under state environmental law, that are acceptable to the community in which they are located, and that are capable of being implemented at reasonable cost.

Screening criteria are distinguished as either exclusionary or discretionary. Exclusionary criteria reflect a state or federal prohibition on sand and gravel mining at a specific site. For example, Stellwagen National Marine Sanctuary regulations prohibit sand and gravel mining within the sanctuary. If any of candidate sites is situated within sanctuary boundaries, this exclusionary criterion would prohibit further evaluation of the site.

Discretionary criteria are those that determine, when applied as a group, which offshore sites are least or best suited for sand and gravel mining. For example, the potential impacts to fin-fish spawning or nursery habitat are evaluated under discretionary criteria: the presence of such habitat in a candidate site would not automatically exclude the site from further consideration, but it would identify that site as less desirable than one in which such habitat was absent. The application of discretionary criteria is the main component of the screening process, and it is the process by which sites compared amongst themselves, using site-specific information to decide which sites are most appropriate.

The screening process begins by evaluating candidate sites under the exclusionary criteria. Those that fail are excluded from further review and are not carried forward in the review. Sites that pass become potential alternatives. Potential alternatives are then reviewed using the discretionary criteria, and they are then assigned a relative ranking. Sites that have significant limitations receive low marks; sites with fewer limitations receive higher marks. Some examples of potential impacts that would receive low marks include:

- mining at sites in shallow water that result in significant impacts to wave energy distribution, alongshore transport rates, and potential increased shoreline erosion;
- direct effects on benthic and pelagic communities resulting from turbidity associated with dredging and its impact on adjacent environments when sediment settles to the seafloor;
- direct and long-term effects on benthic communities that may be associated with dredging a deep borrow pit (may create an anoxic hole and/or fill with fine-grained material);
- long-term alteration of fish habitat associated with food supply, spawning, and/or migratory behavior.

Alternatively, mining at a proposed sand resource site that results in short-term, direct impacts to benthic communities, without long-term adverse impacts to habitat, will receive higher marks. The area most desirable for mining will pose the least environmental effects throughout the impacted region.

The result is a continuum of sites, from least to most appropriate, under the criteria. Sites that are least appropriate are categorized as reserved, and, as the name implies, are carried forward in reserve but are not subject to further analysis. Sites that are more appropriate are categorized as potential alternatives. These sites are then subject to detailed, site-specific analysis. Sites that prove unacceptable under this detailed analysis are placed back in the reserved category; sites that prove acceptable are categorized as preferred alternatives and represent the sites recommended for evaluation in the Federal and State regulatory process.

C. Characterize Existing Environment

An important step in the impact assessment process is describing the environmental resources that exist in the area that could potentially be affected by the mining operations. The characterization process should include the potential resource site, the transport path to the beach, and beach and nearshore areas that may be affected by the proposed action. A full suite of potentially affected resources should be considered, including the physical environment (e.g., meteorology, geology, physical and chemical oceanography, etc.), biological environment (e.g., pelagic and benthic organisms, endangered and threatened species, etc.), and the socioeconomic environment (e.g., commercial and recreational fisheries, cultural resources, vessel traffic and other space-use conflicts, etc.). Although straightforward, this step is time consuming because existing literature and data must be gathered, and field data collection may be required, to describe the resources in the area. The description of existing resources should be concisely written and focused on the resources and issues that are relevant to the assessment of impacts for the specific mining project. The following list summarizes the types of information needed when describing the existing environment.

PHYSICAL ENVIRONMENT
- Geology
  - Seabed Morphology and Bathymetry
  - Sediments
  - Sediment Transport
- Meteorology
  - Weather
  - Air Quality
- Physical Oceanography
  - Tides
  - Waves and Sea State
  - Currents and Circulation
- Chemical Oceanography
  - Turbidity
  - Water Quality (including turbidity and potential contaminants)
  - Sediment Quality (including potential contaminants)

BIOLOGICAL ENVIRONMENT
- Pelagic Environment
  - Phytoplankton
  - Zooplankton (including ichthyoplankton)
  - Fishes
  - Marine Mammals
  - Seabirds
- Benthic Environment
  - Infauna
  - Epifauna
  - Demersal Fishes

SOCIOECONOMIC ENVIRONMENT
- Commercial and Recreational Fisheries
- Archeological Resources
  - Historic Cultural Resources
  - Prehistoric Cultural Resources
- Marine Sanctuaries
- Massachusetts Bays National Estuaries Program
- Military Uses (e.g., operational areas, explosives dumpsites, ordinance, etc.)

Ocean Dredged Material Disposal Sites (ODMDSs)
Other Disposal Sites (acid waste, sewage sludge, etc.)
Artificial Reef Sites and Areas
Recreation
Navigation Aids and Data Buoys
Towers (communications or navigation)
Obstructions and Wrecks
Shipping Lanes and Traffic
Communications Cables
Pipelines
Aesthetics

D. Environmental Impacts

Once the existing environment has been described and the impact producing factors are determined based on an analysis of the proposed action, the information can then be used to develop statements concerning the potential impacts that might occur to all potentially affected resources. Attention should be given to providing statements regarding the nature, likelihood, magnitude, duration, and severity of impacts. The following summarizes the steps followed in determining potential environmental impacts for resource areas (see Appendix A for details).

Physical and Chemical Characteristics of the Ecosystem

- *Substrate Impacts* - Determine the nature and degree of effect that proposed sand and gravel mining operations will have, individually and cumulatively, on the characteristics of the substrate at the proposed offshore borrow site.
- *Suspended Particulates/Turbidity Impacts* - Determine the nature and degree of effect that the proposed sand and gravel mining operation will have, individually and cumulatively, on concentrations of suspended particulate/turbidity in the vicinity of the borrow site. Consideration shall be given to the shape and size of the plume of suspended particulates generated from mining operations, the duration of the resulting plume, and whether or not the potential changes will cause violations of applicable water quality standards.
- *Alteration of Current Patterns and Water Circulation* - Determine the nature and degree of effect that the proposed sand and gravel mining operation will have, individually and cumulatively, on water circulation, current speeds, and normal water-level fluctuations. Consideration shall be given to potential diversion or obstruction of flow, alterations of bottom contours, or other significant changes in the hydrologic regime.

Biological Characteristics of the Aquatic Ecosystem

- *Effect on Threatened/Endangered Species and Their Habitat* - An endangered species is a plant or animal in danger of extinction throughout all or a significant portion of its range. A threatened species is one in danger of becoming an endangered species in the foreseeable future throughout all or a significant portion of its range. The potential impacts on threatened or endangered species from sand and gravel mining include: 1) excavation or otherwise directly killing species; and 2) impairment or destruction of habitat to which these species are limited. Elements of the marine habitat which are particularly crucial to the continued survival of some threatened or endangered species include adequate water quality, spawning and maturation areas, protective cover, and adequate and reliable food supply.

- *Effect on Fish, Crustaceans, Mollusks, and Other Marine Organisms* - Identify habitat for finfish, crustaceans, mollusks, annelids, and the plants and animals on which they feed and depend upon for their needs. All life stages of an organism, throughout its geographic range, are included in this category. Identify other aquatic organisms through site-specific benthic studies. This includes issues concerning essential fish habitat (EFH) under the Sustainable Fisheries Act (Magnuson-Stevens Fishery Conservation and Management Act).
- *Effect on Marine Mammals and Birds* - Identify resident and transient marine mammals and birds in the sand and gravel mining area in coordination with NMFS, Department of Marine Fisheries (DMF), and USFWS records. This includes issues concerning marine mammals protected under the Marine Mammal Protection Act.

Potential Effects on Human Use Characteristics

- *Recreational and Commercial Fisheries* - Recreational and commercial fisheries consist of harvestable fish, crustaceans, shellfish, and other marine organisms used by humans. Sand and gravel mining can affect the suitability of recreational and commercial fishing grounds as habitat for populations of consumable marine organisms. Mining may interfere with the reproductive success of recreational and commercially important marine species through disruption of spawning and migratory areas.
- *Aesthetic Impacts* - Aesthetics associated with the marine ecosystem consist of the perception of beauty by one or a combination of the senses of sight, hearing, touch, and smell. Sand and gravel mining operations may alter the beauty of natural marine ecosystems by degrading water quality and modifying vital elements that contribute to the diversity of an area. Determine the impacts of offshore sand and gravel mining on water quality, natural substrate, denial of access to resources at the resource site or result in changes to odor, air quality, or noise levels at the site.
- *Parks, National and Historical Monuments, National Seashores, Research Sites, and Similar Preserves* - These preserves consist of areas designated under Federal and State laws or local ordinances to be managed for their aesthetic, educational, historical, recreational, or scientific value. Sand and gravel mining in or near such areas may modify the aesthetic, educational, historical, recreational, and scientific qualities thereby reducing or eliminating the uses for which such sites are set aside and managed.

E. Cumulative Impacts

Cumulative impacts are defined as the environmental impacts that result from the incremental impact of the project when added to other past and present actions. Analyzing cumulative impacts is a challenge, particularly for an individual applicant, primarily because of the difficulty defining spatial and temporal boundaries. If the boundaries are set too broad, the analysis becomes too wieldy; if boundaries are set too narrow, significant issues may be missed and decision-makers may be incompletely informed about the consequences of their decisions. A reasonable way to address this dilemma is to carefully consider potential impacts determined above relative to the proposed action and existing conditions, and develop boundaries for evaluating cumulative impacts based on a series of proposed single actions. Although impacts may not be additive, the method does provide a reasonable means of predicting potential cumulative effects in the absence of long-term, comprehensive data sets.

F. Mitigation and Monitoring

Once all of these previous aspects of the impact assessment process have been considered, decisions then can be made regarding mitigation and monitoring. If significant environmental impacts could potentially occur during a project, then mitigation and monitoring should be considered. Mitigation and monitoring measures should be evaluated from technical, scientific, regulatory, and socioeconomic perspectives to ensure feasibility and reasonableness. As an example, there are many actions that can be undertaken to minimize the adverse effects of offshore sand and gravel mining. Some of these, grouped by type of activity, are listed below.

Location of Sand and Gravel Mining - The effects of mining operations can be minimized by the choice of the borrow site. Some of the ways to accomplish this are:

1) Select a borrow site and the method of mining to minimize the extent of any plume;
2) Select a borrow site that has been used previously for sand and gravel mining; and
3) Locate and confine the borrow site to minimize adverse impacts on wave and current processes and the death of organisms.

Mining Technology - Sand and gravel mining technology should be adapted to the needs of each site. In determining whether the mining operation sufficiently minimizes adverse environmental impacts, the applicant should consider:

1) Appropriate equipment or machinery, including protective devices, in activities related to sand and gravel mining; and
2) Appropriate maintenance and operation of equipment or machinery, including adequate training, staffing, and working procedures.

Marine Animal Populations - Minimizing adverse effects on marine animal populations may be achieved by:

1) Avoiding changes in water current speed and circulation patterns which would interfere with the movement of animals;
2) Selecting sites or managing mining operations to prevent or avoid creating habitat conducive to the development of undesirable predators or species which have a competitive edge ecologically over indigenous animals;
3) Avoiding sites having unique habitat or other value, including habitat of threatened or endangered species;
4) Timing mining operations to avoid spawning or migratory seasons and other biologically critical time periods.

Human Use - Minimizing adverse effects on human use characteristics may be achieved by:

1) Selecting sand and gravel borrow sites and following mining procedures to prevent or minimize any potential damage to the aesthetically pleasing features of the marine site, particularly with respect to water quality;
2) Selecting mining sites which are not valuable as natural marine areas;
3) Timing mining operations to avoid the seasons or periods when human recreational activity associated with the marine site is most important; and
4) Following mining procedures which avoid or minimize the disturbance of aesthetic features of a marine site or ecosystem.

G. Permitting Requirements

Due to the scale and complexity of an offshore borrow site and beach nourishment project, environmental regulatory agencies typically require detailed evaluation of potential adverse impacts. Historically, beach fill projects in Massachusetts have been permitted on a project-by-project basis, where the beach nourishment and borrow site are evaluated within the context of a single project. For a sufficiently large offshore borrow site, a single borrow area may provide enough beach compatible sediment for several beach fill projects. For these cases, it may be more appropriate to separate permitting of the offshore borrow site from individual nourishment projects, similar to procedures used for dredged material management planning in Massachusetts.

Although it may be possible to permit an offshore borrow site for several projects, initial permitting requirements will involve evaluation of impacts at the borrow site (associated with the sand mining process) and along the beach (associated with the beach fill process). The following lists the permits required, as well as the appropriate "trigger" conditions for sand mining from Massachusetts State waters:

- Order of Conditions – The Notice of Intent application is filed with the local Conservation Commission and the regional Department of Environmental Protection (DEP) office. The local Conservation Commission administers the Massachusetts Wetlands Protection Act (General Law Chapter 131, Section 40), as well as any local by-laws. Assuming the proposed project meets the requirements of the local Conservation Commission and the DEP, an Order of Conditions is issued regulating activities that will take place.
- Waterways License or Permit (Chapter 91) – This application is filed with the DEP Bureau of Resource Protection – Waterways Program. According to 310 CMR 9.05 (2) a and b, a Chapter 91 permit is required for any beach nourishment or dredging project.
- 401 Water Quality Certification – This application is filed with the DEP Bureau of Resource Protection and is required under the federal Clean Water Act for certain activities in wetlands and waterways. According to 314 CMR 9.04 (9), a 401 Water Quality Certification is required for any activity subject to an individual Section 404 permit by the Corps of Engineers (see below).
- MEPA Certificate – The Environmental Notification Form application is filed with the Executive Office of Environmental Affairs, Massachusetts Environmental Policy Act (MEPA) Office. According to 310 CMR 11.26 (7) (b) 4, an ENF is required for projects that involve dredging or disposal of 10,000 cubic yards or more of materials. Based on economic feasibility, the anticipated scope of offshore dredging projects is in excess of 200,000 cubic yards. Due to the relatively large-scale of an offshore sand mining project, as well as the potential adverse impacts, preparation of an Environmental Impact Report (EIR) is anticipated. The EIR would provide more detailed information regarding alternatives, the existing environment, potential environmental impacts, and mitigation/monitoring requirements. Typically, the scope of this document would be consistent with the requirements of the Army Corps of Engineers (404(b)(1) guidelines).
- U.S. Army Corps of Engineers, Section 404 Permit – This application is filed with the New England District of the Army Corps of Engineers. Under Section 404 of the Clean Water Act, the Corps regulates the discharge of dredged or filled materials into the waters of the U.S. Due to the anticipated size of an offshore sand mining and beach

nourishment project, the work will trigger an Individual Permit (Category III). An Individual Permit is required for projects having more than one acre of waterway fill and/or wetland impacts (e.g. areas drained or flooded). In addition, new dredging greater than 10,000 cubic yards triggers an Individual Permit. Preparation of an Environmental Impact Statement (EIS) is anticipated. If the Corps finds that an EIS is required for its permit activities, it will become a cooperative agency in the EIS/EIR preparation. In this manner, a single EIS/EIR can be adopted for the Army Corps permitting process.

- CZM Federal Consistency Certificate – Through the federal consistency review process, CZM determines whether the proposed activity complies with the Commonwealth's enforceable program policies. Applicants are required to file for federal consistency if the proposed work is located in or affects the resources of the coastal zone, the project requires a federal license or permit or federal funding, or the project exceeds the CZM thresholds for review. In general, CZM thresholds are the same as the MEPA thresholds listed above.
- Other Regulations – Areas of Critical Environmental Concern, Local Wetlands Bylaw, Division of Marine Fisheries, Federal Endangered Species Act, Massachusetts Endangered Species Act, Marine Protection Research and Sanctuaries Act, Ocean Dumping Act (S. 103, outside 404 waters).

SAND AND GRAVEL MINING IN MASSACHUSETTS STATE WATERS

Requests for beach nourishment projects within Massachusetts have increased over the past decade, in part, as a result of Commonwealth policies that encourage the use of non-structural methods of erosion control. There are limited quantities of compatible sediment available from navigation dredging to meet the needs of beach nourishment projects. Furthermore, the availability of cost-effective onshore sand resources to meet beach replenishment needs is limited. As such, nearshore sand resources have been identified and used to meet growing needs (Davison, et al., 1992); however, the physical environmental impact of sand extraction from borrow sites within the littoral transport zone (typically 25 ft and shallower) have focused sand resource searches offshore in water depths 30 ft and greater (Carter, 1988; p.475-480).

Careful consideration should be given to the effect of borrow sites located shallower than the "depth of closure" (the water depth at which no appreciable movement of sediments by wave action occurs [Hallermeier, 1981]). Creating a local depression in the ocean bottom by dredging can focus wave energy and alter littoral drift patterns within the 'shadow region' of the borrow site. Figure 2 illustrates typical alterations to the wave climate from excavation of a nearshore borrow site. The top two subplots illustrate the wave height and direction of wave propagation for existing and post-dredging conditions, where the borrow area is indicated by the outlined box. The bottom subplot shows the difference between wave heights associated with existing conditions and post-dredging conditions. Darkened areas indicate that dredging of the borrow area will reduce wave height directly landward of the dredged hole (creating a 'shadow region'). To either side of the borrow area, post-dredging wave heights are higher than existing wave heights. This refocusing of wave energy can impact sediment transport processes and the associated coastal erosion patterns. Therefore, evaluation of physical alterations to the wave climate should be performed to determine the significance of potential impacts.

Generally, borrow sites in water depths greater than 30 ft should be sought along open-ocean coasts, if possible, to limit potential physical environmental impacts to beaches landward of borrow sites. Mining sands within closure depths should be done primarily as a 'sand bypass' mechanism to mitigate the effects of any geographical feature or structure (e.g., a headland or jetty) that interrupts the natural littoral drift along a beach.

Due to the glacial origin of the Massachusetts coast and nearshore regions, a limited number of sites containing beach compatible material exist. Much of the material utilized for beach nourishment within Massachusetts' waters has been derived from reworked sediments naturally deposited within navigation channels. Since reworked sediments are sorted by wave and tidal current processes, these deposits generally contain uniform-sized material and are good sources of beach compatible sand. Use of this material for beach nourishment provides convenient disposal of sediment inhibiting navigation; however, these projects rarely provide the volume of sediment necessary for an engineered beach nourishment project designed to provide a specific level of shore protection. To provide large-scale beach nourishment programs with sufficient sand, offshore sources of beach compatible sediment are needed.

In Massachusetts Bay and along the South Shore both nearshore (in water depths less than 30 ft) and offshore (water depths greater than 30 ft) areas have been identified along this section of the Massachusetts coast. Many of the nearshore deposits represent historical ebb shoals or beach/dune deposits. Due to the proximity of these deposits to the shoreline, it is anticipated that excavation of this material will change local wave refraction patterns and alter sediment transport along the beach. Several offshore deposits were identified during the New England Offshore Mining Study (NOMES) conducted in the 1970s. Sediments associated with these sites were generally categorized as glacial deposits that were reworked by the advancing post-glacial seas (Paden, 1977). Offshore sites evaluated during the NOMES project consisted of poorly-sorted material ranging in size from fine sand to cobbles. Since the areas identified for NOMES had water depths in excess of 50 feet, it is unlikely that excavation of these areas for beach nourishment would have a significant effect on wave or sediment transport patterns.

Other regions of Massachusetts have tidal inlets that require navigation dredging for navigation and material dredged from these channels often is utilized for beach nourishment projects. Availability of offshore material is uncertain; however, similar issues regarding potential physical and biological impacts associated with the dredging process need to be considered. Likely borrow sites within Cape Cod Bay, Vineyard/Nantucket Sound, and Buzzards Bay have water depths less than 50 feet; therefore, caution should be exercised in the borrow site selection process to ensure that excavation would not significantly alter wave or tidal current patterns. In addition, these regions of Massachusetts' waters are more protected from open ocean wave conditions than Massachusetts Bay waters. Due to this higher level of protection, the impacts of dredging on the local wave climate will be reduced.

Commonwealth waters contain a variety of benthic and pelagic habitat that potentially may be impacted by sand mining activities. For example, many areas of Vineyard and Nantucket Sounds have significant tidal currents in the vicinity of shoals, which are important to physical processes and biological resources. Many other areas of Massachusetts waters have low to moderate tidal currents that likely would not be an important aspect of habitat quality. In general, benthic and pelagic communities often are dependent on the physical characteristics of the environment (e.g. water temperature, sediment type, range of current speeds, etc.). Assessment of impacts to biological resources associated with sand mining should focus on direct impacts to existing communities, as well as the extent of long-term alterations to habitat quality.

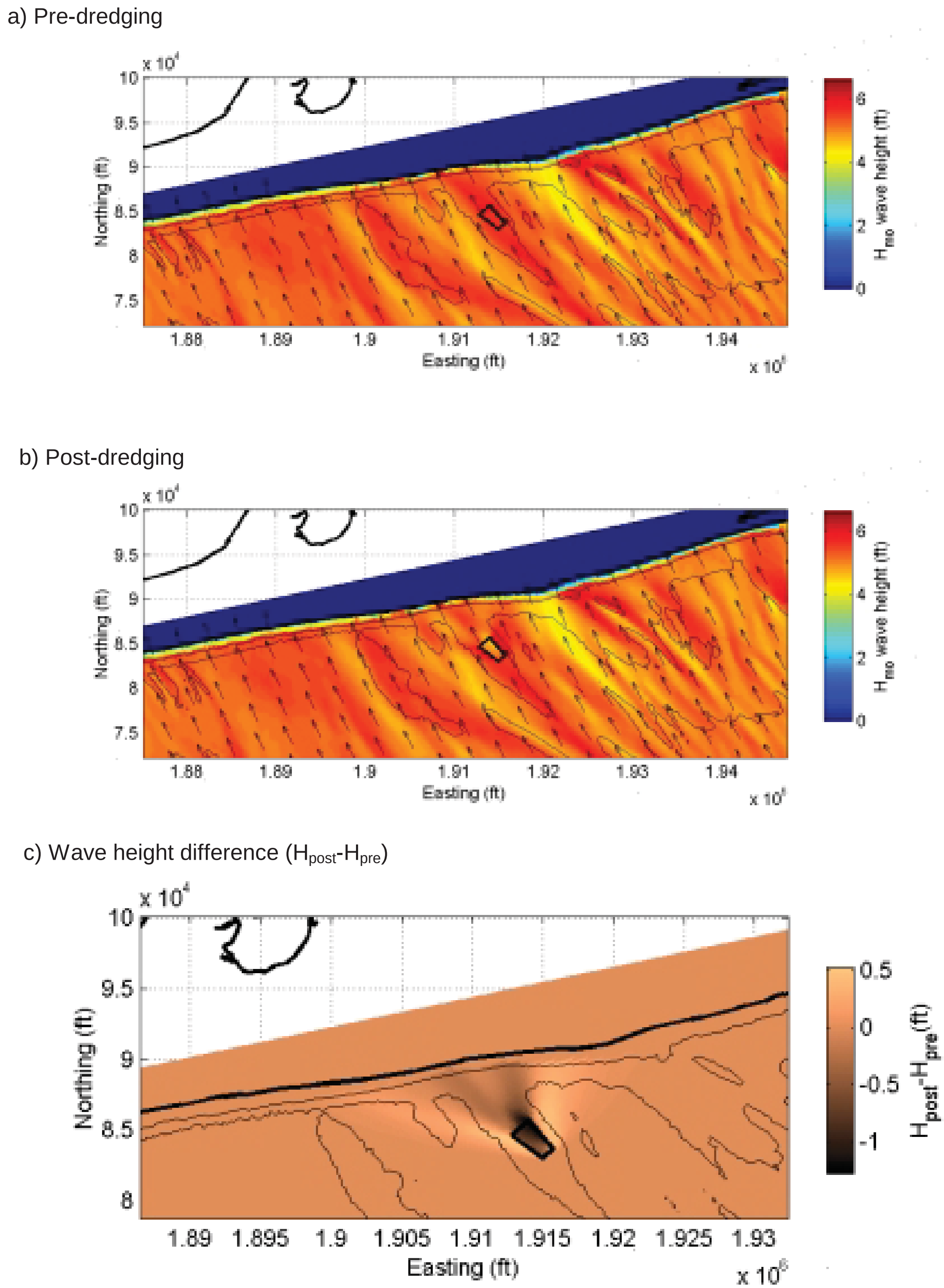

Figure 2. Pre- and post-dredging wave model results offshore of Alabama. Color contours in first two plots indicate wave height, and vectors indicate peak wave direction. Difference in computed wave heights (H_{post} - H_{pre}) between two scenarios is also shown. Borrow site location is indicated by black-line box. Bathymetry contours are at 10 ft intervals.

A. Generic Environmental Concerns

Generic environmental impacts of marine mining and beach nourishment operations have been reviewed by numerous authors (e.g., Thompson, 1973; Naqvi and Pullen, 1982; Pullen and Naqvi, 1983; Cruickshank, et al., 1987; Hurme and Pullen, 1988; Carter, 1988; Herbich, 1992; Hammer, et al., 1993a,b; National Research Council, 1995). Effects vary from detrimental to beneficial, direct to indirect, and short- to long-term (National Research Council, 1995). Sand deposits located in nearshore and offshore areas are the most common sources of beach fill material, where offshore deposits constitute as much as 95 percent of the sand presently used for beach nourishment (National Research Council, 1995). Sediment composition in offshore regions is often compatible with the beach to be nourished; however, costs for dredging these sites is often higher than dredging channels due to downtime associated with offshore sea conditions.

Physical Environment. In nearshore and offshore areas, creation of a borrow pit can affect the stability of shoals or reduce sediment transport to regions down-current of the borrow site. Wave energy and sediment transport pathways may also be affected if the borrow site is located within the depth of closure. Determination of changes to nearshore sediment transport processes as a result of borrow site excavation is an important aspect in the site evaluation process (see Byrnes et al., 1999).

Biological Environment. The primary biological effects of dredging a borrow site are the direct removal of benthic assemblages inhabiting surficial sediments (National Research Council, 1995). In addition, this alteration to the borrow area may indirectly effect other species that utilize the local benthos as a major food source and as habitat. Dredging activities also can increase turbidity within the vicinity of the borrow site during and sometimes after dredging. However, mining offshore sand and gravel deposits is expected to cause minimal turbidity when well-sorted, medium to coarse-grained sand is being dredged for nourishment. If deep holes are created during the dredging process, there presence may affect water quality. For example, researchers have observed decreased dissolved oxygen levels in dredged holes in New Jersey (Murawski, 1969). This problem may be associated with poor circulation in protected waters (e.g. estuaries).

According to the data assembled by the National Research Council (1995), the recovery of benthic communities in borrow sites has been quite variable; ranging from a few months to several years. The abundance and diversity of benthic fauna typically returns to levels comparable to pre-excavation conditions within one year. However, several studies indicated alterations of species composition in areas where bottom sediment composition changed following dredging activities (e.g. Wilber and Stern, 1992 and Johnson and Nelson, 1985). The consequences of long-term alterations are not well understood. In some cases, long-term changes following dredging activities create bottom habitat that may be perceived as an improvement over pre-existing conditions. For example, dredging a layer of fine-grained material can reveal an underlying hard substrata that may result in an increase in local biological diversity (National Research Council, 1995).

B. Sand and Gravel Resources in Massachusetts Bay

Due to significant interest regarding the use of offshore sand and gravel resources for beach nourishment around Massachusetts Bay (e.g., the Metropolitan District Commission and the Department of Environmental Management), this area was selected for baseline review of offshore sand and gravel resources and case study analysis. In addition, this portion of State waters has been the focus of significant efforts to define potential offshore borrow sites. Willett

(1972), Meisburger (1976), and FitzGerald et al. (1990) provide geologic information on sand and gravel resources in Massachusetts Bay.

Willett (1972) used sub-bottom profiling, bathymetry, side-scan sonar, and vibracores to define five sand and gravel sites (NOMES sites) of appreciable aggregates (10 million cubic yards [mcy] or more). As part of a regional sand and gravel resources study, Meisburger (1976) identified seven potential sand and gravel borrow areas, including the NOMES sites described by Willett (1972). Besides NOMES deposits, maximum resource volume estimates never exceeded 3 mcy. Based on limited data, FitzGerald et al. (1990) identified three sites with limited resource (< 1 mcy) seaward of Nantasket and Yirrell Beaches. Based on available resource characterization data, the NOMES deposits appear to provide the greatest potential sand and gravel resources for beach nourishment in Massachusetts Bay. In addition, physical, chemical, and biological data have been obtained for the NOMES sites to document the ecological conditions that would be modified during dredging operations. Because the NOMES sites are part of an investigation by MDC and DEM to evaluate potential sources of sand for beach replenishment, they will be used for describing data needed to evaluate potential environmental impacts associated with offshore sand and gravel mining for beach nourishment at Winthrop Beach. Further information regarding this analysis can be found in the case study later in this report.

C. Potential Sand Resource Costs for Massachusetts Bay

Due to the site-specific nature of beach nourishment projects, the average cost of material placed on a beach varies considerably. In addition, offshore dredging for beach nourishment is a relatively new concept in Massachusetts; therefore, there is limited information regarding potential costs of a major (in excess of 300,000 cubic yards) sand and gravel mining and nourishment effort. To provide some general guidelines for planning purposes, typical ranges of costs were derived from similar projects outside Massachusetts. Because every project has site-specific issues, the following list includes many of the factors controlling overall cost of sand and gravel mining for beach nourishment projects:

- *Size of project*: cost per cubic yard decreases with increasing project size;
- *Distance of borrow site from beach project*: cost per cubic yard increases with increasing distance between borrow site and project site;
- *Depth of water at borrow site*: cost per cubic yard increases with increasing water depth;
- *Potential for other dredging work in the area*: cost per cubic yard generally decreases if the project can be combined with other work in the area;
- *Exposure of borrow and nourishment sites to open ocean conditions*: cost per cubic yard generally increases with increasing exposure to open water conditions;
- *Seasonal restrictions on dredging or sand placement*: cost per cubic yard generally increases with increasing operational restrictions;
- *Characteristics of borrow material*: cost per cubic yard generally decreases as borrow material characteristics become similar to beach sediment characteristics; and
- *Thickness of borrow area sediments*: cost per cubic yard generally decreases with increasing sediment thickness.

Typically, sand that can be dredged from a borrow area in close proximity to the beach being nourished will be less expensive than sand dredged from an offshore source. The primary reason for cost differences is based on (1) the additional pipe and booster pump equipment required to transport sand a greater distance, or (2) the requirement to double-handle the material from an offshore source (i.e., dredge the material into a barge, transport the barge to the beach, and pump out the barge). As examples of beach nourishment projects, Hull and Winthrop have potential nearshore (FitzGerald et al., 1990) and offshore borrow areas (Willett, 1972), where the division between nearshore and offshore borrow sites is defined by the 30-ft bathymetric contour. In general, the zone of active sediment transport along the Massachusetts Bay shoreline extends out to the 30-ft depth contour. For nearshore or offshore borrow sites, all potential environmental impacts of sand mining need to be defined and evaluated prior to selecting a borrow site as the preferred alternative for permitting.

An additional source of sand for beach nourishment is upland borrow sites from which trucks or barges can transport the material to a site. Sand from an upland borrow site requires at least double-handling of the material. For relatively large beach nourishment projects (in excess of 200,000 cubic yards), one drawback of utilizing trucks is the damage to roadways from the increased traffic. As an example, a 200,000 cubic yard nourishment project would require between 10,000 and 20,000 truckloads. Barging the material to the site actually will require triple handling (placing the material into trucks, trucking the sand to the barge, dumping the sand into the barge, transporting the barge to the beach, and pumping out the barge). Due to the economy of scale, it generally is more cost-effective to construct large beach nourishment projects from nearshore or offshore borrow sources, rather than from upland sources. For comparative purposes, Table 1 indicates the relative direct cost of nearshore, offshore, and upland borrow sources, using a 300,000 cubic yard beach nourishment project as an example. Indirect costs associated with mitigating potential environmental impacts or impacts to local infrastructure are not included in the table.

Table 1. Approximate Direct Cost of Beach Nourishment Using Nearshore, Offshore, and Upland Borrow Sources (assuming a 300,000 cubic yard [cy] project).

Borrow Source	Mobilization Cost	Dredging Cost (per cy)	Cost per 300,000 cy
Nearshore (Cutter-head dredge with a pipe directly to shore)	$1,250,000 to $1,750,000	$2.50 to $6.00	$2 to $3.6 million
Offshore (Hopper dredge with a "pump-out" buoy and a pipe to shore)	$800,000 to $1,200,000	$5.00 to $12.00	$2.3 to $4.8 million
Upland (Sand trucked to the beach from a local borrow area)	N/A	$15.00 to $30.00	$4.5 to $9 million

Source: personal communication with Gahagan & Bryant Associates and personal experience

CASE STUDY: POTENTIAL NOURISHMENT OF WINTHROP BEACH WITH SAND AND GRAVEL FROM NEW ENGLAND OFFSHORE MINING ENVIRONMENTAL STUDY (NOMES) SITES

The purpose of the case study is to provide an example of the borrow site screening process, as well as to provide general guidelines regarding issues that should be addressed through the environmental permitting process. First, the case study includes a brief overview of the shore protection alternatives analysis for Winthrop Beach. Determination of beach nourishment as the selected shore protection alternative is the initial step in the scoping process. Utilizing the results of this analysis, an initial screening of potential borrow sites was performed, based strictly on physical properties regarding known borrow sites and financial aspects of the dredging process. This procedure generally follows steps 3 through 7 listed under Section A (Scoping) of the Regulatory Framework.

Although detailed information needed to assess potential impacts of offshore sand mining within Massachusetts Bay is beyond the scope of this study, examples of some of the geologic and oceanographic information needed for the EIR/EIS process has been provided. Where possible, additional information and/or data collection needed to assess the borrow site are noted. In general, the scope of the EIR/EIS likely will follow the outline shown in Table 2.

To date, the Winthrop Beach shore protection project has been proceeding under the Interim Assessment (IA) review developed for the Metropolitan District Commission's "Back to the Beaches" program by MEPA. However, potential use of offshore borrow material for nourishment is beyond the scope of the existing IA; therefore, a separate EIR/EIS will be required for this component of the project. Prior to evaluating offshore borrow sites, the project proponent and appropriate regulatory agencies should determine the extent of evaluation needed to address environmental concerns. At a minimum, the scope developed should require a description of the particular sand and gravel mining project, a determination of reasonable alternatives, identification of important environmental issues for impact analysis, and mitigation and/or monitoring requirements.

A. Identify Need for Beach Nourishment Material - Winthrop Beach

The Winthrop Shore Reservation Restoration Program at Winthrop and Short Beaches is part of the MDC's "Back to the Beaches" program to restore the beaches of Boston Harbor. To accomplish the goals of this program, beach nourishment, as well as other shore protection methods, have been considered along the Winthrop Beach shoreline, primarily for the region north of the "Five Sisters" (Figure 3). The conceptual design process for shore protection required an in-depth analysis of coastal processes including waves and wave-induced sediment transport. By developing numerical models to simulate the local wave processes and longshore (traveling along the shoreline) sediment transport patterns, the existing coastal processes could be determined quantitatively. Various shore protection measures also could be evaluated using numerical models to provide design guidance and optimization for coastal engineering solutions. The complete analysis of wave and sediment transport processes, as well as the conceptual design for shore protection at Winthrop Beach can be found in "Winthrop Shores Reservation Restoration Program, Conceptual Shore Protection Design, Task 2 Draft Report" (Woods Hole Group and Applied Coastal Research and Engineering, Inc., 2000).

Table 2. Preliminary Table of Contents for Addressing Environmental Impacts of Sand and Gravel Mining at NOMES Sites

Table 2, Continued

SOCIOECONOMIC ENVIRONMENT

- Commercial and Recreational Fisheries
- Archeological Resources
  - Historic Cultural Resources
  - Prehistoric Cultural Resources
- Marine Sanctuaries
- Massachusetts Bays National Estuaries Program
- Military Uses (e.g., operational areas, explosives dumpsites, ordinance, etc.)
- Ocean Dredged Material Disposal Sites (ODMDSs)
- Other Disposal Sites (acid waste, sewage sludge, etc.)
- Artificial Reef Sites and Areas
- Recreation
- Navigation Aids and Data Buoys
- Towers (communications or navigation)
- Obstructions and Wrecks
- Shipping Lanes and Traffic
- Communications Cables
- Pipelines
- Aesthetics

ENVIRONMENTAL IMPACTS

(Same Items As Under Existing Environment)

MITIGATION AND MONITORING

CUMULATIVE IMPACTS (Other mining and non-mining projects)

UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS

ENERGY REQUIREMENTS AND CONSERVATION POTENTIAL

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

RELATIONSHIP BETWEEN SHORT-TERM USE OF THE ENVIRONMENT AND MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

RELATIONSHIP WITH FEDERAL, STATE, AND LOCAL PLANS, POLICIES, AND CONTROLS

- NATIONAL ENVIRONMENTAL POLICY ACT
- COASTAL ZONE MANAGEMENT ACT
- ENDANGERED SPECIES ACT
- MARINE MAMMAL PROTECTION ACT
- SUSTAINABLE FISHERIES ACT (MAGNUSON-STEVENS FISHERY CONSERVATION AND MANAGEMENT ACT)
- MARINE PROTECTION, RESEARCH AND SANCTUARIES ACT
- NATIONAL HISTORIC PRESERVATION ACT
- CLEAN WATER ACT
- CLEAN AIR ACT

Table 2, Continued

Figure 3. Aerial photograph of Winthrop Beach, where the “Five Sisters” (breakwaters) are depicted by letters A to E and the groins are numbered from 1 to 5.

1. Background

The natural evolution of Winthrop Beach has been interrupted repeatedly through the installation of several artificial features including seawalls, groins, and breakwaters. Initially, erosion of Winthrop Beach was stabilized to protect Shore Road when the road and seawall were constructed in 1899. This seawall has suffered significant damage, and has been repaired several times. In an attempt to provide additional erosion protection to Winthrop Beach, five offshore rubble mound breakwaters were constructed between 1933 and 1935 (the Five Sisters). These breakwaters altered the beach shape by providing a sheltered area from wave action in their “shadow”. In 1959, a beach replenishment project was completed, consisting of 245,000 cubic yards of sand. In concert with this sand replenishment project, the seawall was repaired and its crest height was raised, five shore-perpendicular groins were constructed, and riprap toe protection was provided to sections of the seawall. This project was implemented in response to ongoing beach erosion that was attributed, among other factors, to the removal of a sediment source by armoring Grovers Cliff.

Along the length of Winthrop Beach, beach width is highly variable due to the numerous coastal structures, as well as the relatively large tide range (mean tide range is approximately 9.5 feet). The shoreline stretch between Wave Way and Beach Road has no high tide beach; however, this beach is approximately 60 to 80 feet wide at low tide. Farther south, a relatively wide high tide beach in the “shadow” of the Five Sisters exists, where a maximum high tide width of 300 to 400 feet is centered landward of breakwaters B and C (Figure 3). Sediment accumulation along the shoreline stretch protected by the breakwaters is dominated by north-to-south sediment transport. As illustrated in Figure 3, the majority of sand accumulation in the lee of the Five Sisters is between breakwaters C and E. Although a significant volume of sediment has accumulated south of breakwater C, beaches to the south are self-armored by a layer of cobbles and gravel, preventing migration of sand sized material from this region. The beaches in the shoreline stretch protected by breakwater A, as well as groins 4 and 5, is primarily composed of gravel/cobble sized material. Overall, a large variation in sediment grain size exists along Winthrop Beach, ranging from fine/medium sand to cobbles.

2. Shore Protection Alternatives

The narrow beaches along the Winthrop shoreline naturally provide storm damage protection and also enhance recreational resources. However, beach erosion during the past century (likely associated with the regional construction of seawalls/revetments) has reduced the beach’s ability to provide adequate storm protection. Winthrop Beach, in particular, is in need of beach replenishment to reduce the high level of damage caused by coastal flooding that has been experienced historically. Specifically, the shoreline region immediately north of the “Five Sisters” has suffered significant damage to dwellings, the roadway, and the seawall during severe coastal storms (e.g. the 1978 northeaster). During northeast storms, it is common for waves to crash against the seawall and drive sediment-laden water 80-to-100 feet above the seawall. The strong northeast winds associated with these events drive water and sediment into the roadway and against nearby buildings.

Several structural shore protection methods have historically been used to stabilize the Winthrop shoreline including seawalls, revetments, groins, and breakwaters. In general, these structures have provided adequate protection of coastal infrastructure over the past 100 years. Due to the armoring of the shoreline, natural sediment sources (the drumlin deposits of Winthrop Highlands and Cottage Hill) no longer provide needed sediment to the littoral system. As the beach continues to lose sediment in the region north of the “Five Sisters”, the groins no longer trap the limited volume of longshore sediment transport and the seawall has become more exposed to storm waves. At some locations, placement of stones at the base of the seawall has provided additional toe protection to the structure. The following lists the various shore protection methods, as well as the benefits and drawbacks of each method along Winthrop Beach:

a. Breakwaters

At Winthrop Beach, the "Five Sisters" constructed in the 1930s are a series of emergent breakwaters parallel to the shoreline. These structures represent one of the few applications of this shore protection technique found along the open coast of the United States. Although the regional littoral system can be considered "sediment starved", a low tide tombolo has formed between the shoreline and the breakwaters. This tombolo effectively blocks longshore sediment transport, creating a closed littoral cell between Winthrop Highlands and the tombolo. Due to the large number of shore protection structures constructed along the Winthrop shoreline, it is difficult to determine the long-term adverse impacts of the "Five Sisters" to downdrift shorelines. However, the large volume of sand trapped in the tombolo has been removed from the littoral system and is not available to adjacent beaches.

By understanding the environmental drawbacks of detached offshore breakwaters and designing the project to mitigate these concerns, they may represent a viable option to control coastal erosion. Unfortunately, the cost of breakwater construction in an open coastal region can be prohibitively expensive. To ensure that tombolos will not form, the offshore distance of any new breakwaters at the site must be increased relative to the existing structures. In addition, the large tide range at Winthrop Beach will increase the design height of an emergent breakwater, further escalating construction costs. It is also mandatory to construct breakwaters far enough offshore to prevent impacts on the natural seasonal cross-shore transport (i.e., perpendicular to the shoreline) of sand. This increase in offshore distance (hence water depth) will directly impact the structure cost and environmental impact, since a breakwater constructed in deeper water will require more material. At Winthrop Beach, construction costs versus anticipated benefits make additional detached offshore breakwaters infeasible. For example, for a typical trapezoidal-shaped cross-section rock breakwater, the construction cost are tripled (or more) when the depth is doubled. In deeper water, the footprint of the breakwater increases (at least 50% increase in footprint with doubled depth), and adverse environmental impacts are increased. Other structural alternatives such as groins, revetments, and seawalls provide cheaper means for controlling coastal erosion with reduced environmental impacts.

The "Five Sisters" adequately stabilize much of the Winthrop Beach shoreline. In addition, the beach system has had over six decades to equilibrate to the influence of the breakwater system. Although this beach condition can be considered unnatural, the formation of the tombolo allows shore protection improvements within a closed littoral cell (between Winthrop Highlands and the tombolo). For this reason, no alterations to the "Five Sisters" or the salient/tombolo have been recommended.

b. Groins

Along Winthrop Beach, several stone groins were constructed to protect the existing beach (see Figure 3). A series of three groins was constructed north of the "Five Sisters" and two additional groins were constructed to the south. Due to the lack of sediment in the littoral system, groins presently have little impact on local sediment transport processes. In regions where there is plenty of sand in the littoral zone, trapping of sand on the updrift side of a groin may lead to downdrift erosion. Since the predominant direction of sediment transport in the region north of the "Five Sisters" is to the south, the existing groin field in this region was constructed immediately updrift of a sediment "sink". Due to construction of the "Five Sisters", the region landward of the breakwaters tends to accrete sand in the form of a salient or tombolo.

This build-up of sediment blocks sediment from migrating farther south. Therefore, coastal engineering structures (such as groins) immediately north of the “Five Sisters” can be constructed without fear of impacting erosion rates on downdrift shorelines.

Based on past engineering experience, it is possible to design groins that will bypass sand during periods of extreme high tides and during storms. The design should always include regular beach nourishment in combination with groins to ensure that the structures are filled to entrapment, i.e. the planform of the beach will allow sediment to migrate past the tips, over, and through the groins naturally.

By utilizing beach nourishment in combination with groins north of the “Five Sisters”, design of lasting shore protection is possible. Based on the wave modeling results, sediment transport potential is directed from north-to-south along this region. Due to this dominant direction of littoral drift, a terminal groin at the north end of a proposed beach nourishment project would not cause adverse impacts to beaches further north.

c. Seawalls and Revetments

For Winthrop Beach, vertical seawalls already exist along much of the shoreline. With the exception of the region fronted by the “Five Sisters”, little or no beach exists at high tide along Winthrop Beach. A wider and higher fronting beach can reduce wave reflection during severe storm conditions and prevents waves from directly impacting the wall during typical wave conditions. Therefore, a seawall can reduce flooding and storm damage landward of the structure. To reduce and/or eliminate wave reflection and the associated beach scour, beach nourishment can be utilized to widen the beach and dissipate wave energy before it can reach the seawall.

d. Beach Nourishment

Coastal erosion typically is a problem where the natural sediment source is deficient. Placement of beach fill is a logical means for improving the stability of a shoreline where such a project is economically and environmentally feasible. Beach nourishment provides sacrificial sediment to the littoral system and is designed to postpone damage of coastal properties by adding sediment to the system and extending the shoreline toward the ocean. Due to the “soft” nature of this shore protection method, the lack of sediment in the littoral system, and the continual movement of sediment alongshore, periodic renourishment must be anticipated. Therefore, a combination of beach nourishment with other erosion mitigation measures may be the most effective way to stabilize a shoreline and extend the life of the beach nourishment.

Fill material may be obtained from an offshore or upland borrow site. To improve the durability of the nourishment and minimize potential impacts to nearby resources, the grain size distribution should be similar to, or larger than, the native sand. Borrowed sediments may be placed onshore in the form of a beach berm, a protective dune, or distributed over the beach face.

Environmental concerns with beach nourishment projects include potential for decreased water quality when sediments are dredged and deposited, and natural habitat may be disturbed when removing or depositing the dredged material. However, scientific evaluation of potential borrow sites, mitigation of short-term damage to natural resources, and monitoring can reduce and/or eliminate most impacts associated with the beach nourishment process. Essentially, beach nourishment is the most environmentally sensitive method of shoreline stabilization accepted by the science/engineering community.

Protective dunes provide additional shore protection when combined with beach berm placement. A dune, which can be vegetated, provides a source of sand that can erode during severe storm events and protects the landward property. Along much of Winthrop Beach, the seawalls serve as a last line of defense. In these areas, the nourished beach will be too narrow to establish a dune system. However, the beach area landward of the breakwaters (the tombolo) is stable and dunes would enhance the storm protection of this region.

Due to the limited amount of sediment naturally available to the littoral system resulting from regional shoreline armoring, beach nourishment will be required to replace the sediment deficit. By providing nourishment material, the existing beach system will be able to dissipate wave energy in a more natural manner. This dissipation of wave energy along the beach will protect landward properties from storm damage and minimize further impacts to the intertidal and subtidal areas caused by the groins and seawalls. In addition, the seawalls backing the beach will continue to provide the last line of defense for regional infrastructure.

The existing system of coastal engineering structures (groins and breakwaters) can be utilized to enhance the design life of a beach nourishment project along Winthrop Beach. Specifically, the compartments between the three groins north of the “Five Sisters” provide “closed cells” that can be nourished. Since groins limit longshore sediment transport, compartments between groins typically will retain nourishment material for a longer period of time than an unstructured coastline. As mentioned above, groins can be utilized as terminal structures for a beach nourishment project. In this manner, the groin will inhibit loss of nourishment material to adjacent shoreline areas. This technique would be effective at the northern end of Winthrop Beach to limit migration of nourishment material into the rocky intertidal area fronting the seawall along Winthrop Highlands. Selection of the most appropriate beach nourishment scenario depends on several factors including cost, design life, and potential environmental impacts. At Winthrop Beach, a beach fill project can be constructed to reestablish the depleted littoral drift system and provide needed shore protection. Based on the sediment transport and shoreline change analysis of beach fill options, it was determined that a 100 foot wide berm constructed along the shoreline north of the “Five Sisters” as well as a short reach to the south would provide the desired storm damage protection to landward areas while minimizing impacts. Potential structural solutions (“hard” engineering structures) also could be used to enhance the performance of beach fill projects. Based on site conditions, the use of “hard” structures (a new terminal groin) would have limited adverse impacts associated with alterations to littoral drift patterns and would help preserve rocky inter-tidal regions north of Winthrop Beach.

3. Selection of Shore Protection Alternatives

Several shore protection options are available to stabilize the existing Winthrop Beach shoreline; however, the sand deficit along much of the beach area indicates that nourishment will be a key component of any shore protection strategy. Alternatives considered in the conceptual design process included a “do nothing” alternative and three different beach nourishment options.

To address the issue of a sediment deficit along the Winthrop Beach shoreline, a beach nourishment project was considered as an alternative that would provide storm damage protection for the next 8-to-15 years. A beach nourishment project can be designed to have a reasonable design life and cause no interruption to the natural sediment transport patterns. If placed properly along the Winthrop Beach shoreline, a beach nourishment program can re-establish a beach in the highly eroded areas and to act as a “feeder beach” to supply sediment to downdrift areas. In addition to restoring the natural littoral system, beach nourishment provides a “soft” form of shore protection. The beach berm acts as a sacrificial barrier during storm conditions, where storm wave energy will be dissipated by the gradually sloping beach and wave reflection/overtopping at the seawall will be eliminated.

The "do nothing" alternative assumes that the beach will continue eroding and coastal engineering structures (breakwaters, groins, and seawalls) are not repaired. In general, the structural condition of the "Five Sisters" and much of the seawall is good; however, structural damage to the seawall occurred during northeast storms in 1978 and 1992. In December 1992, storm waves undermined a section of seawall resulting in a large washout behind the wall (U.S. Army Corps of Engineers, 1994). An area of pavement along Winthrop Shore Drive collapsed, forcing closure of the roadway. Previous storms, particularly the "No Name Storm" of late October 1991, have caused considerable beach erosion along this stretch of Winthrop Beach. The Army Corps of Engineers estimated that over $900,000 of damage occurred in this area from the 1991 and 1992 storms.

Beach erosion has led to increased wave reflection off the seawalls as the beach profile continues to lower. In some areas of Winthrop Beach, armor stones have been placed along the seaward face of the seawall to reduce wave reflection and to protect the toe of the seawall. If no additional shore protection measures are taken, the seawall will continue to have catastrophic failures during northeast storms. As the beach lowers, more of the seawall will become exposed to storm waves, eventually leading to larger failures of the seawall. Additionally, the existing concrete-capped groins north of the "Five Sisters" have begun to fail as a result of beach lowering. This process also is expected to continue if no action is taken.

The "do-nothing" alternative will result in eventual loss of Winthrop Shore Drive, as the series of shore protection structures adjacent to the seawall continue to fail. Assuming efforts are made to continue protection of the roadway, the gradual lowering of the beach will likely result in more frequent and more costly structural failures of the seawall. For these reasons, the "no build" alternative was deemed unacceptable.

Three fill scenarios where considered as part of the conceptual design process, ranging from filling the existing groin cells north of the tombolo, to a two-part fill protecting the seawall north and south of the tombolo. To enhance beach fill longevity, a groin near the north end of Winthrop Beach is proposed to serve as a terminal structure. The three alternatives modeled are as follows:

Alternative 1

To utilize the existing groin field north of the "Five Sisters", a beach nourishment option was developed that extends from the northernmost groin south to the existing tombolo. The beach fill length is approximately 1,400 linear feet and the equilibrated width is 100 feet. Equilibrated width refers to the dry beach width that will exist once the nourishment placed along the beach face is redistributed along the cross-shore profile. This process generally requires several weeks.

Alternative 2

Since historic damage of the seawall has occurred in the region north of the northernmost groin, a beach nourishment project extending an additional 800 feet north was evaluated. To improve the design life of this fill project, a terminal groin was added at the north end of Winthrop Beach. The beach fill length is approximately 2,200 linear feet and the equilibrated width is 100 feet.

Alternative 3

Although the primary region requiring additional shore protection is north of the "Five Sisters", the seawall and boat ramp south of the breakwaters also sustained damage during the

1978 storm (FitzGerald, 1978). To protect this region, a beach fill was evaluated immediately south of the existing tombolo. This beach fill was added to the nourishment project evaluated in Alternative 2. The beach fill length is approximately 3,160 linear feet (2,200 feet north of the tombolo and 960 feet south of the tombolo) and the equilibrated width is 100 feet.

Each of the beach nourishment alternatives were evaluated with a calibrated shoreline model for a simulation period of ten (10) years. The calibrated shoreline model can be utilized to predict future performance of the shoreline, as well as various shore protection scenarios. The resulting computed shoreline, as well as percent of fill remaining at selected cross-shore transects, for each case provides the basis of comparison between each of the options. Selection of the most appropriate beach nourishment scenario depends on several factors including cost, design life, and potential environmental impacts. At Winthrop Beach, a beach fill project can be constructed to reestablish the depleted littoral drift system and provide needed shore protection. Based on the modeling analysis of beach fill options, it was determined that a 100 ft berm constructed along the shoreline north of the “Five Sisters” as well as a short reach to the south would be a viable solution. Potential structural solutions (“hard” engineering structures) also could be used to enhance the performance of beach fill projects. Based on site conditions, the use of “hard” structures (a new terminal groin) would have limited adverse impacts associated with alterations to littoral drift patterns and would help preserve rocky inter-tidal regions north of Winthrop Beach.

4. Cost Analysis

Upland borrow sites can be utilized for beach nourishment, where trucks or barges can transport the material to a site. Sand from an upland borrow site requires at least double-handling of the material. As mentioned previously, large-scale beach nourishment projects such as Winthrop Beach could cause collateral damage to roadways from the increased traffic. Barging the material to the site actually will require triple handling (placing the material into trucks, trucking the sand to the barge, dumping the sand into the barge, transporting the barge to the beach, and pumping out the barge). Due to the economy of scale, it generally is more cost-effective to construct large beach nourishment projects from nearshore or offshore borrow sources, rather than from upland sources.

The dredging and placement costs used in this analysis assumed an offshore borrow site and ranged between $8 and $15 per cubic yard. As an estimate of beach fill volume, a 100 foot berm width with an elevation of 12 feet NGVD and an offshore slope of 1:15 (v:h) was superimposed onto a typical beach profile. Based on this nourishment template, approximately 160 cubic yards of beach fill would be required for every one (1) foot section of beach protected. In addition, a conservative estimate of a 6-year design life and a 12-year design life was assumed for the Scenario 1 and Scenario 2 nourishment projects, respectively. The Scenario 3 beach fill was assumed to have a design life similar to Scenario 2. The results of the cost analysis are shown in Table 3. Table 3 indicates Scenarios 2 or 3 would be most cost-effective.

Table 3. Cost analysis for beach nourishment options at Winthrop Beach utilizing an offshore borrow site.							
	length of shore protected (ft)	beach fill (cubic yards)	estimated design life (years)	cost per linear foot/yr (high)	cost per linear foot/yr (low)	project cost (high)	project cost (low)
Scenario 1	1,400	224,000	6	$400	$213	$3.36 million	$1.79 million
Scenario 2*	2,200	352,000	12	$215	$122	$5.68 million	$3.22 million
Scenario 3*	3,160	505,600	12	$211	$117	$7.98 million	$4.44 million
(*) An additional $400,000 was added for construction of a new terminal groin.							

B. Screening of Alternative Borrow Sites

Once beach nourishment was determined to be the most appropriate shore protection measure and upland borrow sites were deemed inefficient from an economic perspective, the screening process was initiated for the various nearshore and offshore borrow areas. As described previously, Massachusetts Bay has been the focus of significant efforts to define potential offshore borrow sites. Willett (1972), Meisburger (1976), Paden (1977), and FitzGerald et al. (1990) provide geologic information on sand and gravel resources in Massachusetts Bay.

Willett (1972) utilized geophysical techniques and vibracores to define five sand and gravel sites (NOMES sites) of appreciable aggregates (10 million cubic yards [mcy] or more). As part of a regional sand and gravel resources study, Meisburger (1976) identified seven potential sand and gravel borrow areas, including the NOMES sites described by Willett (1972). Besides NOMES deposits, maximum resource volume estimates never exceeded 3 mcy. Paden (1977) described a refined study of one of the sites described by Willett (1972), where 31 additional vibracores were drilled within the vicinity of the deposit and a more intense geophysical survey of this site was performed. In addition to the offshore work provided during NOMES, FitzGerald et al. (1990) identified three nearshore sites with limited resource (< 1 mcy) seaward of Nantasket and Yirrell Beaches.

Utilizing the screening criteria shown in Figure 1, both exclusionary and discretionary criteria were developed, based on physical properties of the borrow site and distance from Winthrop Beach (economic restrictions of transport). All identified nearshore and offshore borrow sites were considered. However, Boston Harbor sediments were not investigated due to the relatively small volumes of beach compatible material, as well as the likelihood of fine-grained contaminated sediments. Using exclusionary criteria, three of the five sites discovered by Willett (1972) could be eliminated from further consideration. Figure 4 indicates that both Sites II and III are in water depths in excess of 100 feet MLW. Based on current dredging technology in the United States, hopper (trailing suction) dredges are not designed to excavate borrow sites deeper than 100 to 110 feet. Although Site IV contained a significant volume of beach compatible sediments, its location (approximately 20 miles southeast of Winthrop) is more suited for nourishment of beaches along the South Shore. Therefore, Site IV was eliminated from further consideration.

Both Meisburger (1976) and FitzGerald et al. (1990) have described smaller deposits of sand ranging from approximately 200,000 to 3,000,000 cubic yards. Due to a variety of discretionary criteria, most of these deposits received a low ranking. However, a deposit in Cat

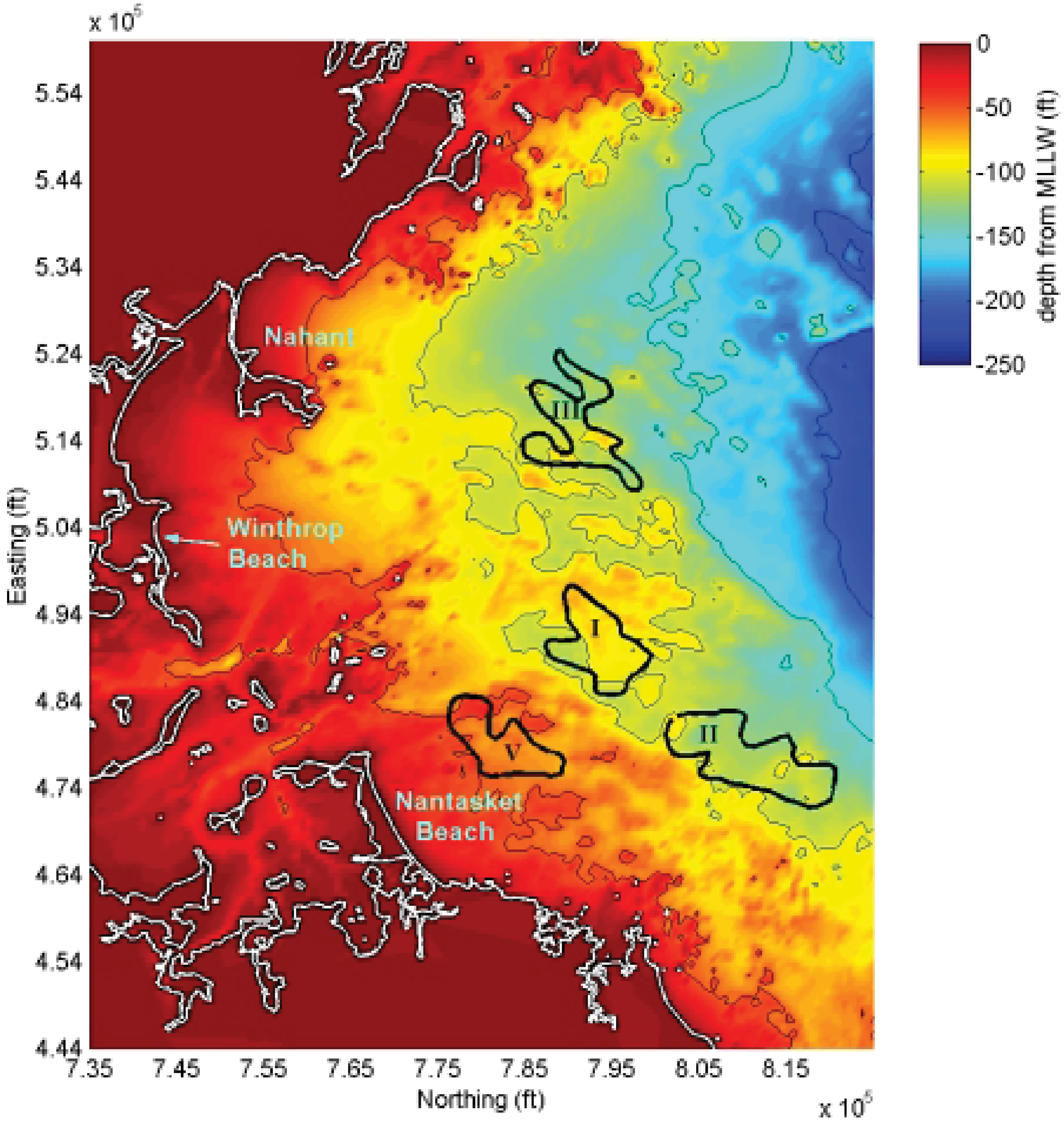

Figure 4. Bathymetric contour map of Massachusetts Bay showing NOMES sites I, II, III, and IV.

Island Channel (Salem Sound) could provide the necessary volume of beach compatible material. The following provides details on the ranking criteria utilized to evaluate each of these sites:

Cat Island Channel: (Meisburger, 1976; centered at 42° 30.2' N, 70° 48.9' W) The deposit lies in 30 to 55 feet of water. The initial estimate of sand (medium to coarse-size range) volume available is approximately 1.1 million cubic yards. Based on the water depth, the average thickness of the deposit (at least 12 feet), and the sediment quality (grain size), the Cat Island

Channel site received a high ranking. The most significant drawback of this site is the distance from Winthrop Beach (approximately 13 miles).

Nahant: (Meisburger, 1976; centered at 42° 24.7’ N, 70° 50.2’ W) The deposit lies in 98 feet of water. The one core taken at this site indicated a 1-foot silt layer overlying 5 feet of coarse sand. Due to this layer of fines, as well as the limited anticipated volume of the site (less than 800,000 cubic yards), this site received a low ranking.

Nantasket East, Nantasket Center, and Nantasket West: (Meisburger, 1976; centered at 42° 18.8’ N, 70° 47.6’ W, 42° 17.8’ N, 70° 49.0’ W, 42° 17.2’ N, 70° 51.2’ W, respectively) The initial estimate of sand (fine to coarse-size range) volume available is less than 700,000 cubic yards for each of theses sites. Both Nantasket East and Nantasket Center sites contained relatively fine material (fine to medium-size range) and, therefore, received a low ranking. The Nantasket West site indicated clean, coarse sand and gravel; however, the location of this site is only 0.7 miles off Nantasket Beach in 25 to 40 feet of water. Therefore, alterations to wave refraction and sediment transport patterns resulting from excavation give this site a low ranking.

Nantasket Beach, South Channel, and Yirrell Beach: (FitzGerald, et al., 1990) Since the evaluation of these sand and gravel reserves was based on limited data, the estimated volumes should be considered approximations of their true potential. Both the South Channel and Yirrell Beach sites were estimated to contain approximately 650,000 cubic yards. Since the volume of material within each of these sites is marginal for the nourishment needs at Winthrop Beach, the two sites received a low ranking. In addition, the Nantasket Beach and Yirrell Beach sites were in water depths ranging from 10 to 40 feet. Therefore, alterations to wave refraction and sediment transport patterns resulting from excavation gave these sites a low ranking.

The remaining NOMES sites (I and V) were evaluated relative to discretionary criteria. Initial estimates indicated that both of these sites contained more than 10 million cubic yards of sand and gravel (Willett, 1972). Utilizing these estimates of borrow site potential, as well as other selection criteria, a test dredging site was located within NOMES site I (Paden, 1977). The following provides details on the ranking criteria utilized to evaluate each of these sites for nourishment at Winthrop Beach:

NOMES Site I: (Willett, 1972 and Paden, 1977; centered at 42° 22’ N, 70° 47’ W) This site is located in approximately 80 to 90 feet of water relative to MLLW. However, the depth at high tide would be nearly 100 feet, which represents the upper water depth limit of existing dredging equipment in the United States. Initial estimates by Willett (1972) indicated nearly 40 million cubic yards of sand and gravel within this deposit. However, a more in-depth analysis of the borrow site revised this volume to over 6.5 million cubic yards of sand and gravel. Due to the average thickness of the deposit (at least 12 feet), and the sediment quality (grain size), this site received a high ranking. In addition, 31 vibracores were drilled in the vicinity of the deposit (Paden, 1977). This high level of detailed analysis provides additional confidence in the quality of material within this borrow area.

NOMES Site V: (Willett, 1972; centered at 42° 18’ N, 70° 49’ W) This site is located in approximately 50 to 60 feet of water relative to MLLW. Initial estimates by Willett (1972) indicated approximately 14 million cubic yards of sand and gravel within this deposit. The single vibracore taken within this deposit indicated only 3 to 3.5 feet of gravelly sand underlying 1.5 feet of fine sand. However, the geophysical analysis indicated increased thickness of the gravel and sand deposit within the southern portion of the site. Due to the potential for a sufficient volume of beach compatible material, this site received a high ranking.

The final ranking of the various borrow sites, based on physical characteristics, indicated that NOMES Site I be considered the primary borrow area for Winthrop Beach. Due to its size, nourishment of other beaches with material from this borrow site should be considered in the future. Secondary borrow sites included the Cat Island Channel and NOMES Site V.

The most economical means of dredging and transporting borrow material from NOMES Site I and Winthrop Beach likely will consist of a hopper dredge operation. The hopper (trailing suction) dredge does not create a single borrow pit, but rather creates a long shallow (<3 feet) trench across the borrow site with each pass. This material is transported to a location offshore of the beach to be nourished, and the material is hydraulically pumped through a pipe to the beach. A map (Figure 5) and diagram (Figure 6) have been provided to illustrate this procedure. An additional advantage of the hopper dredge is its ability to operate in wave conditions exceeding 4 feet.

Based on available resource characterization data, the NOMES Site I provides the greatest potential sand and gravel resources for beach nourishment in Massachusetts Bay. Furthermore, physical, chemical, and biological data have been obtained for these sites to document the ecological conditions that would be modified during dredging operations. As such, the NOMES site will be used for describing data needed to evaluate potential environmental impacts associated with offshore sand and gravel mining for beach nourishment at Winthrop Beach.

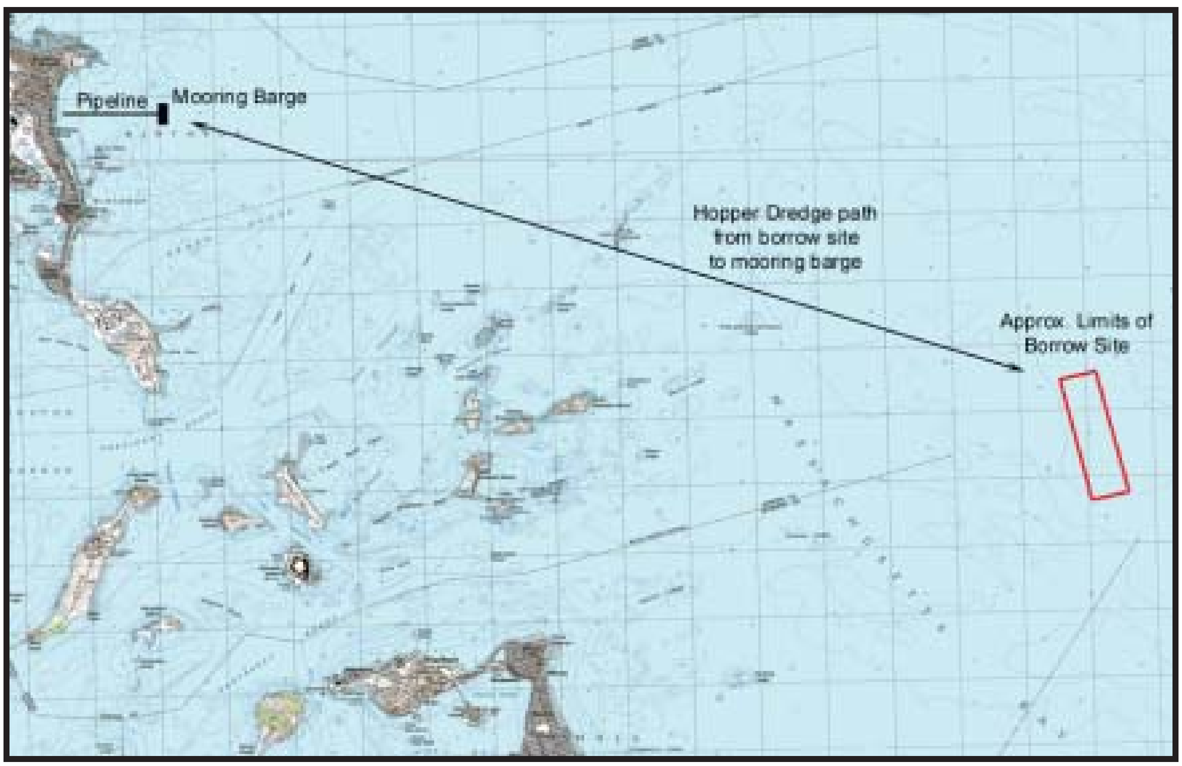

Figure 5. Map of proposed hopper dredge operations using NOMES Site I as the offshore borrow site and a mooring barge with a pipeline to shore in the vicinity of Winthrop Beach.

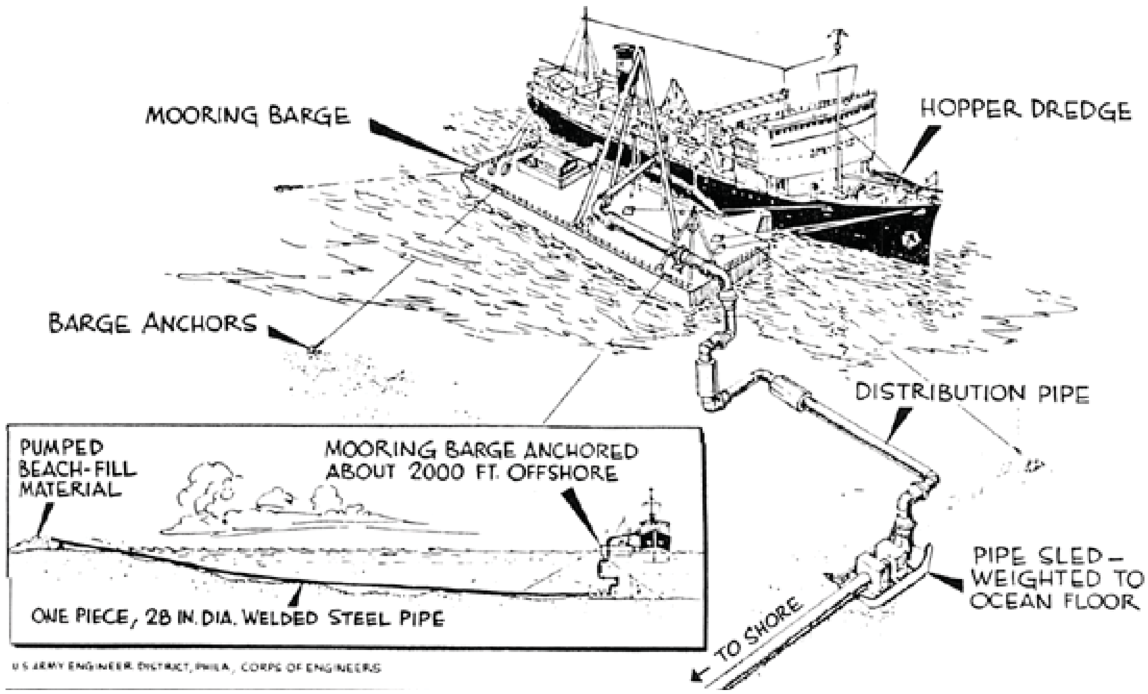

Figure 6. Schematic of a typical hopper dredge pump-out at a barge moored offshore (from Herbich, 1992).

C. Detailed Evaluation of NOMES

Project NOMES was initiated in 1972 for the purpose of resolving marine environmental impact uncertainties regarding marine sand and gravel mining (Padan, 1977). It was jointly sponsored by the Commonwealth of Massachusetts and the National Oceanic and Atmospheric Administration. A one-year baseline conditions study at a sand and gravel deposit in Massachusetts Bay (42°21’41”, 70°47’10”) was planned, followed by two years of detailed monitoring after the test site was to be excavated (see Figure 7). However, the project was terminated before the test site was excavated. As such, the report by Padan (1977) presents the study findings of Project NOMES and provides an origin for future sand and gravel mining operations in Massachusetts Bay. Another document, which was unavailable to the project team but may be a key reference to locate, is the Preliminary Draft Environmental Impact Statement for NOMES (Commonwealth of Massachusetts and National Oceanic and Atmospheric Administration, 1973). A list of other NOMES-related literature is provided at the end of this section.

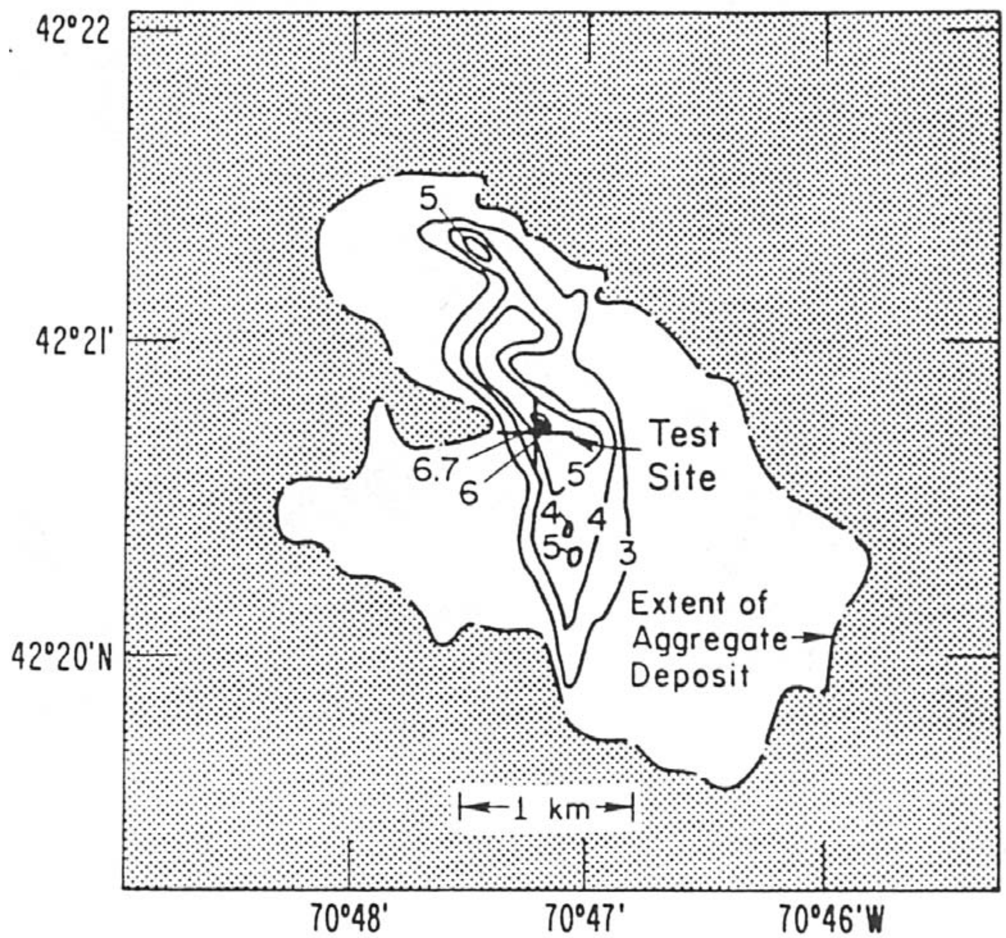

Figure 7. Contours of sand and gravel thickness within NOMES Site I. Thickness of deposit is shown in meters (from Paden, 1977).

1. Baseline Data

NOMES studies were initiated in each of the four disciplines of oceanography (i.e., geology, physics, chemistry, biology). The geology of the NOMES test site was first described by Willett (1972). Additional core, surface grabs, and close-grid bathymetry mapping were completed during NOMES. Core and grab samples were used to determine the physical and chemical properties of the sand and gravel deposit. Underwater photography provided data regarding substrate characteristics.

The physical oceanographic component of the study focused on water current measurements for use in predicting net transport of suspended sediment and as an aid for interpreting chemical and biological data. Current measurements and drogue, dye and test particle studies were conducted to evaluate water mass movements at the NOMES test site.

Chemical characteristics of water and sediment were documented using an extensive data base of information on temperature, salinity, dissolved oxygen, nutrients, total organics, etc. for nearby locations in Massachusetts Bay. Additional data on each of these parameters were collected at the NOMES test site throughout the experimental period, including an assessment of background levels of suspended sediment and organic matter.

The biological study component included characterizing the benthic biological communities and normal seasonal fluctuations at the mining site. Phytoplankton populations were analyzed to determine their distribution, abundance, and variability. From the limited biological information collected, the NOMES project team believed the benthos to be the most sensitive aspect of the ecology.

2. Potential Impacts of Sand and Gravel Mining at NOMES Site I

As stated above, it is not feasible to provide a site-specific analysis of sand and gravel extraction from a NOMES site because basic project specifications have not been defined. Without a specific project, nothing is known regarding the mining location, water depth, sediment type, sediment volume, maximum extraction depth, etc., and the ability to develop alternatives is lacking. However, a general evaluation of the possible environmental impacts of a mining operation can be established.

Padan (1977) established a list of potential economic and environmental effects due to sand and gravel mining at the NOMES sites. After defining project alternatives and existing conditions, the complexities associated with impact analyses are systematically evaluated. As an example, mining an offshore sand and gravel deposit has beneficial economic aspects in that it expands the number of sources available for beach nourishment, which should keep construction costs reasonable. From an environmental perspective, resource pressures on the upland environment should be reduced, and truck hauls via highways that raise traffic and air quality issues, as well as cause roadway damage, should be avoided. However, potential detrimental effects of substrate alterations to the offshore environment may negate these gains. For example, if a pit or series of pits result from the mining operation, these bottom features could cause formation of hypoxic or anoxic water and sediment depending on the excavation depth and wave and current characteristics. Short-term direct impacts on benthic organisms are certain, but if indirect impacts (e.g., hypoxia, anoxia, etc.) at the mining site are minimal, recolonization should occur in the long term.

Indirect impacts resulting from dredging (which directly cause bathymetry change) may include increasing coastal erosion at beaches landward and adjacent to the mining site, thereby altering the littoral sediment budget. Because the primary purpose of sand and gravel mining is to support local beach nourishment needs, a detailed analysis of potential impacts to the littoral sand transport regime is a critical component of environmental effects evaluation. Dredging-induced substrate changes may negatively impact local fisheries or create obstructions to bottom trawls (exposed boulders). However, exposed boulders and other dredging-induced elevation changes may provide new attachment surfaces for organisms, thereby increasing food supply and creating better fish habitat.

Overall, each project poses a different set of environmental circumstances that must be evaluated within the context of project requirements. Besides the basic natural resource considerations, cultural resources and human use factors, discussed previously, often vary widely from project to project. None of these considerations were addressed as part of the NOMES study, but all are significant relative to Massachusetts Bay and the NOMES sites. These conditions must be prioritized and evaluated relative to a specific project and within guidelines dictated by State and Federal regulatory agencies. For Winthrop Beach, a detailed analysis of the proposed borrow site(s) will be required prior to selection of any borrow area as the preferred alternative.

3. Recommendations for NOMES Site I

Although dated from the 1970s, the environmental analyses performed as part of the NOMES Project represent a set of conditions describing the natural environment prior to sand and gravel mining. After a project has been proposed using sand and gravel from one or more of the NOMES sites, it will be necessary to obtain and review all NOMES study reports and manuscripts. In addition, numerous studies have been conducted on the oceanographic characteristics of Massachusetts Bay since NOMES ended, and this information should be evaluated thoroughly before additional data are collected. Once a site-specific project has been planned, an updated description of the physical, chemical, and biological characteristics of a selected site should be completed. Furthermore, additional field surveys may be needed. Presently, additional geophysical and vibracore work is planned within the borrow site to determine (a) compatibility of the borrow material as beach fill at Winthrop, and (b) the amount of fines contained within borrow site sediments. Other field analysis may include collection of benthic grab and trawl samples for documenting infauna and epifauna relative to habitat types and time of year. Water quality characteristics should document fluctuations in ecological conditions throughout the year.

Physical process data collection should build on existing historical data sets for documenting the speed and direction of flow. The spatial variability of flow at the resource site(s) should be documented relative to wave-current interactions at the site and potential impacts on borrow site infilling rates. Wave transformation and nearshore sediment transport modeling may not be required, due to the depth of the borrow site (in excess of 90 feet). Once potential impacts have been identified, measures for addressing these impacts can be identified.

In addition to assessing natural resource information, cultural resources, socioeconomic considerations, and human use factors must be evaluated. Although there are numerous environmental issues to consider, some of the most contentious include modifications to wave and current regimes, protected species, marine sanctuaries, recolonization, commercial and recreational fisheries, essential fish habitat, and cultural resources. As described earlier, the evaluation of environmental impacts related to sand and gravel mining (e.g. the EIR/EIS for the project) should address the issues described in the Section 404 Guidelines (Appendix A) and generally follow the preliminary outline presented in Appendix B.

4. NOMES-Related Literature

The following list of references are provided as pertinent information related to the NOMES Project. The citations are not referenced in the text, except for Commonwealth of Massachusetts and National Oceanic and Atmospheric Administration (1973), Hammer et al. (1993a,b), Padan (1977), and Willett (1972). Many more citations listed in the literature below have relevance to potential sand and gravel mining operations in Massachusetts Bay.

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APPENDIX A

Section 404 Guidelines for Sand and Gravel Mining in Massachusetts State Waters

Section 404 Guidelines for Sand and Gravel Mining in Massachusetts State Waters

Information for Applicants

The following guidelines were developed based on Section 404 (b)(1) of the Clean Water Act (33 U.S.C. 1344; CWA). The intent was to develop a set of guidelines consistent with the Section 404 (b)(1) framework and the U.S. Army Corps of Engineers Highway Methodology for incorporating permitting requirements with project planning and engineering to address offshore sand and gravel mining (dredging) for the purpose of beach nourishment.

The purpose of these Guidelines is to maintain the physical and biological integrity of waters and seafloor deposits in the State of Massachusetts through the regulation of offshore sand and gravel mining. Congress has expressed a number of policies in the CWA, and these Guidelines are intended to be consistent with those policies. Fundamental to these Guidelines is the precept that sand and gravel should be mined from a marine ecosystem when it can be demonstrated that such mining will not have an unacceptable adverse impact either individually or in combination with known and probable impacts of other activities affecting the ecosystems of concern. From a State perspective, the degradation or destruction of special marine sites is considered to be among the most severe environmental impacts covered by these Guidelines. The guiding principle should be that degradation or destruction of special sites may represent an irreversible loss of valuable marine resources.

The Guidelines are meant to be adaptable, or to be applied in a manner specific to the circumstances of each application. For each application, a determination should be made as to the relevance of any portion of the Guidelines and its applicability, therefore requiring that only analyses deemed necessary for determining compliance be completed.

The Guidelines are generally applied in a sequential or iterative fashion. As a guide to applicants, the following checklist is proposed as a short tool for determining compliance with the Guidelines:

1. <u>Review of Compliance</u>

   Note: A sand and gravel mining operation complying with the requirement of these Guidelines will not automatically receive a permit. Although all requirements in this section must be met, the compliance evaluation procedures will vary to reflect the seriousness of the potential for adverse impacts on the marine ecosystems posed by specific sand and gravel mining activities.

   a. No mining of sand and gravel shall be permitted if there is a practical alternative to the proposed mining operation which would have less adverse impact on the marine ecosystem, so long as the alternative does not have other significant adverse environmental consequences.

   b. No sand and gravel mining shall be permitted if it: 1) causes or contributes to violations of any applicable State water quality standard; 2) jeopardizes the existence of species listed as endangered or threatened under the Endangered Species Act of 1973 or their habitat; and 3) violates requirements of any Federally-designated marine sanctuary.

   c. No sand and gravel mining shall be permitted which will cause or contribute to significant degradation of the waters of the State of Massachusetts, including adverse effects on human health, life stages of organisms dependent on aquatic ecosystem, ecosystem diversity, productivity and stability, and recreational, aesthetic values.

d. No sand and gravel mining shall be permitted unless appropriate and practical steps have been taken which will minimize potential adverse impacts of the mining operation on the marine ecosystem.

2. Technical Evaluation Factors

Note: The permitting authority shall determine in writing the potential short-term or long-term effects of proposed sand and gravel mining operations on the physical and biological components of the marine environment. Such factual determinations shall be used in making findings of compliance or non-compliance with the restrictions on sand and gravel mining.

a. Physical and Chemical Characteristics of the Ecosystem

1) *Substrate Impacts* - Determine the nature and degree of effect that proposed sand and gravel mining operations will have, individually and cumulatively, on the characteristics of the substrate at the proposed offshore borrow site. Potential changes in substrate elevation and bottom contours resulting from the proposed method, volume, and location of sand and gravel mining shall be used to evaluate the effects of mining operations on current speeds, water circulation, wind and wave action, and other physical factors that may be affected by the removal of mined material.

2) *Suspended Particulates/Turbidity Impacts* - Determine the nature and degree of effect that the proposed sand and gravel mining operation will have, individually and cumulatively, on concentrations of suspended particulate/turbidity in the vicinity of the borrow site. Consideration shall be given to the shape and size of the plume of suspended particulates generated from mining operations, the duration of the resulting plume, and whether or not the potential changes will cause violations of applicable water quality standards.

3) *Alteration of Current Patterns and Water Circulation* - Determine the nature and degree of effect that the proposed sand and gravel mining operation will have, individually and cumulatively, on water circulation, current speeds, and normal water-level fluctuations. Consideration shall be given to potential diversion or obstruction of flow, alterations of bottom contours, or other significant changes in the hydrologic regime.

b. Biological Characteristics of the Aquatic Ecosystem

1) *Effect on Threatened/Endangered Species and Their Habitat* - An endangered species is a plant or animal in danger of extinction throughout all or a significant portion of its range. A threatened species is one in danger of becoming an endangered species in the foreseeable future throughout all or a significant portion of its range. Listings of threatened and endangered species as well as critical habitats are maintained by some individual States and by the U.S. Fish and Wildlife Service (USFWS) of the Department of the Interior. The National Marine Fisheries Service (NMFS) of the Department of Commerce has authority over some threatened and endangered marine mammals and fish. The potential impacts on threatened or endangered species from sand and gravel mining include: 1) excavation or otherwise directly killing species; and 2) impairment or destruction of habitat to which these species are limited. Elements of the marine habitat which are particularly crucial to the continued survival of some threatened or endangered species include adequate water quality, spawning and maturation areas, protective cover, and adequate and reliable food supply.

2) *Effect on Fish, Crustaceans, Mollusks, and Other Marine Organisms in the Food Web* - Identify habitat for finfish, crustaceans, mollusks, annelids, and the plants and animals on which they feed and depend upon for their needs. All life stages of an organism, throughout its geographic range, are included in this category. Identify other aquatic organisms through site-specific benthic studies. This includes issues concerning essential fish habitat (EFH) under the Sustainable Fisheries Act (Magnuson-Stevens Fishery Conservation and Management Act).

3) *Effect on Marine Mammals and Birds* - Identify resident and transient marine mammals and birds in the sand and gravel mining area in coordination with NMFS, Department of Marine Fisheries (DMF), and USFWS records. This includes issues concerning marine mammals protected under the Marine Mammal Protection Act.

c. Potential Impacts on Special Marine Sites

1) *Marine Sanctuaries* - Sanctuaries consist of areas designated under State and Federal laws or local ordinances to be managed principally for the preservation and use of fish resources. Effects should be evaluated through application of methodologies specified in 2a and 2b above.

2) *Wetlands* - Not applicable to offshore sand and gravel mining sites.

3) *Mud Flats* - Not applicable to offshore sand and gravel mining sites.

4) *Vegetated Shallows* - Not applicable to offshore sand and gravel mining sites.

5) Coral reefs - Probably not applicable to offshore sand and gravel mining sites.

6) Riffle and Pool Complexes - Not applicable to offshore sand and gravel mining sites.

d. Potential Effects on Human Use Characteristics

1) *Municipal and Private Water Supplies* - Not applicable to offshore sand and gravel mining.

2) *Recreational and Commercial Fisheries* - Recreational and commercial fisheries consist of harvestable fish, crustaceans, shellfish, and other marine organisms used by humans. Sand and gravel mining can affect the suitability of recreational and commercial fishing grounds as habitat for populations of consumable marine organisms. Mining may interfere with the reproductive success of recreational and commercially important marine species through disruption of spawning and migratory areas. Effects should be evaluated through application of methodologies specified in 2a and 2b above. Determine constraints on sand and gravel site location and/or use through consultation with NMFS, DMF, and local interests.

3) *Water-Related Recreation* - Determine constraints on sand and gravel site location and use through consultation with NMFS, DMF, and local interests.

4) *Aesthetic Impacts* - Aesthetics associated with the marine ecosystem consist of the perception of beauty by one or a combination of the senses of sight, hearing, touch, and smell. Sand and gravel mining operations may alter the beauty of natural marine ecosystems by degrading water quality and modifying vital elements that contribute to the diversity of an area. Determine the impacts of offshore sand and gravel mining on water quality, natural substrate, denial of access to resources at the resource site or result in changes to odor, air quality, or noise levels at the site.

5) *Parks, National and Historical Monuments, National Seashores, Research Sites, and Similar Preserves* - These preserves consist of areas designated under Federal and

State laws or local ordinances to be managed for their aesthetic, educational, historical, recreational, or scientific value. Sand and gravel mining in or near such areas may modify the aesthetic, educational, historical, recreational, and scientific qualities thereby reducing or eliminating the uses for which such sites are set aside and managed. Effects should be evaluated through application of methodologies specified in 2a and 2b above.

3. Evaluation of Offshore Sand and Gravel Mining

The purpose of these evaluation procedures, and the physical and biological testing sequence outlined below, is to provide information to reach the determinations required under Section 1, Review of Compliance. Where the results of prior evaluations, physical and biological tests, scientific research, and experience can provide information helpful in making a determination, these data should be used. Such prior results may make new testing unnecessary. The information used shall be documented. Where the same information applies to more than one determination, it may be documented once and referenced in later determinations.

a. The sand and gravel borrow site should be examined to assess whether it is sufficiently removed from sources of pollution to provide reasonable assurance that the proposed sand and gravel material is not a carrier of contaminants. Factors to be considered include but are not limited to:

1) Potential routes of contaminants or contaminated sediments to the sand and gravel borrow site, based on hydrographic or other maps, aerial photography, or other materials;

2) Pertinent results from tests previously carried out on the material at the sand and gravel borrow site, or carried out on similar material for other permitted projects in the vicinity. Materials should be considered similar if the sources of contamination, the physical configuration of the sites and the sediment composition of the materials are comparable in light of water circulation and stratification, sediment accumulation, and general sediment characteristics. Tests from other sites may be relied on only if no changes have occurred at the borrow sites to render the results irrelevant;

3) Any records of spills or disposal of petroleum products or substances designated as hazardous under Section 311 of the CWA; and

4) Any possibility of the presence of substandard natural deposits of minerals or other substances which could be released to the marine environment in harmful quantities by sand and gravel mining activities.

b. If the evaluation above indicates that contaminants are not associated with sand and gravel from offshore mining, then the required determinations pertaining to the presence and effects of contaminants can be made without testing. Marine mining operations are most likely to be free from chemical, biological, or other pollutants where it is composed primarily of sand, gravel, or other naturally occurring inert material. However, when such material is discolored or contains other indications that contaminants may be present, further inquiry should be made.

4. Actions to Minimize Adverse Effects

There are many actions that can be undertaken to minimize the adverse effects of offshore sand and gravel mining. Some of these, grouped by type of activity, are listed below.

a. *Location of Sand and Gravel Mining* - The effects of mining operations can be minimized by the choice of the borrow site. Some of the ways to accomplish this are:

1) Select a borrow site and the method of mining to minimize the extent of any plume;

2) Select a borrow site that has been used previously for sand and gravel mining; and

3) Locate and confine the borrow site to minimize adverse impacts on wave and current processes and the death of organisms.

b. *Mining Technology* - Sand and gravel mining technology should be adapted to the needs of each site. In determining whether the mining operation sufficiently minimizes adverse environmental impacts, the applicant should consider:

1) Appropriate equipment or machinery, including protective devices, in activities related to sand and gravel mining; and

2) Appropriate maintenance and operation of equipment or machinery, including adequate training, staffing, and working procedures.

c. *Marine Animal Populations* - Minimizing adverse effects on marine animal populations may be achieved by:

1) Avoiding changes in water current speed and circulation patterns which would interfere with the movement of animals;

2) Selecting sites or managing mining operations to prevent or avoid creating habitat conducive to the development of undesirable predators or species which have a competitive edge ecologically over indigenous animals;

3) Avoiding sites having unique habitat or other value, including habitat of threatened or endangered species;

4) Using planning and construction practices to institute habitat development and restoration to produce a new or modified environmental state of higher ecological value by displacement of some or all of the existing environmental characteristics. Habitat development and restoration techniques can be used to minimize adverse impacts and to compensate for destroyed habitat;

5) Timing mining operations to avoid spawning or migratory seasons and other biologically critical time periods.

d. *Human Use* - Minimization of adverse effects on human use characteristics may be achieved by:

1) Selecting sand and gravel borrow sites and following mining procedures to prevent or minimize any potential damage to the aesthetically pleasing features of the marine site, particularly with respect to water quality;

2) Selecting mining sites which are not valuable as natural marine areas;

3) Timing mining operations to avoid the seasons or periods when human recreational activity associated with the marine site is most important; and

4) Following mining procedures which avoid or minimize the disturbance of aesthetic features of a marine site or ecosystem.

5. <u>Factual Determination</u>

A review of the information identified in Items 2 through 4 above is performed to indicate if there is minimal potential for short or long-term environmental effects of the proposed offshore sand and gravel mining as related to the following factors:

a) Physical substrate at the sand and gravel resource site (2a, 3, and 4)
b) Water circulation and water level fluctuation (2a, 3, and 4)
c) Suspended particulates/turbidity (2a, 3, and 4)
d) Marine ecosystem structure and function (2b, 2c, and 3)
e) Human use (2d, 3, and 4)
f) Sand and gravel resource site (2, 3, and 4)
g) Cumulative impact on the aquatic ecosystem (All items)
h) Secondary impacts on the aquatic ecosystem (All items)

6. Compliance Determination

The permit review staff then performs a compliance determination where one of three findings is generally made: compliance, compliance with imposition of specific conditions, or non-compliance.

APPENDIX B

List of Acronyms

DEM	Department of Environmental Management
DEP	Department of Environmental Protection
DMF	Department of Marine Fisheries
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
MCZM	Massachusetts Coastal Zone Management
MDC	Metropolitan District Commission
MEPA	Massachusetts Environmental Policy Act
MMS	U.S. Minerals Management Service
NEPA	National Environmental Policy Act
NMFS	Nation Marine Fisheries Service
NOMES	New England Offshore Environmental Study
USACE	U.S. Army Corps of Engineers