USE OF GEOGRAPHIC INFORMATION SYSTEMS (GIS) TO AID IN SITING DREDGED MATERIAL DISPOSAL AREAS

by

SCOTT T. FITZGERALD

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Signature of Author ....
Department of Civil and Environmental Engineering
May 8, 1998

Certified by ....
Dr. Judith Pederson
Manager, Center for Coastal Resources, MIT Sea Grant College Program
Thesis Supervisor

Certified by ....
Dr. David H. Marks
James Mason Crafts Professor of Civil and Environmental Engineering
Thesis Supervisor

Accepted by ....
Joseph M. Sussman
Professor, Civil and Environmental Engineering
Chairman, Departmental Committee on Graduate Studies

Accepted by ....
Richard de Neufville
Chairman, Technology and Policy Program

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Abstract

Dredging of the ports and waterways in the United States has implications for the economy and military preparedness and is hampered by a lack of disposal areas. Current dredged material disposal site selection methodologies have several limitations, such as a lack of early public involvement in the decision making process, inadequate documentation of the assumptions entering into decisions, lack of a holistic view, and inadequate consensus building among stakeholders. The use of an interactive Geographic Information System (GIS) approach to site dredged material disposal areas is seen as a way of updating and improving current site selection methodologies.

There were three specific goals of this project:
1. To develop a management approach to improve the identification and selection of dredged material disposal sites;
2. To use GIS technology as a tool to facilitate the implementation and use of that approach; and
3. To evaluate the use of GIS technology and the new approach in siting dredged disposal areas.

Any useful site selection methodology must acknowledge that site selection is an inherently political process based on interpretations and perceptions of the underlying science. A two part process for evaluating, ranking, and weighting data was adopted as an effective management methodology. This process allows for public involvement built upon good science and scientific interpretation of data.

The development of an interactive GIS provides the tools needed to implement this methodology. The use of visual analysis, a holistic approach, and better documentation of the assumptions inherent in any decision contribute to adaptive management of disposal areas. In addition, the interactive capability of the GIS tool allows 'what if' scenarios to be examined and allows users to immediately understand the various factors affecting disposal site location and to examine the tradeoffs inherent in any siting decision.

Feedback from public demonstrations of the proposed methodology confirms that this approach to siting disposal areas is an improvement over current methods. Because it aids consensus building and fosters an adaptive management approach, this methodology has the potential to site disposal areas with less time, cost, and opposition, resulting in a better selection.

Thesis Supervisor: Dr. Judith Pederson
Title: Manager, Coastal Resource Center, MIT Sea Grant College Program

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Peace Always.

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1. Introduction

Dredging of the ports and waterways in the United States is an ongoing activity of vast proportions. And while we most often talk about dredging the real issue is dredged material disposal. With increasingly stringent environmental regulations designed to protect and preserve both aquatic and land-based ecosystems, disposal of dredged material is no longer a matter of simply placing it in the ocean or on an empty plot of land. Rather, because of environmental regulations (USEPA 1990) and public perception, disposal sites must be chosen that minimize environmental impacts, maximize benefits, and are economically feasible. If the dredged material has been deemed contaminated, disposal options are further limited and selecting a disposal site becomes more difficult (Interagency Working Group on the Dredging Process 1994).

Current methods for siting dredged material disposal areas for contaminated sediments are typically long, static processes that attract significant public opposition, especially on the environmental front. Typical limitations of current approaches include bringing in the public too late in the decision making process, inadequate documentation of assumptions and the decision making process, and lack of a holistic planning view. A recent publication by the National Research Council (NRC) titled *Science, Policy, and the Coast: Improving Decisionmaking* (NRC 1995) cites many of these problems and suggests that stakeholders be involved in the initial planning and defining of tasks to be accomplished and in the identification of entities that should be involved. The NRC also recommends that the policy and management processes be integrated to include all stakeholders, regulators, and scientific disciplines that are relevant to the particular coastal problem.

The increasing popularity of Geographic Information Systems (GIS) has encouraged its growth and application to many environmental problems. The use of an **interactive GIS approach** to siting dredged material disposal areas is thought to be a powerful way of **updating and improving** the decision making tools currently used to site dredged material disposal areas and in addressing some of the issues cited by the National Research Council (NRC 1995).

1.1 Scope of this Project

This project is motivated by the recognition that there remains a major need to identify future disposal capacity, both in Boston Harbor and other U.S. ports, and that without improved decision making tools it will become increasingly difficult to do so (NRC 1985). Unless improved tools are developed, situations such as the removal of all the initial preferred sites (as identified in the initial Boston Harbor Navigation Improvement Project (BHNIP) Environmental Impact Report/Statement), from consideration because of public opposition, will become much more common (USACOE and Massport 1994). This could lead to a reduction in dredging, an increase in costs and time required to select disposal areas, or the selection of less environmentally sound sites.

An improved tool for site selection -- one that will aide consensus building -- needs to address the current limitations of the decision making process and allow for increased public input at the start, better documentation of assumptions and decisions, and a more holistic planning view. This will allow for adaptive management, an important component in any environmental solution (Lee 1989). Adaptive management is the use of new information and feedback from policy actions to modify and improve future actions. It has become very popular in the environmental arena because it allows for the implementation of better policies as increased knowledge of complex environmental systems is developed (Lee 1989). New technologies, such as GIS, may provide the necessary tools for implementing these methods.

This project is part of a larger effort encompassed by the MIT Sea Grant College Program Marine Center (see http://massbay.mit.edu/MarineCenter/) on the Behavior of Capped Contaminated Marine Sediments that was established to study the issues surrounding the disposal of contaminated dredged material using Boston Harbor as a case study. Boston Harbor is currently being dredged to clear channels of accumulated sediment and improve port facilities, and presents a unique opportunity for conducting this type of research. The Boston Harbor Navigation Improvement Project (BHNIP) will remove approximately 1.1 million cubic yards (cy) of contaminated sediment from the harbor channels and berthing areas. In addition, 3.4 million cy of clean parent material (Boston Blue Clay) and .1 million cy of rock will be removed (USACOE and Massport 1994). While disposal sites consisting of in-channel disposal for the current contaminated material and open ocean disposal for the parent material have been selected, there is not enough current capacity for future maintenance material anticipated to

collect in the channels and berths. This means that additional disposal sites will need to be identified and selected in the future. If the current trends toward stricter environmental regulations continue, this task will become increasingly difficult and an improved site selection tool will be very valuable. The future disposal needs of the BHNIP provide the focus for the research outlined in this research project.

Because of the current BHNIP occurring locally and the ease of access to data, reports, personnel, and operations relating to that project, Boston Harbor was used as a case study for this project. While it is assumed that the BHNIP is representative of projects nationwide, variations in local and state regulations regarding dredged material disposal might produce some deviation from the process used for the BHNIP. However, this does not in any way invalidate the motivation or conclusions of the approach being developed. In addition, because the scope of this project was to analyze the method and not the results of this new approach, it was limited to the most likely disposal option to be used in the future, that being the use of capped disposal cells in the Boston Outer Harbor.

There were three primary goals for this project:
1. To develop a management approach to improve the identification and selection of dredged material disposal sites;
2. To use GIS technology as a tool to facilitate the implementation and use of that approach; and
3. To evaluate the use of GIS technology and the new approach in siting dredged disposal areas.

The development of the interactive approach and its evaluation can be broken down into several steps. The first step was the identification of the problems and issues surrounding the current decision methodologies, some of which have already been identified. Following this, a conceptual model of an improved decision making tool was developed. This tool provides for scientific and public input to the decision making process and is designed to be used for initial site selection. Next, the GIS interface was designed and implemented. This involved gathering all of the relevant data and performing the programming and customization needed to implement the conceptual model. Finally, in order to evaluate this new approach, several public demonstration sessions were held and a series of surveys were given to the participants. These surveys were designed to capture the response of the group toward the new method and to aid in evaluating its potential for future use.

Finally, it is important to remain aware of the policy implications of this new approach and technology. Can the use of an interactive GIS approach save time and money in the site selection process? Does the use of GIS technology allow for better data management and contribute to better documenting the assumptions and reasons underlying all decisions? Does it provide for a more holistic planning view and is this a better way of addressing the problem? Can it help reduce opposition and build consensus among stakeholders (NRC 1985)? Can this lead to better, scientifically based solutions (NRC 1995)? These questions all address critical aspects of the policy questions surrounding the development and implementation of a new approach to siting dredged material disposal areas (NRC 1985). The ultimate goal is to develop policies, and the underlying decision making tools to carry them out, that will result in minimizing environmental damage, maximizing human benefit, and gaining the support of all the stakeholders.

As will be demonstrated by this thesis, the use of an interactive GIS approach to siting dredged material disposal areas has great potential to improve upon current decision making methodologies and can provide for better policy making in dealing with issues of contaminated sediment disposal options. It champions the inclusion of good scientific data and public participation early in the siting process which should help avoid opposition and build consensus. The interactive GIS approach addresses the problem in a holistic manner which gives rise to a greater range of options, many of which will be better environmental solutions (in the sense that environmental damage is minimized) than would have been developed otherwise. Finally, because this approach allows for real-time interaction with the data, 'what if' scenarios can be developed and analyzed. This capability allows the stakeholders to have a constructive dialog in search of a solution and also allows for the implementation of adaptive management policies that seek to improve decisions based on new information as well as feedback from past decisions.

2. Background

2.1 History / Background of Dredging in the U.S.

Dredging is defined as the process used to deepen harbors and waterways and involves the removal of material, generally sediments, from navigation channels and port areas. Dredging has been carried out for well over 100 years in ports of the United States and is a continual process. The U.S. Army Corps of Engineers (USACOE) is the chief agency in charge of dredging as defined by the Rivers and Harbors Act of 1899. Today, with oversight from the U.S. Environmental Protection Agency (USEPA), the Corps is responsible for maintaining federal ports and channels as well as issuing dredging permits to state, local and private parties (OTA 1987).

2.1.1 Causes and Needs

There are two primary factors that necessitate the need for dredging -- siltation/sedimentation and new generations of larger ships. There are two sources of sediments: (a) fine solids in rivers and streams settle out of the water column in the slower moving harbor and (b) current and wave action wash solids in from the ocean as well as redistribute and erode shorelines and channel boundaries. In addition, organic material from sewer and storm water systems can contribute to an increase in siltation. Over time, this sediment accumulates on the bottom of port and harbors, filling in channels and berthing areas, and reducing the amount of water depth available for navigation. Dredging is then required to remove the sediment to maintain a clear and safe passage for vessel traffic.

The second factor that necessitates the need for dredging is the continual development of deeper draft ships and the improvement in port facilities. Basic science tells us that larger ships can move cargo more efficiently, using less fuel, than smaller ships because the amount of cargo that can be carried is related to the cube of the draft while the energy required is related to the square of the draft. This means that larger ships can carry a unit of cargo for less cost per unit than smaller ships. In order to accommodate these larger ships in the current port areas, the underlying parent material at the bottom of the harbor needs to be dredged (improvement dredging) to increase the available depth (NRC 1985).

Today, the trend in shipping is toward intermodal transportation and the development of superports. These new ports will accommodate the largest intercontinental ships and will be used as transfer areas for cargo to smaller vessels as well as trains and trucks for distribution along the coast and inland. These new port areas will require deeper access and more frequent maintenance dredging than existing ports (NRC 1985). While ports such as Boston Harbor are unlikely to become superports, continued dredging will be necessary to maintain existing port facilities for coastal shipping and military preparedness. It has been estimated that over 400 million cubic yards of material is dredged from U.S. ports every year and that 4-16 million cubic yards, mostly from urban ports, can be classified as contaminated (USACOE, personal communication). Thus, issues of dredged material disposal are significant and policies will need to be developed to address future disposal needs and management options for these large quantities of material.

2.1.2 Dredging Methods

Dredging methods can generally be classified into three categories based on the type of equipment used: mechanical, hydraulic, pneumatic (Barr 1987, Palermo *et al.* 1988). Mechanical dredging involves the use of buckets and backhoes to cut and physically remove material from the harbor bottom and can be used on a wide variety of materials. The advantages of mechanical dredging are that it extracts material at near *in-situ* densities with little disturbance to the material. Typical disadvantages of mechanical dredging include significant losses and leakage from open buckets, release of large amounts of resuspended sediments, imprecise control over depth of cuts, and the slow production speed as compared to other methods. A new type of bucket, called an environmental bucket, eliminates many of the problems with leakage and turbidity, which can contribute to the release of contaminants, and has been used for removing contaminated sediments in ports such as Boston Harbor. It utilizes a series of seals and baffles to prevent material from leaking from the bucket once it has been closed. However, this bucket tends to bring up much more water than a tradition clamshell bucket, can not dredge cohesive or rocky material, and has a much slower production rate than other bucket types.

Hydraulic dredging involves the use of pumps to remove sediments by suction while mixing it with water to create a slurry and is the most common form of dredging in the U.S. (Palermo *et al.* 1988). It is generally used in sandy environments, can remove large quantities of material quickly, has accurate

depth control, can minimize turbidity, and is generally less expensive than other types of dredging. However, because of the need to create a slurry for pumping the material though the pipeline, the disposal area needs to accommodate a large quantity of material and allow for settling and flocculation of the sediment. Because of this, it is not frequently used for fine grain sediments unless there is a need to minimize resuspension of contaminants at the dredging site. In addition, hydraulic dredging cannot remove rocky or very cohesive materials. (Barr 1987, Palermo *et al.* 1988).

Pneumatic methods use compressed air to suck material into a submerged containment chamber and to pump it to the surface. The pneumatic systems are the least used systems in the United States, primarily because of the high expense and low availability of the equipment. Advantages of the pneumatic systems are that they can dredge material with a low water volume in the slurry, they don't create large turbidity problems, and they are good for the removal of contaminated sediments. However, they can not be used for coarse grained sediments which further limits their use (Barr 1987, Palermo *et al.* 1988).

2.1.3 Disposal Options

There are three general types of disposal options, classified based on location: open ocean, near shore, and upland (Dolin and Pederson 1991, OTA 1987). Within each of these categories there is a wide range of alternatives and regulations that govern the disposal of dredged material. The following sections outline some of these options and regulations and also the special considerations for contaminated sediments.

2.1.3.1 Open Ocean

Historically, open ocean disposal of dredged sediments has been the most common disposal option. Costs are low, there is essentially unlimited capacity, and the material is removed from sight and mind. However, with the advent of the Marine Protection, Research and Sanctuaries Act (MPRSA) in 1972, the U.S. Environmental Protection Agency (USEPA) has the authority to designate ocean dumping sites. Permission must be granted by the USEPA, USACOE, and often state agencies before any dumping can take place. Other regulations, such as the Clean Water Act (CWA) also give USEPA and

state agencies authority to manage disposal of dredged material (OTA 1987) See Figure 2-1 for the jurisdictional boundaries affecting marine disposal.

Figure 2-1. Jurisdictional Boundaries of Environmental Laws Affecting Marine Disposal
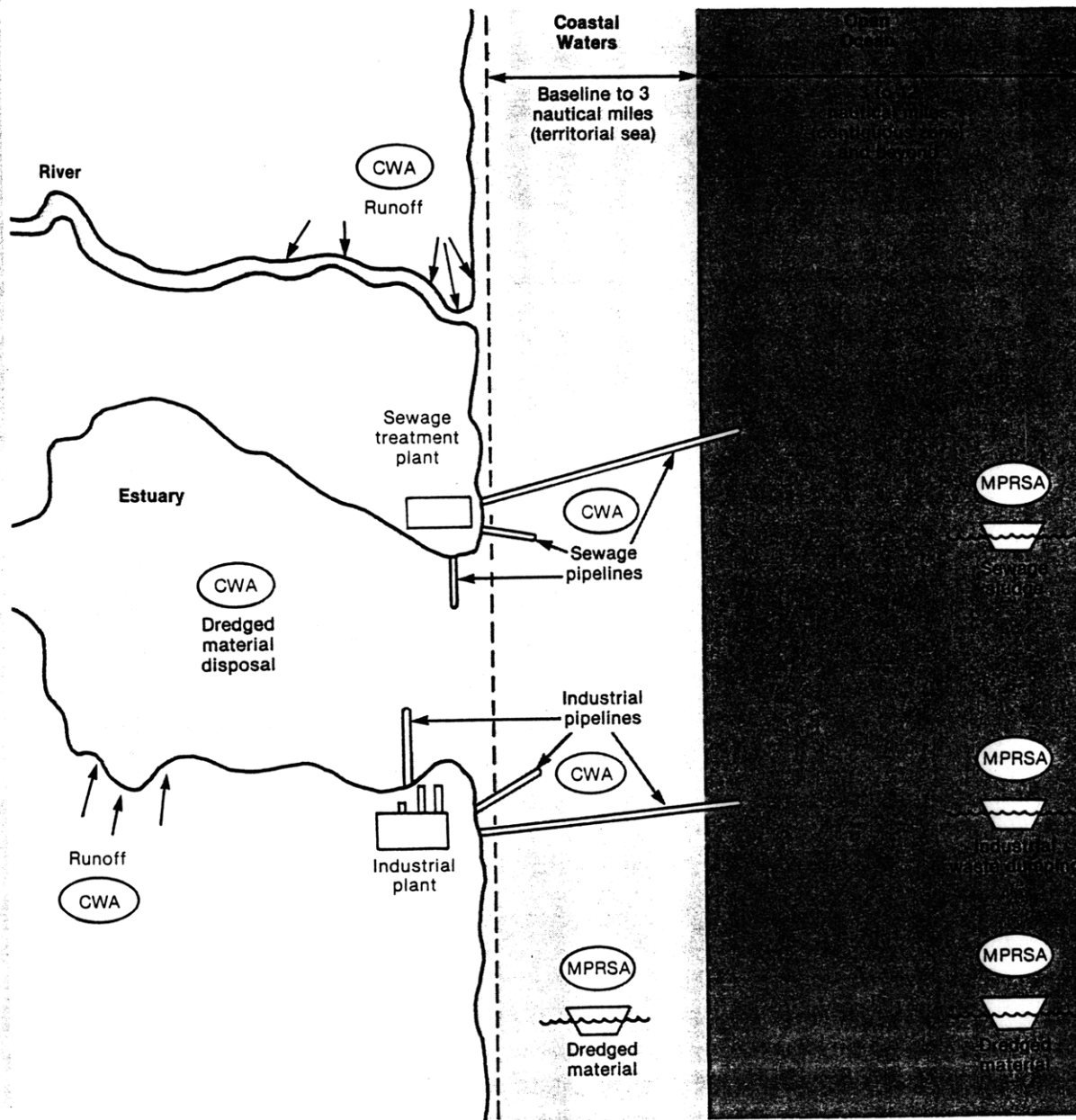
CWA – Clean Water Act, formally known as the Federal Water Pollution Control Act
MPRSA – Marine Protection, Research, and Sanctuaries Act
Dumping beyond the inner boundary of the territorial sea is covered by MPRSA (CWA covers dumping within the territorial sea in principle, but is preempted by MPRSA (see box A)). Estuarine dumping falls under CWA.
Pipelines (wherever they are located) are covered by CWA.

SOURCE: Office of Technology Assessment, 1987; adapted from National Advisory Committee on Oceans and Atmosphere, *The Role of the Ocean in a Waste Management Strategy* (Washington, DC: U.S. Government Printing Office, 1981).

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Under MPRSA, two criteria must be satisfied before dumping can take place. First, it must be shown that all practicable alternatives to ocean disposal have been examined and are not feasible. Second, it must be shown that the dredged material is of sufficient quality, biologically, physically, and chemically, to be disposed of in the ocean. However, through the use of capping, defined as the covering of contaminated sediments with a layer of clean sediment or sand (see Figure 2-2), it may be possible to meet all of the regulatory criteria for disposal of contaminated sediments (Dolin and Pederson 1991).

Figure 2-2. Schematic of Capping Cross Section
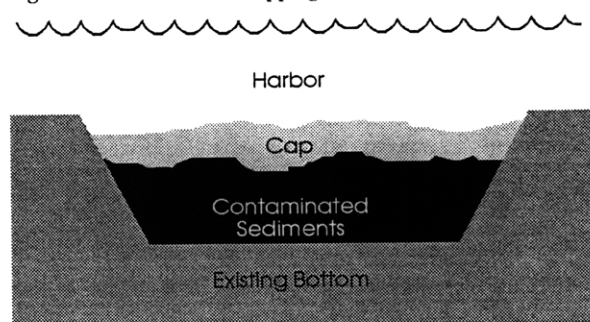
In Massachusetts, USEPA has designated the Massachusetts Bay Disposal Site (MBDS) ocean disposal site in deep water (greater than 100 meters). Historically, this site was used for disposal of contaminated sediments and low-level radioactive wastes. However, regulations have become more stringent and, until capping has been successfully demonstrated in deep water, open ocean disposal of contaminated sediments is not allowed. The MBDS and a state approved site in Cape Cod Bay (CCBDS), accept clean sediments that meet the evaluation requirements set out by USACOE and USEPA. Sediments unsuitable for open water disposal, such as those from Boston's Inner Harbor, must go elsewhere (see Figure 2-3).

2.1.3.2 Near Shore

Many of the practicable options for dredged material disposal lie with the near shore and aquatic disposal sites. Near shore or coastal waters are generally defined as harbors, bays, and estuaries and other waters that extend up to three nautical miles offshore from the mean low water mark (Dolin and Pederson 1991). These options include: containment islands/areas (sometimes referred to as confined disposal facilities or CDFs), borrow pits, capped disposal cells, habitat creation, beach nourishment, and sidecasting.

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Figure 2-3. Map of Boston Harbor
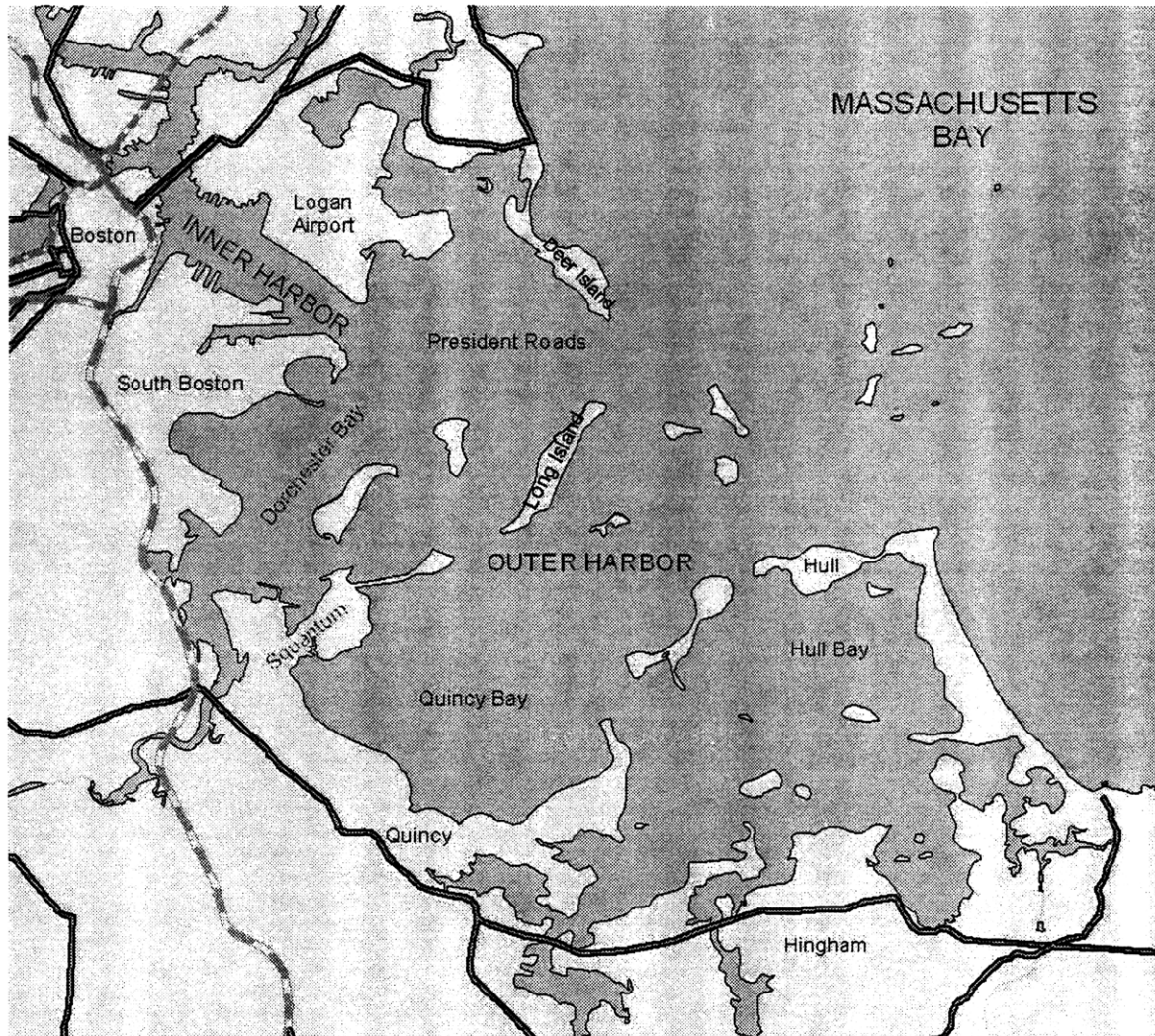
Similar to the requirements for ocean dumping, it must be shown, under either the MPRSA or the CWA, that all practicable alternatives to near shore disposal have been examined and are unfeasible before this option can be pursued. A classic example of conflicting regulations is evidenced here; the CWA states that the preferred disposal option is open ocean, whereas the MPRSA has upland disposal as the preferred option. For both of these regulations, as with the requirements for ocean dumping, it must be shown that the material for disposal is suitable for the near shore environment. This is done, in part, by applying the evaluation requirements set out by USACOE and USEPA and, in Massachusetts, through the issuance of a state Water Quality Certificate from the Department of Environmental Protection.

Containment Islands / Areas

Containment areas (see Figures 2-4 and 2-5), whether an island or attached to an existing land mass, are, as the name implies, designed to contain the dredged material and minimize environmental impacts. Containment areas are constructed by building a dike around the outside perimeter of the area or island and then placing contaminated sediments within the dike. These sediments are dewatered and then the site can be used for development, recreation or habitat enhancement projects.

Figure 2-4. Containment Area Cross Section
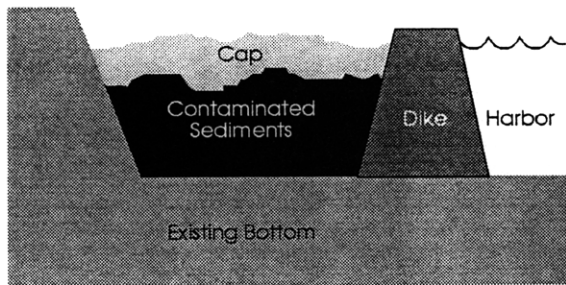
Figure 2-5. Containment Island Cross Section
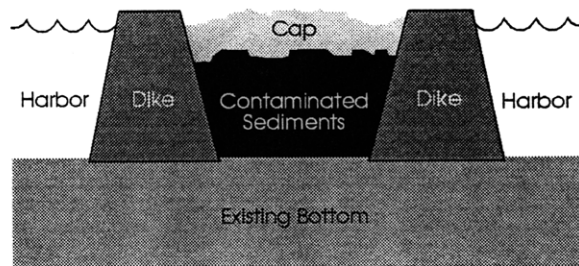
For contaminated sediments special care must be taken when constructing containment areas. The design must include provisions for restricting leaching of the contaminants through the dike and for controlling effluent that might escape over the top of the dike. For these reasons, along with maintenance and monitoring requirements, containment areas and islands tend to be very expensive. See Table 2-1 for a listing of costs.

Table 2-1. Costs of Disposal Options for BHNIP

Type	Cost Range
Landfill	$62-108 / cy
Containment Areas / Island	$21-$362 / cy
Borrow Pits / Disposal Cells (with capping)	$30-$33 / cy
Open Ocean	$16-27 / cy

Source: USACOE and Massport, *BHNIP Final EIR/EIS Volume 1*

Borrow Pits / Capped Disposal Cells

Borrow pits and disposal cells are essentially large depressions in the sea floor into which sediments are disposed (see Figure 2-6). Borrow pits are either natural depressions in the topography or areas which have previously been

Figure 2-6. Disposal Cell or Borrow Pit Cross Section
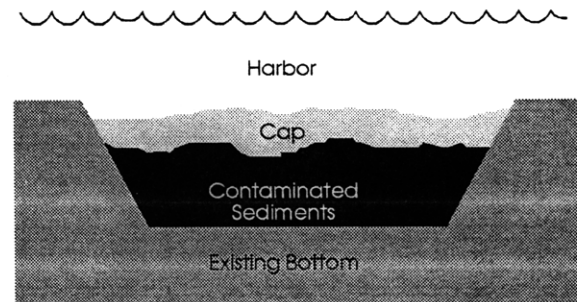
mined for sand or gravel whereas disposal cells are pits that have been dug for the sole purpose of providing an area for the disposal of dredged sediments. A new term, in-channel disposal, has come into use with disposal cells placed in existing channels.

Capping of borrow pits and disposal cells to isolate contaminated sediments has recently been accepted as a disposal option and is generally less controversial than capping in the open ocean (SAIC 1995). However, problems with capping, such as incomplete coverage, in several places around the country, including Boston Harbor, have left unresolved questions as to its actual success in isolating contaminants.

The basic procedure for creating a disposal cell is as follows: First the top layer of contaminated sediments is removed down to clean material and stored. Then a large pit or cell is dug into the clean parent material. This clean material is removed and either disposed of elsewhere (generally in open water) or put to beneficial reuse. Finally, the contaminated dredged material is dumped into the cell or borrow pit and covered, with clean sediment or sand if needed, back to the elevation of the surrounding sea floor (MCZM 1997).

This option is one of the less expensive disposal options for contaminated sediments (see Table 2-1) and has the advantages of providing for potential remediation (by removing the top layer of contaminated sediments), of returning an area to a similar condition after construction, and of potentially isolating the contaminated sediments from the environment. However, there are still a number of technical issues to be resolved concerning the placement of the cap and its success in isolating contaminants from the water column and biota (Averett *et al.* 1989, Dolin and Pederson 1991, SAIC 1995, MCZM 1997).

Habitat Creation / Beach Nourishment

These two options generally fall under the broader category of "beneficial reuse" (Dolin and Pederson 1991, Houston 1998). In these instances dredged material can be used for the creation of wetlands, reefs, oyster beds, and seagrass meadows, or for beach renourishment. Several factors influence the use of dredged material for habitat creation or beach nourishment. First, the material must be compatible with the beneficial use. Silty or contaminated material would not be suitable for beach nourishment, for example. Second, it must be determined that the creation of the new habitat is more beneficial than the

habitat that it will invariably destroy and replace. These considerations severely restrict the use of contaminated sediments for these activities. However, most states and federal agencies heavily promote the beneficial reuse of dredged material where possible (Houston 1998).

Sidecasting

Sidecasting is a technique most often employed in the southern United States. This disposal method consists of discharging hydraulically dredged material to one side of the channel or berthing areas. It is a quick and inexpensive method for disposal but generally can not be used for silty and/or contaminated sediments because of the potential for mixing in the water column and large turbidity plumes.

2.1.3.3 Upland

Upland disposal options include placing material in specially designated landfills, landfill capping, habitat creation, and other types of beneficial reuse such as construction fill. These options tend to be expensive but preferred by the MPRSA. There are several problems with upland disposal such as the need to dewater marine sediments, large transportation distances and number of trips required to move large quantities of material, and adverse impacts on local communities. In Massachusetts, owing to the ~13 million cubic yards of excavated material from the Central Artery Project (MDPW 1989), also known as the "Big Dig," and the closing of many landfills, there is very little, if any, upland capacity for clean sediment and even less for contaminated sediment.

Landfilling / Landfill capping.

Landfilling and landfill capping utilize dewatered sediments either as a daily cover or as a final cap. In addition to the general problems of upland disposal outlined previously, material that is destined for landfills comes under special solid waste regulations. These regulations tend to be unclear, discouraging the use of marine materials in landfills and making permitting such a disposal option very problematic. In Massachusetts many landfills are currently being closed and it is unlikely that new landfills will be designated, especially for dredged material.

Habitat Creation

Upland habitat creation is very similar to aquatic habitat creation except in the final location of the disposal area. Dredged material can be used to create freshwater wetlands, forested areas, and meadows. Again, this option tends to be expensive because of dewatering and transportation costs and generally isn't suitable for contaminated sediments (Houston 1998).

Commercial Re-use.

Commercial re-use is one of the most attractive disposal options. It has the potential to reduce costs by avoiding disposal charges in a landfill or by transferring transportation costs to the end user. Rock, gravel and sand can all be used for large construction projects as fill and base material. Contractors generally will avoid using contaminated sediments, such as those from Boston Harbor, due to liability concerns with the contaminants potentially leaching out into the surrounding environment (Houston 1998).

2.1.3.4 Other Options for Contaminated Material

In addition to the disposal options outlined previously, there is also the option of decontaminating dredged material before it is disposed. Once dredged material has been decontaminated it can be disposed of in the most beneficial manner using one of the disposal options previously described. However, decontamination technologies are very expensive and generally unsuitable for large production volumes. Much research is currently going into improving and developing new decontamination technologies and it is conceivable that this option will be much more viable at a future date (USACOE and Massport 1994, Averett *et al.* 1989).

2.2 GIS Overview

Other technologies, such as Geographic Information Systems, lend themselves to the planning and management of dredged disposal areas. A Geographic Information System (GIS) is the general term given to a suite of computer programs that allow for the manipulation and visualization of spatial data. Two published definitions of GIS are (1) "A system of hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modeling, and display of spatially referenced

data for solving complex planning and management problems" (Rhind 1989) and, a little more compactly, (2) "A computer system that can hold and use data describing places on the earth's surface" (Rhind 1989, ESRI 1996).

2.2.1 Spatial Data

The key to any GIS application is spatial data. Spatial data are data that can be geo-referenced to a place on the earth, meaning that it can be represented by a set of X,Y (and Z) coordinates. Examples of spatial data include a street address, the location and elevation of a mountain top, and the boundaries of a city (ESRI 1996).

There are two primary types of digital spatial data: raster and vector (see Figures 2-7 and 2-8). Raster data is made up of grid cells covering the entire region of interest. All of the grid cells are of equal size and are assigned a value based on the data layer and coverage of the individual cell. For example, a grid (raster) file of elevation might be comprised of many cells in which each takes on the value of the mean elevation of the land within the area encompassed by that cell. The accuracy of the data is determined primarily by the grid size. A larger grid cell results in fewer cells overall and less storage capacity and computation time. However, these savings come at a cost in the form of lost resolution. Another example of raster data is a digital image. In this case, each grid cell represents a color which makes up part of the image. Vector data are represented by points, lines, and polygons (which is made up by points and lines joined together). Owing to the fact that only the location of the points, endpoints of a line, or vertices of a polygon need to be stored, vector data are typically much more compact than raster data and the endpoints are generally stored very precisely (ESRI 1996).

Algorithms have been developed that allow for data of one type to be converted to the other. Elevation contours (vector data) can be created from a raster grid of elevation. Conversely, given a set of contours, a raster grid modeling land elevation can be created. ArcView readily supports vector and image data. If the Spatial Analyst extension is used, ArcView can support raster data and perform the necessary algorithms to convert between data types (ESRI 1996).

Figure 2-7. Example of Vector Data
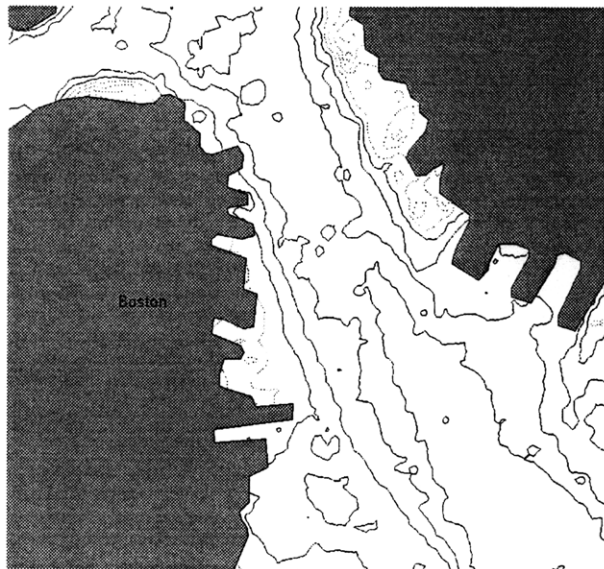
Figure 2-8. Example of Raster Data
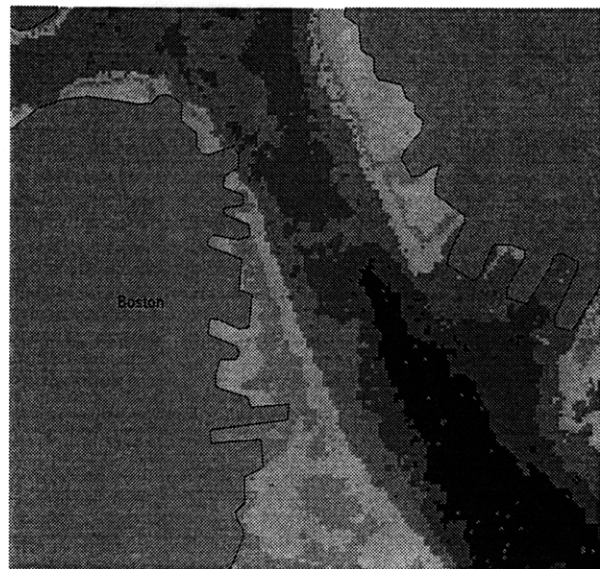
Today GIS data are available from a variety of sources. First, the end user can create data directly. All modern GIS systems allow users to input and manipulate their own data. This might include linking an existing database of say, customer locations or soil samples, to a map for further analysis. This might also include obtaining spatial data, such as digital elevation model data, and converting it for use with a particular GIS software package.

Second, many government agencies distribute data in a GIS ready form. For example, the Commonwealth of Massachusetts distributes GIS data which includes road delineations, political boundaries, environmental resources, census data, and recreational areas. The federal government is a large distributor of data including the U.S. census derived TIGER (Topologically Integrated Geographic Encoding and Referencing) files that allow for the spatial aggregation of census data (see http://tiger.census.gov) and digital elevation models put together by the U.S. Geological Survey (see http://mapping.usgs.gov).

Finally, there are off-the-shelf commercial distributors of data. These companies span a wide range in the services that they provide. Some companies simply modify and make custom data sets, that are geared toward a specific purpose such as address locating, from government data such as the TIGER files. Other companies provide very specialized and high tech services such as satellite and aerial

imagery which is corrected for optical distortions and geo-referenced for inclusion with modern GIS applications.

For the aquatic environment there is relatively little GIS data available when compared to the data available for land-based environments. This is a result of two conditions. The first is that many paper based data sets have not been geo-referenced or digitized. It is anticipated that as government agencies and research institutions continue to develop and migrate towards GIS-based data management solutions that these data limitations will decrease. The second reason for a lack of aquatic data is that relatively little is known about the aquatic environment as compared to land-based environments. Research in the marine environment tends to be more costly and difficult to carry out. As a result, less data is generated that can be used for future studies.

2.2.2 Costs

GIS systems were first developed in the early 1960's for the large mainframe computers of the time and as a result tended to be very costly. However, today, with the continual evolution of computer hardware and software following Moore's Law (see http://developer.intel.com/solutions/archive/issue2/focus.htm), costs have been dropping while computing power and sophistication have risen. Most desktop computers today have enough power to run all but the most sophisticated GIS analyses. With the reduced costs of the various software packages, a GIS system can be put together for $2000 - $10,000, depending on the sophistication and speed desired. These low costs, coupled with the high functionality of the current software, have lead to an explosion in the use of GIS.

2.2.3 Abilities / Application

A Geographic Information System has five basic attributes (Rhind 1989). First, it can map and analyze what exists at a particular location, whether it is land use, customer type, or census data. The second attribute is somewhat the opposite of the first: a GIS can find locations that meet a particular specification. For example, what areas have a certain land use, a customer of a specified type, or a population of a given size? The third attribute is the capability to map changes for a given location or specification over time. This allows one to examine trends in land use change, customer preferences, or population growth. The fourth attribute is the capability to determine patterns or anomalies in the

data. Does there tend to be more pollution in land use areas of a specific type? Do customers with credit cards spend more? Do customers with credit cards but with more than 4 children spend less? These are all examples of the types of patterns GIS can help identify and examine. The last attribute is modeling. This attribute tends to help with planning and management issues such as 'What would happen if we changed the land use in this area?' or 'Where would be the best place to put a new store?' This last attribute tends to be where the real power of GIS exists. Answers to environmental planning and management questions rely on the interpretation of complicated interactions of data that are generally beyond the scope of traditional approaches. GIS can track and model these complex interactions and provide a meaningful analysis of what is occurring for managers. (Rhind 1989, ESRI 1996).

With so many different capabilities, it is no surprise to find that GIS is currently being used in a wide variety of applications. United Parcel Service (UPS) and Federal Express use GIS to track and manage their package delivery systems (see http://www.ups.com and http://www.federalexpress.com). The Massachusetts Water Resource Authority (MWRA) uses GIS to map and manage the many miles of water and sewer pipe under it's jurisdiction. The Boston Redevelopment Authority uses GIS to map its property holdings and for future planning purposes. Large oil companies and state agencies (see http://www.fmri.usf.edu/fmri/programs/ismgt/camra/mrgis/avmsas.html) make use of environmental sensitivity maps and GIS for planning responses to oil spills. Many engineering firms are using GIS to assist with the planning of new construction, the protection of the environment, and analysis of engineering options.

2.2.4 Application to Dredged Material Management

With so much potential and varied applications, GIS can be viewed as a general toolbox. And it is only natural that these many tools and relevant applications can aid in solving some of the problems of dredged material management. The extent, volume and physical properties of the material to be dredged can be mapped and computed. Disposal locations can be mapped and analyzed for suitability. Environmental, physical, and human resources constraints can be mapped and included in the siting analysis of disposal areas. Transportation routes can be determined to minimize cost or traffic through a residential neighborhood. Thus, Geographic Information Systems have the potential to aid in most facets of dredged material management. However, this thesis only examines the use of GIS in locating

dredged material disposal sites utilizing the disposal cell option. This was done to limit the scope of the project to a reasonable level and to minimize the amount of data that needed to be gathered. Obtaining the necessary data is the biggest obstacle to any siting study. For a study to be complete, consideration of the physical, biological, chemical, and human use factors in a region is important. In addition, data must be in the proper format and of sufficient quality to be of use. For the purposes of this study the methodology and evaluation of the new approach was of more interest than the actual results of a siting study which depend highly upon the underlying data.

3. Development of Approach

3.1 Current Siting Methodology

This section focuses on the traditional method of siting dredged disposal areas which is a matrix based approach. Although much of this information can be generalized to the entire United States, each state has a specific set of environmental regulations and guidelines that can create differences in siting methodology. The recent Boston Harbor project is used as a case study and specifics of the siting process, as outlined in the Environmental Impact Reports/Statements (EIR/S) for that project, are presented (USACOE and Massport 1994, 1995).

3.1.1 General Description

The general process for siting dredged material disposal sites can be divided into several steps and is shown for the BHNIP in Table 3-1. The initial site-selection process, before public comments are sought, is generally outlined in a Draft Environmental Impact Report while the final list of sites and a review of the public comments is generally reported in the Final EIR/S (USACOE and Massport 1994, 1995).

Table 3-1. Site Selection Process for BHNIP

Process	Phase
Identify a universe of sites for consideration (upland, near shore, open water)	
Identify "fatal flaws" and remove unsuitable sites	(Phase I)
Eliminate sites from consideration based on some criteria to produce a 'short list' of sites.	(Phase II)
Gather more information on short listed sites and re-evaluate sites in term of Phase II criteria	(Phase III)
Put forth the short list of sites for public comment and review	
Revise the short list and gather more information based on public comment	(Phase IV)
Pick preferred disposal option(s) using set criteria to determine the most suitable site(s).	

The initial universe of sites for consideration, within a given radius, is developed by reviewing other project studies in the area, through discussions with federal, state, and local agencies, and by engineers and consultants identifying sites based on local data and professional judgment.

Once this universe of sites is established, a set of criteria is established by which the sites are to be evaluated. Typically these criteria address environmental, logistical, regulatory, and economic factors such as habitat, capacity, contamination, and cost. Generally a different set of criteria is established for upland, nearshore and open ocean disposal sites owing to the inherent differences in the disposal options. Once these criteria are established, the sites and criteria are typically outlined in a spreadsheet or matrix, hence being called the matrix approach. This facilitates the application of the site selection criteria to the universe of sites previously identified. Using the criteria, sites are removed from consideration until only a short list of sites remains. Often the criteria have to be modified to avoid removing too many or too few sites (USACOE and Massport, 1994).

Once the short list has been established, the process is documented and submitted for public review. This gives the public the opportunity to question the initial universe of sites and the criteria used to develop the short list. After public comments have been received, changes are made to the selection criteria or universe of sites, as needed. A new matrix is set up and after the application of the new selection criteria a preferred site(s) is chosen.

3.1.1.1 Boston Harbor

In the Draft EIR/S (USACOE and Massport 1994), the Boston Harbor Navigation Improvement Project identified a universe of 374 sites for consideration as disposal locations for the dredged material. Table 3-2 outlines sites by type (USACOE and Massport,1994). These sites were identified from reviews of other siting plans, such as the Central Artery/Tunnel Project (CA/T) (MDPW 1989) and a USEPA study on nearshore disposal facilities (USEPA 1992), discussions with local, state, and federal agencies, and from consultation with the Disposal Options Working Group (DOWG). The DOWG was a subset of the Project Advisory Committee which was composed of local and state agencies along with public and private interest groups with the purpose of facilitating communication and advising Massport and the Army Corps of Engineers (the project proponents).

Table 3-2. Phase I Sites

Type	Number
Upland	335
Near Shore /Aquatic	38
Open Ocean	3

Source: USACOE and Massport, *Draft BHNIP EIR/S*, Appendix E

Once the universe of potential sites had been identified, a four phase process was used to screen the sites and develop a short list of proposed disposal areas. Phase I consisted of identifying fatal flaws in sites and removing them from further consideration. Fatal flaws

Table 3-3. Sites Remaining After Phase I Screening

Type of Site	Number Under Consideration
Land-based inland	14
Land-based Coastal	12
Landfills	4
Aquatic Shoreline	10
Subaqueous Depressions	6
Borrow Pits	4
In-Channel Cells	Not Identified in Phase I
Existing Open Water Sites	2
Total	52

Source: USACOE and Massport, *BHNIP Draft EIR/S*, Volume 1

were derived from regulatory prohibitions such as sites located in an Area of Critical Environmental Concern (ACEC), sites containing a water supply well or sole-source aquifer, and sites containing rare or endangered species habitat. Table 3-3 lists the sites remaining under consideration at the completion of phase I. It is important to note that Phase I resulted in the elimination of over 85% of sites considered in the initial universe.

Phase II consisted of developing a set of objective criteria for evaluating sites, establishing a matrix, and applying the criteria. The criteria chosen were based on regulatory guidelines and requirements such as the Clean Water Act and the Massachusetts Wetlands Protection Act. In addition, other items deemed to be of importance to the DOWG were included. Finally, each criterion was designated as being either a standard ("S") or priority ("P") classification. Priority criteria were those that required compliance due to regulations, while standard criteria were important in the context of the overall site evaluation. See Appendix A (table E10, USACOE and Massport, 1994) for a reproduction of the site selection criteria. Using these criteria and matrix, sites were evaluated and either eliminated from consideration or short-listed for Phase III evaluation. See Appendix A (tables E11-E17, USACOE and Massport 1994) for listing of the matrix.

Phase III consisted of developing additional information on each of the short-listed sites and then reevaluating them in terms of the phase II criteria. In addition, the three in-channel disposal cells were added to the list of sites under consideration by the DOWG. This brought the total number of sites under consideration to 24. See Appendix A (table E19, USACOE and Massport 1994) for a listing of sites. Following the development of the short list resulting from Phase III, the Corps and Massport were required by the National Environmental Protection Act (NEPA) to identify the agency's preferred alternative or alternatives, if one or more exists, in the draft statement (USACOE and

Massport 1994). This regulation resulted in the five sites being listed in Table 3-4 being designated as preferred alternatives.

Table 3-4. Preferred Sites Identified Following Phase III

Name	Type	Capacity (cy)	Cost
Mass Bay Disposal Site (MBDS)	Open Water	Unknown / Exceeds project needs	$18 / cy
Boston Lightship	Open Water	Unknown / Exceeds project needs	$18 / cy
Meisburger 2	Borrow Pit	4, 660,000	$20 / cy
Meisburger 7	Borrow Pit	6,125,000	$22 / cy
Spectacle Island CAD	Borrow Pit	1,450,000	$25 / cy

Source: USACOE and Massport, *BHNIP Draft EIR/S*, Volume 1

The next step was to publish and distribute the Draft EIR/S and hold public meetings to solicit both written and oral comments. In response to public comments, two criteria were dropped -- cost was eliminated as a fatal flaw criterion and the 200,000 cy minimum capacity requirement was eliminated. Following the public comment period, Phase IV of the screening process was begun, which consisted of gathering more data concerning water resources on the land based sites and biological conditions at the aquatic sites. Additional studies were also undertaken to assess the availability of treatment technologies to improve sediment quality and to contribute to potential beneficial reuse. It was found that there are not currently any treatment technologies suitable for use with a project of this type (USACOE and Massport, 1994, 1995).

The additional data gathered was used to further screen the short list of 24 sites identified in Phase III. In addition, it was assumed that the rock and parent material removed from the dredging areas would be used for beneficial uses whenever possible and that the remaining material would be disposed of at the Massachusetts Bay Disposal Site (MBDS) because this was the least expensive and most practicable alternative. This meant that from this point on the short listed sites were under consideration for the disposal of the 1.1 million cubic yards or contaminated material considered unsuitable for unconfined ocean disposal. It is interesting to note that the various costs and capacities listed for the short-listed disposal options changed quite a bit on the basis of this new information (see Table 3-5).

Following Phase IV, a detailed environmental and practicability analysis was undertaken as required by NEPA and MEPA. Under these regulations, a project must demonstrate that it avoids or minimizes any adverse impacts to environmental quality, taking into consideration all local, state, and federal

regulations. The two analyses, environmental and practicability, were performed separately in response to comments received during the public review period.

Table 3-5. Disposal Cost Differences Between Draft and Final EIR/S

Type	Cost (Draft EIR/S)	Cost (Final EIR/S)
Upland	$50 - $101 / cy	$44 - $108 / cy
Aquatic	$16 - $ 278 / cy	$19 - $362 / cy
Open Ocean	$18 / cy	$16 - $27 /cy

Source: USACOE and Massport, *BHNIP Draft EIR/S*, Volume 1; *BHNIP Final EIR/S*, Volume 1

At this point a matrix was set up with environmental screening criteria and sites that were a "Least Environmentally Damaging Alternative (LEDA)" were identified. Because of this evaluation, all of the sites picked in the DEIR/S as being a preferred option were removed from further consideration because they did not meet the LEDA standards established. These standards were developed out of comments from the review of the DEIR/S and implicitly stated that disposal within or near the disturbed environment of the dredging areas in the inner harbor was preferred to the relatively undisturbed areas in the outer harbor and in Massachusetts Bay.

Following the LEDA screening, a practicability analysis was carried out to aid in the selection of the preferred options. This analysis consisted primarily of examining the cost and capacity of the LEDA sites. Of the LEDA sites, only the Squantum Point and Little Mystic Channel partial fill sites along with the in-channel sites were considered to be practical. Following this selection the environmental impacts were reexamined and the in-channel disposal sites were chosen as the preferred option for disposal of the dredged material. None of the preferred sites from phase III (table 3-4) were considered to be viable options (USACOE and Massport 1995).

3.1.2 Strengths and Weaknesses

The matrix approach is powerful because it allows for the development of decision criteria and provides for a standardized method of applying it to sites under consideration. This approach also allows for criteria and site selection decisions to be revisited, as needed, based on changes in the project or on the basis of new information. In addition, the matrix approach can be modified in a number of different ways to suit a particular project. For example, the various criteria can be assigned a weighting value to represent the relative importance of any one criterion in relation to the others. It can also be used for both a quantitative and a qualitative comparison of the options (Boraczek 1998).

There are several limitations of the matrix approach that might have solutions through the use of new technologies such as GIS. First, there is the issue of choosing a universe of sites. In the case of Boston Harbor an aquatic disposal alternative was chosen. However, out of the total universe of 374 sites there were only 41 aquatic sites. This means essentially that there were only 41 possible locations for this material. With an area as large as Boston Harbor (~45 square miles) it is very conceivable that many possible aquatic disposal locations were not included in the analysis. Through the choice of the initial site selection, there is the possibility of manipulating and directing disposal options towards a particular region or method. In addition, the initial reasons and methodology for selecting these sites tends to be poorly documented and somewhat arbitrary. This can lead to skepticism or opposition by the public (Interagency Working Group on the Dredging Process 1994).

Another problem is that assumptions and decisions can get buried in the middle of a matrix which can lead to confusion. When faced with 20-30 selection criteria and 40 sites, it becomes very difficult to track all of the decisions and assumptions that contribute to selecting a site. Ironically, this is, in fact, one of the reasons the matrix was created -- to track the various parameters. However, due to the sheer size of the matrix it is possible to overwhelm and confuse the reader with information. While it is important from a documentation point of view to have the full matrix, it is not necessarily the most productive method for producing a decision or conveying information about the methodology or assumptions entering into that decision. Additionally, because of the size of the matrix, it can be difficult to reassess and revise decisions based on new data.

Finally, public input is often sought late in the initial site selection process. In the case of the BHNIP sites were identified, criteria were established and an initial impact report was written before many general public comments were solicited. Even the creation of an advisory committee that integrated input from the various stakeholders, including local and environmental groups failed to capture public concerns in a meaningful way. When all of the proposed options for disposal are thrown out after the public comment period, it raises the question of how effective the advisory committee process really was. By providing for meaningful and informed public input at the initial stages of the project there is the strong potential to save both time and money in the site selection process. This might eliminate or reduce the need to redesign or make significant, and costly, changes to the universe of sites or the selection criteria in the middle of the planning process (Interagency Working Group on the Dredging Process 1994).

3.2 Conceptual Model

It is anticipated that many of the weaknesses of the matrix approach, such as the lack of public input and a holistic planning, can be eliminated through the use of new management tools and new applications of technology. The use of GIS technology for locating dredged material disposal sites is natural given the power and flexibility that it provides. The issue at hand is whether an easy to use, interactive approach that allows for both scientific, engineering and community input and adaptive management could be developed and be a useful tool (Lee 1989, NRC 1995). This section outlines the reasoning and development of the conceptual model used for this GIS application. See Figure 3-1 for a general outline of this model.

Figure 3-1. Outline of Conceptual Model for Interactive GIS Approach

ACTION	Gather Data Layers	Rank Individual Data Layers for Site Suitability	Combine with Other Data Layers Using a Geometric Mean
PRODUCT	Raw GIS Data	Ranked Suitability Map	Final Suitability Map
INPUT		Scientific / Engineering Input	Public Input
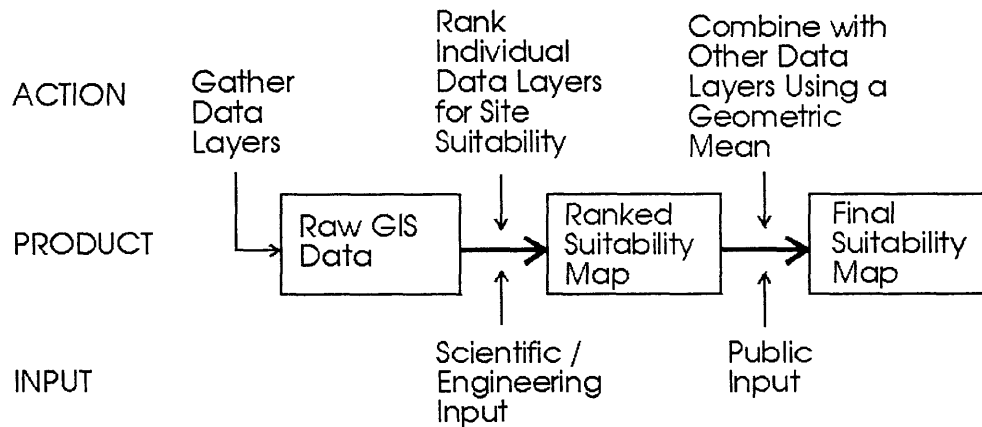
Using GIS and a ranked and weighted set of criteria for screening the data, the New York District of the Army Corps and the Port of NY/NJ developed a similar approach to siting dredged material disposal sites (Palermo et al., 1998). However, this approach, while validating the general methodology outlined in this thesis, ignores the possible gains to be had from the development of an interactive approach. Specifically, the NY/NJ use of GIS is a static approach that raises the questions of how weighting factors are defined and who defines them. The report issued on the NY/NJ approach does not document any of the assumptions or decisions that were made to arrive at the weighted values shown (Palermo et al., 1998). Furthermore, it cannot be determined if the values represent any sort of consensus among harbor users, scientists, regulators, environmentalists, and the general public.

Other approaches to the problem of siting disposal sites and decision making, such as multi-attribute utility analysis (deNeufville 1990), value tree analysis (Kunreuther et al. 1983), and the analytic hierarchy

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process (Kunreuther *et al.* 1983), were not considered because of several perceived limitations. One limitation is that these other approaches constitute radical departures from the current methodology and would not easily fit within the existing institutional arrangements (Kunreuther *et al.* 1983). The time and expertise required to conduct these types of analyses limit their application to trained analysts and also limit the ability of the public, regulators, and scientists to discuss and analyze the results (and underlying assumptions). In addition, while these techniques are useful for obtaining preferences and values of individuals they do little to facilitate the examination of tradeoffs inherent in any consensus building approach.

3.2.1 Use as a Pre-Screening Tool

Traditional approaches to site selection using a matrix evaluation method tend to be limited, both in terms of the sites considered and in community and scientific input. It was recognized from the beginning that possibly the most powerful application of GIS technology would be in the development of a 'pre-screening' tool. Because of the data management capabilities of GIS, it is no longer necessary to start with a finite number of sites for consideration. Rather, a region or domain of consideration can be defined and analyzed. As opposed to the matrix approach, where only a finite number of sites within a domain are analyzed, with the GIS approach every area within the domain is a candidate site. This provides for an almost infinite number of sites from the beginning and allows the data and user input to determine which sites are most suitable for further consideration.

Since the FEIR/S was completed, the Massachusetts Coastal Zone Management (MCZM) office has determined, based on state regulations governing upland disposal, that all land-based disposal sites will be deemed unfeasible and is in the process of completing a generic study that can be applied to any dredging project that presents information attesting to this fact. This study will satisfy all of the applicable state and federal regulations requiring an examination of upland alternatives (Personal communication with Deerin Babb-Brott, MCZM). Currently there is not sufficient capacity identified to provide for the future maintenance dredging of an estimated 7 million cubic yards of contaminated sediment anticipated to infill the project dredging areas (USACOE and Massport 1995). It is likely that disposal cells in the outer harbor will be one of the most promising options for future disposal needs because the open water sites have been eliminated from consideration due to sediment contaminant

levels, the upland sites have been deemed unfeasible, and it is assumed that the Corps will utilize all of the capacity of the inner harbor for disposal cells first.

With this in mind, the current approach was developed to be used as a pre-screening and decision making tool for selecting initial sites for disposal cells in the outer harbor. It was designed to be used at public and regulatory workshops as a tool to facilitate constructive dialog on candidate sites during the pre-screening period of the site selection process. It is anticipated that this tool would be used to develop a short list of 1-10 sites for further investigation and review as part of the federal and state Environmental Impact Review/Statement process.

3.2.2 Scientific / Engineering Input

An important component of any site selection process is the incorporation of good scientific and engineering input. Sites should make sense physically, chemically, and biologically and be technically feasible (NRC 1995, OTA 1987). As such, it is important to incorporate this type of input into the GIS approach developed.

This input is incorporated in two ways. The first is through the inclusion and exclusion of the various data layers. By providing for the inclusion and removal of data layers, as needed, a system can be developed that allows for the proper information needed for good scientific and engineering analysis to be considered. It is necessary at this point to document methods and reasons for including certain data layers while excluding others so that the choice of data cannot be considered arbitrary. Good engineering judgment and regulatory input is needed to ensure that the proper sets of data are included.

The second way this scientific and engineering input is incorporated is through the development of a suitability ranking system for each data layer. In this manner, each data layer can be evaluated by a small committee of expert scientists or engineers and a system for determining areas of better and worse suitability for the siting of a disposal area can be developed. These rankings should be based on sound science and represent, as much as possible, consensus among the scientific and engineering communities. Ranking schemes for the individual data layers should be well documented to allow for peer and public review. This helps ensure reproducibility and accountability in the decision making process which is important to any process affecting the environment and the public.

3.2.3 Community Input

The nature of community/public input can be a critical part of any siting process. Political and community opposition have the potential to derail or force significant modifications to any site selection decision (NRC 1985). An example of this was the adoption of the in-channel disposal sites in Boston Harbor over the 'preferred' borrow pit locations. It was hypothesized that the inclusion of community opinion in the site selection process in the very beginning could help avoid significant modifications or obstructions to the project in the later stages providing both possible time and money savings to the project. Thus, some method of allowing for public input without disregarding the scientific and engineering knowledge was needed. This was provided by developing an interactive interface to the GIS application that allows for users and the public in particular to supply weights to the individual data layers that were ranked previously by the scientists and engineers (see Figure 3-1).

The weighting of the ranked data layers allows for the relative importance of individual data layers to be evaluated. In this way the community valuation of the various aspects and resources that enter into any siting decision can be determined and possible obstacles minimized (NRC 1985, 1995). In addition, this provides for some separation of science and policy. Issues of whether shellfish beds or ships are more important are fundamentally policy choices which should be based on informed public representation and consensus. Science cannot, strictly speaking, address issues of this nature, though a strong understanding of the underlying science is desirable. There is no truth or theorem that governs these choices. Rather, these issues and policies are reflections of a continually changing public society.

3.2.4 Ease of use

In order to inform the public and allow the interactive GIS approach to be successful, an easy-to-use interface is necessary. Because the target audience is the general public in addition to scientists, engineers, and policy makers, it was assumed that the user would have only basic computer experience (use of keyboard and mouse) and no GIS experience. Thus, the challenge is to develop an intuitive interface that requires almost no explanation for it use.

These goals are accomplished through the adoption of a graphical user interface (GUI). This interface utilizes radio slider bars, much like you would find on a graphical equalizer on any home stereo, that control the weighting of the data layers (see Figure 3-2)o. The higher a slider control is placed, the higher the weight assigned to that layer. In addition, the visual representation of the weights allows for a quick summary of the individual and relative weights of the data layers. Finally, computation and display of the final suitability map is automated and requires only the simple click of one button on the weighting screen.

Figure 3-2. Weighting Graphical User Interface (GUI)
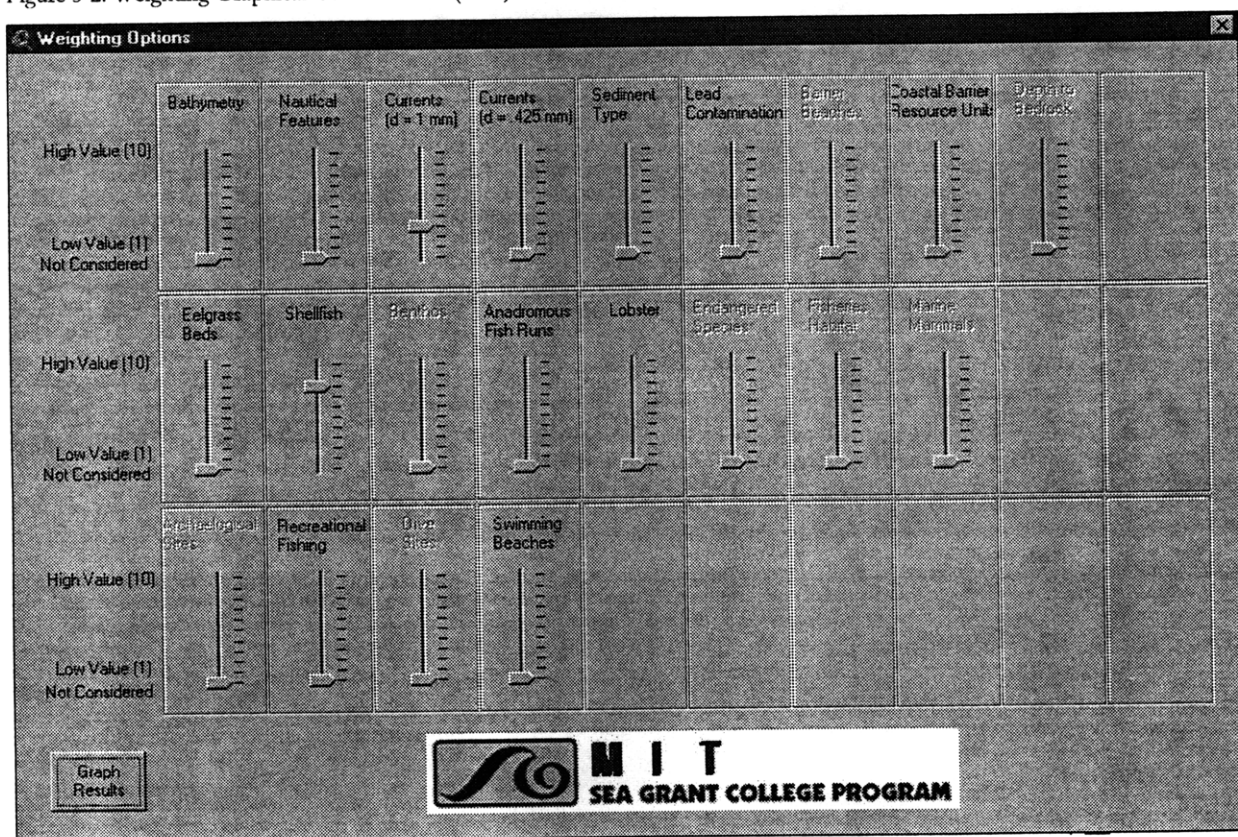
The rest of the user interface, with tools for identifying features, zooming and panning the view, and opening the weighting controls, was simplified to a few easily identified buttons. (See Appendices B and D for more information on the interface.) In this manner the user is not overwhelmed with choices and can perform many tasks with a simple button click. This is necessary to encourage and ensure public interest and participation. Without some means to simplify and strategically analyze the extensive data required to make complicated environmental and public policy decisions the public cannot be expected to make informed choices. With increasing demands being placed on individuals'

and organizations' time, management and decision making tools that provide the most information and knowledge per unit time input will be the most valuable.

3.2.5 Reproducibility / Tracking of Decisions and Assumptions.

As with any decision in the public domain, it is necessary to avoid being arbitrary and capricious. The interactive GIS approach needs to contain methods and means to reproduce any decision. This includes tracking the assumptions and limitations of the base data, documenting the analysis and assumptions in ranking the data layers, and finally recording the weightings that are used to create a final suitability map.

These goals are accomplished in a few different ways. The primary method for tracking these assumptions is through vigorous documentation. Metadata for the datalayers are recorded when available. The ranking scheme for each data layer is recorded along with the assumptions made and an explanation of how it is determined (see Appendix B). Finally, the weighting values used to produce each final suitability map are recorded on the map for reference.

This vigorous documentation has several advantages. First, it allows anyone to easily examine the process, assumptions, and decisions used to come up with a final suitability map. Second, they allow the user to go back and easily modify the system to see what happens when some assumptions or decisions are changed, either on the basis of new information or an audience with a different set of values. Because of the automatic nature of the computer system, changes to any of the underlying data or ranking schemes can be automatically propagated through the system to see how they affect the final suitability map. In this manner decisions can be reproduced and revised as needed. The ability to reproduce and revise decisions is key to adaptive management of environmental systems.

4. Methods

4.1 Suitability Rankings

One of the key components to the interactive GIS approach is the use of suitability rankings for each data layer. A similar approach was adopted by the Army Corps of Engineers, New York District for their latest site selection study in the Port of NY/NJ (Palermo *et al.* 1998). This documents the feasibility of this type of approach. The main differences between the two approaches, however, are that the approach being documented here interactively weights and combines the ranked layers and is designed for community use, whereas the approach used by the Corps is "static" and used primarily as a tool for Corps and Port engineers.

4.1.1 Scope / Availability of Data

Dredged material disposal sites have a potential impact on many resources and are affected by a variety of factors. All of these factors and resources should be included in any analysis of locating disposal sites. For the current study the data layers in Table 4-1 were identified as being important.

Those layers designated with a * were deemed to be of importance to be included in the analysis but unfortunately the data could not be obtained in a timely fashion. Some of these layers such as depth to bedrock and sediment contamination exist in paper form and simply need to be digitized. Other layers such as endangered

Table 4-1. Data Layers Included in Study

Physical / Chemical	Biological
Bathymetry	Eelgrass Beds
Nautical Features	Shellfish Beds
Currents	Benthos*
Sediment Type	Anadromous Fish Runs
Sediment Contamination*	Lobster Habitat*
Depth to Bedrock*	Endangered Species
Submarine Groundwater Discharge*	Fisheries Habitat*
	Marine Mammals*
Human Resources	
Recreational Fishing	
Swimming Beaches	
Archaeological Sites*	
Dive Sites*	

species are not released to the general public due to government policies designed to protect special habitat. In addition, data are simply lacking in some areas. For example, little is known about submarine groundwater discharge (SGD) or lobster habitat and migration patterns. Note that the system was designed to easily allow for additions and deletions from the list of data layers so that it can

be adapted to any changes affecting site selection and accommodate new information as it becomes available.

4.1.2 Future Development of Data

There are two primary needs for the future development of data. The first need is for a wider scope of data that is of better quality than is currently available. As mentioned previously, data on lobster and fisheries habitat are lacking. Almost nothing exists on submarine groundwater discharge. Other data such as the depth to bedrock simply need to be digitized. It is anticipated that digital data will become more accessible in the next few years as federal, state, and local agencies move to GIS to manage their extensive data holdings and convert their present data holdings to digital form.

The second need for data development is related to the determination of the suitability rankings. For this project only one person's expertise was used to develop the ranking schemes for each data layer. To some extent, these rankings are subjective as they are based on the best professional judgment of individual scientists and engineers. For future studies, the use of a small working group to determine data layer rankings should be encouraged. The use of a well-designed working group would help eliminate many of the personal biases that might come into the ranking if done by only one person. In addition, it is a simple form of peer review and could be considered more robust in any planning review.

4.1.3 Procedure

The general procedure for establishing a ranking scheme is as follows. First, basemaps are generated for the areas of interest. In this case Boston Outer Harbor was defined as the domain of interest and the land and water features were mapped. Relevant data were mapped and defined. Thus, for the bathymetry layer, a surface grid file was created from point bathymetric soundings. For the shellfish layer, classification areas were mapped and defined.

Each data layer and supporting layers were then sent out to knowledgeable scientists and engineers to be ranked into suitability areas. Supporting layers are data that are not represented in the actual data layer but that have an impact or association with the data to be ranked. An example of this is the

inclusion of bathymetry and sediment regions with the shellfish layer. Water depth and sediment type both influence the number and quality of shellfish beds and therefore are included in the ranking scheme for completeness. Each scientist or engineer then established a scheme for ranking each data layer and ranked areas on the map on a scale of 0 to 10. Areas receiving a 0 were deemed exclusionary areas. These are areas in which construction of a disposal cell and dumping of contaminated sediments would be prohibited either by regulation or technical issues. Areas receiving a value of 1 were deemed to be the most unsuitable for a disposal cell while areas receiving a value of 10 were deemed to be the most suitable. See Appendix B for a listing of data layer ranking schemes and documentation. Figures 4-1 – 4-4 outline the general procedure used to create the ranked shellfish layer.

Figure 4-1. Map Shellfish Bed Classification Areas
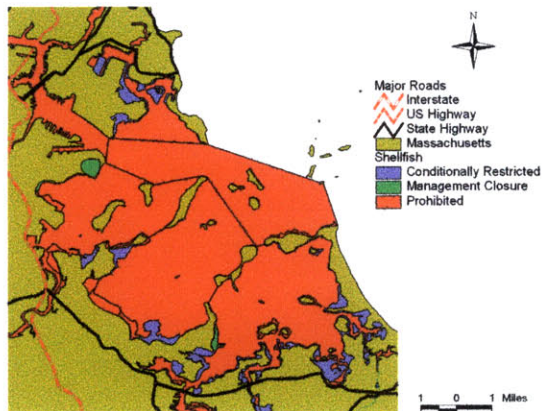
Figure 4-2. Map Sediment Regions
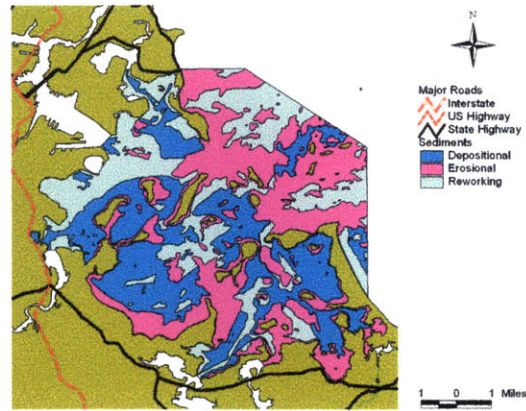
Figure 4-3. Map Bathymetry
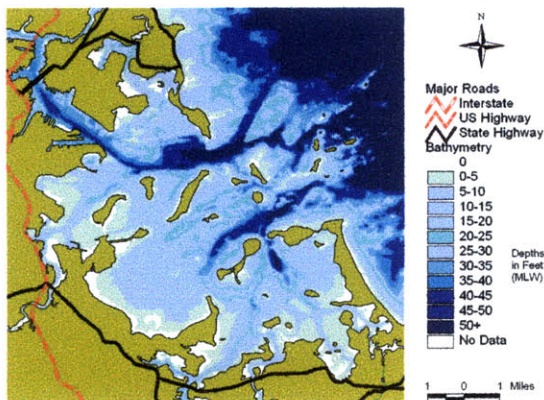
Figure 4-4. Rank Areas for Disposal Site Suitability Based on Classification Areas, Sediment Regions, and Bathymetry (see Appendix B)

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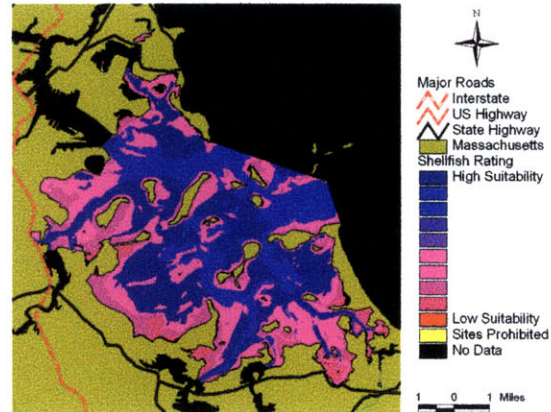
Once the ranking scheme was developed it was mapped using the available tools in ArcView and a grid file was created with the ranking values. See Appendix B for details of this process. The grid cell spacing chosen for this analysis was 10m x 10m. While the choice of grid cell size is somewhat arbitrary, the cell size should be small enough to represent the data accurately but large enough to not introduce any appearance of data being more accurate than it actually is. It should be noted that the final suitability map can be computed using a grid cell size that is the same size or larger than the base grid cell size. This allows for quick but coarse computations to be performed at first and then finer computations to be performed as the accuracy is needed. Once each ranked grid data layer was created it was loaded into the ArcView project containing the interactive interface.

4.2 System Customization

It was necessary to customize an ArcView Project to accomplish all of the goals of this project and convert the conceptual model into a working model. The primary goal of the system customization was to provide an easy-to-use graphical user interface for weighting the ranked data layers. It was assumed for the rest of the project that an experienced user would be available to create the ranked data layers from the base data using ArcView. In reality, creating the ranked data layers required some thought and planning but not a great deal of GIS experience.

Table 4-2. Definitions of Custom Interface Components

Item	Definition
Avenue Script	Custom programming code used in ArcView to automate tasks and create custom applications
Control Box	A dialog box containing buttons which activate custom features or controls
Dialog Box	A window containing buttons, text fields, or slider bars which accepts user input
Grid File	A raster (or grid) based data set. Grid files form the basis for the computations required to develop the final suitability maps.
Ranked Data Layer	A data layer which has been ranked by scientists or engineers to develop suitability areas for dredged material disposal sites
Final Suitability Map	A map created through the weighting and combining of individual ranked data layers. Weighting values are obtained from user input into the 'Weighting Controls' dialog box.

4.2.1 ArcView Interface.

The primary ArcView project interface makes a wide variety of tools available through menus, button bars, and tool bars. As shown in Figure 4-5 this interface can be overwhelming for a new user who is

unfamiliar with all of the capabilities and functions of ArcView. In order to simplify the interface and make it easier to use many of the features which were not needed for the end user such as the shape editing tools, legend editor, and complex query tools were removed from the interface. Only those tools which were deemed to be of use to the novice user such as zoom, pan and identify were retained. This resulted in the vastly simplified interface shown in Figure 4-6.

Figure 4-5. Default ArcView Interface
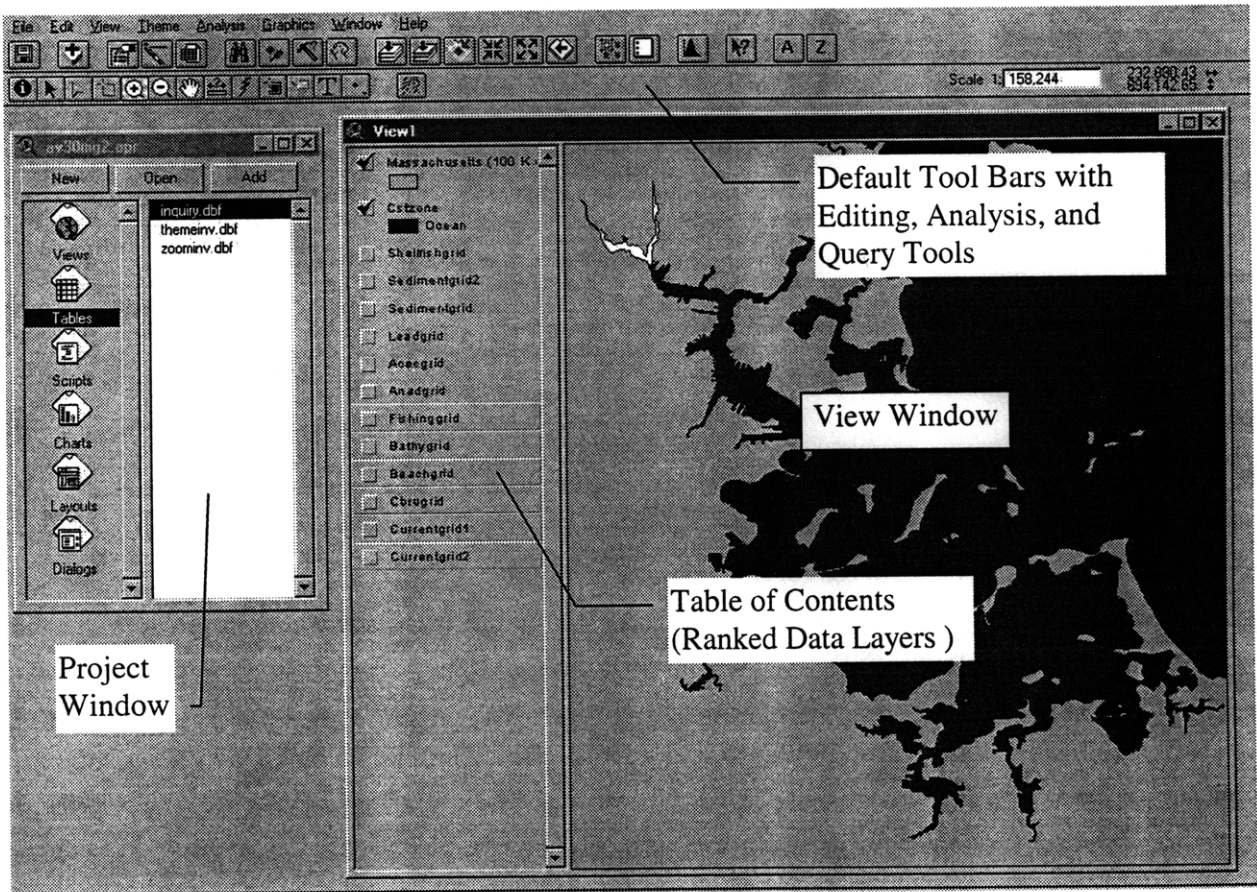
Figure 4-6. Simplified Graphical User Interface (GUI)
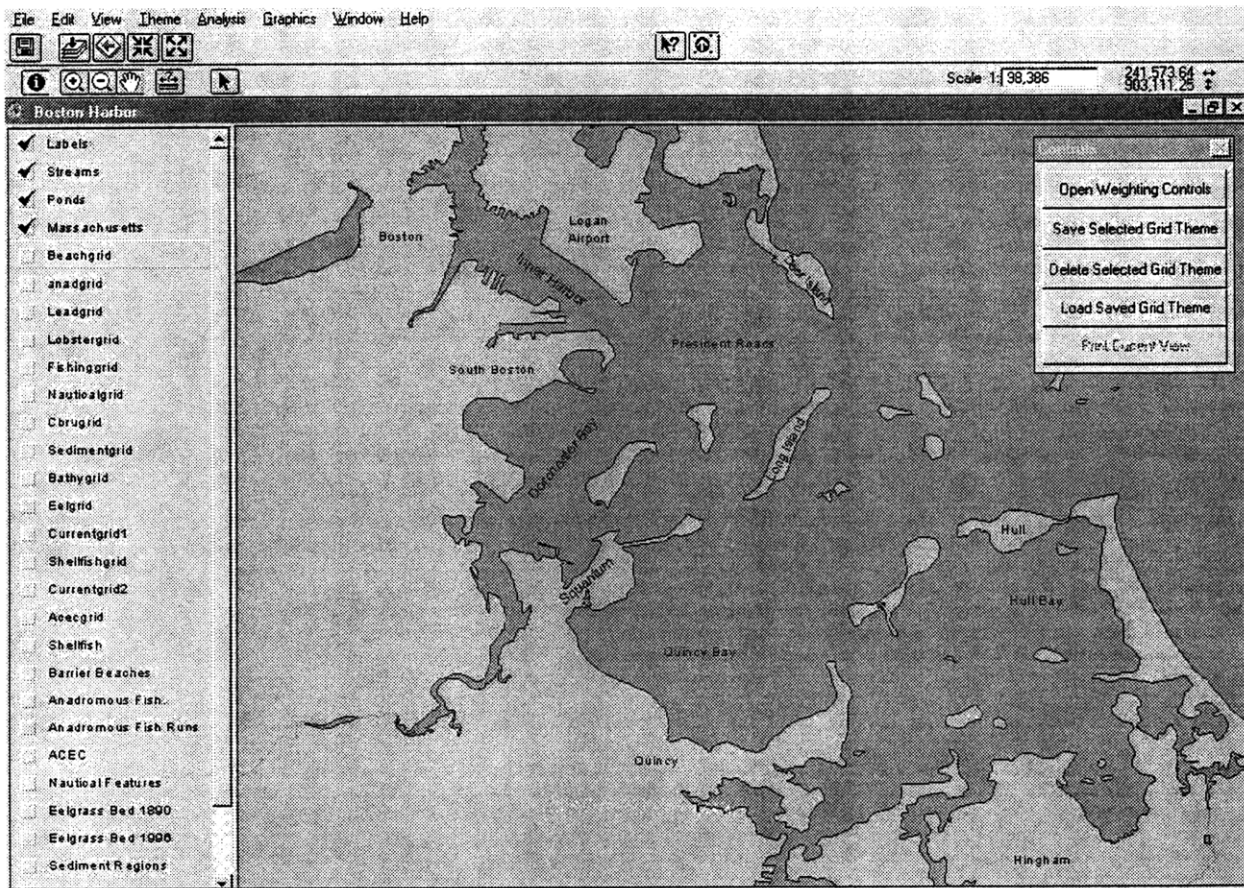
4.2.2 Dialog Designer Interfaces

To further simplify the user interface all of the weighting controls were preprogrammed and put into simple dialog boxes using the ArcView Dialog Designer extension. This extension simplifies the creation of custom dialogs without the need for traditional Visual Basic programming.

Figure 4-7. Control Box

The first dialog box that was created was the control box. See Figure 4-7. This dialog resides permanently on top of the view and contains the buttons that open up the weighting controls and loads, saves, or deletes the final suitability maps. It is anticipated that as the program is developed more controls will be added. A printing control has been added but is inactive because the necessary functionality has not been programmed. Other controls that might be added later would be the ability

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to subtract two final suitability layers from each other to map changes and a script that would identify all areas of a certain size that have a suitability above a specified value.

The second dialog box that was created was the weighting controls shown in Figure 3-2. This dialog is the primary interface for the program and allows users to easily specify weights for each of the ranked data layers using a slider bar. The slider bar can assume the value of 0 to 10 with zero corresponding to the "not considered" notch, 1 corresponding to "low value" and 10 corresponding to "high value." These values are then read by an ArcView Avenue script and used to compute the final suitability map. Avenue is ArcView's native programming language and is used to create custom scripts, macros and applications within the ArcView environment.

The controls in the weighting dialog box are arranged in three rows with like data layers residing in each row. Thus, the top row considers physical and chemical parameters, the second row biological, and the bottom row human resources. This dialog has been designed to allow for the easy addition of additional data layers. While spaces for only 30 controls have been provided for at this time, the dialog can be expanded at a later date to encompass more controls. It is anticipated, however, that any good siting study will be able to reduce the number of options to less than 30 to keep the analysis relatively simple and retain more meaning in the relative rankings of each data layer.

4.2.3 Avenue Scripts

There are seven Avenue scripts that are used to control the GIS application. See Appendix D for a complete listing of these scripts. The primary script, named "BH.GridCreation," performs all of the calculations and manipulations required to generate a final suitability map from the weighting control box and is activated by pressing the Get Results button in the lower left hand corner.

This script first identifies the current view in the project and turns off all of the active themes. It then gets the weighting values for each data layer from their respective slider bars and then divides each value by 10 to convert the weights to a 0 to 1 scale from a 0 to 10 scale. This step is necessary to avoid numerical dimensioning problems when combining the ranked layers using a geometric mean. The script also obtains each ranked data layer grid from the current view at this time.

Once all of the grids and weighting values have been obtained a final suitability grid is computed using a weighted geometric mean. The program computes a final value for each grid cell based on the value and weights put on the cells located in the same spatial position from each of the data layers. See Figures 4-8 – 4-12 for an example of this.

The general equation for the weighted geometric mean is as follows:

$$W.G.M = \sqrt[\Sigma WeightValues]{GridValue_1^{WeightValue_1} * GridValue_2^{WeightValue_2} * ... * GridValue_n^{WeightValue_n}}$$

This function was chosen because it has several beneficial properties. First, it allows for the inclusion of exclusionary areas. If a grid cell has a value of 0 in one of the data layers that cell will retain the value of 0 in the final suitability map owing to the multiplication of the individual terms in the geometric mean. Thus, if an area is prohibited from consideration owing to regulations governing one data layer it will be removed from consideration in the final analysis as well. The second property of the weighted geometric mean is that it retains the spatial properties of the underlying data layers. Another beneficial property was that by setting a weighting value to 0, you could effectively remove that layer from consideration in the final suitability map. This is because a weight of 0 causes the grid cells of that particular layer to all become identity (it raises all grid values of that layer to the zero power which equals one) which, when multiplied by the other values, does not effect the final result. The final property of the weighted geometric mean that was beneficial was that the final range of values was also between 0 and 10. This meant that a set scale for display and legend purposes could be created. With an arithmetic average or sum the data tended to either clump around a middle range or take on a wildly varying range which makes setting a display scale difficult and can influence the interpretation of the results. This is because, depending on the relative weighting values, different suitability maps will need different suitability scales and it becomes difficult to establish a common datum for comparison of results across different final suitability maps.

Figure 4-8. Ranked Shellfish Data Layer
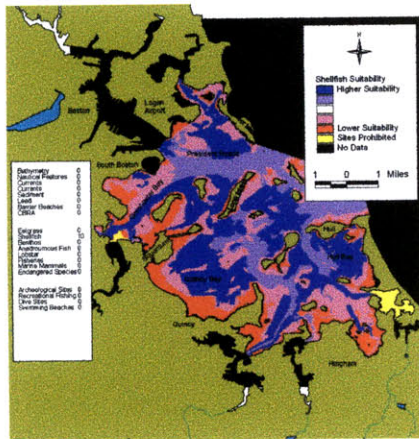
Figure 4-9. Ranked Current Data Layer
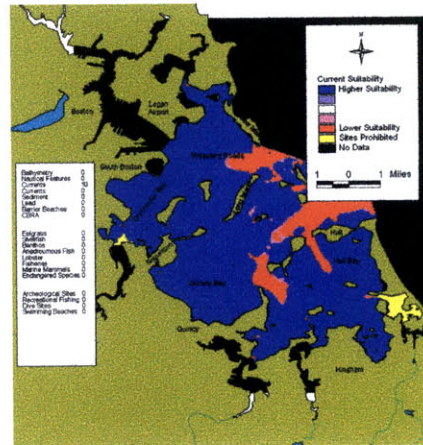
Figure 4-10. Combination 1.
Shellfish Weight: 3, Current Weight: 8
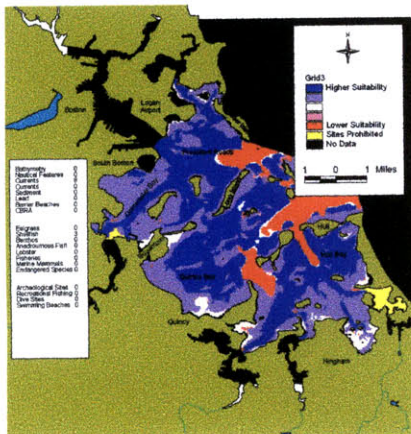
Figure 4-11. Combination 2.
Shellfish Weight: 5; Current Weight: 5
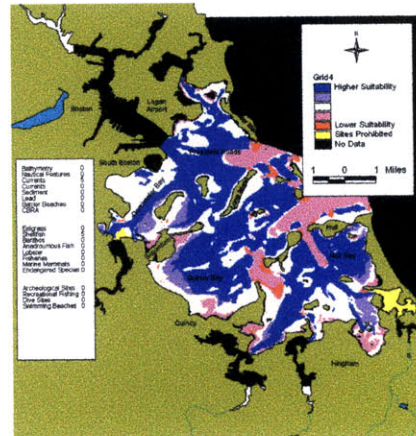
Figure 4-12. Combination 3.
Shellfish Weight: 8; Current Weight 3
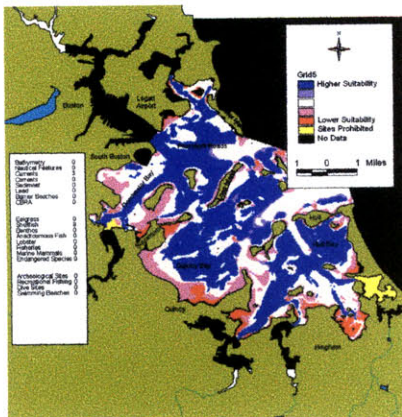
The most suitable areas are designated by the blue and purple colors while the least suitable areas are designated by the red and pink colors.

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After the final suitability grid is computed it is added to the theme in the proper location, made active and visible. All of the other basemap data, such as the harbor outline and labels, are also made visible at this time and the table of contents is locked to prevent the user from inadvertently making any changes. The suitability legend is then loaded in and applied to the theme. This legend classifies the final suitability map into 6 regions (see Figure 4-12). The first region represents prohibited sites (sites with a grid cell value of 0) and is colored yellow. The other five regions represent grid cell values between 1 and 10 and are assigned a color on a gradient from red to blue. Areas of lowest suitability, corresponding to grid cell values between 0 and 2 are colored red. Areas of highest suitability, corresponding to grid cell values between 8 and 10 are colored blue. Intermediate values (2-4, 4-6, and 6-8) take on intermediate colors. Only five colors were used because pre-trial runs demonstrated that it was difficult to differentiate between suitability regions if more colors were used. However, the original 0 to 10 scale was retained underneath because it allows for finer gradations to be used in the underlying ranked data layers.

The legend is only labeled in a qualitative sense indicating which areas are of a higher suitability for placement of a disposal cell, which areas are of a lower suitability, and which areas are prohibited. While a final value for each cell has been computed, it was determined during the development process of the GIS application that it was the relative differences in sites that were the most important. Because of the different types of data, rankings, and weights that contribute to the final suitability map, an absolute quantitative scale would have little overall meaning for comparing two final suitability maps. In addition, it was thought that the use of a quantitative scale would make the system appear to be more accurate than it really was and would tend to mask the uncertainty in the assumptions and weights that contribute heavily to the final suitability map. This could lead to the public championing sites with a final value of 8.2 over sites with a value of 8.1 when in reality the uncertainty of the process means that the sites are most likely relatively equal in suitability.

The next step in the BH.GridCreation script is to create and display a text box with all of the weighting values used to create that particular map. These values are fixed to a geographical location to the southwest of the harbor and are permanently added to the final map. Adding the text box to the map ensures that the weighting values will always be preserved and displayed with that map. This will aid in future reference and documentation of the creation of each suitability map.

Finally, the weighting dialog is closed and the user is free to examine the suitability map that has been created using the zoom, pan, and identify tools that are present in the toolbar. The user can also use the control box dialog to save or delete the map or open the weighting dialog again to create another suitability map.

4.3 Development of the Surveys

In order to evaluate the response to the interactive GIS approach, a set of survey questions was developed to be administered before and after public presentations of the system. The general concept was to administer a pre-questionnaire before the presentation that would be used to provide a datum for measuring responses to the new approach. Responses to this interactive GIS approach would be recorded in the post-questionnaire. From this, and general comments and discussion during the presentations, it was anticipated that an accurate evaluation of the project would be obtained.

The pre and post-questionnaires were developed together as a pair (see Appendix E for copies of the questionnaires). While the pre-questionnaire was designed to establish the participant's level of knowledge and experience with siting dredged material disposal and GIS. the post-questionnaire was designed to measure the participant's reaction to the program and approach. It was felt that pairing questions on the two surveys to measure results would yield the most useful answers. An example of this is question 14 on the pre-questionnaire and question 11 on the post questionnaire. Question 14 asks "Do you think that the current planning system provides the proper balance of public input, scientific analysis, and regulatory decisions?" while question 11 asks "Do you think that this system (the interactive GIS) provides for the proper balance of public input, scientific analysis, and regulatory decisions?"

The pre-questionnaire has two parts: a section on the participant's GIS background and a section on the participant's knowledge and views on the current site selection process. The first part was included to help analyze any biases that might be present between people who have used GIS and those that have not, while the second part was designed to measure the participants view of the current process and to pull out some information on what improvements they feel are needed. This second part

included questions on public participation, scientific input, timing of comments, and ease with which one can review assumptions and decisions.

The post questionnaire had a series of questions that were designed to follow up on specific questions in the pre-questionnaire. The first few questions follow up on the first part of the pre-questionnaire and address participants' willingness to use a GIS and attempt to measure the motivation level present. The rest of the questionnaire addresses the new approach and attempts to gather information that can be used to evaluate it, to provide some constructive criticism, and to improve it.

4.4 Public Demonstrations

Four public demonstrations were given in total over a two week period. A total of 24 people participated in the full demonstration. The group makeup was as follows

- 3 Academics (MIT)
- 14 Consultants (SAIC, ENSR and CDM)
- 5 Government Regulatory / Environmental Officials (DEP, CZM, Corps, MassGIS)
- 2 Other Agency Representatives (Massport, USCG)

Each demonstration took approximately one hour, which is quite reasonable when compared to the average length of most public meetings (See Appendix F for a copy of the talk). Participants were first asked to fill out the pre-questionnaire. After the pre-questionnaires were completed general background on GIS and the development of the interactive GIS application was given. This was followed by detailing the assumptions underlying the data and demonstrating the use of the GIS application. The participants were then asked to try the system and a discussion of the output and approach followed. Finally, the participants were asked to complete the post-questionnaire before leaving.

5. Results / Discussion

The general response to the interactive GIS approach was overwhelmingly positive. Some sample comments included "Great idea and nice job!" "Good effort and approach to the problem." "Excellent documentation of this critical tool and admirable attempt at data collection" "GIS is certainly an improvement in information/data presentation. By that it is more likely to be used." In addition, most participants liked the ease of use, the clarity of the visual representation of data, and the ability to analyze different 'what if' scenarios rapidly. Further analysis of the pre- and post-questionnaires reveals more detailed results and offers suggestions for future modifications to the interactive GIS approach.

5.1 Results

The majority of the participants (71%) had some prior knowledge of GIS or had used a GIS system. Consultants and government agency staff were more likely to have used GIS than the academic participants (see Figures 5-1 and 5-2). Almost all of the participants indicated that they had an improved knowledge of GIS after the demonstration. When asked whether they were interested in using GIS more frequently, all consultants responded with an overwhelming yes, the government agency staff were a mix of yes and not sure, while the academics were not very interested. However, all but one of the participants said that they would use GIS if it were readily available to them and that they would like to have access to the results of GIS analyses. All of the respondents indicated that their organization should be encouraging the use

Figure 5-1. Graph of Respondents Who Have Seen GIS Demonstrated
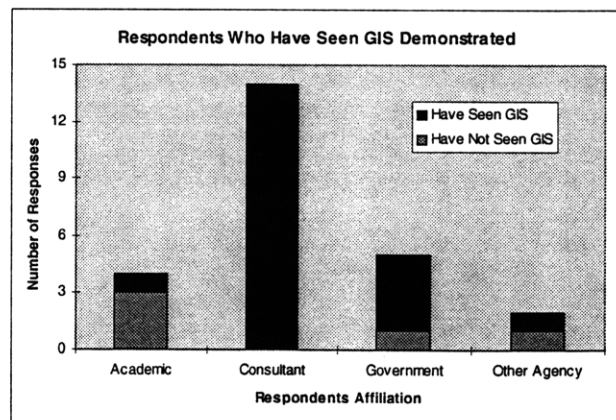
Figure 5-2. Graph of Respondents Who Have Used a GIS
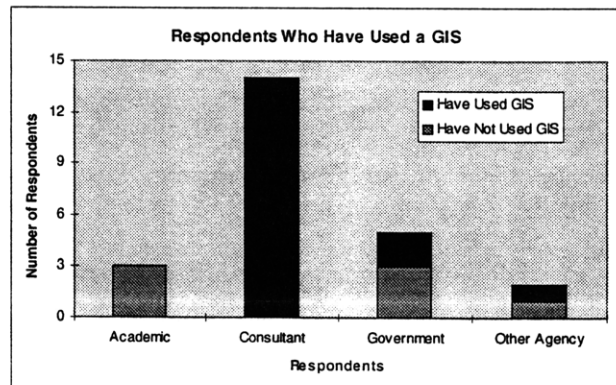
of GIS but 17% of the participants didn't indicate that they would be active in proposing increasing the use of the GIS, mostly due to time limitations (see Figures 5-3 and 5-4). When asked to evaluate their own GIS knowledge, participants with consulting firms consistently ranked their abilities higher than those in the other types of organizations.

Figure 5-3. Graph of Whether Companies Should Encourage the Use of GIS
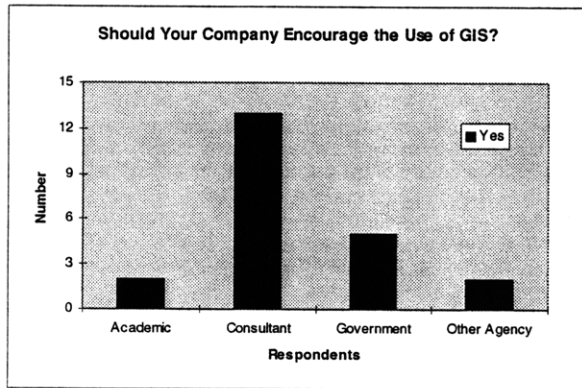
Figure 5-4. Graph of Whether Respondents Will Propose that Their Organization Increase its Use of GIS
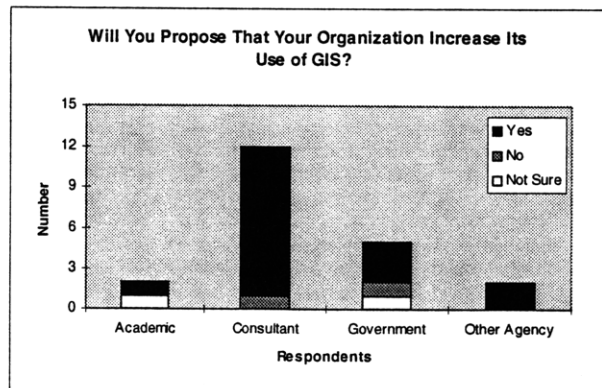
All but three of the participants indicated that GIS could be useful for site selection prior to seeing the demonstration. Following the demonstration, all 24 participants were in agreement that GIS has the potential to be a useful tool and all but one felt that efforts to develop the interactive GIS approach were worthwhile. The one consultant who indicated that efforts would be better spent elsewhere expressed a desire that more money be spent on improving data quality. When asked to rank the best use of GIS, data management and decision making were ranked high by participants. The next best use was for public presentation and education. Lastly, and not deemed to be of much importance, was the use of GIS for engineering studies. The relative ranking of uses did not vary significantly from before and after the presentations.

When asked about the most pressing problems with siting disposal areas participants responded that evaluating ecological and other impacts was the most pressing, followed by identifying cost effective and ecologically acceptable sites, and political "Not-In-My-BackYard (NIMBY)" issues. When asked what the solutions were to those problems the overwhelming response was for more data and better communication between all of the stakeholders.

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The group of participants had mixed feelings on whether the public had a positive or negative effect on the decision making process. Some felt that they did, others did not think so and many were simply unsure (see Figure 5-5). However, all of the participants felt that the public didn't have a thorough understanding of what data, analysis, and assumptions enter into current decisions. As a whole, the group felt that more public education was needed but were split in

Figure 5-5. Graph of the Effect of Public Participation on the Decision Making Process
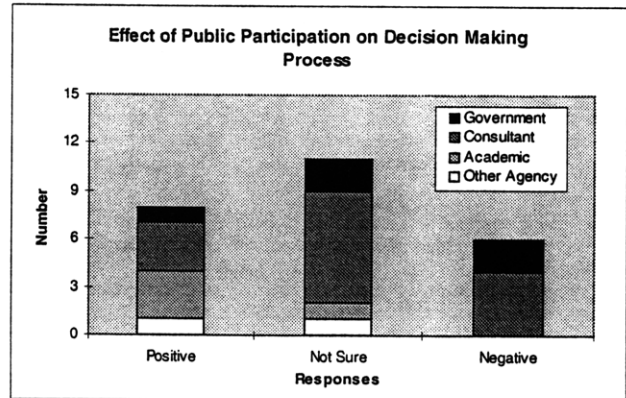
whether more involvement would be positive (see Figures 5-6 and 5-7). It is interesting to note here that the previously cited report by the National Research Council (NRC 1995) states that "the incorrect assumption is that an educated public is an agreeable public. It is not enough simply to inform the public about all the information used in the policy process. The public must have the opportunity to analyze the information and to voice its concerns and desires." This points out the common misperception that more public education is all that is needed to improve the public policy process.

Figure 5-6. Graph of Whether More Public Involvement is Needed
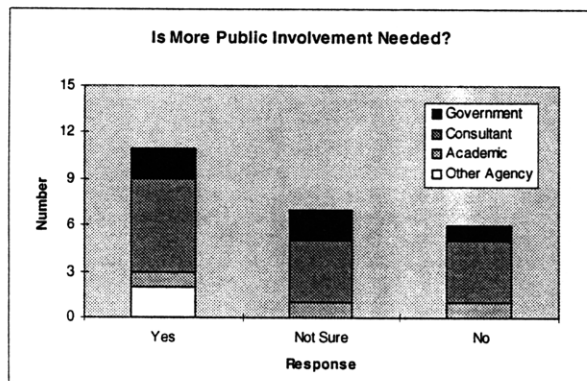
Figure 5-7. Graph of Whether More Public Education is Needed
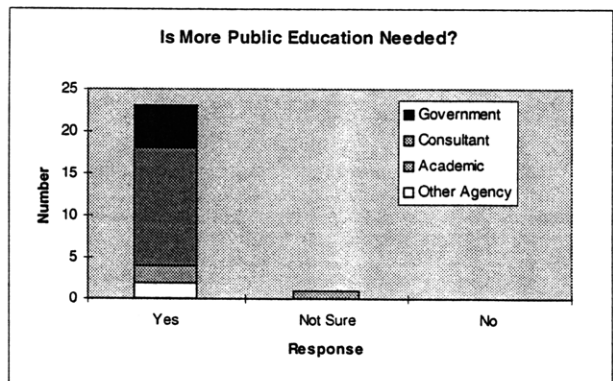
The participants indicated that the interactive GIS system demonstrated provides a good model for future GIS applications. They also felt that it did a much better job of balancing public input, scientific analysis, and regulatory decision making than the current system (see Figures 5-8 and 5-9). Most indicated that the public would appreciate the development and implementation of the system. In addition, most of the participants indicated that the model provided for more constructive public input than the current federal, state, and local planning systems. There was some debate as to whether this

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input was sought at the proper time both in the current and proposed systems. When asked to articulate when the best time was for public involvement about 8 people could be categorized as choosing the beginning of the selection process, about 5 as choosing throughout, and 4 as choosing post-screening with the rest indicating other reasons or limited involvement.

Figure 5-8. Graph of Whether the Current Matrix-Based System Provides the Proper Balance of Inputs
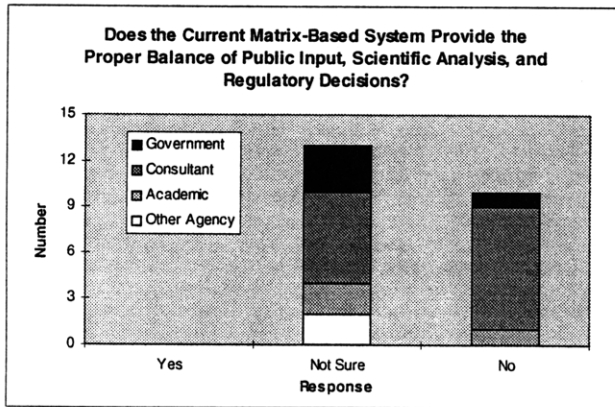
Figure 5-9. Graph of Whether the Proposed GIS-Based System Provides the Proper Balance of Inputs
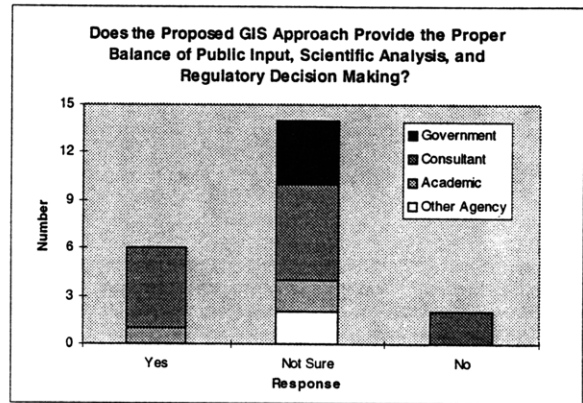
Finally, when asked to outline any reasons for not using a GIS system, the participants all expressed concern about the lack of data and the costs involved with obtaining high quality data. This theme also was exhibited in participants' responses to the question "What limitations do you think that the proposed GIS system will need to overcome in order to be useful?". However, a lack of data will affect any siting methodology and is not necessarily a flaw of the interactive GIS approach. In addition to the data gaps, the participants also expressed concern about a possible lack of public access to the system and also a lack of quantitative analysis.

5.2 Analysis/Discussion

Overall it can be concluded that the interactive GIS approach can be seen as a useful tool for site selection. Measurable changes in responses were recorded in the two questionnaires and demonstrated an increased awareness of GIS capabilities and its application to site selection, along with an overall attitude that an interactive GIS approach has strong potential as an improved method. However, as with any tool or method, there were a few limitations noted as well.

5.2.1 Limitations

One of the most limiting factors, which has been addressed previously in this paper, is the general lack of data for the aquatic environment. We currently do not have that much information on aquatic species numbers and habitats, transport mechanisms, sediment contamination and its effect on the surrounding environment, especially as compared to our knowledge of contaminants effects on land. Much of this problem will affect any siting methodology. Current site selection methods and environmental management policies often rely on relatively little data in making decisions. The data simply do not exist, or if they do exist they are so sparse or of such low quality that they have little value. Thus, the lack of data in general should not be seen as a primary limitation of this approach in particular.

There is a class of data that exists and are of high quality but has not either been transferred to digital form or is not easily mapped. Examples of this type of data for Boston Harbor include sediment depth that is useful for calculation of disposal cell capacities. The data are in paper form but have not been digitized and geo-referenced for use in a GIS system owing primarily to the large time requirement to do so. However, because of ongoing work at MassGIS, the primary state agency in charge of geographic data, and other agencies around the U.S., this problem should decrease in the next few years as more and more data are converted to GIS-compatible formats and as agencies and organizations turn to GIS and digital systems to store and manage their data. Two things motivate this move towards digital data. The first is that as we learn more about natural systems we require more data to support our understanding. The second is that because the data are so vast we have to rely on computer based tools to aid us in analyzing it. Having more data does not imply more knowledge. Rather, knowledge (and sound decision making based on that knowledge) is obtained from good analysis using the proper tools and data (Lee 1993). Thus, good digital data will become a necessity in the future.

Another issue that was raised was public access to the system. While it was anticipated that this system would provide an excellent tool to bring to public workshops and demonstration meetings, it was suggested that the public and, to some extent, regulatory officials needed greater access to the program and data (Interagency Working Group on the Dredging Process 1994). Some suggestions were to place computers in public locations such as the Museum of Science and the New England Aquarium as part

of an informational kiosk. However, it is anticipated that the greatest method for distributing the data and program is through the Internet. The MIT Sea Grant Marine Center on Capped Contaminated Sediments views the use of the Internet to incorporate public comments as a future research topic. This may be the most favorable approach for public involvement because it means that any member of the public can turn on their computer and interact with the GIS system. With the ever-increasing placement of computers in local libraries, it is anticipated that almost any member of the community could easily access the system. However, participants in the demonstration sessions did indicate that the best use for this type of interactive GIS system was for data management and decision making purposes. Any Internet-based system should have mechanisms in place to obtain public input and incorporate it into the decision making process rather than using it in a limited manner as just another public education tool.

5.2.2 Positive Results

From the survey questionnaires, it can be concluded that the proposed interactive GIS approach has significant potential to increase the opportunities for public input and communication. This was cited earlier as a possible solution to the problem of evaluating impacts and identifying cost effective and ecologically acceptable sites. Following up on the recommendations from the NRC, it also appears that the interactive approach has significant potential to allow the public to carefully assess the data involved in making siting decisions and allows it to voice its concerns (NRC 1995). The participants in the demonstration session all felt that this approach provided for effective public and scientific input and thought that it could provide a more constructive approach to siting disposal areas. This is important from a policy-making viewpoint because it allows for consensus building among stakeholders and the development of better, more scientifically based, environmental solutions to the problem of dredged material management.

In addition, through the discussions that evolved during the demonstration sessions, it became apparent that some of the real strengths of the interactive GIS approach lie in two areas. The first is the visual representation of the data and the ability to view the data in a holistic manner. Many of the workshop participants familiar with Boston Harbor were surprised at some of the data and saw connections between different types of data for the first time when viewing the maps. GIS allows the inherent spatial connections between data to be realized. The environment is not a system of discrete

entities, but rather a complex system of interactive parts (Lee 1989). Because of this, tools that can account for these more complex interactions in a holistic manner have greater potential than tools that cannot.

The second strength is the ease of use and quickness of the program. The demonstration participants indicated that the capability of the program to easily and quickly create 'what if' scenarios was especially powerful. Using 'what if' scenarios, one can identify data that has a large effect on site placement and data that has a lesser effect. Sites can be identified that tend to have a high suitability no matter what weighting values are used for the individual layers. The interactive GIS approach also allows for the demonstration and identification of compromise solutions through changes in the various weighting factors. Adaptive management techniques are also easier to apply because new information can be instantly incorporated into the analysis by changing the weighting values.

6. Conclusions / Recommendations

The use of an interactive Geographic Information System to implement the decision making method proposed in this thesis can be a powerful new tool for siting dredged material disposal areas. It allows for increased public and scientific participation, consideration of a larger universe of potential sites, analysis in a holistic manner, powerful visual representation of data and decisions, and clear documentation of decisions and underlying assumptions. While this approach is currently limited by data availability, other approaches have similar limitations.

All of the goals outlined for this project have been met. The use of a two part process for evaluating, ranking, and weighting data is an effective management methodology for site selection. This methodology has been proven feasible through its use by the U.S. Army Corps of Engineers for the Port of NY/NJ (Palermo *et al.* 1998). In addition, it is logical to assume that the methodology is compelling because two separate entities developed it independently.

Conclusions
- The use of the decision making method proposed in this thesis is an improvement over current siting methodologies and aids consensus building by allowing for public involvement while retaining a sound scientific foundation;
- The interactive GIS approach allows for better adaptive management of the environmental issues surrounding dredged material disposal through the documentation of assumptions and decisions and the reproducibility inherent in any computer based system;
- The use of visual analysis, coupled with a holistic approach, better communicates the complicated nature of environmental systems and results in an improved understanding of the issues;
- The interactive capability of the system and the ease with which 'what if' scenarios can be examined allows users of the GIS system to immediately understand the important factors in siting disposal areas and to examine the tradeoffs inherent in any siting decision.

The use of GIS technology, owing to its powerful spatial analysis abilities, facilitates the adoption of that methodology for site selection studies. It is apparent, however, that the extra capabilities provided by the interactive approach extend and enhance the power of GIS many times over that of the Corps method. The key benefit is the ability for the user to look at 'what if' scenarios and evaluate the effect of different parameters on site selection instantaneously. This method is a clear improvement over the static matrix method and lends itself to good adaptive management policies.

Feedback from the demonstration sessions and questionnaires provides an evaluation of this new approach and use of GIS technology. It can be concluded from participants' responses that the

interactive GIS approach is an improvement over current siting methods. However, until issues involving data availability are resolved, such as the lack of biological resource data, it is likely that there will be reservations about adopting this type of system. However, problems with data availability should decline in the next few years and the overwhelming advantages of the interactive GIS approach will support its adoption.

Overall, the interactive GIS approach has the potential to move us toward the goal of developing better policies for the management of dredged material disposal problems that result in minimizing environmental damage, maximizing human benefit, and gaining the support of all stakeholders. It facilitates the implementation of an adaptive management approach which allows for improved decisions to be made based on new information. Good scientific data and judgment are provided for in the analysis and stakeholder involvement is championed early in the process. Finally, this approach looks at the problem in a holistic manner and acknowledges the many complicated interactions that occur in the natural environment. Because of this, an interactive GIS approach should allow us to site dredged material disposal areas with less cost, time, and opposition, while protecting the environment and meeting our disposal needs in the best way possible.

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Appendix A - Boston Harbor Site Selection Matrices

TABLE E-10
PHASE II SCREENING CRITERIA
LAND-BASED SITES

	CRITERIA	PRIORITY/ STANDARD	310 CMR 16.40	DISPOSAL OPTIONS WORKING GROUP	M&E, 1992	PRIOR EXPERIENCE	404(b)(1)	EXPLANATION FOR P/S DESIGNATION
1	>20 non-wetland acres	P		X		X		Minimum site requirement (100K cy)
2	Allows buffering and total area >20 acres	S	X	X		X		Accomodated through site planning
3	Soils do not have severe constraints	S				X		Accomodated through site planning
4	<50% steep slopes (>15%)	S				X		Accomodated through site planning
5	No utility or other public infrastructure which affects site development	S				X		Accomodated through site planning
6	Site is vacant (no active development or use)	S				X		Cost consideration
7	No competing public development plans	S		X		X		Accomodated through site planning
8	No park/conservation/agricultural land on site	S	X			X		Accomodated through site planning
9	Does not abut park/agricultural conservation land	S	X			X		Accomodated through site planning
10	Vacant or commercial/ industrial adjacent land use	S	X					Accomodated through site planning

TABLE B-10
PHASE II SCREENING CRITERIA
LAND-BASED SITES

		CRITERIA	PRIORITY/ STANDARD	3 10 CMR 16 40	DISPOSAL OPTIONS WORKING GROUP	M&E 1992	PRIOR EXPERIENCE	404 (b)(1)	EXPLANATION FOR P/S DESIGNATION
CRITICAL RESOURCE ISSUES	11	Site not in conflict with Superfund or M.G.L. 21E	P				X		Project policy
	12	Site able to meet standards and criteria of Mass. Wetlands Protection Act (310 CMR 10.00)	P	X					Regulatory requirement
	13	Site is in Coastal Drainage Area	S		X				Accomodated through site planning
	14	Site not within potected area, e.g., ACEC or National Seashore	P	X					Regulatory requirement
	15	Site does not impact National Register or state listed historic site	P				X		Regulatory requirement
	16	Site does not contain ecologically significant habitat or species	P	X					Regulatory requirement
	17	Site not within significant aquifer	P	X					Regulatory requirement
	18	Odor/Air Quality/Nuisances: acceptable to sensitive receptors	S	X					Accomodated through site planning
REGULATORY SETBACKS	19	Site not within ZOC of current or interim Wellhead Protection Area	P	X					Regulatory requirement
	20	>250' upgradient from watercourse going to a surface water supply	P	X					Regulatory requirement
	21	>250' to non-drinking freshwater lake, river or waterbody	S	X					Accomodated through site planning

		CRITERIA	PRIORITY/ STANDARD	310 CMR 16.40	DISPOSAL OPTIONS WORKING GROUP	M&E 1992	PRIOR EXPERIENCE	404(b)(1)	EXPLANATION FOR P/S DESIGNATION
	22	>500' to sensitive receptor	P	X					Regulatory requirement
	23	>4' to groundwater	S	X					Accomodated through site planning
	24	>500' downgradient from public surface water supply	P	X					Regulatory requirement
	25	1/2 mile upgradient of surface drinking water supply	P	X					Regulatory requirement
	26	Site not within 100' of active farmland	P	X					Regulatory requirement
SITE ACCESS	27	Site directly accessible from regional highway, rail, or navigable waterway w/o additional infrastructure	P		X				Project policy
	28	Local route has no lateral/ vertical obstruct. or restrictions, including level of service restrictions	S				X		Accomodated through site planning
	29	Local route does not pass residential area	P	X					Project policy
	30	Local route does not pass sensitive receptors other than residential	S	X					Accomodated through route planning
	31	Site is within 3 hrs. travel of Project Site	S		X				Cost consideration
DESCRIPTORS	32	Ownership							
	33	Land Use Issues (e.g., Zoning)							

	CRITERIA	PRIORITY/ STANDARD	3 to CMR 16.40	DISPOSAL OPTIONS WORKING GROUP	M&E 1992	PRIOR EXPERIENCE	404(b)(1)	EXPLANATION FOR P/S DESIGNATION
1	Site is not a spawning or nursery habitat for fish, shellfish or benthic populations	P			X			Regulatory requirement
2	Site is not a feeding habitat for fish, shellfish or benthic populations	S		X	X	X		Accomodated through site planning
3	Site is not a feeding or nursery habitat for marine mammals	P			X	X		Regulatory requirement
4	Site is not a protected area e.g., ocean sanctuary	P			X			Regulatory requirement
5	Site is within 22 miles of dredging site	S		X				Cost consideration
6	Site has adequate depth	S					X	Accomodated through site planning
7	Site not restricted by erosional/depositional factors	S					X	Accomodated through site planning
8	Site not in conflict with navigational channels or commercial shipping lanes or: cruise ships, whale watch routes, or military/research use	S				X		Accomodated through site planning
9	Site is near sewage outfall or other disposal areas	S					X	Regulatory requirement
10	Contaminated sediments have been recorded or are expected at site	S		X				Accomodated through site planning
11	Site is not near fishing grounds	P		X			X	Project policy
12	Site does not impact National Register or state listed site	P				X		Regulatory requirement

		CRITERIA	PRIORITY/ STANDARD	310 CMR 16.40	DISPOSAL OPTIONS WORKING GROUP	M&E 1992	PRIOR EXPERIENCE	404 (b)(1)	EXPLANATION FOR P/S DESIGNATION
	13	Does not abut park and conservation land	S				X		Accomodated through site planning
	14	Disposal avoids aesthetic impacts to recreational areas	S			X			Accomodated through site planning
	15	Channels, ledges, shoals &/or anchorage areas do not restrict site use	S			X			Accomodated through site planning
	16	No competing public development plans	S		X				Accomodated through site planning
ADDITIONAL FACTORS FOR USE OF BORROW PITS	17	Site is located in sand or gravel deposits	P			X			Minimum site requirement
	18	Depth to bedrock is sufficient for excavating borrow pit	P			X			Minimum site requirement
	19	Site avoids aesthetic impacts to borrow pits	S			X			Accomodated through site planning
	20	Uses of borrow pit material are within economically feasible zone of site	S			X			Cost consideration
ADDITIONAL FACTORS FOR USE OF CONFINED DISPOSAL FACILITY	21	Vacant, commercial or industrial adjacent land use	S	X					Accomodated through site planning
	22	Facility will not result in significant alteration of circulation patterns	S			X			Accomodated through site planning
	23	Disposal is consistent with adjacent existing land uses	S			X			Accomodated through site planning

OTHER FEDERAL
OR STATE SITING
CRITERIA

		CRITERIA	PRIORITY/ STANDARD	310 CMR 16 40	DISPOSAL OPTIONS WORKING GROUP	M&E 1992	PRIOR EXPERIENCE	404 (b)(1)	EXPLANATION FOR P/S DESIGNATION
	24	No utility or other public infrastructure which affects site development	S				X		Accomodated through site planning
	25	Site accessible without additional infrastructure	S		X				Cost consideration
	26	Site able to meet standard and criteria of Mass. Wetlands Protection Act (310 CMR 10:00)	P	X					Regulatory requirement
	27	Site not in conflict with Superfund on M.G.L. 21E	P		X				Project policy
	28	Odor/Air Quality/Nuisances: acceptable to sensitive receptors	S	X					Accomodated through site planning

TABLE E-12
PHASE II SCREENING CRITERIA
LANDFILLS

	CRITERIA	PRIORITY/ STANDARD	310 CMR 16.40	DISPOSAL OPTIONS WORKING GROUP	M&E 1992	PRIOR EXPERIENCE	404(b)(1)	EXPLANATION FOR P/S DESIGNATION
1	Facility operator indicates interest	P				X		Project requirement
2	Permitted beyond 1993	P				X		Project requirement
3	Facility able to dispose, cover or stockpile (lined) > 500 cy per day	P				X		Project requirement
4	Within 3 hours travel of Project Site	S				X		Cost consideration
5	Local route does not pass residental areas	P				X		Project policy
6	Local route does not pass sensitive receptors	S				X		Accomodated through route planning

TABLE E-13. SUMMARY OF PHASE 2 EVALUATIVE CRITERIA NOT MET OR WITH UNDETERMINED STATUS FOR LANDFILLS AS OF MARCH 31, 1993.

	CRITERIA	PRIORITY/ STANDARD	FALL RIVER	FITCHBURG/ WESTMINISTER	EAST BRIDGEWATER	GRC-PEABODY	PLAINVILLE/ LAIDLAW
1	Facility operator indicates interest	P					
2	Permitted beyond 1993	P					
3	Facility able to dispose, cover or stockpile (lined) > 500 cy per day	P					N
4	Within 3 hours travel of Project Site	S					
5	Local route does not pass residental areas	P		U	N		U
6	Local route does not pass sensitive receptors	S	U	U	U	U	U

Blank = criterion is met
U = Undetermined
N = Not met

		CRITERIA	PRIORITY/ STANDARD	BRN -06	CAN -17	E. BROOK	HLB -13	NAT -02	NOR -02	RAYN	RED -03	SAG -02	W- 495	WEY -13	WIL -06	WIL -07	WOB -11
SITE SETTING	1	>20 non-wetland acres	P														
	2	Allows buffering and total area >20 acres	S														
	3	Soils do not have severe constraints	S	N											N		N
	4	<50% steep slopes (>15%)	S												N		
	5	No utility or other public infrastructure which affects site development	S		N												
	6	Site is vacant (no active development or use)	S	N	N				N		N	N	N	N	N	N	N
	7	No competing public development plans	S							N		U					
	8	No park/conservation/agricultural land on site	S														
	9	Does not abut park/agricultural conservation land	S								N	N					
	10	Vacant or commercial/industrial adjacent land use	S		N	N	N		N	N				N	N	N	N
CRITICAL RESOURCE ISSUES	11	Site not in conflict with Superfund or M.G.L. 21E	P		N										N		
	12	Site able to meet standards and criteria of Mass. Wetlands Protection Act (310 CMR 10.00)	P														
	13	Site is in Coastal Drainage Area	S	N	N	N	N	N	N	N	N	N	N	N	N	N	N

(Continued)

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TABLE E-14. (CONTINUED)

		CRITERIA	PRIORITY/ STANDARD	BRN -06	CAN -17	E. BROOK	HLB -13	NAT -02	NOR -02	RAYN	RED -03	SAG -02	W- 495	WEY -13	WIL -06	WIL -07	WOB -11
	14	Site not within protected areas, e.g., ACEC or National Seashore	P														
	15	Site does not impact National Register or state listed historic site	P						N						N		
	16	Site does not contain ecologically significant habitat or species	P			N			N	U	N				N		
	17	Site not within significant aquifer	P			N										N	
	18	Odor/Air Quality/Nuisances: acceptable to sensitive receptors	S		N	N			N	N	N	N	N		N		
REGULATORY SETBACKS	19	Site not within ZOC of current or Interim Wellhead Protection Area	P			N		U				N			U	U	
	20	>250' upgradient from watercourse going to a surface water supply	P														
	21	>250' to non-drinking freshwater lake, river or waterbody	S		N	N				N			N	N	N		
	22	>500' to sensitive receptor	P		N	N			N	N			N	N	N	N	N
	23	>4' to groundwater	S												N		
	24	>500' downgradient from public surface water supply	P														
	25	1/2 mile upgradient of surface drinking water supply	P	U	U	U	U	U		N	U	U	U	U	N	N	U
	26	Site not within 100' of active farmland	P		U	U			U	U	U	U	U	U	U	U	

TABLE E-14. (CONTINUED)

		CRITERIA	PRIORITY/ STANDARD	BRN -06	CAN -17	E., BROOK	HLB -13	NAT -02	NOR -02	RAYN	RED -03	SAG -02	W- 495	WEY -13	WIL -06	WIL -07	WOB -11
SITE ACCESS	27	Site directly accessible from regional highway, rail, or navigable waterway w/o additional infrastructure	P			N	N			N				N			
	28	Local route has no lateral/vertical obstruct. or restrictions, including level of service restrictions	S			U									N		
	29	Local route does not pass residential area	P		N	N	N		N	N	N		N	N	N	N	N
	30	Local route does not pass sensitive receptors other than residential	S			U	N			N			N	N	N		N
	31	Site is within 3 hrs. travel of Project Site	S														

Blank = Criterion is met
U = Undetermined
N = Not met

TABLE E-15. SUMMARY OF PHASE 2 EVALUATIVE CRITERIA NOT MET OR WITH UNDETERMINED STATUS FOR LAND-BASED COASTAL SITES AS OF MARCH 31, 1993.

		CRITERIA	PRIORITY/ STANDARD	BOS-13	BOS-23	BOS-25	BOS-31	EVR-04	LOGAN	LYNN-2	MAL-01	CHAR-01	QUI-03	QUI-09
SITE SETTING	1	>20 non-wetland acres	P					N	U	N		U		
	2	Allows buffering and total area >20 acres	S	N				N				U		
	3	Soils do not have severe con- straints	S		N	N		N		U	N	U	N	N
	4	<50% steep slopes (>15%)	S											
	5	No utility or other public in- frastructure which affects site development	S						N	N			N	
	6	Site is vacant (no active de- velopment or use)	S				N		N	N	N		N	N
	7	No competing public develop- ment plans	S	N	N	N		U	N	U		U		N
	8	No park/conservation/agricultural land on site	S			N							N	U
	9	Does not abut park/agricultural conservation land	S		N		N	N			N	N		
	10	Vacant or commer- cial/industrial adjacent land use	S			N					N		N	
CRITICAL RESOURCE ISSUES	11	Site not in conflict with Sup- erfund or M.G.L. 21E	P		N			U	N		N	U	N	N
	12	Site able to meet standards and criteria of Mass. Wetlands Protection Act (310 CMR 10.00)	P											
	13	Site is in Coastal Drainage Area	S								N			

(Continued)

		CRITERIA	PRIORITY/ STANDARD	BOS-13	BOS-23	BOS-25	BOS-31	EVR-04	LOGAN	LYNN-2	MAL-01	CHAR-01	QUI-03	QUI-09
	14	Site not within protected area, e.g., ACEC or National Seashore	P			N								
	15	Site does not impact National Register or state listed historic site	P											
	16	Site does not contain ecologically significant habitat or species	P			N			N			U		
	17	Site not within significant aquifer	P											
	18	Odor/Air Quality/Nuisances: acceptable to sensitive receptors	S	N	N	N	N	N	N		N	N	N	N
REGULATORY SETBACKS	19	Site not within ZOC of current or Interim Wellhead Protection Area	P							U				
	20	>250' upgradient from watercourse going to a surface water supply	P											
	21	>250' to non-drinking freshwater lake, river or waterbody	S											
	22	>500' to sensitive receptor	P								N	N	N	
	23	>4' to groundwater	S		N			N	N		N	N	N	U
	24	>500' downgradient from public surface water supply	P											
	25	1/2 mile upgradient of surface drinking water supply	P											
	26	Site not within 100' of active farmland	P											

(Continued)

TABLE E-15. (CONTINUED)

		CRITERIA	PRIORITY/ STANDARD	BOS-13	BOS-23	BOS-25	BOS-31	EVR-04	LOGAN	LYNN-2	MAL-01	CHAR-01	QUI-03	QUI-09
SITE ACCESS	27	Site directly accessible from regional highway, rail, or navigable waterway w/o additional infrastructure	P											
	28	Local route has no lateral/vertical obstruct. or restrictions, including level of service restrictions	S											
	29	Local route does not pass residential area	P	N										
	30	Local route does not pass sensitive receptors other than residential	S											
	31	Site is within 3 hrs. travel of Project Site	S											

Blank = Criterion is met
U = Undetermined
N = Not met

TABLE E-16. SUMMARY OF PHASE 2 EVALUATIVE CRITERIA NOT MET OR WITH UNDETERMINED STATUS FOR AQUATIC SHORELINE FACILITIES, AS OF MARCH 31, 1993, EXCEPT AS NOTED.

	CRITERIA	PRIORITY/ STANDARD	AMSTAR	CABOT PAINT	CHELSEA -1	FORT POINT CHANNEL	HANGMAN'S ISLAND*	ISLAND END RIVER*	LITTLE MYSTIC CHANNEL	MYSTIC PIERS	NORTH- END PARK	RE- SERVED CHANNEL	REVERE SUGAR	SPECTACLE ISLAND CDF-W
1	Site is not a spawning or nursery habitat for fish, shellfish or benthic populations	P	N				U				N		N	
2	Site is not a feeding habitat for fish, shellfish or benthic populations	S	U	N		N	N	U	U	U	U	U	U	N
3	Site is not a feeding or nursery habitat for marine mammals	P												
4	Site is not a protected area e.g., ocean sanctuary	P												
5	Site is within 22 miles of dredging site	S												
6	Site has adequate depth	S		U			N	N			N			
7	Site not restricted by erosional/depositional factors	S	U		U	U	U		U	U	U		U	
8	Site not in conflict with navigational channels or commercial shipping lanes or: cruise ships, whale watch routes, or military/research use	S												
9	Site is near sewage outfall or other disposal areas	S		N	N	N	N		N	N	N	N	N	
10	Site is not near fishing grounds	P					N							N

(Continued)

	CRITERIA	PRIORITY/ STANDARD	AMSTAR	CABOT PAINT	CHELSEA -1	FORT POINT CHANNEL	HANGHAN'S ISLAND*	ISLAND END RIVER*	LITTLE MYSTIC CHANNEL	MYSTIC PIERS	NORTH- END PARK	RE- SERVED CHANNEL	REVERE SUGAR	SPECTACLE ISLAND CDF-W
11	Site does not impact National Register or state listed site	P		U			U	U			U			
12	Does not abut park and conservation land	S				N					N	N		N
13	Disposal avoids aesthetic impacts to recreational areas	S				N	N		N		N			N
14	Site has no exceptional state/federal permitting requirements	P				N	N		N		N			N
15	Channels, ledges, shoals &/or anchorage areas do not restrict site use	S						N						
16	No competing public development plans	S		U		N	U	U			U			N
	ADDITIONAL FACTORS FOR USE OF BORROW PITS													
17	Site is located in sand or gravel deposits	P	D	D	D	D	D	D	D	D	D	D	D	D
18	Depth to bedrock is sufficient for excavating borrow pit	P	D	D	D	D	D	D	D	D	D	D	D	D
19	Site avoids aesthetic impacts to borrow pits	S	D	D	D	D	D	D	D	D	D	D	D	D
20	Uses of borrow pit material are within economically feasible zone of site	S	D	D	D	D	D	D	D	D	D	D	D	D
	ADDITIONAL FACTORS FOR USE OF CONFINED DISPOSAL FACILITY													
21	Vacant, commercial or industrial adjacent land use	S					N				N			N

(Continued)

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TABLE E-16. (CONTINUED)

	CRITERIA	PRIORITY/ STANDARD	AMSTAR	CABOT PAINT	CHELSEA -1	FORT POINT CHANNEL	HANGMAN'S ISLAND*	ISLAND END RIVER*	LITTLE MYSTIC CHANNEL	MYSTIC PIERS	NORTH- END PARK	RE- SERVED CHANNEL	REVERE SUGAR	SPECTACLE ISLAND CDF-W
22	Facility will not result in significant alteration of circulation patterns	S				U	U	U	U			U		
23	Disposal is consistent with adjacent existing land uses	S					U				N			
24	No utility or other public infrastructure which affects site development	S		U	N	N						N		N
25	Site accessible without additional infrastructure	S							N			N		
OTHER FEDERAL OR STATE SITING CRITERIA														
26	Site able to meet standards and criteria of Mass. Wetlands Protection Act (310 CMR 10:00)	P												
27	Site not in conflict with Superfund on M.G.L. 21E	P												
28	Odor/Air Quality/Nuisances: acceptable to sensitive receptors	S		U	U	U	U	U	U		U	U		U

Blank = Criterion met
D = Does not apply
N = Not met
U = Undetermined
* Sites included as result of DOWG meeting on 4/15/93; information on these sites was gathered and evaluated according to the Phase 2 screening process.

TABLE E-17. SUMMARY OF PHASE 2 EVALUATIVE CRITERIA NOT MET OR WITH UNDETERMINED STATUS FOR BORROW PITS, SUBAQUEOUS DEPRESSIONS AND EXISTING AQUATIC DISPOSAL SITES AS OF MARCH 31, 1993.

	CRITERIA	PRIORITY/ STANDARD	CHEL R-02	SUBAQ B	SUBAQ D	SUBAQ E	SUBAQ F	WINTHROP HARBOR	MEIS 2	MEIS 7	SPEC. IS. CAD	WILL I	WILL III	MBDS	BOSTON LIGHT SHIP
1	Site is not a spawning or nursery habitat for fish, shellfish or benthic populations	P		U	N	N	N	N	N	N	N	U	U	N	U
2	Site is not a feeding habitat for fish, shellfish or benthic populations	S	N	U	N	N	N	N	N	N	N	N	N	N	N
3	Site is not a feeding or nursery habitat for marine mammals	P								N		N	N	N	N
4	Site is not a protected area e.g., ocean sanctuary	P													
5	Site is within 22 miles of dredging site	S													
6	Site has adequate depth	S													
7	Site not restricted by erosional/depositional factors	S	N	U	U	U	U	U	U	U	U	U	U		
8	Site not in conflict with navigational channels or commercial shipping lanes or: cruise ships, whale watch routes, or military/research use	S	U						N	N			N		N
9	Site is near sewage outfall or other disposal areas	S		N	N			N	N			N	N		
10	Site is not near fishing grounds	P		N	N	U		N	N	N	N	N	N	N	N
11	Site does not impact National Register or state listed site	P													

(Continued)

TABLE E-17. (CONTINUED)

	CRITERIA	PRIORITY/ STANDARD	CHEL R-02	SUBAQ B	SUBAQ D	SUBAQ E	SUBAQ F	WINTHROP HARBOR	MEIS 2	MEIS 7	SPEC. IS. CAD	WILL I	WILL III	MBDS	BOSTON LIGHT SHIP
12	Does not abut park and conservation land	S							D	D	N				
13	Disposal avoids aesthetic impacts to recreational areas	S					N	N							
14	Site has no exceptional state/federal permitting requirements	P					N	N							
15	Channels, ledges, shoals &/or anchorage areas do not restrict site use	S	U	N			N		U						
16	No competing public development plans	S			N		N	N	D	D	N	D	D	D	D
	ADDITIONAL FACTORS FOR USE OF BORROW PITS														
17	Site is located in sand or gravel deposits	P	D	D	D	D	D	D						D	D
18	Depth to bedrock is sufficient for excavating borrow pit	P	D	D	D	D	D	D	U	U		U	U	D	D
19	Site avoids aesthetic impacts to borrow pits	S	D	D	D	D	D	D	U	U		U		D	D
20	Uses of borrow pit material are within economically feasible zone of site	S	D	D	D	D	D	D	U	U	N	U	U	D	D
	ADDITIONAL FACTORS FOR USE OF CONFINED DISPOSAL FACILITY														
21	Vacant, commercial or industrial adjacent land use	S						U	N	N	N			D	D

TABLE E-17. (CONTINUED)

	CRITERIA	PRIORITY/ STANDARD	CHEL R-02	SUBAQ B	SUBAQ D	SUBAQ E	SUBAQ F.	WINTHROP HARBOR	MEIS 2	MEIS 7	SPEC. IS. CAD	WILL I	WILL III	MBDS	BOSTON LIGHT SHIP
22	Facility will not result in significant alteration of circulation patterns	S	U	U											
23	Disposal is consistent with adjacent existing land uses	S					N								
24	No utility or other public infrastructure which affects site development	S			N					N	N			D	D
25	Site accessible without additional infrastructure	S							D	D	D	D	D	D	D
OTHER FEDERAL OR STATE SITING CRITERIA														D	D
26	Site able to meet standards and criteria of Mass. Wetlands Protection Act (310 CMR 10:00)	P												D	D
27	Site not in conflict with Superfund on M.G.L. 21E	P													
28	Odor/Air Quality/Nuisances: acceptable to sensitive receptors														

Blank = Criterion met P = Primary criterion
D = Does not apply S = Secondary criterion
N = Not met
U = Undetermined

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TABLE E-18. POTENTIAL DISPOSAL SITE LISTS BY CATEGORY PRODUCED
AT THE END OF EACH SCREENING PHASE.

PHASE 1	PHASE 2	PHASE 3 (DEIR/S)
LAND-BASED OPTIONS:		
Land-based Inland		
BRN-06	BRN-06	
CAN-17		
EBROOK		
HLB-13	HLB-13	
NAT-02	NAT-02	
NOR-02	NOR-02	
RAYNHAM		
RED-03	RED-03	
SAG-02	SAG-02	
W-495		W-495
WEY-13		
WIL-06		
WIL-07		
WOB-11		WOB-11
Land-based Coastal		
BOS-13	BOS-13	
BOS-23	BOS-23	
BOS-25		
BOS-31	BOS-31	
EVR-04		EVR-04
LOGAN		
LYN-02	LYN-02	
MAL-01		
CHAR-01	CHAR-01	
PROV		
QUI-03		QUI-03
QUI-09	QUI-09	

(Continued)

TABLE E-18. CONTINUED

PHASE 1	PHASE 2	PHASE 3 (DEIR/S)
Landfills		
Agawam		
E. Bridgewater	E. Bridgewater	E. Bridgewater
Fall River	Fall River	
Plainville	Plainville	Plainville
Fitchburg/Westminister	Fitchburg/-Westminister	Fitchburg/-Westminister
	GCR Peabody*	
AQUATIC OPTIONS: Aquatic Shoreline Sites		
Amstar	Amstar	Amstar
Cabot Paint	Cabot Paint	Cabot Paint
CHEL-01	CHEL-01	
FPC	FPC	
LMC	LMC	LMC
Mystic Piers	Mystic Piers	Mystic Piers
Northend Park	Northend Park	
ResChn	ResChn	ResChn
Revere Sugar	Revere Sugar	Revere Sugar
Spec CDF	Spec CDF	
	Hangman's Island*	
	Island End River*	
Subaqueous Depressions		
Subaq B	Subaq B	Sub B
Subaq D		
Subaq E	Subaq E	Subaq E
Subaq F		
CHEL-02	CHEL-02	
Winthrop		Winthrop

(Continued)

TABLE E-18. CONTINUED

PHASE 1	PHASE 2	PHASE 3 (DEIR/S)
Borrow Pits		
Willet I	Willet I	
Willet III	Willet III	
Meis 2		Meis 2
Meis 7		Meis 7
	Spec Is CAD	Spec Is CAD
In-Channel Sites		
		Chelsea Creek**
		Mystic River**
		Inner Confluence**
Existing Disposal Sites		
MBDS	MBDS	MBDS
Boston Lightship	Boston Lightship	Boston Lightship

*Added after DOWG meeting, 1/25/93
**Added after DOWG meeting, 4/15/93

TABLE E-19. BOSTON HARBOR DREDGING PROJECT SHORT-LIST OF
             DISPOSAL SITES FOR EVALUATION IN THE EIR/S

SITES INCLUDED FOR FURTHER CONSIDERATION IN DEVELOPING
                  DISPOSAL OPTIONS:

I. LANDFILLS

Plainville   Meets criteria, good site access.

Westminister   Site access not insurmountable;
                    appropriate for small quantities.

E. Bridgewater   Site Access not insurmountable;
                    appropriate for small quantities.

II. LAND-BASED INLAND SITES

Wrentham - 495   Site size adequate to design around
                    constraints.

Woburn - 11   Site size adequate to design around
                    constraints.

III. LAND-BASED COASTAL SITES

Everett - 04   Proximity to dredging site; barge access;
                    capacity may be limited by intertidal
                    wetlands.

Quincy - 03   Proximity to dredging site; barge access
(Squantum Point)   may require limiting dredging; truck
                    access would impact residential
                    development.

IV. AQUATIC SHORELINE SITES

Revere Sugar   Provides in-place disposal, benefit of
                    capping in-situ contaminated materials and
                    is consistent with Designated Port Area
                    uses.

Amstar   Provides in-place disposal, benefit of
                    capping in-situ contaminated materials and
                    is consistent with Designated Port Area
                    uses.

Mystic Piers   Provides in-place disposal, benefit of
                    capping in-situ contaminated materials and
                    is consistent with Designated Port Area
                    uses.

Reserved Channel   Benefit of capping in-site contaminated
                    sediments, although could displace
                    existing water-related uses. Outside
                    Designated Port Area.

                                        (Continued)

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TABLE E-19. (CONTINUED)

Cabot Paint	Benefit of capping in-situ contaminated sediments and providing additional containment of terrestrial contaminants.	
Little Mystic Channel	Within Designated Port Area, site access limited by low bridge. Large capacity provides several options for use.	

V. SUBAQUEOUS DEPRESSIONS

Subaqueous Containment Site B	Proximity to dredging operations; ability to retain sediments within confines of Boston Harbor.
Subaqueous Containment Site E	Proximity to dredging operations; ability to retain sediments within confines of Boston Harbor.
Winthrop Harbor	Depauperate benthos indicates water quality stresses; partial filling could improve circulation.

VI. IN-CHANNEL DISPOSAL SITES

Chelsea Creek

Inner Confluence

Mystic River

VII. BORROW PIT

Meisburger 2	Water depth within range where capping has been successfully demonstrated; proximity to MWRA outfall; significant sand and gravel deposit.
Meisburger 7	Water depth within range where capping has been successfully demonstrated; proximity to MWRA outfall; significant sand and gravel deposit.
Spectacle Island CAD	In-harbor location; previous exposure to disturbances.

VIII. EXISTING DISPOSAL FACILITIES

Mass Bay Disposal Site	Designated disposal site, benefit/cost ratio favors site.
Boston Light Ship	Previously used disposal site, located in Section 103 waters. Capping possible at these water depths.

Appendix B - Data Layers

This appendix documents the ranking scheme and data that was used to create the individual data layer grid files which are used in the suitability analysis. Each data layer is broken up into several sections. The first section is a general overview of the data layer. The second section outlines the numerical ranking scheme used to create the data layer. The third section consists of notes from the individual ranking that data layer. The final section details the data sources and the process used to manipulate and create the grid file.

Bathymetry

Bathymetry is the measurement of water depths from a given datum. For this project all depths are measured from Mean Low Water (MLW) which is the average height of the daily low tides. Bathymetry is an important component of siting disposal areas because shallow areas can prevent the entry of ships or barges into certain areas and can require additional dredging.

Rating Scheme

      10: All areas with depths greater than 20 ft., within 1 mile of land, and within ½ mile of navigable water (defined to be marked ship channels).

      8: Areas within ½ mile of navigable water

      5: Areas greater than 20 ft. deep.

      1: All other areas

Notes from Tom Fredette, United States Army Corps of Engineers.

      "Because a borrow pit can be dredged, bathymetry may not be a critical factor. Certainly areas that are accesssible and are already deep would have some advantages, but even shallow areas could have channels provided for access and then be dredged to whatever depths are needed. Thus areas near land (protected), near a channel (access), and already deep would have the highest potential."

Data Sources /Methodology

      The bathymetric data was obtained from Rich Signell at the U.S.G.S in Woods Hole. The data set can be obtained at http://oracle.er.usgs.gov/GoMaine/bathy/index.htm. Rich and a coworker created this data set from several data sources including NOAA surveys. They corrected several errors in the data sets and converted it to a common datum. A subset of the Gulf of Maine sounding data was obtained for just Boston Harbor and the datum was converted to Mean Low Water (MLW) by Rich at the USGS.

This raw sounding data was imported into MS Access, saved as a .dbf table, and then added into an ArcView project. The horizontal datum was then converted to Massachusetts State Plane 1983 (meters) using the Projector! Extension in ArcView. Next a surface grid file was created from the sounding data using the `Interpolate Surface` function available with AV Spatial Analyst. The IDW (Inverse Distance Weighted) interpolation method with a fixed radius of 20 meters was used to create a grid with 10 meter grid cells. This gave a tight interpolation of the data while ensuring full coverage of the harbor area. This bathymetric surface was then saved as `BosHarborGrid` for use with other data layers. Following the creation of the base bathymetric grid a grid mask was created to reduce the computational load. This grid mask outlined the analysis extents to an area slightly bigger than Boston Harbor and set the cell size for all future grids to 10 meters.

Bathymetry
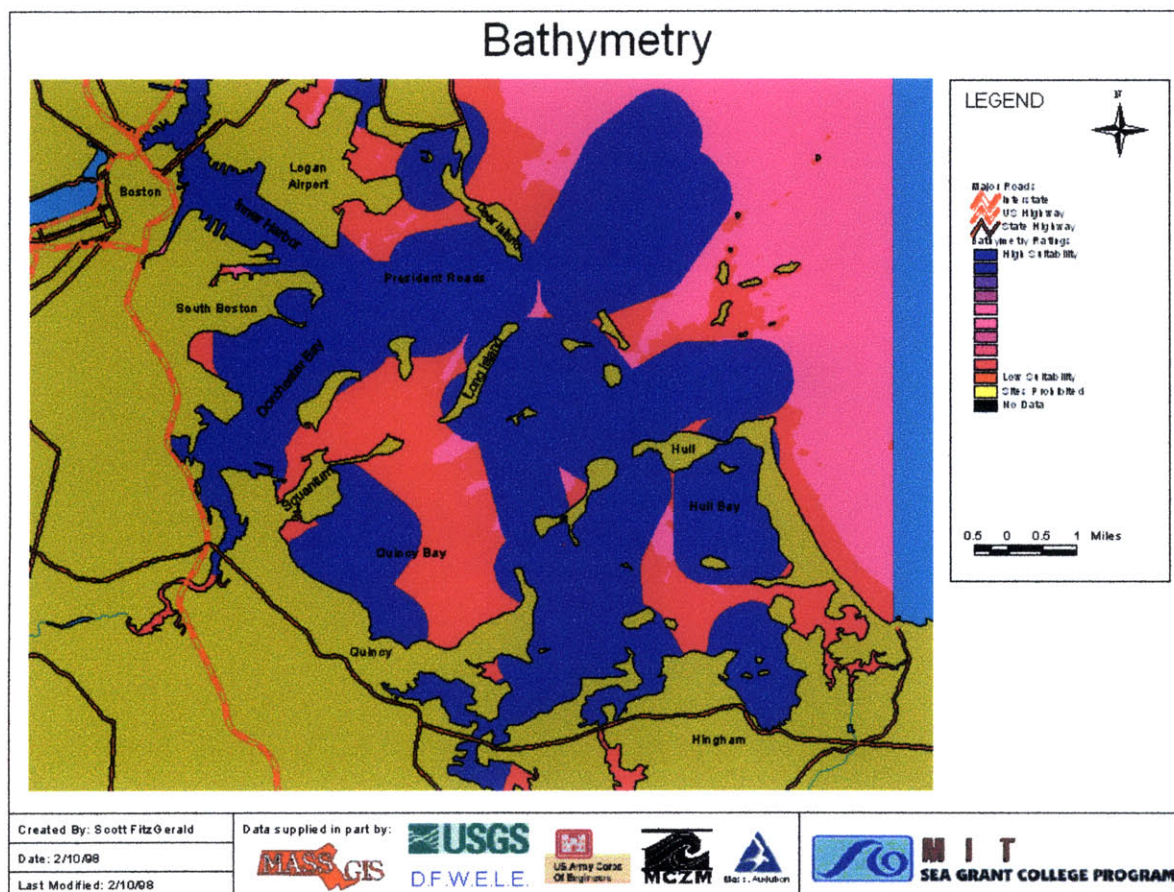
To create the ranked grid file several intermediate data layers were created. The first layer consisted of areas with depths greater than 20 ft., the second layer consisted of areas within ½ mile of navigable water, and the final layer had all areas within 1 mile of land. These layers were then assigned unique values and combined. After they were combined the resulting data layer was queried and reclassified into the final ranking values. The final grid file is named `bathygrid`. (See Figure B-1)

Nautical Features

Nautical features include anchorages, ship channels, disposal areas, pipelines, tunnels and cables. These features all expedite or impede the passage of ships and barges and have the potential to limit the construction of borrow pits.

Rating Scheme

        10: Anchorage, channel
        8: No feature
        6: Disposal area
   1: Tunnel, cable, pipeline, sewer line

Notes from Tom Fredette, United States Army Corps of Engineers.

"Because channel areas are already disturbed the least impact potential may exist here. Need to be cautious of future needs to deepen, however. Areas with no feature offer the next least potential for conflict in this data layer. Disposal areas may be advantageous or not depending on case-by-case conditions. Previous disturbance would be an advantage from a cumulative impact perspective (limit impacts in new areas), but a disadvantage may be the need to deal with the previously disposed material. Dredging that has potential to interfere with subsurface features needs careful consideration and is unfavorable to this feature."

Data Sources / Methodology

This data set was obtained from MassGIS who digitized the information from NOAA charts. To created the ranked grid file the source data was queried to identify the different classification areas (e.g. anchorages, disposal areas). Next, a new layer was created and polygons were created to link the identified line features into areal extents. This polygon layer was then converted to a grid file and all of the areas were assigned the appropriate ranking value. This grid file is named `nauticalgrid`. (See Figure B-2)

Figure B-2. Nautical Features Ranking
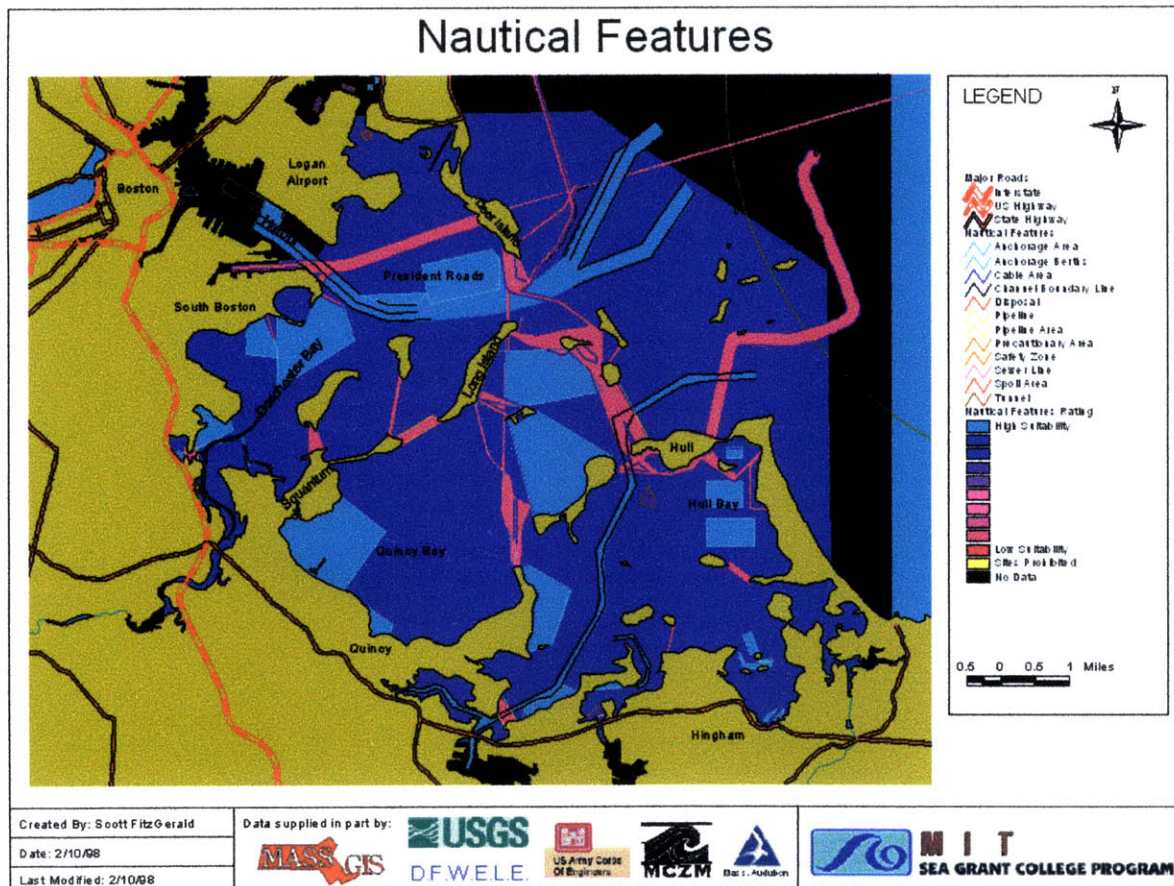
Currents

Currents are an important consideration in the siting of disposal areas because they have the potential to resuspend and transport capping material and the underlying contaminated sediments. It is desirable to place material in areas where the bottom shear stress developed by the tidal current flow is less than the necessary stress required to initiate movement of the capping material to ensure that contaminated sediments remain isolated and are not transported away from the disposal site.

Rating Scheme
>   10: Ratio of bottom shear stress to critical shear stress < 0.8
>   4:   0.8 < Ratio of bottom shear stress to critical shear stress < 1.0
>   1:   Ratio of bottom shear stress to critical shear stress > 1.0

Notes from Scott FitzGerald, MIT.
>   These data layers looks at the bottom shear stress developed by the maximum yearly tidal currents (as predicted by a current model for Boston Harbor developed by Rich Signell at the U.S.G.S. in Woods Hole) and compares that stress to the stress required to initiate movement of two different sizes of capping material

Data Sources / Methodology
>   A data set of the maximum current from the M2 tidal cycle in Massachusetts Bay was obtained from Rich Signell at the U.S.G.S in Woods Hole (see http://crusty.er.usgs.gov/mbay/modeling.html for a description of the model). This data was imported directly into and ArcView table and a surface grid file was created in the same manner as for the bathymetric points. Next a grid of bottom current shear stress was created using the following formulas:

$$U_* = \frac{k \cdot U}{\ln \dfrac{h}{e \cdot z_0}} \qquad (1)$$

where U = depth-average velocity or the output from the current model
       U_* = shear velocity
       k = von Karman's constant = 0.4
       z_0 = effective hydraulic roughness (equation 2)
       h = water depth
       e = 2.71

$$z_0 = \max\left\{ \begin{array}{l} d/30 \\ v/9 \cdot U_* \end{array} \right. \qquad (2)$$

where v = kinematic velocity of fluid ($\sim 10^{-6}$ m^2/s)
       d = diameter of surface sediment

then

$$\tau_b = \rho \cdot U_*^{\,2} \tag{3}$$

where τ_b = bottom shear stress

ρ = fluid density

Next the critical shear stress to initiated movement of bottom sediments was calculated for two different grain sizes of capping material (1mm and .425 mm diameters).

$$\Psi_{cr} = 0.095 \cdot S_*^{-\frac{2}{3}} + 0.056 \left(1 - e^{\left(\frac{-S_*^{\frac{2}{3}}}{20} \right)} \right) \tag{4}$$

where Ψ_{cr} = critical shield paramter

and

$$S_* = \frac{d}{4 \cdot \upsilon} \cdot \sqrt{(S-1) \cdot g \cdot d} \tag{5}$$

then

$$\tau_{cr} = \Psi_{cr} \cdot (S-1) \cdot \rho \cdot g \cdot d \tag{6}$$

Now when $\tau_b > \tau_{cr}$ sediments are transported due to the action of the current. The ratio of bottom shear to critical shear was computed and a grid file was created for two grain sizes. Finally these files were reclassified into designated areas according to the ranking scheme. The files are named `currentgrid1` and `currentgrid2`. (See Figures B-3 and B-4)
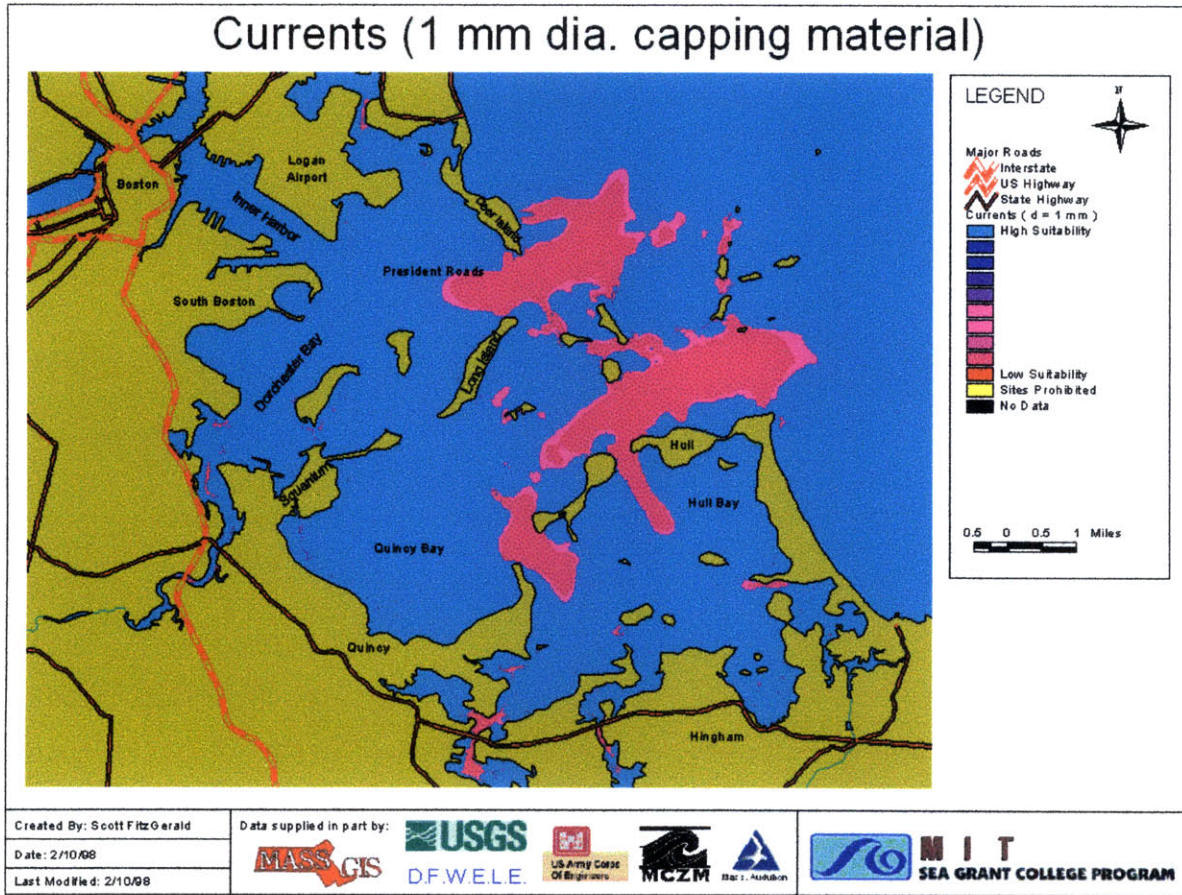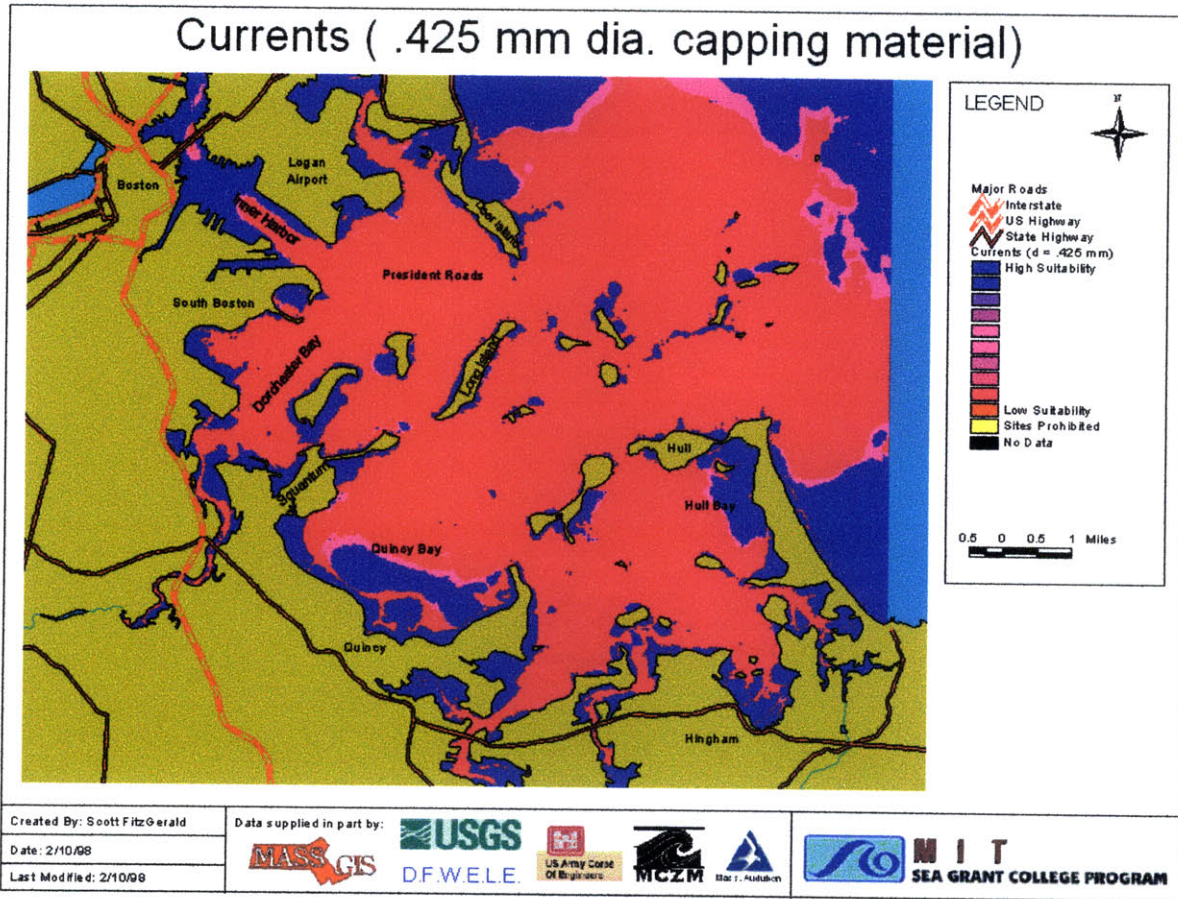
Figure B-3. Current Ranking

Currents (.425 mm dia. capping material)

Sediment Regions

Regions of the harbor floor can be classified based on whether the sediments tend to be eroded, reworked, or deposited. Reworked areas are those that depending on local tidal, wave, and current amplitude and direction can be both eroded and deposited. Depositional areas are preferred over erosional areas because depositional areas will remain more secure and will be less likely to have contaminated material leave the containment pit.

Rating Scheme
    10: Depositional areas
    5: Reworked areas
   1: Erosional areas
Notes from Tom Fredette, United States Army Corps of Engineers.
    "Certainly if an area is depositional that confers some degree of protection to the site that will minimize the amount of artificial protection that needs to be provided in project design. However, erosional sites could be made suitable via dredging depth / final fill depth or engineering protection."

The sediment regions data layer was obtained from Susan Ford at the Massachusetts Water Resource Authority (MWRA). It is a digitized version of a sediment region map created by Harley Knebel at the U.S.G.S. in Woods Hole. (Knebel and Circe, 1994) This map was converted to a grid file and the sediment regions were reclassified according to the rating scheme developed. The final grid file name is `sedimentgrid`. (See Figure B-5)

Figure B-5. Sediment Region Ranking
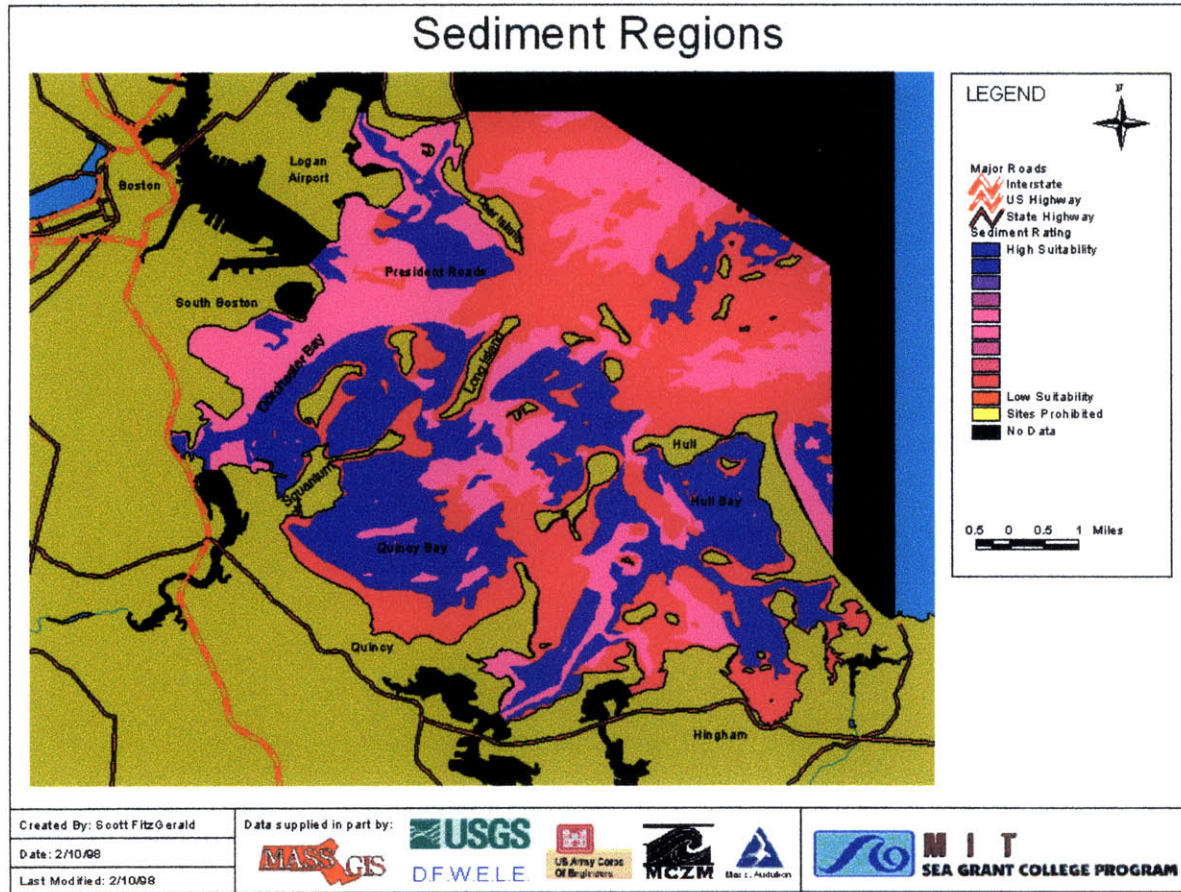
Lead Contamination

Lead contamination is a serious concern in Boston Harbor. Sediments with high amounts of lead are believed to be serious human and ecological health hazards. In siting disposal areas it is important to minimize the transfer of highly contaminated sediments to areas of lower contamination.

Ranking Scheme

> 10: Lead concentrations greater than 200 μg/g
>
> 5: Lead concentrations between 100 - 200 μg/g
>
> 1: Lead concentrations between 0 - 100 μg/g

Notes from Judy Pederson, MIT Sea Grant

This ranking scheme follows from standards set out in Massachusetts 314 CMR 9.00 which classifies sediments into the three divisions above based on lead concentrations. Disposal cells are preferred in areas with the most lead contamination because this will minimize the relative impacts of placing more contaminated sediment in the region and has the potential to remediate the region by isolating sediments from the biota.

Data Sources / Methodology

This data source was digitized manually from a figure contoured by Gordon Wallace at University of Massachusetts, Boston (Wallace 1987) Once the data was digitized into polygon regions the data was aggregated and reclassified into the appropriate rating scheme. The final grid file is named `Leadgrid`. (See Figure B-6)

Figure B-6. Lead Contamination Ranking
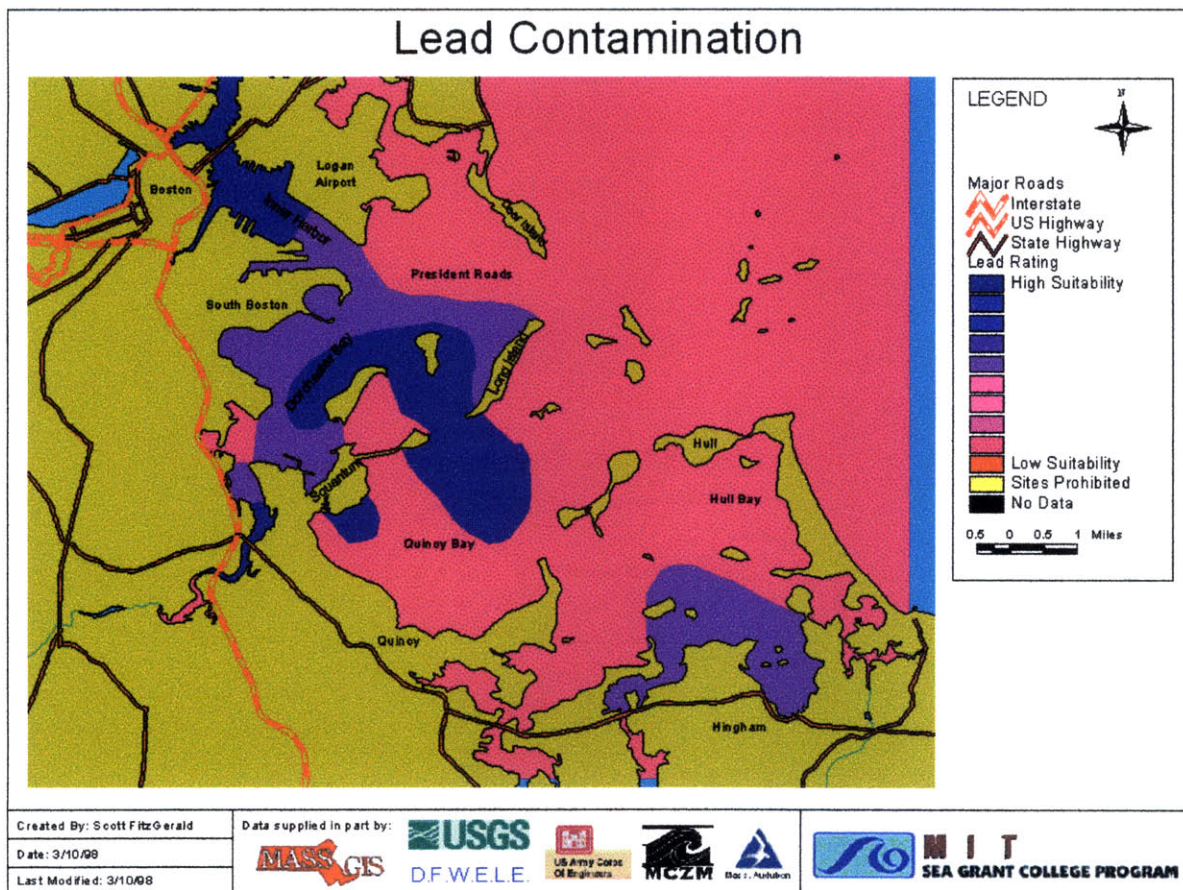
Coastal Barrier Resource Units (CBRU)

Coastal Barrier Resource Units are areas designated by the U.S. Fish and Wildlife Service as being exceptional natural resource areas. The areas include barrier beaches and their associated aquatic habitat. This layer is important because the siting of a disposal areas within a CBRU has the potential to destroy or harm the resources found there.

Rating Scheme

10: Areas more than 200 meters away from a CBRU

5: Areas within 200 meters of a CBRU

1: Areas within a CBRU

Notes from Scott FitzGerald, MIT.

When looking at the CBRUs it is desirable to site disposal areas some distance away. However, it is difficult to ascertain what appropriate distances might be. Thus, a buffer zone of 200 meters was established to limit the siting of disposal areas near CBRUs.

Data Sources / Methodology

This data layer was obtained from the MassGIS statewide data set (see http://www.magnet.state.ma.us/mgis/). Using the buffering tools available with the spatial analyst the data was grouped and reclassified into the areas identified by the rating scheme. The final grid file is named Cbrugrid. (See Figure B-7)

Figure B-7. CBRU Ranking

Coastal Barrier Resource Units
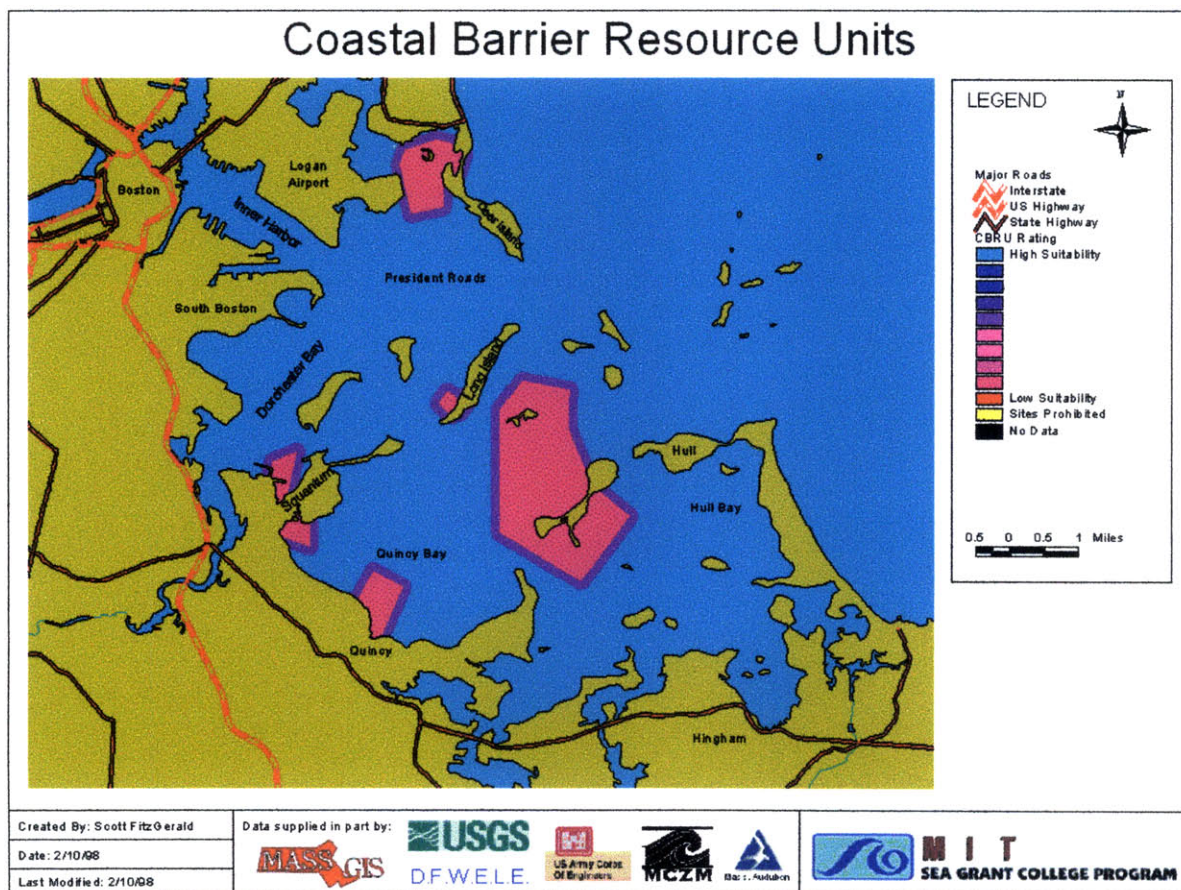
Areas of Critical Environmental Concern (ACEC)

Areas of Critical Environmental Concern have been designated by the Massachusetts Secretary of Environmental Affairs as "some of the most significant ecosystems in the Commonwealth" and accordingly all of the Massachusetts environmental agencies have been directed to "preserve, restore and enhance the resources of these areas." As such, it is important that dredged disposal areas avoid these areas.

Rating Scheme
> 10: Areas outside an ACEC
> 0: Areas within an ACEC

Notes from Leslie Luchonok, Massachusetts Department of Environmental Management
> "There are specific regulatory standards contained in the Waterways Regulations (310 CMR 9:00) regarding ACECs and the disposal of dreged material. The Waterways Regulations, administrered by the state Department of Environmental Protection (DEP), prohibit the disposal of dredged material within an ACEC, except for the purposes of beach nourishment; dune construction or stabilization with proper vegetative cover; or the enhancement of fishery or wildlife resoureces [310 CMR 9.409 (1)(b)]."

Data Sources / Methodology
> This data layer was obtained from the MassGIS statewide data set (See http://www.magnet.state.ma.us/mgis/). Using the tools available with the spatial analyst the data was grouped and reclassified into the areas identified by the rating scheme and the rating values were assigned. The final grid file is named ACECgrid. (See Figure B-8)

Figure B-8. ACEC Ranking
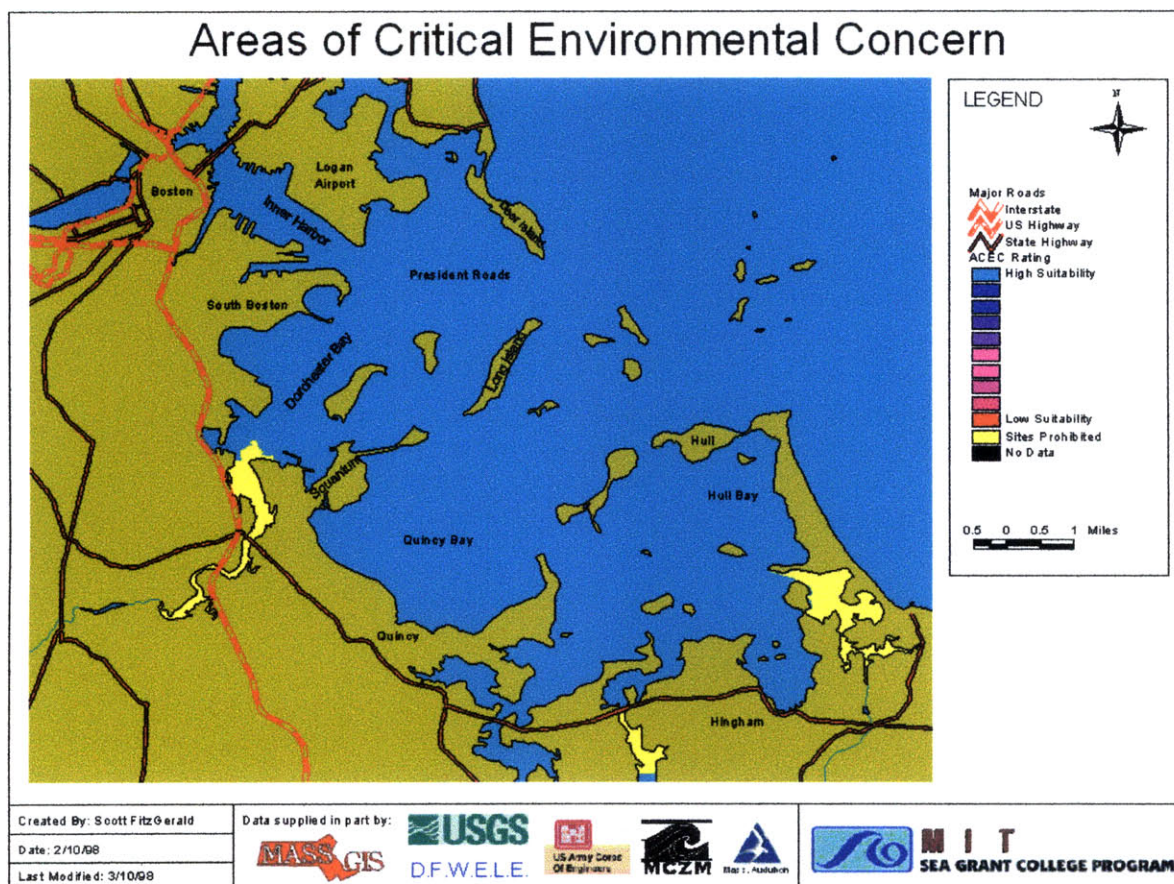
Eelgrass Beds

Beds of subtidal eelgrass provide a variety of ecological services such as food production and habitat for other animals. Dredging and silting adversely affect the health and strength of this important natural resource and disposal sites should avoid prime eelgrass growing areas as much as possible.

Rating Scheme

> 10: Areas more than 6 meters deep or above mean low tide.
> 8: Areas 3-6 meters deep.
> 3: Areas 2-3 meters deep.
> 1: Areas 0-2 meters deep or areas within 500 meters of an existing eelgrass bed.

Notes from "Ecosystems and Resources of the Massachusetts Coast"

> Eelgrass "is found in waters of varying salinity in depths ranging from just under low tide level to twenty feet below sea level in places where sunlight penetrates to the ocean floor, currents are not too swift, and bottom sediments are favorable to growth… Disaster struck the eelgrass beds of the North Atlantic coast in 1931 [when] a 'wasting disease' destroyed 99 percent of the standing stock" In recent years the beds have made a comeback and with the Boston Harbor cleanup it is expected that we might see more beds return.

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This data set was created using to additional data sets. The first is the bathymetric data set described previously. The second data set is the locations of existing Eelgrass bed which were obtained from Susan Ford at the MWRA. The first step was to reclassify the bathymetric grid into regions according to the ranking scheme. Next a buffer was placed around the existing Eelgrass beds. Finally, the reclassified bathymetric data and Eelgrass buffers were combined and assigned values according to the rating scheme. The final grid file is name `Eelgrid`. (See Figure B-9)

Figure B-9. Eelgrass Bed Ranking
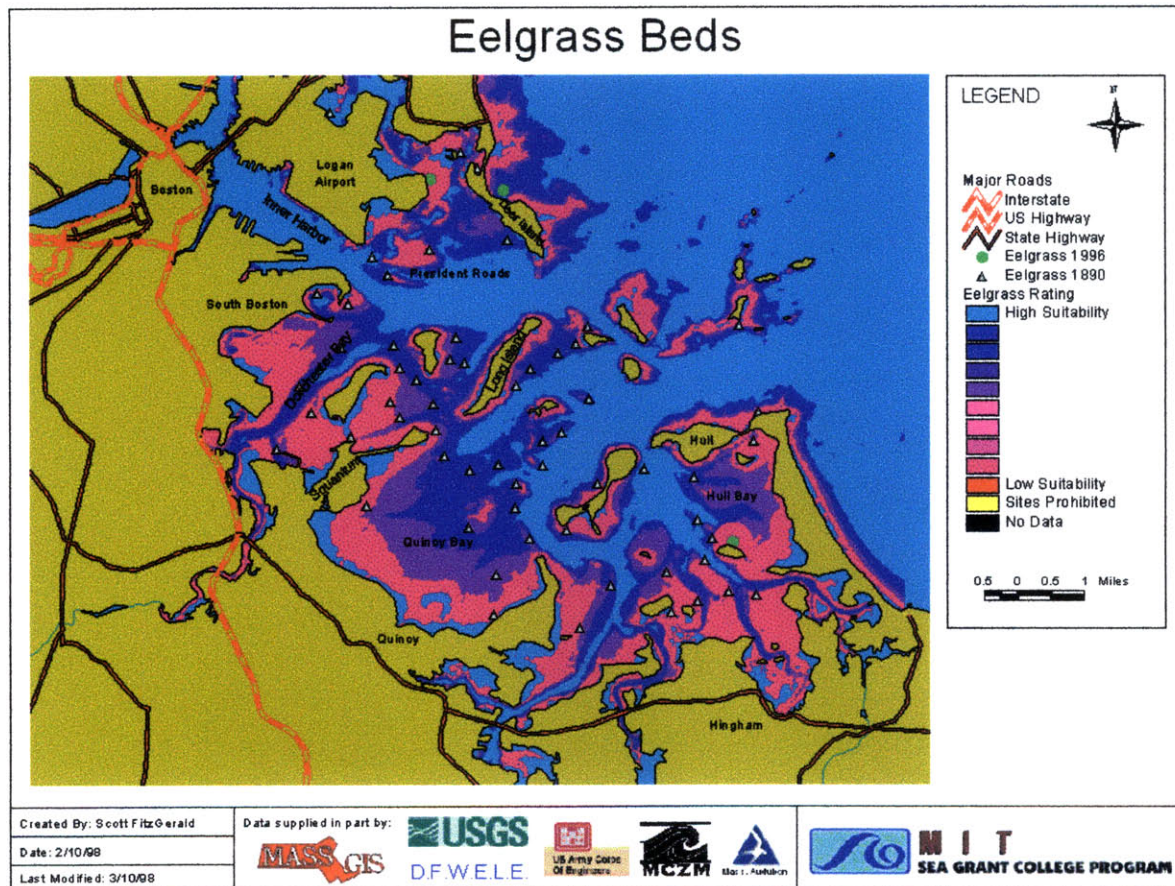
Shellfish

Shellfish are a valuable part of the harbor ecosystem and have significant commercial value. Destruction of shellfish habitat coupled with the uptake of contaminates would adversely affect this resource.

Rating Scheme:

        10: Deep Water

        9: Depositional areas in the sublittoral zone to depths greater than 6' MLW.

8: Erosional areas and areas of sediment reworking to depths greater than 15' MLW.

4: Depositional areas in the sublittoral zone to depths of 6 feet MLW

3: Erosional areas and areas of sediment reworking in the sublittoral zone to depths of 15' MLW.

2: The intertidal zone to extreme low water and currently closed to shellfishing.

1: The intertidal zone to extreme low water and classified for shellfishing.

Notes from Dave Roach, Division of Marine Fisheries

"The mainstay for the Boston Harbor shellfisheries is, past and present, the soft shell clam (Mya arenaria) which is distributed throughout the intertidal area to extreme low water. Additionally, Massachusetts General Lows Chapters 90 and 131, Wetlands and Waterways regulations, respectively, would severely limit the use of the intertidal areas to extreme low for a contaminated dredge spoils disposal site... Please keep in mind that as the Boston Harbor "clean up" project moves towards completion, many of the intertidal areas now closed to shellfishing will eventually be reclassified to permit shellfishing."

Data Sources / Methodology

This data set was created from three data sets. The first data set is the bathymetric grid file outlined previously and the second data set is the sediment region data set from the MWRA. The third data set is a listing of shellfish bed classification areas obtained from Tom Hoopes at the Massachusetts Division of Marine Fisheries. This data set is also available through MassGIS.

The first step was to classify the bathymetric grid into regions according to the rating scheme. Next the sediment regions data set and the shellfish classification area data set were converted to grid themes. All of these themes were combined and reclassified into the seven categories identified by the rating scheme. Finally each of the seven regions was assigned the appropriate ranking value. This grid file is named shellfishgrid. (See Figure B-10)

Figure B-10. Shellfish Ranking
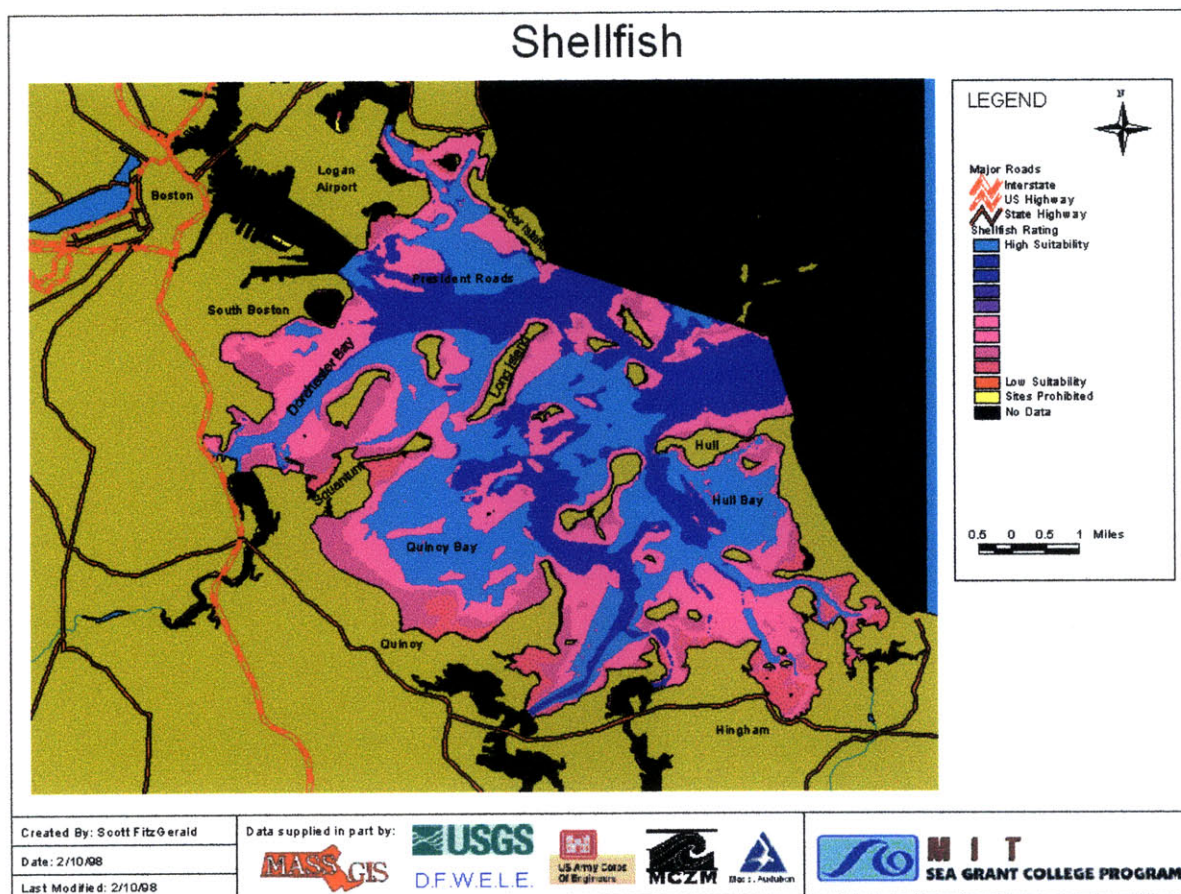
Anadromous Fish

Anadromous fish are fish that return to fresh water areas to breed. These fish are a valuable part of the marine ecosystem and disturbance of their migration paths and spawning areas has the potential to reduce their reproductive success and lead to the decline of these species.

Rating Scheme:
>   7: Fish Migration Routes (These areas would get a 1 during migration times)
>   1: Fish Spawning Sites

Notes from Robert Buchsbaum, Massachusetts Audubon Society
>   "Anadromous fish spawning sites ... depend on the natural substrate remaining clean and are obviously inappropriate for any kind of disposal of dredged material. Smelt typically spawn just above the upper limit of salt water. In most of the Commonwealth, smelt are in serious decline and the Boston Harbor runs are among the only really good ones left, hence it is particularly important to leave them undisturbed. Disposal activity should be restricted... [in the anadromous fish migration routes]...to the periods of time when adult fish are not migrating upriver and juveniles are not migrating downstream."

Data Sources / Methodology

This data layer is based on the anadromous fish data set available from MassGIS. The first step was to query the existing data set to identify the fish migration routes and spawning sites. Next polygon areas encompassing the migration routes and spawning sites were created. Then the polygon areas were converted to a grid file and assigned the appropriate ranking value. The final grid name is `anadgrid`. (See Figure B-11)

Figure B-11. Anadromous Fish Ranking
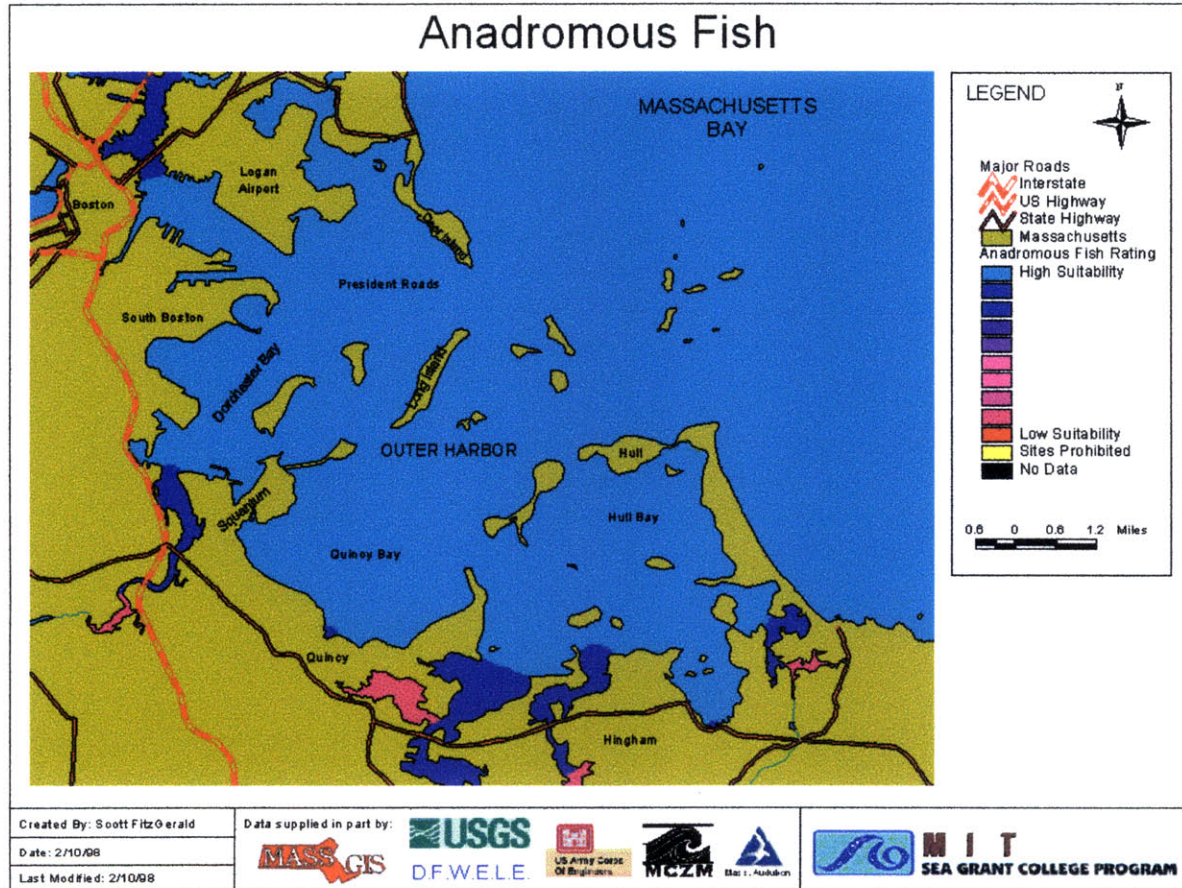
Lobsters

Lobsters are a central part of New England life. A significant economy is built around the catch and sale of lobsters. In recent years lobstermen in Boston Harbor have seen a serious decline in catch. It is important to avoid impacting this valuable resource in order to preserve the lobster catch and sustain the economy built around them.

Rating Scheme:

       7: Areas less than 5 feet deep

       1: All other areas

Notes from Ron Valicenti, Hingham Lobsterman

       After consulting with lobstermen (particularly the older, more experienced ones) in both the northern and southern sections of the harbor it has to be concluded that Boston Harbor in its entirety is valuable lobster habitat. While the catch moves around depending on the season and year there is not any single area which yields such a poor catch that it could be considered a good location for the disposal of contaminated sediments. For the purposes of this study areas less than 5 feet deep where deemed to be acceptable because most lobstermen cannot operate their vessels in that depth. However, not much is known about lobster growth and migration patterns and should this zone be deemed especially valuable habitat we would not approve of disposal in that area either.

Data Sources / Methodology

       This data layer was developed after speaking with many lobstermen in the Boston Harbor areas. While it is by no means a scientific data set and lacking in information it is a first attempt to develop a suitability ranking scheme for lobsters. The data set was created by querying and reclassifying the bathymetric grid set into the two bathymetric zones identified by the ranking scheme and assigning the zones the appropriate values. The final grid name is `lobstergrid`. (See Figure B-12)

Figure B-12. Lobster Ranking
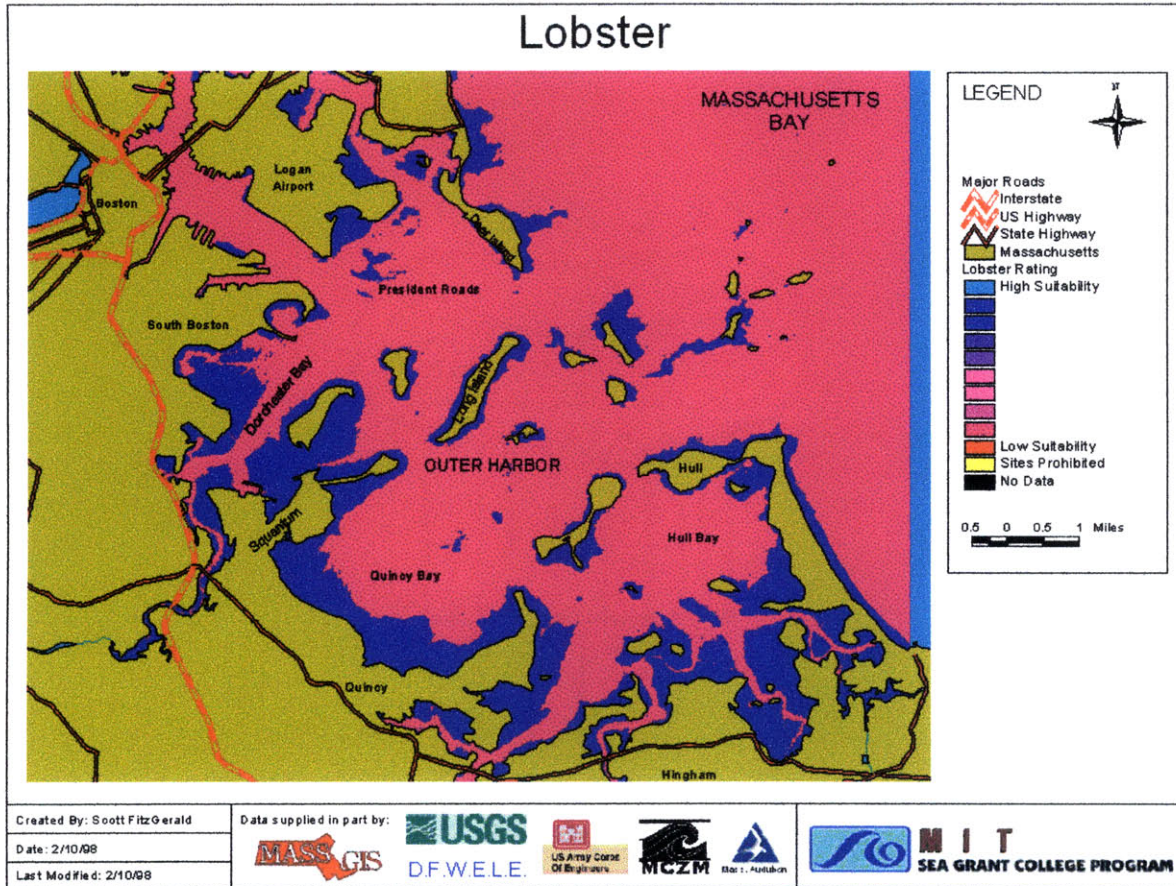
Recreational Fishing

Fishing in Boston Harbor is an activity enjoyed by many. Placement of disposal areas should avoid prime fishing areas to protect this resource.

Rating Scheme
> See map for a representation of the ranking scheme. The site specific data is best represented by polygons on a map and not a general scheme.

*Notes from Bruce Berman, Save the Harbor / Save the Bay*
> Some of the best fishing in the Harbor is right next to edges and structures. These areas are characterized by rapidly moving water and sharp drop-offs and attract multitude of fish. The shallow flat areas are filled with bait and fish and represent another excellent resource. The best place to put borrow pits to avoid impacting recreational fishing is in the center (not along the edge) of ship channels and areas with a relatively flat bottom.

Data Sources / Methodology
> This data set was obtained by speaking with Bruce Berman of Save the Harbor/Save the Bay. He is an experienced recreational fisherman who is active on Boston Harbor. He outlined various areas on a bathymetric map and assigned the areas ranking values based on his experience. These

areas were inputted into ArcView by hand as polygons and then converted into a grid file. Finally each of the areas was assigned the values given by the rating scheme. The final grid name is `fishinggrid`. (See Figure B-13)

Figure B-13. Recreational Fishing Ranking
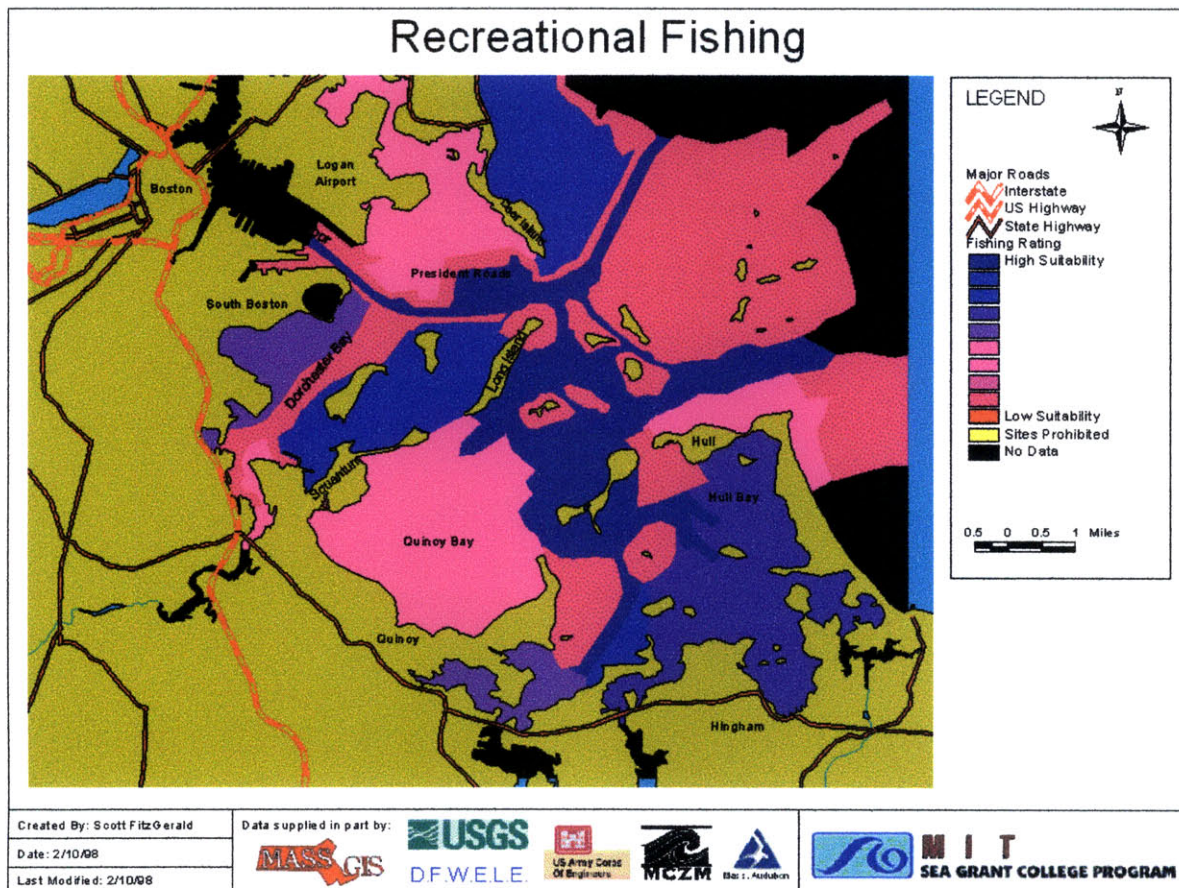
Swimming Beaches

Beaches along Boston Harbor are enjoyed by many people. As the Harbor water quality continues to improve it is anticipated that these beaches will see more use and become a valuable asset to the harbor region.

Rating Scheme
> 10: Areas farther than 200 meters from a beach
> 4: Areas 200 feet - 200 yards from a beach
> 1: Areas within 200 feet of a beach

Notes from Scott FitzGerald, MIT.
> Areas within 200 feet of a swimming area are generally off limits to boat traffic and unsuitable for dredged disposal activities. Scuba divers and long distance swimmers often swim farther out

from shore to avoid recreational bathers and would warrant moving disposal areas past that limit.

Data Sources / Methodology

This data set was obtained by manually outlining beaches identified in a joint commission report (Joint Commission on the Future of Boston Harbor Beaches, 1993) using digital orthophotos to identify the extent of the beaches. Once the beaches were identified, buffer areas were created using the tools available with the Spatial Analyst. Finally the data was converted to a grid file and the buffer zones were assigned values based on the rating scheme. The final grid file name is `beachgrid`. (See Figure B-14)

Figure B-14. Beaches Ranking
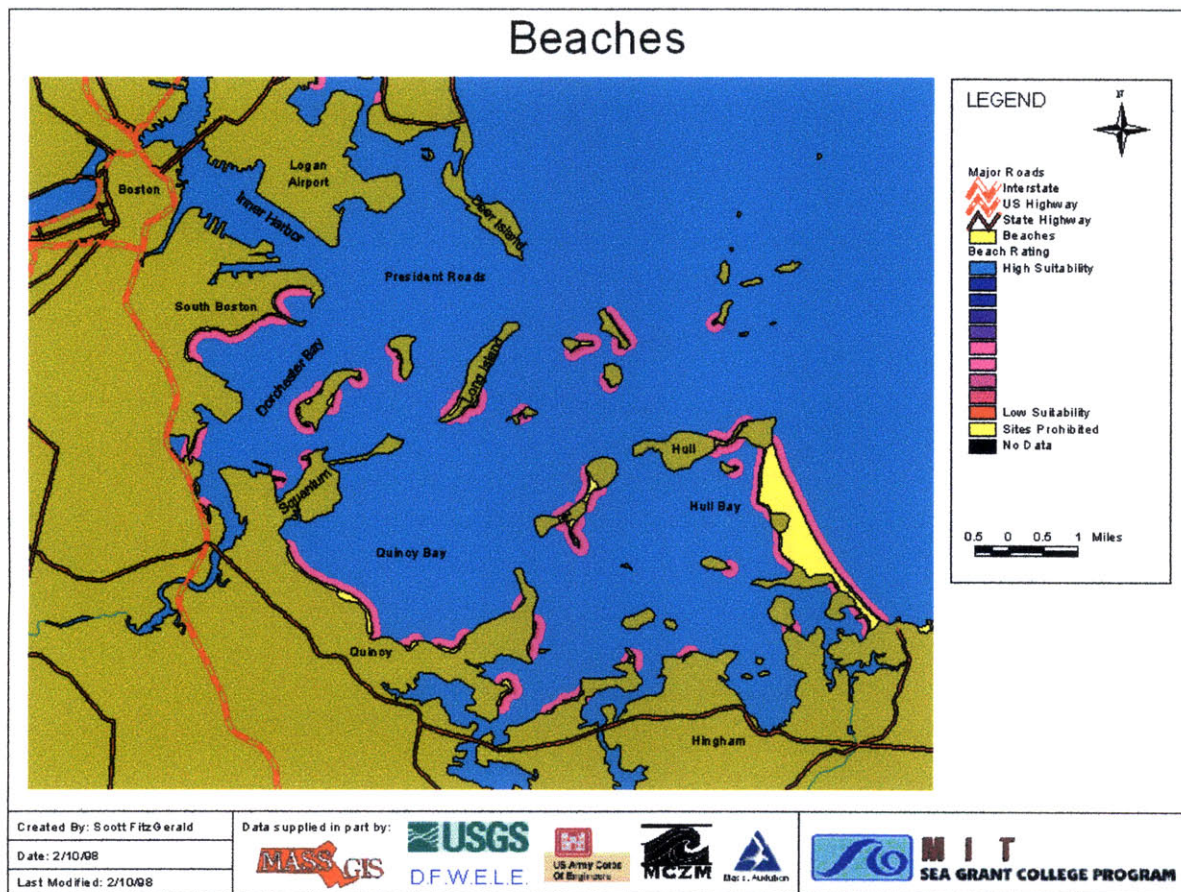
Appendix C - Use of Program

A primary goal of this project was to create a simple, easy-to-use graphical user interface. What follows is a detailed set of instructions on the use of this interface and the interactive GIS program in general. The program files are supplied on a CD-Rom and it is not necessary to transfer any of the files to your hard drive. However, the program does run substantially faster if copied to the hard drive. Additionally, if you wish to save or modify the project after making changes, you will need to copy the contents of the CD-Rom to a local directory on your hard drive. This directory must be named gisite and must be located under the root diretory (e.g. c:\ or d:\) of the drive.

This project requires ArcView 3.0a with the Spatial Analyst and Dialog Designer extensions. The Dialog Designer extension is supplied on the CD-Rom. To install the extension, named `dialog.avx`, copy it to the `ESRI\av_gis30\ArvView\ext32\` directory on your hard drive. You must obtain the Spatial Analyst directly from ESRI.

Open the project

1. Start ArcView. If you are using Windows 95 or NT, this generally involves clicking on the **Start** Button, selecting **Programs**, selecting **ESRI,** selecting **ArcView GIS Version 3.0a**, and finally **ArcView GIS Version 3.0a.**
2. Open up the main project file `gisite.apr`. This file should be located in the `gisite` directory of the CD-ROM included with this thesis. To do this go to File, then Open Project. Navigate to the CD-ROM drive and select gisite.apr. Click OK to continue.
3. The project will open and you will be presented with the main screen. See Figure C-1 for an explanation of the various items and toolbars.

Create a Suitability Map

1. To create a suitability map click on the **Open Weighing Controls** button. You will then see a dialog box as shown in Figure C-2.
2. Weight the various data layers as desired and press the **Graph Results** button. The program will carry out the necessary computations and will display the suitability map based on your weightings when complete. A green indicator in the lower left hand corner of the screen will indicate the progress of the calculations.

To create another suitability map, simply repeat steps 1 and 2 above.

Save a Suitability Map

1. To save a suitability map, first make that map the active theme by clicking on it in the Table of Contents on the left side of the screen. The active theme is indicated by the raised appearance of the legend.

Click on the **Save Selected Grid File** button to save the map. A dialog box will come up asking you where to save the file. Select a convenient location, type in a meaningful filename and click **OK.**

Figure C-1. Main Graphical User Interface
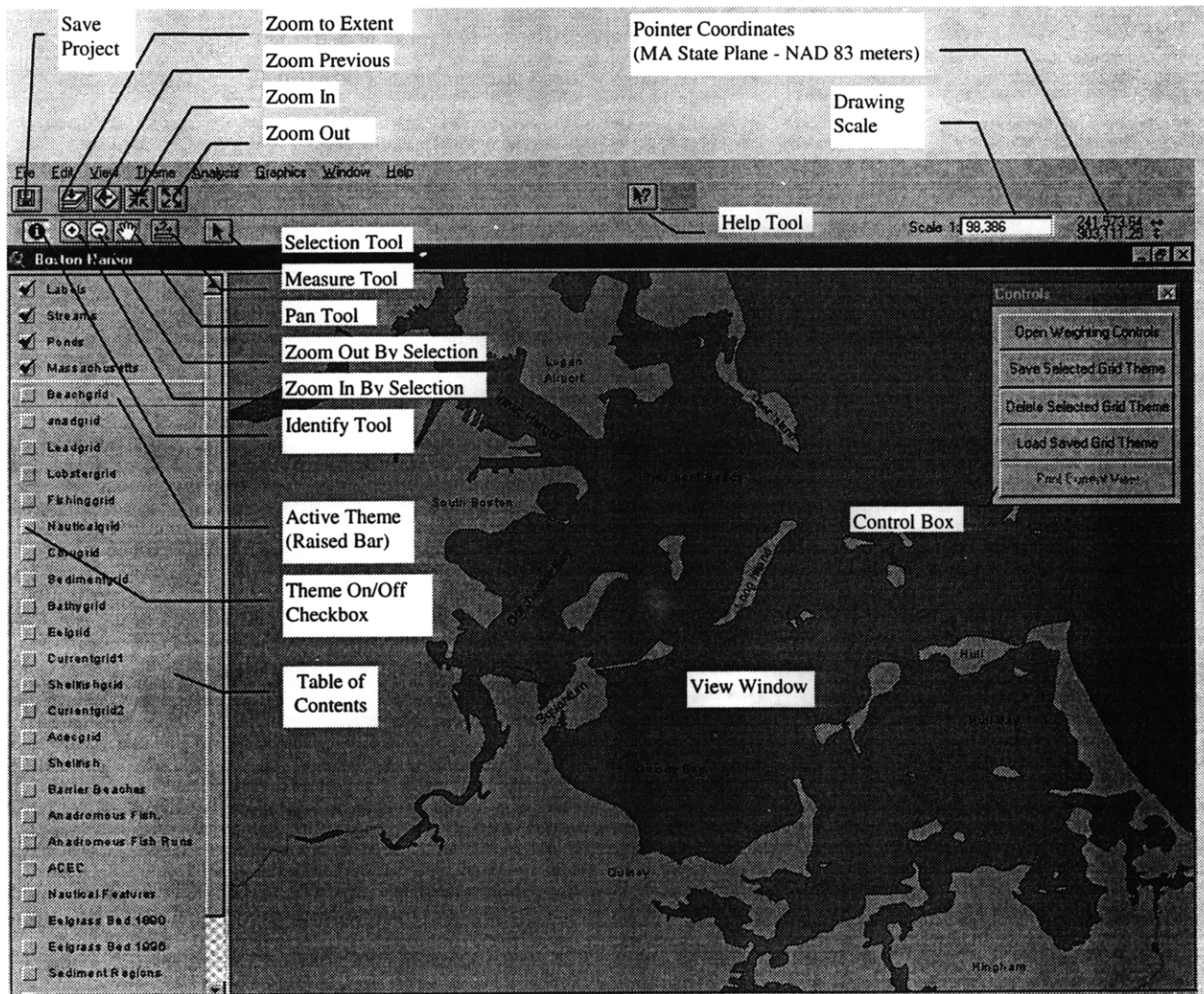
Delete a Suitability Map.

1. To delete a suitability map, first make that map the active theme by clicking on it in the Table of Contents on the left side of the screen.
2. Click on the **Delete Selected Grid File Button** to delete the map.
3. A dialog box asking if you want to delete the grid file will appear. Click **Yes** to delete the file or **No** to cancel the deletion and return to the main screen.

*Note: When a suitability map is first created, the map grid file is temporarily saved to the working directory. Note that if you save the project file by going to **File**, and then selecting **Save Project**, these temporary files become permanent. To avoid filing up your hard drive with unneeded grid files you should be sure to use the **Save Selected Grid File** command to keep those maps that you wish to save and use the **Delete Selected Grid File** command to erase all others before saving the main project, **gisite.apr**. If you inadvertently save a grid file in this manner you will have to use the Grid Manager to delete it from within ArcView. Do not attempt to move or delete grid files using Windows Explorer as you can potentially corrupt the system. Consult your ArcView Documentation for more information on the Grid Manager.*

Figure C-2. Weighting Controls
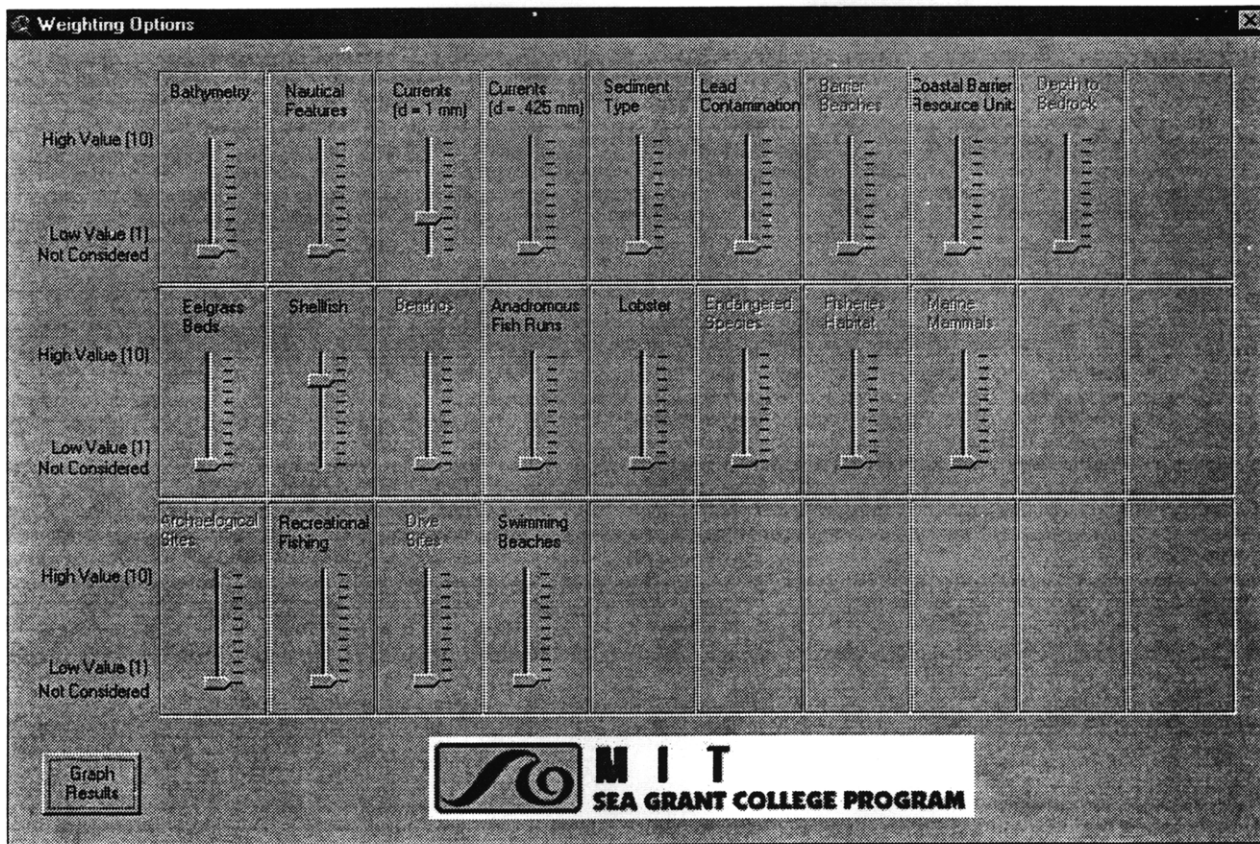
To load a previously saved suitability map

1. Click on the **Load Save Grid File** button.
2. Under **Data Source Types** specify **Grid Data Source.**
3. Navigate to the directory in which you save the grid theme and select it.
4. Press **OK.**
5. The saved suitability map will be added to the view.

Note: At this time the graphic that stores the weights used to create a saved suitability map will not load into the view. This is a known problem to which a solution was not able to be developed in time for the distribution of this project. To avoid this problem do not delete grid files from the view that you wish to save. You can turn off the file by unclicking the check box in the table of contents if desired.

To save the project file

1. Go to **File,** then **Save Project.**
2. If you have previously transferred the contents of the CD-ROM to the hard drive, the project will save itself.
3. If you did not previously transfer the contents of the CD-ROM to your hard drive, you will need to specify a location to save the project file, **gisite.apr.** When you work with the program again, you will need to have the CD-ROM in the drive for it to work properly.

To Zoom In or Out or pan

There are seven zoom tools available. They are outlined below with a listing of how they work.

Zoom to the Extent of Active Themes. This button will zoom out the view until everything included in the active theme highlighted in the table of contents can be shown. It is useful for getting back a view of the whole harbor by selecting a grid theme to zoom out on.

Zoom Previous - This tool will zoom to the previous view you were looking at. It works much like the "Back" Button in any web browser.

Zoom In - This button allows you to zoom in on the center of the view with a zoom factor of 2x.

Zoom Out - This button allows you to zoom out on the center of the view with a zoom factor of 2x.

Zoom In By Selection - This tool allows you to zoom in 2x on a point by just clicking with the tool in the view. Or it allows you to zoom in on a region you define by using the tool to draw a rectangle around the region of interest. To draw a rectangle around the region of interest, click and hold down the mouse button at one corner of the rectangle then drag the pointer to the other corner and release the mouse button.

Zoom Out By Selection - This tool allows you to zoom out 2x, centered on the point that you select.

Pan - This button allows you to scroll the view in any direction without changing the zoom level. To use, just click and hold down the mouse button on the view and drag the view in any direction. When you are satisfied with the new view, release the mouse button.

To Identify attributes.

The identify tool can be used to view attributes of a layer which are stored in the underlying layer data tables. For instance, you can use this tool to find out the value of a grid at a specified point. To use this tool, first select the layer or layers you wish identify in the table of contents and then select the point you wish to identify on the map. A small dialog box will appear with all of the attributes of the chosen layers at the specified point.

To Measure distances on the map.

Use the measure tool to measure distances on the map. To use, simply draw a line representing the distance you wish to measure. Click the mouse button at the start of the line and then drag the mouse to the endpoint of the line. If you wish to measure multiple line segments, click and draw the next line segment. If you are finished measuring, double click the mouse.

To get help

To get help with any tool on the screen use the Help Tool. To use select the help tool and then click on the tool for which you wish to see the help topics.

To access the extensive on-line help which comes with ArcView go to the **HELP** menu and select one of the topics shown.

You can also get help on the current dialog or window you are working with by pressing the F1 key.

Other Notes

Often errors in running the program result from selecting a working directory which doesn't have write privileges. To change the working directory, go to **File,** and then select **Set Working Directory.** Specify a new working directory in the space provided and click **OK.**

Appendix D - Program Documentation

The custom interactive interface was developed using ArcView version 3.0a with the AV Spatial Analyst, Dialog Designer and Metadata Collection Tool Extensions. A customized ArcView project (gisite.apr) was created to manage the data and interactive user interface. There are five primary components to this ArcView Project. They are:

- Views - Windows in which data and suitability maps are displayed.
- Dialogs - Windows with control features for manipulating the system and creating suitability maps
- Scripts - Computer code used to program and activate the interface and also create the suitability maps.
- Legends - Established graphical representations of data theme features.
- Grid Files - Ranked data themes for use in the suitability analysis.

Views

There is one primary view, "Boston Harbor," which shows the entire harbor region by default. This view also contains the **Controls** Dialog Box . When the project file is first opened this view is displayed and maximized. The view contains all of the grid files necessary for inclusion in the suitability analysis and also contains general basemap data such as the harbor shoreline. See Appendix ?? for a listing of themes and metadata. By default, all themes except Labels, Rivers, Ponds, and Massachusetts are not visible.

Dialogs

There are two dialogs that have been created as part of the graphical user interface (GUI) to the project. The first dialog is BHControls (see Figure D-1) which contains the control buttons for opening the weighting control box, saving, loading, or deleting a grid theme, and printing the view. By design this dialog remains on top of all windows. The Open Weighting Controls button (BH.OpenDialog) activates the BH.OpenDialog script which opens the BHWeights dialog. The Save Selected Grid Theme button (BH.SaveGrid) opens up the Spatial.SaveDataSet script which brings up a standard ArcView system dialog box to save the theme. The Delete Selected Grid Theme button (BH.DeleteTheme) activates the View.DeleteThemes script which deletes the selected theme from the view. The Load Saved Grid Theme button (BH.LoadGrid) activates the BH.LoadGrid script which opens a system dialog box to load in grid themes. The print current view is currently inactive because the functionality has not been programmed.

Figure D-1. BHControls Dialog Box
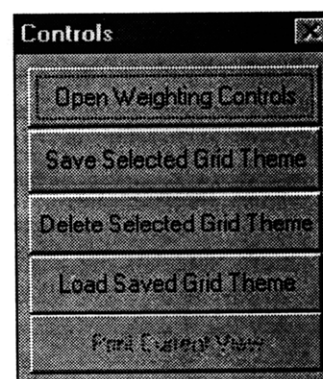
The second dialog is BHWeights (see Figure D-2) which is activated by the Open Weighting Controls button. This dialog contains 30 slider bars for weighting the various data layers. The user simply moves each slider bar up or down as desired and then presses the Graph Results button. In general the top row of sliders are for physical or chemical data layers. The middle row is for biota or natural resource data, and the bottom row is for human resources. Each slider bar can assume integer

values from 0 to 10 inclusive. The naming convention for sliders is `BHweights.sld_datalayername`, where `datalayername` is a short data layer identifier. The Graph Results button (`BHweights.lbt_graph`) activates the `BH.GridCreation` script which computes a suitability map based on the values of the individual slider bars.

Figure D-2. BHWeights Dialog Box
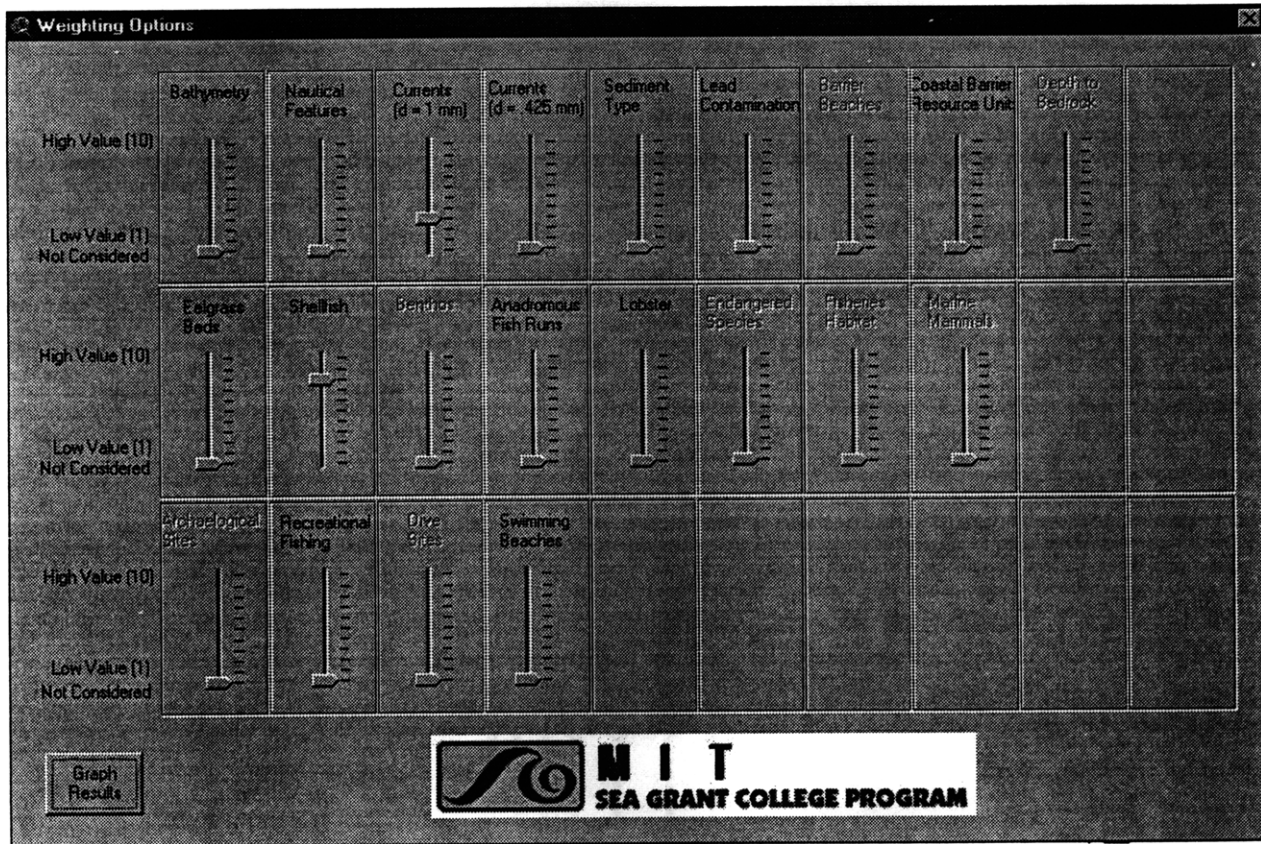
Scripts

There are six scripts that have been created to automate various tasks in the custom interface. All scripts are written in Avenue, which is the custom object-oriented programming language which accompanies ArcView.

BH.GridCreation

This script takes the values from the various slider bars in the `BHWeights` dialog and combines all of the grid files using a weighted geometric mean based on those values. Then it creates a new grid file for display and applies a legend for the suitability areas. In addition it creates a graphic box on the map which contains all of the values of the individual slider bars which were used to create that particular map. It is called from the `Graph Results` button in the `BHWeights` dialog box.

The documentation in the code below explains the various functions. All documentation lines are preceeded by a single quote '.

```
' Name: BH.GridCreation
```

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```
'
' Title: Creates a grid theme using a weighted geometric mean.
'
' Topics: Grids
'
' Description: This script creates a new grid theme from existing
' grid themes by combining the existing themes with a weighted
' geometric mean. The weighting values are obtained from the values
' of the slider bars in the BHweights dialog box.
'
' Requires: Spatial Analyst, Dialog Designer, grid themes loaded
' into view, Suitability.avl on disk
'
' Self:
'
' Returns: Grid Theme


' Get the Boston Harbor View and Weighting Dialog Box

theView = av.GetProject.FindDoc("Boston Harbor")
aDialog = av.FindDialog("BHweights")

' Open the View

theWindow = theView.GetWin
theWindow.Open
theWindow.Maximize

' Lock the TOC  so that the display is always correct.

aTOC = theView.GetTOC
aTOC.SetOrderLocked(true)

' Deactivate all themes
theActiveView = theView.GetThemes
for each t in theView.GetThemes
   t.SetActive(False)
   t.SetVisible(False)
end

theView.Invalidate
theView.GetDisplay.Invalidate(true)

' Get each grid and the weighting values from it's slider.
' Divid all weighing values by ten to reduce computational
' dimensioning problems (e.g. 10^9 * 5^7)

theBathyTheme = theView.FindTheme ("Bathygrid")
g01 = theBathyTheme.GetGrid
w01 = aDialog.FindByName("BHweights.sld_bathy").GetValue / 10

theNauticalTheme = theView.FindTheme ("Nauticalgrid")
g02 = theNauticalTheme.GetGrid
w02 = aDialog.FindByName("BHweights.sld_nautical").GetValue / 10

theCurrent1Theme = theView.FindTheme ("currentgrid1")
g03 = theCurrent1Theme.GetGrid
w03 = aDialog.FindByName("BHweights.sld_currents1").GetValue / 10

theCurrent2Theme = theView.FindTheme ("currentgrid2")
g04 = theCurrent1Theme.GetGrid
w04 = aDialog.FindByName("BHweights.sld_currents2").GetValue / 10

theSedimentTheme = theView.FindTheme ("Sedimentgrid")
```

```
g05 = theSedimentTheme.GetGrid
w05 = aDialog.FindByName("BHweights.sld_sediment").GetValue / 10

theLeadTheme = theView.FindTheme ("Leadgrid")
g06 = theLeadTheme.GetGrid
w06 = aDialog.FindByName("BHweights.sld_contaminants").GetValue / 10

'theBarrierBTheme = theView.FindTheme ("Barrierbgrid")
'g07 = theBarrierBTheme.GetGrid
w07 = aDialog.FindByName("BHweights.sld_barrierb").GetValue / 10

theCBRUTheme = theView.FindTheme ("CBRUgrid")
g08 = theCBRUTheme.GetGrid
w08 = aDialog.FindByName("BHweights.sld_CBRU").GetValue / 10

'theBedrockTheme = theView.FindTheme ("Bedrockgrid")
'g09 = theBedrockTheme.GetGrid
w09 = aDialog.FindByName("Bhweights.sld_Bedrock").GetValue / 10

'g10 =
'w10 =

theEelTheme = theView.FindTheme ("eelgrid")
g11 = theEelTheme.GetGrid
w11 = aDialog.FindByName("BHweights.sld_eelgrass").GetValue / 10

theShellfishTheme = theView.FindTheme ("Shellfishgrid")
g12 = theShellfishTheme.GetGrid
w12 = aDialog.FindByName("BHweights.sld_shellfish").GetValue / 10

'theBenthosTheme = theView.FindTheme ("Benthosgrid")
'g13 = theBenthosTheme.GetGrid
w13 = aDialog.FindByName("BHweights.sld_benthos").GetValue / 10

theAnadTheme = theView.FindTheme ("Anadgrid")
g14= theAnadTheme.GetGrid
w14 = aDialog.FindByName("BHweights.sld_anad").GetValue / 10

theLobsterTheme = theView.FindTheme ("Lobstergrid")
g15 = theLobsterTheme.GetGrid
w15 = aDialog.FindbyName("BHweights.sld_lobster").GetValue / 10


'theFisheriesTheme = theView.FindTheme ("fisheriesgrid")
'g16 = theFisheriesTheme.GetGrid
w16 = aDialog.FindByName("BHweights.sld_fisheries").GetValue / 10

'theMammalTheme = theView.FindTheme ("Mammalgrid")
'g17 = theMammalTheme = Get.Grid
w17 = aDialog.FindByName("BHweights.sld_mammals").GetValue / 10

'theEndangeredTheme = theView.FindTheme ("Endangeredgrid")
'g18 = theEndangeredTheme = Get.Grid
w18 = aDialog.FindByName("Bhweights.sld_endangered").GetValue / 10

'g19 =
'w19 =

'g20 =
'w20 =

'theArchTheme = theView.FindTheme ("Archgrid")
'g21 = theArchTheme.GetGrid
w21 = aDialog.FindByName("BHweights.sld_Archeological").GetValue / 10
```

```
theFishingTheme = theView.FindTheme ("Fishinggrid")
g22 = theFishingTheme.GetGrid
w22 = aDialog.FindByName("BHweights.sld_fishing").GetValue / 10

'theDiveTheme = theView.FindTheme ("Divegrid")
'g23 = theDiveTheme.GetGrid
w23 = aDialog.FindByName("Bhweights.sld_diving").GetValue / 10

theBeachTheme = theView.FindTheme ("Beachgrid")
g24 = theBeachTheme.GetGrid
w24 = aDialog.FindByName("Bhweights.sld_beaches").GetValue / 10

'g25 =
'w25 =

'g26 =
'w26 =

'g27 =
'w27 =

'g28 =
'w28 =

'g29 =
'w29 =

'g30 =
'w30 =

' get the acec for the analysis. Needed for final output, but doesn't use a
slider.

theACECTheme = theView.FindTheme ("acecgrid")
acecgrid = theACECTheme.GetGrid

' Compute the sum of the weighting values

t = w01 + w02 + w03 + w04+ w05 + w06 + w08 + w11 + w12 + w14 + w15 + w22 + w24

' Calculate the new grid values using a weighted geometric mean

newgrid = acecgrid * ((g01^w01) * (g02^w02) * (g03^w03) * (g04^w04) * (g05^w05)
* (g06^w06) * (g08^w08) * (g11^w11) *(g12^w12) * (g14^w14) * (g15^w15) *
(g22^w22) * (g24^w24))^(1/(t))

' Make newgrid a GridTheme for viewing

thenewgrid = GTheme.make(newgrid)

' Deactivate all themes in preparation for adding new GridTheme

theActiveView = theView.GetThemes
for each t in theView.GetThemes
  t.SetActive(False)
  t.SetVisible(False)
end

' Add the new GridTheme to the Boston Harbor view and make it active

theView.AddTheme(thenewgrid)
thenewgrid.SetVisible(True)
thenewgrid.SetActive(True)

' Load in the Legend for the new theme and apply it
```

```
GridLegend = Legend.Make(#SYMBOL_FILL)
GridLegend.Load("d:\gis\bhlegends\suitability2.avl".AsFileName,
#LEGEND_LOADTYPE_ALL)
thenewgrid.SetLegend(GridLegend)
thenewgrid.UpdateLegend   ' Redraw



' Move the Theme to its proper location in the TOC

theThemeList = theView.GetThemes
theThemeList.Shuffle(theThemeList.Get(0), 5)
theview.InvalidateTOC(nil)
theView.GetDisplay.Invalidate(true)
theThemeList.Get(0).SetVisible(True)
theThemeList.Get(1).SetVisible(True)
theThemeList.Get(2).SetVisible(True)
theThemeList.Get(3).SetVisible(True)
theThemeList.Get(4).SetVisible(True)


' Display the Slider Values for the GridTheme

textalign = 233000  ' Left Stateplane coord for text and box
vertalign = 889000  ' Botton Stateplan coord for text and box
numalign = textalign + 3000 ' Offset for numeral from text
vertsep = 300               ' Vertical separation for text

textSym = TextSymbol.Make
textSym.SetSize(9)

Point1 = Point.Make(textalign,vertalign +(30*vertsep))
Point1a = Point.Make(numalign, vertalign+(30*vertsep))
Point2 = Point.Make(textalign,vertalign+(29*vertsep))
Point2a = Point.Make(numalign, vertalign+(29*vertsep))
Point3 = Point.Make(textalign,vertalign+(28*vertsep))
Point3a = Point.Make(numalign, vertalign+(28*vertsep))
Point4 = Point.Make(textalign,vertalign+(27*vertsep))
Point4a = Point.Make(numalign, vertalign+(27*vertsep))
Point5 = Point.Make(textalign,vertalign+(26*vertsep))
Point5a = Point.Make(numalign,vertalign+(26*vertsep))
Point6 = Point.Make(textalign,vertalign+(25*vertsep))
Point6a = Point.Make(numalign,vertalign+(25*vertsep))
Point7 = Point.Make(textalign,vertalign+(24*vertsep))
Point7a = Point.Make(numalign, vertalign+(24*vertsep))
Point8 = Point.Make(textalign,vertalign+(23*vertsep))
Point8a = Point.Make(numalign, vertalign+(23*vertsep))
Point9 = Point.Make(textalign,vertalign+(22*vertsep))
Point9a = Point.Make(numalign, vertalign+(22*vertsep))
Point10 = Point.Make(textalign,vertalign+(21*vertsep))
Point10a = Point.Make(numalign, vertalign+(21*vertsep))
Point11 = Point.Make(textalign,vertalign+(20*vertsep))
Point11a = Point.Make(numalign, vertalign+(20*vertsep))
Point12 = Point.Make(textalign,vertalign+(19*vertsep))
Point12a = Point.Make(numalign, vertalign+(19*vertsep))
Point13 = Point.Make(textalign,vertalign+(18*vertsep))
Point13a = Point.Make(numalign, vertalign+(18*vertsep))
Point14 = Point.Make(textalign,vertalign+(17*vertsep))
Point14a = Point.Make(numalign, vertalign+(17*vertsep))
Point15 = Point.Make(textalign,vertalign+(16*vertsep))
Point15a = Point.Make(numalign, vertalign+(16*vertsep))
Point16 = Point.Make(textalign,vertalign+(15*vertsep))
Point16a = Point.Make(numalign, vertalign+(15*vertsep))
Point17 = Point.Make(textalign,vertalign+(14*vertsep))
```

```
Point17a = Point.Make(numalign, vertalign+(14*vertsep))
Point18 = Point.Make(textalign,vertalign+(13*vertsep))
Point18a = Point.Make(numalign, vertalign+(13*vertsep))
Point19 = Point.Make(textalign,vertalign+(12*vertsep))
Point19a = Point.Make(numalign, vertalign+(12*vertsep))
Point20 = Point.Make(textalign,vertalign+(11*vertsep))
Point20a = Point.Make(numalign, vertalign+(11*vertsep))
Point21 = Point.Make(textalign,vertalign+(10*vertsep))
Point21a = Point.Make(numalign, vertalign+(10*vertsep))
Point22 = Point.Make(textalign,vertalign+(9*vertsep))
Point22a = Point.Make(numalign, vertalign+(9*vertsep))
Point23 = Point.Make(textalign,vertalign+(8*vertsep))
Point23a = Point.Make(numalign, vertalign+(8*vertsep))
Point24 = Point.Make(textalign,vertalign+(7*vertsep))
Point24a = Point.Make(numalign, vertalign+(7*vertsep))
Point25 = Point.Make(textalign,vertalign+(6*vertsep))
Point25a = Point.Make(numalign, vertalign+(6*vertsep))
Point26 = Point.Make(textalign,vertalign+(5*vertsep))
Point26a = Point.Make(numalign, vertalign+(5*vertsep))
Point27 = Point.Make(textalign,vertalign+(4*vertsep))
Point27a = Point.Make(numalign, vertalign+(4*vertsep))
Point28 = Point.Make(textalign,vertalign+(3*vertsep))
Point28a = Point.Make(numalign, vertalign+(3*vertsep))
Point29 = Point.Make(textalign,vertalign+(2*vertsep))
Point29a = Point.Make(numalign, vertalign+(2*vertsep))
Point30 = Point.Make(textalign,vertalign+(1*vertsep))
Point30a = Point.Make(numalign, vertalign+(1*vertsep))


theRectangle   =   Rect.MakeXY(textalign   -   300,vertalign   -   500,numalign   +
700,vertalign +(32*vertsep))
theRectSymbol = Symbol.Make(#Symbol_Fill)
theRectSymbol.SetColor(Color.GetWhite)
GraphicRectangle = GraphicShape.Make(theRectangle)
GraphicRectangle.SetSymbol(theRectSymbol)

GraphicBathy =    GraphicText.Make("Bathymetry",Point1)
GraphicBathy.SetSymbol(textSym)
GraphicBathya = GraphicText.Make((w01*10).AsString,Point1a)
GraphicBathya.SetSymbol(textSym)

GraphicNautical = GraphicText.Make("Nautical Features",Point2)
GraphicNautical.SetSymbol(textSym)
GraphicNauticala = GraphicText.Make((w02*10).AsString,Point2a)
GraphicNauticala.SetSymbol(textSym)

GraphicCurrents1 = GraphicText.Make("Currents",Point3)
GraphicCurrents1.SetSymbol(textSym)
GraphicCurrents1a = GraphicText.Make((w03*10).AsString,Point3a)
Graphiccurrents1a.SetSymbol(textSym)

GraphicCurrents2 = GraphicText.Make("Currents",Point4)
GraphicCurrents2.SetSymbol(textSym)
GraphicCurrents2a = GraphicText.Make((w04*10).AsString,Point4a)
Graphiccurrents2a.SetSymbol(textSym)

GraphicSediment = GraphicText.Make("Sediment",Point5)
GraphicSediment.SetSymbol(textSym)
GraphicSedimenta = GraphicText.Make((w05*10).AsString,Point5a)
GraphicSedimenta.SetSymbol(textSym)

GraphicContaminant = GraphicText.Make("Lead",Point6)
GraphicContaminant.SetSymbol(textSym)
GraphicContaminanta = GraphicText.Make((w06*10).AsString,Point6a)
```

```
GraphicContaminanta.SetSymbol(textSym)

GraphicBarrierB =   GraphicText.Make("Barrier Beaches",Point7)
GraphicBarrierB.SetSymbol(textSym)
GraphicBarrierBa = GraphicText.Make((w07*10).AsString,Point7a)
GraphicBarrierBa.SetSymbol(textSym)

GraphicCBRU =       GraphicText.Make("CBRA",Point8)
GraphicCBRU.SetSymbol(textSym)
GraphicCBRUa = GraphicText.Make((w08*10).AsString,Point8a)
GraphicCBRUa.SetSymbol(textSym)

GraphicBedrock = GraphicText.Make ("Depth to Bedrock",Point9)
GraphicBedrock.SetSymbol(textSym)
GraphicBedrocka = GraphicText.Make((w09*10).AsString, Point9a)
GraphicBedrocka.SetSymbol(textSym)

GraphicEel = GraphicText.Make("Eelgrass",Point11)
GraphicEel.SetSymbol(textSym)
GraphicEela = GraphicText.Make((w11*10).AsString,Point11a)
GraphicEela.SetSymbol(textSym)

GraphicShellfish = GraphicText.Make("Shellfish",Point12)
GraphicShellfish.SetSymbol(textSym)
GraphicShellfisha = GraphicText.Make((w12*10).AsString,Point12a)
GraphicShellfisha.SetSymbol(textSym)

GraphicBenthos = GraphicText.Make("Benthos",Point13)
GraphicBenthos.SetSymbol(textSym)
GraphicBenthosa = GraphicText.Make((w13*10).AsString,Point13a)
GraphicBenthosa.SetSymbol(textSym)

GraphicANAD =       GraphicText.Make("Anadroumous Fish",Point14)
GraphicANAD.SetSymbol(textSym)
GraphicANADa = GraphicText.Make((w14*10).AsString,Point14a)
GraphicANADa.SetSymbol(textSym)

GraphicLobster =    GraphicText.Make("Lobster",Point15)
GraphicLobster.SetSymbol(textSym)
GraphicLobstera = GraphicText.Make((w15*10).AsString,Point15a)
GraphicLobstera.SetSymbol(textSym)

GraphicFisheries =      GraphicText.Make("Fisheries",Point16)
GraphicFisheries.SetSymbol(textSym)
GraphicFisheriesa = GraphicText.Make((w16*10).AsString,Point16a)
GraphicFisheriesa.SetSymbol(textSym)

GraphicMammals =        GraphicText.Make("Marine Mammals",Point17)
GraphicMammals.SetSymbol(textSym)
GraphicMammalsa = GraphicText.Make((w17*10).AsString,Point17a)
GraphicMammalsa.SetSymbol(textSym)

GraphicEndangered =     GraphicText.Make("Endangered Species",Point18)
GraphicEndangered.SetSymbol(textSym)
GraphicEndangereda = GraphicText.Make((w18*10).AsString,Point18a)
GraphicEndangereda.SetSymbol(textSym)

GraphicArch =       GraphicText.Make("Archeological Sites",Point21)
GraphicArch.SetSymbol(textSym)
GraphicArcha = GraphicText.Make((w21*10).AsString,Point21a)
Graphicarcha.SetSymbol(textSym)

GraphicFishing =        GraphicText.Make("Recreational Fishing",Point22)
GraphicFishing.SetSymbol(textSym)
GraphicFishinga = GraphicText.Make((w22*10).AsString,Point22a)
```

```
GraphicFishinga.SetSymbol(textSym)

GraphicDive =        GraphicText.Make("Dive Sites",Point23)
GraphicDive.SetSymbol(textSym)
GraphicDivea = GraphicText.Make((w23*10).AsString,Point23a)
GraphicDivea.SetSymbol(textSym)

GraphicBeaches =        GraphicText.Make("Swimming Beaches",Point24)
GraphicBeaches.SetSymbol(textSym)
GraphicBeachesa = GraphicText.Make((w24*10).AsString,Point24a)
GraphicBeachesa.SetSymbol(textSym)



theGraphicList = theView.GetGraphics
theGraphicList.Add(GraphicRectangle)
theGraphicList.Add(GraphicBathy)
theGraphicList.Add(GraphicBathya)
theGraphicList.Add(GraphicNautical)
theGraphicList.Add(GraphicNauticala)
theGraphicList.Add(GraphicCurrents1)
theGraphicList.Add(GraphicCurrents1a)
theGraphicList.Add(GraphicCurrents2)
theGraphicList.Add(GraphicCurrents2a)
theGraphicList.Add(GraphicSediment)
theGraphicList.Add(GraphicSedimenta)
theGraphicList.Add(GraphicContaminant)
theGraphicList.Add(GraphicContaminanta)
theGraphicList.Add(GraphicBarrierB)
theGraphicList.Add(GraphicBarrierBa)
theGraphicList.Add(GraphicEel)
theGraphicList.Add(GraphicEela)
theGraphicList.Add(GraphicShellfish)
theGraphicList.Add(GraphicShellfisha)
theGraphicList.Add(GraphicBenthos)
theGraphicList.Add(GraphicBenthosa)
theGraphicList.Add(GraphicANAD)
theGraphicList.Add(GraphicANADa)
theGraphicList.Add(GraphicLobster)
theGraphicList.Add(GraphicLobstera)
theGraphicList.Add(GraphicCBRU)
theGraphicList.Add(GraphicCBRUa)
theGraphicList.Add(GraphicFisheries)
theGraphicList.Add(GraphicFisheriesa)
theGraphicList.Add(GraphicMammals)
theGraphicList.Add(GraphicMammalsa)
theGraphicList.Add(GraphicEndangered)
theGraphicList.Add(GraphicEndangereda)
theGraphicList.Add(GraphicArch)
theGraphicList.Add(GraphicArcha)
theGraphicList.Add(GraphicFishing)
theGraphicList.Add(GraphicFishinga)
theGraphicList.Add(GraphicDive)
theGraphicList.Add(GraphicDivea)
theGraphicList.Add(GraphicBeaches)
theGraphicList.Add(GraphicBeachesa)



theGraphicList.SelectAll

theActiveTheme = theView.GetActiveThemes.Get(0)
theGraphicSet = theActiveTheme.GetGraphics
```

```
for each g in theView.GetGraphics.GetSelected
  theGraphicSet.Add(g)
end
theGraphicSet.SetVisible(true)
theGraphicList.UnselectAll

aDialog.Close
```

BH.LoadGrid

This script activates a system dialog to load in a grid theme saved on disk. It is called from the
BHControls dialog.

```
' Deactivate all themes in preparation for adding new GridTheme

theView = av.GetProject.FindDoc("Boston Harbor")

theActiveView = theView.GetThemes
for each t in theView.GetThemes
  t.SetActive(False)
  t.SetVisible(False)
end

' Add the new GridTheme to the Boston Harbor view and make it active

theView = av.GetActiveDoc
srcnames = SourceDialog.Show("")
zoom = (theView.GetThemes.Count = 0)
for each n in srcnames
  theView.AddTheme(Theme.Make(n))
end
if ((theView.GetActiveThemes.Count = 0) and (srcnames.Count > 0)) then
  theView.GetThemes.Get(0).SetActive(TRUE)
end
if (zoom) then  theThemes = theView.GetThemes
  r = Rect.MakeEmpty
  for each t in theThemes
    r = r.UnionWith(t.ReturnExtent)
  end
  if (r.IsEmpty) then
    return nil
  elseif ((r.ReturnSize) = (0@0)) then
    theView.GetDisplay.PanTo(r.ReturnOrigin)
  else
    theView.GetDisplay.SetExtent(r.Scale(1.1))
  end
end

thenewgrid = theView.GetThemes.Get(0)

' Load in the Legend for the new theme and apply it

GridLegend = Legend.Make(#SYMBOL_FILL)
GridLegend.Load("d:\gis\bhlegends\suitability2.avl".AsFileName,
#LEGEND_LOADTYPE_ALL)
thenewgrid.SetLegend(GridLegend)
thenewgrid.UpdateLegend   ' Redraw

' Move the Theme to its proper location in the TOC
```

```
theThemeList = theView.GetThemes
theThemeList.Shuffle(theThemeList.Get(0), 5)
theview.InvalidateTOC(nil)
theView.GetDisplay.Invalidate(true)
theThemeList.Get(0).SetVisible(True)
theThemeList.Get(1).SetVisible(True)
theThemeList.Get(2).SetVisible(True)
theThemeList.Get(3).SetVisible(True)
theThemeList.Get(4).SetVisible(True)
```

BH.LockTOC

This script locks the table of contents so that users cannot move the data layers. This is necessary to preserve the proper ordering for drawing the suitability maps. It is called from the BH.GridCreation script.

```
theView = av.GetProject.FindDoc("Boston Harbor")
aTOC = theView.GetTOC
aTOC.SetOrderLocked(true)
```

BH.OpenDialog

This script opens up the BHWeights dialog box. It is called from the BH.OpenDialog button in the BHControls dialog.

```
'Get the View and Turn off all themes
'The themes need to be off for the weighting legend
'box to work properly

theView = av.GetProject.FindDoc("Boston Harbor")

theActiveView = theView.GetThemes
for each t in theView.GetThemes
  t.SetActive(False)
  t.SetVisible(False)
end

'Open the Weighting Dialog Box

aDialog = av.FindDialog("BHweights")
aDialog.Open
```

BH.UnlockTOC

This script unlocks the table of contents. It is called from BH.GridCreation.

```
theView = av.GetProject.FindDoc("Boston Harbor")
aTOC = theView.GetTOC
aTOC.SetOrderLocked(false)
```

BH.WeightsStartup

This script opens up the `Boston Harbor` view and the `BHControls` dialog box. It is called by the `BH.Startup` script.

```
theView = av.GetProject.FindDoc("Boston Harbor")

theWindow = theView.GetWin
theWindow.Open
theWindow.Maximize


aDialog = av.FindDialog("BHcontrols")
aDialog.Open
```

BH.Startup

```
This script opens up the GISite logo screen and then calls BH.WeightsStartup.

theView = av.GetProject.FindDoc("GISite")


theWindow = theView.GetWin
theWindow.Open
theWindow.Maximize

av.DelayedRun ("BH.WeightsStartup", nil, 5)
```

Meta.Help

This script consists of documentation outlining how to use the Metadata Collection tool. As it is not central to this project the code has not been included here.

Legends

Several legends were created for use with this project. Legends assign colors and/or shapes to various items in a data theme to simplify and empower the graphical representation of the data. A total of 18 legends were created. They are stored in their own directory, BHLegends, located under the main project directory. The legends are as follows:

- ACEC.avl - for the ACEC data layer.
- Anadfish.avl - for the anadromous fish layer.
- Barrierb.avl - for the barrier beaches data layer.
- Bathymetry.avl - for the bathymetry data layer. Note that the data layer has depths in meters but that the graphical representation is relabeled to read in feet.
- CBRU.avl - for the Coastal Barrier Resource Units data layer.
- Eel1890 - for the 1890 Eelgrass layer.
- Eel1996 - for the 1996 Eelgrass layer.
- Labels.avl - contains text properties for the labels layer.
- Mass.avl - for the Massachusetts basemap layer.
- Nautical.avl - for the nautical line features layer.
- Ocean.avl - for the ocean basemap layer.

- Ponds.avl - for the ponds basemap layer.
- Roads.avl - for the roads basemap layer.
- Sediments.avl - for the sediment region data layer
- Streams.avl - for the streams basemap.
- Suitability.avl - the legend for the suitability maps created for use with the BH.GridCreation Script. This legend has a 10 color suitability spread.
- Suitability2.avl - the legend for the suitability maps created with the BH.GridCreation Script. This legend has a 5 color suitability spread.

Grid Files

Grid files are raster files created for each data layer based on the ranking scheme developed by knowledgeable scientists, engineers, and regulators. All grid files are located in the BHGrids directory located under the main project directory. For a description of all of the grid files and data layer documentation (see Appendix B).

Appendix E - Survey Questionnaires

Use of GIS to Aid in Disposal Site Selection

Pre-Questionnaire

The emergence of Geographic Information Systems (GIS) software for the desktop PC provides an inexpensive tool for manipulating the spatial data typical of siting decisions. As part of my thesis research at M.I.T. I'm developing and assessing the viability of using a custom GIS application to aid in dredged disposal siting decisions. This questionnaire will aid me greatly in my research and will help evaluate the proposed GIS system which will be demonstrated and evaluated at a later date.

I would like to thank you in advance for your time and assistance in this project.

Scott FitzGerald

Respondent Information

Name: Company / Agency:

Phone: E-mail:

GIS Background

1. Have you ever had a Geographic Information System (ArcView/ArcInfo, Intergraph, etc...)
   demonstrated for you?   ☐ Yes ☐ No ☐ Not Sure

2. Have you ever used a GIS yourself?   ☐ Yes ☐ No ☐ Not Sure

3. Are you interested in using GIS more frequently?   ☐ Yes ☐ No ☐ Not Sure

4. Does you company / agency currently make use of some sort of GIS?
                                                      ☐ Yes ☐ No ☐ Not Sure

5. On a scale of 1-5 (1 being best) how would you rate your knowledge of the capabilities and
   applications of GIS? (circle one)   1   2   3   4   5

6. Do you think that GIS can be useful for aiding in dredged material disposal site selection?
                                                      ☐ Yes ☐ No ☐ Not Sure

7. In what areas do you think it has the most promise? (please rank preference, 1 being best)
   ☐ Data management
   ☐ Engineering studies
   ☐ Public education / presentation
   ☐ Decision making
   ☐ Other (please describe):

Disposal Site Selection

8. What do you think is the most pressing problem involving disposal site selection in the future?

9. What steps do you think should be taken to work towards a solution to that problem?

10. Would you say on average that public participation as it is now allowed has a positive or negative
    impact on the decision making process?   ☐ Positive   ☐ Negative   ☐ Not Sure

11. At what point(s), if any, do you feel the public ought to be involved in the decision making process?

12. Do you feel that the public has a through understanding of what data, analysis and assumptions enter in to current decisions? ☐ Yes ☐ No ☐ Not Sure
Comments:

13. Do you feel that more public involvement or more education is needed?
        Public Involvement ☐ Yes ☐ No ☐ Not Sure
        Education ☐ Yes ☐ No ☐ Not Sure

14. Do you think that the current planning system provides the proper balance of public input, scientific analysis, and regulatory decisions? ☐ Yes ☐ No ☐ Not Sure

15. Do the current federal, state, and local government planning systems and the consultants hired to evaluate and/or put forth proposals provide for constructive public and scientific input?

	Public Input		Scientific Input		
Federal Government	☐ Yes ☐ No		☐ Yes ☐ No		☐ Not Sure
State Government	☐ Yes ☐ No		☐ Yes ☐ No		☐ Not Sure
Local Government	☐ Yes ☐ No		☐ Yes ☐ No		☐ Not Sure
Consultants	☐ Yes ☐ No		☐ Yes ☐ No		☐ Not Sure

16. Is this input sought at the proper time in the decision making process?
Comments: ☐ Yes ☐ No ☐ Not Sure

17. Do you trust Environmental Impact Reports / Statements (EIR/EIS) to present accurate data in a useful format? ☐ Yes ☐ No ☐ Not Sure

18. Do you feel that the current planning methods allow one to accurately review the assumptions and methods used to make decisions? ☐ Yes ☐ No ☐ Not Sure
Comments:

19. How would you compare the matrix approach to evaluating dredged disposal sites to a GIS approach? ☐ Matrix is more appropriate ☐ GIS is more appropriate ☐ Not sure
Comments:

20. Other Comments:

Thank You!!

Use of GIS to Aid in Disposal Site Selection
Post-Questionnaire

The emergence of Geographic Information Systems (GIS) software for the desktop PC provides an inexpensive tool for manipulating the spatial data typical of siting decisions. As part of my thesis research at M.I.T. I'm developing and assessing the viability of using a custom GIS application to aid in dredged disposal siting decisions. This questionnaire will aid me greatly in my research and will help evaluate the proposed GIS system which has just been demonstrated for you.

I would like to thank you in advance for your time and assistance in this project.

Scott FitzGerald

Respondent Information
_____

Name: Company / Agency:

Phone: E-mail:

_____

1. After viewing the demonstration do you feel that you have an improved understanding of the capabilities and applications of GIS? ☐ Yes ☐ No ☐ Not Sure

2. If a GIS system were available do you think you would use it? ☐ Yes ☐ No ☐ Not Sure

3. What reasons would you give for not wanting to use a GIS system?

4. Would like you to have access to the results from GIS analyses? ☐ Yes ☐ No ☐ Not Sure

5. Do you think that your agency / company should encourage the use of GIS throughout? Do you think that you will propose that your agency / company increases its use of GIS?
   Company should encourage use of GIS ☐ Yes ☐ No ☐ Not Sure
   I will propose that my organization increase its use of GIS ☐ Yes ☐ No ☐ Not Sure

6. Do you feel that GIS has the potential to be a useful tool in dredged disposal site selection? ☐ Yes ☐ No ☐ Not Sure

7. Do you feel that development of this technology is worthwhile or do you feel that efforts should be focused elsewhere?
   ☐ Efforts better focused elsewhere   ☐ Efforts to develop GIS applications worthwhile
   Where?

8. What do you think is the best use for GIS? (please rank preferences, 1 being best)
   ☐ Data management
   ☐ Engineering studies
   ☐ Public education / presentation
   ☐ Decision making
   ☐ Other (please describe):

9. Do you feel that the system demonstrated provides a good model for future application of GIS?
   Comments: ☐ Yes ☐ No ☐ Not Sure

10. What limitations do you think that the proposed GIS system will need to overcome in order to be useful?

11. Do you think that this system provides for the proper balance of public input, scientific analysis, and regulatory decisions? ☐ Yes ☐ No ☐ Not Sure
Comments:

12. Do you think that the public would appreciate the development and implementation of this system?
Comments: ☐ Yes ☐ No ☐ Not Sure

13. Do you think the public would make use of such a system? ☐ Yes ☐ No ☐ Not Sure

14. Does the GIS model proposed provide for constructive public and scientific input? Is this input sought at the proper time in the decision making process?

Provides for constructive public input	☐ Yes	☐ No	☐ Not Sure
Provides for constructive scientific input	☐ Yes	☐ No	☐ Not Sure
Input is sought at proper time in decision making process	☐ Yes	☐ No	☐ Not Sure

15. What agency(ies) / company(ies) do you think should take the lead in continuing the development of this system?

M.I.T.	☐ Yes	☐ No
Other Educational Institution (who?)	☐ Yes	☐ No
Consultant (who?)	☐ Yes	☐ No
Local Agency (who?)	☐ Yes	☐ No
State Agency (who?)	☐ Yes	☐ No
Federal Agency (who?)	☐ Yes	☐ No
Other:		

16. How would you compare the matrix approach to evaluating dredged disposal sites to a GIS approach? ☐ Matrix is more appropriate ☐ GIS is more appropriate ☐ Not sure
On what basis did you make your decision? Why?:

17. Other Comments

Thank you!!!

Use of Geographic Information Systems (GIS) to Identify Marine Sediment Disposal Sites in Boston Harbor

"GISite"

Scott FitzGerald

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Dredging in the U.S.

- Approximately 400 million cubic yards (cy) of sediment is dredged every year.
- Somewhere between 1% - 4% of the 300 million cy federal portion is contaminated
- In order to maintain national security and the economic viability of U.S. ports this material must be dredged.

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Disposal Options

- There are 3 primary disposal options for disposal of dredged sediments
  - Open Ocean
  - Near Shore
    - Borrow Pits
    - Containment Areas / Islands
    - Habitat Creation / Beach Nourishment
  - Upland
    - Landfilling / Landfill Capping
    - Commercial Reuse

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Contaminated Sediment Disposal

- For contaminated sediments the disposal options are reduced
  - ~~Open Ocean~~
  - Near Shore
    - Borrow Pits
    - Containment Areas / Islands
    - ~~Habitat Creation / Beach Nourishment~~
  - Upland
    - Landfilling / Landfill Capping
    - ~~Commercial Reuse~~

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The Massachusetts Experience
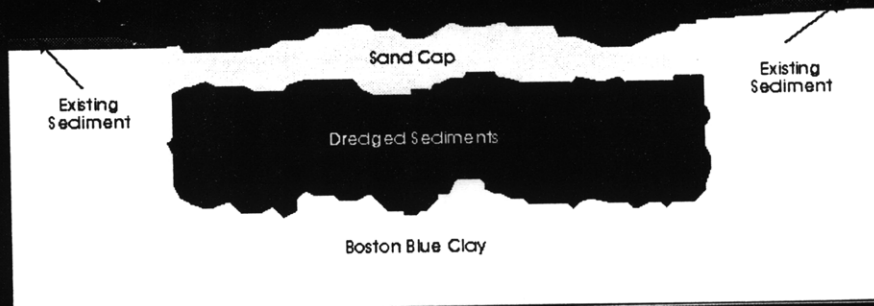
- Upland disposal sites have proven to be infeasible due to high costs and regulatory obstacles.
- Containment areas, while permittable, prove to be much more problematic than subaqueous borrow pits.

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Borrow Pits

Existing Sediment

Sand Cap

Existing Sediment

Dredged Sediments

Boston Blue Clay

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Borrow Pits

- One of the least expensive methods for isolating contaminated sediments
- Material is placed near source in existing, impacted regions
- Difficult and expensive to site disposal areas
  - Regulatory difficulties
  - Political opposition (NIMBY)
  - How to identify likely candidate sites?

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Geographic Information Systems

- GIS software is a promising new tool that allows for complex spatial analysis of data
- Pertinent data layers such as regulatory boundaries, bathymetry, sediment quality, aquatic species, recreational uses, can all be overlaid and analyzed to meet regulatory constraints and minimize impacts based on given criteria

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Boston Harbor Future

- Over the next 50 years an estimated additional 7.1 million cy of sediment will need to be dredged and disposed.
  - It is assumed that all of this sediment will be contaminated and unsuitable for ocean disposal.
  - It is likely that borrow bits will be the best option for disposal.
  - Examine the use of GIS to site future aquatic disposal areas in Boston Harbor for this sediment.

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Goals of GISite

- Develop an easy-to-use graphical user interface (GUI)
  - Allow for the manipulation and weighting of the various data layers that affect siting decisions
  - Look at the problem in a holistic manner
- Allow for community, scientific, and regulatory input in the beginning of the siting process before sites are picked for a more detailed examination during the EIR/S process.

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Questions to be Addressed

- Is GIS technology an appropriate tool for managing and analyzing the data required for siting decisions?

- Is an interactive GIS program an effective tool for communicating and distributing information and data to the public?

- Can the use of a GIS program be an improvement over the current methods of siting disposal areas?

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Other Questions to Ponder

- What is the best use for GIS technology?
  - Data management, engineering studies, public education, decision making, other…?

- What are the critical issues to be addressed in siting disposal areas?
  - Regulatory issues, environmental issues, public opposition or participation, scientific input / analysis, other…?

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Design of GISite

- Functionality comes from use of an simple Graphical User Interface (GUI)
  - All data comes preloaded
  - Use of large on-screen buttons and slider bars make data manipulation as simple as clicking a button or two.
- Results of analyses can be saved for later reference or comparison to other analyses.
- Data can be added, removed, or updated easily as needed
  - Compatible with most other systems in Massachusetts

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GISite Data

- Data gaps prove to be a large limitation
  - Generally a limitation of all siting studies
- Not all available data are easily inputted into a GIS system
- Two step process for data manipulation
  1. Knowledgeable persons rank each individual data layer for suitability areas. This ranked data is then loaded into GISite.
  2. GISite allows users to weight each layer and then combines all the layers using a weighted geometric mean.

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Future Development

- Improve data coverage and quality!
- Make GISite accessible to the general public through the web
- Add in more sophisticated data analysis tools to the GUI

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And now.....

.....GISite!

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