4.0 PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE CANDIDATE SITES

This section of the DEIR describes the physical and chemical characteristics of candidate sites 1 and 2, including general information to characterize both sites as well as any distinctions that would make one site more suitable for future disposal activities than the other site. This section includes the following:

Section 4.1: Information on bottom topography (bathymetry) and estimates of the capacity of each site to accommodate dredged material;

Section 4.2: A description of the physical and chemical characteristics of the surface sediments at each site;

Section 4.3: Information on hydrodynamics, including tidal currents and waves, under both average and very rare wind conditions (Hurricane Bob). This information is used to provide a preliminary assessment of the erosion potential of the substrate, using both first-order analyses and a wave-current model. Information on sediment grain size characteristics is compared to the model results and used to evaluate differences between the two candidate sites;

Section 4.4: A detailed hydrodynamic study, including a site-specific field program, to better characterize flow and provide a more-detailed analysis of historical wind and wave data; and

Section 4.5: A description of water column characteristics, including water chemistry and temperature-salinity profiles, to determine water column structure.

Potential impacts to the physical characteristics of each site from disposal activities are evaluated in Section 7.0.

4.1 Bathymetry and Site Capacity

As illustrated previously in Figure 3-16, a high-resolution bathymetric survey was conducted across a relatively large area encompassing the central and southern portions of the historic CLDS in 1998 (Maguire 1998b). A follow-up bathymetric survey was conducted in 2000 to document the seafloor conditions further south, including candidate site 1 and the surrounding area (Figure 3-16; Maguire 2001a). All of the depth data from these bathymetric surveys is presented referenced to the mean low water (MLW) datum. The survey maps were combined to create a single plot showing the bathymetry of candidate sites 1 and 2 in relation to the CLDS (Figures 4-1 and 4-2). A side-scan sonar survey also was conducted in May 2002 to provide additional detail on bottom features and sediment textural characteristics within the two candidate sites (Maguire 2002d).

The bathymetric surveys (Maguire 1998b; Maguire 2001a) indicated overall depths in the CLDS ranged from shallowest in the northwest to deepest in the southeast portion of the site. The target depth for the candidate disposal site is at least 12 meters (39 feet) to accommodate deeper-drafeet hopper dredges and provide sufficient capacity to accommodate dredged material deposits. The northwest portion of CLDS had fairly uniform depths shallower than 11 meters

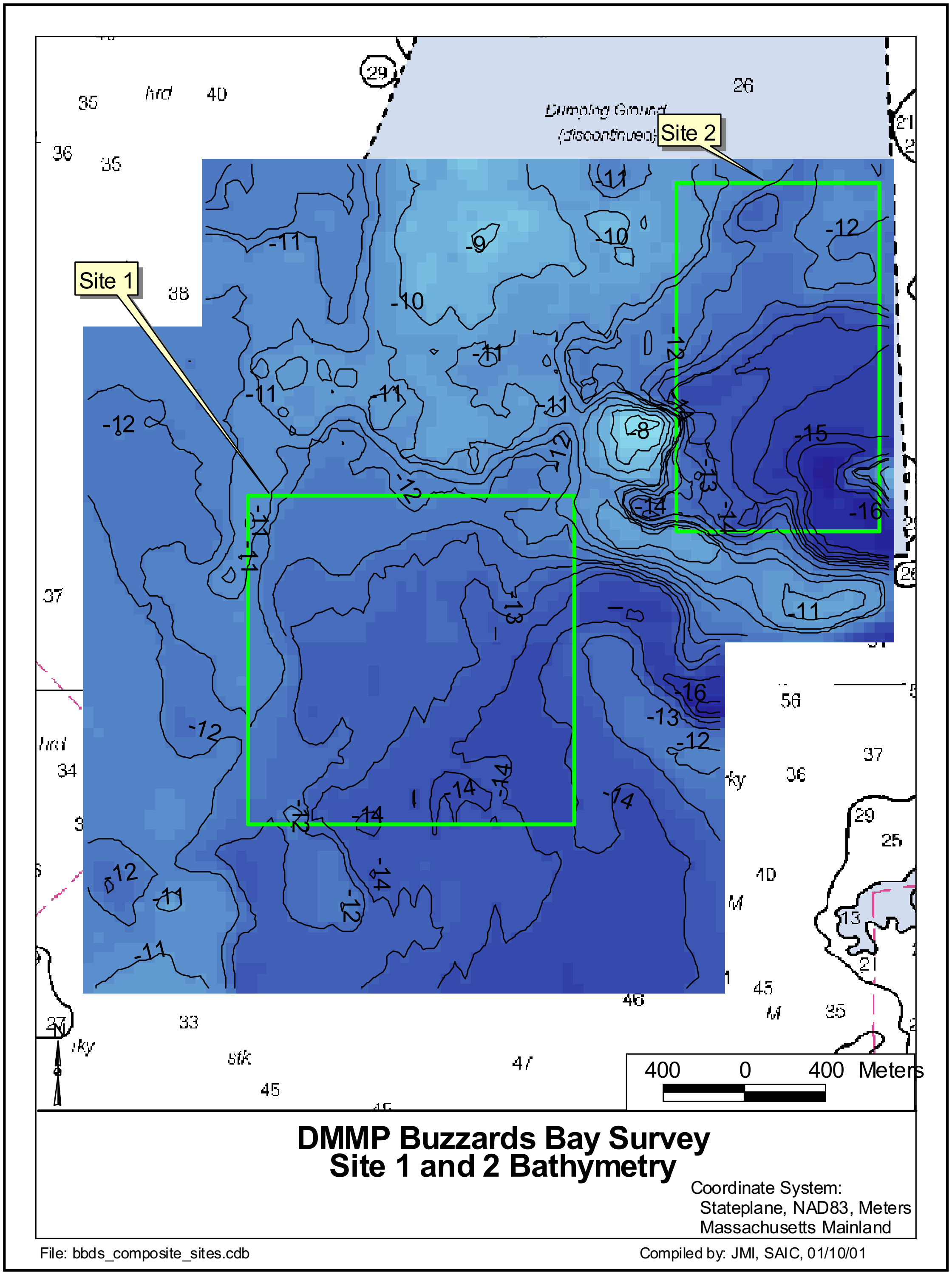
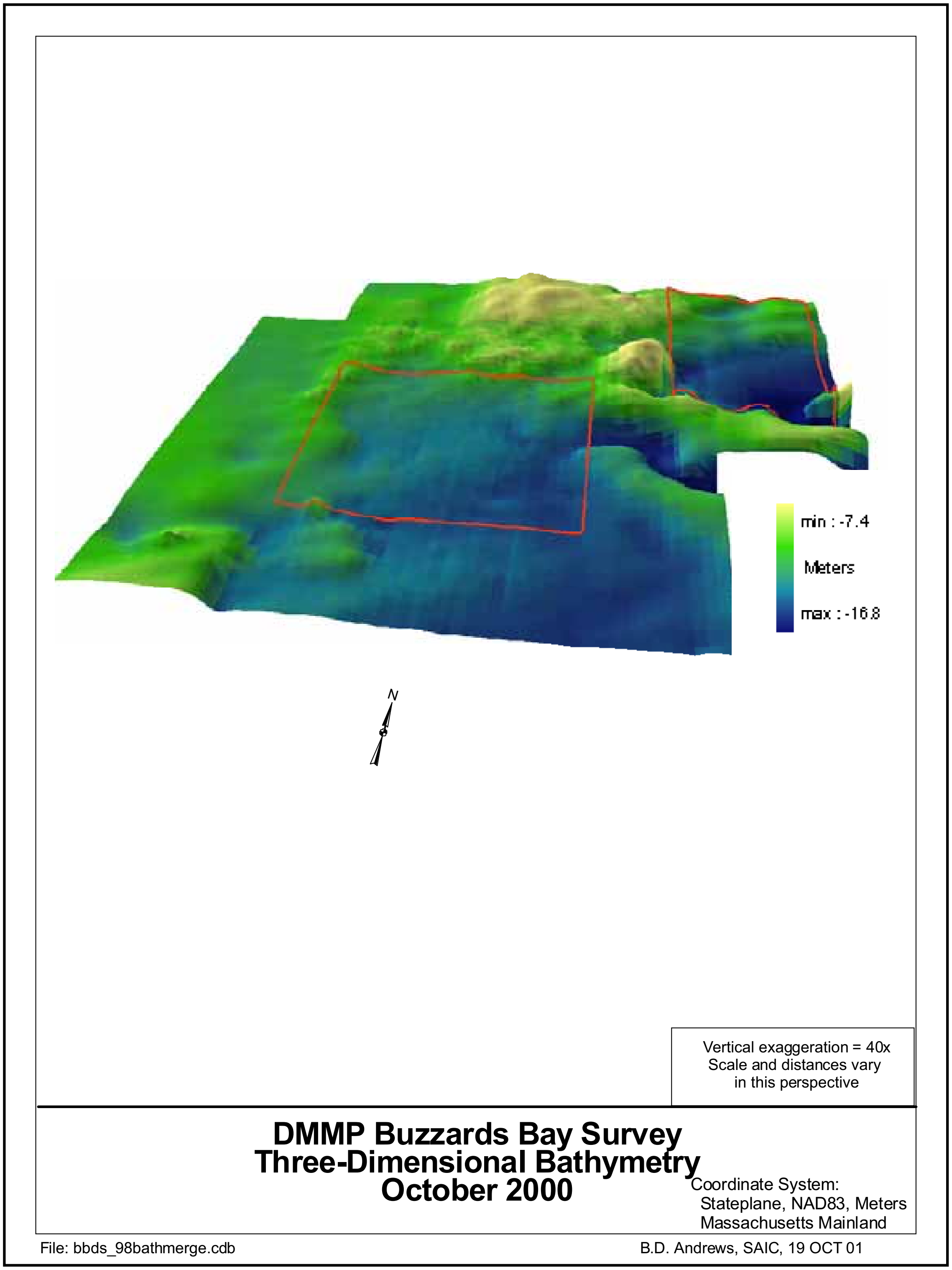


Figure 4-1. Two-dimensional contour map showing bottom topography in and around candidate disposal sites 1 and 2 based on the combined results of the May 1998 and October 2000 bathymetric surveys (depths are MLW).



Vertical exaggeration = 40x
Scale and distances vary
in this perspective

DMMP Buzzards Bay Survey
Three-Dimensional Bathymetry
October 2000

Coordinate System:
Stateplane, NAD83, Meters
Massachusetts Mainland

File: bbds_98bathmerge.cdb

B.D. Andrews, SAIC, 19 OCT 01

Figure 4-2. Three-dimensional map showing bottom topography in and around candidate disposal sites 1 and 2 based on the combined results of the May 1998 and October 2000 bathymetric surveys (vertical exaggeration is 40x).

(36 feet), in part reflecting past disposal activities in that area. The broad basin along the southern boundary of CLDS provided the basis for delimiting candidate site 1, and the deep trough surrounding Gifford Ledge to the southeast, with a maximum depth of 16.9 meters (55 feet), was the basis for delimiting candidate site 2.

The seafloor within the 1,600 meters by 1,600 meters (approximately one square mile) area constituting candidate site 1 slopes gently downward from northwest to southeast, with depths of 11 meters (36 feet) in the northwest corner increasing to 14 meters (46 feet) in the southeast corner. Almost all of the area within candidate site 1 has water depths greater than 10 meters (33 feet), with depth over the majority of the site ranging from 13 meters to 14 meters (43 to 46 feet; Figures 4-1 and 4-2).

The seafloor within the 100 meters by 1,700 meters (0.66 square miles) area constituting candidate site 2 consists of a relatively deep trough with maximum depths reaching 16.9 meters surrounding the prominent Gifford Ledge. Relatively shallow areas including Gifford Ledge to the east (average depths of 3 meters), a distinct, historical dredged material disposal mound to the west, and a natural east-west trending ridge to the south surround the trough (Figures 4-1 and 4-2; Maguire 2001a). However, the trough feature extends further east than the survey area, and may indicate an area of scour around the south side of Gifford Ledge. As such, the hydrodynamics of the area must be considered in evaluating whether candidate site 2 will provide effective containment of dredged material placed in the trough.

The dredged material disposal mound is located immediately west of the candidate site 2 boundary and approximately 250 meters south of the former BBDS (Figure 4-1; Maguire 2001a). This disposal mound is depicted as a lightened area of blue background showing contour depth of 8 meters (26 feet) located between the green outlined proposed candidate site areas of Figure 4-1. The apex of the mound constitutes the shallowest depth within the CLDS, 7.8 meters (25.5 feet), and the mound feature is approximately 500 by 500 meters (1,640 by 1,640 feet) in size. Potential impacts of this shallow feature on dredged material disposal vessels navigating to and from candidate site 2 must be considered. Based on the bathymetric survey results, capacity estimates for candidate sites 1 and 2 were determined by assuming uniform "filling" of each site within the existing depth contours. As summarized in Table 4-1, if candidate site 1 were to be filled with dredged material until reaching a uniform water depth of 10 meters across the site, the capacity would be 8,100,837 cubic meters (m^3) (10,596,255 cy). If candidate site 2 were to be filled to a uniform depth of 10 meters, the capacity would be 5,744,175 m^3 (7,513,636 cy). If a more conservative final depth of 12 meters is used, considerably less dredged material could be accommodated at the sites; candidate site 1 capacity would be 3,036,107 m^3 and candidate site 2 capacity would be 2,505,104 m^3 (Table 4-1).

Table 4-1. Estimated capacity of candidate sites 1 and 2, assuming each site would be filled with dredged material to a uniform depth.

Depth to which site is filled with dredged material	Candidate site 1 capacity	Candidate site 2 capacity
10 meters (33 feet)	8,101,418 m^3 (10,596,255 cy)	5,744,587 m^3 (7,513,636 cy)
12 meters (39 feet)	3,036,107 m^3 (3,971,078 cy)	2,505,104 m^3 (3,276,552 cy)
12.5 meters (41 feet)	1,613,761 m^3 (2,110,799 cy)	1,613,761 m^3 (2,110,799 cy)

The two candidate sites have varied bathymetric features and as planar polygons they differ in area expressed in square meters and equivalent square yards. Table 4-1 was constructed to show simple volumetric relationship for the two candidate site areas when filled with dredged materials. Table 4-1 assumes each site was filled with the 20-year dredged materials capacity and that due to varied bathymetric features the two filled candidate sites appear balanced with 12.5 meters water depth above the fill. Table 4-1 shows the relationship of capacity available for each candidate site from a leveled bottom if each site were filled to greater than 20-year capacities and the resulting water depths above these levels of fill.

These capacity estimates assume each site would be filled to a uniform depth in the site development process, but in reality, using current technology, the dredged material disposed at the site is expected to form a series of discrete deposits or mounds on the seafloor. These mounds would be distributed evenly across the site as the target disposal location is moved at periodic intervals. Mound distribution will be determined by site managers based on the results of regular monitoring surveys, as described in the SMMP (Section 11.0 of this DEIR). As such, the numbers provided in Table 4-1 somewhat overestimate the volume of material that can be accommodated at each site. Nonetheless, they indicate that either of the two candidate sites has more than adequate capacity to accommodate the conservative projection of 1,613,761 m^3 of dredged material that may require open-water disposal in the Buzzards Bay region over a 20-year time frame. The water depth at the candidate sites with the conservative 20-year projected dredged material deposition would be approximately 12.5 meters (Table 4-1).

Candidate sites 1 and 2 were selected for further study because each appears to be a depositional environment with sufficient water depth and capacity for continued dredged material disposal. Based on bathymetry, both basins appear to provide increased protection from erosional forces like tidal currents and storm waves and, therefore, provide long-term containment of dredged material compared to nearby shallower areas. Additionally, side-scan sonar surveys indicated evidence of past disposal activities within the boundaries of both sites, lending evidence to the stability of disposed material over time (refer to Section 4.2 below for additional detail).

Based solely on bathymetry, candidate site 2 has the drawback of being close to the very shallow area of Gifford Ledge to the east. The historical dredged material mound located immediately west of the site boundary may also affect access for deeper drafeet vessels and potentially represents a hazard to navigation; potential impacts on navigation are discussed in Section 7.11. Additionally, based on the coarser nature of the bottom sediments and the extension of the trough feature around the south side of Gifford Ledge, hydrodynamic conditions at candidate site 2 may not be as favorable to long-term containment of dredged material as at candidate site 1. A specific hydrodynamic condition concern for candidate site 2 is whether the scouring action of bottom currents at the base of Gifford Ledge would result in transport of disposed sediment eastward through the trough beyond the boundary of the site. This hydrodynamic transport condition at candidate site 2 does not exist and is not a concern at candidate site 1. Preliminary and detailed analyses of hydrodynamic conditions at both sites were conducted for this DEIR and presented in Sections 4.3 and 4.5. The potential impacts of disposal to the bottom topography at each site are discussed in Section 7.1, while potential water quality impacts are evaluated in Section 7.3.

4.2 Sediment Grain Size and Chemistry

Data regarding the character of the sediments throughout CLDS and candidate sites 1 and 2 were obtained from multiple sources, including the scientific literature (Moore 1963; Howes and Goehringer 1996; Figure 4-3); a side-scan sonar survey conducted at CLDS in 1981 (Germano et al. 1989); a side-scan sonar survey conducted in 1998 (Maguire 1998b); a side-scan sonar and underwater video bottom habitat survey conducted in 2002 (Maguire 2002d; Figure 4-4), and baseline characterization surveys conducted in 2000 at candidate sites 1 and 2 and two nearby reference areas (Maguire 2001b and c) (See Appendix F and G)1. The historical studies were useful for establishing ambient substrate conditions at the sites (i.e., prior to disposal activities known to have occurred in the vicinity since at least 1970) and confirming that grain size generally correlates with water depth and is reflective of the localized hydrodynamic regime. The 1981 and 1998 side-scan data for CLDS provided evidence of the limits of surface sediment disturbance from dredged material disposal activities. The 2000 baseline characterization surveys consisted of a more comprehensive evaluation of the surface sediments at candidate sites 1 and 2, including measurements of grain size, TOC and analysis for a suite of chemical contaminants.

4.2.1 Historical References

Based on previous studies of Buzzards Bay (Moore 1963; Howes and Goehringer 1996), fine-grained sediments occur in the deeper basins and troughs, representative of lower-energy depositional environments, while coarser sediments are found in shallower, higher-energy areas overlying glacial till and bedrock. Moore's (1963) study indicated that the coarse sand and gravel areas located within pockets of Buzzards Bay were primarily due to scouring by tidal currents. Moore's surface sediment map showed medium to fine sands throughout most of CLDS, including BBDS, with a few small areas of coarser sand and a band of finer-grained silts in the southwest corner of the site in the vicinity of candidate site 1 (Figure 4-3). One area of gravel and coarse sand occurred in the northwest corner of CLDS, and another extensive area of gravel substrate occurred just outside the CLDS boundary to the southeast, extending to the shoreline in Falmouth. Based on the historical surveys, the substrate in candidate site 1 would be characterized as silt and fine to medium sand, and areas of fine, medium, and coarse sand would characterize candidate site 2.

4.2.2 Side-Scan Sonar Surveys

The side-scan sonar surveys conducted over CLDS in 1981 (Figure 4-5) and 1998 (Figure 4-6) provided information on substrate conditions and evidence of past dredged material disposal at candidate sites 1 and 2. Portions of candidate site 1 that lie within the CLDS boundary are within the area characterized as "rubble field" from the 1981 survey, which had a high-reflectance, chaotic return on the side-scan records suggesting physical disturbance from dredged material disposal (Germano et al. 1989). The sediment texture was interpreted to be dredged material and rocks deposited on finer-grained ambient sediments. The more extensive survey area in 1998 (Maguire 1998b) indicated that apparent physical disturbance from dredged material disposal extended south of the CLDS boundary by about 250 meters. Therefore approximately one third of candidate site 1 may contain historic dredged material. Based on the 1981 survey, much of the western side of candidate site 2 encompassed a "crater field", that indicates deposition of coarser dredged material on finer-grained substrate (Germano et al. 1989). The 1998 survey (Maguire 1998b) identified these features primarily in the northern part of the basin in candidate site 2. The eastern side of candidate site 2 contains a flat area interpreted as consisting of ambient, fine-grained sediments around the prominent Gifford Ledge.

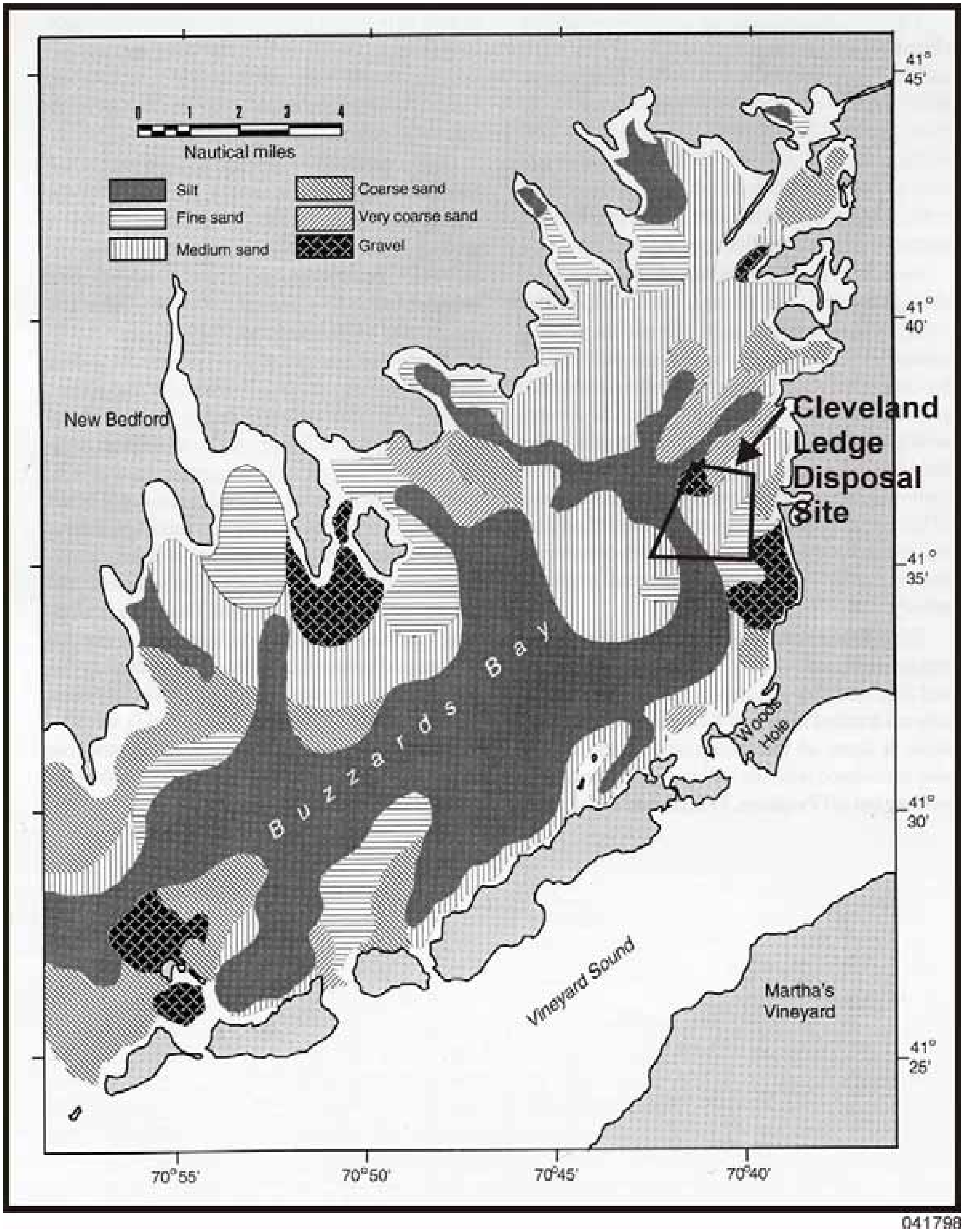
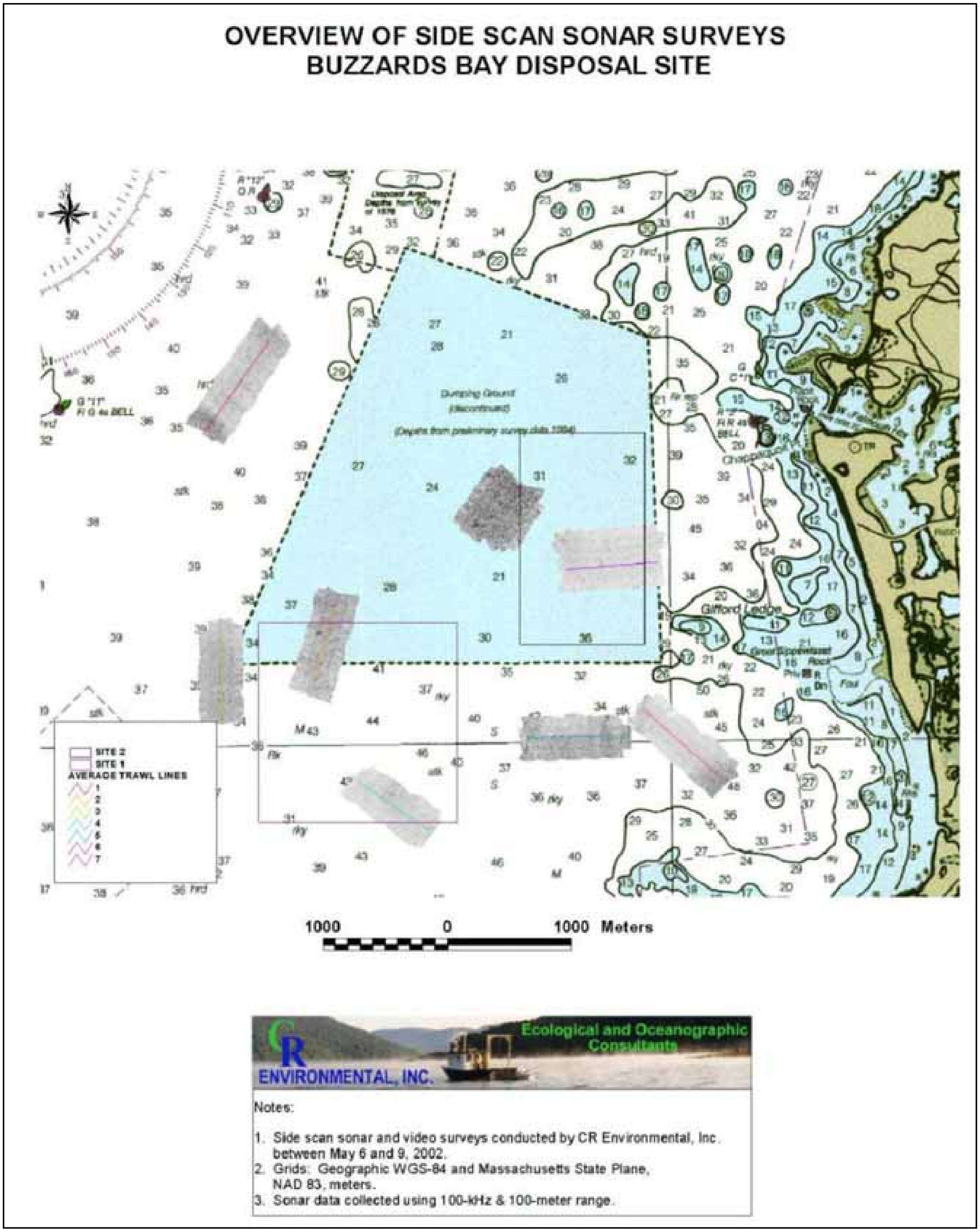


Figure 4-3. Textural distribution of Buzzards Bay sediments (reproduced from Howes and Goehringer 1996, original map from Moore 1963) showing approximate location of CLDS.



OVERVIEW OF SIDE SCAN SONAR SURVEYS
BUZZARDS BAY DISPOSAL SITE

Notes:

1. Side scan sonar and video surveys conducted by CR Environmental, Inc. between May 6 and 9, 2002.
2. Grids: Geographic WGS-84 and Massachusetts State Plane, NAD 83, meters.
3. Sonar data collected using 100-kHz & 100-meter range.

Figure 4-4. Overview of side scan sonar surveys of BBDS 2002.

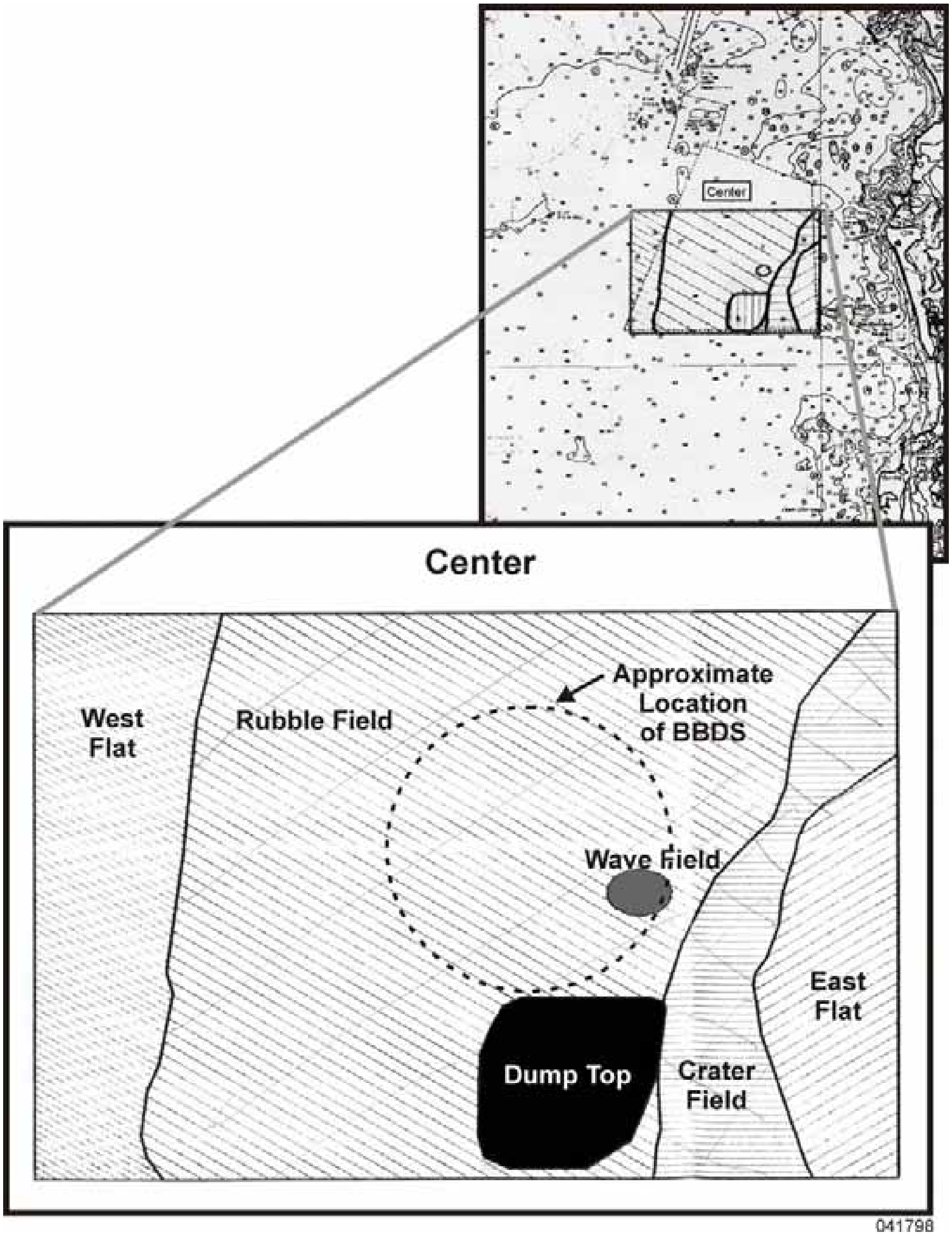


Figure 4-5. Process map of textural regions of CLDS area from the 1981 side-scan sonar survey (reproduced from Maguire 1997a, original map from Germano et. al. 1989).

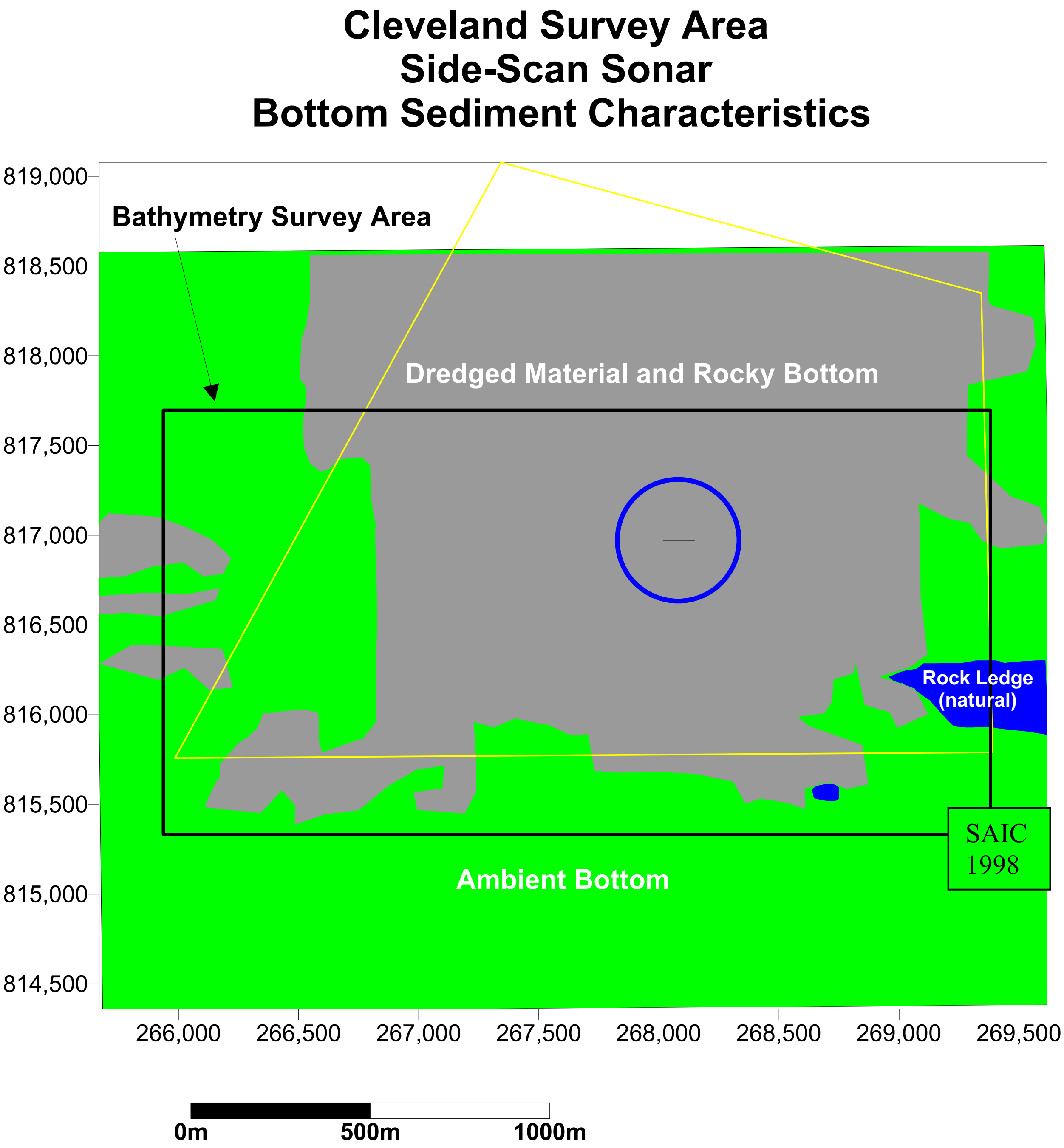


Figure 4-6. Interpretive process map of bottom character at the former CLDS (based on a side-scan sonar survey conducted by SAIC in 1998 and reported in Maguire 1998b).

The 2002 side-scan sonar and bottom video survey showed evidence of historical dredged material covered by a veneer of fine sediment in the northern area of candidate site 1 (Figures 4-4 and 4-7). The 2002 side-scan survey results from the southwest area of the CLDS/northern part of candidate site 1 showed indications of hard mud/sand bottom and evidence of historical dredged material deposits. The side-scan survey of the southern section of candidate site 1 revealed a diminished amount of historical dredged material and a mud/sand bottom (Figures 4-4 and 4-8). Harder mud/sand bottom was apparent in the side-scan survey southeast of the CLDS boundary, due east of candidate site 1 and south of candidate site 2 (Maguire 2002d; Figures 4-4 and 4-9). At candidate site 2, the 2002 side-scan survey showed an area of sofeet mud bottom in the central area of the site just north of Gifford Ledge (Figures 4-4 and 4-10).

4.2.3 Grab Sampling and Sediment-Profile Imaging (SPI) Results

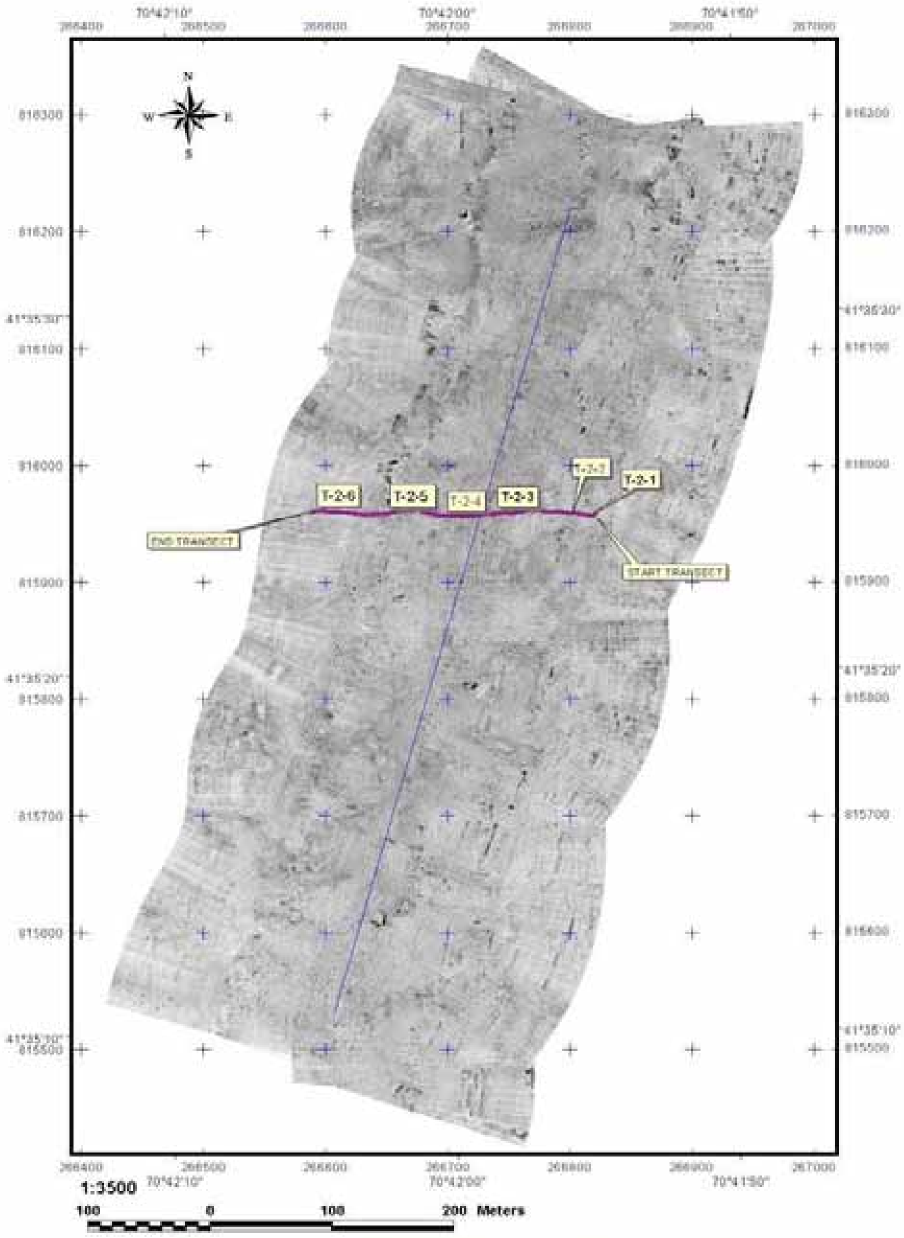
Grab samples of surface sediments collected at six stations within each site were analyzed for grain size distribution. The results indicated a predominance of fines (58% to 93% silt and clay) at all but the shallowest, western station in candidate site 1. Fine to medium sand (66% to 69% sand) predominated at the shallower, northern stations of candidate site 2, while fines (61% to 69% silt-clay) were the dominant grain size component at the two deeper stations in the southern basin area of candidate site 2.

Much more extensive sampling coverage of each site was accomplished in a sediment-profile imaging survey conducted in November 2000 (Maguire 2001c). Three replicate sediment-profile images were collected at each of 81 stations located throughout candidate site 1 and 54 stations throughout candidate site 2. Estimates of sediment grain size obtained from the images at candidate site 1 indicated that muddy sediments with a component of fine sand occurred at stations with water depths between 8 meters (26 feet) and 12 meters (36 feet), while silt and clay predominated at stations greater than 12 meters (36 feet) depth. Images from site 2 indicated the presence of a substantial component of fine sand to slightly deeper depths, at stations from 7 meters (23 feet) to 13 meters (43 meters). Sampling stations at depths greater than 13 meters (43 feet) had a predominance of fines. Coarser grain sizes, including medium to very coarse sands, were identified at stations outside the boundary of site 2 to the south (natural east-west trending ridge), northeast, and at the former disposal mound to the west.

The grain size distribution of surface sediments provides an indicator of the hydrodynamic forces acting on the seafloor. Grain size results from these survey efforts indicate that the shallower areas of both sites are dominated by very fine sands and sand-over-mud stratigraphy, likely the result of longer-term winnowing of fine sediment fractions (i.e., selective, localized resuspension of silts and clays during extreme events). This is consistent with preliminary wave analyses indicating that average wave conditions would start to affect the bottom at depths of around 11 meters (36 feet), and with the results of the modeling effort that indicated that extreme wind-wave and current conditions may result in some winnowing of fines.

In contrast, the deeper areas of both sites were dominated by silt-clay, indicating net long-term accumulation (i.e., deposition) of fines as a result of bathymetric entrapment and less dynamic current activity. This is consistent with the fact that typical wave conditions would not impact areas deeper than about 11 meters (36 feet) and suggests that wave and current effects combined are not eroding fine-grained sediments from these deeper areas.

SIDE SCAN SONAR MOSAIC AND VIDEO DRIFT SURVEY
TRAWL LANE 2
BUZZARDS BAY DISPOSAL SITE

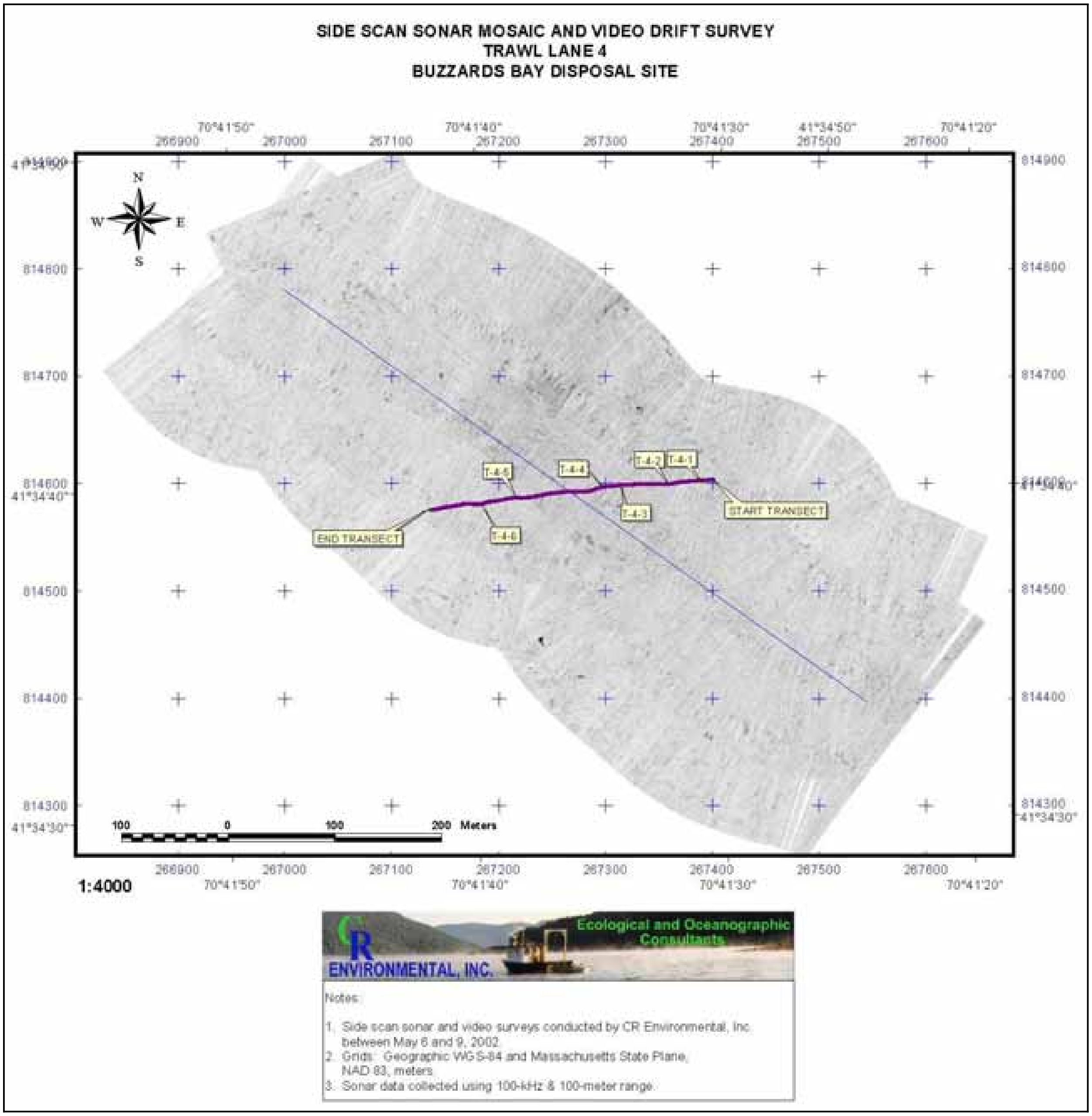


CR ENVIRONMENTAL, INC. Ecological and Oceanographic Consultants

Notes:

1. Side scan sonar and video surveys conducted by CR Environmental, Inc. between May 6 and 9, 2002.
2. Grids: Geographic WGS-84 and Massachusetts State Plane, NAD 83, meters.
3. Sonar data collected using 100-kHz & 100-meter range.

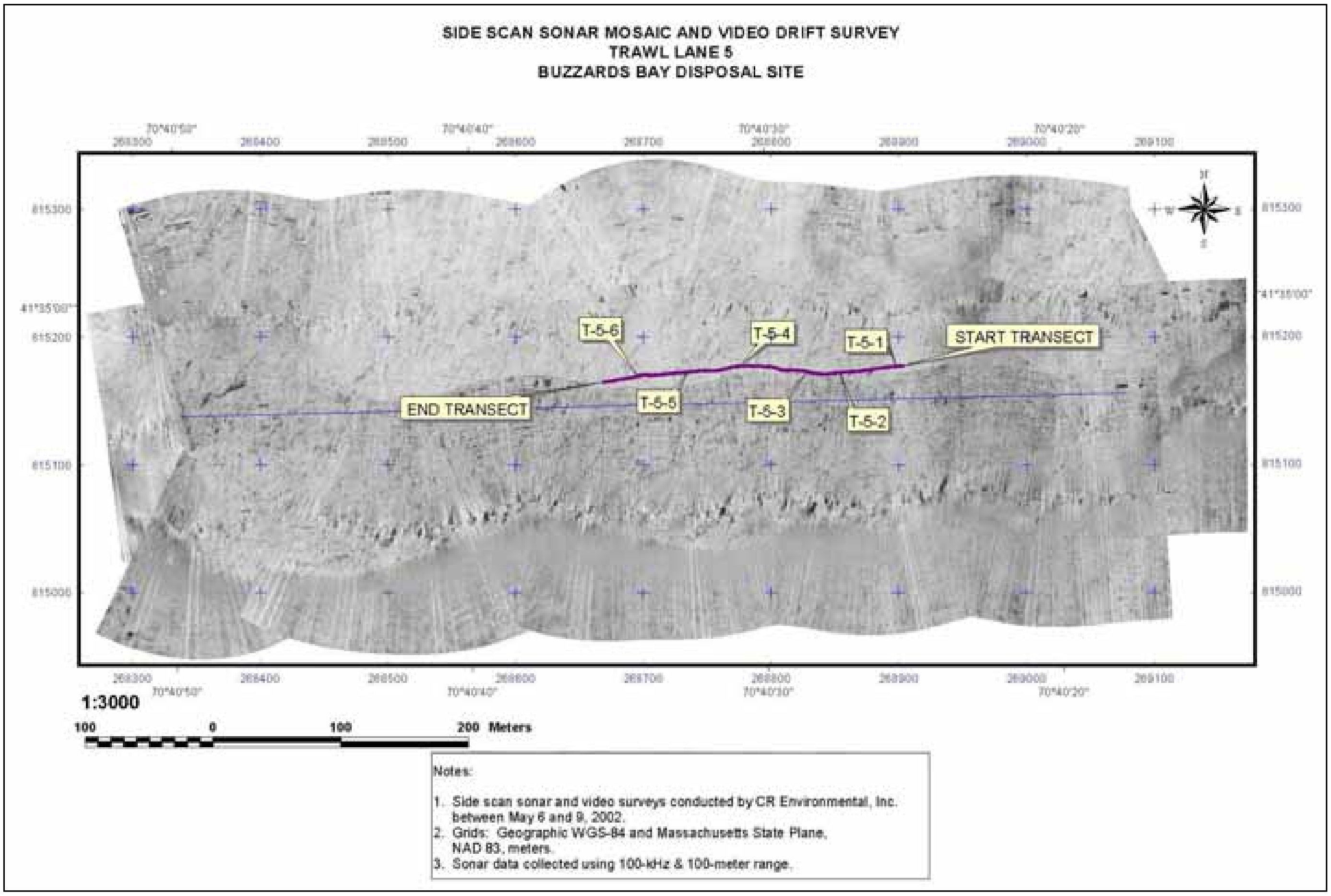
Figure 4-7. Side Scan Sonar Mosaic and Video Drift Survey – Trawl Lane 2, BBDS.



Notes:

1. Side scan sonar and video surveys conducted by CR Environmental, Inc between May 6 and 9, 2002.
2. Grids: Geographic WGS-84 and Massachusetts State Plane, NAD 83, meters.
3. Sonar data collected using 100-kHz & 100-meter range.

Figure 4-8. Side scan sonar survey of the southern section of candidate site 1.

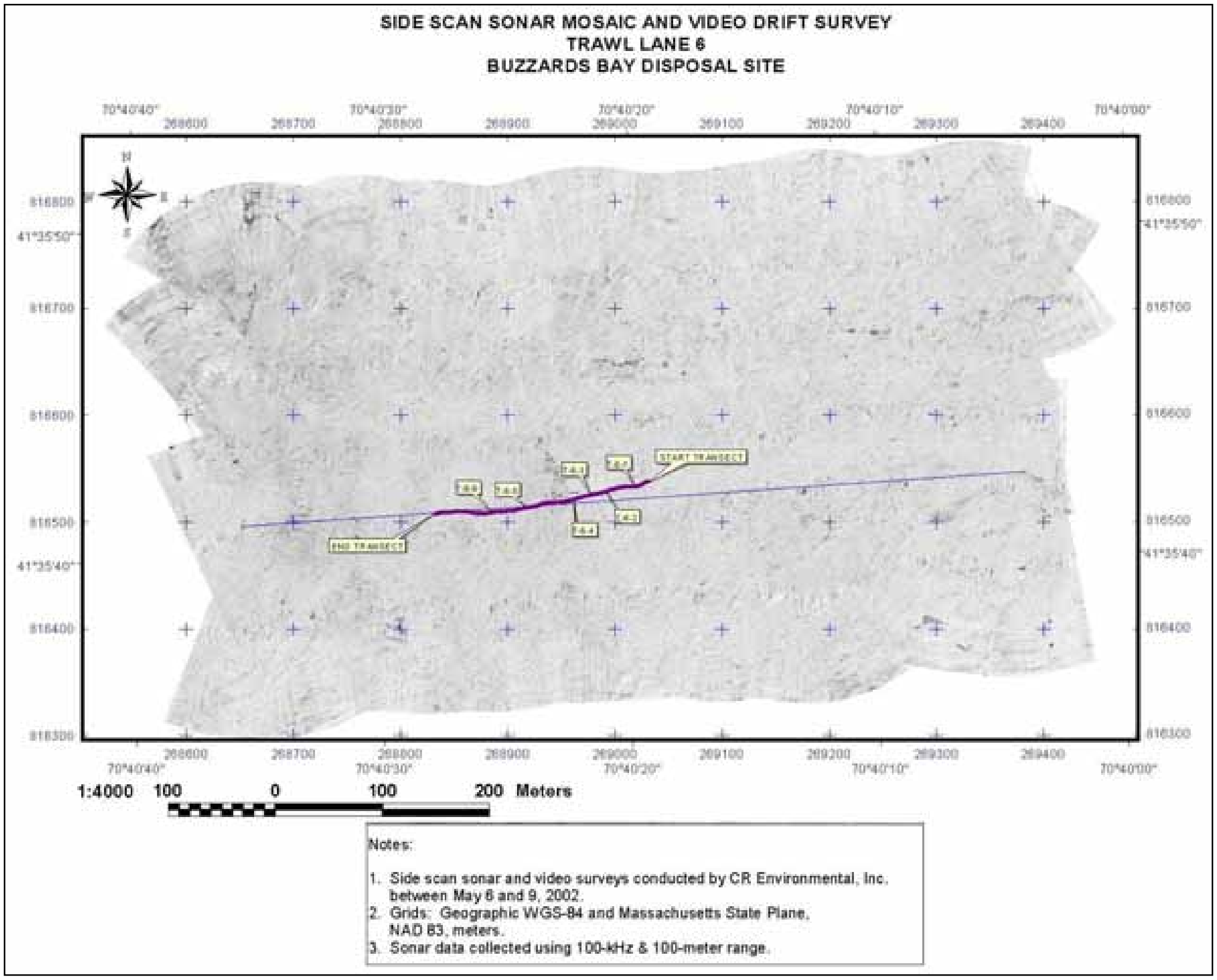


SIDE SCAN SONAR MOSAIC AND VIDEO DRIFT SURVEY
TRAWL LANE 5
BUZZARDS BAY DISPOSAL SITE

Notes:

1. Side scan sonar and video surveys conducted by CR Environmental, Inc. between May 6 and 9, 2002.
2. Grids: Geographic WGS-84 and Massachusetts State Plane, NAD 83, meters.
3. Sonar data collected using 100-kHz & 100-meter range.

Figure 4-9. Side scan sonar mosaic of the area located southeast of the CLDS boundary and due east of candidate sites 1 and 2.



SIDE SCAN SONAR MOSAIC AND VIDEO DRIFT SURVEY
TRAWL LANE 6
BUZZARDS BAY DISPOSAL SITE

Notes:

1. Side scan sonar and video surveys conducted by CR Environmental, Inc. between May 6 and 9, 2002.
2. Grids: Geographic WGS-84 and Massachusetts State Plane, NAD 83, meters.
3. Sonar data collected using 100-kHz & 100-meter range.

Figure 4-10. Side scan sonar survey for the central area of candidate site 2.

It appears that sands are present as a more substantial component of the grain size distribution to slightly deeper depths at candidate site 2, which may therefore experience slightly greater hydrodynamic forces acting on the substrate than candidate site 1. However, grain size evidence suggests that the trough surrounding Gifford Ledge is depositional in nature, and there was no evidence from either the grain size data or the sediment-profile images that currents are winnowing fines from the sediment surface (i.e., no evidence of scour by currents directed through the trough around Gifford Ledge).

4.2.4 Sediment Chemical Analyses

As part of a comprehensive survey undertaken in November 2000 to characterize baseline physical, chemical, and biological conditions at the two candidate disposal sites and two nearby reference areas, eighteen sediment grab samples were collected, including six from within candidate site 1, six within candidate site 2, and three at each of two nearby reference areas, REF-NEW and REF-2 (Figure 4-11). The surface sediment (upper 2 to 4 centimeters) was removed from each grab sample and analyzed for grain size, TOC, selected PAHs, PCB congeners, pesticides, and eight metals (Table 4-2). The analytes in Table 4-2 represent common "contaminants of concern" in coastal sediments and are taken from Tables I-A and I-B of the New England regional guidance document for dredged material testing (EPA/USACE 1989).

4.2.4.1 Grain Size and Total Organic Carbon (TOC)

Results of grain size analyses were consistent with the historical surveys, indicating a predominance of silt-clay throughout the broad topographic depression in site 1 (overall average of 66% silt-clay), with lesser average amounts of sand and gravel (overall average 33.6%; Table 4-3 from Maguire 2001b). Station B6 at the western edge of site 1 (Figure 4-11) had a substantially higher percentage of sand (85%) than the other five stations in site 1, which were each dominated by a silt-clay fraction greater than 57%. TOC concentrations ranged from 0.5% (at the sandier Station B6) to 2.3% at station E6; this range is typical for Buzzards Bay sediments removed from anthropogenic inputs of organic matter.

Grain size results for site 2 were also consistent with historical surveys, and indicated, on average, a predominance of sandier sediments (overall average 56%) and lesser amounts of silt and clay (overall average 42%; Table 4-3 from Maguire 2001b). Sand was the dominant grain size fraction at 4 of the 6 stations in the shallower, northern portion of the site and along Gifford Ledge (66% to 85% sand). Silt-clay was the dominant grain size fraction at the two stations located closer to the trough in the western and southwestern portion of the site (61% fines at Station K14 and 69% fines at Station J17; Figure 4-11). Gravel was present in slightly higher percentages at more stations in site 2 than site 1, although the range of values was comparable, from 0.17% to 3.4% of the total.

TOC for the six stations in site 2 ranged from 0.82% to 1.8% (overall average 1.1%; Table 4-3), with the higher values occurring at stations with the highest percentage of fine-grained sediment. As with site 1, TOC values for all the site 2 samples were typical of Buzzards Bay sediments that are not in direct proximity to anthropogenic sources of organic enrichment. These results support the premise that the deeper areas (i.e., basins) within sites 1 and 2 have conditions that are conducive to deposition of fine-grained sediments and organic matter.

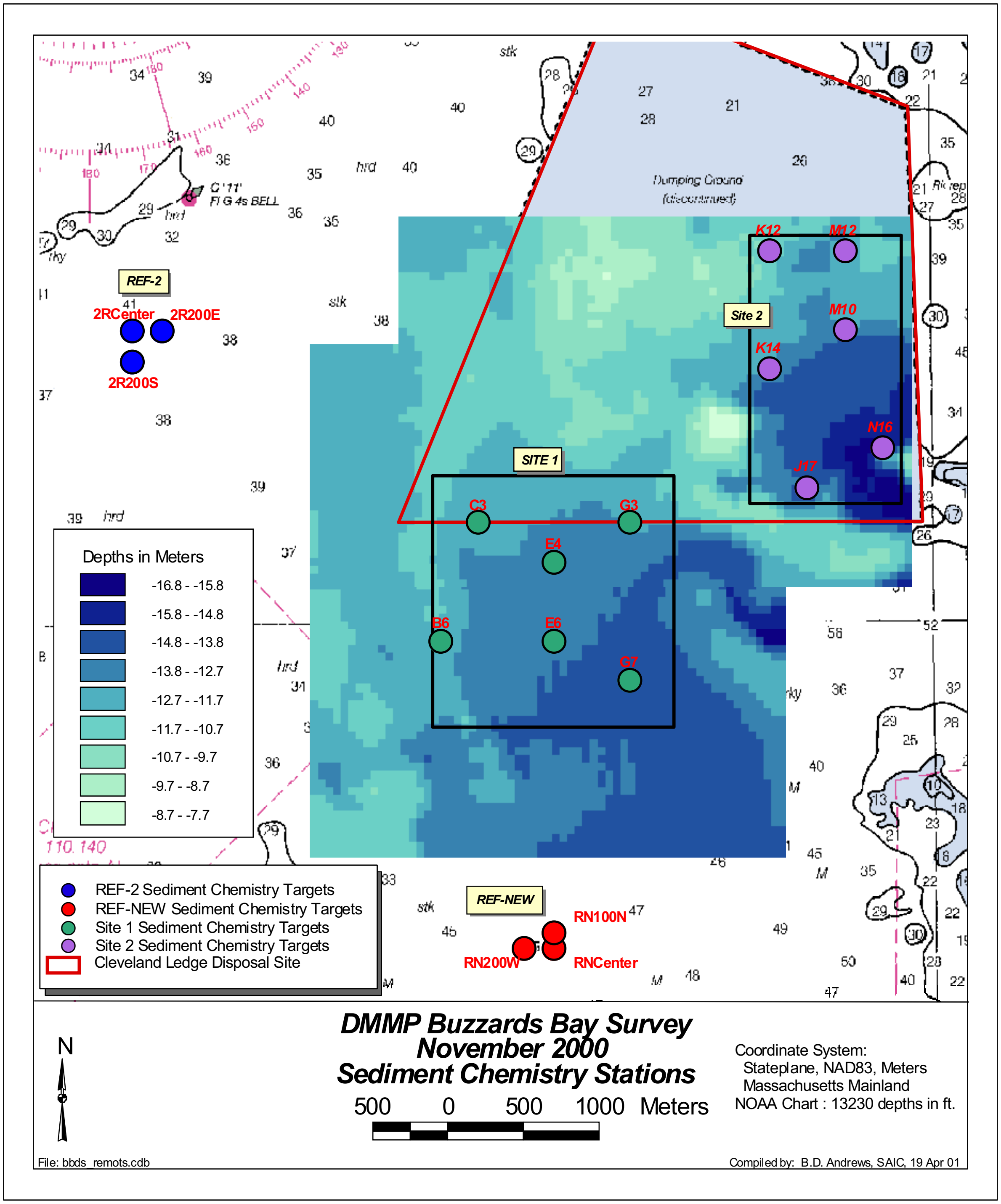


Figure 4-11. Map showing the location of sediment grab sampling stations at candidate sites 1 and 2 and reference areas REF-NEW (station prefix = "RN") and REF-2 (station prefix = "2R"). Color bathymetry results underlying Sites 1 and 2 are in meters, from SAIC surveys conducted in May 1998 and October 2000. Depth values on the underlying NOAA chart are in feet.

Table 4-2. Target sediment contaminants for chemical analyses.

PAHs	PCBs	Pesticides	Metals
Low Molecular Weight:	Congeners:	4,4´ DDD	Arsenic (As)
Naphthalene	PCB008	4,4´ DDE	Cadmium (Cd)
2-Methylnaphthalene	PCB018	4,4´ DDT	Chromium (Cr)
1-Methylnaphthalene	PCB028	Aldrin	Mercury (Hg)
Biphenyl	PCB044	Alpha-BHC	Lead (Pb)
2,6-Dimethylnaphthalene	PCB052	Alpha Chlordane	Copper (Cu)
Acenaphthylene	PCB066	Beta-BHC	Nickel (Ni)
Acenaphthene	PCB101	Delta-BHC	Zinc (Zn)
Fluorene	PCB105	Dieldrin	
Phenanthrene	PCB118	Endosulfan I	
Anthracene	PCB128	Endosulfan II	
1-Methylphenanthrene	PCB138	Endosulfan Sulfate	
	PCB153	Endrin	
High Molecular Weight:	PCB170	Endrin Aldehyde	
Fluoranthene	PCB180	Gamma-BHC	
Pyrene	PCB187	Gamma Chlordane	
Benzo[a]anthracene	PCB170	Heptachlor	
Chrysene	PCB180	Heptachlor Epoxide	
Benzo[b]fluoranthene	PCB187	Methoxychlor	
Benzo[k]fluoranthene	PCB 195	Toxaphene	
Benzo[e]pyrene	PCB 206		
Benzo[a]pyrene	PCB 209		
Perylene			
Indeno[1,2,3-cd]pyrene			
Dibenz[a,h]anthracene			
Benzo[g,h,i]perylene			

Table 4-3. Average grain size distributions and TOC concentrations in surface sediments collected at the various sites.

Site	% Gravel	% Sand	% Silt	%Clay	% Silt & Clay	TOC
Site 1	0.1	33.5	35.2	31.2	66.3	1.6
Site 2	1.6	56.4	23.2	18.7	41.9	1.1
REF-2	0.2	9.1	46.4	44.3	90.7	2.2
REF-NEW	0.4	6.8	50	42.7	92.7	2.2

Note: Values shown are overall averages for the 6 samples collected in each of the two candidate disposal sites and the 3 samples collected in each of the two reference areas (see Figure 4-11).

4.2.4.2 Trace Metals

All the metals analyzed were detected at relatively low concentrations at all of the stations within candidate sites 1 and 2 (Table 4-4); cadmium and mercury were not detected at Station B6 in candidate site 1. There was little variability in metal concentrations among the stations in each site. Within candidate site 1, Station B6 consistently had the lowest concentration of each metal, reflecting its substantially lower silt-clay content (15%). Station E6, in the center of candidate site 1, had the highest metal concentrations among all the candidate site 1 stations, which is likely related to its comparatively high percentage of fines (93% silt-clay). Additionally, the average metal concentrations at candidate site 2 were slightly lower than the average concentrations at candidate site 1, attributed to the generally finer grain size distributions throughout candidate site 1. Variations in metal concentrations primarily reflected variations in grain size; there was no indication of higher metal concentrations associated with the historical disposal areas in the northern portions of either site. Metal concentrations at candidate sites 1 and 2 and the reference areas were either comparable to or lower than concentrations found in other nearshore areas of Massachusetts, including the two existing disposal sites (CCDS and MBDS; Table 4-4).

Table 4-4. Average metal concentrations (in micrograms per kilogram (μg/kg) dry weight) in surface sediments collected within candidate sites 1 and 2 and in nearby reference areas.

Sample I.D.	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
BBDS								
Site 1	6.8	0.1	25.5	10.1	17.9	0.04	12.1	51.3
Site 2	4.3	0.09	16	7.6	13.6	0.035	7.7	36
REF-2	9.8	0.14	36	14	25	0.057	16	70
REF New	10	0.17	35.7	14.3	23.7	0.044	70	71
Buzzards Bay[1]	na	na	33	18	25	na	11	na
CCDS[2]	15	0.8	40	18	33	0.4	24	92
MBDS[3]	10.0-19.0	<3	38.0-220.0	20.1-112.0	30.0-190.0	0.07-0.24	11.9-31.0	77.3-270.0
Mass. Bay[4]	61	tr.-3	110	12	39	tr.-0.4	20	110
Deep Sea Clay[5]	13	<1	90	25	80	na	225	165

Notes: Values are averages for 6 samples collected within each of the candidate disposal sites and 3 samples collected in each of the reference areas (Figure 4-11). For comparative purposes, average metal concentrations found in other areas also are shown.

[1] Moore, 1963 (CCDS DEIR)
[2] CCDS avg. of four sites (CCDS DEIR)
[3] MBDS DEIR
[4] NEAQ (CCDS DEIR)
[5] Chester & Alston, 1976 (CCDS DEIR)
na = not analyzed

4.2.4.3 Polycyclic Aromatic Hydrocarbons (PAHs)

Many PAH compounds were either not detected or found at relatively low concentrations in the samples of surface sediments collected within candidate sites 1 and 2. Average concentrations are presented for the sum of the low molecular weight (LMW) PAHs, high molecular weight (HMW) PAHs, and total PAHs (Table 4-5). The sum of LMW PAHs at candidate site 1 stations ranged from essentially non-detected (sandy Station B6) to 839 micrograms per kilogram (μg/kg). HMW PAHs ranged from non-detected (Station B6) to 395 μg/kg. The maximum total PAH concentration was 1,234 μg/kg. The higher site 1 PAH concentrations all occurred at Station E4 in the north-central section of the site, which had detected concentrations of LMW PAHs that were largely undetected at the other candidate site 1 stations. The overall average total PAH concentration for the site 1 stations was 421 μg/kg (Table 4-5).

Candidate site 2 had similar low concentrations of PAHs, with the overall average concentrations less than the averages at candidate site 1 (Table 4-5). The concentrations of LMW PAHs at the individual stations within candidate site 2 ranged from non-detected to 86 μg/kg; the HMW PAH concentrations ranged from non-detected to 88 μg/kg; and the maximum total PAH concentration was 274 μg/kg.

Table 4-5. Average concentrations of organic contaminants (in µg/kg dry weight) in surface sediments collected within candidate sites 1 and 2 and in nearby reference areas.

	Site 1	Site 2	REF-2	REF-NEW
Average PAHs (µg/Kg dry weight)				
Sum of Low Molecular Weight PAHs	214	66.3	102	116.7
Sum of High Molecular Weight PAHs	207.3	107.2	138.7	132
Total PAHs (LMW + HMW)	421.3	173.5	240.7	248.7
Average Total Pesticides (µg/kg dry weight)				
Total Pesticides (sum of compounds)	26.2	20.9	31.03	30.72
Average Total PCBs (µg/kg dry weight)				
Total PCBs (sum of congeners)	13	11.2	28.2	16.2

Note: Values are averages for 6 samples collected within each of the candidate disposal sites and 3 samples collected in each of the reference areas (Figure 4-11).

4.2.4.4 Pesticides and Polychlorinated Biphenyls (PCBs)

No pesticides were detected above the method detection limits for the sediment samples collected at candidate sites 1 and 2; the average values presented in Table 4-5 result from using one-half of the detection limit to calculate “total pesticides” (sum of all the individual pesticide compounds that were analyzed). PCB congeners were only detected at two stations at site 1 (Stations C3 and G3) and one station at site 2 (Station K14). The PCB concentrations detected at Stations C3 and G3 in candidate site 1 were very low, 3.30 µg/kg and 2.80 µg/kg, respectively. Similarly, only trace amounts of four PCB congeners (PCBs 8, 66, 101 and 153) were detected at Station K14 in site 2. Similar to the pesticides, the average values presented in Table 4-5 result from using one-half of the detection limit to calculate “total PCBs” (sum of all the individual PCB congeners that were analyzed)

4.2.4.5 Reference Areas

Despite comparable water depths at REF-NEW (approximately 14 meters) and REF-2 (approximately 12 meters), surface sediments were consistently more fine-grained within these two reference areas (90% to 96% silt-clay) compared to the sediments at candidate sites 1 and 2 (Table 4-3). Average TOC concentrations also were slightly higher, consistent with the higher proportions of fine grained sediments (Table 4-3).

The eight metals analyzed were detected in all of the samples from both reference areas, with minimal variability among stations. Average metal concentrations at the reference areas were comparable to those at candidate sites 1 and 2 and lower than those found in other seafloor areas in waters off Massachusetts (Table 4-4).

Most of the individual PAH compounds were not detected in the reference area sediments. The concentration of LMW PAHs at the individual stations within REF-NEW and REF-2 ranged from 99 µg/kg to 137 µg/kg; the HMW PAH concentration ranged from 127 µg/kg to 156 µg/kg; and the total PAH concentration ranged from 201 µg/kg to 264 µg/kg, with only minor differences between the two reference areas. The overall average PAH concentrations at the reference areas were comparable to those at candidate sites 1 and 2 (Table 4-5).

Similar to the candidate site 1 and 2 stations, pesticides and most of the PCB congeners were not detected at any of the reference area stations. The average total PCB concentration was 16.2

μg/kg for the REF-NEW stations, and 28.2 μg/kg for the REF-2 stations (Table 4-5). A relatively large standard deviation of 22 μg/kg for the REF-2 stations is attributed to the higher reported PCBs at Station 2R-200S compared to the other two stations, which had primarily non-detects. Total PCBs ranged from 14.4 μg/kg at Station 2R-200E to 53.6 μg/kg at Station 2R-200S. At the MBDS, PCB levels in sediment samples collected from seabed areas near dredged material deposits ranged between 38 and 105 ppb (USEPA 1989). At the CCDS, PCB levels were less than the detectable limits (Battelle 1990).

4.2.5 Evaluation of Results

The results showed that the candidate disposal sites are characterized by predominantly fine-grained surface sediments considered indicative of a largely depositional seafloor environment. Total organic carbon concentrations in sediments at the two candidate sites and nearby reference areas are comparable to other areas of Buzzards Bay that are not in direct proximity to anthropogenic sources of organic enrichment.

The concentrations of the various chemical contaminants in surface sediments at candidate sites 1 and 2 can be evaluated by comparing them to the results obtained at the nearby reference areas, to the results of on-going regional monitoring programs, and to ecological effects benchmarks.

On-going regional monitoring programs used for comparison data include the NOAA’s National Status and Trends Program (NS&T) and the EPA’s Environmental Monitoring and Assessment Program for Estuaries (EMAP-Estuaries). These programs have measured concentrations of a variety of inorganic and organic chemicals in surface sediments throughout U.S. coastal waters, including at several stations in Buzzards Bay comprising a representative mix of both sandy and muddy sediments (Figure 4-12). These data are useful for characterizing “average” sediment chemistry conditions within Buzzards Bay, allowing the site-specific sampling results to be interpreted within a wider, regional context.

Several different “ecological effects benchmarks” or “screening values” are available for use in evaluating the potential for adverse biological effects of different inorganic and organic chemical contaminants in marine sediments. Buchman (1999) has assembled a set of Screening Quick Reference Tables (SQuiRTS) that list several of these values, including Apparent Effects Thresholds (AETs), Threshold Effects Level/Probable Effects Level (TEL/PEL), and Effects Range Low/Effects Range Median (ERL/ERM). Each set of values was developed using an “effects-based” approach wherein two screening values are identified: a low value below which adverse biological impacts are rarely anticipated, and a high value that is frequently associated with adverse impacts to resources (e.g., toxicity to benthic organisms or change in benthic community structure). Concentrations falling between the low and high values are occasionally associated with biological effects. None of the different sets of screening values is considered superior to the others; each has its merits and drawbacks. In the following discussion, the ERL/ERM values of Long et al. (1995) were selected for use in providing a screening level assessment of the results from candidate sites 1 and 2.

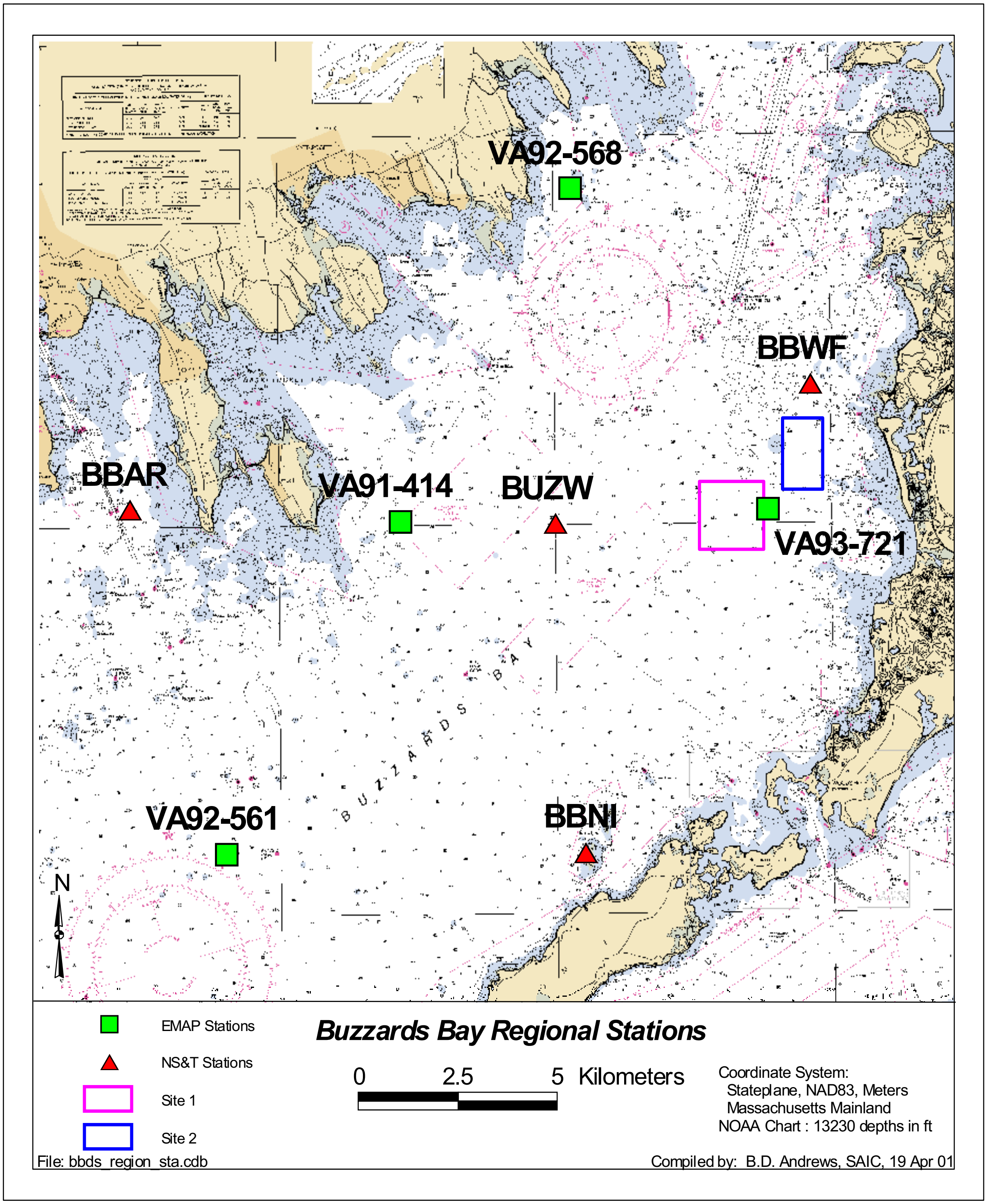
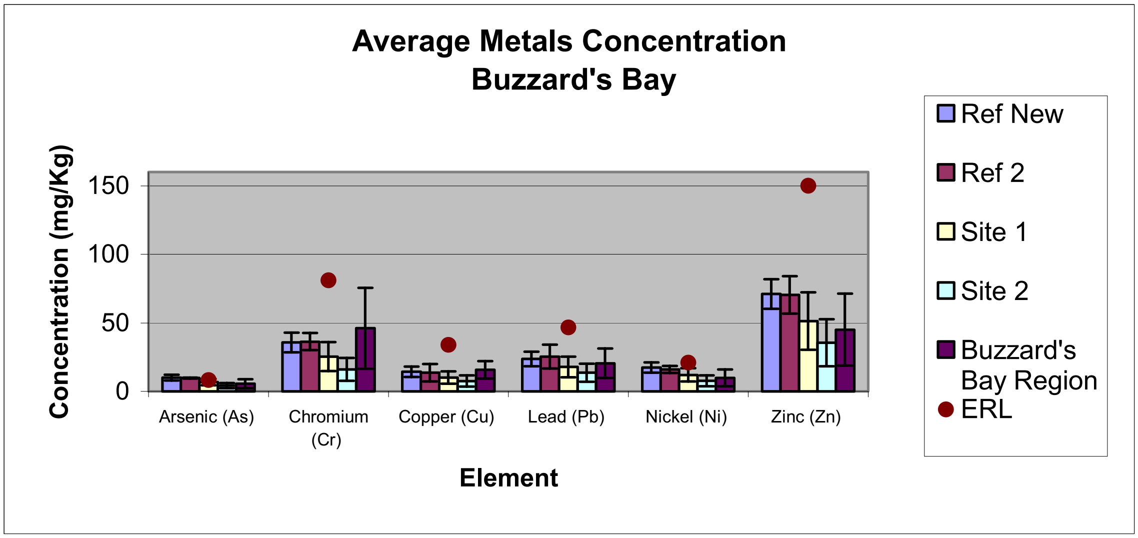


Figure 4-12. Map of stations in Buzzards Bay where sediment chemistry data have been collected under the NOAA NS&T and EPA EMAP regional monitoring programs.

4.2.5.1 Evaluation of Metal Concentrations

Average metal concentrations were consistently higher at the two reference areas compared to the two candidate disposal sites (Figure 4-13). A statistical test of the equality of average values was performed, assuming heterogeneous variances. This test involved unplanned comparisons among each pair of means using the Games and Howell method (Sokal and Rohlf 1981). This test showed that the differences in the average metal concentrations among the sites were generally not statistically significant at the P = 0.05 level, with the following exceptions: each reference area had a significantly higher average concentration of arsenic and chromium than candidate site 2, and the average concentration of nickel at REF-NEW was significantly higher than that at candidate site 2. These differences are attributed more readily to the significantly higher silt-clay content of the reference area sediments rather than to any anthropogenic influences.



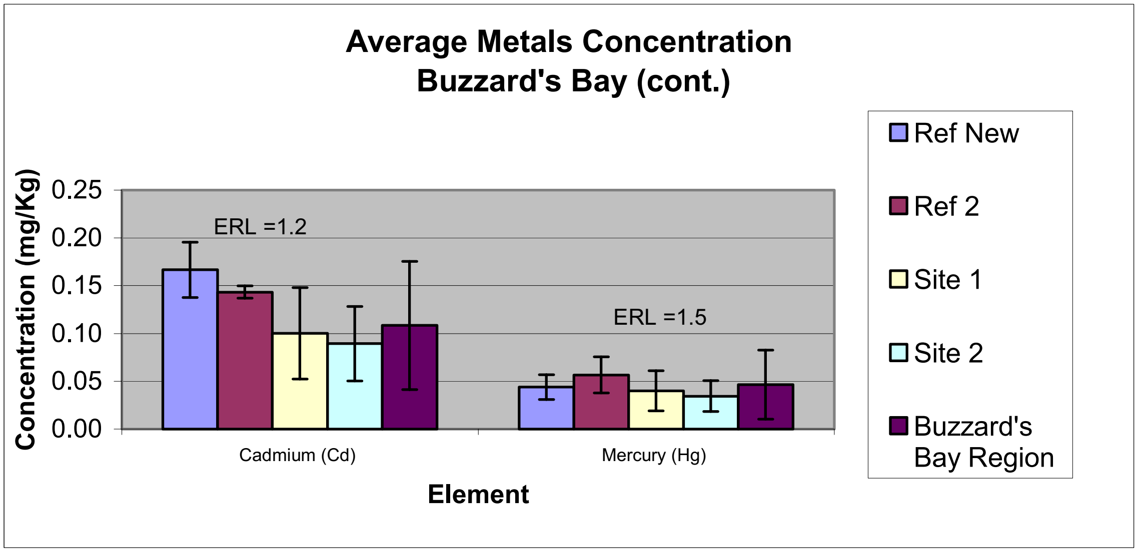


Figure 4-13. Average sediment concentrations of various metals at the two candidate disposal sites, two reference areas, and Buzzards Bay regional stations.

Error bars represent 95% confidence intervals. Effects Range Low (ERL) screening values from Long et al. (1995) also are shown.

As illustrated in Figure 4-13, the average metal concentrations at the Buzzards Bay regional stations (i.e., the EMAP and NS&T stations depicted in Figure 4-12) were generally comparable to and not statistically different from those at the two reference areas and two candidate sites (P >0.05; unplanned comparisons among pairs of means by the Games and Howell method). It is possible to conclude that sediment metal concentrations measured within candidate sites 1 and 2 and nearby reference areas are generally low and consistent with background concentrations that exist in the wider surrounding Buzzards Bay region. Furthermore, the average metal concentrations at candidate sites 1 and 2 are lower than the average values measured in other, similar sea bed areas in waters off Massachusetts (Table 4-4).

All metal concentrations were well below the USACE and EPA minimum sediment guidelines for Massachusetts (Wiley et al. 1996). With the exception of arsenic, the average metal concentrations measured at candidate sites 1 and 2 and the reference areas also were considerably below the ERL screening values (Figure 4-13). As previously indicated, chemical concentrations at or below the ERL have been found to be rarely associated with adverse biological effects. In the case of arsenic, the average concentrations at REF-NEW and REF-2 (10 and 9.8 milligrams per kilogram (mg/kg), respectively) slightly exceeded the ERL value of 8.2 mg/kg, while the candidate disposal sites were below this threshold. The reference area values were considerably below the arsenic ERM value of 70 mg/kg, and the slight exceedance of the ERL value is again attributed to the high reference area silt-clay content rather than an anthropogenic enrichment effect.

Overall, the comparisons to the ERL/ERM values serve to support the conclusion that metal concentrations at the candidate disposal sites and reference areas are relatively low. These concentrations are considered representative of background levels within Buzzards Bay, typical of areas that have not experienced significant inputs of chemical contaminants or excessive organic enrichment as a result of anthropogenic activities.

4.2.5.2 Evaluation of PAH Concentrations

The average concentrations of LMW, HMW and Total PAHs among the four study locations (Figure 4-14) exhibited no statistically significant differences based on unplanned comparisons among pairs of means using the Games and Howell method (Sokal and Rohlf 1981). Likewise, the average PAH concentrations at the four sites did not differ significantly from those at the Buzzards Bay regional stations, and, more significantly, were considerably below the ERL values (Figure 4-14). It is concluded that there were no significant elevations of PAHs at the two candidate disposal sites and two reference areas. The average PAH concentrations at all four study locations were very low and comparable to background concentrations in the wider Buzzards Bay region and beyond at two existing disposal sites, CCDS and MBDS, (Battelle 1990, USEPA 1989).

4.2.5.3 Evaluation of Pesticides and PCBs

All of the pesticides were reported as “not detected” at both the candidate disposal sites and the reference areas. With the exception of toxaphene, the detection limit for each pesticide in each sample was less than 2 μg/kg. Toxaphene was not detected in any of the samples at sample-specific detection limits ranging from 18 to 34 μg/kg. These results are consistent with those of the EMAP and NS&T programs showing only very low or non-detected levels of pesticides in

Buzzards Bay. It is concluded that the candidate disposal sites and reference areas show no elevations of any pesticides above regional background levels.

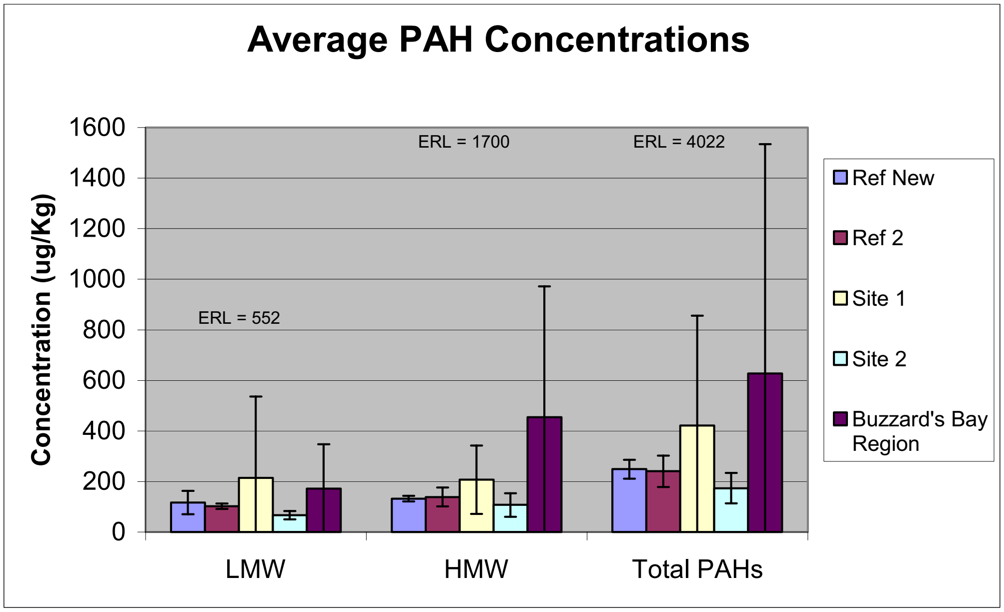


Figure 4-14. Average sediment concentrations of LMW PAHs, HMW PAHs, and Total PAHs at the two candidate disposal sites, two reference areas, and Buzzards Bay regional stations.
Error bars represent 95% confidence intervals. Effects Range Low (ERL) screening values from Long et al. (1995) also are shown.

Likewise, with the exception of a few congeners measured at very low levels, PCBs were essentially not detected in the candidate disposal sites and reference area samples. In general, there were more PCB congeners detected at low levels at the reference area stations than at sites 1 and 2 (Figure 4-15). This is considered a reflection of the higher silt-clay and TOC content of the reference area sediments. The average total PCB concentrations at the two candidate disposal sites and REF-NEW were below both the ERL value and the average total concentration for the Buzzards Bay regional stations from the EMAP/NS&T datasets (Figure 4-15). The average total PCB value for REF-2 was slightly above the ERL value, but this is primarily an artifact of summing the one-half the detection limit values to calculate the total. All of the average total PCB values for the present study were less than the average total for the regional stations (Figure 4-15), but there were no statistically significant differences found between any pair of average values ($P > 0.05$; unplanned comparisons among pairs of means by the Games and Howell method).

Overall, Figure 4-15 suggests a slight elevation of PCB congeners at the regional stations, but at levels considerably below the ERM value of 180 µg/kg. It is concluded that the candidate disposal sites and reference areas are essentially free of PCB contamination: total PCB concentrations at these sites are barely above detection and less than concentrations found on average in the surrounding Buzzards Bay region. Similarly PCB concentrations from samples taken at CCDS were below detectable limits (Battelle 1990). However, PCBs were found at a more elevated level at MBDS, ranging from 38-105 ppb in areas near dredged material deposits (USEPA 1989).

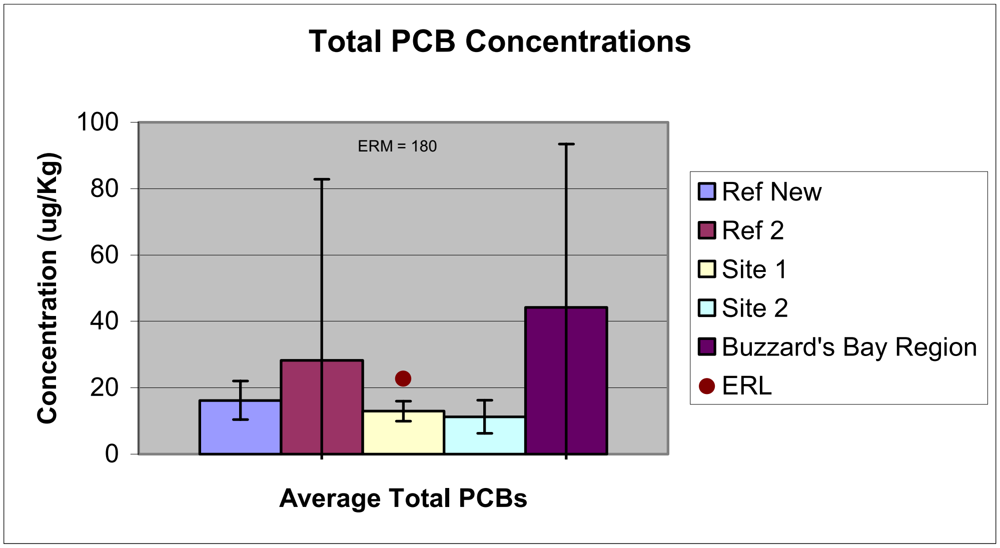


Figure 4-15. Average sediment concentrations of total PCBs at the two candidate disposal sites, two reference areas, and Buzzards Bay regional stations.
Error bars represent 95% confidence intervals.

4.2.6 Summary

Despite evidence of historical dredged material disposal in the vicinity, sediment chemistry results indicate that sites 1 and 2 have negligible levels of contaminants. Sediment chemical concentrations at both sites are comparable to ambient sediments and reflect the lack of direct anthropogenic inputs in the vicinity. Minor fluctuations in the low concentrations of some detected analytes reflect variations in grain size distribution, with minor increased concentrations associated with a higher percentage of fines and higher levels of TOC. These results suggest that there are no appreciable differences in sediment chemistry conditions that would favor one candidate site over the other for future disposal activities. They also indicate that past disposal activities in and around candidate sites 1 and 2 have not resulted in any differences in sediment chemistry compared to ambient sediments in the wider surrounding Buzzards Bay region. Differences in grain size and implications with respect to the hydrodynamics of each site are discussed in the following section.

4.3 Preliminary Analysis of Hydrodynamics and Erosion Potential

The evaluation and comparison of the suitability of candidate sites 1 and 2 for disposal of dredged material includes the important determination of whether each site represents an erosional (i.e., dispersive) or a depositional (i.e., containment) environment, and whether the hydrodynamic regime indicates that the material to be placed there will remain stable. Consequently, significant effort was directed toward evaluating the potential impact of currents and storm events at candidate sites 1 and 2, specifically with respect to the potential for sediment resuspension and transport (Maguire 2001e and 2004a) (See Appendix H and P).

This DEIR requirement was addressed using a multi-step approach, including both a preliminary "desk-top" analysis using existing datasets (this section) and a subsequent, more-detailed analysis involving the collection and use of site-specific data (Section 4.4). The preliminary analysis presented in this section consisted of the following steps:

1) "Depth-difference" comparisons of high-resolution bathymetric data collected near the candidate sites in 1990, 1998 and 2000 were used to evaluate whether there has been any large-scale erosion or deposition of sediments in this part of Buzzards Bay over a ten-year period;
2) Existing data from nearby locations were used to characterize both average and "extreme" winds, waves, and bottom currents likely to be experienced at the two candidate disposal sites; and
3) A model was used to calculate the potential for sediment re-suspension at the sites under average and extreme conditions.

4.3.1 Preliminary Analysis: Bathymetric Depth-Difference Comparisons

To assess changes in bottom topography (i.e., bathymetry) over time, a depth difference comparison was conducted within the study area. This methodology is used routinely by the USACE to monitor the development and long-term stability of dredged material disposal mounds on the bottom, as part of their DAMOS program (monitoring reports are available for downloading at: www.nae.usace.army.mil/environm/damos/splash_page.htm). Bathymetric "depth difference" comparisons were evaluated for the areas of overlap between the 1990 and 1998 surveys (Figure 4-16), and between the 1998 and 2000 surveys (Figure 4-17). Depth difference maps were generated by subtracting depth values on the older survey from the depth values on the more recent survey. The results were contoured as a bathymetric map to depict any positive or negative changes in depth between the two surveys. Depth changes smaller than about ±0.5 meters (1.6 feet) are generally below the resolution of the method and are not reliable indications of actual depth changes. Therefore, the method provides a screening evaluation that can be used to assess whether substantial erosion or deposition (i.e., changes greater than ±0.5 meters, or 1.6 feet) may have occurred between surveys. More refined seafloor monitoring techniques are required to determine if smaller-scale deposition or erosion of substrate has occurred between surveys.

A limitation to this approach is that if a loss of height is measured over a mound of dredged material that has been deposited on the bottom, the method does not distinguish whether the loss was caused by erosion or mound consolidation. Consolidation occurs as a result of *in situ* overburden stresses that force water out of the pore spaces within a dredged material mound. This process begins as soon as the dredged material reaches the sea floor. There is generally a high rate of consolidation during the initial 6 to 12 months following mound creation and then the process gradually slows over time. As water is squeezed out of the mound, the mound volume is reduced (Brandes et al 1991).

The precision bathymetric surveys conducted in March 1990 and May 1998 included a region of overlap encompassing a 600 meters by 600 meters (0.4 mile by 0.4 mile) area surrounding the former BBDS. In both surveys, the lanes were spaced 25 meters apart and oriented north-south, and comparable field procedures and data processing methods were used (Maguire 1998b). The depth difference comparison showed negligible positive or negative change over most of the 600 meters by 600 meters area (Figure 4-16). Topographic changes were generally less than 0.5 meters (1.6 feet), which is less than reliably detected within the resolution of the method. Most of the depth changes were less than 0.25 meters (0.8 feet), with several small areas indicating accumulation between 0.5 meters (0.8 feet) and 0.75 meters (2.5 feet; Figure 4-16). The random

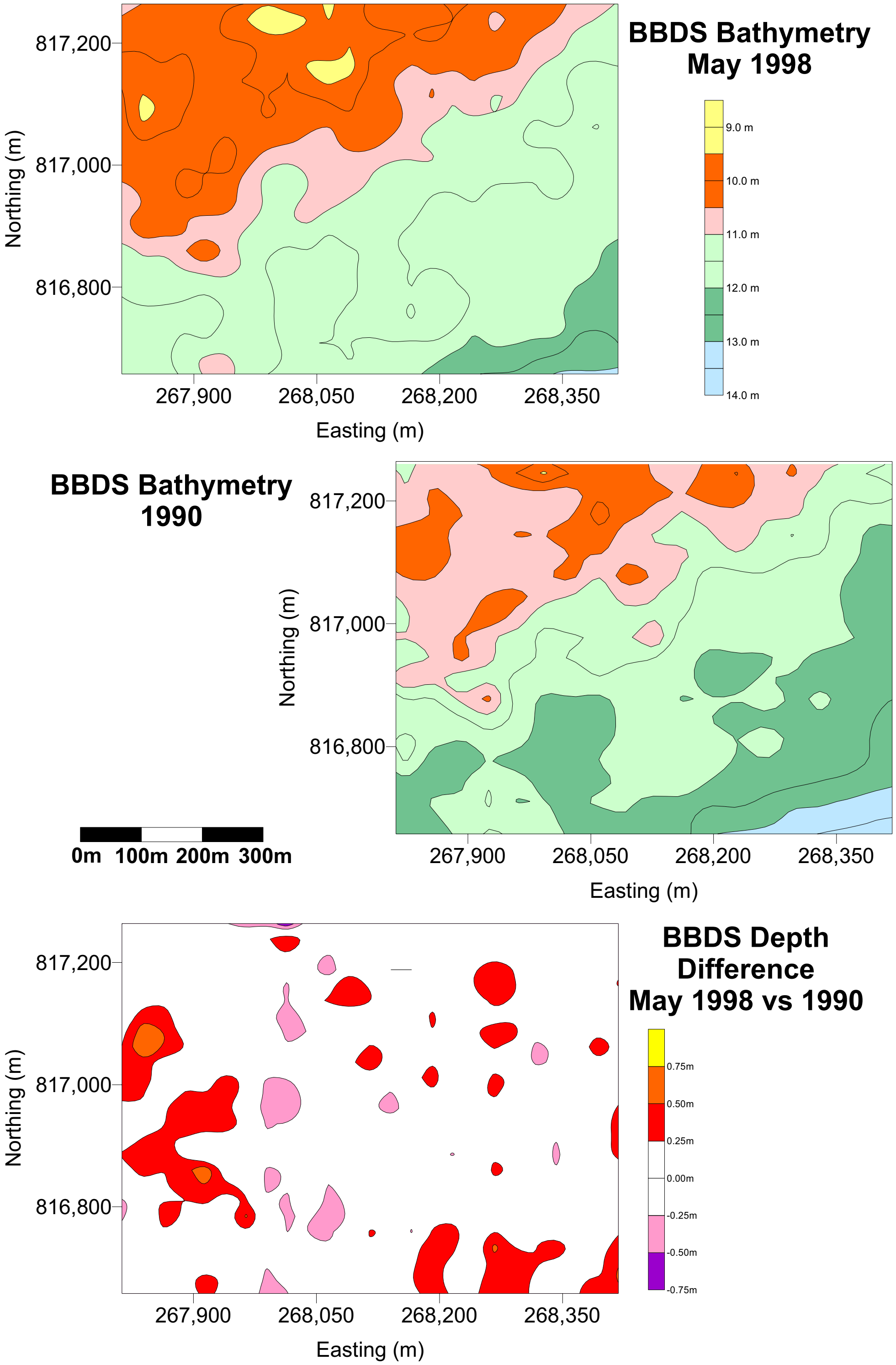


Figure 4-16. Contour map of depth differences (bottom) between the May 1998 (top) and March 1990 (middle) bathymetric surveys at the former BBDS (from Maguire Group Inc., 1998c).

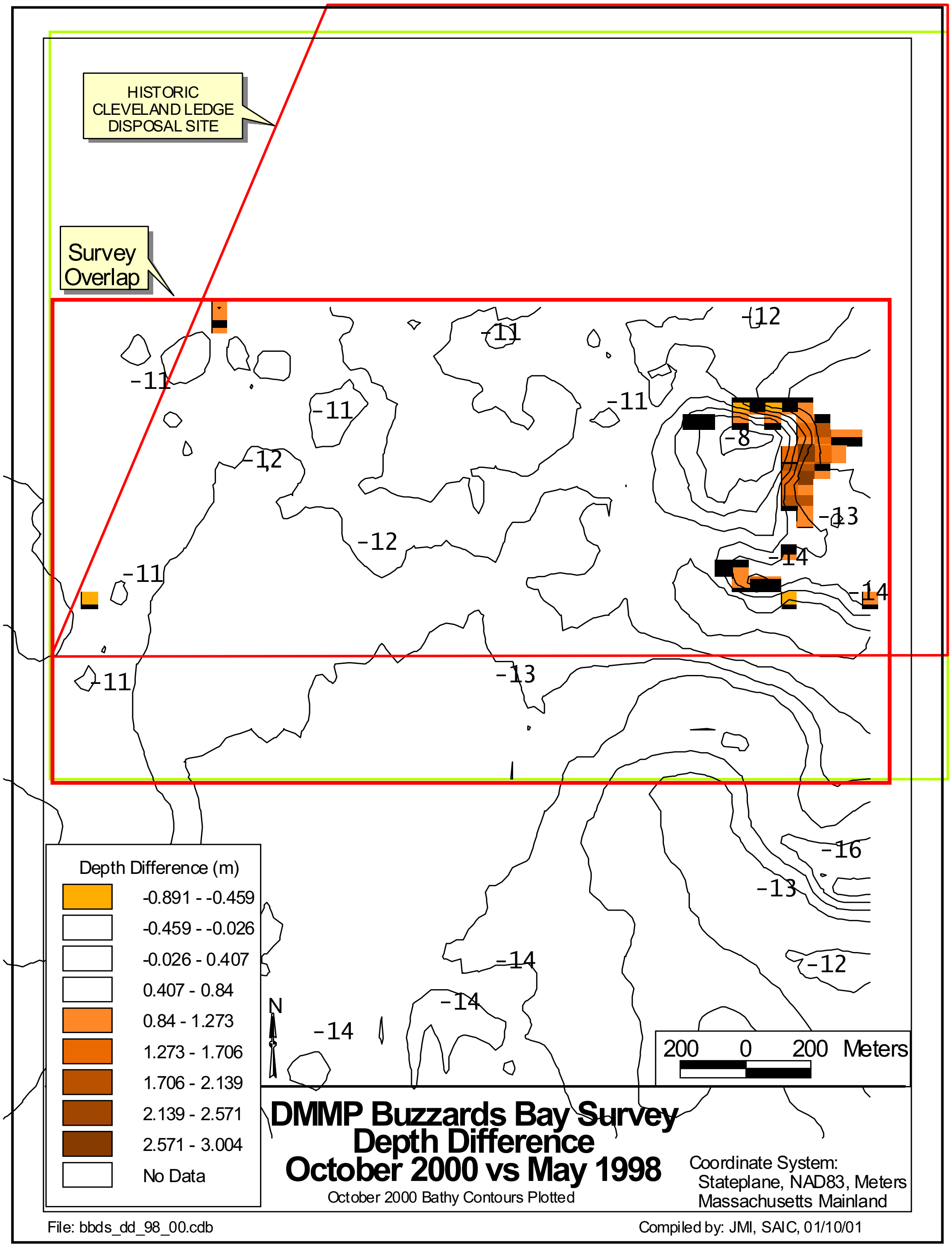


Figure 4-17. Map showing the results of the depth difference comparison between the October 2000 and May 1998 bathymetric surveys.

The depth difference results (in meters) are superimposed on the bathymetric contours from the October 2000 survey.

pattern of the positive and negative depth differences depicted in Figure 4-16 provides additional evidence that these apparent topographic changes are "artifacts" of the depth-differencing procedure (i.e., false positive or negative changes produced due to lack of accuracy of the method in detecting changes smaller than ±0.5 meters), rather than areas of true erosion or deposition. The data are consistent with the record of no disposal of dredged material at BBDS during the interim period between surveys. The relative absence of any significant *negative* depth changes in Figure 4-16 is particularly relevant to the site designation effort, as it indicates that surface sediments in this area have not experienced appreciable erosion over this eight-year period.

A second depth-difference comparison was conducted using the results of the May 1998 survey and an October 2000 bathymetric survey. The May 1998 survey in its entirety covered a 2,300 meters by 3,400 meters (1.4 miles x 2.1 miles) area encompassing the southern half of the former CLDS (Figure 4-17), which includes the northern-most portion of site 1. The October 2000 survey in its entirety covered a 3,200 meters by 3,200 meters (2 miles by 2 miles) area centered at candidate site 1; the area of overlap between this survey and the May 1998 survey measured 1,500 meters by 2,600 meters (.9 miles by 1.6 miles; Figure 4-17).

The results of the depth difference comparison between the October 2000 and May 1998 bathymetric surveys indicated that depth differences over the majority of the area were within the range ±0.5 meters (±1.6 feet), again equivalent to the estimated "detection limit" of the method. There were two small areas of apparent increased depths greater than 0.5 meters (1.6 feet) in the eastern portion of the survey area. However, these areas were located at topographic high points with vertical relief greater than that found on the surrounding seafloor (Figure 4-17). When using the depth difference procedure, minor deviations in depth measurements can become exaggerated in areas with increased relief. Therefore, these apparent depth changes are considered to be exaggerations or artifacts of the depth differencing procedure. Overall, the depth difference comparison depicted in Figure 4-17 was interpreted as showing no significant topographic changes between the two consecutive surveys, indicating an overall absence of significant sediment erosion or deposition in the area during the period from May 1998 to October 2000.

In summary, the results of the depth difference comparisons indicated no significant changes in depth (greater than ±0.5 meters or 1.6 feet) in the vicinity of candidate sites 1 and 2 during the time periods between surveys. Despite limitations in the resolution of depth changes reliably detected with this method (i.e., changes smaller than ± 0.5 meters or 1.6 feet), the comparisons made over an eight-year period at the former BBDS are particularly relevant to the present investigation. This former disposal site occurs at shallower depths than candidate sites 1 and 2 and is therefore more susceptible to erosion. Additionally, the depth-difference comparison for the site spanned a period of time with at least one major storm event, Hurricane Bob (August 1991). These results provide useful evidence for the lack of significant, long-term sediment erosion potential in the vicinity of candidate sites 1 and 2.

4.3.2 Preliminary Analysis: Characterization of Wind, Wave and Current Conditions

4.3.2.1 Wind

In general, the predominant winds in the vicinity of Buzzards Bay are directed from the northwest in the winter months and from the southwest in the summer months (Howes and Goehringer 1996). The southwesterly winds correspond to the maximum fetch, extending from the mouth of Buzzards Bay and running across the greatest length of the waterbody. The seabed at each of the candidate disposal sites is on average 12 meters (39 feet) below the surface of the bay. Seabed sediments at these candidate sites lay essentially undisturbed beneath the wind-driven surface currents and wind-generated waves. Readily available information from existing sources was used in the first-order wind, wave and current analysis for this DEIR.

NOAA maintains a meteorological station near the entrance to Buzzards Bay west of Cuttyhunk Island, called the BUZM3 C-MAN station (Figure 4-18), and long-term data records are available for downloading from their Web site. Instruments at this station continuously measure wind speed and direction at an elevation of 24.8 meters (81 feet) above mean sea level. This station is approximately 6.5 nm (12 kilometers) offshore of the mainland which lies to the north, and between approximately 17.5 and 20 nm (32 and 37 kilometers) from the areas of the Bay encompassed by candidate sites 1 and 2. It is assumed that the basic patterns of wind speed and direction at this meteorological station are generally comparable to conditions at the candidate disposal sites. In reality, it is likely that the winds at the BUZM3 station would tend to be somewhat higher on average than those experienced in more sheltered areas of Buzzards Bay located closer to land. Therefore, in the absence of site-specific wind data, using the wind data from the BUZM3 station provides a conservative estimate of the wind conditions likely to be experienced at the candidate sites.

In order to quantify the long-term wind conditions at the two candidate sites, a continuous record of wind speed and direction covering a nine-year period from 1985 to 1994 at the BUZM3 C-MAN station was downloaded from the NOAA's National Data Buoy Center (NDBC) website. The time period from 1985 to 1994 provided the longest, continuous record that was readily available from the BUZM3 station. More recent records from this station were not included as the instruments became unavailable for several years in the mid-1990s. However, this nine-year dataset encompasses a time-span that is long enough to provide an accurate characterization of average wind patterns and thereby lend considerable realism to the modeling approach taken below.

Once the long-term dataset was obtained, a bivariate analysis (speed versus direction) was performed to provide summary information and a corresponding "wind rose" diagram. Following standard meteorological convention, wind direction in this report is given as the direction from which the wind was blowing.

The bivariate (speed and direction) evaluation of the nine-year record from BUZM3 indicates that 49.1% of the winds were in the arc from the south to the west-northwest (180° through 300°; Figure 4-19). Although these directions accounted for a significant portion of the record, the

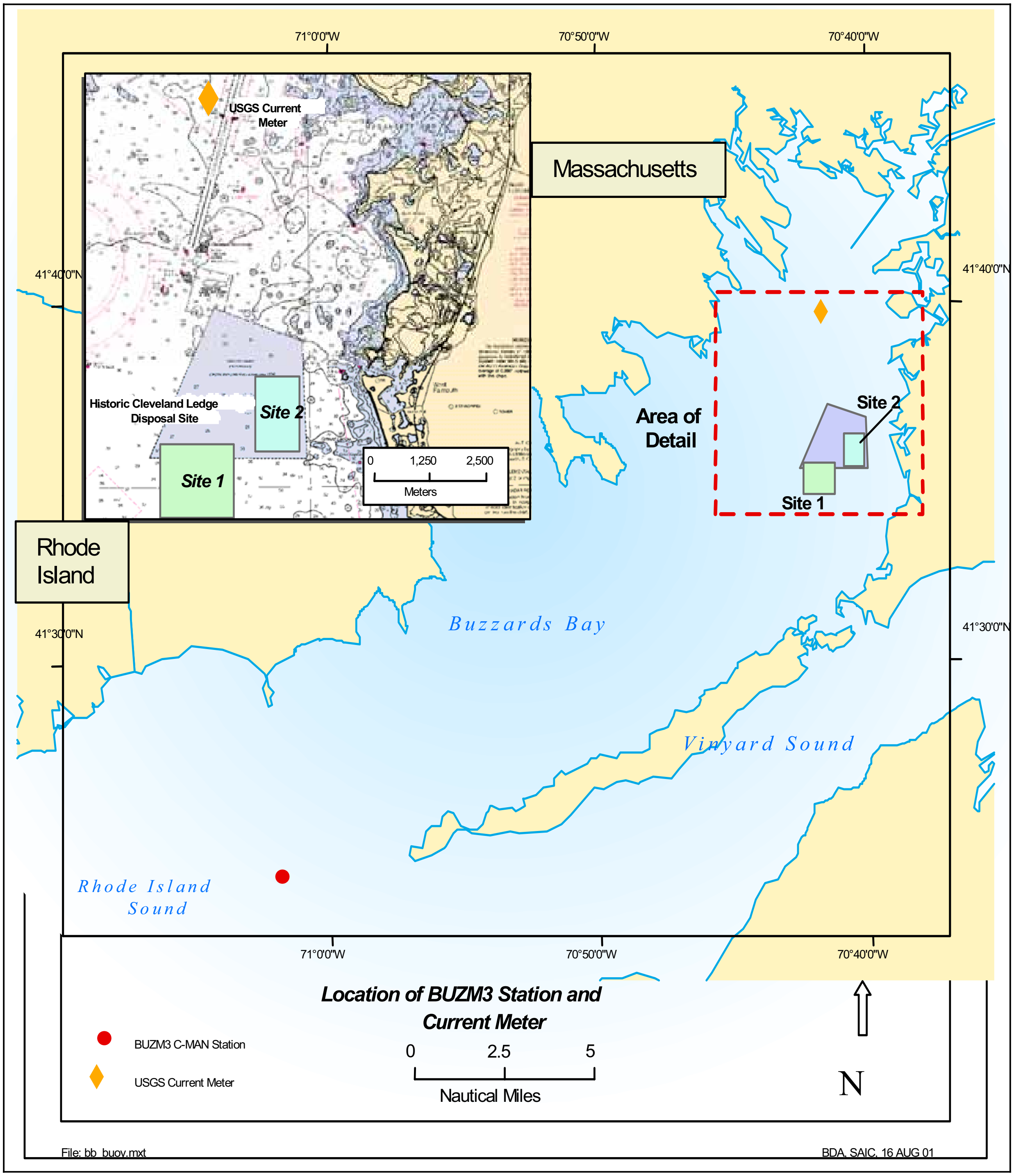


Figure 4-18. Map showing the location of the NOAA BUZM3 C-man station at the entrance to Buzzards Bay and the deployment location of the USGS current meter (inset).

mean wind speeds in each of the 12 30°-directional increments were comparable, ranging from 6.7 to 8.7 meters per second ((m/s) equivalent to 14.9 to 19.5 miles per hour (mph)). The maximum measured speeds in each 30° directional increment were also similar, varying between 21.1 m/s (47.2 mph) from the north-northwest and 34.5 m/s (77.2 mph) from the east-southeast (the latter measurement was obtained during Hurricane Bob on August 19, 1991). The average wind velocity from the indicated measurements was directed *toward* approximately 80° true (i.e., *from* the west-southwest), with a speed of approximately 2.2 m/s (5 mph). This composite summary is consistent with the seasonal summary provided by Howes and Goehringer (1996), and the predominant southwesterly winds represent the maximum fetch distance across the Bay for candidate sites 1 and 2.

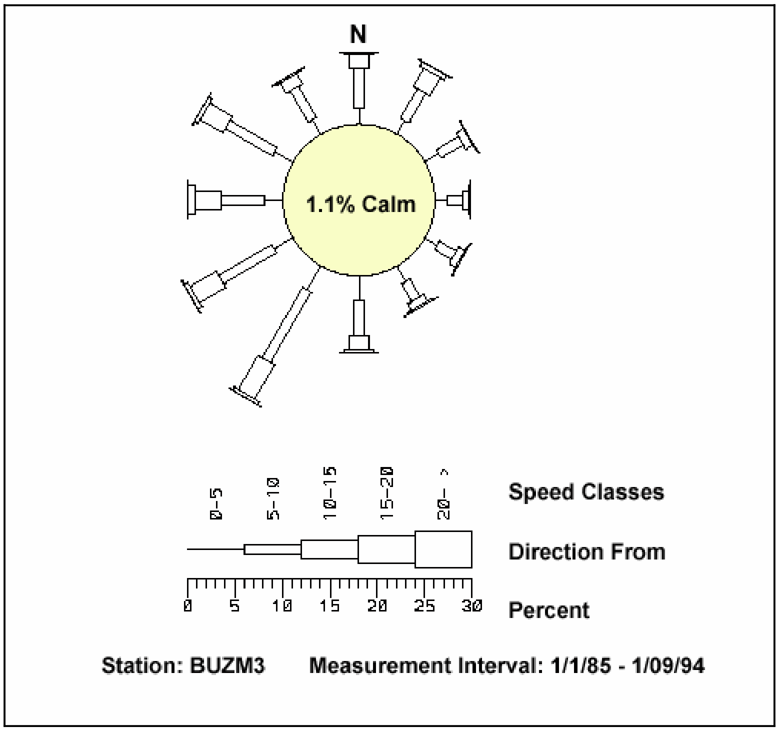


Figure 4-19. A wind rose based on data collected over the period 1985 to 1994 at the NOAA meterological station at the entrance to Buzzards Bay.

Wind speeds are in units of meters per second (m/s). The relative occurrence of winds from the west-southwest (essentially blowing up the axis of Buzzards Bay) is evident.

4.3.2.2 Waves

The eastern portion of Buzzards Bay is relatively well-protected from the effects of large, long-period, open-ocean waves (i.e., swells). As open ocean swells enter the mouth of Buzzards Bay from the southwesterly direction, they are refracted and slowed along the east and west shorelines as they progress towards the area of candidate sites 1 and 2. Evaluating contributions to the hydrodynamics of these two candidate sites from the influence of ocean swells would be difficult without field measurements. Therefore, this preliminary evaluation focuses on the effects of waves produced by winds blowing across the open waters of the bay. The highest waves experienced at candidate sites 1 and 2 would be expected to occur when winds blow from the southwest, across the greatest possible fetch. Therefore, to estimate the maximum waves potentially experienced at the candidate disposal sites under both average and very rare wind conditions, the fetch was taken to be 35 kilometers (22 miles), or the distance from the NOAA BUZM3 C-MAN station at the Bay entrance to the candidate disposal sites. Even though longer fetch distances may be measured beyond this station, this 35-kilometer (22-mile) fetch is appropriate for the purpose of the following wave modeling. Calculations of maximum wave height were made following standard coastal engineering procedures as described in the Shore Protection Manual (Horikawa 1978).

Using this fetch distance, waves were calculated for both "average" and "very rare" wind conditions. The bivariate analysis of the nine-year wind record described above indicated an *overall* average wind speed of 7.76 m/s (17 mph) for Buzzards Bay. A wind of this speed, blowing from the southwest up the center of the bay, generates a fetch-limited significant wave height of 0.635 meters (2 feet), with a prevailing wave period of 3.77 seconds. For the "very rare" condition, a wind speed of 15 m/s (33.6 mph) was selected. While 15 m/s (33.6 mph) is not the absolute maximum wind speed observed over the nine-year period, it is considered a realistic "very rare" value because, as shown in Figure 4-19, 96% of the wind speeds measured over the 9-year period were equal to or less than this value. In other words, the long-term record indicates that winds as high as 15 m/s (33.6 mph) are relatively rare in Buzzards Bay, occurring only 4% of the time. Assuming a "very rare" wind of 15 m/s (33.6 mph) from the west-southwest as the generating process, the computed significant wave height, H_s, at the candidate disposal sites was calculated to be 1.6 meters (5.25 feet), with a period of 6.6 seconds.

A first-order approximation of the effects of such waves on the substrate at candidate sites 1 and 2 can be made by determining if these waves would be characterized as shallow, intermediate, or deep-water waves in the typical water depths that occur within the sites. For deep-water waves, the effects of the wave orbital motion do not reach the substrate, and, when considered independently of other hydrodynamic factors, would not affect sediment transport. Deep-water waves can be generally characterized when the water depth is greater than one-half the wavelength. Shallow water waves have flattened orbital motion at the substrate that exerts an influence on sediment transport, and can be characterized by water depths less than 1/20 the wavelength. Intermediate waves occur between these two depth values, with increasing effects on the substrate as the water depth becomes shallower.

For the calculated average and maximum waves that might develop from the direction of greatest fetch at candidate sites 1 and 2, determinations were made of whether they represent shallow, intermediate or deep-water waves. The average wind condition waves with a height of 0.635 meters (2 feet) and a period of 3.77 seconds would be considered a shallow-water wave in water depths of 1.1 meters (3.6 feet), and a deep-water wave in water depths greater than 11 meters (36 feet). The average wind waves, therefore, would not be expected to affect sediment transport in candidate sites 1 and 2, where depths are generally greater than 11 meters (36 feet).

The very rare wind condition waves, with a height of 1.6 meters (5.25 feet) and a period of 6.6 seconds would be considered a shallow-water wave in water depths of 3.4 meters (11.2 feet), a deep-water wave in water depths greater than 3.4 meters (11.2 feet), and an intermediate wave in the water depths between 3.4 meters (11.2 feet) and 34 meters (112 feet) that characterize candidate sites 1 and 2. As such, these waves would be expected to exert some influence on the substrate at candidate sites 1 and 2 and surrounding areas. The modeling effort described below (Section 4.3.3) examines this potential in greater detail.

4.3.2.3 Bottom Currents

Information on bottom currents in the vicinity of sites 1 and 2 was obtained by the Woods Hole Field Center of the United States Geological Survey (USGS) for the period January 1982 to November 1985. USGS deployed a current meter during this time period at a site to the north of Cleveland Ledge, about 6 kilometers north of candidate sites 1 and 2 (Figure 4-18). It is assumed that currents at the USGS current meter location would be comparable to those experienced at the candidate sites based on the following: (a) the current meter site was located in the same general area of the bay; (b) the site had water depths comparable to the depths at candidate sites 1 and 2 (13 to 14 meters (43 to 46 feet.) at the current meter deployment location); and (c) a Bay-wide summary of flood tidal currents (Howes and Goehringer 1996) indicated relatively uniform current speeds throughout the northeastern portion of the bay encompassing both the USGS current meter site and candidate sites 1 and 2 (Figure 4-20).

Conditions in the north-central portion of the Bay are fairly consistent due in part to a relatively smooth, shallow substrate, in contrast to the more variable topography near the Bay entrance (Howes and Goehringer 1996). This area of the Bay, including candidate sites 1 and 2 and the USGS current meter location, is removed from stronger tidal currents that occur along Naushon Island as far north as Woods Hole (the effect of differences in tidal phase and amplitude between Buzzards Bay and Vineyard Sound), as well as the predominant flood- and ebb-tidal current that follows the north shoreline of the Bay (Figure 4-20; Howes and Goehringer 1996). Therefore, ignoring localized interference from small-scale topographic features (e.g., Gifford Ledge), conditions at the USGS current meter site can be used to characterize the general effect of tidal currents at candidate sites 1 and 2.

The substantial USGS current meter data consist of hourly recordings of current speed and direction one meter above the seafloor, for multiple data collection events of over 30 days time during the greater than 3-year period of the study. Records of hourly, near-bottom current measurements were obtained for a total of 291 days over the period January 1982 to November 1985. Because it is such a long-term record, these data provide a more reliable indicator of conditions than a 30-day tidal cycle data set. As with the wind data, a bivariate analysis was conducted to produce a summary of the current speed and direction (Figure 4-21). Current directions in this report are given in terms of the direction *toward which* the current is flowing.

The analysis shows that tidal currents are dominated by the semi-diurnal (M_2) tidal constituent, and the tidal current vector rotates counterclockwise, resulting in a north-northeast to south-southwest dominance in tidal current strengths. This suggest that the tides predominantly run parallel to the main axis of the Bay, consistent with the available summary of flood tidal directions presented by Howes and Goehringer (1996) and illustrated in Figure 4-20.

The maximum current speed measured during the 291 days of the USGS current meter deployment was 32.7 centimeters per second (cm/s, 0.64 knots). The bivariate analysis of these data indicates that the overall average current speed (irrespective of direction) was 7.1 cm/s (0.14 knots), and approximately 97.7% of the measured currents were less than 15 cm/s (0.29 knots).

This value is consistent with the average tidal currents for the north-central portion of Buzzards Bay shown in Howes and Goehringer (1996). The current rose diagram generated from these data indicates that the predominant current orientation was southwest/northeast (Figure 4-21).

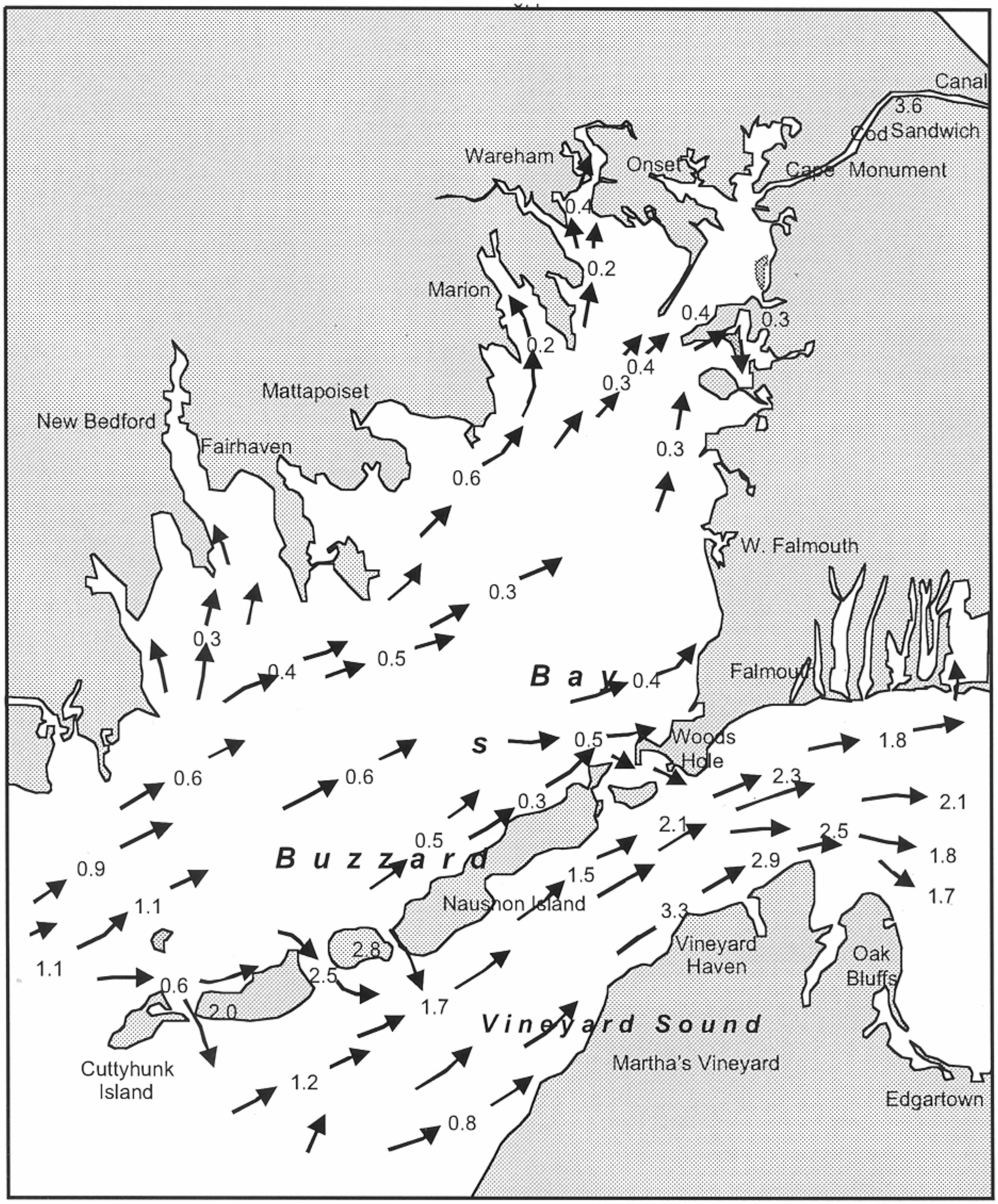


Figure 4-20. Buzzards Bay tidal current chart showing flood currents 4 hr afeeter slack tide. Note the general north-northeast orientation of the current vectors at the head of the Bay and specifically near the candidate disposal sites off of West Falmouth (from Howes and Goehringer 1996).

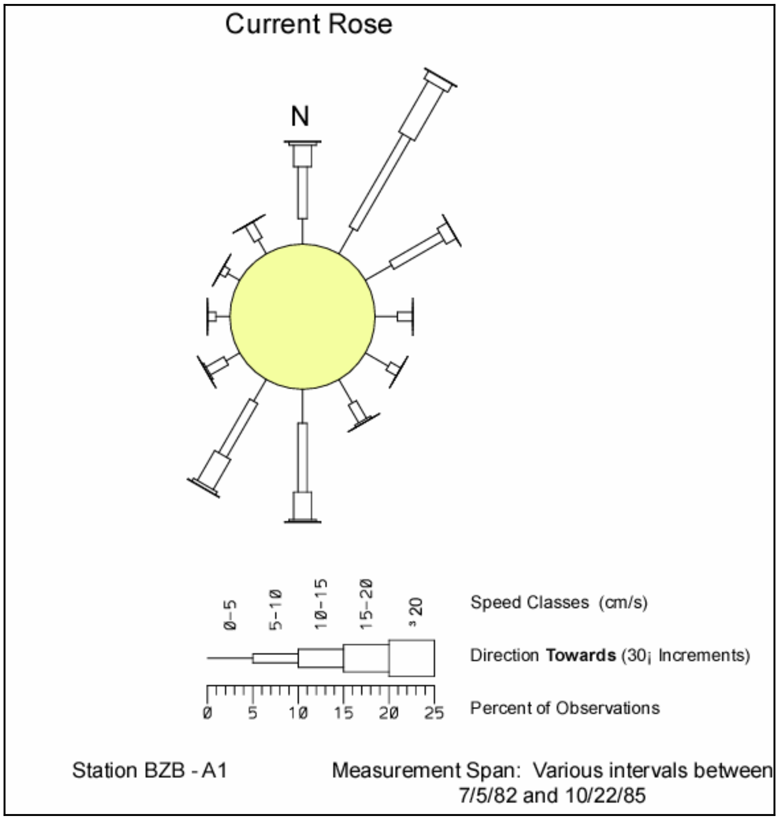


Figure 4-21. A current rose based on the USGS current meter data collected over various intervals from 1982 to 1985.

The relative occurrence of currents oriented east-northeast to west-southwest is evident. The orientation of the M_2 (semi-diurnal lunar) tidal ellipse coincides with this orientation.

While the maximum current speed of 32.74 cm/s (4.9 knots) measured during the meter deployment period was considerably greater than the overall average 7.08 cm/s (0.014 knots), it should be noted that only 0.1% of the measured currents exceeded 25 cm/s (0.49 knots). Thus, if it is assumed that these data statistically represent currents experienced at the candidate disposal sites, then current speeds greater than 25 cm/s (0.49 knots) would have a cumulative duration for all occurrences of approximately 9 hours out of 291 days. Under this same scenario, currents in excess of 15 cm/s (0.029 knots) would have a cumulative duration for all occurrences of approximately 200 hours, or 8.4 days out of the total 291 days.

In summary, an average current speed of 7.1 cm/s (0.138 knots) appears to provide reasonable estimate of conditions in the vicinity of candidate sites 1 and 2. A current velocity of 15 cm/s (0.029 knots) was taken to represent a very rare condition, since less than 3% of the observed current speeds shown in Figure 4-21 were above this value. Localized topographic features would be expected to have some effect on tidal currents within the sites. Most notably, Gifford Ledge, with a minimum depth of 3 meters (9.8 feet), and the historical dredged material disposal mound with a minimum depth of 8 meters (24.25 feet), could create localized areas of increased tidal current strength within candidate site 2.

4.3.3 Preliminary Analysis: Modeling of Sediment Re-suspension

A key objective of this preliminary analysis concerns the potential ability of waves and currents to mobilize and transport sediments at the candidate disposal sites. Therefore, using the average and extreme wave and bottom currents conditions estimated above, and information on the grain size of existing surface sediments at the sites, sediment resuspension potential was evaluated using the one-dimensional Glenn and Grant (1987) bottom boundary layer model.

The Glenn and Grant (1987) model requires measurements or estimates of the following parameters: wave amplitude or significant wave height; peak wave period; current velocity at a given distance from the sea-bed (usually one meter); and the angle between the current vector and the direction of the waves. The model is not particularly sensitive to this angle, and if it is not known, it is assumed to be 90°, because waves generally propagate perpendicular to, and currents generally flow along, the isobaths. The sediment parameters required as input to the model are grain size and density of the bed sands. The model's dimensionless concentration of sediment at the bed also needs to be estimated and is usually taken at $C_{bed} = 0.6$ (Glenn and Grant 1987). The other important input is the total depth of water.

This model outputs a multitude of boundary layer and sediment concentration parameters. Of interest here is the bottom friction velocity caused by the combined action of waves and bottom currents, U_{*cw}, the apparent bottom roughness length, Z_{OC}, the mean sediment concentration in the boundary layer, and the instantaneous depth of the seabed that needs to be mobilized to provide the calculated quantity of sediment in suspension. The latter will be referred to herein as the erosion depth. Glenn and Grant (1987) provide additional details regarding the definitions of these quantities. The reliability of the Grant and Madsen (1979) and the Glenn and Grant (1987) models have been examined for a number of bottom boundary layer field studies on continental shelves (Wiberg and Smith 1983; Grant et al. 1984; Cacchione et al. 1987; Drake et al. 1989).

The Glenn and Grant (1987) model is a one dimensional (depth and time) boundary layer formulation, and, as such, it neither takes into account larger-scale variations in topography nor calculates redistribution of sediment by the spatially and time-varying bottom currents. Therefore, the model-computed, instantaneous erosion depth should not be viewed as the amount of sediment that is removed by the bottom stresses, but rather as the depth of the bed that is instantaneously stirred and mixed by the waves and currents. The amount of sediment removed from a site cannot be calculated in a one-dimensional model. In a major storm, most of the sediment put into suspension would come from the entire bay seabed and not just the disposal site areas. However, despite these limitations, the model provides useful information on the potential disturbance to the substrate caused by the action of wind waves and currents acting together.

Sediment resuspension at the candidate sites was modeled for both “average” and “very rare” wind/wave and bottom current conditions. As described above, the average wind of 7.76 m/s (17 mph) blowing across the maximum fetch of 35 kilometers (21.7 miles) was found to generate a significant wave height of 0.635 meters (2 feet), with a period of 3.77 seconds, at the candidate sites. Using these conditions in combination with the observed overall average current speed of 7.0 cm/s, directed toward 15° in a water depth of 12 meters (39 feet), the Glenn and Grant (1987) model indicates that no sediment resuspension would occur, even for fine silt, the smallest diameter grains evaluated.

The very rare wind conditions of 15 m/s (34 mph) described above resulted in a calculated significant wave height of 1.6 meters (5.2 feet), with a period of 6.6 s, directed toward 30°. As further input to the Glenn and Grant (1987) model, these wind conditions were combined with the very rare bottom current of 15 cm/s (0.29 knots), directed toward 15°, in a water depth of 12 meters (39 feet). The speed of 15 cm/s (0.29 knots) is considered representative of a very rare current condition because approximately 98% of the actual measurements were less than this value. Using these input parameters, estimates of the depth of the active bottom sediment layer ("erosion depth") were made for five different sediment size classes (Table 4-6).

Table 4-6. Sediment resuspension ("erosion depth") calculated using the Glenn and Grant model (1987) for "very rare" wind, wave, and current conditions at the candidate disposal sites.

Size Description	Grain Size Diameter (mm)	Erosion Depth (mm)
Fine silt	0.0078	5.688
Coarse silt	0.044	0.158
Very fine sand	0.088	0.129
Fine sand	0.177	0.127
Medium sand	0.35	0.146

* The following very rare conditions were used as input to the model to produce the results shown in the table: wind speed = 15 m/s (3.4 mph), significant wave height = 1.6 meters(2feet), current speed = 15 cm/s (0.029 knots). The resulting erosion depth shown in the table was calculated for five different sediment grain sizes.

The erosion depth shown in Table 4-6 reflects the depth, in millimeters, of the layer of bottom sediment with the indicated size that would be put into suspension by the very rare wind/wave and current conditions specified. Thus, for surface sediments at the candidate disposal sites consisting entirely of unconsolidated, fine silt, the model predicts that a layer of 5.688 milimeters (0.57 centimeters) will be eroded off the bottom and put in suspension. For coarser sediments (i.e., sediment grains having larger diameters than those of coarse silt), the modeled depth of erosion is considerably less and essentially negligible (<0.016 centimeters).

These Glen and Grant model results indicate that no sediment re-suspension would occur under the conditions defined as average, and only the finest sediment fraction tested (i.e., fine silt) would be subject to limited re-suspension under the conditions defined as very rare, while coarser sediment fractions experienced negligible re-suspension. During the rare instances, it is reasonable to assume that resuspension of surface sediments would be widespread throughout Buzzards Bay. Therefore, the potential erosion and/or sediment resuspension experienced at either candidate site would represent an extremely minor contribution to that occurring throughout the bay.

4.4 Detailed Analysis of Hydrodynamics

The purpose of the detailed hydrodynamic study was to verify the results of the preliminary analysis and provide an independent, more comprehensive evaluation of the erosion potential and long-term stability of dredged material placed on the bottom at the two candidate sites. A multiphase approach, similar to that undertaken in the preliminary analysis but utilizing a different type of model to evaluate erosion potential, was employed (Maguire 2004b). First, a field program was undertaken to characterize the currents actually occurring at the proposed candidate disposal sites (Section 4.4.1 below). This was followed by an analysis of historical records to characterize both average and extreme storm conditions at the sites (Section 4.4.2 below). Finally, a computer modeling study was conducted to evaluate the long-term stability of dredged material deposited on the seafloor at each of the candidate disposal sites (evaluation of impacts in section 7.0).

4.4.1 Field Program to Monitor Currents

A field survey to measure tidal currents in the vicinity of the two candidate disposal sites was conducted on November 11 and 12, 2003 (Maguire 2004b) (Also see Appendix Q). A Nortek Acoustic Doppler Current Meter (ADCM) was placed on the bottom to measure surface elevation and bottom currents at 5-minute intervals at a location midway between the two sites (Figure 4-22). In addition, thirty four transects were run across the candidate sites over a 12-hour period using a ship-mounted RD Instruments 1200-kHz Acoustic Doppler Current Profiler (ADCP) to characterize horizontal and vertical variability in currents throughout the water column (Figure 4-22).

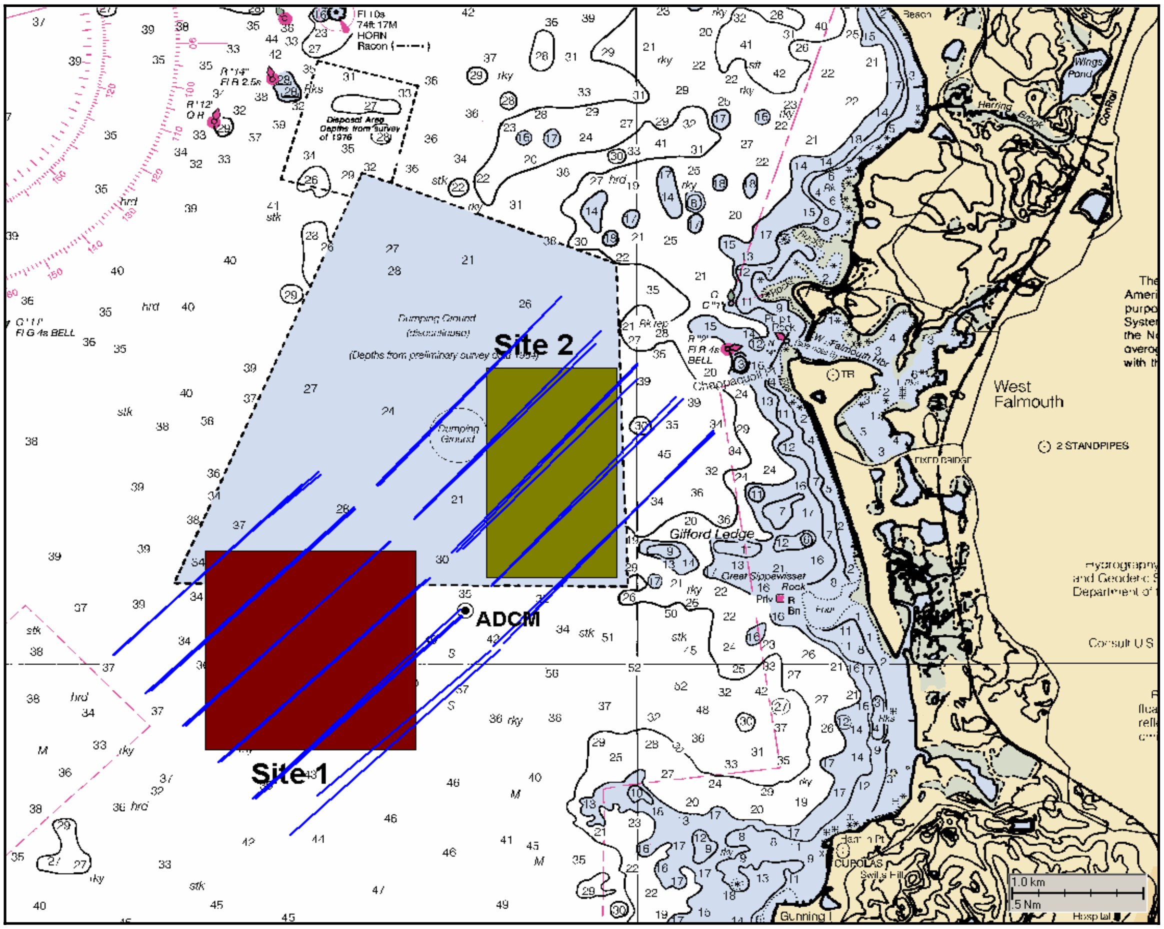


Figure 4-22. Map showing the location of the ADCM deployment and the ADCP transect lines used to measure currents during the November 2003 field survey.

The mean bottom current speed at this location during the deployment period was 0.086 knots (4.45 cm/s; Figure 4-23). The maximum current speed during this period was 0.131 knots (6.75 cm/s), and the minimum speed was 0.039 knots (2.0 cm/s). Flow was strongly oriented northeast/southwest during the latter half of the deployment (Figure 4-24), consistent with the orientation of Buzzards Bay as a whole.

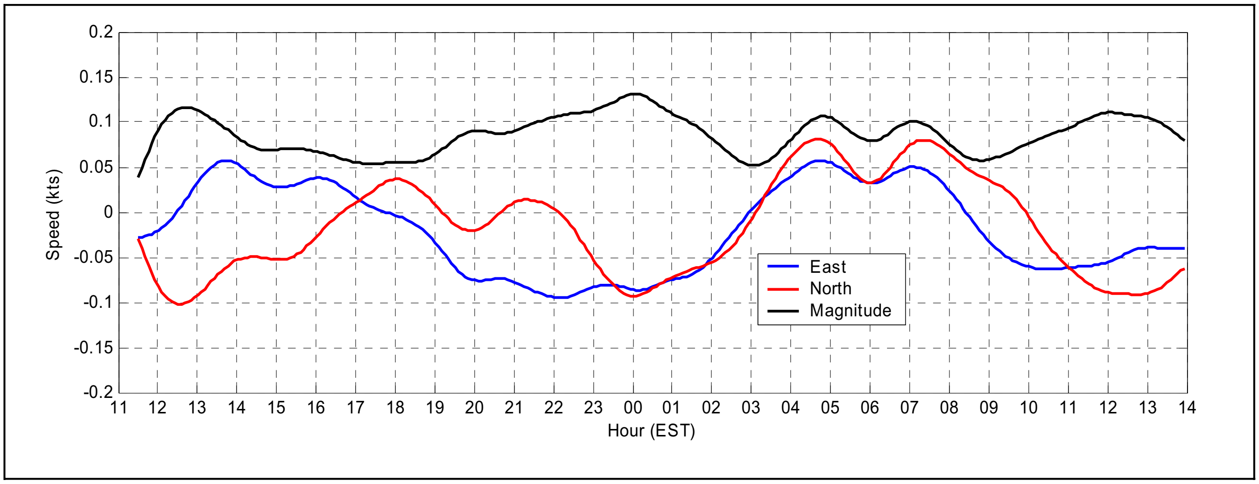


Figure 4-23. Bottom current speeds at the ADCM station, 11-12 November 2003.

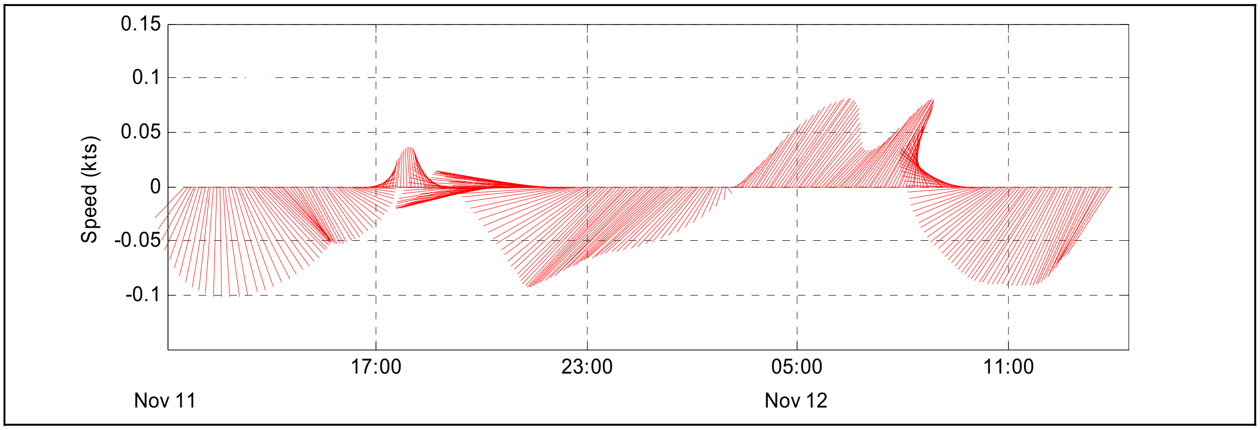


Figure 4-24. Vector plot showing speed and direction of bottom currents at the ADCM station, 11-12 November 2003.

There was very little variation in current speed and direction along individual transect lines (i.e., flow was relatively uniform throughout the surveyed area). Given the lack of spatial variability, all the measurements along a given transect were averaged to create a single vertical profile of currents for each of the transect lines. Current speeds typically either decreased gradually with depth (Figure 4-25) or were relatively uniform throughout the water column (Figure 4-26). Maximum observed current speeds were located near the surface and had velocities on the order of 0.3 knots (15.4 cm/s). The direction of the currents was largely a function of the tidal phase at the time of measurement.

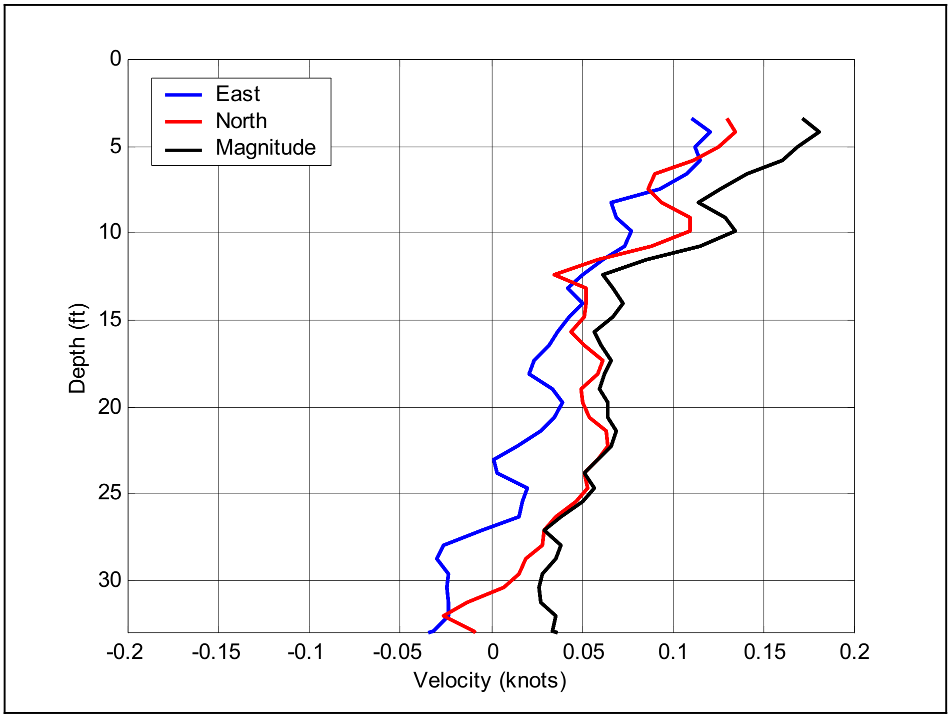


Figure 4-25. Average current velocities with depth along transect 08, at approximately 09:15 on 12 November 2003.

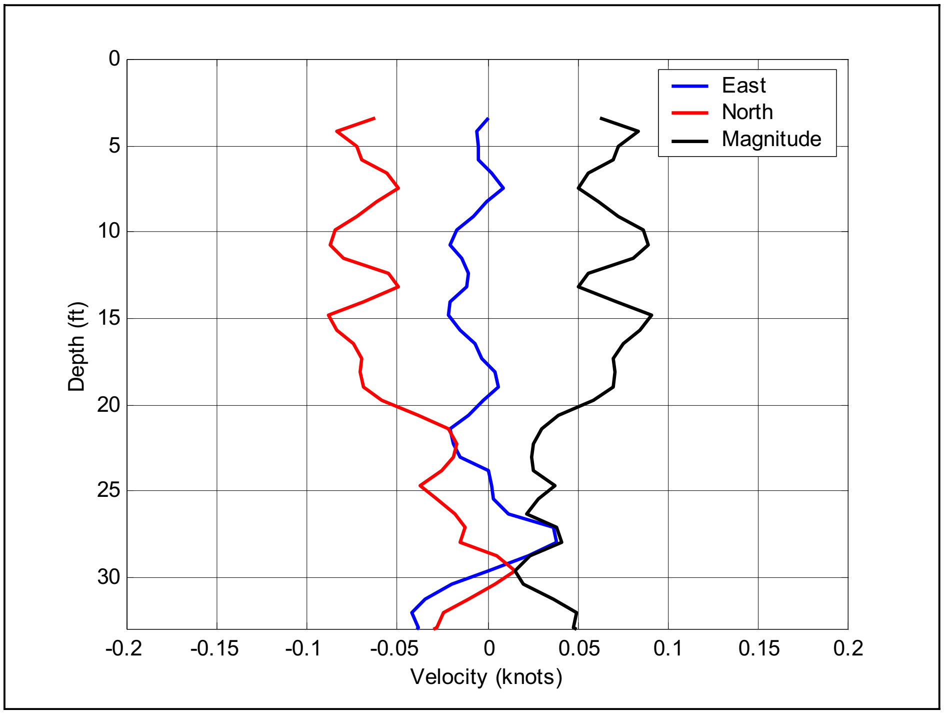


Figure 4-26. Average current velocities with depth along transect 30, at approximately 16:50 on 12 November 2003.

4.4.2 Detailed Wind and Wave Data Analysis

Similar to the preliminary analysis, data from the NOAA's NDBC BUZM3 C-MAN station at the entrance to Buzzards Bay (Figure 4-27) were used to estimate wind and wave conditions likely to be experienced at candidate sites 1 and 2. The data from BUZM3 used for the detailed analysis spanned a period of almost 18 years, from July 1985 through December 2003 (Maguire 2004b). This is twice the nine-year database reviewed for the preliminary analysis. Although a gap exists in the BUZM3 record from February 22, 1994 to April 27, 1997, data for this period were found to be available from a second buoy (Station 44028) that was deployed roughly 3 miles from the BUZM3 station (Figure 4-27). The record from Station 44028 covers the period from July 13, 1994 to April 20, 1997. Both stations were fully exposed from the southwest and southeast. Instruments on these stations measured a variety of standard meteorological data including continuous wind speed, wind direction, significant wave height, and dominant wave period.

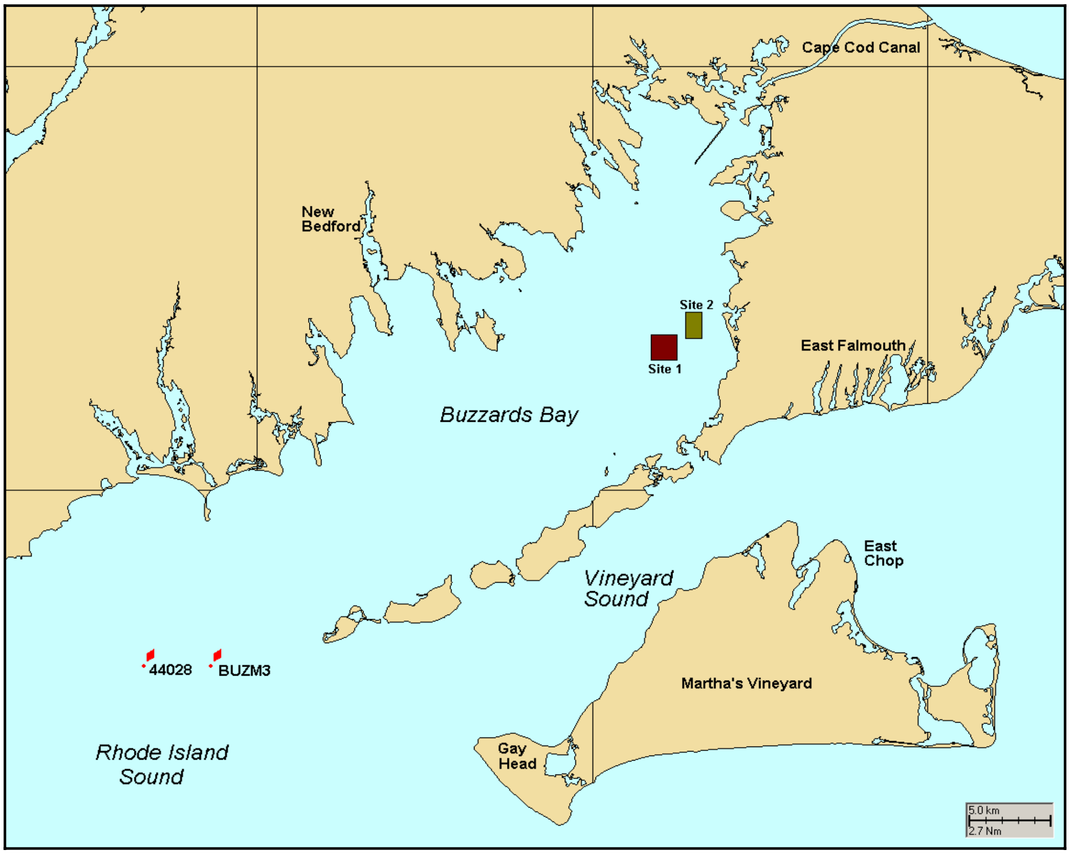
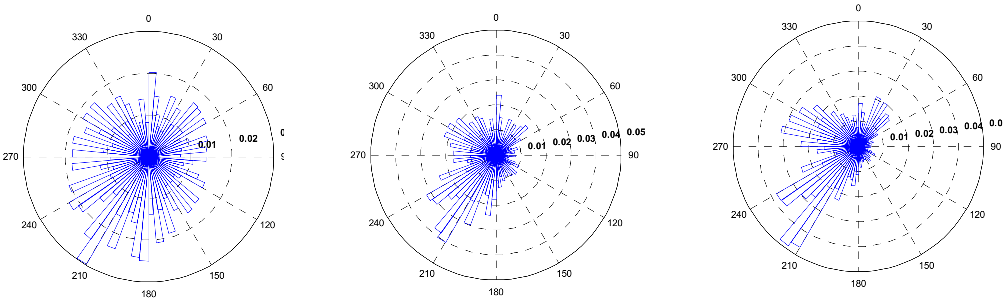


Figure 4-27. Map showing locations of NOAA's NDBC data buoys.

4.4.2.1 Winds

Wind speed and direction were recorded at both stations. Wind speed and direction were averaged over an eight minute period and recorded hourly. Note that wind directions are reported following standard meteorological convention and represent *the direction the wind comes from* in degrees clockwise from true North.

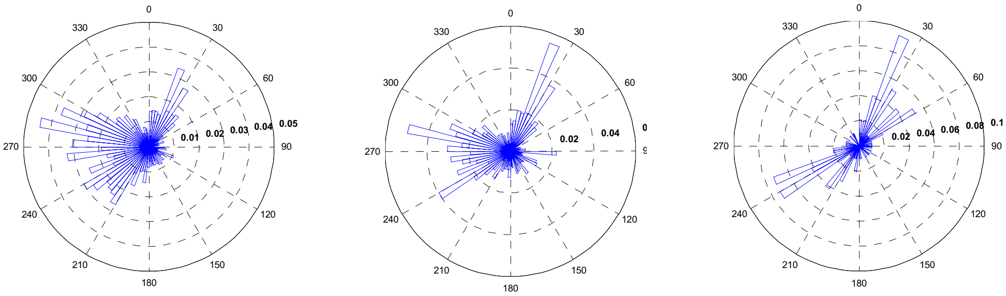
The distribution of winds at the entrance to Buzzards Bay, based on the long-term datasets from the two stations, is illustrated graphically in rose diagrams (Figure 4-28) which show the percentage of winds coming from particular directions (directions are binned in 5º increments) at a given speed. For the lower speeds (0 to 30 mph), winds are predominantly from the south and southwest. For speeds between 30 and 60 mph, the predominant direction shifts to between WSW and NNE. Winds between 60 and 70 mph come predominantly from the south and southwest, though some also come from the northeast. It is difficult to determine the dominant direction for the highest wind speeds (70 to 80 mph) because these speeds were only achieved on two discrete occasions. However, both of these events originated in the southeast.



Wind Rose for wind speeds 0 to 10 mph

Wind Rose for wind speeds 10 to 20 mph

Wind Rose for wind speeds 20 to 30 mph



Wind Rose for wind speeds 30 to 40 mph

Wind Rose for wind speeds 40 to 50 mph

Wind Rose for wind speeds 50 to 60 mph

Wind Rose for wind speeds 60 to 70 mph

Wind Rose for wind speeds 70 to 80 mph

Figure 4-28. Wind roses for wind speeds in 10-mph increments. Note: Fractional occurrences shown in radial direction.

The mean wind speeds were relatively similar for each of the 30º directional increments, ranging from 14.8 to 19.6 mph. The maximum wind speeds for these directional bins ranged from 50.7 mph to 77.2 mph.

The BUZM3 station is fully exposed over a considerable arc, ranging from the west to the southeast. The bivariate analysis and wind rose diagrams both indicate the majority of winds recorded at this site originate within this arc. Because the proposed candidate disposal sites are in a considerably more sheltered area, only exposed from the southwest, using conditions at the BUZM3 station to evaluate storm conditions at these sites represents a relatively extreme characterization (Maguire 2004b).

4.4.2.2 Waves

Both the BUZM3 station and Station 44028 measured significant wave height and dominant wave period. The significant wave height is taken as the average of the highest one-third of all wave heights measured in a 20-minute sampling period. The dominant wave period is the period with the maximum wave energy. Both parameters were reported hourly. The distribution of significant wave heights recorded at the two stations show very similar distributions in Figures 4-29 (BUZM3) and 4-30 (Station 44028).

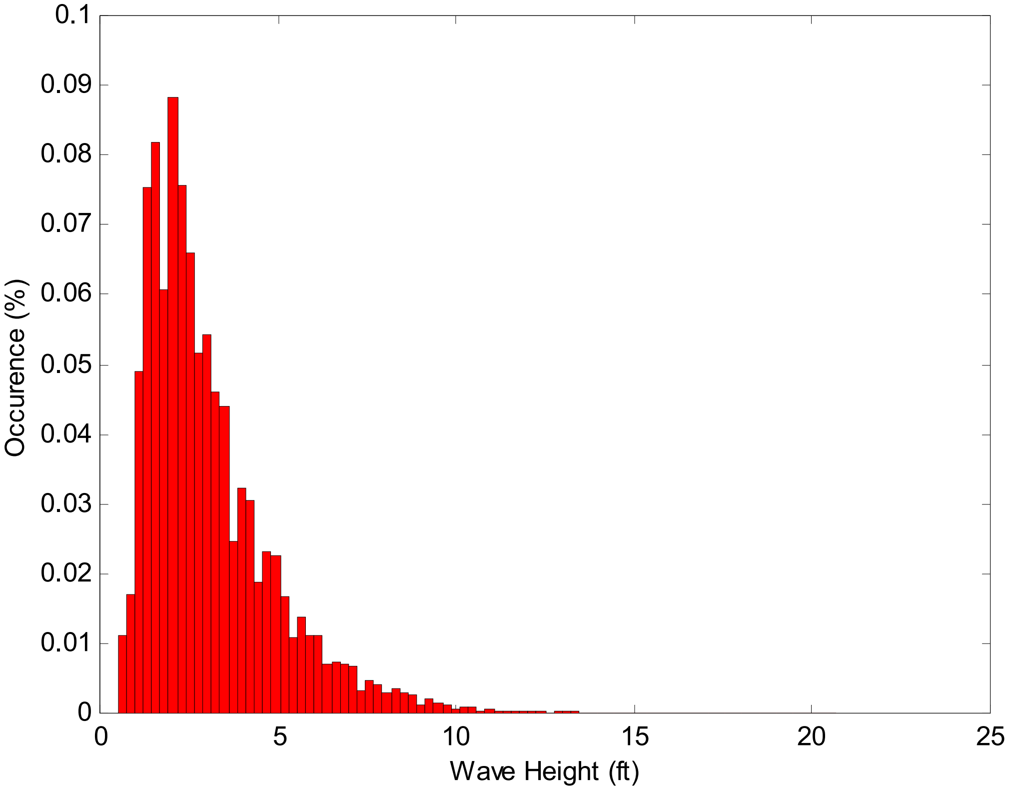


Figure 4-29. Percent occurrence of wave heights at BUZM3.

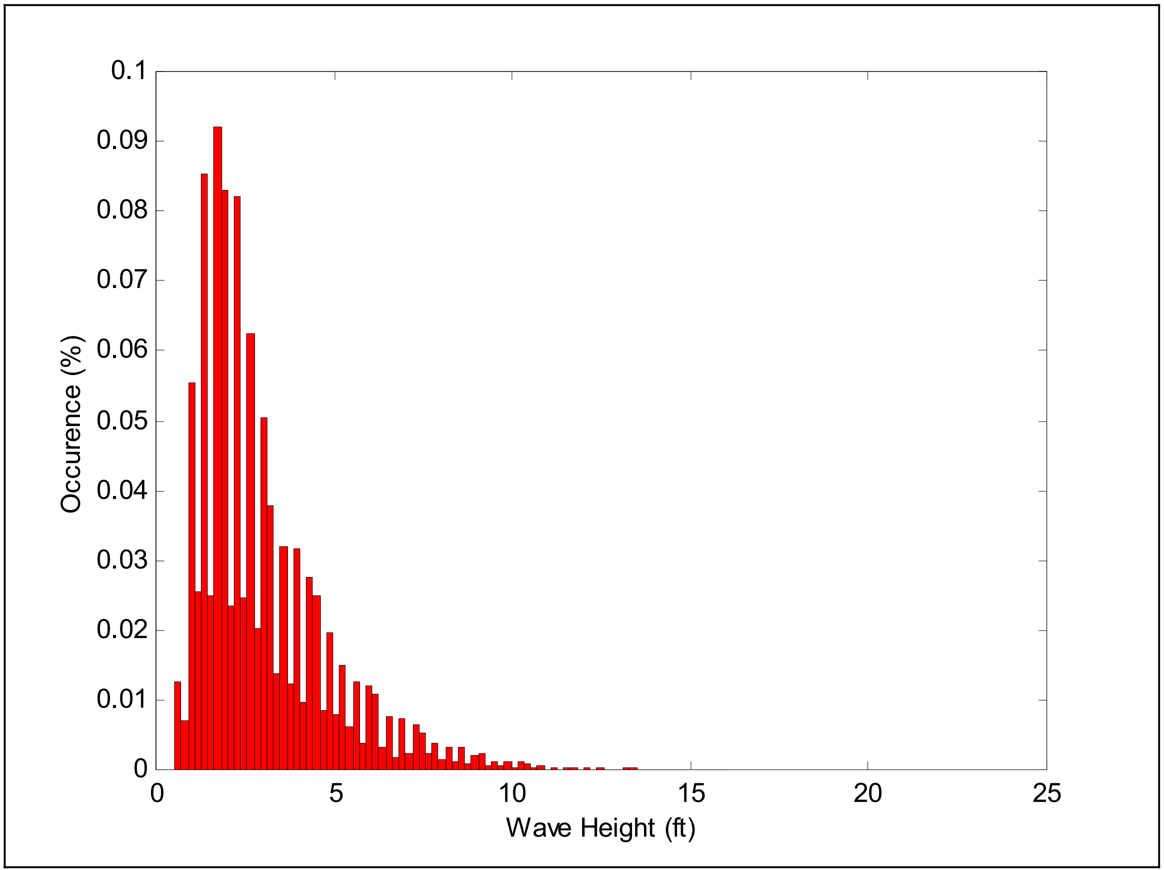


Figure 4-30. Percent occurrence of wave heights at Station 44028.

The proposed candidate disposal sites are well protected from the effects of open ocean waves, with their only real exposure from the southwest. The records from these two stations therefore reflect generally more extreme conditions than would be expected at the two candidate sites (Maguire 2004b).

4.4.2.3 Model Storm Conditions

In general, erosion of bottom sediments in most coastal environments occurs to the greatest extent when high winds associated with a storm, such as a Nor'easter or hurricane, cause bottom currents and/or waves to become significantly elevated above normal. Therefore, to evaluate the maximum potential impact of erosion and off-site transport of dredged material placed at the candidate sites (presented in Section 7.0), a set of worst-case, yet realistic, storm conditions first had to be defined. The most extreme storm conditions on record were those associated with Hurricane Bob in August 1991. These were chosen as representative of extreme storm conditions at the sites. The eye of Hurricane Bob, a category 2 storm, passed to the west of Buzzards Bay resulting in storm surge elevations of 10 to 15 feet in the Bay and wind speeds of 100 mph along the southern coasts of Rhode Island and Massachusetts. By comparison, the 1938 hurricane, a category 3 storm, had sustained winds of 121 mph and storm surge elevations in the range of 15 to 25 feet. A storm event of the magnitude of the 1938 hurricane has a 100 year return frequency in southeastern New England (Maguire 2004b).

To account for the fact that no wave data were recorded at either of the two offshore stations during the period of Hurricane Bob, and water depths are significantly shallower at the proposed candidate disposal sites than at the offshore stations, wind data recorded at the BUZM3 station were used to generate wave heights for the period of the storm. Significant wave height and period for the Hurricane Bob event were calculated using the wind record from the BUZM3 station for the 24 hour period from 1200 on August 19, 1991 to 1200 on August 20, 1991. Wind speeds during this period reached a peak of 77.2 mph, the highest wind speeds recorded at the BUZM3 station between 1985 and 2003. Wave heights and period were calculated using the restricted fetch forms of the equations for shallow water wave growth (Leenknecht et al. 1992), assuming water depths of 45.9 feet (site 1) and 42.7 feet (site 2). A fetch of 22 miles was assumed for these calculations, corresponding to the entire length of Buzzards Bay and consistent with the assumption made in the preliminary hydrodynamic analysis (Maguire 2001e).

It is important to note that fetch distances within Buzzards Bay are typically much shorter than the value assumed here. Fetches this large only occur over an arc of roughly 15° to the southwest (Figure 4-31). Winds during Hurricane Bob were predominantly from the east and southeast, with the highest speeds coming from 105°, before shifeeting to come out of the west. The fetch at the proposed candidate sites therefore would have been significantly shorter (i.e., less than 6 miles) during the period of maximum wind speeds than the value assumed here. Furthermore, large waves entering the Bay lose energy through a number of processes as they travel along (e.g., frictional interaction with the shallowing bottom, wave breaking, etc.). Such processes are not considered here. These calculations, therefore, represent a worst-case scenario for Hurricane Bob.

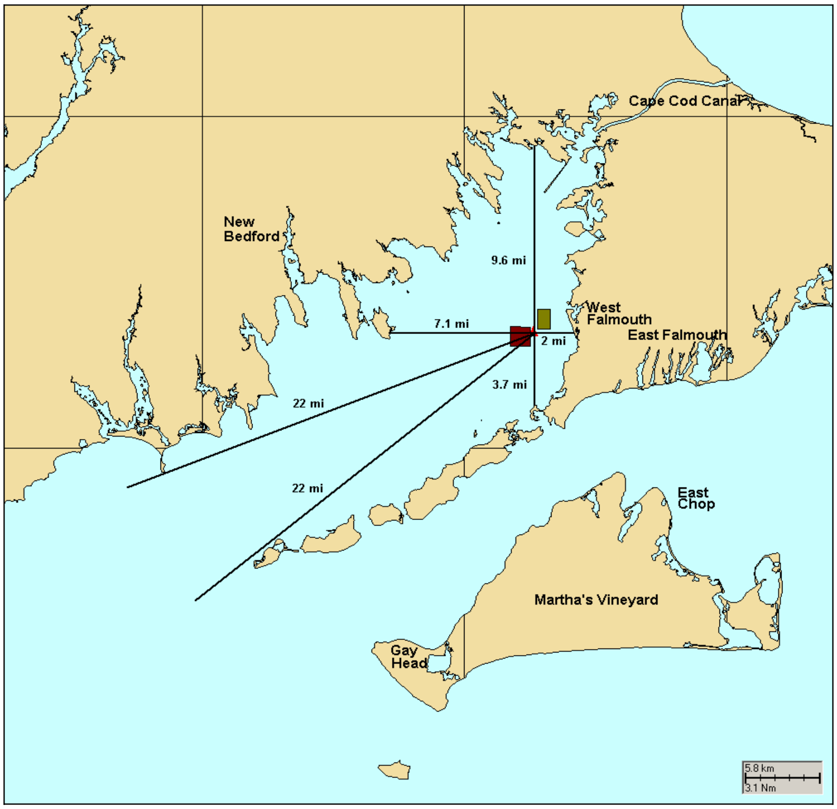


Figure 4-31. Map showing fetch in various directions at the proposed candidate disposal sites.

A maximum wave height of 12.779 feet was obtained from these calculations, with a corresponding period of 6.950 seconds. These wave heights far exceed the 95th percentile wave height of 6.76 feet observed at the much more exposed BUZM3 and Station 44028 buoys. These synthetic wave conditions are therefore representative of the most extreme conditions likely to ever be experienced at the relatively sheltered candidate disposal sites.

4.4.2.4 Currents

A sophisticated, predictive model called WQMAP/BFHYDRO (Swanson 1986, Spaulding et al. 1999) was applied to Buzzards Bay for the detailed hydrodynamic study. The tidal currents predicted by the model in the vicinity of the proposed candidate disposal sites are predominantly aligned in a northeast/southwest direction, paralleling the axis of the bay. Currents flow to the northeast during flood tide (Figure 4-32) and to the southwest during ebb tide (Figure 4-33). The actual observed principal axis tidal currents are reproduced well by the model, with errors less than 0.12 knots and directions and phases within 14° of observations. Minor axis currents are very small throughout the bay, except at the head, and are also reproduced well by the model (maximum error of 0.06 knots (3.08 cm/s); Maguire 2004b).

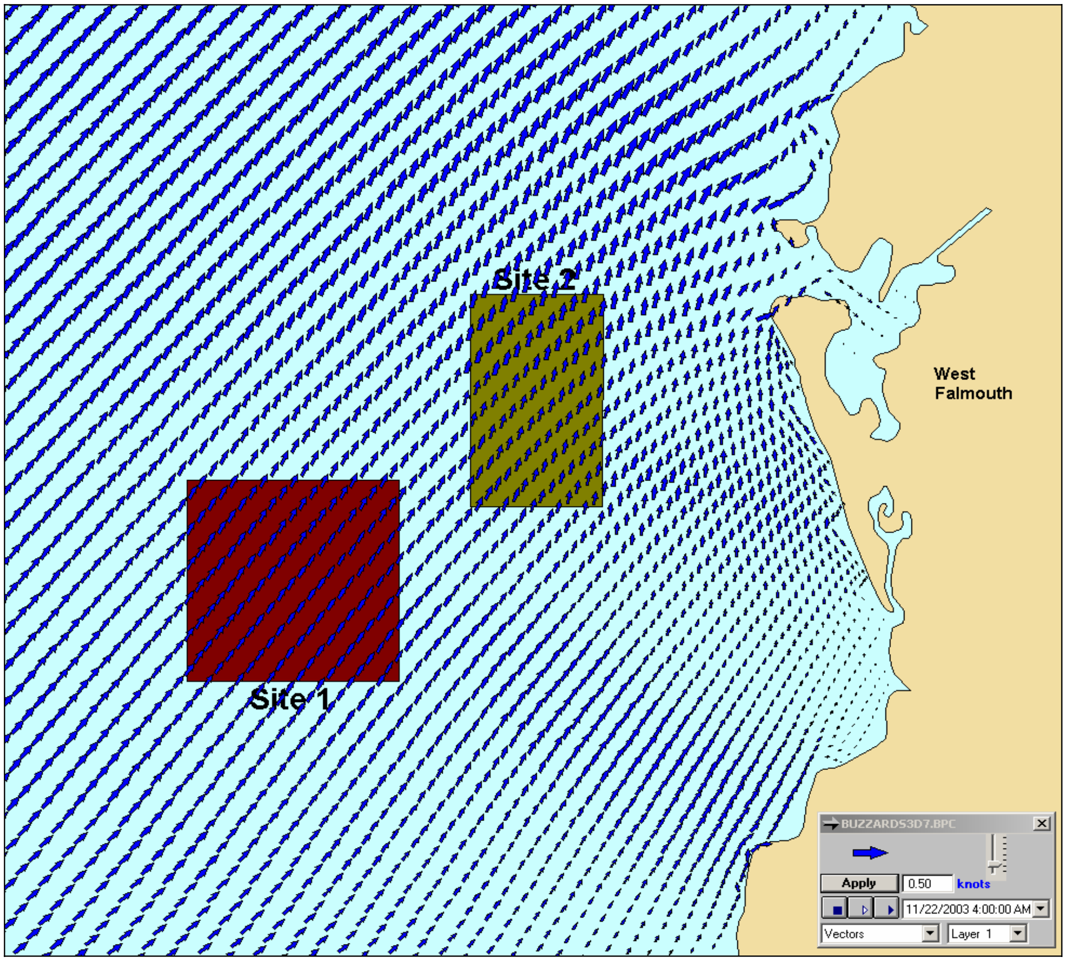


Figure 4-32. Model predicted bottom currents in the vicinity of the proposed candidate disposal sites during maximum flood tide.

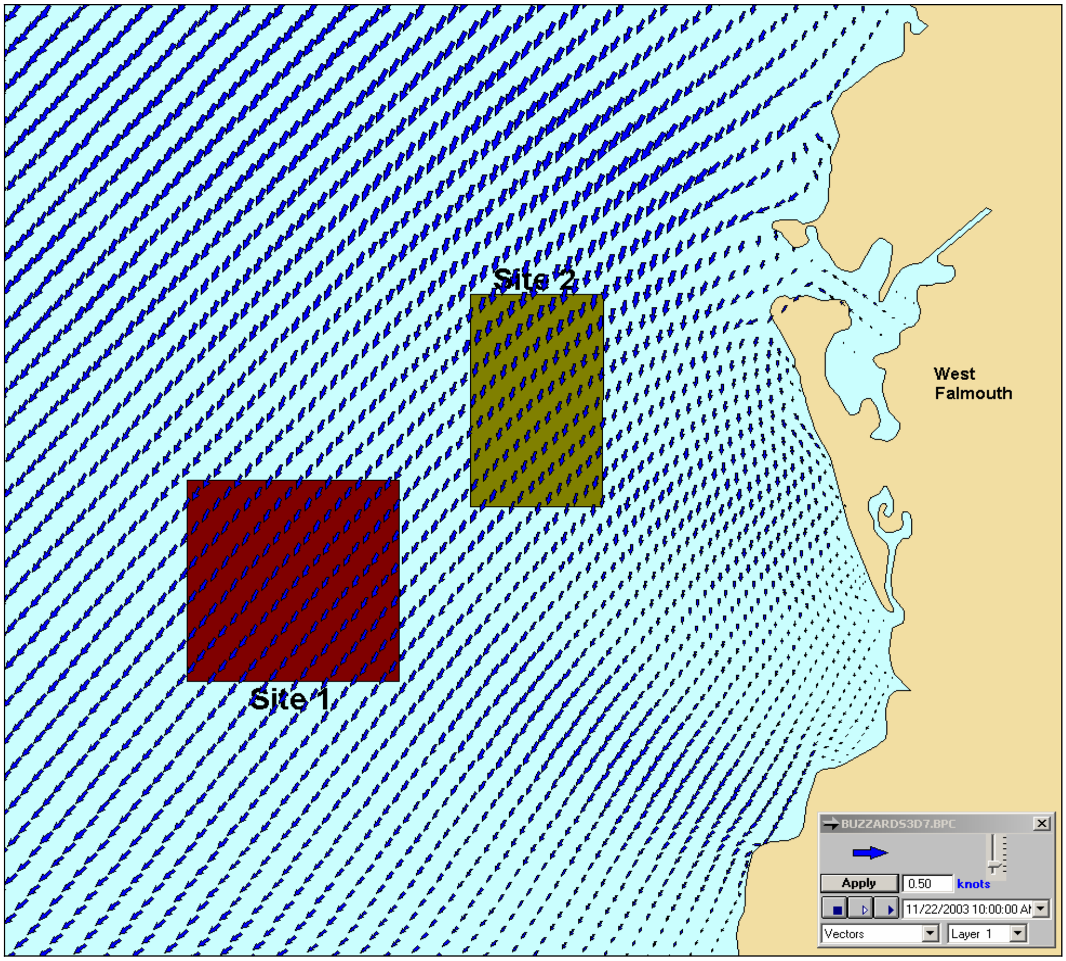


Figure 4-33. Model predicted bottom currents in the vicinity of the proposed candidate disposal sites during maximum ebb tide.

4.4.2.5 Measured Currents (Field Program)

Currents measured using the ADCM for the 20-hour period during November 11 and 12, 2003 as part of the field survey were used for validation of the predicted model currents. The model-predicted bottom currents did not compare well with the observations during the first 10-hour period, during which the bottom boundary layer effects seemed to dominate over the tides in the current meter measurements (Figure 4-24). The model tended to over-predict current speeds somewhat during this period. However, the model compared well with the observations during the latter half of the 20-hour period (Maguire2004b).

4.4.3 Summary

The detailed hydrodynamic study was undertaken with the ultimate objective of assessing the long term stability of dredged material deposited on the seafloor at two candidate disposal sites in Buzzards Bay. This section has presented the results of a field program to measure actual tidal currents at the candidate sites over a relatively short timeframe, the results of a modeling effort to predict tidal current at the sites, and an analysis of historical records to characterize potential winds, currents and waves under worst-case storm conditions. The potential for sediment transport at the proposed candidate disposal sites, under both average and worst-case conditions, is evaluated in Section 7.3.3, as part of the overall impact assessment presented in Section 7.0

4.5 Water Column Structure and Chemistry

A requirement of this DEIR under MEPA requires that the candidate sites be characterized with respect to basic water column structure and water chemistry. General information on water column stratification in the Buzzards Bay was compiled from previous studies. Additionally, the comprehensive baseline surveys conducted in November 2000 included measurements of the vertical structure and chemical components of the water column at each of the two candidate disposal sites (Maguire 2001b). Specifically, vertical water column profiles of temperature, salinity, and density were recorded using an electrical conductivity, temperature, and denisty (CTD) probe at a sampling location in the center of each site. In addition, near-surface (within 1 meter of surface) and near-bottom (roughly 1 meter above the substrate) water samples were collected at each station for laboratory chemical analysis.

4.5.1 Stratification in Buzzards Bay

Stratified conditions occur periodically in the central portions of the bay, including in the vicinity of candidate sites 1 and 2, occasionally due to freshwater inflow associated with storms, and during the summer months due to thermal stratification (Howes and Goehringer 1996). However, freshwater effects are much more pronounced in small harbors and embayments along the shoreline. Additionally, given that the bay is relatively shallow, tidal currents and wind waves are effective at producing a well-mixed water column, and stratified conditions are generally not persistent. Camisa and Wilbur (2002) found no evidence of stratification within the water column above the candidate disposal sites during 20 sampling events conducted over the consecutive 13-month sampling period of March 2001 to March 2002.

4.5.2 Water Column Profiles

CTD probe measurements were collected at roughly 2- to 3-hour intervals over the course of two different days during the November 2000 survey effort to detect any temporal or tide-induced variations in water column structure. The water column at sites 1 and 2 at the time of the survey was found to be vertically well-mixed. Temperature throughout the entire water column was consistently between 11° and 12° C (51.8°F and 53°F), while salinity throughout the entire water column was equally constant at around 32 parts per thousand (ppt). There was little variability in water column structure observed within each site at different stages of the tide over the course of a day, and equally little variability between sites or over the course of the two days. These results indicate that the water column was vertically well mixed at the time of the November 2000 sampling.

The lack of water column stratification at the time of the November 2000 survey can be attributed to the action of winds and the lack of suitable conditions to establish thermal stratification at that time of year. This is consistent with the overall characterization of the central portions of the bay (Howes and Goehringer 1996). It can be presumed that in general, stratification events that may occur at sites 1 and 2 would not be very pronounced and would generally be of short duration, given the propensity of the semi-diurnal tidal currents and wind waves to mix the water column adequately in the open waters of Buzzards Bay.

Vertical water column profiles of temperature, salinity and dissolved oxygen were collected by Camisa and Wilbur (2002) at each of the candidate disposal sites over a consecutive thirteen-month period. In general, during any given sampling event, there was only minor variation observed between surface and bottom waters in the measured parameters. On a seasonal basis, surface water temperatures in the study area ranged from 2.0° C (35.6° F) in January 2002 to 25.1° C (77.2° F) in August 2001, while bottom water temperatures ranged from 2.0° C (35.6° F) in January 2002 to 22.0° C (71.6° F) in September 2001. Surface salinities ranged from 26.6 ppt in April 2001 to 31.9 ppt in July 2001, and bottom salinities ranged from 23.3 ppt in June 2001 to 32.2 ppt in July 2001. Surface dissolved oxygen levels ranged from 6.1 miligrams per liter (mg/L) in July 2001 to 19.8 mg/l in February 2002, and bottom dissolved oxygen levels ranged from 4.7 mg/L in August 2001 to 19.1 mg/L in February 2002. Camisa and Wilbur attributed the lack of significant vertical stratification in their observations to the relatively shallow depths (12.5 to 18.3 meters, or 41 to 60 feet) of the sampling stations within and adjacent to the candidate disposal sites.

4.5.3 Water Chemistry

Water samples were analyzed for "total recoverable" concentrations of selected metals, pesticides, and industrial chemicals, including PCBs and pentachlorophenol. The specific compounds analyzed are those identified by Region 1 of the USEPA and the USACE as "required contaminants" for determining compliance with water quality criteria in evaluating the suitability of dredged material for open water disposal (USEPA/USACE 1989).

Concentrations of chemical contaminants (metals, pesticides, PAHs and PCBs) in near-surface and near-bottom water samples from candidate sites 1 and 2 were consistently below EPA Water Quality Criteria, with the exception of copper. Most analytes were either not detected, or, in the case of several of the metals, detected at very low concentrations. Concentrations of several of the metals (cadmium, copper, lead, nickel, and zinc) were higher in the surface water sample than in the bottom water sample at each of the sites. However, with the exception of copper, the concentrations of all of the metal, pesticide and PCB analytes were considerably below the corresponding EPA Water Quality Criteria. Copper concentrations in the surface water samples from both sites (3.2 micrograms per liter (µg/L) at site 1 and 3.0 µg/L at site 2) were slightly higher than the water quality criterion of 2.9 µg/L. Howes and Goehringer (1996) note that copper was used historically in the New Bedford metal plating industry, and the use of copper-containing antifouling paints and copper pipes for water lines both provide low-level inputs of copper to Buzzards Bay in the present day.

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