Monitoring Cruise
at the Boston Lighthouse Disposal Site,
August 1994

Disposal Area Monitoring System DAMOS

D A M O S

DISPOSAL AREA MONITORING SYSTEM

Contribution 113
August 1996

US Army Corps of Engineers
New England Division

REPORT DOCUMENTATION PAGE	*Form approved* OMB No. 0704-0188

1. AGENCY USE ONLY (LEAVE BLANK)	2. REPORT DATE August 1996	3. REPORT TYPE AND DATES Final Report

4. TITLE AND SUBTITLE MONITORING CRUISE AT THE BOSTON LIGHTSHIP DISPOSAL SITE, AUGUST 1994	6. FUNDING NUMBERS
6. AUTHORS Ed DeAngelo	
7. PERFROMING ORGANIZATION NAME(S) AND ADDRESS(ES) Science Applications Intenational Corporation, 221 Thrid Street, Newport, RI 02840	8. PERFORMING ORGANIZATION REPORT SAIC No. 328
9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES) US Army Corps of Engineers-New England Division, 424 Trapelo Road, Waltham, MA 02254-9149	10. SPONSORING/ MONITORING AGENCY DAMOS Contribution Number 113
11. SUPPLEMENTARY NOTES Avaiable from : DAMOS PROGRAM MANAGER Regulatory Division, USACE-NED, 424 Trapelo Road, Waltham, MA 02254-9149	
12a. DISTRIBUTION/AVAIABILTY STATEMENT Approved for public release; distribution unlimited	12b. DISTRIBUTION CODE

13. ABSTRACT

Science Applications International Corporation (SAIC) conducted a reconnaissance REMOTS® sediment-profile and plan view photographic survey of the Boston Lightship Disposal Site (BLDS) from 9 to 11 August 1994. From the 1940's to 1976, when disposal stopped at BLDS, a majority of the Boston area's dredged material and other debris had been released at this site. The last recorded disposal at this site was in 1976 when about 8,000m3 were disposed. The REMOTS® sediment-profile and plan view photographic stations were located to examine possible historic dredged material that had been identified in a 1991 side-scan sonar survey of the area. The 1994 surveys were conducted as part of a long-term effort to examine historical disposal areas to determine whether remediation activity is recommended. The assessment of the REMOTS® and plan view data, in conjunction with the 1991 side-scan results, determined that remediation at the site was not necessary. Recolonization of old dredged material has been extensive. The benthos in the areas sampled was populated by a diverse community composed of Stage II and Stage III organisms representing a healthy benthic habitat with OSI values ³6. No difference was observed between the historic dredged material and the ambient sediment. In light of the healthy benthic habitat, only periodic monitoring is recommended. Sediment samples were collected at BLDS in 1994. They were archived and are available for analysis.

The REMOTS® sediment-profile and plan view photographic surveys were also conducted to gather information on the area's sedimentary environment. This information would determine if the BLDS was suitable to potentially receive dredged material from the Boston Harbor Navigation Improvement Project and Berth Dredging Project. The 1991 side-scan sonar survey had mapped areas of circular or track-like dredged material patterns at the site. The use of the area for dredged material disposal was consistent with its characterization as depositional or nonerosive (Knebel 1993). By focusing on the areas of dredged material disposal with the REMOTS® sediment-profile and plan view photographic survey, the reconnaissance effort produced no evidence to preclude the future use of BLDS for dredged material disposal. The major modal grain size was the silt/clay size class (>4 phi) with very fine sands found in the surface sediments. Evidence of sediment resuspension was limited primarily to winnowing of silts/clays from surface sediments.

The assessment of BLDS was efficiently accomplished by basing the REMOTS® sediment-profile and plan view photographic survey on the results of the previous side-scan survey. The combined data sources provided a broad picture of the status of the historical dredged material which has been at the disposal site for more than 20 years. Based on the 1994 survey results, remediation is not necessary for BLDS, and the depositional environment does not preclude its use as a disposal area.

14. SUBECT TERMS Boston Lightship Disposal Site (BLDS) , Boston Harbor Improvement Project , benthic habitat, Remote Monitoring of the Seafloor (REMOTS) , dredged material, nonerosive or depositional	15.NUMBER OF PAGES 31
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20.LIMITATION OF ABSTRACT

MONITORING CRUISE AT THE BOSTON LIGHTHOUSE DISPOSAL SITE AUGUST 1994

CONTRIBUTION #113

August 1996

Report No.
SAIC No. 328

Submitted to:

Regulatory Division
New England Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Prepared by:
Ed DeAngelo

Submitted by:
Science Applications International Corporation
Admiral's Gate
221 Third Street
Newport, RI 02840
(401) 847-4210

US Army Corps
of Engineers
New England Division

MONITORING CRUISE AT THE HISTORIC BOSTON LIGHTSHIP DISPOSAL SITE AUGUST 1994

24 July 1996

Contract No. DACW33-93-D-0002
Work Order 21, Task 2
SAIC Report No. 328

Submitted to:
New England Division
US Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Prepared by:
Ed DeAngelo

Submitted by:
Science Applications International Corporation
Admiral's Gate
221 Third Street
Newport, RI 02840
(401) 847-4210

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EXECUTIVE SUMMARY

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The assessment of BLDS was efficiently accomplished by basing the REMOTS® sediment-profile and plan view photographic survey on the results of the previous side-scan survey. The combined data sources provided a broad picture of the status of the historical dredged material which has been at the disposal site for nearly 20 years. Based on the 1994 survey results, remediation is not necessary for BLDS, and the depositional environment does not preclude its use as a disposal area.

1.0 INTRODUCTION

The consideration of BLDS as an alternative site for future disposal operations (Normandeau Associates 1994) and the existence of an extensive data set on observed dredged material at the site (Schoenherr et al. 1992) provided impetus for the study described here. A reconnaissance survey of the Boston Lightship Disposal Site (BLDS), a currently inactive site located 16 nmi east of Boston (Figure 1-1), was conducted under the Disposal Area Monitoring System (DAMOS) Program as part of a long-term effort to investigate historical disposal areas. From the 1940s to 1976, when disposal stopped at BLDS, a majority of the Boston area's dredged material and other debris had been released at the site. During the late 1960s and early 1970s, BLDS received approximately 2.3 million m^3 of material dredged from Boston Harbor (Normandeau Associates 1994). Disposal at the site was directed toward the Dumping Ground (DG) buoy. However, the buoy location only served as a general guide for the barges and was not used for point dumping. Although disposal activity was concentrated in an area surrounding the buoy, material was apparently disposed throughout the site.

Prior to the early 1970s, the oversight of the nature and placement of disposed materials was less stringent than at present. The US Army Corps of Engineers, New England Division (NED), has initiated a cooperative effort to investigate historical disposal sites, whenever possible, to determine existing environmental conditions. One potential remediative activity might be to use present disposal activities to cover old deposits.

Science Applications International Corporation (SAIC) conducted short (9-11 August 1994) REMOTS® sediment-profile and plan view photographic surveys of small areas within the disposal area. These areas were deemed likely to contain dredged material based on a previous side-scan survey. The primary objective of the survey was to explore the need for dredged material remediation. The relative health of the benthic environment was determined by the recolonization status of relic dredged material compared to results obtained from ambient sediment. The secondary objective was to determine if there was any evidence to preclude future use of the site for dredged material disposal. Small scale sediment characteristics in the REMOTS® and plan view photographs, in conjunction with features identified in the side-scan records, were examined to determine if the sedimentary environment was suitable for future dredged material disposal.

Until recently, little was known regarding the location and nature of the material that had been disposed at BLDS. In 1991, the US Environmental Protection Agency (EPA) sponsored a side-scan and Remotely Operated Vehicle (ROV) survey of BLDS. SAIC supported efforts to locate, identify, and determine the condition of waste containers in the area (Schoenherr et al. 1992). Interpretation of the side-scan records over a 16 nmi^2

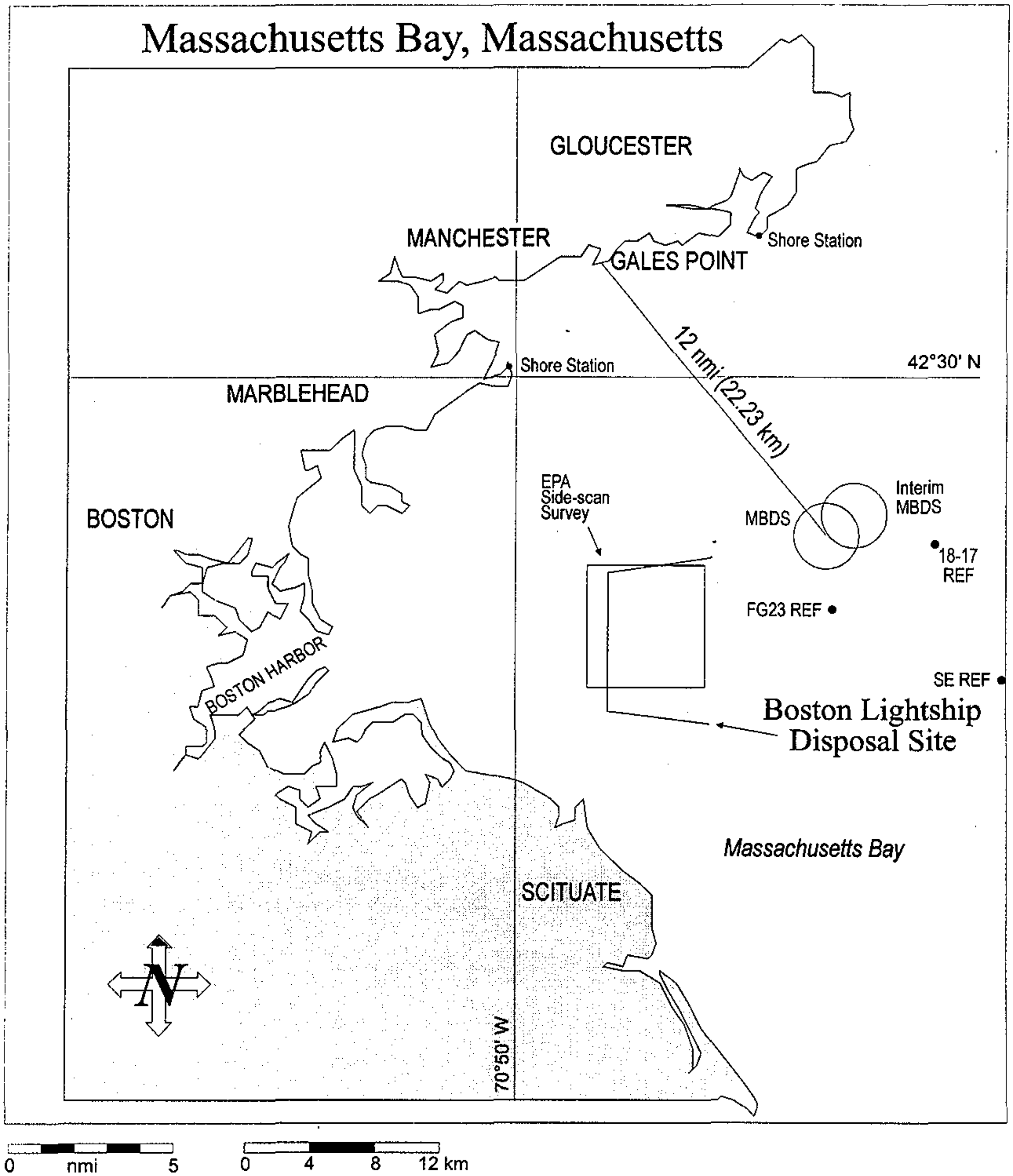


Figure 1-1. Site location map of the Boston Lightship Disposal Site. The Boston Lightship Disposal Site is located approximately 16 nmi east of Boston, MA.

area (Figure 1-2) located 469 dredged material targets in addition to 43 potential waste barrel fields, and 136 debris fields. Dredged material targets generally appeared on the side-scan records as circular or track-like patterns of sediment with a marked contrast to the surrounding natural sediments. While the dredged material targets were scattered throughout the disposal area, high concentrations were located in a ring around the former DG buoy location and to the south of the buoy beyond the 50 m depth contour. In the 1994 reconnaissance survey, the REMOTS® and plan view photography station locations corresponded to areas of dense dredged material targets. This sampling scheme supported the primary objective of the survey by maximizing the probability of collecting data from relic dredged material where the potential need for remediation would be the greatest.

A secondary objective of the present survey was to characterize the dominant processes controlling the sedimentary environment and to determine the suitability of the area for potential future disposal. The area greater than 50 m depth at BLDS has been suggested as a potential site for future disposal, such as 0.9 million m^3 of silty maintenance material from the proposed Boston Harbor Navigation Improvement Project and Berth Dredging Project (Normandeau Associates 1994). This material would be capped with approximately one meter of parent material that lies under the silts of Boston Harbor. Approximately half of BLDS lies below the 50 m depth contour on the slope of Stellwagen Basin. Based on the sedimentary fabric observed in the REMOTS® and plan view photographs, it was determined that below the 50 m contour BLDS is primarily a depositional environment and that there is no evidence to preclude its use for the deposition of silty dredged material.

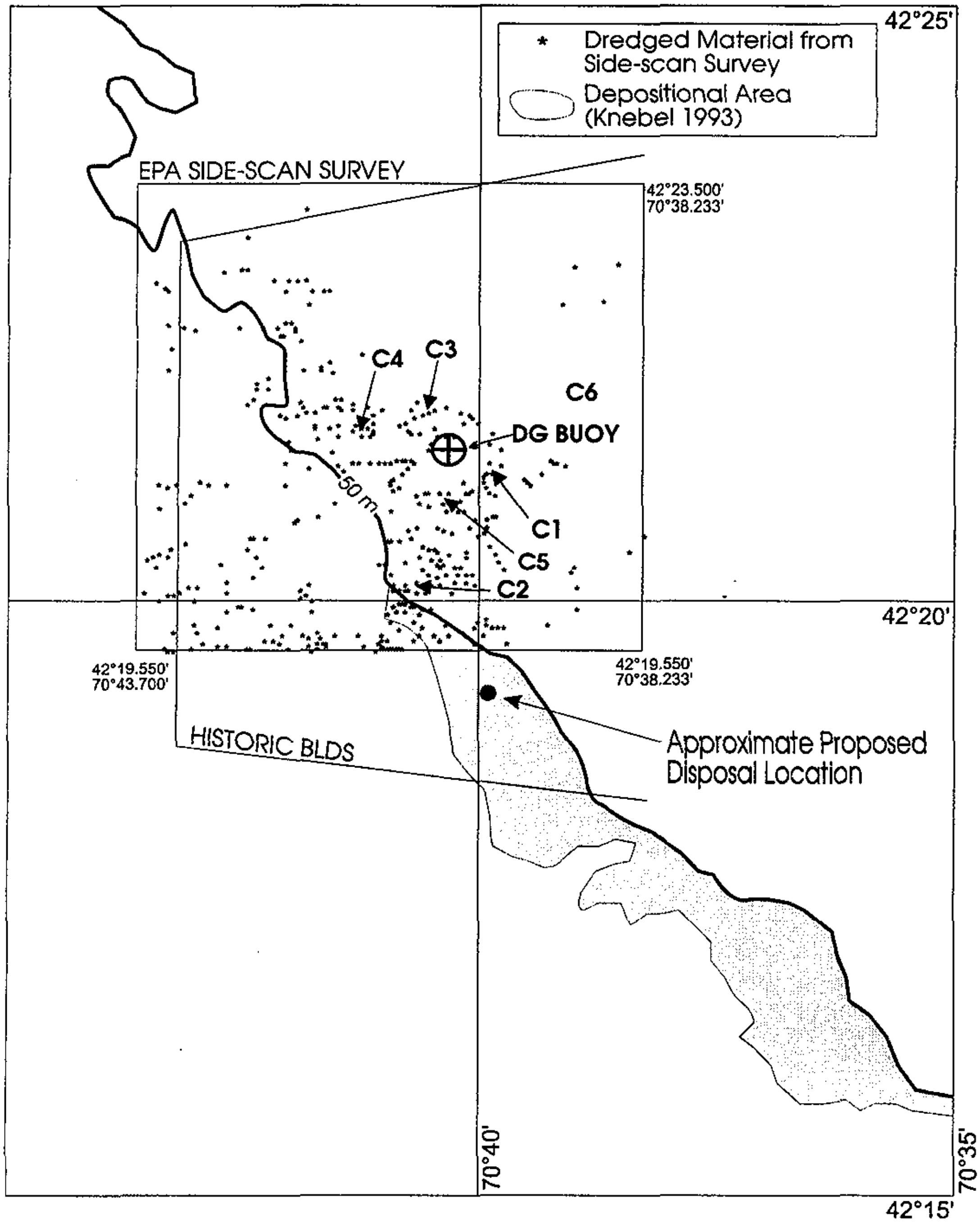


Figure 1-2. The relative locations of dredged material located by side-scan sonar (Schoenherr et al. 1992); 1994 REMOTS® sampling transects; a depositional sedimentary environment above the 50 m depth contour (Knebel 1993); and a proposed disposal location (Normandeau Associates 1994)

2.0 METHODS

2.1 REMOTS® Sediment-Profile and Plan View Photography

The August 1994 REMOTS® sediment-profiling survey was conducted along six transects labeled C1 through C6. Transects C1, C3, C4, and C5 surrounded the DG buoy, and transect C2 was south of the buoy in an area of dense dredged material targets. This allowed us to maximize the potential of encountering dredged material (Figures 1-2 and 2-1) and to focus on depositional areas determined suitable for future disposal (Normandeau Associates 1994). Transect C6 was situated in an area where side-scan records did not contain any targets interpreted as dredged material in order to assess benthic recolonization on ambient sediments located within BLDS. Two of the transects, C1 and C6, were oriented north to south while the remainder were oriented east to west. Each transect was 500 m long and consisted of ten stations spaced 50 m apart (a total of 60 stations; Table 2-1). Two replicate photographs were taken at each station.

Surficial sediments were photographed with a Photosea submersible plan view camera to permit evaluation of surface features including benthic animals and sedimentological features. The plan view camera was attached to the REMOTS® camera frame and photographed the sediment surface prior to camera frame touch-down in order to record an image of undisturbed sediments.

2.2 Sediment Grab Sampling

Sediment samples were collected with 0.1 m^2 van Veen grab sampler at three of the six transects (C2, C3, and C4) and at the reference area FG-23. Grab samples were collected at Stations 1, 5, and 10 (Table 2-1) of each transect for a total of nine grabs. Three replicate samples were collected at the reference area.

Once the grab was brought aboard, four to five subcores were collected for chemical analysis, and the remaining sediment was saved for benthic community analysis. The chemistry subsample was composited in a teflon container and subsampled again for polycyclic aromatic hydrocarbons (PAHs), metals, and grain size/total organic carbon (TOC) analysis. The PAHs and metal subsamples were each placed in pre-cleaned 110 ml I-CHEM jars, and the grain size/TOC subsamples were stored in ziplock plastic bags.

The remaining sediment set aside for benthic community analysis was sieved through a 500 micron screen. The residue was placed in one liter nalgene jars with both internal and external labels. Each biological sample was fixed in 10% formalin and stained with rose bengal, an organic stain. Following field collection, all sediment samples,

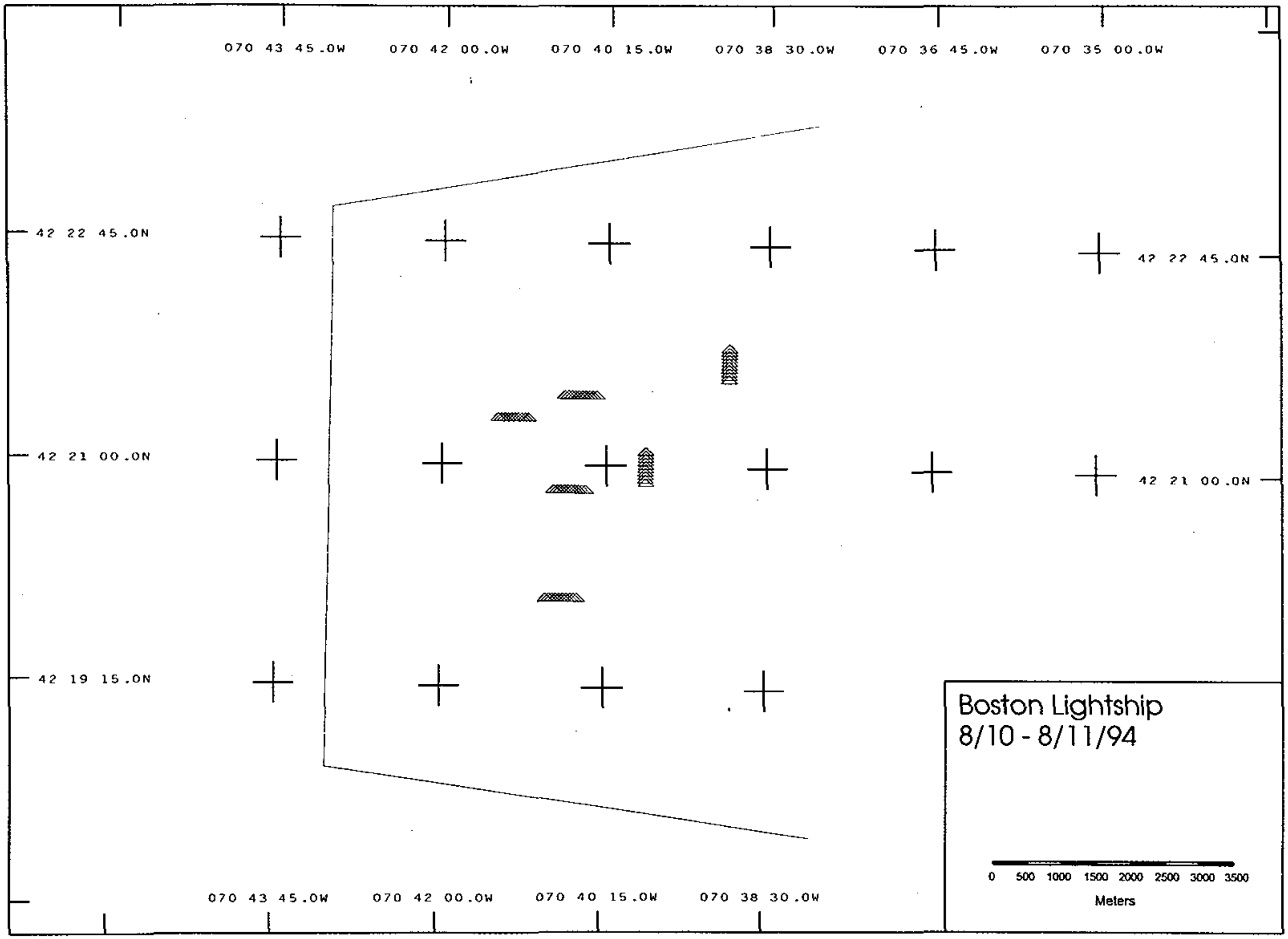


Figure 2-1. REMOTS® sampling transects

Table 2-1

Station Target Locations for REMOTS® Sampling at BLDS (REMOTS® Stations Datum WGS84)

Transect	Station Number	Latitude		Longitude		Transect	Station Number	Latitude		Longitude	
C1	1	42° 21.112'	N	70° 39.825'	W	C4	1	42° 21.372'	N	70° 41.075'	W
C1	2	42° 21.085'	N	70° 39.825'	W	C4	2	42° 21.372'	N	70° 41.111'	W
C1	3	42° 21.058'	N	70° 39.825'	W	C4	3	42° 21.372'	N	70° 41.148'	W
C1	4	42° 21.031'	N	70° 39.825'	W	C4	4	42° 21.372'	N	70° 41.184'	W
C1	5	42° 21.003'	N	70° 39.825'	W	C4	5	42° 21.372'	N	70° 41.221'	W
C1	6	42° 20.977'	N	70° 39.825'	W	C4	6	42° 21.372'	N	70° 41.257'	W
C1	7	42° 20.949'	N	70° 39.825'	W	C4	7	42° 21.372'	N	70° 41.294'	W
C1	8	42° 20.922'	N	70° 39.825'	W	C4	8	42° 21.372'	N	70° 41.330'	W
C1	9	42° 20.895'	N	70° 39.825'	W	C4	9	42° 21.372'	N	70° 41.366'	W
C1	10	42° 20.868'	N	70° 39.825'	W	C4	10	42° 21.372'	N	70° 41.403'	W
C2	1	42° 19.948'	N	70° 40.537'	W	C5	1	42° 20.805'	N	70° 40.468'	W
C2	2	42° 19.948'	N	70° 40.574'	W	C5	2	42° 20.805'	N	70° 40.504'	W
C2	3	42° 19.948'	N	70° 40.610'	W	C5	3	42° 20.805'	N	70° 40.541'	W
C2	4	42° 19.948'	N	70° 40.647'	W	C5	4	42° 20.805'	N	70° 40.577'	W
C2	5	42° 19.948'	N	70° 40.683'	W	C5	5	42° 20.805'	N	70° 40.613'	W
C2	6	42° 19.948'	N	70° 40.719	W	C5	6	42° 20.805'	N	70° 40.650'	W
C2	7	42° 19.948'	N	70° 40.756'	W	C5	7	42° 20.805'	N	70° 40.687'	W
C2	8	42° 19.948'	N	70° 40.792'	W	C5	8	42° 20.805'	N	70° 40.723'	W
C2	9	42° 19.948'	N	70° 40.828'	W	C5	9	42° 20.805'	N	70° 40.759'	W
C2	10	42° 19.948'	N	70° 40.865'	W	C5	10	42° 20.805'	N	70° 40.796'	W
C3	1	42° 21.550'	N	70° 40.360	W	C6	1	42° 21.938'	N	70° 38.936'	W
C3	2	42° 21.550'	N	70° 40.396'	W	C6	2	42° 21.911'	N	70° 38.936'	W
C3	3	42° 21.550'	N	70° 40.432'	W	C6	3	42° 21.884'	N	70° 38.936'	W
C3	4	42° 21.550'	N	70° 40.469'	W	C6	4	42° 21.857'	N	70° 38.936'	W
C3	5	42° 21.550'	N	70° 40.502'	W	C6	5	42° 21.830'	N	70° 38.936'	W
C3	6	42° 21.550'	N	70° 40.542'	W	C6	6	42° 21.803'	N	70° 38.936'	W
C3	7	42° 21.550'	N	70° 40.578'	W	C6	7	42° 21.776'	N	70° 38.936'	W
C3	8	42° 21.550'	N	70° 40.614'	W	C6	8	42° 21.749'	N	70° 38.936'	W
C3	9	42° 21.550'	N	70° 40.651'	W	C6	9	42° 21.722'	N	70° 38.936'	W
C3	10	42° 21.550'	N	70° 40.687'	W	C6	10	42° 21.695'	N	70° 38.936'	W

biological and chemical, with the proper chain of custody forms were delivered to the US Army Corps of Engineers, New England Division (NED) laboratory where the samples were archived.

2.3 Navigation

Navigation for the survey was provided by an SAIC Portable Integrated Survey System (PINSS). The PINSS is a PC-based system that receives navigation data, mathematically weights these signals based on signal strength (via a Kalman filter), and calculates both the position of the ship and the position error. The PINSS was interfaced to a Magnavox MX4200 Global Positioning System (GPS) with a Magnavox MX50R Differential-GPS (DGPS) receiver for vessel positioning with an accuracy of ± 5 m.

3.0 RESULTS

3.1 REMOTS® Sediment-Profile Photography

3.1.1 Presence of Dredged Material

Dredged material was observed at five of the six transects sampled (Figure 3-1; Appendix). Dredged material in the REMOTS® photographs appeared in two forms: 1) dark silty material typically found in dredged material throughout New England and 2) Boston Blue Clay (Figure 3-2, A and B). Boston Blue Clay, formed from silt and clay particles in glacial melt water, is a common constituent of material dredged from Boston Harbor (Camp, Dresser, and McKee, Inc. 1991). In most cases dredged material appeared as a horizon below a sandy mud layer of reworked sediments several centimeters thick and extended below camera penetration (Figure 3-3). However, in two instances (Figure 3-2, A and B) the sandy layer was very small or absent, and dredged material was near the sediment-water interface.

Spatial distribution of dredged material was patchy. Dredged material was often seen in only one replicate per station even though the replicates were only a few meters apart. The two transects containing the greatest number of stations with dredged material (six stations) were C3 and C6 (Figure 3-1). Transects C1, C2, and C5 contained two to three stations with dredged material while none was observed at transect C4.

3.1.2 Grain Size Distribution

Sediment grain size distribution was uniform throughout the area sampled. Sediments were predominantly silts and clays with a major mode size of >4 phi (Appendix). With the exception of two stations, C4-2 and 4, grain sizes ranged from very fine sands (3 phi) to silts and clays (>4 phi). Fine-grained sediments were overlain by a surface layer of very fine sands in most of the photographs. Stations C4-2 and 3 contained coarse-grained surface material as large as -1 phi.

3.1.3 Apparent Redox Potential Discontinuity (RPD) Depth

The apparent redox potential discontinuity describes the region in which sediments change from a surface oxidizing environment to an underlying reducing environment. The depth of the RPD is determined by the net rate of transport of dissolved oxygen (DO) across the sediment-water interface, and the rate of consumption of DO in the sediment column. Mean apparent RPD depths (Figure 3-4), averaged for each transect by station, were between 1.5 cm and 2.0 cm below the sediment-water interface (Appendix). The

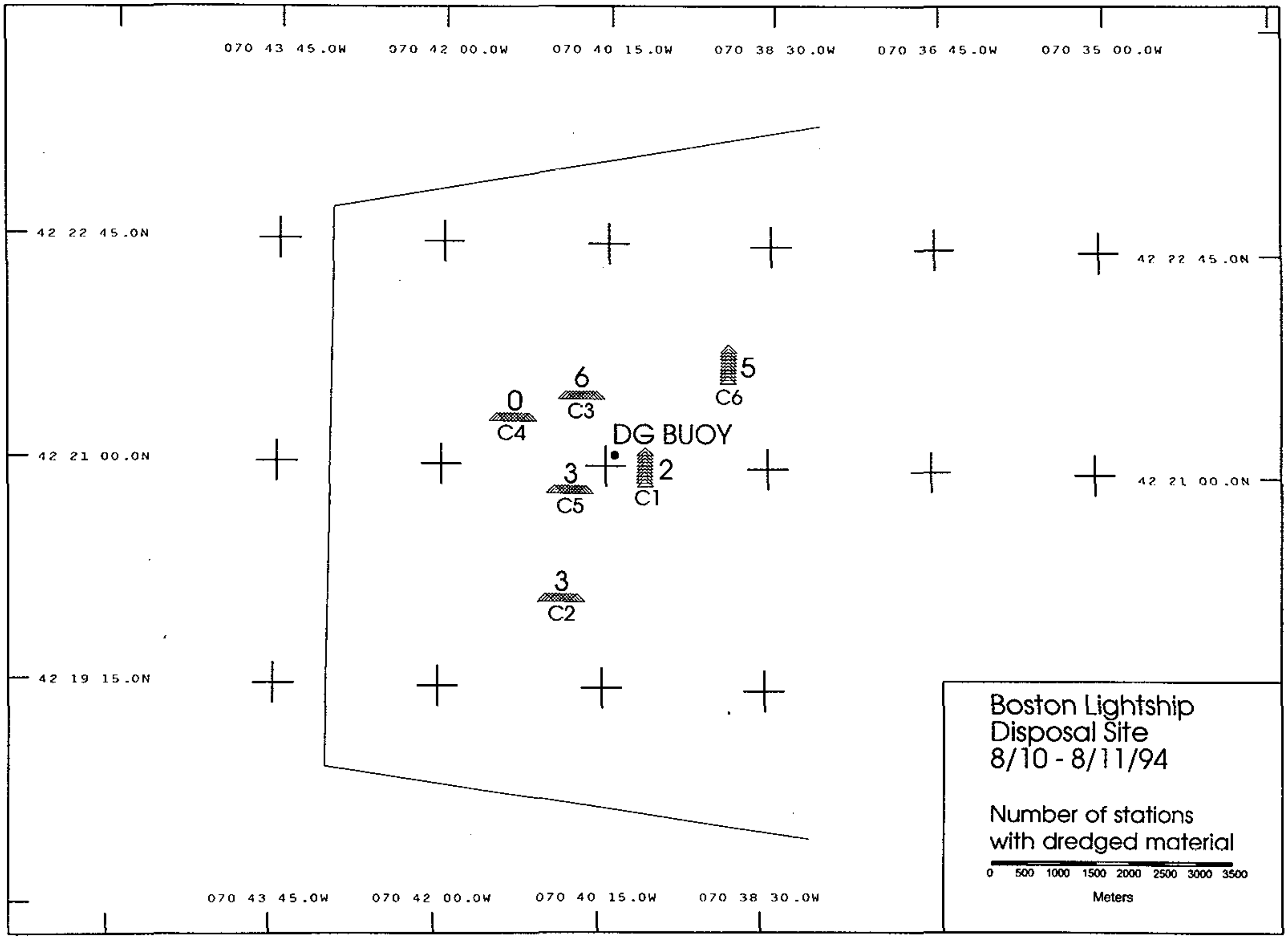


Figure 3-1. The number of stations per transect where dredged material was observed in the REMOTS® images

(A) (B)

Figure 3-2. Light gray, high reflectance Boston Blue Clay located at Stations C3-10 (A) and C2-7 (B). Note the large pellet-filled burrow (A) and the actively feeding Stage III polychaete (B).

Figure 3-3. Layer of biogenically reworked sediments over dredged material and large Stage III polychaete feeding in the dredged material layer

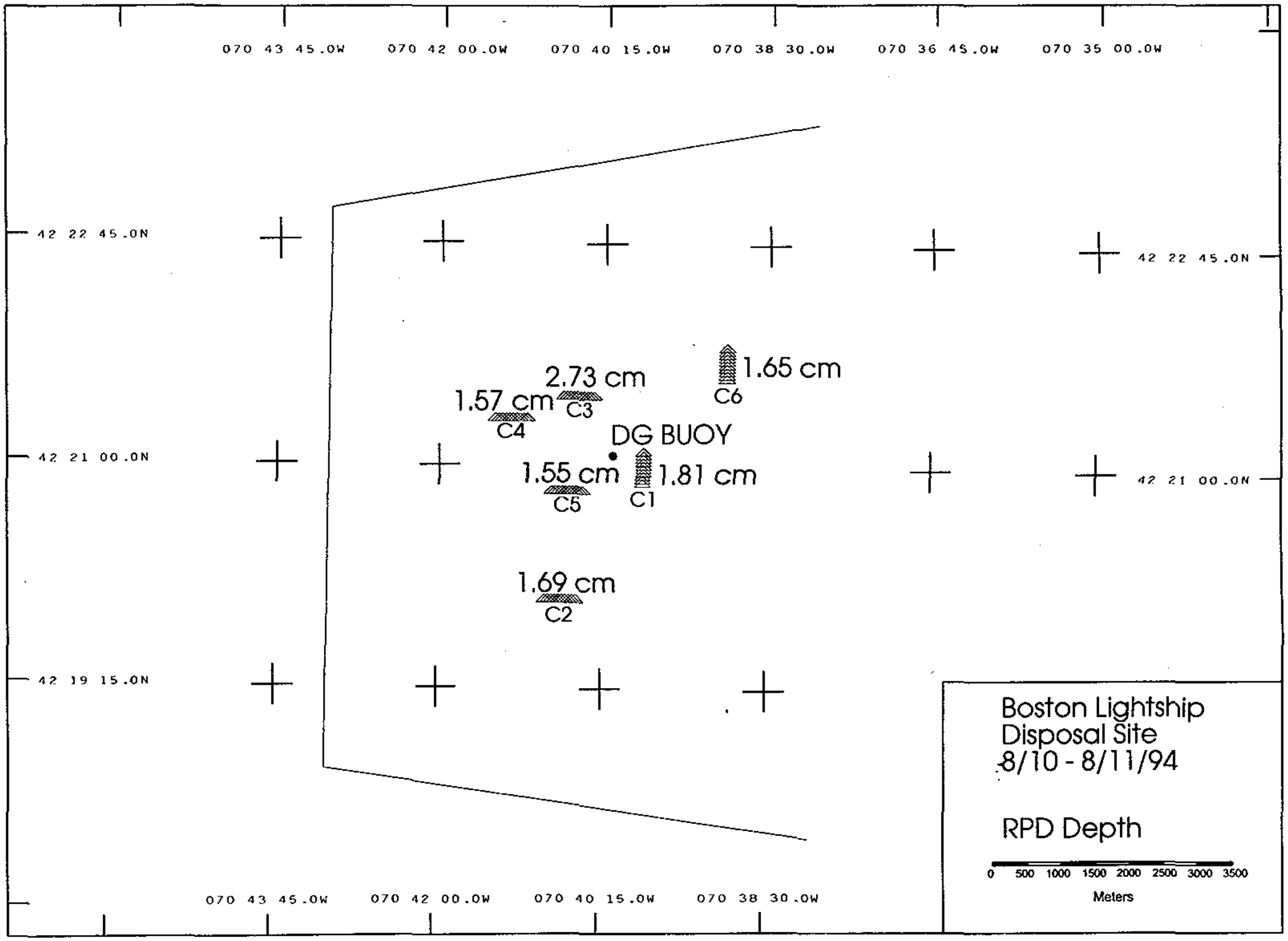


Figure 3-4. Transect average apparent redox potential discontinuity depths (cm)

shallowest RPD depth measured was 0.73 cm, and the deepest was 4.76 cm (Figure 3-5). Because of shallow camera penetration, the RPD was deeper than penetration and could not be measured in 11 photographs. Of these eleven photographs, prism penetration ranged from 0.5 to 2 cm in 4 photographs, 2 to 3 cm in 6 photographs, and greater than 8 cm in one photograph.

3.1.4 Successional Stage

Sediments at BLDS contained a relatively robust benthic community. Infaunal communities were dominated by the Stage II-on-Stage III class. Surface sediments at all stations were populated by stick-building amphipods (Family Podocerdiae; Figure 3-6, A). Sedentary polychaete tubes extended above the sediment-water interface at varying densities throughout the study area (Figure 3-6, B). Below the surface Stage II community, evidence of an abundant Stage III community was commonly observed as burrowing polychaetes (Figures 3-3 and 3-2, B) and/or subsurface feeding voids (Figure 3-7). Pelletized sediments, indicative of actively feeding infauna, were found near the sediment-water interface as well as inside feeding voids. Infaunal species were not limited to polychaetes; a bioturbating caudate holothurian *Molpadia oolitica* was photographed at C2-10 (Figure 3-8). In addition to infaunal species, several epifaunal species were observed including large mud anemones, hydroids, and bryozoans.

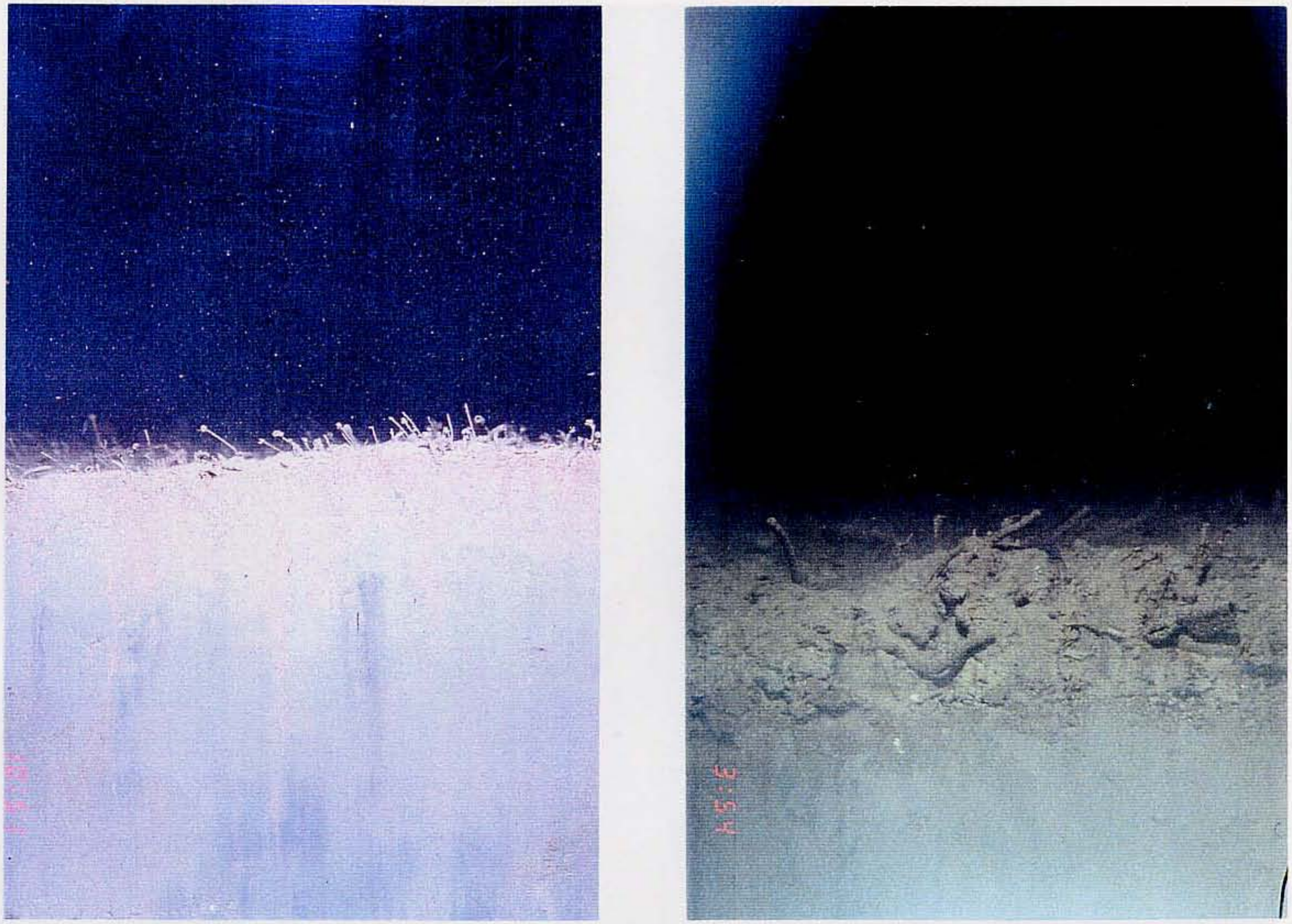
3.1.5 Organism-Sediment Index

The REMOTS® Organism-Sediment Index (OSI) is a multiparameter tool used to evaluate the interaction of infauna and the sediment in which they live. OSI values can range between -10 and +11 and are based on RPD depth, successional stage, and the presence of methane associated with anoxic sediments. As there was no indication of low oxygen conditions, OSI values from BLDS were a function of RPD depth and successional stage. Values ranged from a minimum station mean of 5 to a maximum station mean of 10 (Appendix). Mean transect OSI values ranged from 6 to 9 (Figure 3-9). OSI values ≥6 are indicative of relatively healthy sediments. OSI values could not be calculated for twelve photographs: eleven due to indeterminate RPD depths, and one (replicate C1-7a) due to indeterminate successional stage. (The plan view photograph for replicate C1-7a shows the camera frame resting on a rock, restricting penetration.)

3.2 Plan View Photography

The plan view photographs provided useful information about surface sediment characteristics which were not always discernible from the REMOTS® photographs. Surface sediments at BLDS were composed primarily of silts and sands (Figure 3-10).

Figure 3-5. Example of a thick RPD (4 cm) observed at Station C3-1



(A) (B)

Figure 3-6. Surface sediments at BLDS colonized by Stage II "stick-building" amphipods (Family Podocerdiae; A) and Stage III tube-dwelling polychaetes (B)

Figure 3-7. Water-filled feeding void below the RPD at Station C6-4; note the halo of oxygenated sediments surrounding the void

Figure 3-8. Bioturbating caudate holothurian *Molpadia oolitica* at Station C2-10

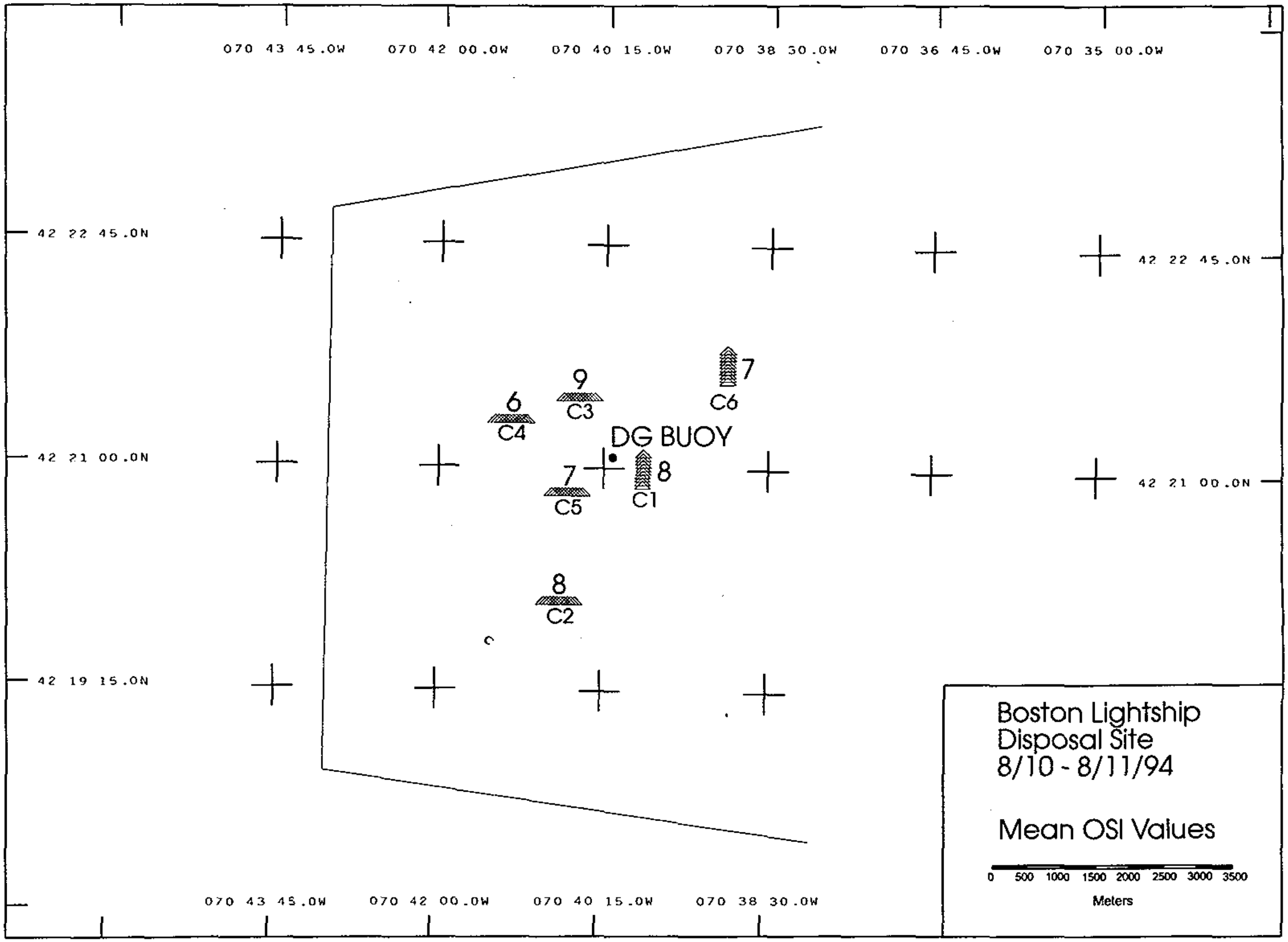


Figure 3-9. Transect average Organism-Sediment Index values. OSI values ≥6 represent relatively healthy sediment environments.

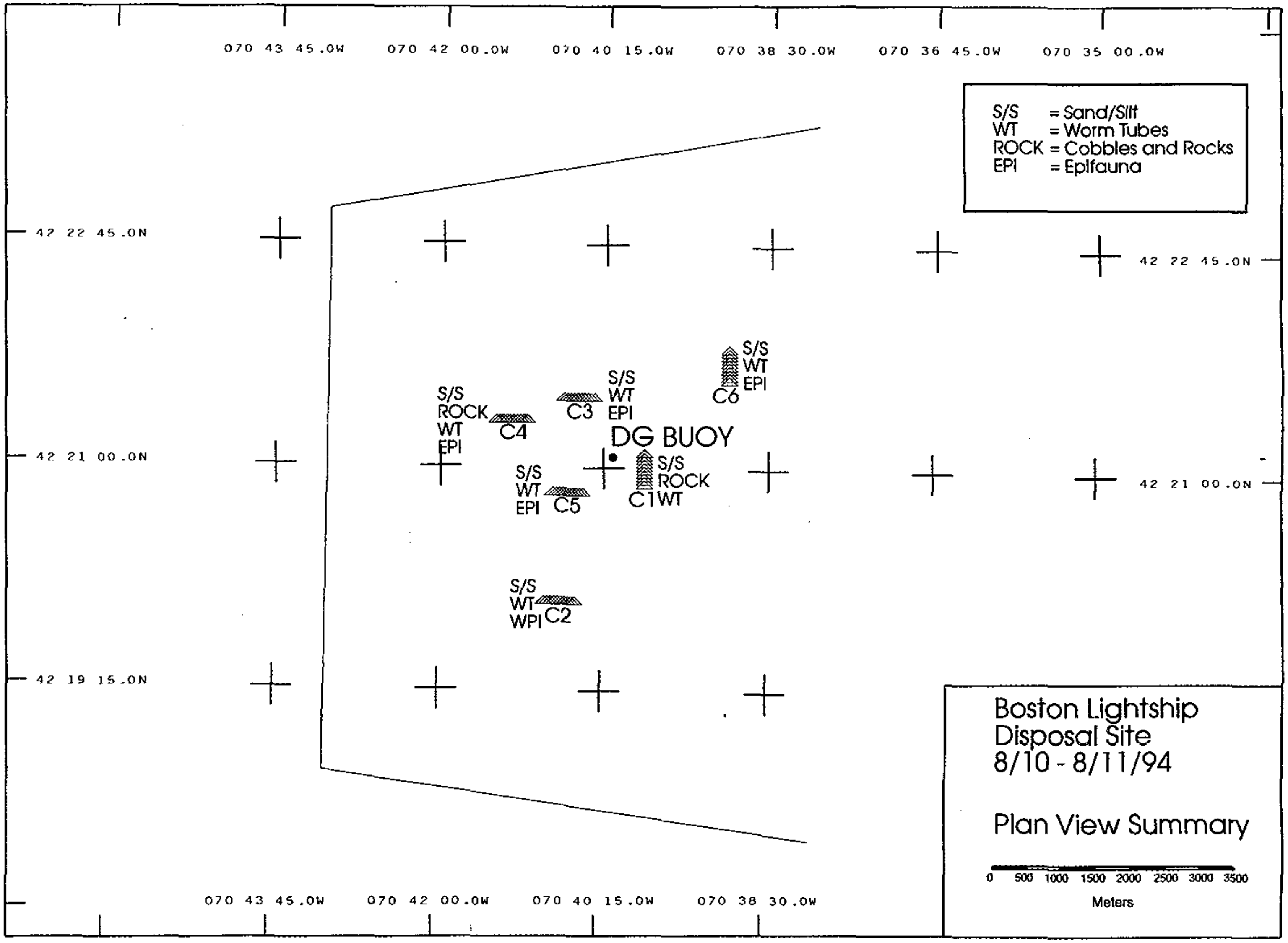
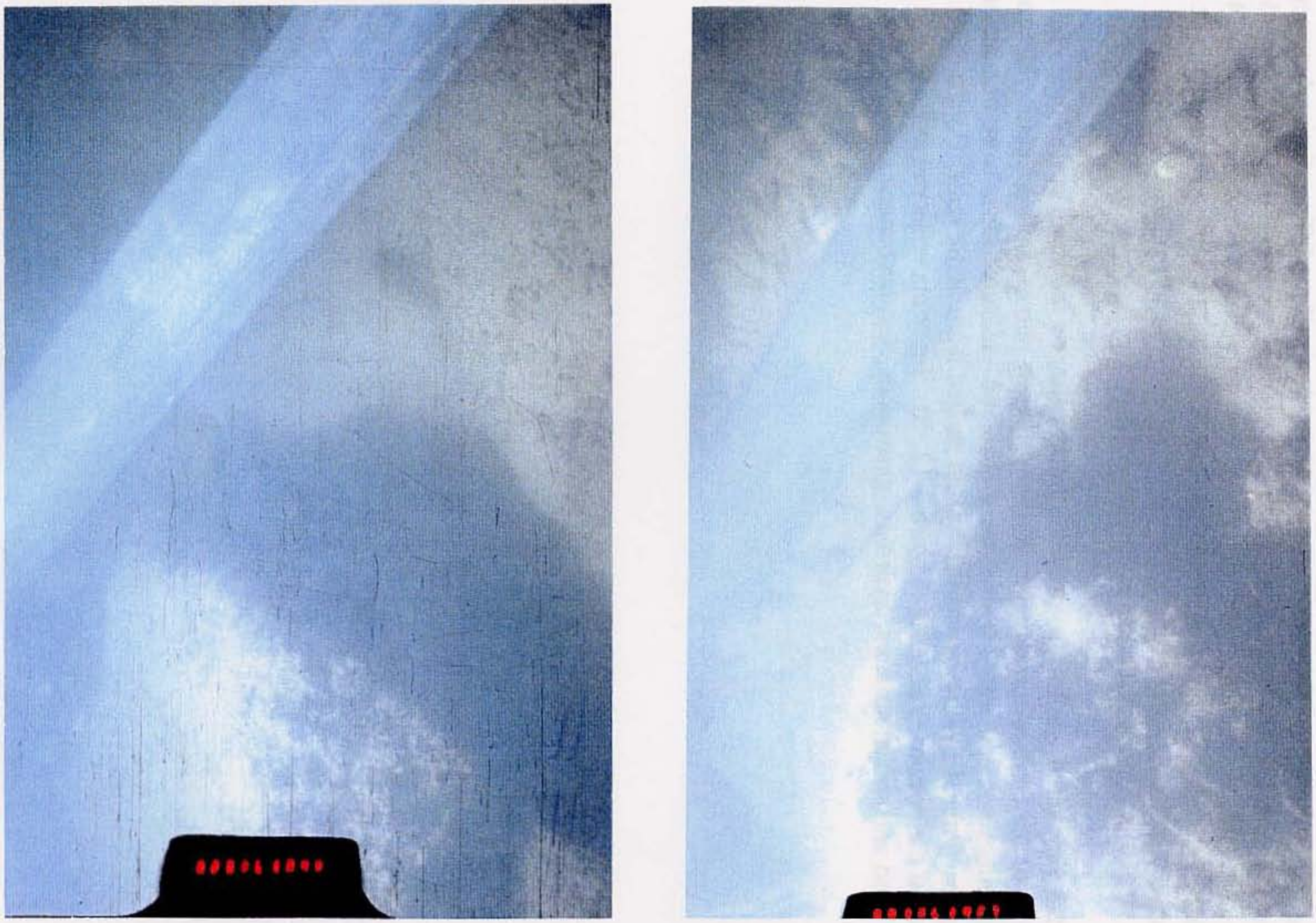


Figure 3-10. Summary of bottom features observed in plan view photographs

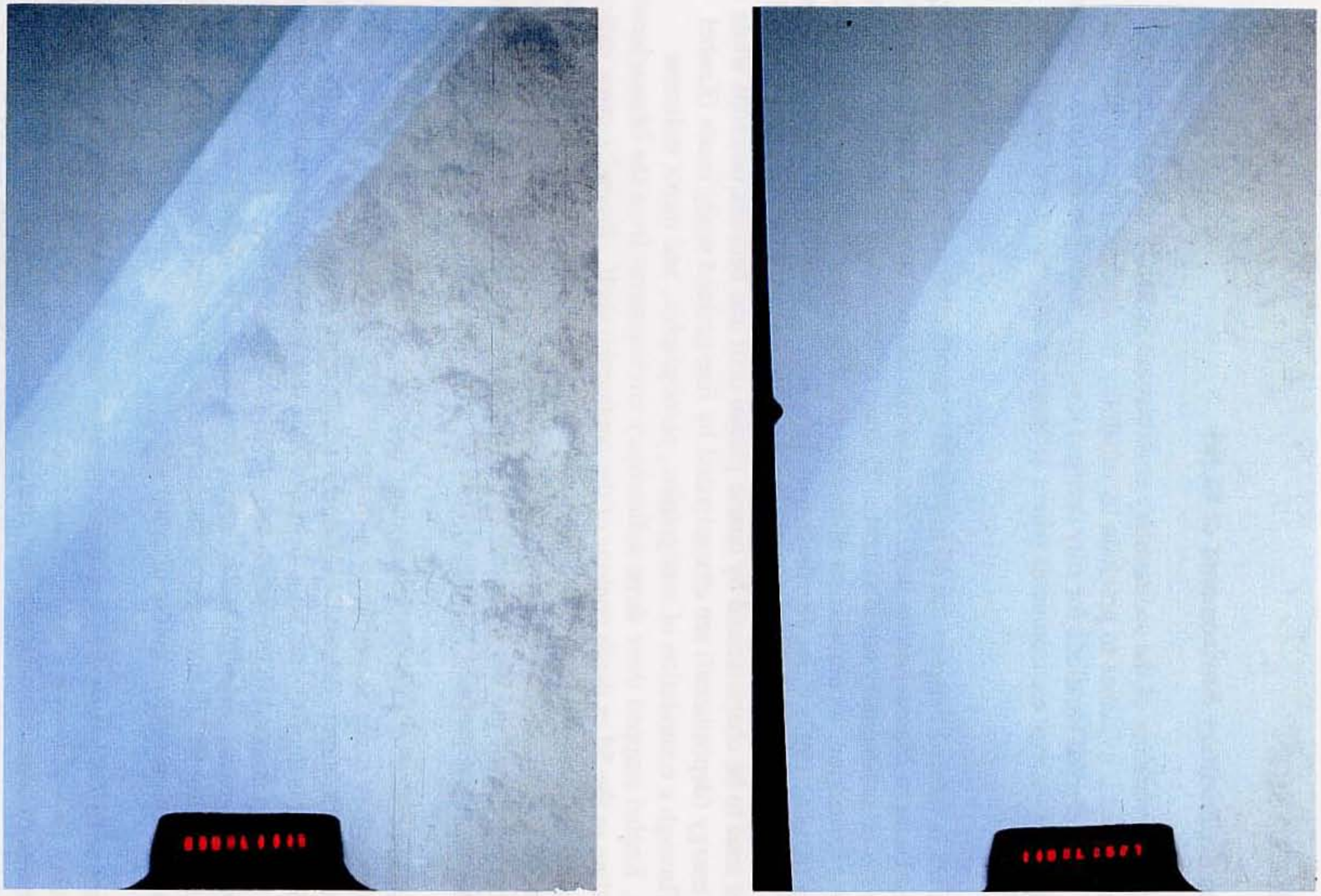
While the resolution of the plan view photographs did not allow differentiation between fine sands and silts, sediments containing pebbles, cobble, and rocks were clearly evident. The plan view photos revealed two rocky areas, one at transect C1 and the other at C4 (Figure 3-11, A and B). The larger rocks at both of these sites were covered with silt and encrusting bryozoans. Many of the rocks observed had sharp angular edges and were probably disposed construction debris.

Plan view photographs also provided information on the small scale horizontal distribution of the benthic community. In the plan view photos, both sedentary infaunal polychaete tubes and epibenthic species were observed. Infaunal tubes were present at all six transects. Tube distribution was patchy and ranged from dense mats (Figure 3-12, A) that carpeted the bottom to absence (Figure 3-12, B). Epifauna observed at BLDS included mud anemones, seastars, hydroids, gastropods, and bryozoans.



(A) (B)

Figure 3-11. Possible construction debris—large, sharp-angled, silt-covered rocks observed in plan view photographs from transects C1 (A) and C4 (B)



(A) (B)

Figure 3-12. Heterogeneous distribution of surface polychaete tubes ranging from a dense carpet (A) to nearly absent (B)

4.0 DISCUSSION

4.1 The Sedimentary Environment of BLDS

An understanding of the sedimentary environment at BLDS is necessary to determine if there is evidence to preclude its suitability for dredged material disposal. For example, the preferred locations for silty dredged material, such Boston Harbor sediment, have been in low-energy environments where sediment resuspension and transport is minimal.

BLDS is located between the 40 m and 70 m depth contours on the western slope of Stellwagen Basin in Massachusetts Bay. The seafloor of Massachusetts Bay can be divided into three major sedimentary environments: 1) areas of erosion or nondeposition; 2) areas of sediment reworking, a combination of erosion and deposition; and 3) areas of sediment deposition (Knebel 1993). The distribution of these sedimentary environments reflects the dominant processes in operation. Areas in the bay subjected to high-energy (erosional) conditions tend to be characterized by coarse glacial drift and bedrock outcrops while areas of lower energy (depositional) are characterized by fine-grained sandy muds (Knebel 1993). Through a compilation of sonographic, photographic, and direct sediment sampling, Knebel mapped these three sedimentary environments from the Massachusetts Bay coastline to the 50 m depth contour of the continental shelf. Knebel's maps indicated that erosional and sediment reworking environments comprise the majority of the shelf bottom in the Bay. Depositional environments are found primarily in Boston Harbor and at the 50 m contour of the Basin slope. The transects used in the present survey are all just beyond the area characterized by Knebel (1993).

Based on Knebel's (1993) sedimentary environment maps, the majority of the Massachusetts Bay Inner Shelf region is composed of erosional and sediment reworking environments. However, deeper depositional areas appear along the 50 m depth contour (Figure 4-1). This depositional zone begins within the southern portion of BLDS (Figure 1-2), but was not mapped in the initial study of Massachusetts Bay. The REMOTS® and plan view photographs provided some insight about the nature of the sedimentary environment within BLDS and support the extension of the depositional regime mapped by Knebel north and eastward into the disposal site.

Grain sizes at BLDS below the 50 m depth contour ranged from very fine sands (3 phi) to silt plus clay (>4 phi) with a major modal size of silt plus clay. Sediments in depositional environments of Massachusetts Bay are composed primarily of sandy muds and muddy sands and have average concentrations of 0.5% gravel, 45.8% sand, and 53.7% silt plus

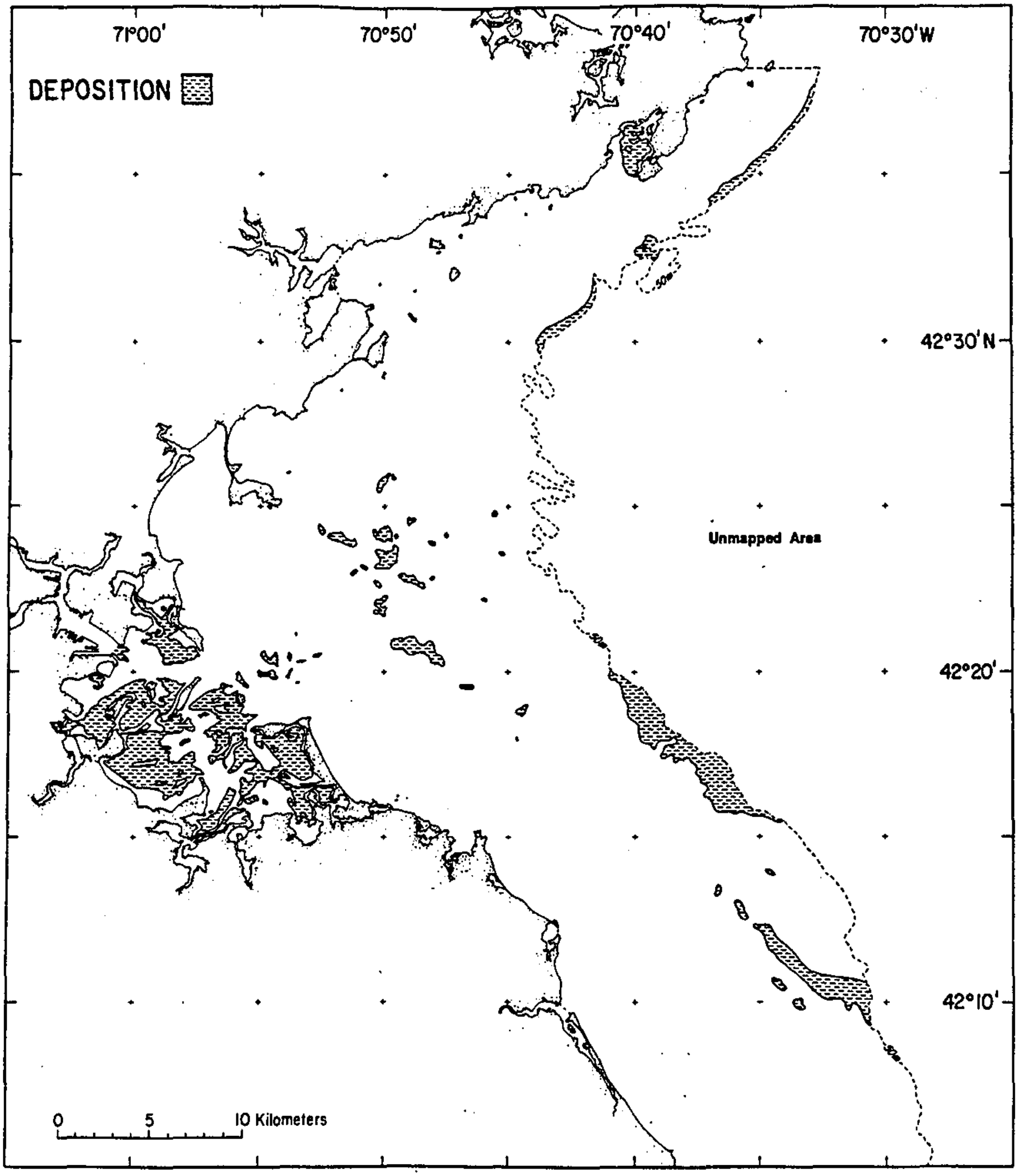


Figure 4-1. Location of depositional environments in Massachusetts Bay from the shore to the 50 m depth contour (from Knebel 1993)

clay (Knebel 1993). Following this definition the areas sampled may be described as depositional environments.

Defining an area as a depositional environment does not preclude the potential for resuspension of fine-grained particles, but merely implies that the combined result of the dominating dynamic processes is net sedimentation. The deficiency of silt/clay particles in the upper centimeter compared to deeper sediments is at least in part due to episodic resuspension. The smaller fine-grained particles are more easily entrained in bottom currents and are winnowed from the surface sediments, leaving behind coarser grained material. Although periodic resuspension may occur during the stormy winter months (Knebel 1993), there is no evidence of extensive sediment movement that might limit the future use of this site for dredged material disposal.

4.2 Presence of Dredged Material

The primary purpose for this survey was to examine a historic unconfined disposal site and attempt to determine if any deleterious environmental conditions still persist nearly twenty years after disposal activity had ceased. The combined use of side-scan sonar with REMOTS® sediment-profile and plan view photography allowed the 1994 reconnaissance effort to be focused on areas where dredged material, and the need for remediation, was more likely.

Disposal of dredged material at BLDS was widespread with material deposited in localized patches throughout the site. The highest concentrations of dredged material, located by side-scan sonar, encompassed the former DG buoy location and extended south below the 50 m depth contour (Figure 1-2). REMOTS® photographs collected from the transects surrounding the DG buoy location and to the south confirmed that the side-scan records were indicative of dredged material deposits (Figure 3-1). However, the presence of relic dredged material at transect C6, where no dredged material was detected in the side-scan survey, indicates that limitations exist in the use of side-scan sonar as the only tool for locating relic dredged material. Side-scan sonar, by detecting changes in the acoustic signature of the surface sediments, displays patterns that are characteristic of dredged material disposal. When dredged material is spread over a wide area or buried beneath the surface, side-scan sonar may not detect it. Dredged material in the regions surrounding the DG buoy was light gray, high-reflectance, fine-grained Boston Blue Clay (Figures 3-2 and 3-3). This material may be part of the 2.3 million m^3 of Boston Harbor dredged material deposited in the 1960s and 1970s (Normandeau Associates 1994).

Even though fine-grained dredged material was not observed in the REMOTS® images from transect C4, which was also located in an area of concentrated dredged material targets, the plan view photographs revealed areas of cobble and larger sharp-edged rocks (Figure 3-11). The sharp angularity of the rocks, and their presence at a known disposal site, suggest that they may be construction debris. More solid evidence that transect C4 contained construction debris was found while sieving one of the grab samples. A small rounded piece of concrete with two planar sides was found in the grab sample from Station C4-5. This small piece probably was bored from a larger slab either for blasting or attachment of lifting cables.

4.3 Benthic Recolonization

The identification of a dredged material signature on side-scan records, and the further investigation of the dredged material by REMOTS® sediment-profile photography, were necessary to determine if remediation was needed. The primary step in determining if remediation was required at BLDS was to examine the status of benthic recolonization and compare the dredged material with apparent ambient sediments within the disposal area. There was no preexisting reference area for BLDS; however, the ambient sediment at Station C6 should provide a good basis for comparing the effects of dredged material disposal on the benthic habitat. Information derived from sediment structures was compiled into the multiparameter REMOTS® Organism-Sediment Index. At BLDS the OSI value was primarily a function of the successional stage of the populating infauna and the depth of biogenically enhanced oxygen penetration (RPD).

The most striking evidence for a healthy benthic habitat at BLDS was the abundant and diverse benthic community. The subsurface sediments were populated by burrowing polychaetes both large and small as well as other Stage III genera including caudate holothurians (Figures 3-2, B; 3-3; and 3-8). The surface sediments were dominated by sedentary, tube-dwelling Stage III polychaetes and by Stage II stick-building amphipods (Family Podoceridae) (Figure 3-6, A). The presence of Stage II organisms in the surface sediments is probably from secondary colonization, and not indicative of a recovery from a recent disturbance. Following disposal activity and the progression of recolonization to a Stage III community, the Stage III organisms began to feed in deeper sediments. The movement of the Stage III group out of the upper sediment cleared space for reoccupation by surface-dwelling Stage II infauna.

In addition to the abundant benthic community, several pieces of information from the sedimentary structure suggested a healthy benthic habitat has persisted for some time. Numerous water-filled voids were observed in subsurface sediments (Figures 3-2 and 3-7). These voids were created by the feeding activity of head-down deposit feeding Stage III organisms. A halo of oxidized sediments, which surrounded the voids, suggested recent active feeding. In addition, several of the voids contained coarse-grained particles that were presumably discarded during particle-selective feeding habits (Figure 3-7).

Despite the healthy benthic community at BLDS, the RPD values are relatively shallow. Normally, the combined activity of the subsurface burrowing Stage III organisms, the sedentary tube-dwelling polychaetes, and surface-dwelling Stage II infauna served to transport oxygen into the sediments resulting in relatively deep RPD depths. While irrigating their tubes, sedentary tube-dwelling polychaetes pump high dissolved oxygen concentration seawater out of the tube bottoms directly into the sediments, forcing a unidirectional upward displacement of interstitial fluid. However, the net diffusion of dissolved oxygen from seawater injection and subsequent advective porewater transport will be less where there is high sediment oxygen demand (SOD). With high SOD, oxygen that is transported across the sediment-water interface is rapidly consumed by microbial respiration and oxidation reactions. The observed RPD depths of only a few centimeters at BLDS, combined with a well-established infaunal deposit-feeding community (Figure 3-5), suggest that BLDS sediments have relatively high SOD.

5.0 CONCLUSION

The reconnaissance plan view and REMOTS® sediment-profile surveys identified areas of historic dredged material at BLDS. The identification of dredged material by these surveys was accomplished with a low level of effort by focusing on areas targeted for the presence of dredged material in the side-scan sonar survey of BLDS. However, dredged material was also found in an area devoid of side-scan sonar targets, and some areas of side-scan sonar targets did not yield the expected fine-grained dredged material. Side-scan sonar has a limited ability to locate relic dredged material. This technology is unable to detect dredged material that does not present a distinct surface acoustic signature. Even when a distinct surface feature is present, the disposal pattern may be due to rock or construction debris which is impenetrable to REMOTS®. Based on the results of all surveys, dredged material at the site was distributed in patches over both large (side-scan sonar) and small (REMOTS®) horizontal spatial scales.

Sediments which can support the level of recolonization observed at BLDS generally should not require remediation action, only periodic monitoring (Germano et al. 1994). Twenty years after the cessation of disposal activity, the benthos of BLDS has a Stage II and Stage III benthic community. The presence of these communities and the evidence for extensive biogenic reworking of dredged material suggest a healthy benthic habitat. Chemical analysis of the archived sediment samples is not recommended at this time for the purpose of evaluating remediation. If the site is designated for additional disposal, these archived sediments might be analyzed for evaluating baseline conditions.

The depositional environment characterized at BLDS beyond the 50 m contour shows no evidence to preclude its use for future dredged material disposal. Any resuspension and transport that may occur is most likely episodic and does not occur frequently.

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APPENDIX

REMOTS® Sediment-Profile Data

Transect	Station	Replicate	Average Penetration (cm)	Grain Size Major Mode	Grain Size Range	Average RPD	Dredged Material Penetration (cm)	Successional Stage	OSI
C1	1	b	8.00	>4	3 to >4	1.63	0	Stage II ON Stage III	8
C1	1	d	11.87	>4	3 to >4	1.85	0	Stage II ON Stage III	8
C1	2	b	10.99	>4	3 to >4	1.87	0	Stage II ON Stage III	8
C1	2	c	10.00	>4	3 to >4	1.50	0	Stage II ON Stage III	8
C1	3	a	7.23	>4	3 to >4	1.05	2.02	Stage II	5
C1	3	b	6.37	>4	3 to >4	1.97	0	Stage II ON Stage III	8
C1	4	a	2.92	>4	3 to >4	1.59	0	Stage II	6
C1	4	b	9.27	>4	3 to >4	2.06	9.61	Stage II ON Stage III	8
C1	5	a	7.12	>4	3 to >4	1.76	0	Stage II ON Stage III	8
C1	5	c	12.19	>4	3 to >4	1.76	0	Stage II ON Stage III	8
C1	6	a	9.44	>4	3 to >4	2.32	0	Stage II ON Stage III	9
C1	6	b	10.64	>4	3 to >4	2.49	0	Stage II ON Stage III	9
C1	7	a	2.40	>4	3 to >4	1.57	0	INDET	INDET
C1	8	c	10.56	>4	3 to >4	1.74	0	Stage II ON Stage III	8
C1	9	a	7.10	>4	3 to >4	1.78	0	Stage II ON Stage III	8
C1	9	c	6.48	>4	3 to >4	2.06	0	Stage II ON Stage III	8
C1	10	b	6.27	>4	3 to >4	1.33	0	Stage II ON Stage III	7
C1	10	c	7.15	>4	3 to >4	2.00	0	Stage II ON Stage III	8

INDET = Indeterminate
Grain Size = phi units

REMOTS® Sediment-Profile Data (continued)

Transect	Station	Replicate	Average Penetration (cm)	Grain Size Major Mode	Grain Size Range	Average RPD	Dredged Material Penetration (cm)	Successional Stage	OSI
C2	1	c	7.43	>4	3 to >4	1.54	0	Stage II ON Stage III	8
C2	1	d	2.24	>4	3 to >4	1.10 cm reduced layer	0	Stage II	INDET
C2	2	c	4.54	>4	3 to >4	1.58	0	Stage II ON Stage III	8
C2	2	d	3.68	>4	3 to >4	1.38	0	Stage II	5
C2	3	a	2.98	>4	3 to >4	sand/mud	0	Stage II ON Stage III	INDET
C2	3	c	2.63	>4	3 to >4	sand/mud	0	Stage II	INDET
C2	4	a	8.82	>4	3 to >4	1.78	0	Stage II ON Stage III	8
C2	4	b	3.36	>4	3 to >4	1.12	0	Stage II ON Stage III	7
C2	5	a	8.07	>4	3 to >4	1.56	0	Stage II	6
C2	5	b	9.30	>4	3 to >4	2.06	9.69	Stage II ON Stage III	8
C2	6	a	2.83	>4	3 to >4	1.21	0	Stage II	5
C2	6	b	7.11	>4	3 to >4	1.97	0	Stage II ON Stage III	8
C2	7	a	1.93	>4	3 to >4	INDET	0	Stage II	INDET
C2	7	c	8.00	>4	3 to >4	1.86	8.51	Stage II ON Stage III	8
C2	8	a	8.51	>4	3 to >4	pull away	0	Stage II ON Stage III	INDET
C2	8	c	1.80	>4	3 to >4	INDET	0	Stage II	INDET
C2	9	a	7.63	>4	3 to >4	2.63	4.34	Stage II ON Stage III	9
C2	9	b	4.14	>4	3 to >4	1.64	0	Stage II ON Stage III	8
C2	10	a	7.59	>4	3 to >4	1.75	0	Stage II ON Stage III	8
C2	10	b	5.61	>4	3 to >4	1.56	0	Stage II ON Stage III	8

INDET = Indeterminate
Grain Size = phi units

REMOTS® Sediment-Profile Data (continued)

Transect	Station	Replicate	Average Penetration (cm)	Grain Size Major Mode	Grain Size Range	Average RPD	Dredged Material Penetration (cm)	Successional Stage	OSI
C3	1	a	10.43	>4	3 to >4	2.49	0	Stage II ON Stage III	9
C3	1	b	9.96	>4	3 to >4	3.99	0	Stage II ON Stage III	11
C3	2	a	9.31	>4	3 to >4	3.00	4.12	Stage II ON Stage III	10
C3	2	b	7.43	>4	3 to >4	2.30	0	Stage II ON Stage III	9
C3	3	a	7.15	>4	3 to >4	2.64	7.73	Stage II ON Stage III	9
C3	3	b	8.82	>4	3 to >4	3.35	9.1	Stage II ON Stage III	10
C3	4	a	6.09	>4	3 to >4	2.12	7.04	Stage II ON Stage III	8
C3	4	b	5.21	>4	3 to >4	2.79	5.92	Stage II ON Stage III	9
C3	5	a	6.59	>4	3 to >4	1.74	0	Stage II ON Stage III	8
C3	5	b	7.62	>4	3 to >4	2.12	0	Stage II ON Stage III	8
C3	6	a	5.94	>4	3 to >4	2.60	0	Stage II	7
C3	6	b	5.94	>4	3 to >4	3.07	0	Stage II ON Stage III	10
C3	7	a	7.23	>4	3 to >4	3.24	0	Stage II ON Stage III	10
C3	7	b	7.02	>4	3 to >4	2.51	0	Stage II ON Stage III	9
C3	8	a	7.12	>4	3 to >4	1.91	7.94	Stage II	6
C3	8	b	5.84	>4	3 to >4	1.85	0	Stage II ON Stage III	8
C3	9	b	8.61	>4	3 to >4	3.41	9.57	Stage II ON Stage III	10
C3	9	c	5.90	>4	3 to >4	2.73	6.95	Stage II ON Stage III	9
C3	10	b	11.91	>4	4 to >4	4.76	12.4	Stage II ON Stage III	11
C3	10	c	5.43	>4	3 to >4	2.06	6.18	Stage II ON Stage III	8

INDET = Indeterminate
Grain Size = phi units

REMOTS® Sediment-Profile Data (continued)

Transect	Station	Replicate	Average Penetration (cm)	Grain Size Major Mode	Grain Size Range	Average RPD	Dredged Material Penetration (cm)	Successional Stage	OSI
C4	1	a	5.86	>4	3 to >4	1.57	0	Stage II	6
C4	1	b	7.04	>4	3 to >4	1.73	0	Stage II	6
C4	2	b	7.95	>4	2 to >4	4.23	0	Stage II	9
C4	2	c	6.29	>4	3 to >4	2.43	0	Stage II	7
C4	3	a	6.57	>4	3 to >4	1.43	0	Stage II ON Stage III	7
C4	3	b	10.39	>4	3 to >4	1.80	0	Stage II	6
C4	4	a	6.57	>4	-1 to >4	1.84	0	Stage II ON Stage III	8
C4	4	b	1.09	>4	3 to >4	INDET	0	INDET	INDET
C4	5	a	7.59	>4	3 to >4	1.57	0	Stage II	6
C4	5	b	6.66	>4	3 to >4	1.80	0	Stage II ON Stage III	8
C4	6	a	4.45	>4	3 to >4	1.00	0	Stage II	5
C4	6	b	2.36	>4	3 to >4	INDET	0	INDET	INDET
C4	7	a	3.45	>4	3 to >4	0.73	0	Stage II	4
C4	7	b	4.55	>4	3 to >4	0.82	0	Stage II	5
C4	8	a	6.36	>4	2 to >4	1.82	0	Stage II ON Stage III	8
C4	8	d	4.02	>4	3 to >4	1.27	0	Stage II ON Stage III	7
C4	9	d	3.89	>4	3 to >4	1.00	0	Stage II	5
C4	9	f	2.16	3 to 4	2 to >4	RPD>PEN	0	Stage II	INDET
C4	10	a	7.50	>4	3 to >4	1.36	0	Stage II	5
C4	10	b	7.77	>4	3 to >4	1.11	0	Stage II ON Stage III	7

INDET = Indeterminate
Grain Size = phi units

REMOTS® Sediment-Profile Data (continued)

Transect	Station	Replicate	Average Penetration (cm)	Grain Size Major Mode	Grain Size Range	Average RPD	Dredged Material Penetration (cm)	Successional Stage	OSI
C5	1	a	7.25	>4	3 to >4	1.48	0	Stage II ON Stage III	7
C5	1	b	6.34	>4	3 to >4	1.86	0	Stage II ON Stage III	8
C5	2	a	9.09	>4	3 to >4	1.7	0	Stage II ON Stage III	8
C5	2	b	8.61	>4	3 to >4	1.89	8.91	Stage II ON Stage III	8
C5	3	a	7.64	>4	3 to >4	1.57	7.95	Stage II ON Stage III	8
C5	3	b	9.50	>4	3 to >4	1.64	0	Stage II ON Stage III	8
C5	4	a	8.29	>4	3 to >4	2.39	0	Stage II ON Stage III	9
C5	4	b	8.93	>4	3 to >4	1.52	0	Stage II	6
C5	5	a	8.20	>4	3 to >4	1.36	0	Stage II	5
C5	5	b	10.00	>4	3 to >4	2.3	0	Stage II ON Stage III	9
C5	6	a	9.39	>4	3 to >4	1.61	0	Stage II	6
C5	6	c	6.29	>4	3 to >4	0.89	0	Stage II	5
C5	7	a	9.45	>4	3 to >4	1.34	0	Stage II ON Stage III	7
C5	7	b	9.00	>4	3 to >4	1.61	0	Stage II	6
C5	8	a	8.48	>4	3 to >4	1.11	0	Stage II ON Stage III	7
C5	8	c	10.68	>4	3 to >4	1.55	0	Stage II ON Stage III	8
C5	9	b	8.86	>4	3 to >4	0.93	0	Stage II ON Stage III	7
C5	9	c	6.25	>4	3 to >4	1.18	6.91	Stage II ON Stage III	7
C5	10	a	2.36	>4	3 to >4	RPD>PEN	0	Stage II ON Stage III	INDET
C5	10	b	0.52	>4	3 to >4	INDET	0	INDET	INDET

INDET = Indeterminate
Grain Size = phi units

REMOTS® Sediment-Profile Data (continued)

Transect	Station	Replicate	Average Penetration (cm)	Grain Size Major Mode	Grain Size Range	Average RPD	Dredged Material Penetration (cm)	Successional Stage	OSI
C6	1	a	10.09	>4	3 to >4	2.50	0	Stage III	9
C6	1	b	12.09	>4	3 to >4	1.61	0	Stage I ON Stage III	8
C6	2	a	12.16	>4	3 to >4	2.18	0	Stage II ON Stage III	8
C6	2	b	12.93	>4	3 to >4	1.59	0	Stage II ON Stage III	8
C6	3	a	7.29	>4	3 to >4	1.66	6.64	Stage I -> II	5
C6	3	b	12.43	>4	3 to >4	1.36	0	Stage II ON Stage III	7
C6	4	a	14.11	>4	3 to >4	2.50	0	Stage II ON Stage III	9
C6	4	b	14.13	>4	3 to >4	2.34	0	Stage II	7
C6	5	a	10.59	>4	3 to >4	1.32	10.73	Stage II ON Stage III	7
C6	5	b	11.57	>4	3 to >4	1.39	0	Stage III	7
C6	6	a	11.77	>4	3 to >4	1.64	11.85	Stage II ON Stage III	8
C6	6	b	10.95	>4	3 to >4	0.86	0	Stage II ON Stage III	7
C6	7	a	10.86	>4	3 to >4	1.09	0	Stage II ON Stage III	7
C6	7	d	13.07	>4	3 to >4	0.98	13.18	Stage II ON Stage III	7
C6	8	b	3.43	>4	3 to >4	1.16	0	Stage II	5
C6	8	d	9.16	>4	3 to >4	1.50	0	Stage II ON Stage III	7
C6	9	a	6.75	>4	3 to >4	1.52	0	Stage II	6
C6	9	b	11.66	>4	3 to >4	1.70	12.04	Stage II ON Stage III	8
C6	10	b	8.98	>4	3 to >4	1.25	0	Stage II ON Stage III	7
C6	10	c	13.00	>4	3 to >4	2.75	13.32	Stage II ON Stage III	9

INDET = Indeterminate
Grain Size = phi units