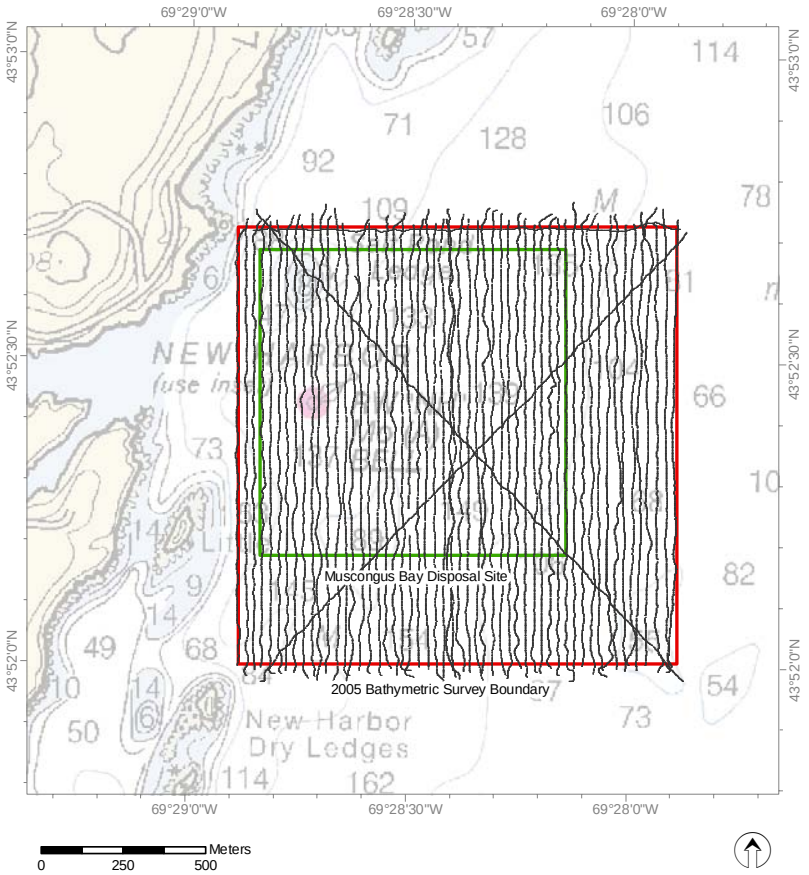
Monitoring Survey at the Muscongus Bay Disposal Site
Lincoln County, Maine
July/September 2005

Disposal Area Monitoring System DAMOS



Contribution 171
June 2007

US Army Corps of Engineers ®
New England District

This report should be cited as:

ENSR; Coastal Vision; CR Environmental; Germano & Associates; U.S. Army Corps of Engineers, New England District, Engineering/Planning Division. 2007. Monitoring Survey at the Muscongus Bay Disposal Site, Lincoln County, Maine, July/September 2005. DAMOS Contribution No. 171. U.S. Army Corps of Engineers, New England District, Concord, MA, 43 pp.

REPORT DOCUMENTATION PAGE

form approved
OMB No. 0704-0188

1. AGENCY USE ONLY (LEAVE BLANK)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	June 2007	FINAL REPORT

4. TITLE AND SUBTITLE
Monitoring Survey at the Muscongus Bay Disposal Site, Lincoln County, Maine, July/September 2005

5. FUNDING NUMBERS

6. AUTHOR(S)
ENSR International, Coastal Vision, Germano & Associates, CR Environmental, and U.S. Army Corps of Engineers, New England District, Engineering/Planning Division

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

ENSR International	Coastal Vision	Germano & Assoc.	CR Environmental	U.S. Army Corps of Eng.
2 Technology Park Dr.	215 Eustis Ave.	12100 SE 46th Place	639 Boxberry Hill Road	New England District
Westford, MA 01886	Newport, RI 02840	Bellevue, WA 98006	East Falmouth, MA 02536	696 Virginia Road
				Concord, MA 01742

8. PERFORMING ORGANIZATION REPORT NUMBER
ENSR-9000-383-200

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Corps of Engineers-New England District
696Virginia Rd
Concord, MA 01742-2751

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DAMOS Contribution No. 171

11. SUPPLEMENTARY NOTES
Available from DAMOS Program Manager, Regulatory Division
USACE-NAE, 696 Virginia Rd, Concord, MA 01742-2751

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT

A monitoring survey was conducted at the Muscongus Bay Disposal Site (MuBDS) as part of the Disposal Area Monitoring System (DAMOS). The July and September 2005 field efforts consisted of bathymetric and sediment-profile imaging surveys designed to evaluate the physical distribution of the dredged material and assess the status of the benthic community relative to ambient sediment conditions.

The MuBDS is located in southwestern Muscongus Bay, Lincoln County, Maine immediately offshore of the mouth of New Harbor in Bristol. MuBDS was last used during the period of November 1965 to March 1966 for disposal of about 22,142 cubic meters of material removed from the New Harbor Federal Navigation Project during improvement dredging of the upper harbor channel extension and the new Back Cove anchorage. Maintenance dredging of New Harbor in 1936 and the original improvement dredging in 1905 may also have used the site, but no records are available to confirm the disposal site used for those operations. There is interest in using the site again for the next maintenance operation at New Harbor, proposed improvement dredging of Round Pond Harbor, and for future work at these and other harbors on the Pemaquid Peninsula and western Muscongus Bay area.

The July/September field operations mark the first monitoring surveys conducted at MuBDS under the DAMOS program. This survey provides a characterization of existing conditions at the disposal site that can serve as a baseline against which future impacts can be assessed. As part of the July field effort, a bathymetric survey was performed to map the seafloor and to detect any remnants of prior disposal mounds. In addition a Sediment-Profile Imaging (SPI) and Plan-View Imaging survey was conducted in September 2005 to assess the recolonization status and benthic habitat characteristics of the disposal site and three reference areas.

There is no evidence of long-term impacts from past dredged material disposal at MuBDS, no discernible difference among stations at the disposal site and those in the reference areas in terms of sediment type, depth of the apparent RPD, or infaunal successional stage was identified. The sediments within MuBDS are a classic example of complete benthic ecosystem recovery given sufficient time following a disturbance and it is anticipated that the sediments and benthic community at MuBDS will recover from any future disposal event in the area.

14. SUBJECT TERMS
DAMOS, Muscongus Bay Disposal Site, Dredged Material

15. NUMBER OF TEXT PAGES: 43

16. PRICE CODE

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

MONITORING SURVEY AT THE MUSCONGUS BAY DISPOSAL SITE LINCOLN COUNTY, MAINE JULY/SEPTEMBER 2005

Contribution #171

June 2007

Report No.
ENSR-9000-383-200

Prepared by:
ENSR International, CoastalVision,
Germano & Associates, CR Environmental

and

Engineering/Planning Division, New England District
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

US Army Corps of Engineers ®
New England District

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

EXECUTIVE SUMMARY

A monitoring survey was conducted at the Muscongus Bay Disposal Site (MuBDS) as part of the Disposal Area Monitoring System (DAMOS). The July and September 2005 field efforts consisted of bathymetric and sediment-profile and plan view imaging surveys designed to evaluate the physical distribution of the dredged material and assess the status of the benthic community relative to ambient sediment conditions. The July/September field operations mark the first monitoring surveys conducted at MuBDS under the DAMOS program. This survey provides a characterization of existing conditions at the disposal site that can serve as a baseline against which future impacts can be assessed.

The MuBDS is located in southwestern Muscongus Bay, Lincoln County, Maine immediately offshore of the mouth of New Harbor in Bristol. [The NAD83 coordinates for MuBDS are: Center: -69.4749, 43.8739; NW: -69.4807, 43.8780; SW: -69.4806, 43.8696; SE: -69.4690, 43.8697; NE: -69.4691, 43.8781.] MuBDS was last used during the period of November 1965 to March 1966 for disposal of about 22,142 cubic meters of material removed from the New Harbor Federal Navigation Project during improvement dredging of the upper harbor channel extension and the new Back Cove anchorage. Maintenance dredging of New Harbor in 1936 and the original improvement dredging in 1905 may also have used the site, but no records are available to confirm the disposal site used for those operations. There is interest in using the site again for the next maintenance operation at New Harbor, proposed improvement dredging of Round Pond Harbor, and for future work at these and other harbors on the Pemaquid Peninsula and western Muscongus Bay area.

The bathymetric survey indicated a prominent ledge in the northwest corner of the site, where depths were as shallow as 4 meters. A deep natural channel ran from the northeast corner of the site to the south where it split into two channels ranging in depth from 40 to 50 meters. Less prominent ledges were present along the sides of the channel in the southern portion of the site. No disposal mounds were evident within MuBDS.

The sediment-profile and plan view imaging survey indicated that surface sediments at most of the disposal site stations were composed of fine-grained mud and the grain-size major mode within the disposal site was $\geq$4 phi. There was no distinct sedimentary layer or unique optical marker identifying the presence of historic dredged material. There was no evidence of low dissolved oxygen in the overlying water or subsurface methane generation at any of the sampled locations. All stations in the disposal site and reference areas showed evidence of mature infaunal successional communities with deposit-feeding Stage 3 taxa present. The sediments throughout the site showed deep biological reworking. The results of bioequivalence testing showed the mean RPD values within the disposal site to be no different than those on the ambient seafloor.

There was no evidence of long-term impacts from past dredged material disposal at

MuBDS, no discernible difference among stations at the disposal site and those in the reference areas in terms of sediment type, depth of the apparent RPD, or infaunal successional stage was identified. The sediments within MuBDS are a classic example of complete benthic ecosystem recovery given sufficient time following a disturbance and it is anticipated that the sediments and benthic community at MuBDS will recover from any future disposal event in the area.

1.0 INTRODUCTION

A monitoring survey was conducted at the Muscongus Bay Disposal Site in July and September 2005 as part of the U.S. Army Corps of Engineers (USACE) New England District (NAE) Disposal Area Monitoring System (DAMOS). DAMOS is a comprehensive monitoring and management program designed and conducted to address environmental concerns associated with use of open-water disposal sites throughout the New England region. An introduction to the DAMOS Program and the Muscongus Bay Disposal Site is provided below.

1.1 Overview of the DAMOS Program

The DAMOS Program features a tiered management protocol designed to ensure that any potential adverse environmental impacts associated with dredged material disposal activities are promptly identified and addressed (Germano et al. 1994). For over 25 years, the DAMOS Program has conducted monitoring surveys at open-water disposal sites throughout New England and evaluated the patterns of physical, chemical, and biological responses of seafloor environments to dredged material disposal activity. The DAMOS Program features a tiered disposal site management protocol designed to ensure that any potential adverse environmental impacts associated with dredged material disposal are promptly identified and addressed (Fredette and French 2004; Germano et al. 1994).

The DAMOS monitoring surveys are designed to test hypotheses related to expected physical and ecological response patterns following placement of dredged material on the seafloor at established disposal sites. The results of each monitoring survey are then evaluated to determine appropriate management actions.

1.2 Introduction to the Muscongus Bay Disposal Site

The Muscongus Bay Disposal Site (MuBDS) is an infrequently used dredged material disposal site located in the waters of mid-coastal Maine (Figure 1-1). MuBDS is located off the eastern shore of the Pemaquid Peninsula in Muscongus Bay, just outside of New Harbor, Bristol, Maine. Coordinates for MuBDS (NAD83) are: Center: -69.4749, 43.8739; NW: -69.4807, 43.8780; SW: -69.4806, 43.8696; SE: -69.4690, 43.8697; NE: -69.4691, 43.8781. MuBDS is approximately 300 meters (984 feet) east of the New Harbor Flashing Buoy and is defined as a square 930 x 930 meter (3051 x 3051 feet) area on the seafloor.

MuBDS lies in approximately 43 meters (141 feet) of water. Depths within the site range from approximately 5 meters (16 feet) in the northwest corner of the site to approximately 46 meters (151 feet) in the southeast quadrant.

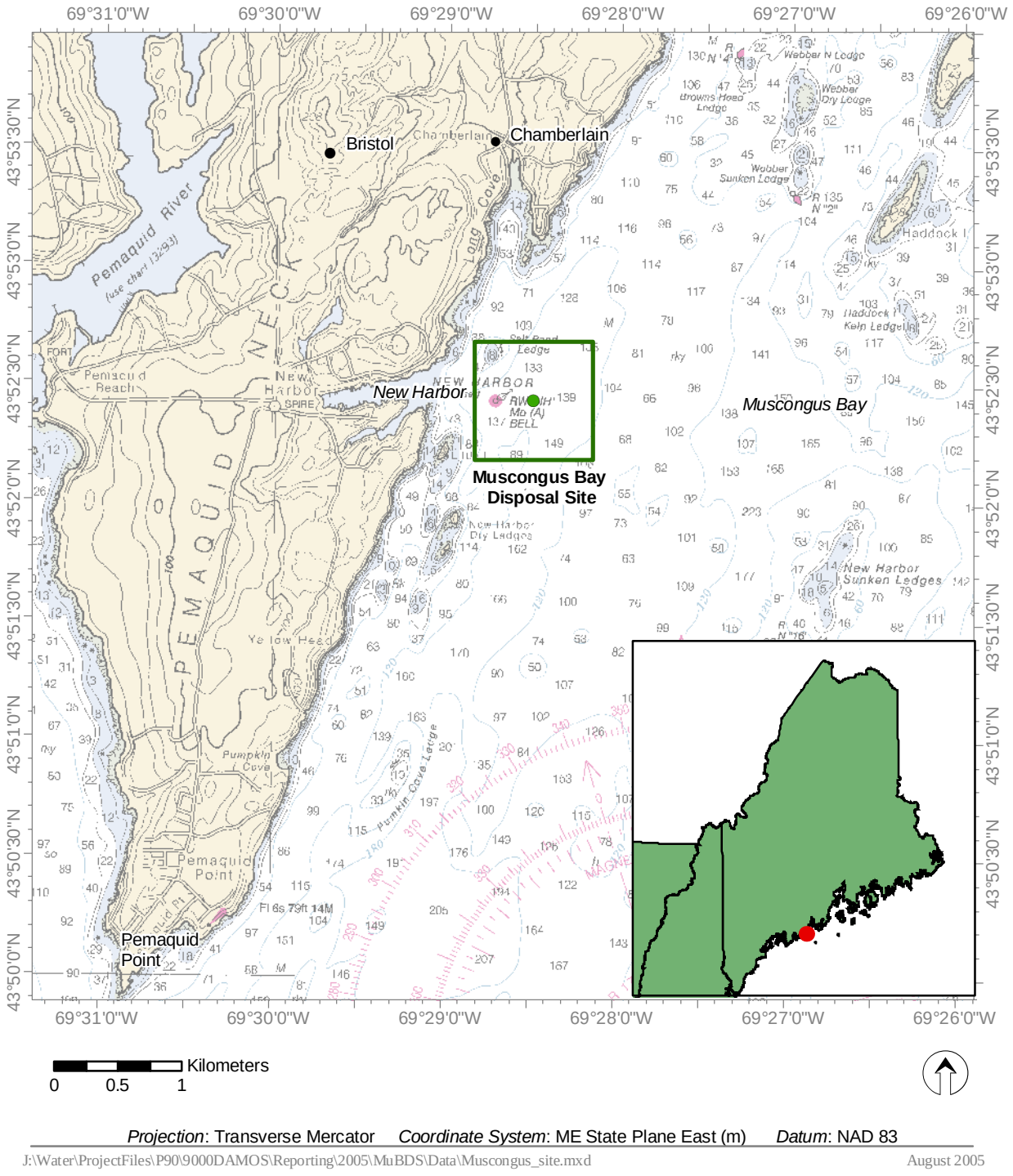


Figure 1-1. Location of the Muscongus Bay Disposal Site

1.3 Recent MuBDS Disposal Activity and Monitoring Events

The Muscongus Bay Disposal Site was last used in the 1960's for disposal of dredged material originating from New Harbor, ME. There has been no previous monitoring of MuBDS under the DAMOS Program.

1.4 Survey Objectives

The objectives of the 2005 MuBDS survey were to (1) document the distribution of dredged material and disposal mound morphology within Muscongus Bay Disposal Site using single-beam bathymetry and (2) assess the benthic status of the Muscongus Bay Disposal Site seafloor using sediment-profile and plan view imaging. MuBDS was surveyed for the purpose of assessing the suitability of this historic site for potential use by future maintenance and improvement dredging projects in the region.

2.0 METHODS

The following section will provide an overview of the methods employed during the 2005 environmental monitoring survey at MuBDS. A team of investigators from ENSR International, CR Environmental, and Germano and Associates performed the 2005 surveys at MuBDS. The bathymetric survey was conducted 15-17 July 2005 to document the distribution of dredged material within MuBDS. The sediment-profile and plan view camera imaging survey was conducted 6-7 September 2005 to assess the benthic status of MuBDS.

2.1 Navigation and Data Acquisition

Navigation and horizontal positioning was performed using a Trimble 4000 series Global Positional System (GPS) receiver interfaced with a Trimble Probeacon differential beacon receiver. The system received and processed satellite and land-based beacon data and provided real-time vessel position to sub-meter accuracy. The accuracy was confirmed at the beginning and end of each survey day by comparing the observed GPS coordinates to an established reference point with known coordinates. Coastal Oceanographics, Inc. HYPACK® hydrographic survey software was used to acquire, integrate, and store all positional data from the DGPS as well as bathymetric and station data.

2.2 Bathymetry

The initial plan for the 2005 single-beam bathymetric survey called for the survey to encompass the entire area of MuBDS and extend approximately 200 m outside the site boundaries on each side, covering a 1330 m x 1330 m area. Due to navigational hazards, the bathymetric survey area was shifted southeast to avoid the exposed rocky ledges just outside of New Harbor (Figure 2-1). The survey was initiated on 15 July 2005 aboard the *R/V Seahawk* and completed on 17 July 2005. A total of 54 survey lines, each 25 m apart, were occupied as part of the survey. Additional tie-lines were occupied perpendicular and diagonal to the main survey lines to assess data quality.

The bathymetric data were collected using an Ocean Data Equipment Corporation (ODEC) MF500 precision echo sounder outfitted with a narrow (3°) beam 200-kHz transducer. The accuracy of this system was approximately 0.1% of the water depth, or approximately 4 cm in the waters of MuBDS. The system was calibrated at the dock prior to the survey. In addition, local measurements of temperature and salinity were taken using an In-situ® Troll 9000. Bathymetric data were recorded by means of a high-resolution trace on a thermal printer in addition to the digital data stored within Hypack®. Hypack® managed data acquisition and storage of data from the echosounder and the Trimble DGPS. In addition, Hypack® recorded depth, heading, position, and time along each survey transect line. Water depths were recorded in feet and referenced to a MLLW (mean lower low water) vertical datum based on the NOAA tide gauge located in Portland, ME. Once processed,

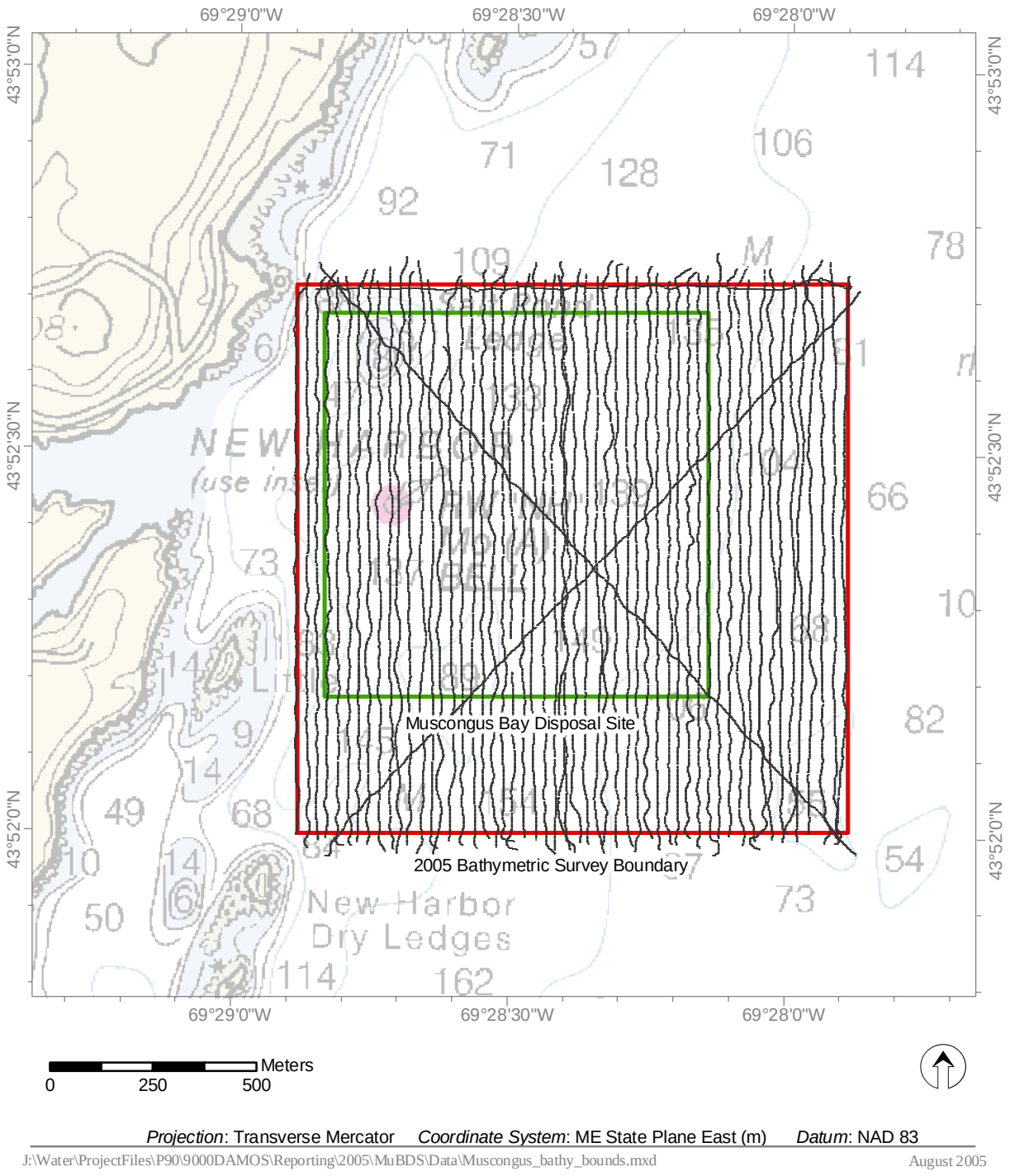


Figure 2-1. MuBDS with bathymetric survey boundary and survey lines indicated

the water depth data were converted to meters.

2.3 Sediment-Profile and Plan View Imaging

Sediment-profile imaging (SPI) is a monitoring technique used to provide data on the physical characteristics of the seafloor as well as the status of the benthic biological community. The technique involves deploying an underwater camera system that photographs a cross section of the sediment-water interface. Computer-aided analysis of the resulting images provides a set of standard measurements that can be compared between different locations and different surveys. The DAMOS Program has successfully used this technique for over 20 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites. A detailed discussion of SPI methodology and terminology is provided in Appendix A (modified from ENSR 2004).

2.3.1 SPI Data and Plan View Imaging Acquisition

The 2005 sediment-profile and plan view imaging survey design included 45 stations: 30 stations located within the disposal site and 15 stations located within three reference areas (Table 2-1, Figures 2-2 and 2-3). The 30 MuBDS stations were randomly located within the boundaries of MuBDS. As part of the 2005 survey, three reference areas were established, east of the disposal site (EREF), south of the disposal site (SREF), and southwest of the disposal site (SWREF), to provide a basis of comparison between MuBDS sediment conditions and the ambient sediment conditions in Muscongus Bay. Five stations were randomly selected within a 300-m radius of each of the three reference areas.

The sediment-profile and plan view imaging survey was initiated 6 September 2005 aboard the *F/V Shanna Rose* and completed 7 September 2005. At each station, the vessel was positioned at the target coordinates, and the camera was deployed within a defined station tolerance of 10 m. In addition to the SPI camera, a plan view camera was affixed to the frame and deployed simultaneously. Three replicate SPI and plan view images were collected at each of the 45 stations.

The SPI system consisted of a metal frame, a Benthos Model 3731 pressure housing, a prism chamber, a Nikon digital camera, and a Benthos Model 2216 Deep Sea Pinger. The camera was mounted inside the pressure housing and sat atop a wedged-shaped prism with a front faceplate and back mirror (see Figure 2-4). The mirror was mounted at a 45-degree angle to reflect the profile of the sediment-water interface. As the prism penetrated the seafloor, a trigger activated a time-delay circuit that fired the internal strobe to obtain a cross-sectional image of the upper 20 cm of the sediment column. The pinger was attached to the camera and output a constant signal of one ping per second. Upon discharge of the camera strobe, the ping rate doubled for 10 seconds. The doubling of the ping rate provided confirmation that a successful image had been obtained.

Table 2-1

MuBDS Sediment-Profile and Plan View Image Target Sampling Locations

Area	Station	Latitude (N)	Longitude (W)	Area	Station	Latitude (N)	Longitude (W)
MuBDS	Musc-01	43° 52.404'	69° 28.556'		Musc-30	43° 52.244'	69° 28.700'
	Musc-02	43° 52.381'	69° 28.481'		Musc-31	43° 52.657'	69° 28.492'
	Musc-03	43° 52.616'	69° 28.612'	Reference	EREF-01	43° 52.34'	69° 27.046'
	Musc-04	43° 52.538'	69° 28.658'		EREF-02	43° 52.327'	69° 27.264'
	Musc-05	43° 52.292'	69° 28.283'		EREF-03	43° 52.486'	69° 27.372'
	Musc-06	43° 52.280'	69° 28.333'		EREF-04	43° 52.535'	69° 27.053'
	Musc-07	43° 52.291'	69° 28.586'		EREF-05	43° 52.398'	69° 27.355'
	Musc-08	43° 52.499'	69° 28.508'		SWREF-01	43° 51.244'	69° 29.204'
	Musc-09	43° 52.266'	69° 28.499'		SWREF-02	43° 51.124'	69° 29.222'
	Musc-10	43° 52.537'	69° 28.228'		SWREF-03	43° 51.367'	69° 29.165'
	Musc-11	43° 52.498'	69° 28.585'		SWREF-04	43° 51.281'	69° 29.254'
	Musc-12	43° 52.452'	69° 28.768'		SWREF-05	43° 51.208'	69° 29.272'
	Musc-13	43° 52.344'	69° 28.768'		SWREF-06	43° 51.150'	69° 29.237'
	Musc-14	43° 52.410'	69° 28.411'		SWREF-07	43° 51.313'	69° 29.182'
	Musc-15	43° 52.472'	69° 28.832'		SREF-01	43° 50.755'	69° 28.408'
	Musc-16	43° 52.634'	69° 28.286'		SREF-02	43° 50.723'	69° 28.567'
	Musc-17	43° 52.230'	69° 28.398'		SREF-03	43° 50.616'	69° 28.613'
	Musc-18	43° 52.335'	69° 28.519'		SREF-04	43° 50.709'	69° 28.306'
	Musc-19	43° 52.390'	69° 28.322'		SREF-05	43° 50.656'	69° 28.290'
	Musc-20	43° 52.670'	69° 28.177'		SREF-06	43° 50.236'	69° 28.836'
	Musc-21	43° 52.457'	69° 28.653'		SREF-07	43° 50.269'	69° 28.800'
	Musc-22	43° 52.561'	69° 28.384'		SREF-08	43° 50.313'	69° 28.778'
	Musc-23	43° 52.636'	69° 28.240'		SREF-09	43° 50.325'	69° 28.888'
	Musc-24	43° 52.369'	69° 28.645'		SREF-10	43° 50.257'	69° 28.914'
	Musc-25	43° 52.291'	69° 28.766'				
	Musc-26	43° 52.441'	69° 28.275'				
	Musc-27	43° 52.396'	69° 28.181'				
	Musc-28	43° 52.279'	69° 28.656'				
	Musc-29	43° 52.486'	69° 28.698'				

Notes: Coordinate system NAD83; shading indicates station was eliminated due to rocky substrate.

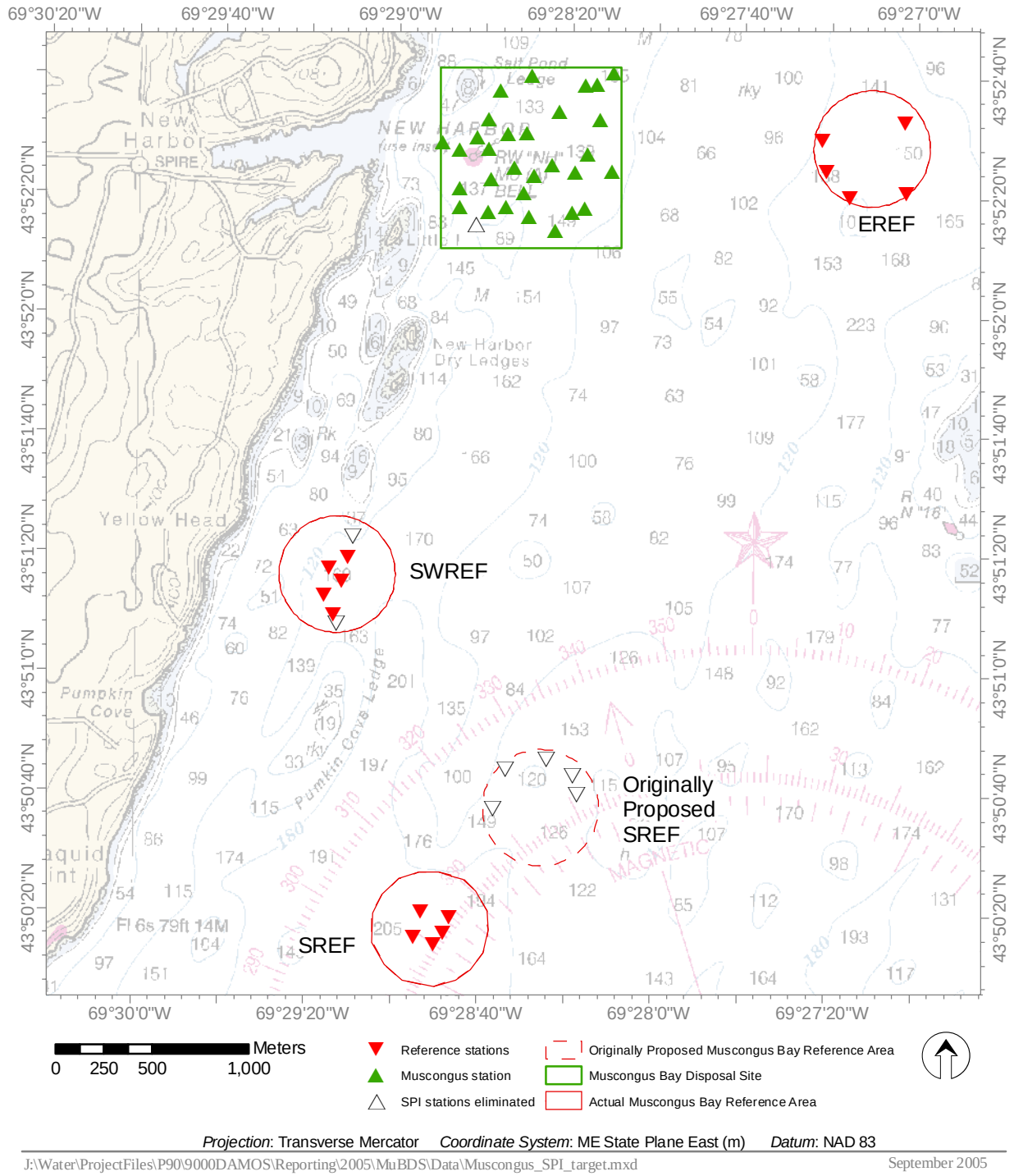
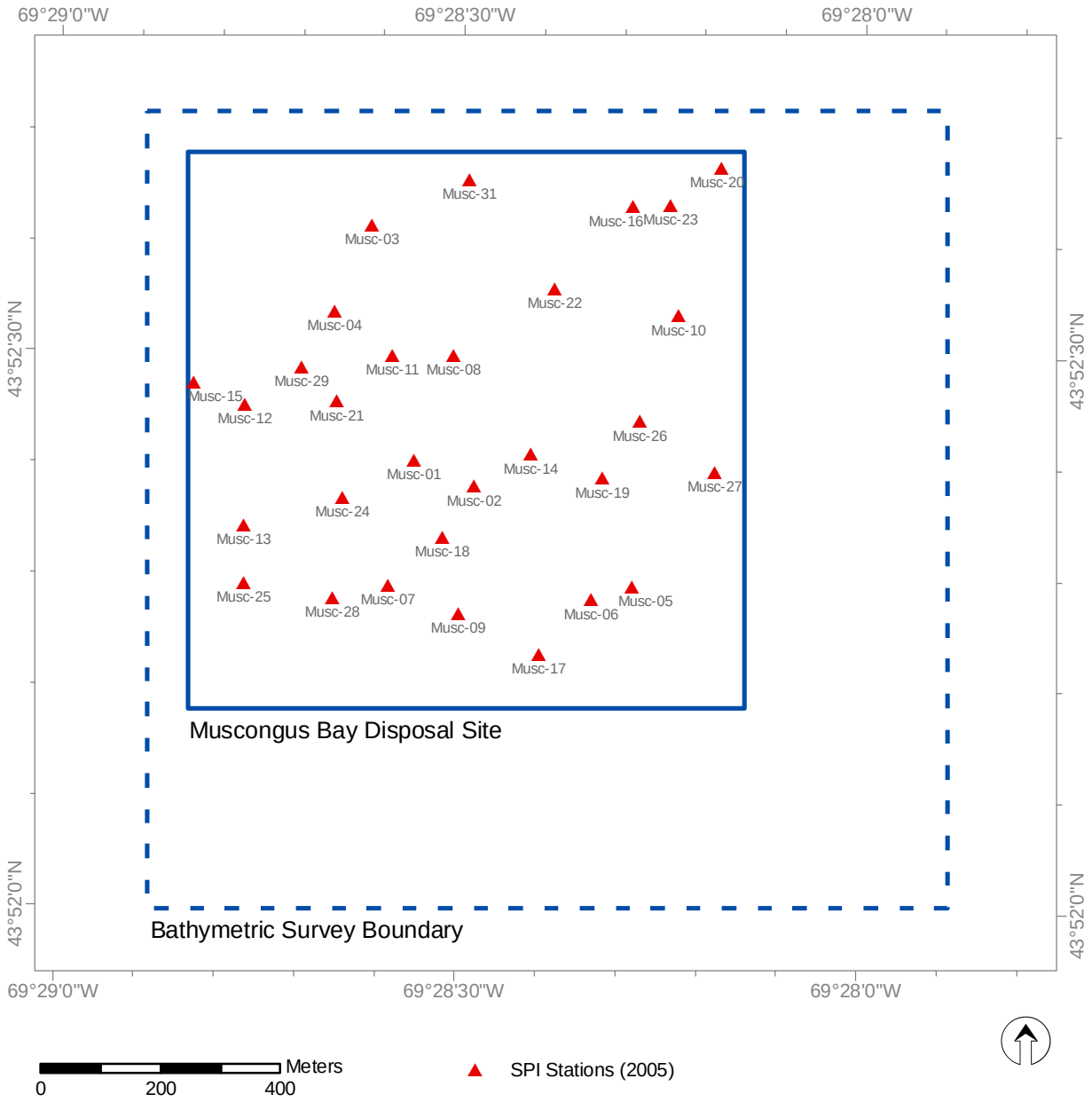


Figure 2-2. Originally proposed and actual SPI station locations at the Muscongus Bay Disposal Site in September, 2005 (see text for discussion)



Projection: Transverse Mercator *Coordinate System*: ME State Plane East (m) *Datum*: NAD 83

Figure 1 J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2005\MuBDS\Draft\Figures\Muscongus_SPI.mxd March 2006

Figure 2-3. SPI station locations surveyed at the Muscongus Bay Disposal Site in September, 2005

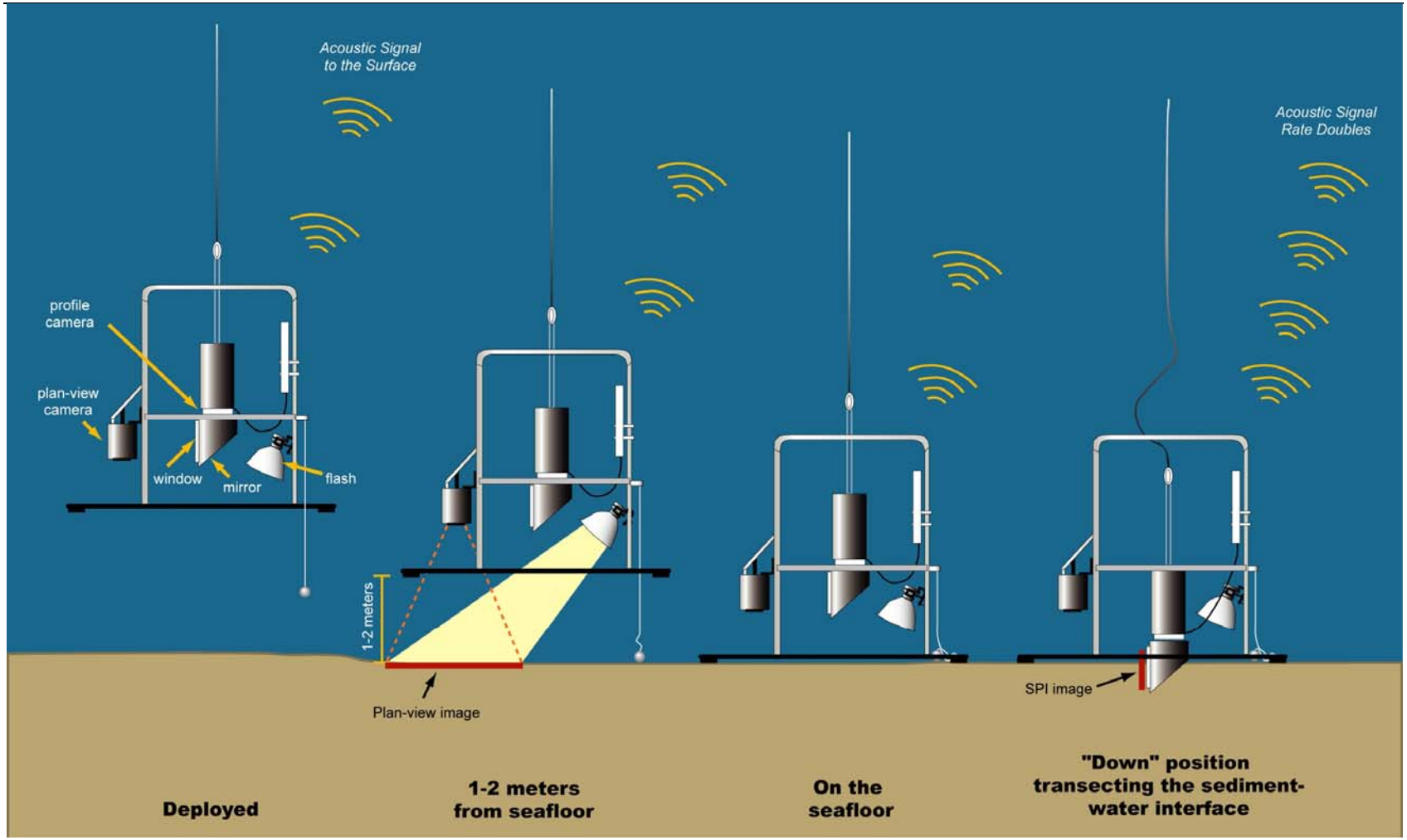


Figure 2-4. Operation of the combined Ocean Imaging Model 3731 sediment profile and Model DSC-6000 plan view camera.

Due to the rocky nature of the seafloor within MuBDS, the camera was not able to penetrate the sediment at Station MuBDS-30. As a result, Station MuBDS-30 was replaced by Station MuBDS-31 (see Figures 2-2 and 2-3). Hard bottom was also present at all five stations within the SREF area and two stations within the SWREF area. As a result, a new south reference area was selected approximately 900 meters southwest of the original SREF area and two additional stations were chosen within the SWREF area (see Figure 2-2).

Plan-view underwater images were also collected at each station sampled with the sediment-profile camera. An Ocean Imaging Model DSC6000 plan-view underwater camera (PUC) system was attached to the Model 3731 camera frame and used to collect plan-view photographs of the seafloor surface; both SPI and PUC photographs were collected during each "drop." (Figure 2-4). The PUC system consisted of Nikon D-70 encased in a titanium housing, a 24 VDC autonomous power pack, a 500W strobe, and a bounce trigger. A weight was attached to the bounce trigger with a stainless steel cable so that the weight hung below the camera frame. As the camera apparatus was lowered to the seafloor, the weight attached to the bounce trigger contacted the seafloor prior to the camera frame hitting the bottom and triggered the PUC (Figure 2-4). The length of the stainless steel trigger cable was adjusted for changing conditions in water clarity within the site. All PUC images were collected as 6 megapixel raw Nikon Exchange Format (*.nef) files and converted to Joint Photographic Expert Group (*.jpg) files after the survey.

2.3.2 SPI Data Analysis

Computer-aided analysis of each SPI image provided measurement of the following standard set of parameters:

Sediment Type: The sediment grain size major mode and range were estimated visually from the images using a grain-size comparator at a similar scale. Results were reported using the phi scale; a conversion to other grain size scales is provided in Appendix A. The presence and thickness of disposed dredged material was also assessed by inspection of the images.

Penetration Depth: The depth to which the camera penetrates into the seafloor was measured to provide an indication of the sediment density or bearing capacity. The penetration depth can range from a minimum of 0 cm (i.e., no penetration on hard substrates) to a maximum of 20 cm (full penetration on very soft substrates).

Surface Boundary Roughness: Surface boundary roughness is a measure of the vertical relief of features at the sediment-water interface in the sediment-profile image. Surface boundary roughness was determined by measuring the vertical distance between the highest and lowest points of the sediment-water interface. The surface boundary roughness (sediment surface relief) measured over the width of sediment-profile images typically ranges from 0 to 4 cm, and may be related to physical structures (e.g., ripples, rip-up

structures, mud clasts) or biogenic features (e.g., burrow openings, fecal mounds, foraging depressions). Biogenic roughness typically changes seasonally and is related to the interaction of bottom turbulence and bioturbational activities.

Apparent Redox Potential Discontinuity (RPD) Depth: RPD provides a measure of the integrated time history of the balance between near surface oxygen conditions and biological reworking of sediments. Sediment particles exposed to oxygenated waters oxidize and lighten in color to brown or light grey. As the particles are moved downwards by biological activity or buried, they are exposed to reduced oxygen concentrations in subsurface pore waters and their oxic coating slowly reduces, changing color to dark grey or black. When biological activity is high, the RPD depth increases; when it is low or absent, the RPD depth decreases. The RPD depth was measured by assessing sediment color and reflectance boundaries within the images.

Infaunal Successional Stage: Infaunal successional stage is a measure of the biological community inhabiting the seafloor. Current theory holds that organism-sediment interactions in fine-grained sediments follow a predictable sequence of development after a major disturbance (such as dredged material disposal), and this sequence has been divided subjectively into three stages (Rhoads and Germano 1982, 1986). Successional stage was assigned by assessing what types of species or organism-related activities were apparent in the images.

Additional components of the SPI analysis included calculation of means and ranges for the parameters listed above and mapping individual values as well as noting and describing any distinctive biological or sedimentological features seen in images.

2.4 Statistical Analysis

The objective of the SPI and plan-view camera survey at MuBDS was to assess the benthic community status within the site relative to reference conditions. Traditionally, this objective has been addressed using point null hypotheses of the form "There is no difference in benthic conditions between the Reference area and Disposal Mound." More recently, DAMOS has adopted an approach using bioequivalence or interval testing which is believed to be more informative than the point null hypothesis test of "no difference" (McBride 1999, Schuirmann 1987, Zar 1996). There is always some small difference with the point null hypothesis, and the statistical significance of this difference may or may not be ecologically meaningful. Also, without an associated power analysis, the results of this type of point null hypothesis provides an incomplete picture of the results.

In this application of bioequivalence (interval) testing, we have chosen to specify the null hypothesis as one that presumes the difference is great, i.e., an inequivalence hypothesis (McBride 1999). This is recognized as a 'proof of safety' approach because rejection of this inequivalence null hypothesis requires sufficient proof that the difference is actually small. The null and alternative hypotheses to be tested are:

$$H_0: \ d \leq -\delta \ \text{ or } \ d \geq \delta \text{ (presumes the difference is great)}$$
$$H_A: \ -\delta < d < \delta \text{ (requires proof that the difference is small)}$$

Where d is the difference between reference mean and a site mean. If the null hypothesis is rejected, then we conclude that the two means are not different from one another within $\pm\delta$ units. The size of δ should be determined from historical data and/or best professional judgment to identify a maximum difference that is within background variability/noise and is therefore not ecologically meaningful. To determine the size of δ for RPD values, we looked at both the mean value and range of values from the reference areas for the expected difference between different areas on an undisturbed seafloor. Based on these data, we determined that a realistic δ for RPD would be 1 cm.

The test of this interval hypothesis can be broken down into two one-sided tests (TOST) (McBride 1999 after Schuirmann 1987) which are based on the normal distribution, or on Student's *t*-distribution when sample sizes are small and variances must be estimated from the data (the typical situation). The statistics used to test the interval hypotheses shown here are based on such statistical foundations as the Central Limit Theorem (CLT) and basic statistical properties of random variables. A simplification of the CLT says that the mean of any random variable is normally distributed. Linear combinations of normal random variables are also normal so a linear function of means is also normally distributed. When a linear function of means is divided by its standard error the ratio follows a *t*-distribution with degrees of freedom associated with the variance estimate. Hence, we can use the t-distribution to construct a confidence interval around any linear function of means.

(a) If this confidence interval contains a specified δ then the true difference is greater than δ (H_0 above);

(b) if δ is not contained in this interval then the true difference is less than δ (H_A above) and you conclude equivalence within δ units.

In this sampling design, there are actually four distinct areas; three of which are categorized as reference locations, so the difference equation of interest is defined as the average of the three reference means minus the mound mean (disposal site mean for this project since there is no mound), or

$$[⅓ (\text{Mean}_{\text{EREF}} + \text{Mean}_{\text{SREF}} + \text{Mean}_{\text{SWREF}}) - \text{Mean}_{\text{Mound}}]$$

The three reference areas collectively represent ambient conditions, but if there are mean differences among these three areas then pooling them into a single reference group will increase the variance beyond true background variability. The effect of keeping the three reference areas separate has no effect on the grand reference mean (when n is equal among these areas) but it will maintain the variance as a true background variance for each individual population with a constant mean. If the three reference areas have similar means and variances, then they may be pooled for a simpler test on the difference between 15 reference and 30 mound stations.

The difference equation, $\hat{d}$, for the comparisons of interest are:

$$⅓ (\text{Mean}_{\text{EREF}} + \text{Mean}_{\text{SREF}} + \text{Mean}_{\text{SWREF}}) - \text{Mean}_{\text{SITE}} \quad \textit{or} \quad \text{Mean}_{\text{Pooled Refs}} - \text{Mean}_{\text{SITE}}$$

and the standard error of each difference is calculated knowing that the variance of a sum is the sum of the variances for independent variables, or:

$$se(\hat{d}) = \sqrt{\sum_j \left(S_j^2 c_j^2 / n_j \right)}$$

Where:

c_j = coefficients for the *j* means in the difference equation, $\hat{d}$ (i.e., for the difference equation shown above, the coefficients are 1/3, 1/3, 1/3, and -1 for areas EREF, SREF, SWREF, SITE, respectively; or they would be 1 and -1 for Reference and SITE, respectively, if the three reference areas can be pooled).

S_j^2 = variance for the *j*th area. If we can assume equal variances, a single pooled variance estimate can be substituted for each group, equal to the mean square error from the ANOVA.

n_j = number of replicates for the *j*th area (5, 5, 5, 30, for areas EREF, SREF, SWREF, SITE, respectively, or 15 and 30 for both areas if reference areas can be pooled).

The inequivalence null hypothesis is rejected if the confidence interval on the difference of means, $\hat{d}$, contains neither +δ nor -δ, i.e., if

$$T_a = \frac{\hat{d} - (-\delta)}{se(\hat{d})} \geq t_{\alpha,\upsilon} \quad \text{and} \quad T_b = \frac{\hat{d} - (+\delta)}{se(\hat{d})} \leq -t_{\alpha,\upsilon}$$

Where:

$\hat{d}$ = observed difference in means between the reference and mound (disposal site)

$t_{\alpha,\upsilon}$ = upper 100α percentile of a Student's t-distribution with υ degrees of freedom

$se(\hat{d})$ = standard error of the difference.

υ = degrees of freedom for the standard error. If a pooled variance estimate is used, the degrees of freedom is equal to the sum of the sample sizes for all groups included in the $\hat{d}$ minus the number of groups; if separate variance estimates are used, degrees of freedom are calculated based on the Brown and Forsythe estimation (Zar 1996, p. 189).

Equality of the reference areas were graphically evaluated using boxplots and summary statistics. Validity of the normality and equal variance assumptions were tested using Shapiro-Wilk's test for normality on the area residuals (α=0.05) and Levene's test for equality of variances among the four areas (α =0.05). If normality was not rejected but equality of variances was, then the variance for the difference equation was based on separate variances for each group. If systematic deviations from normality were identified, then the data were transformed to approximate normality, if possible.

3.0 RESULTS

3.1 Bathymetry

Figure 3-1 presents the MuBDS bathymetric data. Water depths at MuBDS ranged from 5 to 46 meters (16 to 151 feet). There was a prominent ledge in the northwest corner of the site, where depths were as shallow as 5 meters (16 feet). A deep channel ran from the northeast corner of the site to the south where it split into two channels ranging in depth from 40 to 50 meters (131 to 164 feet). Less prominent ledges were present along the sides of the channel in the southern portion of the site. No disposal mounds were evident within MuBDS.

3.2 Sediment-Profile Imaging

The intent of the SPI survey was not to delineate the distribution of dredged material, but to assess the recolonization status and benthic habitat characteristics of representative areas within the disposal site and at the reference areas. A complete set of all SPI results can be found in Appendix B and are summarized in Tables 3-1 and 3-2.

3.2.1 Muscongus Bay Disposal Site: Physical Sediment Characteristics

The sediment grain-size major mode at most of the stations sampled within the disposal site was $\geq$ 4 phi; most of the seafloor within the disposal site boundary was composed of fine-grained mud (Table 3-1; Figure 3-2). A few of the stations near the disposal site boundary (Stations 3, 4, 12, 15, 27) had a slightly higher component of fine sand (Figure 3-3), and one station (Station 16) had a surface layer of silty, very fine sand over mud (Figure 3-4). While some stations initially appeared to have some signature of historic dredged material present, it became apparent that these subsurface pockets of reduced material were due to natural processes, because they were also present in images from the reference stations (Figure 3-4). The only station that did have atypical sediments was Station 25 (Figure 3-5); not only were the sediments much softer than those found at other locations (initial sampling attempts resulted in camera prism over-penetration), the sediments at this one location also appeared to have a higher organic content than any of the others sampled within the site. Other than Station 25, there was no distinct sedimentary layer or unique optical marker identifying the presence of the historic dredged material; any trace of that material had been eliminated by biological mixing combined with natural depositional and/or transport processes. There also was no evidence of low dissolved oxygen in the overlying water or subsurface methane generation at any of the locations sampled.

Camera prism penetration varied quite a bit across the site, ranging from 8.1 cm (on the sandy sediments at Station 3) to 18.2 cm (Table 3-1; Figure 3-6). Small-scale boundary roughness ranged from 0.7 to 2.3 cm across the site, with an overall site average of 1.3 cm (Appendix B); the origin of this small-scale topography was primarily due to biogenic processes by resident infauna (Appendix B).

Table 3-1

Summary of SPI Results for MuBDS Stations, September 2005

Area	Station	Station Average RPD (cm)	Station Average Penetration (cm)	Station Grain Size	Successional Stage
Disposal	Musc-01	3.66	17.11	>4	Stage 1 on 3
	Musc-02	3.77	18.23	>4	Stage 1 on 3
	Musc-03	2.56	8.14	3-2	Stage 1 on 3
	Musc-04	2.27	12.12	3-2	Stage 1 on 3
	Musc-05	4.32	17.76	>4	Stage 1 on 3
	Musc-06	3.39	15.40	>4	Stage 1 on 3
	Musc-07	3.78	15.80	>4	Stage 1 on 3
	Musc-08	3.90	14.63	>4	Stage 1 on 3
	Musc-09	3.54	15.87	>4	Stage 1 on 3
	Musc-10	3.89	14.78	>4	Stage 1 on 3
	Musc-11	3.60	16.74	>4	Stage 1 on 3
	Musc-12	2.54	8.57	3-2	Stage 1 on 3
	Musc-13	3.39	14.60	>4	Stage 1 on 3
	Musc-14	3.68	17.42	>4	Stage 1 on 3
	Musc-15	2.20	9.11	3-2	Stage 1 on 3
	Musc-16	3.71	16.02	4-3/>4	Stage 1 on 3
	Musc-17	2.82	17.12	>4	Stage 1 on 3
	Musc-18	3.27	15.20	>4	Stage 1 on 3
	Musc-19	4.93	15.81	>4	Stage 1 on 3
	Musc-20	3.42	15.49	>4	Stage 1 on 3
	Musc-21	3.57	15.74	>4	Stage 1 on 3
	Musc-22	3.73	15.40	>4	Stage 1 on 3
	Musc-23	3.77	15.56	>4	Stage 1 on 3
	Musc-24	4.22	13.88	>4	Stage 1 on 3
	Musc-25	3.54	13.82	>4	Stage 1 on 3
	Musc-26	4.05	17.54	>4	Stage 1 on 3
	Musc-27	2.89	11.65	3-2	Stage 1 on 3
	Musc-28	4.62	14.29	>4	Stage 1 on 3
	Musc-29	3.92	15.27	>4	Stage 1 on 3
	Musc-31	4.00	16.31	>4	Stage 1 on 3
AVG		3.56	14.85		
MIN		2.20	8.14		
MAX		4.93	18.23		

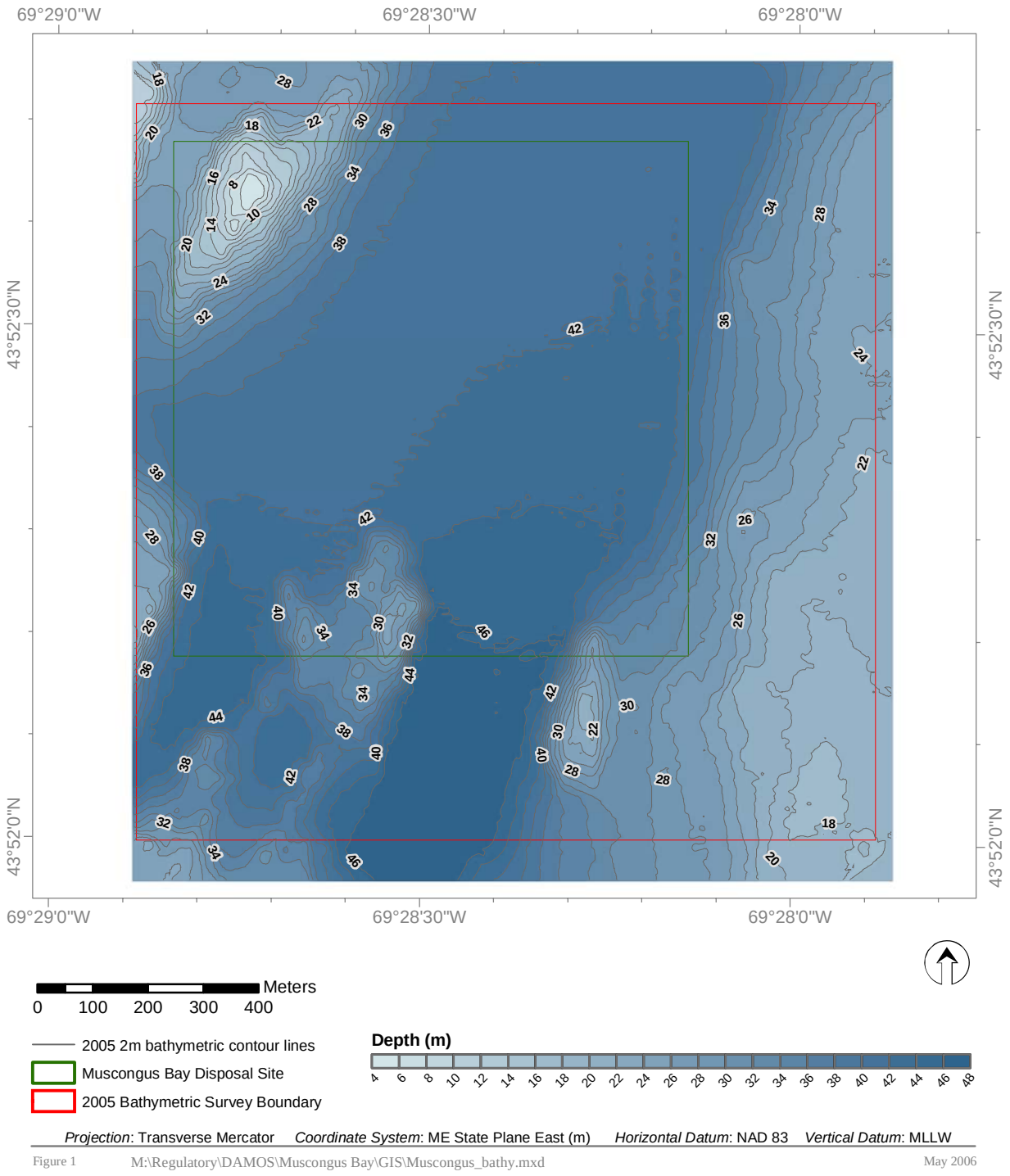


Figure 3-1. Bathymetric contour map of MuBDS – July 2005

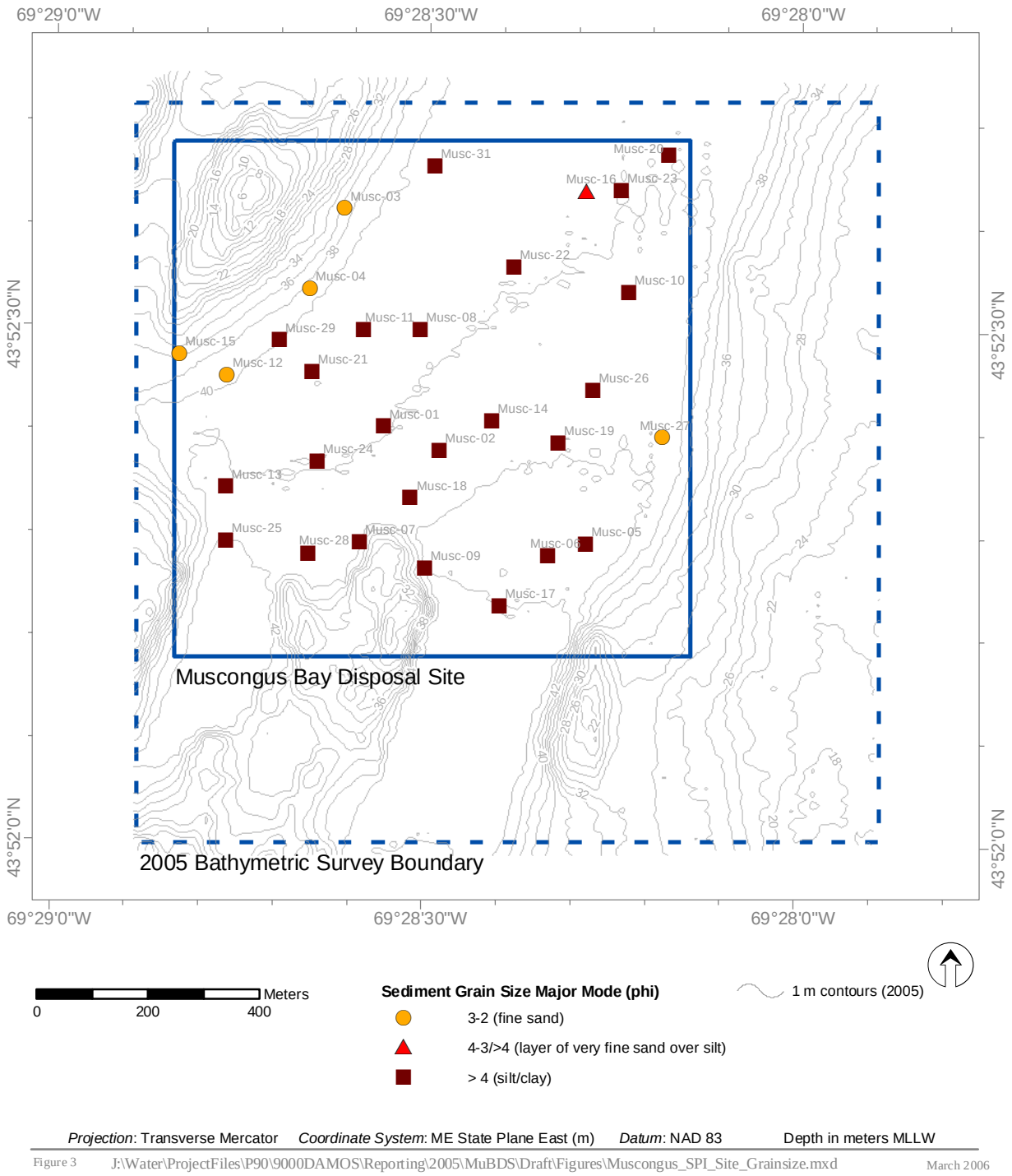


Figure 3-2. Distribution of sediment grain-size major mode (phi units)

Figure 4a J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2005\MuBDS\Draft\Figures\SPI-Images\MUSC_026-C.mxd

Figure 4b J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2005\MuBDS\Draft\Figures\SPI-Images\MUSC_027-D.mxd

Figure 3-3. The sediment grain-size major mode at Station 26 (left) was > 4 phi, representative of most of the stations at the disposal site. A small handful of stations had a higher fine sand component, as can be seen in this image from Station 27 (right).

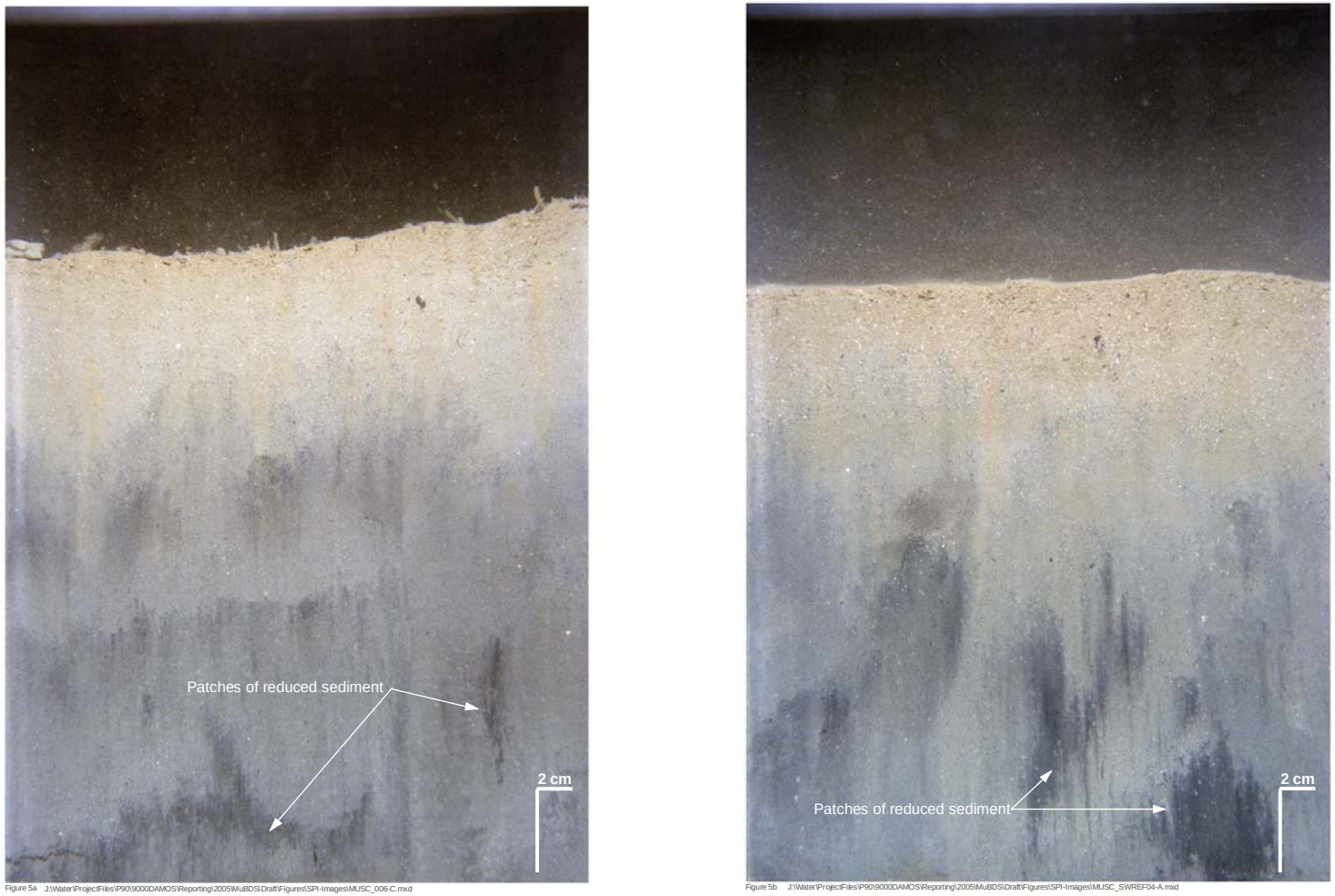


Figure 3-4. The layers of reduced subsurface sediment in this profile image from Station 6 (left) have an optical signature typical of historical dredged material deposits, but similar subsurface sediments are also found at the reference stations, as seen in this image from SWREF 04 (right)

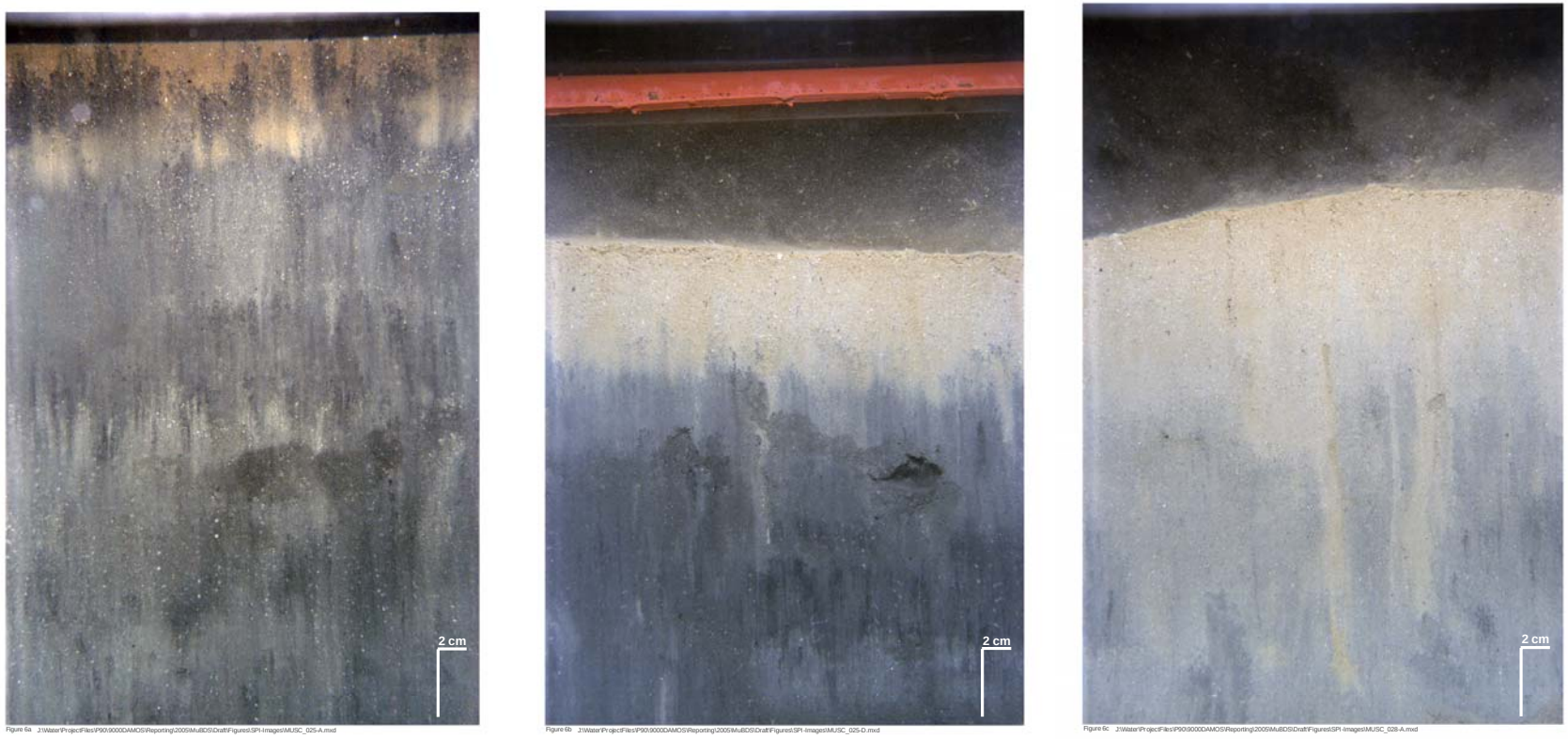


Figure 3-5. While initial sampling attempts resulted in camera prism over penetration at Station 25 (left), adjusted camera settings allowed collection of usable profile images (middle). Note the darker color of the subsurface sediments at this location as compared with those at nearby Station 28 (right), indicating a higher organic content in the sediments at Station 25.

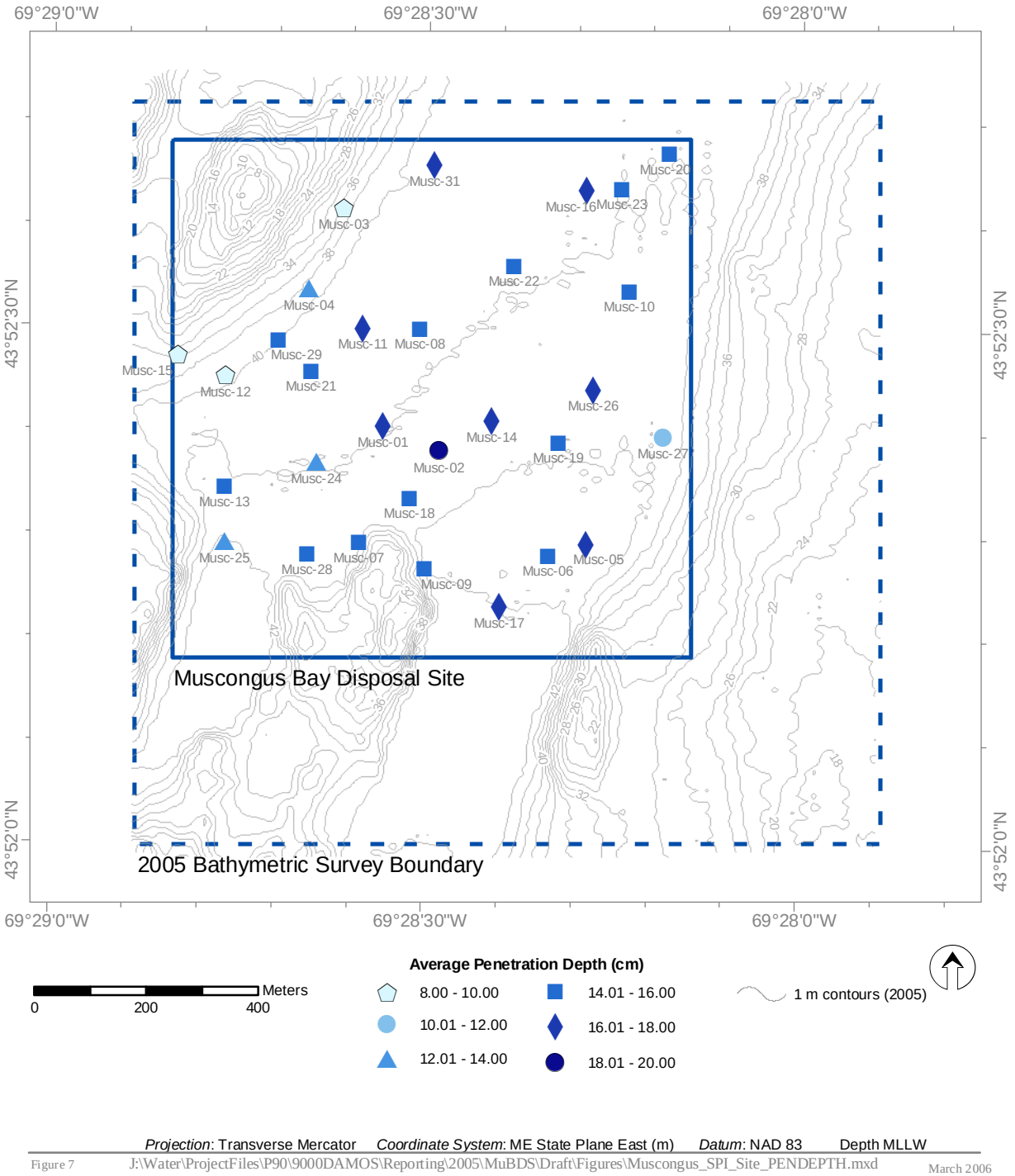


Figure 3-6. Distribution of average camera prism penetration depth (cm) at MuBDS

3.2.2 Biological Conditions and Benthic Recolonization

The mean apparent RPD values at the stations within the disposal site ranged from 2.2 to 4.9 cm, with an overall site average of 3.6 cm (Table 3-1; Figure 3-7). The distribution of infaunal successional stages within the disposal site was mapped in Figure 3-8; every station showed evidence of mature infaunal successional communities with deposit-feeding Stage 3 taxa present (Table 3-1; Appendix B). The sediments throughout the site showed deep biological reworking (Figure 3-9) with maximum feeding void depths ranging from 5.7 to 19.0 cm (Appendix B).

3.2.3 Reference Areas Physical Sediment Characteristics

Sediments at the three reference areas were uniformly well-sorted, fine-grained sediments with a grain-size major mode of $\geq$ 4 phi (Table 3-2; Figure 3-10). There was relatively small variation in camera prism penetration given the sediment grain-size uniformity, with average penetration values ranging from 13.1 to 18.8 cm (Table 3-2; Figure 3-11). As with the stations at the disposal site, there was no evidence of low dissolved oxygen or sedimentary methane. Small-scale boundary roughness values ranged from 0.5 to 2.1 cm (Appendix B), with their origin due mainly to biogenic processes (Appendix B).

3.2.4 Biological Conditions

The average apparent RPD among stations at the reference areas ranged from 2.3 to 5.2 cm (Figure 3-12), with an overall ambient seafloor or reference area average of 4.0 cm (Table 3-2). Similar to all the stations sampled within the disposal area, all replicate images from the reference areas showed evidence of Stage 3 taxa, with maximum biological mixing depth ranging from 7.5 to 19.2 cm (Table 3-2; Appendix B). Evidence of intense subsurface particle advection from resident infauna was also seen in images from the reference stations (Figure 3-13).

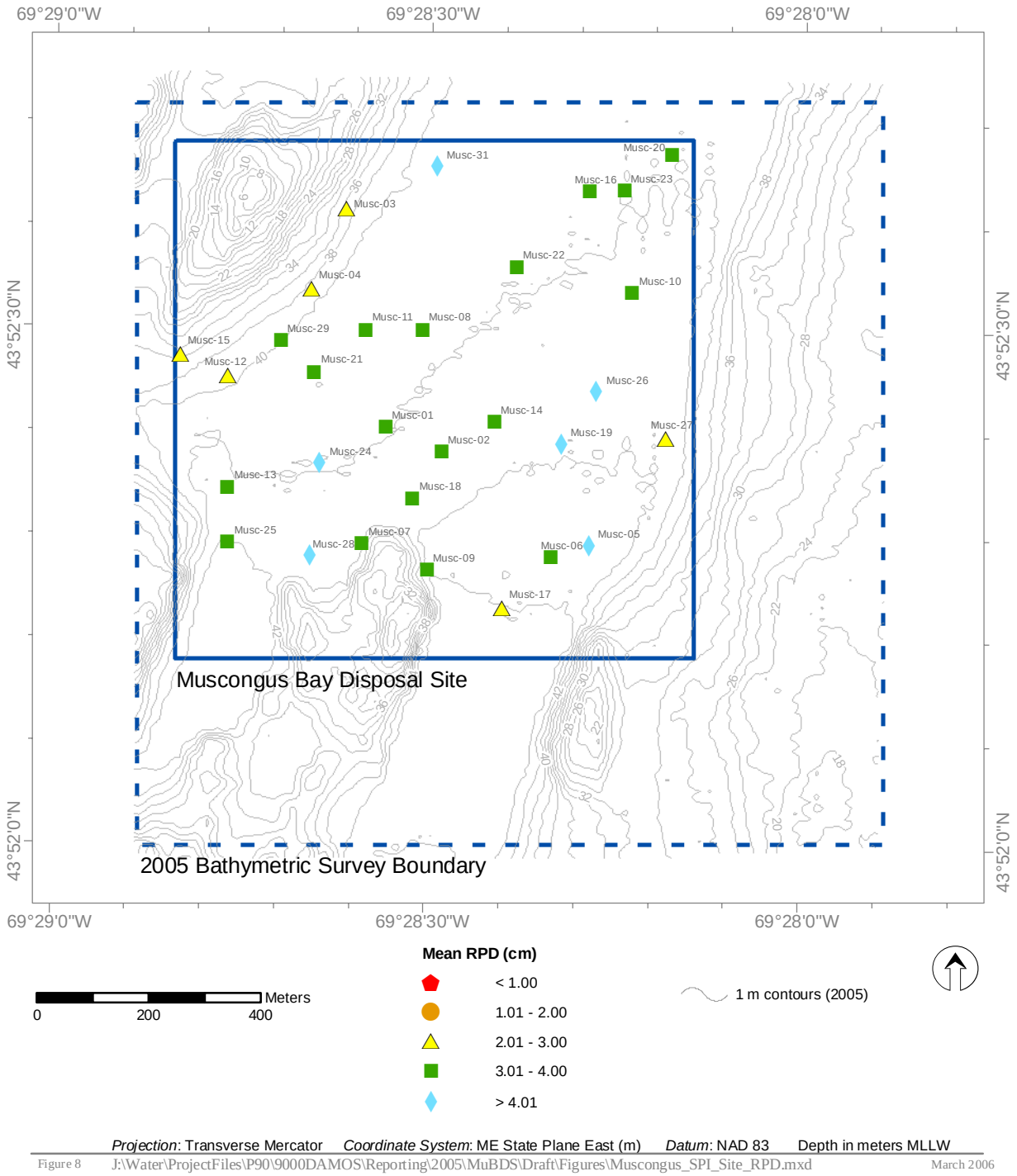


Figure 3-7. Distribution of mean apparent RPD depth (cm) at MuBDS

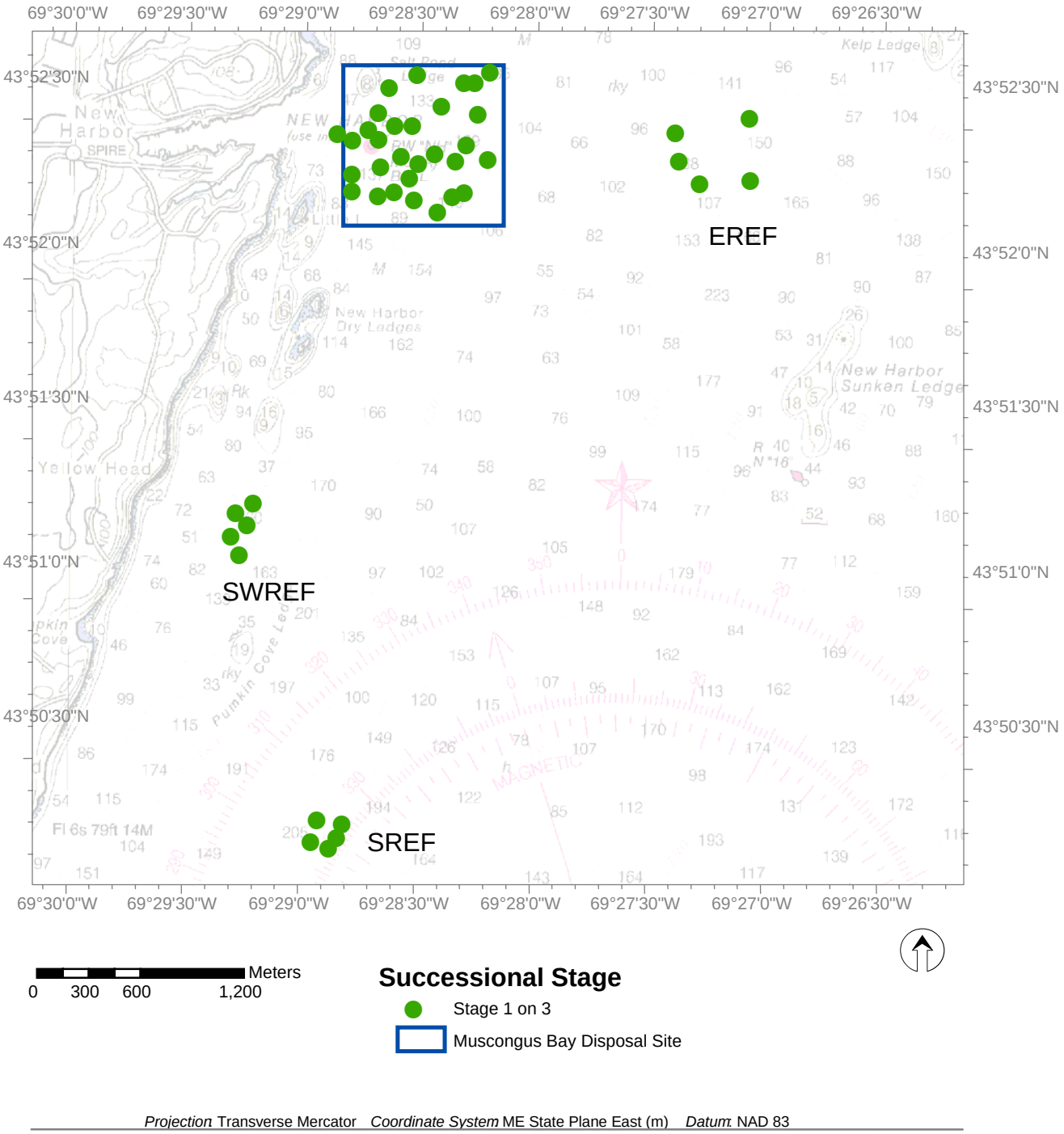


Figure 3-8. Map of infaunal successional stages at the reference stations and MuBDS

Figure 3-9. The deep biogenic reworking seen in these profile images from Station 29 (left) and Station 2 (right) are excellent examples of why any evidence of past depositional events has been obliterated more than 40 years after the last disposal event

Table 3-2

Summary of SPI Results for MuBDS Reference Stations, September 2005

Area	Station	Station Average RPD (cm)	Station Average Penetration (cm)	Station Grain Size	Successional Stage
Reference	EREF-01	5.04	17.27	>4	Stage 1 on 3
	EREF-02	4.53	16.10	>4	Stage 1 on 3
	EREF-03	4.59	14.76	>4	Stage 1 on 3
	EREF-04	3.16	17.44	>4	Stage 1 on 3
	EREF-05	4.71	16.91	>4	Stage 1 on 3
	SREF-06	4.61	18.03	>4	Stage 1 on 3
	SREF-07	4.98	17.95	>4	Stage 1 on 3
	SREF-08	3.83	18.83	>4	Stage 1 on 3
	SREF-09	4.71	16.80	>4	Stage 1 on 3
	SREF-10	5.19	18.64	>4	Stage 1 on 3
	SWREF-01	3.58	14.95	>4	Stage 1 on 3
	SWREF-04	2.83	14.54	>4	Stage 1 on 3
	SWREF-05	2.32	14.89	>4	Stage 1 on 3
	SWREF-06	2.51	14.35	>4	Stage 1 on 3
	SWREF-07	2.99	13.11	>4	Stage 1 on 3
AVG		3.97	16.28		
MIN		2.32	13.11		
MAX		5.19	18.83		

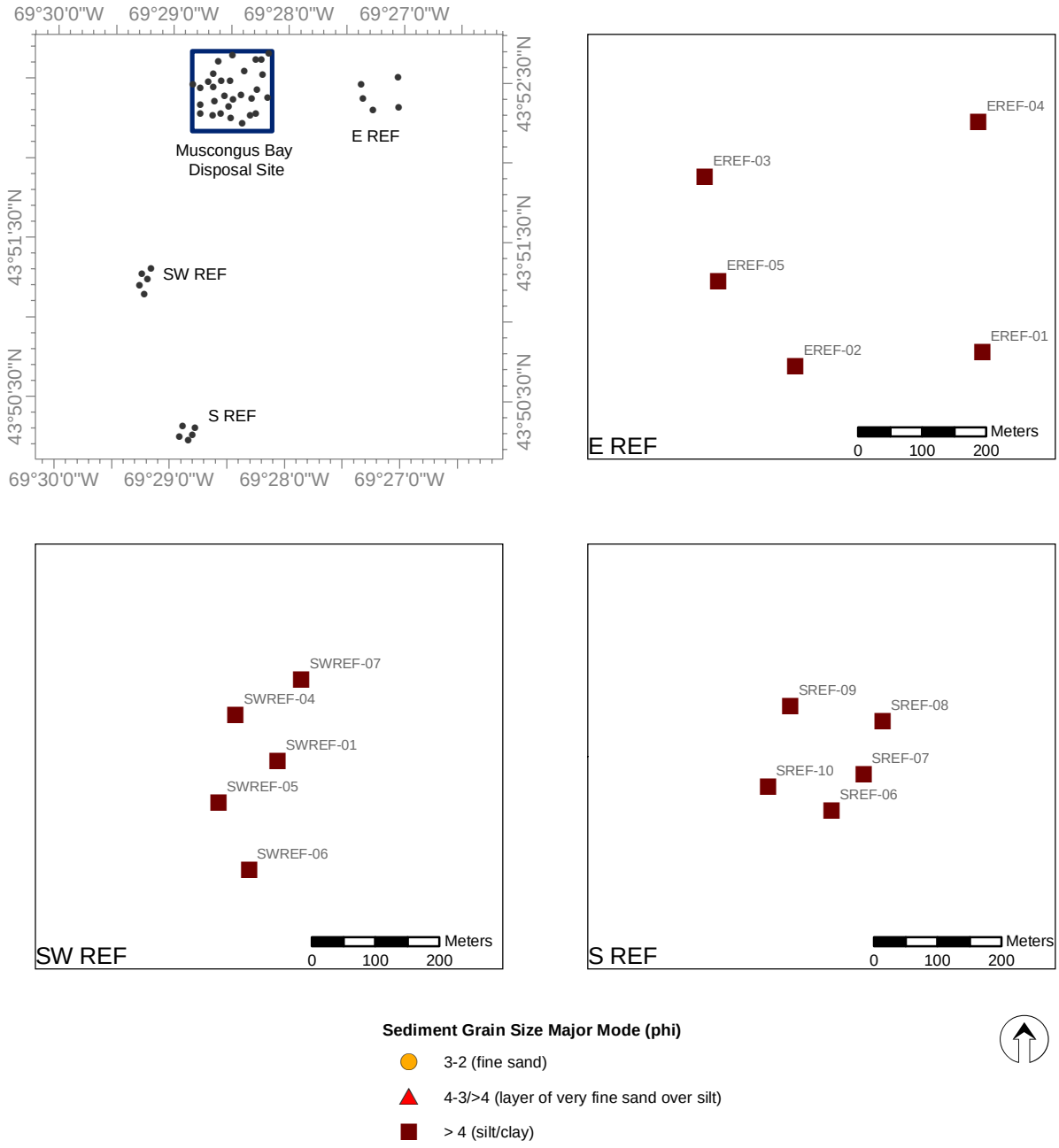


Figure 3-10. Distribution of sediment grain-size major mode at Muscongus Bay reference sites

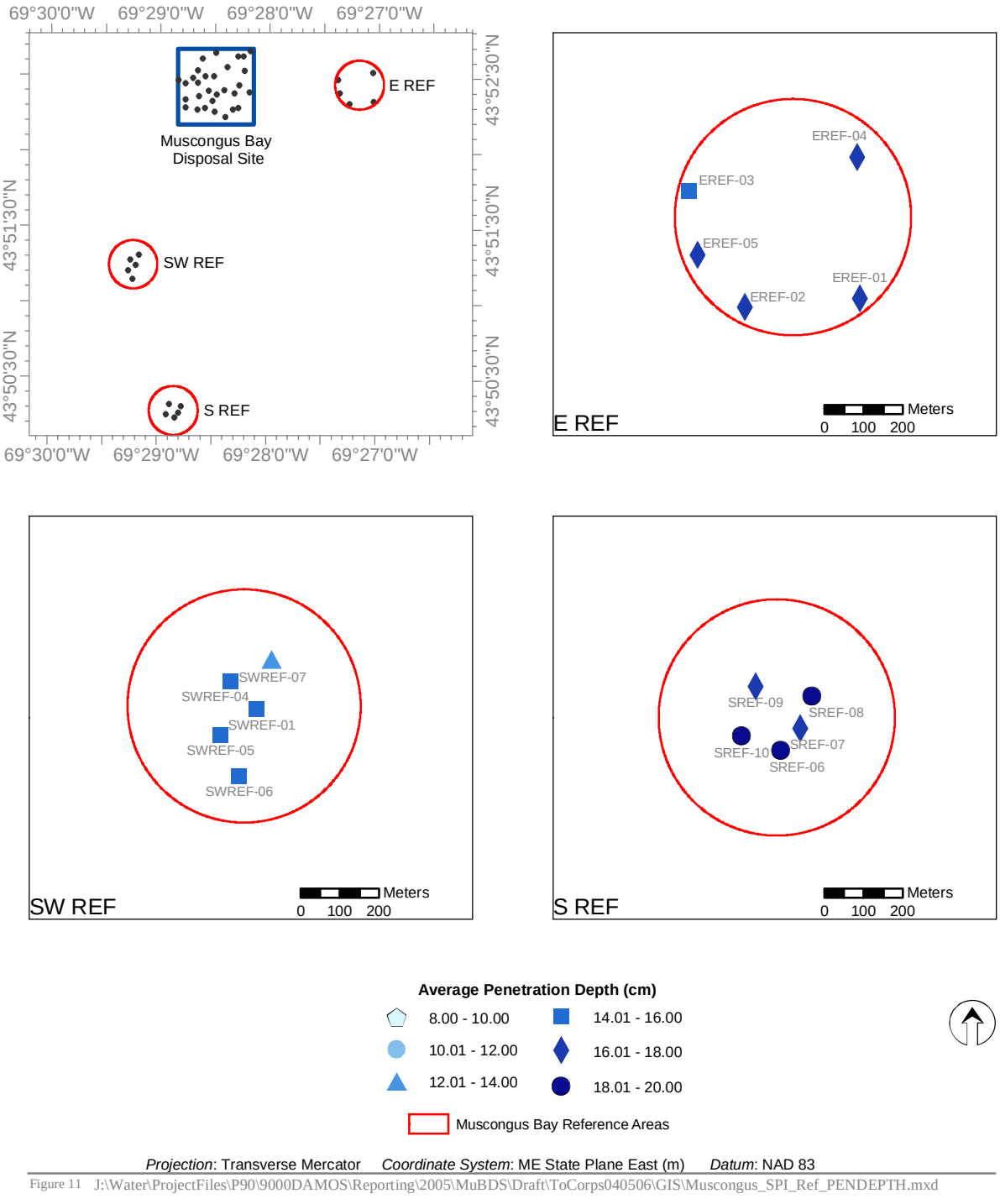


Figure 3-11. Distribution of average camera prism penetration depth (cm) at the Muscongus Bay reference sites

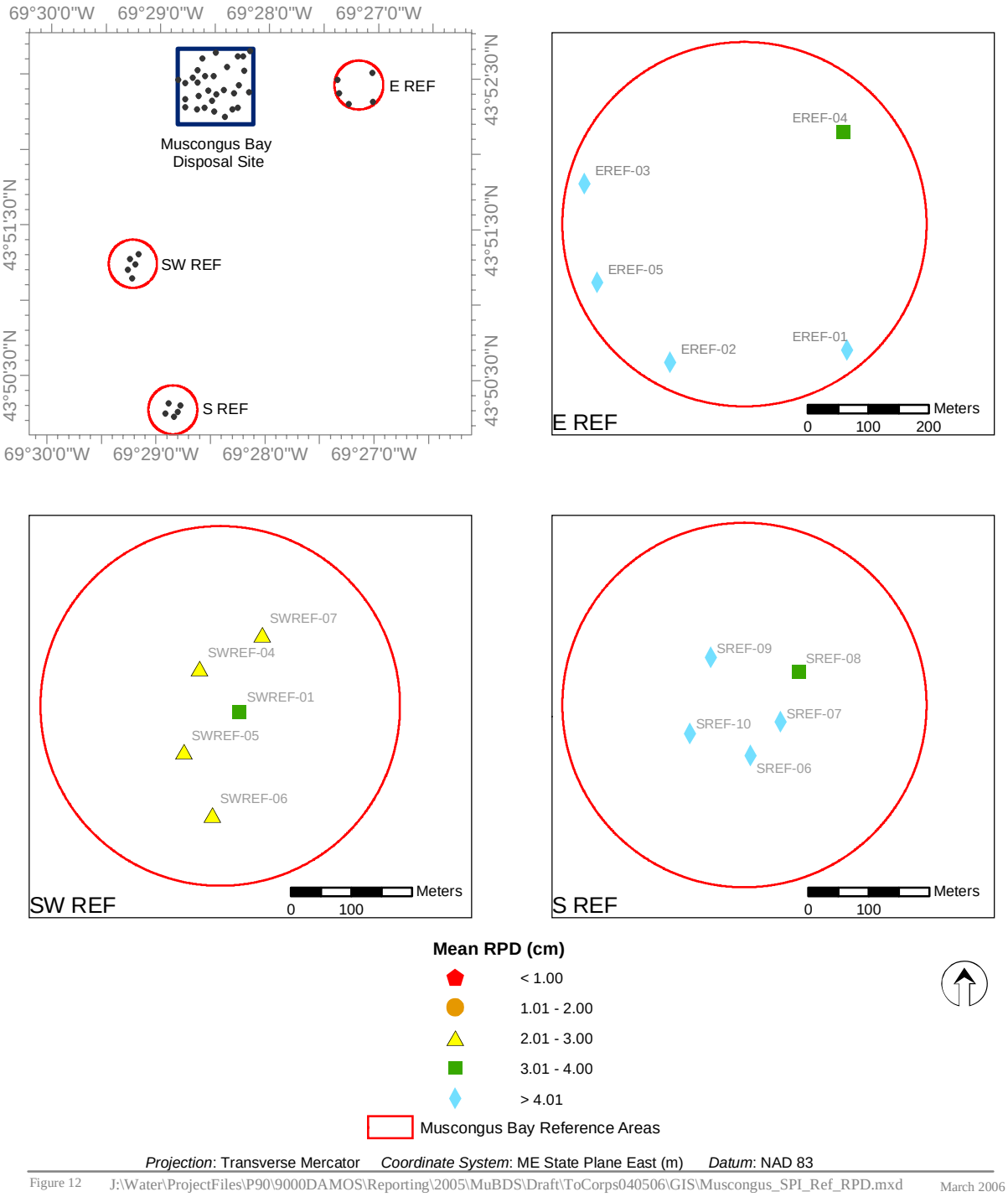


Figure 3-12. Distribution of mean apparent RPD depths (cm) at the Muscongus Bay reference sites

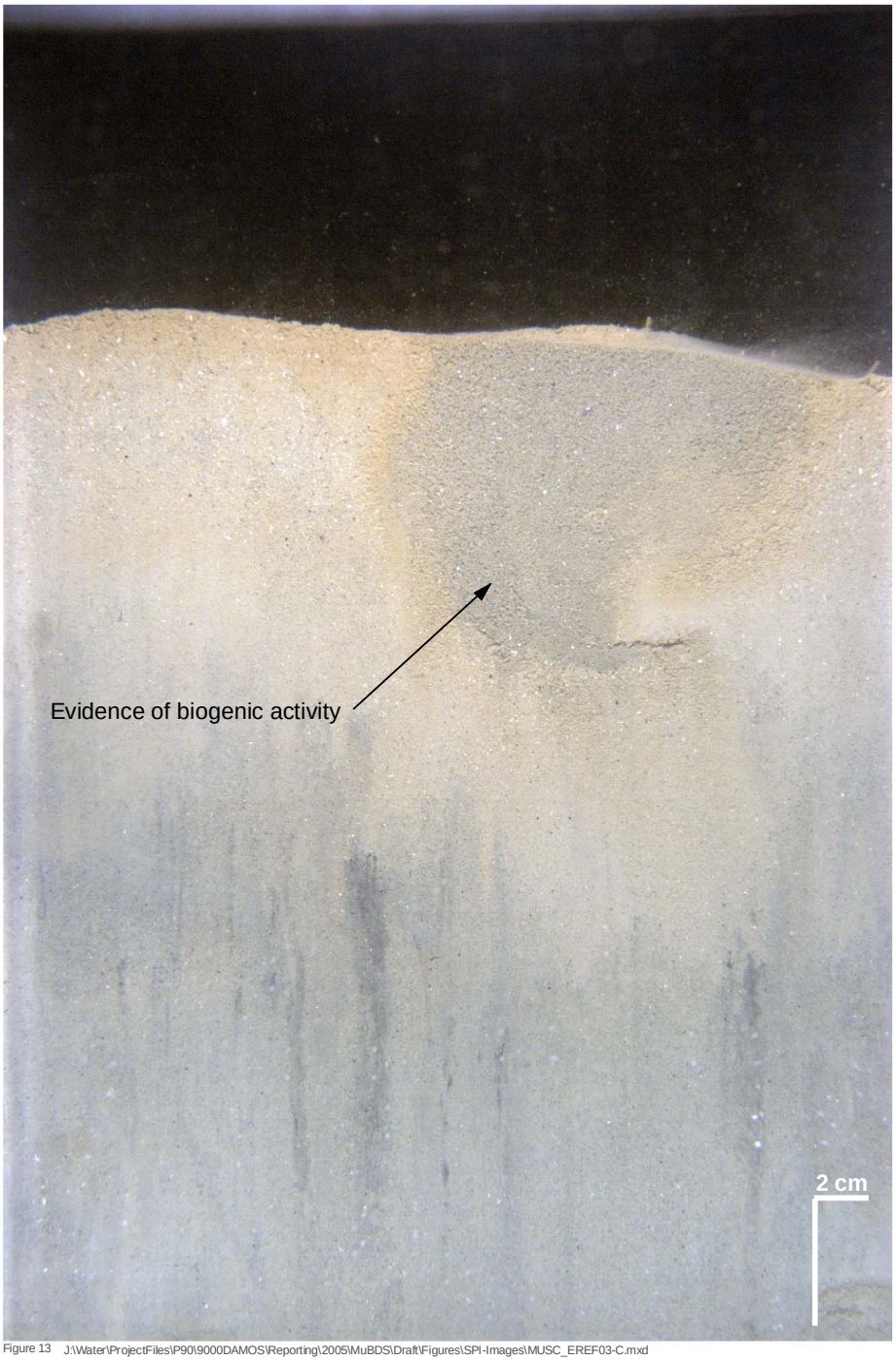


Figure 13 J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2005\MuBDS\Draft\Figures\SPI-Images\MUSC_EREF03-C.mxd

Figure 3-13. Evidence of subsurface particle advection to the sediment-water interface is readily visible in this profile image from EREF Station 3. Intense biogenic mixing of the upper sediment layers was frequently evident in the images at the reference station as well as in those from the disposal site

3.2.5 Comparison of Mound to Reference Conditions

Mean RPD Variable

The three reference areas were different (Table 3-3; Figure 3-14) in both RPD means and variances. This is depicted in Figure 3-14 the box and whisker plot which shows the RPD median surrounded by a box confined by the upper and lower quantile (75 and 25 percentile respectively). The whisker lengths are the upper and lower extreme values and then any outliers are plotted. Consequently, the three reference areas were treated as separate groups to compare the disposal site to reference area conditions.

Table 3-3

Summary of Station RPD Means by Sampling Location

		Mean RPD (cm)	
Area	**N**	**Mean**	**Stdev**
Reference Locations			
EREF	5	4.40	0.73
SREF	5	4.66	0.52
SWREF	5	2.84	0.49
Mean:		3.97	
Disposal Site			
Muscongus	30	3.56	0.64

The data were approximately normally distributed. Even though the Shapiro-Wilk's test for normality was rejected ($p = 0.048$), the Quantile Quantile (Q-Q) plot was not that aberrant (Figure 3-15) and indicated that the rejection was due to a slightly longer left tail than expected under normality. The assumption of equal variances was not rejected by Levene's test ($p=0.90$). A pooled variance estimate was used to compute the variance for the difference equations.

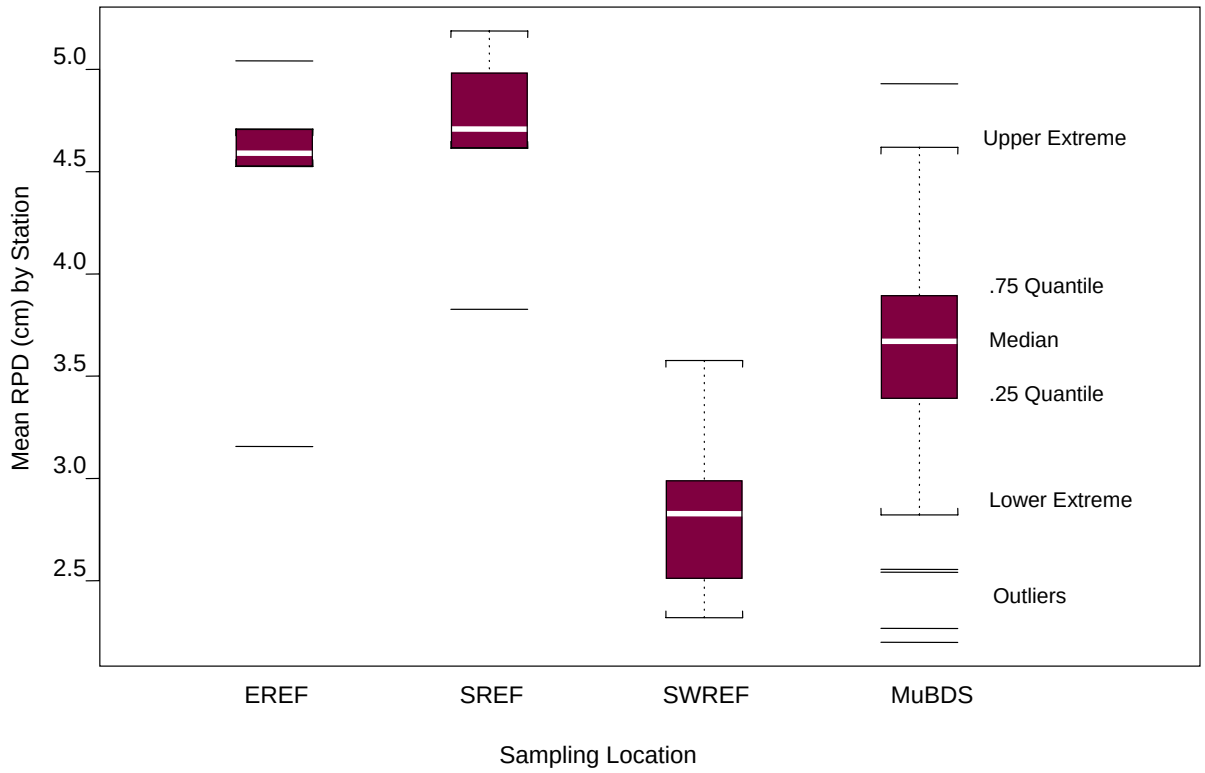


Figure 3-14. Box and whisker plot of mean apparent RPD values at the Muscongus Bay reference and disposal areas. The box contains the RPD mean confined by the upper and lower quantiles (75 and 25 percentile values respectively). The whisker lengths are the upper and lower extreme values

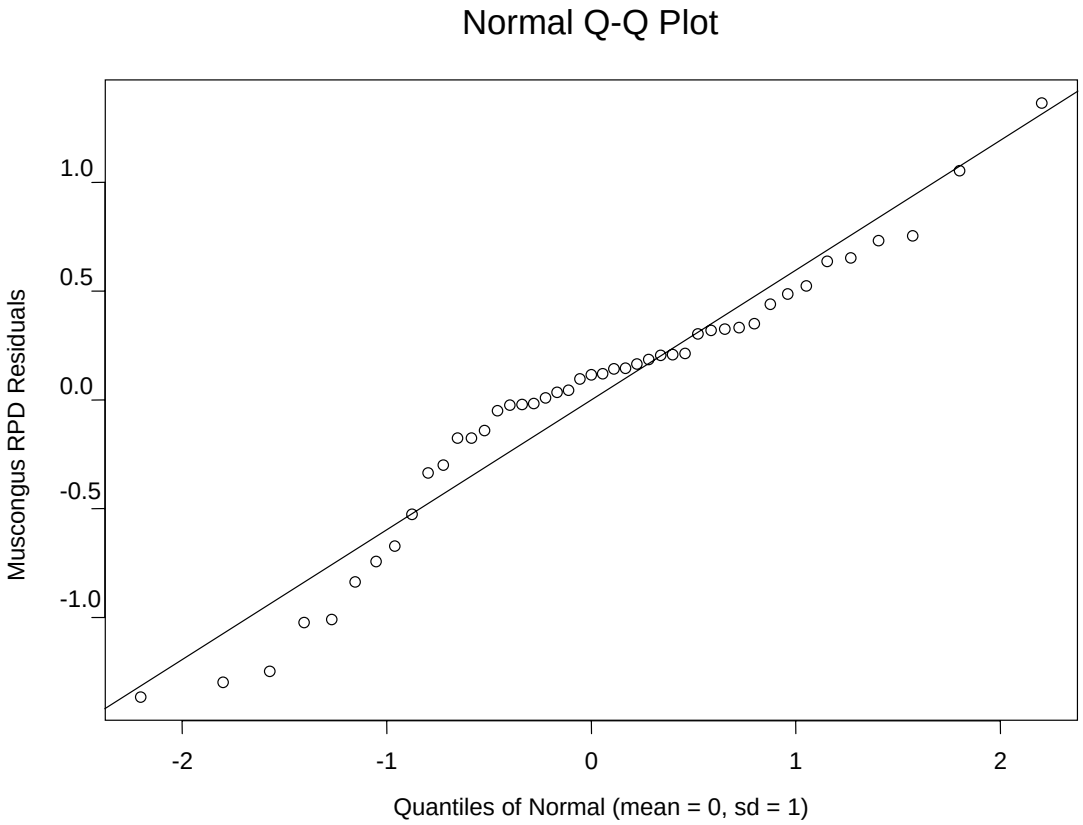


Figure 3-15. Normal probability plot for RPD depth area residuals (deviations of each observation from its area mean). (A Q-Q plot is a graphical technique for determining if two data sets come from populations with a common distribution. The normal Q-Q plot graphically compares the distribution of a given variable to the normal distribution (straight line)).

The specified δ value of ±1 (see Section 2.4) was outside of the 95% lower and upper confidence bounds for the observed difference (Table 3-4). This indicates that the true difference between the mean RPD values from the reference areas and mean RPD value from the disposal site was within 1 RPD unit (cm), and therefore the group means are equivalent within our definition of "ecologically meaningful". The infaunal successional stages were also uniform throughout the disposal site and all three reference areas, so there really is no meaningful difference between the benthic community on the disposal site or ambient seafloor.

Table 3-4

Summary Statistics and Results of Bioequivalence Testing for RPD Values

Difference Equation	Observed Difference ($\hat{d}$)	se($\hat{d}$)	df for se($\hat{d}$)	95% Lower Confidence Bound	95% Upper Confidence Bound
1. Ref – Mound	0.41	0.197	41	0.08	0.74

3.3 Plan View Imaging Results

Most of the plan view images taken at the Muscongus Bay Disposal Site and the reference areas were unusable because of extremely high turbidity levels in the water column; of the 135 images collected, only 18 images had discernible features (Appendix C). Maps depicting which stations had plan view images that had discernible features can be found in Figure 3-16 for the reference sites and Figure 3-17 for the disposal site. The features common to all the visible images were rippled bedforms on the sediment surface with evidence of large openings from burrowing invertebrates (Figure 3-18). Occasional fish and shrimp could be seen in a few of the images, and one station had what appeared to be juvenile squid swimming just above the bottom (Figure 3-19).

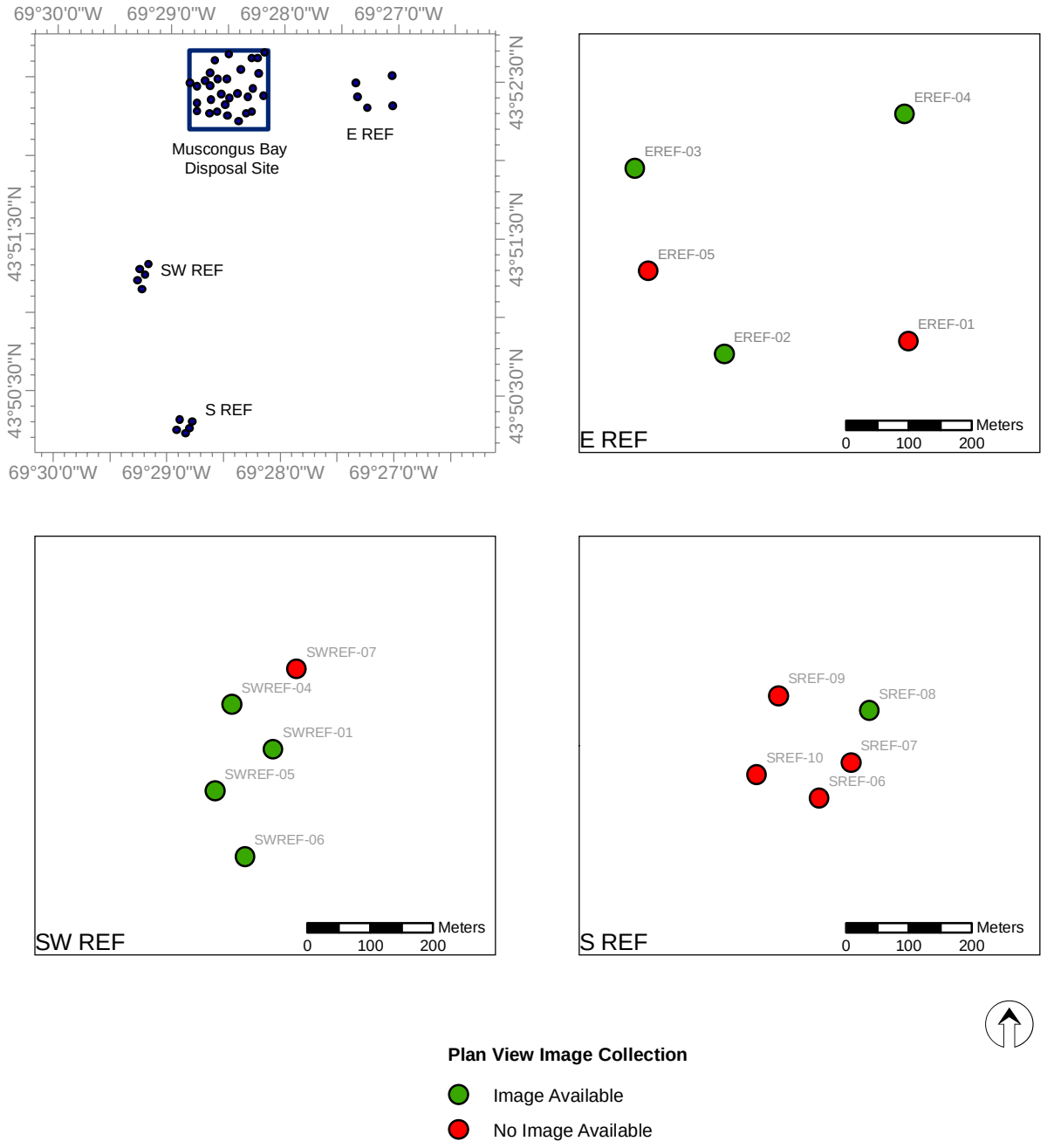


Figure 3-16. Plan view image availability at the Muscongus Bay reference sites

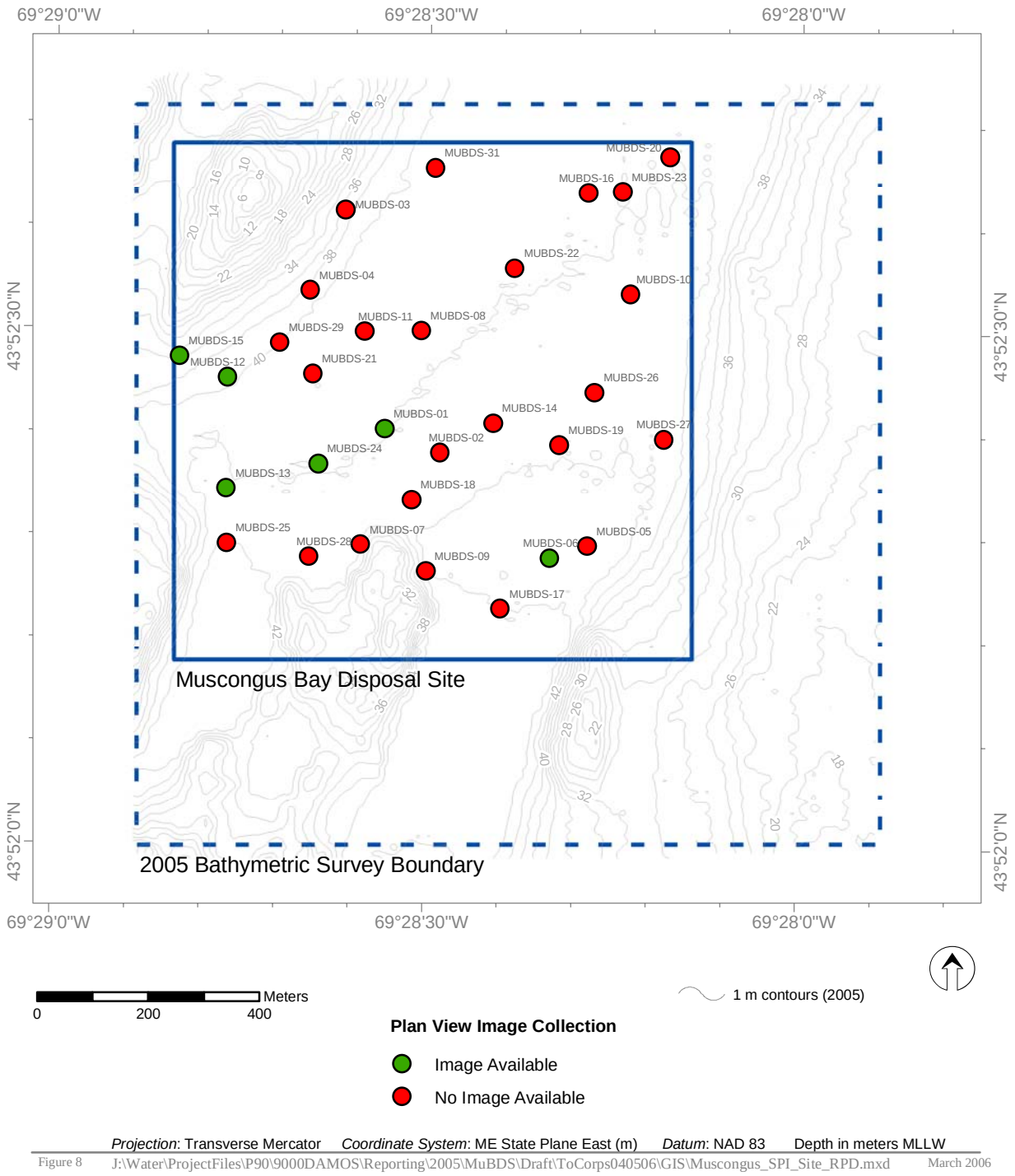


Figure 3-17. Plan view image availability at the Muscongus Bay Disposal Site

Figure 16a J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2005\MuBDS\Draft\Figures\PlanImages\MUSCPV_15-C.mxd

Figure 16b J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2005\MuBDS\Draft\Figures\PlanImages\MUSCPV_EFEF03-A.mxd

Figure 3-18. Plan view images from Station 15 (left) and EREF 03 (right) showing rippled silty sands with burrow openings on the sediment surface

Figure 17 J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2005\MuBDS\Draft\Figures\PlanImages\MUSCPV_EFEF02-C.mxd

Figure 3-19. The hummocked muddy sands seen in this image from EREF 02 has numerous burrows and tubes on the sediment surface as well as a collection of what appear to be juvenile squid in the overlying water

4.0 DISCUSSION

The objectives of the 2005 MuBDS survey were to document the distribution of dredged material and disposal mound morphology within Muscongus Bay Disposal Site and to assess the benthic status of the Muscongus Bay Disposal Site seafloor using sediment-profile and plan view imaging. Deteriorating sea conditions and fast-moving currents hindered use of the plan view camera. Poor water clarity at deeper stations resulted in mostly cloudy, unusable images.

The bathymetric survey showed no evidenced of a disposal mound at MuBDS. There are several possible explanations for the lack of a disposal mound. This could be attributed to the relatively small volume of material disposed (22,142 cubic meters) and the time elapsed since disposal. It is also possible that the disposal material was released from a moving vessel spreading the material through the disposal area as opposed to creating a mound. It is most likely that a mound could be detected after 40 years only if all the material was placed in one specific area. Historically the practice of dredged material disposal was confined only to a given area and not confined to a single point within that area.

Whatever dredged material was placed at MuBDS over 40 years ago has been thoroughly recolonized by resident benthic taxa and re-worked into the underlying substrate through bioturbational activities. There was no evidence of methanogensis or low dissolved oxygen conditions in the overlying water at any of the stations sampled, and there was also no discernible difference among stations at the disposal site and those in the reference areas either in terms of sediment type, depth of the apparent RPD, or infaunal successional stage. Given the length of time that has passed since disposal occurred at this site, these results are not surprising; benthic community recovery at most disposal sites that have been studied typically takes anywhere from 2 to 5 years (Bolam and Rees, 2003).

The three reference areas were statistically different in both RPD means and variance. The SW Reference area had the lowest mean ranges for RPD and camera penetration. Softer substrates tend to be related to the deeper camera penetrations and higher biological activity associated with larger RPD means. Interpretation of recovery from future disposal activity might be confounded by the different habitat types found among these three reference areas.

The data provided from the bathymetric and sediment-profile imaging surveys of MuBDS will provide a baseline to evaluate the effects of any future disposal events at this site.

5.0 CONCLUSIONS

• Dredged material placed at MuBDS over 40 years ago has been thoroughly recolonized by resident benthic taxa and re-worked into the bottom through the bioturbational activities of resident infauna to depths of 12 to 15 cm or more. There was no evidence of methanogensis or low dissolved oxygen conditions in the overlying water at any of the stations sampled.

• There were no unique or distinguishing characteristics of sediments within MuBDS as compared to those found in the reference areas. The sediments at MuBDS exhibited classic infaunal succession or complete benthic ecosystem recovery. There was no discernible difference among stations at the disposal site and those in the reference areas either in terms of sediment type, depth of the apparent RPD, or infaunal successional stage.

• The bathymetric survey revealed no obvious disposal mounds present at MuBDS.

• This survey will serve as a baseline dataset for future MuBDS disposal monitoring activities and comparisons to assess disposal related impacts.

6.0 REFERENCES

Bolam, S. G.; Rees, H. L. 2003. Minimizing Impacts of Maintenance Dredged Material Disposal in the Coastal Environment: A Habitat Approach. Environmental Management 32:171–188.

ENSR. 2004. Monitoring Survey at the Rockland Disposal Site, September 2003. DAMOS Contribution No. 156 (ENSR Report No. ENSR-09000-340-30C). U.S. Army Corps of Engineers, New England District, Concord, MA.

Fredette, T. J.; French, G. 2004. Understanding the physical and environmental consequences of dredged material disposal: history in New England and current perspectives. Marine Pollution Bulletin 49:93-102.

Germano, J. D.; Rhoads, D. C.; Lunz, J. D. 1994. An integrated, tiered approach to monitoring and management of dredged material disposal sites in the New England region. DAMOS Contribution No. 87. (SAIC Report No. 90/7575&234). U.S. Army Corps of Engineers, New England Division, Waltham, MA.

McBride, G. B. 1999. Equivalence tests can enhance environmental science and management. Austral. & New Zealand J. Statist. 41(1):19-29.

Schuirmann, D. J. 1987. A comparison of the two one-sided tests procedure and the power approach for assessing the equivalence of average bioavailability. J. Pharmacokinetics and Biopharmaceutics. 15:657-680.

Zar, J. H. 1996. Biostatisical Analysis, Third Edition. Prentice Hall, New Jersey. 662 pp.

INDEX

Appendix A

SEDIMENT-PROFILE IMAGING METHODOLOGY

(modified from ENSR 2004)

1.0 INTRODUCTION

Sediment-profile imaging (SPI) is a benthic sampling technique that enables investigators to evaluate the thickness and distribution of thin dredged material layers, delineate benthic disturbance gradients, and monitor the process of benthic recolonization following seafloor disturbance. SPI surveys obtain undisturbed, vertical cross-sectional images of the upper 15 to 20 cm of the seafloor. Each image is analyzed for a suite of standard parameters, including sediment grain size, penetration depth, surface boundary roughness, depth of apparent redox potential discontinuity (RPD), and infaunal successional stage.

2.0 SPI DATA ACQUISITION

Standard SPI system hardware includes a metal frame, pressure housing, a prism chamber, and a camera (Figure A-1). The hardware may also include a deep sea pinger or a video feed. The camera is mounted inside the pressure housing and sits atop a wedge-shaped prism with a front faceplate and a back mirror mounted at a 45-degree angle to reflect the profile of the sediment-water interface.

The frame is lowered through the water column in a controlled manner and, once on the bottom, the prism penetrates the seafloor (Figure A-2). A passive hydraulic piston ensures that the prism enters the bottom slowly (approximately 6 cm/sec) to minimize disturbance of the sediment-water interface. As the prism penetrates the seafloor, a trigger activates a time delay circuit that fires the internal strobe twice with each lowering to obtain two cross-sectional images of the upper 20 cm of the sediment column. After the two replicate images are obtained at the first location, the camera is raised about 2 or 3 m off the bottom to reposition it nearby and to allow the strobe to recharge. The strobe recharges within 5 seconds, and the camera is lowered again for another two images.

Three camera lowerings (six replicate images) are performed at each station. If a deep sea pinger is attached to the camera, a constant 12 kHz signal of one ping per second is output. Upon discharge of the camera strobe, the ping rate doubles for 10 seconds (Figure A-2). Sound from the pinger is audible on-deck and provides scientists with confirmation that a successful image has been obtained. If the system is equipped with a video feed, real-time plan view observation of the frame on the seafloor is performed concurrent with image collection.

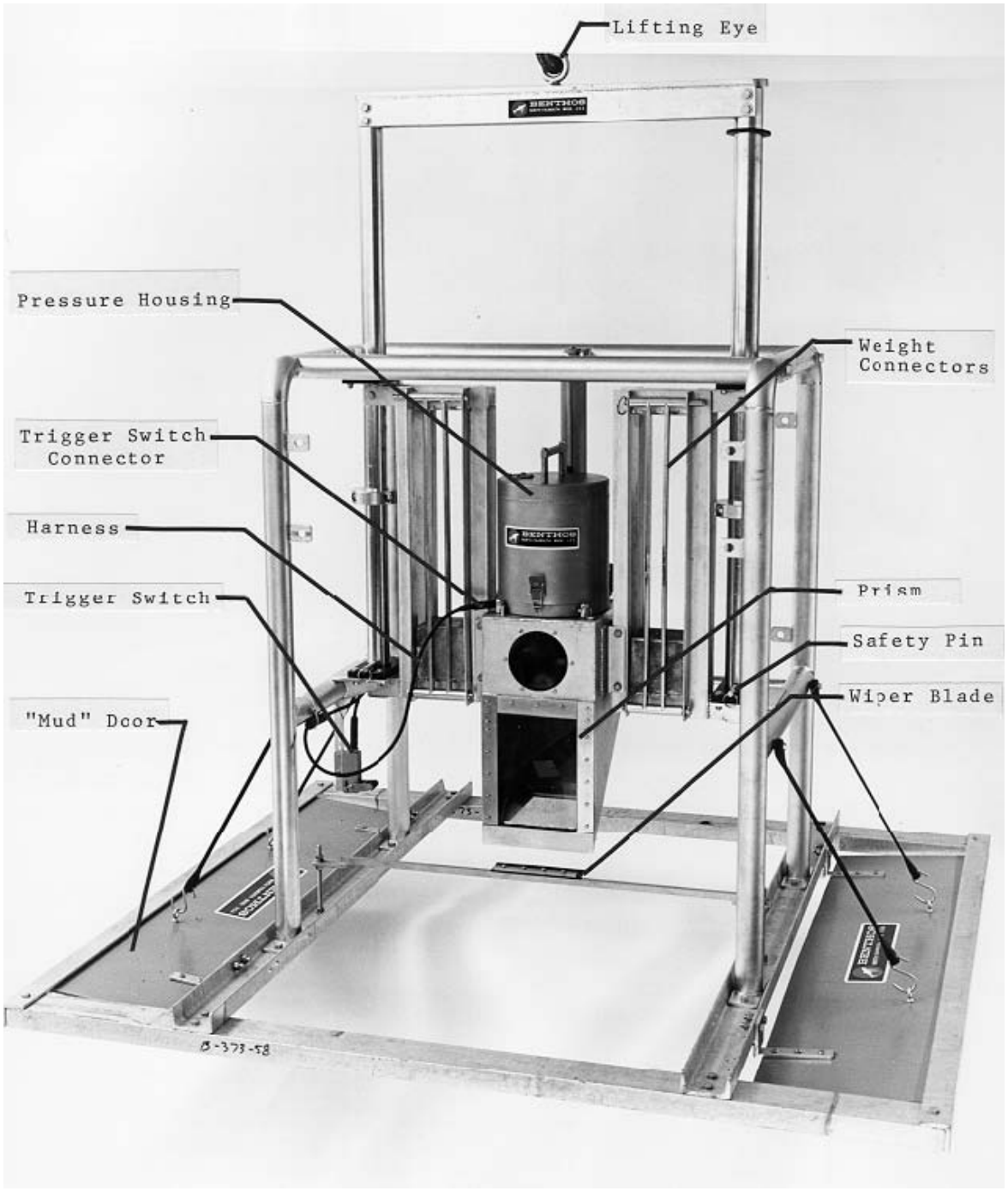


Figure A-1. Photograph of the SPI system

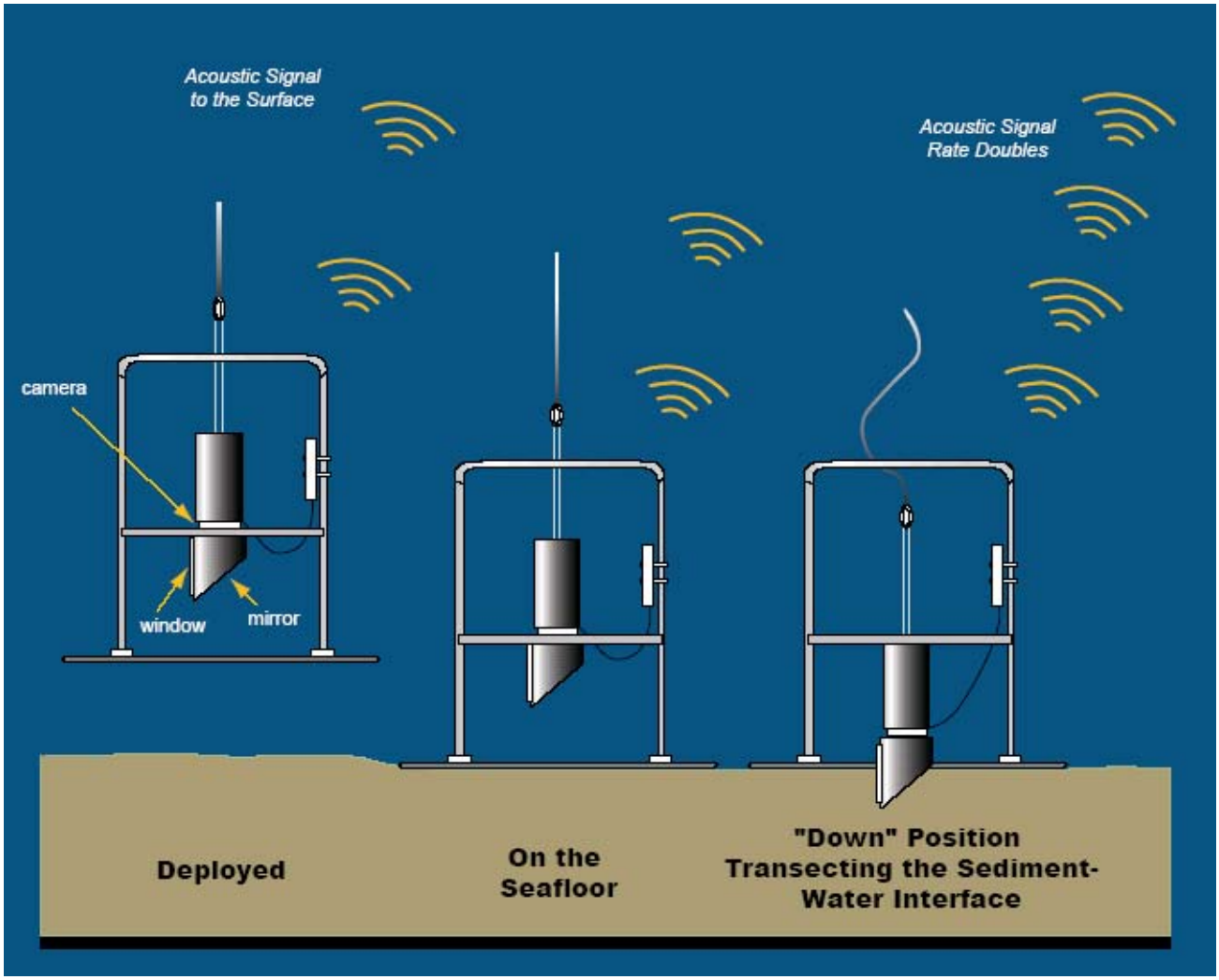


Figure A-2. Schematic diagrams of the SPI system in operation

After deployment of the camera at each station, the frame counter is checked to make sure that the proper number of images has been taken. In addition, a prism penetration depth indicator on the camera frame is checked to verify that the prism penetrated the bottom to a depth sufficient to acquire a profile image. In the event that penetration depth is insufficient, (e.g., if hard packed bottom is encountered), additional weight is added to the SPI hardware frame, and the system is re-deployed. In the event that extremely soft sediment is encountered and the prism over-penetrates, the frame is outfitted with a set of mud doors (Figure A-1). Mud doors increase the surface area and distribute the weight of the camera system over the soft sediment preventing the sediment-water interface from being obscured due to over-penetration of the window.

3.0 SPI DATA ANALYSIS

In general, three replicate camera images are analyzed from each sampling location, allowing for characterization of variability in benthic habitat conditions that may exist at small spatial scales. One image from each of the three lowerings is selected based on image clarity and quality. Computer-aided analysis of each image yields a suite of standard measured parameters. For mapping purposes, the measured values for the three replicate images at each station are averaged in order to characterize the larger-scale spatial patterns in seafloor conditions existing within each surveyed area. Each of the SPI analysis parameters is described below.

3.1 Sediment Type

The sediment grain size major mode and range are estimated visually from the camera images using a grain-size comparator at a similar scale. The phi (Φ) scale is typically used for this measurement, where phi is a unitless measure of grain size:

$$\Phi = -\log2(g/g0);$$

where g is the grain size in mm and g0 is defined as 1 mm. The lower limit of optical resolution for humans is approximately 62 microns (0.062 mm), allowing recognition of grain sizes equal to or greater than coarse silt (≥ 4 phi). Seven grain size classes are identified: silt/clay (>4 phi), very fine sand (4 to 3 phi), fine sand (3 to 2 phi), medium sand (2 to 1 phi), coarse sand (1 to 0 phi), very coarse sand (0 to –1 phi), and granules or larger (<-1 phi) (Table A-1). During analysis, the major modal grain size that is assigned to an image is the dominant grain size as estimated by area within the imaged sediment column.

Table A-1

Grain Size Scale for Sediments

Phi (Φ) size	Size range (mm)	Size class (Wentworth class)
< -1	> 2	Gravel
0 to –1	1 to 2	Very coarse sand
1 to 0	0.5 to 1	Coarse sand
2 to 1	0.25 to 0.5	Medium sand
3 to 2	0.125 to 0.25	Fine sand
4 to 3	0.0625 to 0.125	Very fine sand
> 4	< 0.0625	Silt/clay

3.2 Penetration Depth

The penetration depth into the seafloor depends on the force exerted by the prism and the bearing strength of the sediment. If the weight of the frame is held constant, the change in penetration depth over a surveyed site will reflect changes in the geotechnical properties of the bottom. The prism penetration depth is measured from the bottom of the image to the sediment-water interface. The average penetration depth is determined by measuring across the entire cross-sectional image so that differences in height across the sediment-water interface are taken into account. The depth of penetration of the prism can be used to map gradients in the bearing strength (hardness) of seafloor sediments. Sediments that are older and highly bioturbated and/or comprised primarily of silts and clay tend to be soft and allow deeper penetration than sediments that are overconsolidated/relic deposits and/or with a higher sand content, which tend to create resistance to prism penetration. Bioturbation is defined as the exchange of particles and porewater at the seafloor as the result of biological activity.

3.3 Surface Boundary Roughness

Small-scale surface boundary roughness is a measure of vertical relief of features in the sediment-profile image; it is calculated by the computer image analysis software. This parameter is defined as the vertical measurement from the highest point at the sediment-water interface to the lowest point across the image. Typical values measured over the horizontal 15-cm span of the image range from near zero to 4 cm. In most cases, the source of the roughness is either biogenic (mounds and depressions formed by bioturbation or foraging activity) or relief formed by physical processes (ripples, scour depressions, rip-ups, mud clasts, etc.).

3.4 Apparent Redox Potential Discontinuity Depth

Aerobic near-surface marine sediments typically have higher reflectance values relative to underlying hypoxic or anoxic sediments. Sand also has higher optical reflectance than mud. These differences in optical reflectance are readily apparent in sediment-profile images; the oxidized surface sediment contains particles that are coated with ferric hydroxide (an olive color when associated with particles), while reduced and muddy sediments below this oxygenated layer are darker, generally gray to black. The optical reflectance boundary between the colored ferric hydroxide surface sediment and underlying gray to black sediment is called the apparent redox potential discontinuity (RPD). The depth of the apparent RPD in the sediment column is an important indicator of dissolved oxygen conditions over time within sediment pore waters.

In the absence of bioturbating organisms, the high reflectance layer (in muds) will typically reach a thickness of 2 mm (Rhoads 1974). This depth is related to the supply rate of molecular oxygen by diffusion from the overlying water into the bottom sediments and the consumption of that oxygen by the sediment and associated microflora. In sediments that have very high sediment-oxygen demand, the sediment may lack a high reflectance layer even when the overlying water column is aerobic. In the presence of bioturbating organisms, the thickness of the high reflectance layer may be several centimeters.

The apparent RPD is mapped as a mean value across the image. The actual boundary separating the oxidized sediment from the underlying reduced sediment can be determined accurately only with microelectrodes. In general, the depth of the actual boundary will be either equal to or slightly shallower than the depth of the optical reflectance boundary. As a result, the apparent mean RPD depth can be used as an estimate of the depth of porewater exchange.

The depression and rebound of the apparent RPD within the sediment is relatively slow, and measurable changes can typically be detected over a period of one or two months. Hence, this parameter is used effectively to document changes (or gradients) which develop over a seasonal or yearly cycle related to water temperature effects on bioturbation rates, seasonal hypoxia, sediment oxygen demand, and infaunal recruitment. Time-series RPD measurements following a disturbance can be a critical diagnostic element in monitoring the degree of recolonization in an area by the ambient benthos (Rhoads and Germano 1986).

Another important characteristic of the apparent RPD is the contrast in reflectance values at this boundary. This contrast is related to interactions among the degree of organic-loading, the bioturbational activity in the sediment, and bottom-water dissolved oxygen level in a given area. High inputs of labile organic material increase sediment oxygen demand and, subsequently, sulfate reduction rates (and the abundance of sulfide end products). This results in more highly reduced (lower reflectance) sediments at depth and higher RPD contrasts. In a region of generally low RPD contrasts, images with high RPD contrasts indicate localized sites of relatively high past inputs of organic-rich material (e.g., organic or

phytoplankton detritus, dredged material, sewage sludge, etc.).

3.5 Infaunal Successional Stage

The mapping of successional stages is based on the theory that organism-sediment interactions in fine-grained sediments follow a predictable sequence after a major seafloor perturbation (e.g., passage of a storm, disturbance by bottom trawling, dredged material deposition, hypoxia). The theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest, our definition does not demand a sequential appearance of particular invertebrate species or genera" (Rhoads and Boyer 1982).

The continuum of change in animal communities after a disturbance has been divided subjectively into three stages. Pioneering or Stage I assemblages may appear shortly after the disturbance and eventually consist of dense aggregations of near-surface living, tube-dwelling polychaetes. These functional types are usually associated with a shallow redox boundary and shallow bioturbation depths, and are characterized by high rates of recruitment and high ontogenic growth rates. These animals feed at or near the sediment-water interface and physically stabilize the sediment surface by building tubes that incorporate sediment particles bound with mucous.

In the absence of further disturbance, infaunal deposit feeders eventually replace these early successional assemblages; the start of this process is designated as Stage II. Typical Stage II species are shallow dwelling bivalves or, as is common in New England waters, tubiculous amphipods. Stage III taxa in turn, represent higher successional stages typically found in low disturbance areas. Many feed at depth in a head-down orientation; this activity results in distinctive excavations called feeding voids. Diagnostic features of these feeding structures include a generally semicircular shape with a flat bottom and arched roof and a distinct change in the sediment particles overlying the floor of the structure. This change is caused by the accumulation of coarse particles that are rejected by the animals feeding selectively on fine-grained material. The bioturbational activities of these deposit-feeders are responsible for aerating the sediment and causing the redox horizon to be located several centimeters below the sediment-water interface.

It is possible for Stage I polychaetes or Stage II tubiculous amphipods to be present at the sediment surface, while at the same time, Stage III organisms are present at depth within the sediment. In those instances where two types of assemblages are visible

Infaunal successional stages apply only to soft-bottom habitats, where the camera is able to penetrate into the sediment. In hard bottom environments (i.e., sand, cobble, or rocky substrata), camera penetration is prevented and the infaunal successional stage is identified

as “indeterminate.” Although hard-bottom areas can support abundant and diverse epibenthic communities and therefore may represent habitat that is biologically productive, the faunal status of hard-bottom habitats is not reflected in the successional stage designation.

3.6 Sediment Thickness

Sediment-profile imaging can be used to detect the thickness of depositional and dredged material. Recently deposited material is usually evident because of its unique optical reflectance and/or color relative to the underlying material representing the pre-disposal surface. In most cases, the point of contact between the two layers is clearly visible as a textural change in sediment composition, facilitating measurement of the thickness of the newly deposited layer. Layers ranging in thickness from approximately 1 mm to 20 cm (height of the optical window) can be measured. The thickness of newly deposited layers can be determined by measuring the linear distance between the pre- and post-disposal sediment-water interface.

4.0 REFERENCES

Germano, J. D.; Rhoads, D. C. 1984. REMOTS® sediment profiling at the Field Verification Program (FVP) Disposal Site. Dredging '84: Proceedings of the Conference, ASCE/Nov. 14-16, Clearwater, Fla., pp. 536-544.

Germano, J. D.; Rhoads, D. C.; Lunz, J. D. 1994. An integrated, tiered approach to monitoring and management of dredged material sites in the New England region. DAMOS Contribution No. 87 (SAIC Report No. 90/7575&234). U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Rhoads, D. C. 1974. Organism-sediment relations on the muddy seafloor. Oceanogr. Mar. Biol. 12:263-300.

Rhoads, D. C.; Boyer, L. F. 1982. The effects of marine benthos on physical properties of sediments. In: McCall, P. L.; Tevesz, M. J. S. eds. Animal-sediment relations. New York: Plenum Press. pp. 3-52.

Rhoads, D. C.; Germano J. D. 1982. Characterization of organism-sediment relations using sediment-profile imaging: An efficient method of Remote Ecological Monitoring of the Seafloor (REMOTS® System). Mar. Ecol. Prog Ser. 8:115 128.

Rhoads, D. C.; Germano J. D. 1986. Interpreting long-term changes in community

structure: A new protocol. Hydrobiologia 142:291-308.

Revelas, E. C.; Germano, J. D.; Rhoads, D. C. 1987. REMOTS® reconnaissance of benthic environments. Coastal Zone ’87 Seattle, May 1987.

Valente, R. M.; Rhoads, D.C.; Germano J. D.; Cabelli, V. J. 1992. Mapping of benthic enrichment patterns in Narragansett Bay, RI. Estuaries 15:1-17.

APPENDIX B

Sediment-Profile Image Results for MuBDS September 2005 Survey

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
E Ref-01 A	9/7/2005	13:22:06	>4	1	>4	>4 - 1	259.52	18.01	17.48	18.33	0.85	B	73.11	5.07	0	-	N	N	2	10.49	17.96	14.22	Stage 1 on 3	Tan to light gray, fine sandy silt/clay. Oxidized void/burrow in center and at lower right. Numerous small polychaetes in sediment column and some organics. Sediment column is well bioturbated and processed of organics. Several tubes at SWI and biogenic depression in center SWI. Slight pull-away at SWI.
E Ref-01 B	9/7/2005	13:23:15	>4	1	>4	>4 - 1	213.91	14.85	14.32	16.04	1.72	P	84.94	5.90	1	R	N	N	3+	6.80	13.51	10.15	Stage 1 on 3	Tan to light gray, fine sandy silt/clay. Multiple oxidized voids in center and bottom center of frame and are likely part of same gallery complex. A few mud tubes at SWI and several shallow burrows. Several small polychaetes in sediment column. Sediment column deeply bioturbated and well-processed of labile organics. Mudclast at left SWI is an artifact.
E Ref-01 C	9/7/2005	13:24:27	>4	1	>4	>4 - 1	272.93	18.94	18.64	19.14	0.51	B	59.86	4.15	3	O	N	N	1	3.95	5.44	4.69	Stage 1 on 3	Tan to light olive gray, fine sandy silt/clay. Void burrow in upper left. Two large polychaetes in mid right. Large oxidized patch of sediment dissociated from RPD in bottom center of frame. Slightly more organics that previous two reps but sediment column is obviously bioturbated and moderately processed. A few tubes of two different types at SWI.
E Ref-02 A	9/7/2005	13:15:21	>4	1	>4	>4 - 1	245.90	17.07	16.83	17.23	0.39	B	83.36	5.79	0	-	N	N	5	2.93	8.74	5.84	Stage 1 on 3	Tan to light gray, fine sandy silt/clay. Upper sediment column is riddled with voids that are active and extensive instantaneous bioturbation. Several clots of oxidized sediment at the bottom of the sediment column and entire column is well-bioturbated and processed on a short time-scale. Numerous small mud tubes at the SWI. Very nice pic.
E Ref-02 B	9/7/2005	13:16:14	>4	1	>4	>4 - 1	263.35	18.28	17.40	18.72	1.33	B	57.75	4.01	0	-	N	N	1	4.85	5.92	5.39	Stage 1 on 3	Tan to light-medium gray, slightly sandy silt/clay. Small oxidized-sediment filled void in upper left. Shallow burrow upper left and a few small mud tubes at SWI. Several very small polychaetes in sediment column and some scattered particulate organics in sediment column. Not as well-processed as rep A.
E Ref-02 C	9/7/2005	13:17:15	>4	1	>4	>4 - 1	186.82	12.97	12.01	14.32	2.31	B	54.48	3.78	0	-	N	N	1	4.62	5.13	4.88	Stage 1 on 3	Tan to light gray, slightly sandy silt/clay. Small oxidized, active void in upper left. Large patch of subsurface oxidized sediment in center of frame. A few small thin polychaetes in sediment column. Biogenic depression in center SWI. Three reps generally similar although rep A shows much more extensive bioturbation.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
E Ref-03 A	9/7/2005	13:01:14	>4	1	>4	>4 - 1	267.96	18.60	18.16	18.81	0.65	B	72.28	5.02	0	-	N	N	3	2.26	5.44	3.85	Stage 1 on 3	Tan to light gray, slightly sandy silt/clay. Large voids in upper sediment column and several oxidized sediment-filled voids/burrows in subsurface. Distinct oxidized burrow trace in lower center. A few small mud tubes at SWI. Sediment column well-bioturbated and processed of organics.
E Ref-03 B	9/7/2005	13:02:14	>4	1	>4	>4 - 1	133.92	9.30	8.68	10.04	1.35	B	47.94	3.33	0	-	N	N	4	2.34	3.52	2.93	Stage 1 on 3	Tan to light gray slightly sandy silt clay with a band of medium to dark gray sediment immediately below the RPD. Several oxidized sediment-filled voids/burrows in upper sediment column. Several small mud tubes at the SWI. Numerous small, thin polychaetes in sediment column and abundant particulate organics scattered throughout sediment column. Not as much penetration as other reps at this station.
E Ref-03 C	9/7/2005	13:03:12	>4	1	>4	>4 - 1	235.99	16.38	15.76	16.78	1.02	B	78.18	5.43	0	-	N	N	2	4.71	15.65	10.18	Stage 1 on 3	Tan to light gray slightly sandy silt clay. Active voids in upper right and bottom right corner. Reduced sediment and fecal pellets at SWI at right from intensive bioturbation. A few well-formed mud tubes at SWI. Nice pic. Reps A and C are similar.
E Ref-04 A	9/7/2005	13:28:59	>4	2	>4	>4 - 2	253.07	17.56	16.04	18.36	2.31	B	37.79	2.62	0	-	N	N	3	2.99	9.67	6.33	Stage 1 on 3	Soft, tan to light-medium gray slightly sandy silt/clay. Small active, oxidized sediment filled voids in upper left, mid left and oxidized burrow trace/void in upper right. Well-defined RPD and distinct contrast. Subsurface sediment contains numerous small polychaetes and some particulate organics. Generally well-processed but appears slightly more sulfidic than previous stations from this reference area.
E Ref-04 B	9/7/2005	13:29:58	>4	1	>4	>4 - 1	224.58	15.59	14.75	16.27	1.52	B	58.16	4.04	2	R	N	N	1	4.93	5.81	5.37	Stage 1 on 3	Soft, tan to light-medium gray slightly sandy silt/clay. Small oxidized, sediment-filled void in upper right center and nice burrow trace at far upper right. Mudclasts at SWI are artifacts. Several shallow burrow at SWI. Patches of oxidized sediment throughout sediment column. Several small thin polychaetes in sediment column and some particulate organics in sediment column.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
E Ref-04 C	9/7/2005	13:30:56	>4	1	>4	>4 - 1	276.15	19.17	18.52	19.76	1.24	B	40.49	2.81	0	-	N	N	0	-	-	-	Stage 1 on 3	Very soft, tan to light-medium gray slightly sandy silt/clay. No voids visible but several polychaetes present in sediment column as well as subsurface patches of oxidized sediment indicative of deep bioturbation. Subsurface sediment has some particulate organics and appear slightly more sulfidic than previous stations at this reference area. The three reps from this station are generally similar.
E Ref-05 A	9/7/2005	13:08:13	>4	1	>4	>4 - 1	250.81	17.41	16.69	17.99	1.30	B	70.86	4.92	0	-	N	N	1	4.97	5.13	5.05	Stage 1 on 3	Soft, tan to light gray, slightly sandy silt/clay. Small active void in upper left. Biogenic mound at left SWI and several mud tubes at SWI. Red polychaete at center of frame and several thin small polychaetes in sediment column. Patches of subsurface oxidized sediment a few oxidized burrow traces at depth. Sediment column well processed of organics and highly bioturbated.
E Ref-05 B	9/7/2005	13:09:13	>4	1	>4	>4 - 1	261.53	18.15	17.96	18.27	0.31	B	67.83	4.71	1	O	N	N	1	7.53	8.32	7.92	Stage 1 on 3	Soft, tan to light gray, slightly sandy silt/clay with patch of black organic sediment in center of frame. Void traces around reduced sediment from faunal mining of organics. Several polychaetes of different types in upper sediment column and numerous patches of subsurface oxidized sediment. Sediment column highly bioturbated and well-processed of organics - subtle RPD contrast. Similar to rep A.
E Ref-05 C	9/7/2005	13:10:12	>4	1	>4	>4 - 1	218.54	15.17	14.80	15.54	0.73	B	64.82	4.50	0	-	N	N	5	6.77	11.48	9.12	Stage 1 on 3	Tan to light gray slightly sandy silt/clay. Numerous oxidized sediment filled voids running from left to right across the middle of the frame. Voids likely part of same gallery complex. Sediment column highly bioturbated and well-processed of organics. Subtle RPD contrast. A few small tubes at SWI and several tube fragments. All three reps from this station are very similar.
S Ref-06 A	9/7/2005	15:51:34	>4	2	>4	>4 - 2	256.65	17.81	17.54	18.50	0.96	B	65.05	4.51	0	-	N	N	1	13.93	14.44	14.18	Stage 1 on 3	Soft. Tan to light gray silt/clay with a few small patches of dark gray reduced sediment at depth. Small active void in lower right. Sediment column well-bioturbated and processed. Invaginated RPD and possible recent deposition.
S Ref-06 B	9/7/2005	15:52:36	>4	2	>4	>4 - 2	258.53	17.94	16.75	20.27	3.52	P	86.58	6.01	0	-	N	N	3	6.66	13.54	10.10	Stage 1 on 3	Very soft, tan to light gray silt/clay. High surface relief. Active sediment-filled void in upper left and two voids at lower right. Sediment column well-bioturbated and processed of organics. Deep RPD. A few small mud tubes at SWI. Similar to rep A.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
S Ref-06 C	9/7/2005	15:53:47	>4	2	>4	>4 - 2	263.95	18.32	17.85	18.81	0.96	B	47.82	3.32	0	-	N	N	1	14.18	16.07	15.13	Stage 1 on 3	Soft, tan to light gray, slightly sandy silt/clay. Large oxidized void at bottom of frame. Tear of sediment in mid right. A couple of mud tubes at SWI and several shallow burrows. Red polychaete in mid-right. RPD well-defined and invaginated. Three reps are generally similar.
S Ref-07 A	9/7/2005	15:59:10	>4	2	>4	>4 - 2	204.29	14.18	13.28	15.39	2.11	P	Ind	determina	1	R	N	N	5	1.13	10.15	5.64	Stage 1 on 3	Tan to light gray, fine sandy silt/clay. SWI appears recently physically disturbed and distinct increase in very fine sand in center SWI. Numerous active voids with oxidized sediment. Several mud tubes at left SWI. RPD unmeasurable. Interesting pic.
S Ref-07 B	9/7/2005	16:00:24	>4	2	>4	>4 - 2	287.79	19.97	19.06	21.09	2.03	B	50.09	3.48	0	-	N	N	0	-	-	-	Stage 1 on 3	Very soft, tan to light gray silt/clay with patch of black sulfidic sediment at lower right. No visible voids but numerous patches of subsurface oxidized sediment and oxidized burrow traces. A couple of mud tubes at left SWI and a few shallow burrows in RPD.
S Ref-07 C	9/7/2005	16:01:30	>4	2	>4	>4 - 2	283.79	19.70	18.30	20.55	2.26	B	93.51	6.49	0	-	N	N	1	11.87	12.97	12.42	Stage 1 on 3	Very soft, tan to light gray silt/clay. Active sediment-filled void in center of frame and several sediment-filled relict voids throughout sediment column. Biogenic depression at left SWI and several small mud tubes at SWI. A few polychaetes of different species in sediment column. Reps B and C are similar and appear highly depositional.
S Ref-08 A	9/7/2005	16:06:43	>4	2	>4	>4 - 2	231.10	16.04	15.54	16.38	0.85	B	46.67	3.24	0	-	N	N	4	6.71	13.68	10.19	Stage 1 on 3	Soft, tan to light gray silt/clay. Numerous subsurface voids and oxidized burrow traces at depth within the sediment column. A couple of small mud tubes at SWI and biogenic depression in center of SWI. Polychaete in lower left corner. Sediment column is extensively bioturbated and well processed of organics.
S Ref-08 B	9/7/2005	16:07:43	>4	2	>4	>4 - 2	280.99	19.50	19.37	19.76	0.39	B	63.59	4.41	2	O	N	N	0	-	-	-	Stage 1 on 3	Very soft, tan to light gray silt/clay. No voids evident but there are numerous patches of oxidized sediment at depth as well as oxidized relict void traces. Numerous intact and recumbent mud tubes at SWI. Sediment column appears bioturbated and processed of organics. Subtle RPD contrast.
S Ref-08 C	9/7/2005	16:08:38	>4	2	>4	>4 - 2	301.60	20.93	20.75	20.98	0.23	Ind	Ind	determina	Ind	-	N	N	1	-	-	-	Stage 1 on 3	Image clipped by wiper blade at top. Very soft, tan to gray fluid sediment. Small void upper left and subsurface oxidized sediment. Three reps at this station are generally similar.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
S Ref-09 A	9/7/2005	16:15:14	>4	2	>4	>4 - 2	260.00	18.05	17.65	18.38	0.73	B	88.23	6.12	0	-	N	N	4	4.94	14.86	9.90	Stage 1 on 3	Soft, tan to light gray silt/clay. Several well-formed feeding voids with oxidized sediment throughout the sediment column. Polychaete in lower right corner. A few small mud tubes and biogenic depression at SWI. Sediment column intensively and actively bioturbated as well as well-processed of organics. Nice pic.
S Ref-09 B	9/7/2005	16:16:07	>4	2	>4	>4 - 2	284.62	19.75	18.13	20.70	2.57	P	42.78	2.97	0	-	N	N	2	18.02	19.15	18.58	Stage 1 on 3	Very soft, tan to light gray silt/clay. Two small voids with oxidized traces at bottom center. Sediment column does not appear to be highly bioturbated, but it also does not appear to have an excess inventory of organics. A few small mud tubes at right SWI along with some fecal castings.
S Ref-09 C	9/7/2005	16:17:04	>4	2	>4	>4 - 2	181.40	12.59	11.90	12.89	0.99	B	72.47	5.03	0	-	N	N	2	3.47	4.68	4.08	Stage 1 on 3	Tan to light gray silt/clay. Small voids in upper center and edge of a void/burrow in upper left. Biogenic depression at far left SWI. Several small mud tubes and tube fragments at SWI. Numerous shallow burrows in the RPD. Reps A and C are similar and B appears more highly depositional.
S Ref-10 A	9/7/2005	16:23:46	>4	2	>4	>4 - 2	274.57	19.06	18.33	19.48	1.16	B	61.06	4.24	0	-	N	N	3	6.80	15.39	11.10	Stage 1 on 3	Very soft, tan to light gray silt/clay. Three distinct feeding voids and traces of several more. Numerous patches of oxidized sediment at depth and some evidence of pore water fluid expression at bottom of frame. Two large polychaetes in the center and left center of frame. Sediment column intensively bioturbated and well processed of organics. Highly invaginated RPD. Nice pic.
S Ref-10 B	9/7/2005	16:24:51	>4	2	>4	>4 - 2	273.78	19.00	18.64	19.51	0.87	B	86.72	6.02	0	-	N	N	1	7.33	14.18	10.76	Stage 1 on 3	Very soft, tan to light gray silt clay. Single, enormous multi-voided gallery complex running across the entire center of the frame. Biogenic mound and burrow in left SWI and a few very small mud tubes at right SWI. Sediment column is intensively bioturbated and well-processed of organics. Gallery complex is stunning. Nice pic.
S Ref-10 C	9/7/2005	16:25:49	>4	2	>4	>4 - 2	257.34	17.86	17.26	18.30	1.04	B	76.45	5.31	0	-	N	N	1	7.61	7.84	7.73	Stage 1 on 3	Very soft, tan to medium gray water-rich silt. Fluidization streaks at depth in the sediment column. Small void/burrow in center of frame. RPD is unusual that it show a RDSI being assimilated into RPD. Reps A and B are similar and rep C shows less biogenic activity presumably to a recent depositional event.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-01 A	9/6/2005	17:03:37	4-3	1	>4	>4 - 1	237.89	16.51	16.10	16.89	0.79	B	48.51	3.37	0	-	N	N	3	5.70	13.25	9.47	Stage 1 on 3	Tan to medium gray very silty very fine sand. Numerous well-formed mud tubes at SWI and several active voids in center and right of frame. Possible old DM but distinct signature has been obliterated. Two red polychaetes in center-right.
Musc-01 B	9/6/2005	17:05:12	>4	1	>4	>4 - 1	252.11	17.50	17.17	17.93	0.76	B	47.32	3.28	1	O	N	N	0	-	-	-	Stage 1 on 3	Tan to light olive gray very fine sandy silt/clay. Numerous mud tubes at SWI. No clearly evident voids but several patches of oxidized sediment at depth within the sediment column as well as a few burrow traces and polychaete against faceplate in lower left. Particulate organics in sediment column. Biogenic mound at SWI.
Musc-01 C	9/6/2005	17:06:14	>4	1	>4	>4 - 1	249.63	17.33	16.75	18.13	1.38	B	62.43	4.33	>10	R	N	N	0	-	-	-	Stage 1 on 3	Tan to light olive gray very fine sandy silt/clay. Broken mud tubes at SWI as well as many small mudclast artifacts. No clearly evident voids but several patches of oxidized sediment at depth within the sediment column as well as a few burrow traces. Particulate organics in sediment column. Not clearly evident as DM but slightly darker gray than reference. If DM, any distinct signature has been obscured through physical and biological reworking. Three reps similar this way.
Musc-02 A	9/7/2005	7:29:58	>4	1	>4	>4 - 1	269.27	18.69	18.16	19.51	1.35	B	48.66	3.38	0	-	N	N	2	4.65	6.60	5.63	Stage 1 on 3	Soft, tan to light gray, very fine sandy silt/clay. Intensive bioturbation in upper half of sediment column. Voids with oxidized sediment in upper left and several void traces in sediment column. Band of medium gray sediment 16.9 cm below SWI, it may be old DM but there is not enough independent evidence to conclusively call it DM. Polychaete at left. Sediment column well-processed even thou there are a couple of clots of reduced sediment in lower left corner.
Musc-02 B	9/7/2005	7:30:49	>4	1	>4	>4 - 1	269.35	18.70	18.47	19.03	0.56	B	45.66	3.17	0	-	N	N	1	17.62	19.03	18.33	Stage 1 on 3	Soft, tan to light olive gray very fine sandy silt/clay. Oxidized burrow in lower center of frame and several large patches of subsurface oxidized sediment, large burrow at base of image. Particulate organics scattered throughout sediment column. Several mud tubes at SWI. If Dm, Dm is old and biogenically processed to be unrecognizable from ambient.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-02 C	9/7/2005	7:31:46	>4	1	>4	>4 - 1	249.17	17.29	16.58	17.79	1.21	B	68.61	4.76	0	-	N	N	2	4.45	9.39	6.92	Stage 1 on 3	Soft, tan to light olive gray very fine sandy silt/clay. Void in upper center and mid-right along with several distinct patches of subsurface oxidized sediment. Particulate organics scattered throughout sediment column. Possible Cerianthid at right. Deep, even RPD. If Dm, Dm is old and biogenically processed to be unrecognizable from ambient. Three reps are similar.
Musc-03 A	9/7/2005	12:29:52	3-2	0	>4	>4 - 0	126.35	8.77	8.12	10.86	2.73	B	39.37	2.73	0	-	N	N	4	2.12	6.54	4.33	Stage 1 on 3	Firm, tan to light gray silty fine to medium sand. Voids in upper left and center. Numerous sand-encrusted tubes at SWI. Possible old DM but unequivocally recognizable as DM due to the extensive bioturbation and processing of organics.
Musc-03 B	9/7/2005	12:30:47	3-2	0	>4	>4 - 0	105.05	7.29	6.80	8.12	1.33	B	33.18	2.30	0	-	N	N	1	6.12	7.02	6.57	Stage 1 on 3	Firm, tan to light gray silty fine to medium sand. Void at lower left. Numerous sand-crusted and mud tubes at SWI. Several small polychaete of different species in sediment column. Similar to rep A.
Musc-03 C	9/7/2005	12:31:48	3-2	0	>4	>4 - 0	120.46	8.36	7.61	8.97	1.35	B	37.91	2.63	0	-	N	N	4	3.75	7.42	5.58	Stage 1 on 3	Firm, tan to light gray silty fine to medium sand. Active voids and void traces throughout sediment column. Numerous polychaetes in sediment column of at least 4 species. Proteinaceous and sand crusted tubes at SWI. Biogenic depression at right SWI. Three reps are very similar and distinctly sandy. Any distinct DM signature (if present) has been obscured by biogenic and physical processes.
Musc-04 A	9/7/2005	10:58:32	3-2	0	>4	>4 - 0	181.78	12.62	12.15	13.22	1.07	B	37.41	2.60	0	-	N	N	1	10.97	11.31	11.14	Stage 1 on 3	Firm, tan to light gray silty fine to medium sand. Void in lower center and oxidized patches and void traces in sediment column. Several polychaetes of at least three different species in sediment column. Numerous mud and sand encrusted tubes at SWI. Possibly old DM but distinct signature has been obscured. Similar to Musc-03.
Musc-04 B	9/7/2005	10:59:43	3-2	0	>4	>4 - 0	168.29	11.68	11.39	11.95	0.56	B	31.39	2.18	0	-	N	N	2	3.92	5.27	4.60	Stage 1 on 3	Firm, tan to light gray silty fine to medium sand. Oxidized sediment filled void in upper left and void in upper right. A few fine mud tubes at SWI. Very subtle RPD contrast. Patches of oxidized sediment at depth. Possibly old DM but distinct signature has been obscured. Similar to rep A.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-04 C	9/7/2005	11:00:31	3-2	0	>4	>4 - 0	173.92	12.07	11.67	12.32	0.65	B	29.17	2.02	0	-	N	N	1	4.54	5.47	5.01	Stage 1 on 3	Firm, tan to light gray silty fine to medium sand. Active void at right. Numerous small thin polychaetes at left and lower right as well as a larger annelid in right center. Patches of oxidized sediment at depth. Possibly old DM but distinct signature has been obscured. All three reps similar and similar to Musc-03.
Musc-05 A	9/7/2005	8:41:16	>4	0	>4	>4 - 0	234.68	16.29	15.79	16.78	0.99	B	41.32	2.87	0	-	N	N	0	-	-	-	Stage 1 on 3	Soft, tan to medium gray very sandy silt/clay. Numerous patches of oxidized sediment at depth as well as oxidized burrow traces in subsurface sediment. At least five polychaete of at least two species at left. Possibly old DM based on reflectivity of subsurface sediment but there is no distinct characteristic that unequivocally causes this to be labeled DM. Distinct RPD with strong contrast.
Musc-05 B	9/7/2005	8:42:08	>4	0	>4	>4 - 0	246.09	17.08	16.32	17.51	1.18	B	41.44	2.88	0	-	N	N	1	14.86	16.66	15.76	Stage 1 on 3	Soft, tan to medium gray very sandy silt/clay. Sediment column appears to be composed of old, reworked DM based on the difference in reflectivity between the subsurface sediment and the reference stations. Sediment column is well bioturbated with a void in lower left and numerous patches of subsurface oxidized sediment. Several mud tubes at SWI. Similar to rep A.
Musc-05 C	9/7/2005	8:42:54	>4	0	>4	>4 - 0	286.75	19.90	18.35	20.72	2.37	P	103.93	7.21	0	-	N	N	0	-	-	-	Stage 1 on 3	Very soft, tan to medium gray very sandy silt/clay. Appears highly depositional and RPD influenced by recent deposition. Subsurface sediment is homogeneous. Unclear whether this is reworked old DM, but gray signature in subsurface is consistent with that seen in reps A and B. Other than hue of subsurface sediment, rep C is different from the other reps.
Musc-06 A	9/7/2005	8:49:17	>4	1	>4	>4 - 1	206.69	14.35	13.65	15.08	1.44	B	45.61	3.17	4	O	N	N	0	-	-	-	Stage 1 on 3	Tan to light gray, sandy silt/clay. Biogenic mound at left SWI, several intact mud tubes at SWI, a few broken tube fragments at right and rounded mudclasts in right SWI background. Two polychaetes at bottom center. If this is old DM, it is virtually unrecognizable from ambient with the exception of the chroma of the subsurface sediment.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-06 B	9/7/2005	8:50:13	4-3	0	>4	>4 - 0	228.88	15.89	15.23	16.64	1.41	B	43.85	3.04	0	-	N	N	0	-	-	-	Stage 1 on 3	Soft, tan to light-medium gray very silty very fine sand. Numerous small clots of dark organic sediment in subsurface. No distinct feeding voids but very large, oxidized burrow halo running from upper right to lower left of frame. Funky sulfide reactions fringe bottom of oxidized burrow trace. Possibly old DM but very little in the way of unique, distinct optical signature. Cool pic.
Musc-06 C	9/7/2005	8:51:01	>4	1	>4	>4 - 1	230.03	15.97	15.48	17.03	1.55	B	57.04	3.96	1	O	N	N	1	5.19	5.70	5.44	Stage 1 on 3	Layered, soft, tan to dark gray very sandy silt/clay. Layering at 3-4 cm intervals with relict RPD over dark gray sediment. Appears to classic DM signature, however, this signature can also be attributed to periodic natural deposition, Small void in upper layer. Several tubes at SWI. Very interesting pic, it is called DM although the layering observed is probably from natural processes and the DM is just being physically reworked.
Musc-07 A	9/7/2005	9:09:22	>4	0	>4	>4 - 0	252.47	17.52	16.69	18.33	1.63	B	45.44	3.15	0	-	N	N	0	-	-	-	Stage 1 on 3	Soft , tan to medium gray very sandy silt/clay. Patch of black sediment in center of frame. Subsurface patches of oxidized sediment and oxidized burrow traces. A few well-formed mud tubes at SWI. Possible old DM but optical signature has been obscure by biogenic and physical processes. Similar to 3 and 4.
Musc-07 B	9/7/2005	9:10:13	>4	1	>4	>4 - 1	176.69	12.26	10.80	14.07	3.27	P	58.58	4.07	5	O	N	N	1	4.03	11.67	7.85	Stage 1 on 3	Tan to light fray, slightly sandy silt/clay. Some disturbance at SWI based on mudclasts and void + dragdown scar in center of frame. Numerous tubes at SWI. If old Dm, signature has been obscured by bioturbation and processing of organics.
Musc-07 C	9/7/2005	9:11:03	>4	0	>4	>4 - 0	253.78	17.61	17.20	17.79	0.59	B	59.30	4.12	0	-	N	N	1	1.49	2.28	1.89	Stage 1 on 3	Soft, tan to medium gray, sandy silt/clay. Bottom part of sediment column is likely old DM although it has been processed and is converging with native in terms or optical signature. Void in upper center of sediment column and two red polychaetes of different species at right. Several small mud tubes at SWI. Appears to be a natural RDSI in RPD. Slightly different from previous two reps.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-08 A	9/7/2005	11:10:43	>4	1	>4	>4 - 1	216.23	15.01	13.79	15.85	2.06	B	51.21	3.55	0	-	N	N	2	3.89	5.98	4.93	Stage 1 on 3	Tan to medium gray, sandy silt/clay. Two well-formed prominent voids in upper left and upper right. Subsurface sediment may be old DM based on hue but it is converging with native sediment in terms of optical signature. A few fine mud tubes at SWI. If admixed old Dm present it starts 8 cm below SWI. Some particulate organics in sediment column.
Musc-08 B	9/7/2005	11:11:32	>4	1	>4	>4 - 1	199.83	13.87	13.31	14.52	1.21	B	56.65	3.93	1	O	N	N	0	-	-	-	Stage 1 on 3	Tan to medium gray, sandy silt/clay. No voids present but numerous oxidized burrow traces at depth as well as relict void traces with oxidized sediment. Possible old DM at depth but optical signature has been obscured by bioturbation and processing of organics. Oxidized and colonized mudclast in center of biogenic depression at left SWI. Numerous small tubes at SWI as well as an accumulation of fecal pellets at right.
Musc-08 C	9/7/2005	11:12:28	3-2/>4	1	>4	>4 - 1	216.21	15.01	14.63	15.62	0.99	B	60.58	4.20	0	-	N	N	1	8.21	13.08	10.64	Stage 1 on 3	Tan very silty fine to medium sand over medium to dark gray, slightly sandy silt. Sediment at bottom of frame appears to be old DM and has medium to dark gray signature - although the old dm appears to be somewhat processed. Large void/burrow complex in center of frame. A few small tubes at SWI. Interesting pic. Old Dm is very similar to native sediment and optical signature of "old DM" may be alternatively attributable to in-situ sulfide complexation.
Musc-09 A	9/7/2005	9:02:58	>4	1	>4	>4 - 1	251.74	17.47	16.72	17.93	1.21	B	53.16	3.69	0	-	N	N	1	5.78	6.68	6.23	Stage 1 on 3	Soft, tan to dark gray very sandy silt/clay. Possible old Dm at bottom of demarcated by continuous, invaginated band of dark gray sediment. If truly old DM it has been somewhat processed of organics. Void in upper sediment and large red polychaete at left. Particulate organics in upper sediment column.
Musc-09 B	9/7/2005	9:03:52	>4	1	>4	>4 - 1	238.24	16.54	16.10	17.00	0.90	B	48.05	3.34	0	-	N	N	2	2.93	5.95	4.44	Stage 1 on 3	Soft, tan to medium gray sandy, silt/clay. Two active voids/burrows in upper left and are probably related. Several oxidized sediment-filled relict voids in upper half of the sediment column. Biogenic mound at right SWI and a couple of very small mud tubes. Fecal castings at SWI. Possibly old DM but optical signature is not distinctive enough from native.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-09 C	9/7/2005	9:04:52	>4	1	>4	>4 - 1	195.89	13.60	12.94	14.07	1.13	B	51.84	3.60	0	-	N	N	1	8.23	8.74	8.49	Stage 1 on 3	Tan to light-medium gray, sandy silt/clay. Active void with oxidized sediment and polychaete above it at left-center. Large patch of oxidized sediment and a polychaete in lower left corner. Abundant fecal material SWI and a couple of small mud tubes. Sediment column highly bioturbated and well-processed. Has gray hue and may be old DM but optical signature is or has converged with native. Reps B and C are similar.
Musc-10 A	9/7/2005	11:23:42	>4	1	>4	>4 - 1	198.56	13.78	12.97	14.18	1.21	B	36.14	2.51	0	-	N	N	1	8.83	11.81	10.32	Stage 1 on 3	Tan to light-medium gray, very sandy silt/clay. Void burrow running from lower left to bottom center. Large polychaete in lower center of frame. Possible old DM but optical signature is not distinct. Well-bioturbated and processed sediment column. Several small mud tubes of two types at SWI.
Musc-10 B	9/7/2005	11:24:44	>4	1	>4	>4 - 1	206.27	14.32	13.28	15.31	2.03	B	57.54	3.99	0	-	N	N	2	8.77	10.15	9.46	Stage 1 on 3	Tan to medium gray very sandy silt/clay. Two active voids with an animal in lower right. Large oxidized burrow trace running from SWI to lower left. Quite possible old DM but insufficient distinct optical signature to clearly differentiate from native sediment. If old DM, it has been processed to approach native in terms of hue and texture.
Musc-10 C	9/7/2005	11:25:40	>4	1	>4	>4 - 1	233.81	16.23	15.87	16.49	0.62	B	74.48	5.17	0	-	N	N	2	7.13	12.12	9.63	Stage 1 on 3	Tan to medium gray, very sandy silt/clay with some dark gray streak at left. Large sediment-filled void-burrows in upper right and right center which contain a mix of oxidized and reduced sediment. RPD may be artificially thickened by fall down of surface oxidized sediment. There is likely old DM at the bottom of the frame but it is not present in a distinct layer. Sediment column is likely a mix of reworked old DM and admixed recent deposition that is converging with native sediment in terms of optical appearance.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-11 A	9/7/2005	11:05:03	4-3	0	>4	>4 - 0	251.57	17.46	16.69	17.96	1.27	B	45.74	3.17	0	-	N	N	2	6.15	14.35	10.25	Stage 1 on 3	Faintly layered, very silty poorly sorted fine to medium sand. Layering consists of bands of light colored sand that are mostly continuous across frame. Unclear whether banding is due to natural physical or biological process as it doesn't appear to be related to DM deposition. Sediment column fairly well bioturbated and processed of organics, Small void in upper center of sediment column and a large lateral void-burrow in bottom 1/3 of frame. A few small tubes in SWI foreground and a large tube in background. Nice pic.
Musc-11 B	9/7/2005	11:05:52	>4	1	>4	>4 - 1	218.62	15.17	13.82	16.24	2.42	B	52.00	3.61	0	-	N	N	0	-	-	-	Stage 1 on 3	Tan to medium gray very sandy silt/clay. No visible voids but large patch of oxidized sediment in lower left that is related to infaunal activity. Cluster of mud tubes of two sizes at left SWI. Possibly old, reworked DM admixed with recent deposition but optical signature is not distinct enough to say conclusively. Distinctly finer grained than rep A.
Musc-11 C	9/7/2005	11:06:40	>4	1	>4	>4 - 1	253.37	17.59	17.17	18.38	1.21	B	57.86	4.02	0	-	N	N	0	-	-	-	Stage 1 on 3	Tan to dark-medium gray slightly sandy silt/clay. Appears to reworked and partially admixed old DM at bottom of frame, although it is not very distinct from native. Patches of oxidized sediment that were once voids in upper sediment column and large Stage 3 polychaete in upper center of frame. Three reps are slightly dissimilar.
Musc-12 A	9/7/2005	10:47:40	3-2	1	>4	>4 - 1	128.60	8.93	8.68	9.16	0.48	P	31.14	2.16	0	-	N	N	1	6.15	6.65	6.40	Stage 1 on 3	Firm, poorly sorted very silty fine to medium sand. Small void in lower center of sediment column and dragdown of shell at right. Several small mud and sand tubes at SWI. Polychaete in lower left corner. Possibly old DM but indistinct. Fecal strings suspended in water column and gentle bedform.
Musc-12 B	9/7/2005	10:48:29	3-2	1	>4	>4 - 1	72.46	5.03	4.43	5.36	0.93	P	42.65	2.96	0	-	N	N	0	-	-	-	Stage 1 on 3	Hard, poorly sorted, tan to light gray very silty fine to medium sand. Bedforms at SWI. Several small sand-encrusted tubes at SWI. Several shallow burrows and a deep burrow at right (Stage 3). Obviously not extensively bioturbated due to hardness. Physically active sediment column. If Dm present, it is indistinct.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-12 D	9/7/2005	16:47:21	3-2	1	>4	>4 - 1	169.48	11.76	11.42	12.32	0.90	P	36.04	2.50	0	-	N	N	5	2.09	6.96	4.53	Stage 1 on 3	Firm, poorly sorted, tan to light gray very silty fine to medium sand with some gray cohesive clay at bottom right corner. Void in upper left to upper right and a small oxidized sediment filled void at lower left. Possibly old DM but signature is indistinct. Physically active. Three reps from this station similar and are very different from previous stations.
Musc-13 A	9/7/2005	9:33:51	>4	1	>4	>4 - 1	225.98	15.68	14.89	16.16	1.27	B	54.42	3.78	0	-	N	N	1	13.51	13.70	13.60	Stage 1 on 3	Soft, layered tan to medium-dark gray sandy silt/clay. Layers are from sand stringers in normally graded sequence. This is like reworked and redeposited old DM based on gray signature. Material has been both bioturbated and physically processed. Small burrow void in lower right center. Although DM is likely present, the laminations present are from recent physical processes and consist of admixed and reworked DM+native sediment.
Musc-13 B	9/7/2005	9:34:46	>4	1	>4	>4 - 1	228.25	15.84	15.42	15.87	0.45	B	54.88	3.81	0	-	N	N	2	9.08	14.80	11.94	Stage 1 on 3	Soft, layered tan to medium-dark gray sandy silt/clay. Layers are from sand stringers in normally graded sequence. This is likely reworked and redeposited old DM based on gray signature. Material has been both bioturbated and physically processed. Two active voids at left and lower left. Relict RPD 10 cm down. Although DM is likely present, the laminations present are from recent physical processes and consist of admixed and reworked DM+native sediment. Similar to rep A.
Musc-13 C	9/7/2005	9:35:38	>4	1	>4	>4 - 1	176.95	12.28	11.87	13.00	1.13	B	37.19	2.58	0	-	N	N	3	4.31	10.41	7.36	Stage 1 on 3	Tan to dark gray very sandy silt/clay. Prominent voids in center of frame. Polychaete smeared between voids. Particulate organics in sediment column. Similar in appearance to other two reps, but without the stringers of sand. It is possible that there is some old DM admixed within the sediment column. SWI is distinctly sandier than subsurface sediment.
Musc-14 A	9/7/2005	7:38:16	>4	1	>4	>4 - 1	257.34	17.86	16.32	18.95	2.62	B	59.08	4.10	0	-	N	N	2	7.16	17.14	12.15	Stage 1 on 3	Soft, tan to light olive gray sandy silt/clay. Large biogenic depression at left SWI. Small void/burrow in upper left and large part of void/burrow complex in lower right. Several patches of oxidized sediment at depth within the sediment column. Several tubes at the SWI. Id old DM is present, it is optically indistinguishable from native sediment.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-14 B	9/7/2005	7:39:02	>4	1	>4	>4 - 1	257.03	17.84	16.95	18.33	1.38	B	48.37	3.36	0	-	N	N	0	-	-	-	Stage 1 on 3	Soft, tan to light olive gray sandy silt/clay. If old DM is present, it is optically indistinguishable from native sediment. No voids clearly visible, small oxidized burrow at bottom left and numerous patches of oxidized sediment at depth within the sediment column. Burrowing worm at mid-right. Several very small mud tubes at SWI. Similar to rep A.
Musc-14 C	9/7/2005	7:39:51	4-3/>4	1	>4	>4 - 1	238.54	16.56	16.30	16.86	0.56	B	51.60	3.58	0	-	N	N	3	6.32	15.88	11.10	Stage 1 on 3	Tan, moderately sorted, silty fine sand over light olive gray very sandy silt/clay. If old DM is present, it has converged with native in terms of optical properties. Three active voids at left, two upper and one classic lower. Oxidized burrow traces at right. Several small mud and sand tubes at right SWI. Nice pic. Three reps are similar.
Musc-15 A	9/7/2005	10:52:44	3-2	0	>4	>4 - 0	128.56	8.92	8.57	9.19	0.62	B	31.55	2.19	0	-	N	N	3	2.06	3.89	2.97	Stage 1 on 3	Firm, poorly sorted, tan to light gray very silty fine to medium sand. Three oxidized sediment filled small voids in upper sediment column. A few tubes at SWI background and abundant infaunal fecal matter suspended in water column. If this is old DM, it has lost its optical signature and is now indistinguishable from native.
Musc-15 B	9/7/2005	10:53:33	3-2	0	>4	>4 - 0	147.68	10.25	10.07	10.46	0.39	B	35.27	2.45	0	-	N	N	4	5.19	7.70	6.44	Stage 1 on 3	Firm, poorly sorted, tan to light gray very silty fine to medium sand. Four oxidized voids sediment column. A few tubes at SWI background. Several large red polychaete in sediment column. If this is old DM, it has lost its optical signature and is now indistinguishable from native. Very similar to rep A.
Musc-15 D	9/7/2005	16:40:21	3-2	0	>4	>4 - 0	117.70	8.17	7.58	8.60	1.01	P	28.21	1.96	0	-	N	N	2	4.20	5.55	4.88	Stage 1 on 3	Firm, poorly sorted, tan to light gray very silty fine to medium sand. Two oxidized sediment filled voids in upper sediment column. Abundant mud and sand tubes at SWI. If this is old DM, it has lost its optical signature and is now indistinguishable from native. All three reps very similar and similar to Station Musc-03.
Musc-16 A	9/7/2005	12:15:30	3-2/>4	1	>4	>4 - 1	216.54	15.03	14.49	15.11	0.62	B	36.65	2.54	0	-	N	N	0	-	-	-	Stage 1 on 3	Banded tan to medium dark olive gray sand and sandy silt/clay. SWI is moderately sorted silty fine to medium sand. Very likely that banding is a mixture of old DM and natural sedimentation that has been both physically and biologically admixed. Sand filled relict void at bottom right. Thick relict RPD in mid frame. Two polychaetes at right and oxidized burrow traces extending from RPD into subsurface sediment. Interesting pic.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-16 B	9/7/2005	12:16:22	>4	1	>4	>4 - 1	260.59	18.09	17.11	18.75	1.64	B	58.90	4.09	0	-	N	N	2	4.09	9.48	6.78	Stage 1 on 3	Very soft, tan to light olive very fine sandy silt/clay. Prominent classic void in upper right and oxidized void/burrow trace at upper left. Water rich. Several tubes of at least two types at left SWI. Biogenic mound at center SWI. If old DM present, it is not discernible from native sediment. Sediment column appears both depositional and well processed/bioturbated. Different from Rep A.
Musc-16 C	9/7/2005	12:17:29	4-3/>4	1	>4	>4 - 1	215.14	14.93	14.41	15.37	0.96	B	64.69	4.49	1	O	N	N	0	-	-	-	Stage 1 on 3	Tan moderately sorted silty fine sand over light gray slightly fine sand silt/clay. RPD physical influenced. Oxidized burrow traces at right and lower center. SWI appear periodically mobile. If old DM present it is not discernible from ambient. Three reps at this station are slightly different.
Musc-17 A	9/7/2005	8:55:56	>4	1	>4	>4 - 1	225.59	15.66	15.45	16.10	0.65	B	53.10	3.69	0	-	N	N	1	8.18	9.16	8.67	Stage 1 on 3	Soft, tan to light olive gray sandy silt/clay. Void in center of center sediment column and polychaetes at far left and far right. Deep, even RPD and several patches of oxidized sediment at depth. If old DM present, it is indiscernible from native sediment. Mud tube at right SWI.
Musc-17 B	9/7/2005	8:57:05	>4	1	>4	>4 - 1	268.20	18.62	16.83	19.29	2.45	P	43.53	3.02	0	-	N	N	0	-	-	-	Stage 1 on 3	Very soft, tan to light olive gray sandy silt/clay. If old DM present, it is indiscernible from native sediment. Station appears highly depositional with RDSI as SWI. Oxidized sand patches at depth which are likely void traces. Polychaete at right. Several small mud tubes at SWI and burrow at center SWI extending downward below RPD. Similar to Rep A.
Musc-17 C	9/7/2005	8:58:05	3-2/>4	1	>4	>4 - 1	246.06	17.08	16.69	17.31	0.62	B	25.34	1.76	0	-	N	N	0	-	-	-	Stage 1 on 3	Very soft, banded, silty fine to medium sand over olive gray banded sandy silt/clay. RDSI at SWI with buried RPD below current RPD. Sediment column is banded with normally graded sequences that are from natural depositional/physical processes. Polychaete at left Several shallow burrows evident. Interesting slide. Reps B and C are similar.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-18 A	9/7/2005	10:26:59	>4	1	>4	>4 - 1	183.15	12.71	11.76	13.45	1.69	B	54.73	3.80	0	-	N	N	4	4.26	11.90	8.08	Stage 1 on 3	Tan to light olive gray sandy silt/clay with a few dark gray clots of organics sediment at lower left. Two active voids in upper left, one mid-right and one bottom left-center. Biogenic depression at left SWI and large oxidized burrow trace extending downward from biogenic depression. A couple of tubes at SWI and abundant infaunal fecal matter at SWI. Sediment column well-processed. If old DM is present it has been reworked sufficiently to converge with ambient.
Musc-18 B	9/7/2005	10:27:49	>4	1	>4	>4 - 1	230.72	16.01	15.11	16.95	1.83	P	24.33	1.69	0	-	N	N	1	14.24	14.49	14.37	Stage 1 on 3	Tan to medium gray moderately sorted fine to medium sand over tan to olive gray sandy silt/clay. RDSI at SWI and overlies former RPD. RPD only measured in RDSI but will thicken over time. Small void in lower left center and whitish organism in lower right center. Several patches of oxidized sediment and void traces at depth. If old DM present, it is indiscernible from native sediments. A few tubes at SWI. Nice pic of RDSI.
Musc-18 C	9/7/2005	10:28:48	>4	0	>4	>4 - 0	243.20	16.88	16.47	17.14	0.68	B	62.08	4.31	0	-	N	N	1	6.09	7.59	6.84	Stage 1 on 3	Soft, tan to medium olive gray very sandy silt/clay with a dark organic patch in mid-left. Small sediment filled void/burrow complex in upper center. Very faint sand banding in sediment column similar to stacked RDSIs seen elsewhere. If old DM present, it has converged with ambient. Three reps are somewhat similar.
Musc-19 A	9/7/2005	7:46:05	>4	1	>4	>4 - 1	192.64	13.37	12.89	14.32	1.44	B	79.48	5.52	0	-	N	N	1	2.54	5.47	4.00	Stage 1 on 3	Tan to light gray very fine sandy silt/clay. Active void in lower center of RPD and active churning of sediment column. Exceptionally deep RPD is related to the churning surrounding the void where reduced and oxidized sediment are biogenically mixed. A few small tubes at SWI that are classic secondary colonization. If DM present, it cannot be distinguished from native sediment. Interesting pic.
Musc-19 B	9/7/2005	7:47:05	>4	1	>4	>4 - 1	240.48	16.69	15.99	17.14	1.16	B	70.02	4.86	4	)x; 3 F	N	N	1	5.36	9.39	7.37	Stage 1 on 3	Soft, tan to medium-dark gray sandy silt/clay. Active, sediment-filled void at upper right of sediment column. Mudclasts at SWI are artifacts. Although there is an organic signature in subsurface sediment it is not unequivocally old DM. Numerous very small mud tubes at SWI. Different from RPD in terms of stratigraphy.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-19 C	9/7/2005	7:47:49	>4	1	>4	>4 - 1	250.17	17.36	15.54	19.74	4.20	B	63.57	4.41	1	R	N	N	0	-	-	-	Stage 1 on 3	Cross section appears to be at edge of large burrow opening just beyond faceplate; evidence of gallery at bottom of image; most likely not disturbance from previous camera sample because of intact polychaete tubes at left. Clearly Stage 3 based on the processing and patches of oxidized sediment in subsurface sediment in the areas not disturbed. RPD measured at edge of image. Similar to rep B.
Musc-20 A	9/7/2005	12:02:31	>4	1	>4	>4 - 1	226.79	15.74	15.39	16.21	0.82	B	57.87	4.02	1	O	N	N	1	4.29	5.72	5.00	Stage 1 on 3	Tan to medium olive gray silty very fine sand over medium olive gray sandy silt.clay. Sediment-filled void in upper center. A few mud tubes at SWI. Several oxidized burrow traces below RPD. Faint normally graded banding at depth and very old relict RPD. Similar to banding seen elsewhere and is likely related to natural depositional processes rather than DM. If old DM present it is not distinguishable from native sediment.
Musc-20 B	9/7/2005	12:03:33	>4	1	>4	>4 - 1	227.97	15.82	15.28	16.18	0.90	B	32.67	2.27	0	-	N	N	0	-	-	-	Stage 1 on 3	Soft tan to medium olive gray sandy silt/clay. No voids visible but several patches of oxidized sediment and some burrows at depth within the sediment column. SWI appears to have been recently disturbed. Possible relict RPD halfway down. Slightly different from Rep A and if old DM is present it cannot be discerned from native.
Musc-20 C	9/7/2005	12:04:30	>4	1	>4	>4 - 1	214.92	14.92	13.59	15.70	2.11	B	57.46	3.99	0	-	N	N	4	3.24	14.36	8.80	Stage 1 on 3	Soft, tan to light-medium olive gray sandy silt/clay. Biogenic mound and burrow in center of SWI and numerous mud tubes across entire SWI. Voids with oxidized sediment in upper left and upper right and reduced void in lower left. Well processed and hydric halo can be seen around central large burrow. If old DM present, it cannot be discerned from native sediment. Three reps show different features and are within the range of features seen elsewhere across the site.
Musc-21 A	9/7/2005	10:33:50	>4	1	>4	>4 - 1	224.29	15.57	14.89	16.27	1.38	B	52.32	3.63	0	-	N	N	4	2.51	12.75	7.63	Stage 1 on 3	Tan to medium olive gray very sandy silt/clay. Intense bioturbation in the sediment column with mixed reduced sediment/oxidized sediment and infaunal fecal pellets at SWI. Numerous voids likely part of the same gallery with one void being enormous and sediment filled. Dense tubes at SWI background. If old Dm present it is not discernible from native sediment. Nice pic.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-21 B	9/7/2005	10:34:49	>4	1	>4	>4 - 1	214.92	14.92	14.69	15.14	0.45	B	51.81	3.60	0	-	N	N	2	2.65	6.99	4.82	Stage 1 on 3	Tan to medium olive gray very sandy silt/clay. Void in upper center and oxidized sediment-filled active void in mid-left. Deep oxidized burrow trace at far right and hydric halo around farfield void/burrow in lower right. Upper sediment column is definitely sandier than subsurface sediment. If old DM present, it cannot be discerned from native sediment. Similar to rep A but with less bioturbation.
Musc-21 C	9/7/2005	10:35:38	3-2/>4	1	>4	>4 - 1	240.93	16.72	16.10	17.73	1.64	P	50.37	3.50	0	-	N	N	2	5.22	6.49	5.85	Stage 1 on 3	Tan, poorly sorted silty fine to medium sand over medium olive gray very sandy silt/clay. Two active voids in upper right of sediment column; deep oxidized burrow at far left; numerous fine mud tubes, a proteinaceous tube at SWI. Some faint banding of sand as well as a stripe of organic sediment in subsurface. Features appear related to natural processes. DM may be present but it cannot be unequivocally discerned from native sediment. This rep slightly different from previous two in terms of stratigraphy.
Musc-22 A	9/7/2005	11:16:46	3-2/>4	1	>4	>4 - 1	221.97	15.41	14.83	15.82	0.99	B	15.42	1.07	0	-	N	N	2	11.17	14.07	12.62	Stage 1 on 3	Tan to light gray moderately sorted fine to medium sand over tan to light gray silt/clay. Distinct RDSI at SWI that based on RPD is very recent. Well developed buried RPD at depth under RDSI - this 3+ cm relict RPD is probably more reflective of longer term biological conditions than incipient present RPD. Small voids in lower right and lower left. Cool pic. If old DM is present it is indiscernible.
Musc-22 B	9/7/2005	11:17:53	>4	1	>4	>4 - 1	239.32	16.61	15.85	17.17	1.32	B	94.36	6.55	0	-	N	N	0	-	-	-	Stage 1 on 3	Soft, tan to light-medium olive gray sandy silt/clay. SWI slightly sandier than underlying sediment. Very deep RPD and active deep burrow at left. Several distinct shallow burrows in RPD. Several patches of oxidized sediment at depth along with void traces. Old DM, if present, is unrecognizable.
Musc-22 C	9/7/2005	11:18:55	>4	1	>4	>4 - 1	204.40	14.19	12.94	16.02	3.07	P	51.46	3.57	0	-	N	N	1	8.97	10.01	9.49	Stage 1 on 3	Tan to light olive gray, sandy silt/clay. Burrow with oxidized wall in lower right. A few small polychaetes in subsurface sediment. A few fine tubes at SWI. Older RDSI at SWI. Three reps show a range of features that are consistent with features seen elsewhere across the site.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-23 A	9/7/2005	12:09:35	>4	1	>4	>4 - 1	222.90	15.47	14.80	16.01	1.21	B	43.37	3.01	0	-	N	N	0	-	-	-	Stage 1 on 3	Tan to medium dark olive gray, slightly sandy silt/clay. Numerous mud tubes at SWI of several types. No voids evident but several large patches of oxidized sediment at depth. This station/rep has higher organic inventory than many previously observed stations. Numerous small polychaetes at right. Appears depositional although dark signature may or may not be related to old DM.
Musc-23 B	9/7/2005	12:10:27	>4	1	>4	>4 - 1	219.22	15.22	14.58	15.54	0.96	B	61.13	4.24	0	-	N	N	1	6.65	6.99	6.82	Stage 1 on 3	Tan to light medium olive gray, slightly sandy silt/clay. Small void in upper right and several oxidized void traces throughout sediment column. Sediment column well-processed and bioturbated. Nice polychaete in upper left center. A few small mud tubes at SWI and biogenic mound at right SWI. Different from rep A.
Musc-23 C	9/7/2005	12:11:22	>4	1	>4	>4 - 1	230.62	16.01	15.45	16.16	0.70	B	58.57	4.07	0	-	N	N	2	5.13	5.61	5.37	Stage 1 on 3	Soft, tan to light medium olive gray very sandy silt/clay. Two active small voids in upper left. Polychaetes in upper left and center. Fain relict banding from natural processes (not DO) at depth. A few shallow burrows and several broken tube fragments in RPD. If old DM present it is not discernible. Three reps show different features.
Musc-24 A	9/7/2005	9:40:24	>4	1	>4	>4 - 1	217.55	15.10	14.72	15.37	0.65	B	48.33	3.35	0	-	N	N	1	4.46	6.46	5.46	Stage 1 on 3	Tan to medium gray, very fine to medium sandy silt/clay. Active void in upper center. RDSI in various states of reincorporation into sediment column. A few tubes at SWI background and abundant infaunal fecal matter. If old DM present, it cannot be discerned from native sediment.
Musc-24 B	9/7/2005	9:41:18	>4	1	>4	>4 - 1	166.87	11.58	10.63	11.98	1.35	B	64.34	4.47	3	O	N	N	1	6.01	9.14	7.57	Stage 1 on 3	Firm, poorly sorted, tan to light gray sandy silt to very fine silty sand. Large void at right with numerous polychaetes surrounding void. Biogenic mound at right. Deep RPD. Similar yet different from Rep A.
Musc-24 C	9/7/2005	9:42:07	>4	0	>4	>4 - 0	215.48	14.96	13.67	15.70	2.03	B	69.63	4.83	0	-	N	N	1	10.77	11.33	11.05	Stage 1 on 3	Soft, tan to light olive gray, very sandy silt/clay with faint banding of sand in normally graded sequences throughout sediment column. Large oxidized burrow and small void in left center along with a few larger polychaetes in sediment column. Numerous tubes at left SWI and biogenic mound at left SWI. If DM present, its optical signature has been obscured. Different from reps A and B, but station shows range of features seen elsewhere at the site.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-25 D	9/7/2005	16:56:40	>4	1	>4	>4 - 1	208.97	14.50	14.29	14.46	0.17	B	44.37	3.08	0	-	N	N	2	3.86	7.95	5.91	Stage 1 on 3	Tan to dark gray fine sandy silt/clay. Voids in upper sediment column. Subsurface sediment is very organic and shows some layering. It is possible that this is a mix of old DM and reworked native sediment or that its just organic-rich native sediment in a topographic low.
Musc-25 E	9/7/2005	16:57:37	>4	1	>4	>4 - 1	212.56	14.75	13.73	15.23	1.49	B	63.79	4.43	1	R	N	N	2	2.73	10.97	6.85	Stage 1 on 3	Tan to medium dark gray very sandy silt/clay. Void in upper left and enormous void/burrow in bottom center of frame. Several mud tubes at SWI. Polychaete left of large void. Possible old DM present but it is not distinct from native or ambient depositional processes.
Musc-25 F	9/7/2005	16:58:34	>4	1	>4	>4 - 1	175.63	12.19	11.87	12.60	0.73	B	45.01	3.12	0	-	N	N	1	8.60	11.37	9.98	Stage 1 on 3	Tan to dark gray sandy silt/clay. Dark sediment in band across image and is likely natural. Void and oxidized burrow to void at right. Several tubes at SWI and biogenic mound in center with related biogenic depression w/conveyored reduced sediment at right. Three reps are generally similar and at most, represent reworked old DM that is not distinguishable from native sediments.
Musc-26 A	9/7/2005	7:52:44	>4	1	>4	>4 - 1	227.67	15.80	15.23	16.10	0.87	B	47.06	3.27	0	-	N	N	1	13.62	15.99	14.80	Stage 1 on 3	Tan to light gray, sandy silt/clay. Large void+tear at bottom of frame. Polychaete in upper left mining a patch of organic sediment. Patches of oxidized sediment at depth within the sediment column. Numerous mud tubes of at least two types at SWI. If old DM is present, it cannot be distinguished from native sediment.
Musc-26 B	9/7/2005	7:53:29	>4	1	>4	>4 - 1	283.06	19.65	19.12	20.10	0.99	B	76.36	5.30	0	-	N	N	1	7.47	7.73	7.60	Stage 1 on 3	Very soft, tan to light olive gray sandy silt/clay. Very deep RPD. Small void in the upper left. Several polychaetes in the subsurface sediment and either a large molpadia or large nemertean in lower right. Sediment column well processed of organics. If DM present, it cannot be distinguished from native sediment.
Musc-26 C	9/7/2005	7:54:17	>4	1	>4	>4 - 1	247.59	17.18	16.75	17.73	0.99	B	51.69	3.59	0	-	N	N	0	-	-	-	Stage 1 on 3	Soft, tan to light gray, slightly sandy silt/clay. Possible relict RPD 8 cm below SWI. Void and oxidized sediment traces in subsurface sediment. A few small mud tubes at SWI. If old DM present it is not distinguishable from native sediment. Three reps are generally similar.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-27 A	9/7/2005	7:59:01	3-2	0	>4	>4 - 0	139.97	9.71	8.83	10.38	1.55	P	37.72	2.62	0	-	N	N	0	-	-	-	Stage 1 on 3	Firm, poorly sorted, tan to light gray very silty fine to medium sand. Numerous sand and mud tubes at SWI. Oxidized sediment at depth and pink organism in center of frame. RPD physically influenced. If old DM present, it cannot be discerned from native.
Musc-27 B	9/7/2005	7:59:54	3-2	0	>4	>4 - 0	186.52	12.95	12.80	13.08	0.28	B	39.81	2.76	0	-	N	N	3	1.18	8.66	4.92	Stage 1 on 3	Firm, poorly sorted, tan to light gray very silty fine to medium sand. Numerous sand and mud tubes at SWI. Voids in upper left and one oxidized sediment filled active void in lower right. RPD physically influenced. If old DM present, it cannot be discerned from native. Similar to Rep A.
Musc-27 D	9/7/2005	8:34:43	3-2	0	>4	>4 - 0	177.02	12.29	12.07	12.66	0.59	P	47.48	3.30	0	-	N	N	1	11.51	12.04	11.77	Stage 1 on 3	Firm, poorly sorted, tan to light gray very silty fine to medium sand. A few small tubes at SWI. Void with oxidized sediment at far lower right. Bedform at SWI. RPD physically influenced. If old DM present, it cannot be discerned from native. Three reps are very similar.
Musc-28 A	9/7/2005	9:14:56	>4	1	>4	>4 - 1	226.43	15.72	14.52	16.18	1.66	B	66.71	4.63	0	-	N	N	3	4.35	6.82	5.58	Stage 1 on 3	Soft, tan to light medium olive gray sandy silt/clay. Voids in upper left, upper center and upper right. Several large oxidized burrow traces extending down from RPD. If old DM present, it cannot be distinguished from native sediment.. Polychaete at right.
Musc-28 B	9/7/2005	9:15:50	>4	1	>4	>4 - 1	196.22	13.62	12.77	13.93	1.16	B	75.10	5.21	2	R	N	N	1	3.53	5.61	4.57	Stage 1 on 3	Tan to light olive gray sandy silt/clay with a patch of black reduced sediment at bottom right. Classic active, oxidized void in upper center and polychaete to right of void. Deep, invaginated RPD with numerous oxidized burrows extending deep into the sediment column. If old DM present, it cannot be distinguished from native sediment. Relict voids present at depth. Sediment column is well bioturbated and processed, Generally similar to Rep A.
Musc-28 C	9/7/2005	9:16:40	>4	1	>4	>4 - 1	195.07	13.54	12.80	14.66	1.86	B	57.84	4.01	>10	R	N	N	0	-	-	-	Stage 1 on 3	Tan to light olive gray sandy silt/clay with patch of black, organic sediment at far lower left. No distinct voids but there are discrete sand lags from infaunal feeding activity throughout the sediment column and subsurface burrowing polychaetes visible. Patches of oxidized sediment in the subsurface also. Red polychaete in upper left-center. Small reduced mudclasts at the RPD are in the process of being assimilated into the sediment column and are behaving as discrete particles. Mudclast is artifact. Three reps are somewhat similar.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
Musc-29 A	9/7/2005	10:40:14	3-2	1	>4	>4 - 1	188.68	13.10	12.55	13.51	0.96	B	54.58	3.79	1	O	N	N	2	3.64	12.52	8.08	Stage 1 on 3	Tan to medium gray very silty fine to medium sand. Two prominent large voids/burrows with oxidized sediment in center of frame. A recumbent tube and abundant infaunal fecal material at SWI. If old DM present, it has been reworked beyond recognition as DM. Nice pic.
Musc-29 B	9/7/2005	10:41:01	>4	1	>4	>4 - 1	239.00	16.59	15.85	17.40	1.55	B	53.77	3.73	1	O	N	N	1	12.32	13.08	12.70	Stage 1 on 3	Soft, tan to light-medium olive gray very sandy silt/clay. Void in lower right with sand lag around void. A few patches or organic sediment but very localized. Biogenic depression and burrow at left SWI. Several well-formed mud tubes at SWI. DM not discernible.
Musc-29 C	9/7/2005	10:41:51	>4	1	>4	>4 - 1	232.30	16.12	15.71	16.49	0.79	B	60.88	4.23	3	R	N	N	1	2.28	3.67	2.97	Stage 1 on 3	Soft tan to medium-dark olive gray very sandy silt/clay. Sulfidic band 6 cm below SWI. Numerous mud tubes at SWI of at least three types. Small void in upper left and old void traces and sand lags throughout sediment column. If old DM is present, it is not discernible. Three reps are generally similar but also show different features in each.
Musc-31 A	9/7/2005	12:22:14	>4	1	>4	>4 - 1	230.66	16.01	15.51	16.58	1.07	B	70.48	4.89	0	-	N	N	0	-	-	-	Stage 1 on 3	Soft, tan to medium olive gray sandy silt clay. No voids visible but there is abundant evidence of infaunal subsurface feeding and burrowing ranging from oxidized burrow trace, sand lags, and oxidized relict void traces. A couple of small mud tubes at SWI. If old DM present, it cannot be distinguished from native sediment.
Musc-31 B	9/7/2005	12:23:19	4-3	1	>4	>4 - 1	235.59	16.35	12.86	17.14	4.29	P	Ind	2.43	2	R	N	N	2	11.70	12.38	12.04	Stage 1 on 3	Soft, poorly sorted, tan to medium olive gray very silt fine sand. Left SWI appears to be disturbed with fabric disrupted under disturbance (camera frame?). RPD measured as linear measurement and not mean over frame. Voids in lower left center. Patches or organic-rich and oxidized sediment at depth. Not discernible solely as DM. Different from Rep A.
Musc-31 C	9/7/2005	12:24:22	>4	1	>4	>4 - 1	238.76	16.57	15.56	17.14	1.58	B	67.62	4.69	0	-	N	N	0	-	-	-	Stage 1 on 3	Very soft, tan to medium olive ray very sandy silt/clay. No voids visible but there is evidence of subsurface deposition feeding and burrowing based on the patches of oxidized sediment at depth. Patch of organic sediment at right. Biogenic mound at left SWI and a couple of mud tubes flanking biogenic depression at right SWI. The three reps at this station are generally morphologically similar but show slightly different features.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
SW Ref-01 A	9/7/2005	14:56:06	>4	2	>4	>4 - 2	207.19	14.38	14.13	14.61	0.48	B	60.03	4.17	0	-	N	N	2	9.95	14.18	12.07	Stage 1 on 3	Tan to light olive gray slightly sandy silt/clay. Void in mid left and lower right - both active and have oxidized sediment. Several patches of subsurface oxidized sediment. Numerous small and large mud tubes of at least two types at SWI. Sediment column well bioturbated and processed of organics.
SW Ref-01 B	9/7/2005	14:57:16	>4	2	>4	>4 - 2	180.98	12.56	11.67	13.90	2.23	B	55.40	3.85	0	-	N	N	2	9.05	13.31	11.18	Stage 1 on 3	Tan to light olive gray sandy silt/clay. Highly invaginated RPD with deep RPD at burrow at right that leads to void in lower right. Small void at mid-left edge. Hydric halo at left. Infaunal fecal casting at SWI. Similar to rep A.
SW Ref-01 C	9/7/2005	14:58:24	>4	1	>4	>4 - 1	258.23	17.92	17.40	18.33	0.93	B	39.18	2.72	2	O	N	N	0	-	-	-	Stage 1 on 3	Tan to light olive gray, very soft sandy silt/clay. Images appears to be highly depositional. No distinct voids but evidence of subsurface deposit feeding and bioturbation. A few mud tubes in background. Three reps are generally similar although C is by far the softest, and without large voids.
SW Ref-04 A	9/7/2005	15:03:48	>4	1	>4	>4 - 1	213.20	14.80	14.69	15.00	0.31	B	43.96	3.05	0	-	N	N	1	5.64	6.03	5.84	Stage 1 on 3	Tan to medium gray very silty fine sand over olive medium gray to black sandy silt. Small void in upper right. Several patches of blackish organic sediment at depth and are interspersed with relict oxidized sediment from former infaunal feeding activities. Interesting pic.
SW Ref-04 B	9/7/2005	15:05:07	>4	1	>4	>4 - 1	214.75	14.91	13.68	16.69	3.02	P	21.04	1.46	0	-	N	N	0	-	-	-	Stage 1 on 3	Tan to medium dark gray very sandy silt/clay. SWI has been recently disturbed and mudclasts are being reincorporated into sediment column and RPD is incipient. Evidence of Stage 3 activity in lower left. Some particulate organics in sediment column. Different from Rep A.
SW Ref-04 C	9/7/2005	15:06:11	>4	1	>4	>4 - 1	200.55	13.92	12.89	15.17	2.28	B	57.21	3.97	0	-	N	N	1	7.11	7.50	7.31	Stage 1 on 3	Tan to light gray poorly sorted very silty fine sand over gray very sandy silt. Void in center of frame and polychaetes to left and right of void. Appears to be a RDSI at SWI that is being obscured by bioturbation. Shows same range of features seen on site.
SW Ref-05 A	9/7/2005	14:48:59	>4	2	>4	>4 - 2	204.81	14.22	14.24	14.29	0.06	B	34.58	2.40	0	-	N	N	0	-	-	-	Stage 1 on 3	Tan to light medium gray sandy silt clay. Several deep oxidized burrows and polychaetes in upper center. Numerous small mud tubes at the SWI.
SW Ref-05 B	9/7/2005	14:50:02	>4	2	>4	>4 - 2	207.42	14.40	13.73	14.72	0.99	B	35.46	2.46	0	-	N	N	2	5.56	12.04	8.80	Stage 1 on 3	Tan to medium olive gray very sandy silt/clay. Prominent void with oxidized sediment at left and lower right. Biogenic depression at right SWI and a few mud tubes at SWI. Nice pic.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
SW Ref-05 C	9/7/2005	14:51:09	>4	1	>4	>4 - 1	214.56	14.89	13.45	15.90	2.45	B	30.18	2.09	0	-	N	N	0	-	-	-	Stage 1 on 3	Tan to dark gray very sandy silt/clay. Burrow at right SWI with reduced sediment being brought to SWI. Numerous medium to large polychaetes in right and right center. Large patch of organics being mined at right. Three reps show slightly different features although generally similar.
SW Ref-06 A	9/7/2005	14:42:14	>4	2	>4	>4 - 2	171.96	11.94	11.45	12.41	0.96	B	55.88	3.88	0	-	N	N	4	7.42	11.79	9.60	Stage 1 on 3	Tan to light gray slightly fine sandy silt/clay with patch of dark organic sediment in lower left and patch of gray clay at left. Four active voids in lower sediment column. A couple of tubes at SWI. Range of features in this pic are similar to that seen at the site.
SW Ref-06 B	9/7/2005	14:43:16	>4	1	>4	>4 - 1	192.61	13.37	12.86	13.73	0.87	B	36.84	2.56	0	-	N	N	0	-	-	-	Stage 1 on 3	Tan to light medium gray slightly sandy silt/clay. Burrow in upper center and oxidized burrow traces extending below RPD. Biogenic mound at left. Tube at right SWI. Oxidized hydric halo at bottom left. Sediment column appears well-processed of organics.
SW Ref-06 C	9/7/2005	14:44:19	>4	1	>4	>4 - 1	255.53	17.74	16.69	18.38	1.69	B	15.72	1.09	3	R	N	N	2	10.15	16.64	13.39	Stage 1 on 3	Very soft tan to light-medium gray sandy silt/clay. Reduced layer of biogenically transported subsurface sed at SWI and incipient RPD. Several tubes in SWI background. Mudclasts are artifacts. Voids at left and lower left. Three distinct polychaetes in center and left. Faint relict layering in sediment column from natural depositional processes.
SW Ref-07 A	9/7/2005	15:12:50	>4	1	>4	>4 - 1	198.96	13.81	13.08	14.30	1.21	B	62.30	4.32	0	-	N	N	1	9.96	13.39	11.67	Stage 1 on 3	Tan to medium gray very sandy silt/clay with large patch of black organic sediment at right. Void to left of organic patch. Several shallow burrows at left SWI. Organism in void appears to be mining patch of black organics sediment.
SW Ref-07 B	9/7/2005	15:13:58	>4	1	>4	>4 - 1	209.37	14.53	14.13	14.69	0.56	B	42.41	2.94	0	-	N	N	0	-	-	-	Stage 1 on 3	Tan to light gray sandy silt/clay. Burrow at left with reduced sediment nearing the SWI. Unusual ring pattern of oxidized and reduced sediment at lower right. No voids but evidence of deep subsurface bioturbation and deposit feeding. Similar to rep A but without the large patch of black sediment.

Table B-1

Summary of Sediment-Profile Imaging Data for MuBDS 2005 Survey

Station	Date	Time	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B-Biological, P-Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized)	Methane (N-No)	Low DO? (N-No, Y-Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	Comment
SW Ref-07 C	9/7/2005	15:15:11	>4	1	>4	>4 - 1	158.26	10.98	8.91	12.52	3.61	P	24.55	1.70	0	-	N	N	1	9.64	10.07	9.86	Stage 1 on 3	Tan to medium, even gray slightly sandy silt/clay. SWI appear to have been recently disturbed. Evidence of subsurface bioturbation throughout sediment column with void in lower left-center and oxidized void traces everywhere. Tube in center SWI. Different from reps A and B. NOTE: after completion of all SWREF images, all features present in these images are present throughout rest of site, confirming whatever DM was dumped on site has been completely re-worked into ambient features, with the exception of Station 25, which is notably distinct.

APPENDIX C

Plan-View Image Results for MuBDS
September 2005 Survey

Table C-1

Plan View Imaging Data from Muscongus Bay Disposal Site

Station	Rep	Substrate	Bedforms	Infauna	Burrows	Tubes	Tracks	Epifauna	Mudclasts	Debris	Comment
Musc-01	G	sand/mud	distinct	Ind	Yes	Ind	Yes	Shrimp	No	No	Cloudy. Distinct ripple field that has been modified with burrows. >100 burrows in picture. Shrimp at right. Not clear enough to determine sediment type. Important to note that the sediment-water interface is subject to resuspension based on the ripples.
Musc-06	B	Ind	Ind	Ind	Yes	Ind	Ind	Ind	Ind	Ind	All cloudy except for right edge where a large burrow can be seen.
Musc-12	C	Ind	Yes	Ind	Ind	Ind	Ind	Ind	Ind	Ind	Very cloudy but a cobble, shell and bedform can be discerned.
Musc-15	C	Muddy sand	Distinct	Bivalve, polychaetes	>100	>100	Yes	No	No	No	Nice pic. Well formed ripples that have numerous burrows and tubes. Two red polychaetes partially in burrow holes. Clam siphon at bottom left. Leaf at lower right. Again, shows evidence of periodic physical reworking.
Musc-15	A	Ind	Yes	Ind	Yes	Ind	Ind	Ind	Ind	Ind	Cloudy. Bedforms and a few large burrows discernible but not much else.
Musc-13	C	Ind	distinct	Ind	Ind	Ind	Ind	Fish	No	No	Cloudy, bedform field clearly discernible and fish at lower left. Focus insufficient to determine sediment-type or biological features other than large macrofauna. Seaweed at lower left.
Musc-24	C	Ind	Yes	Ind	Yes	Yes	Ind	Ind	Ind	Shell	Very cloudy, bedform discernible, some tubes at SWI and shell fragments in upper left.
E Ref-3	A	Muddy sand	distinct	Yes	Yes	>100	Yes	No	No	No	Rippled muddy sand with abundant tubes and burrows. Rhythmic ripples, frequent resuspension and physical reworking.
E Ref-2	C	Muddy sand	Ind	Yes	Yes	Yes	Yes	Yes	Yes	No	Hummocked muddy sand. Burrows and tubes visible over most of frame. Presence of squid in water column. Some mudclasts on seafloor indicated recent disturbance - possible from foraging.
E Ref-2	B	Ind	Yes	Yes	Yes	Yes	Ind	Shrimp	No	No	Rippled muddy sand with visible large burrows and some tubes at SWI. Shrimp in center of frame. Shows physical reworking of SWI.
E Ref-4	A	Ind	distinct	Yes	Yes	Yes	Yes	Ind	No	No	Rippled sediment with cloud of suspended sediment at left. Burrows and small tubes in ripple troughs. Active, persistent physical reworking of sediment column.
E Ref-4	C	Ind	Ind	Ind	Yes	Ind	Ind	Ind	Ind	Ind	Very cloudy and only notable because of the extremely large burrows visible through the cloud.
E Ref-4	B	Muddy sand	Yes	Yes	Yes	>100	No	No	No	No	Rippled muddy sand with dense small tubes at SWI. A few burrows.
S Ref-8	B	Ind	Yes	Yes	Yes	Ind	Ind	Ind	Ind	No	Very cloudy but ripples and a few burrows can be identified through the haze. Physical reworking.
SW Ref-1	A	Ind	Yes	Yes	Yes	Ind	Ind	Ind	Ind	No	Very cloudy but ripples and a few burrows can be identified through the haze. Physical reworking.
SW Ref-1	B	sand/mud	distinct	Ind	Yes	Ind	Ind	Ind	Ind	No	Cloudy, two large burrows and distinct bedform field. Indicative of periodic physical reworking and large burrowing organisms.
SW Ref-6	B	Ind	Ind	Yes	Yes	Ind	Ind	Ind	Ind	No	Very cloudy but a few burrows can be identified through the haze.
SW Ref-6	A	Ind	Yes	Yes	Yes	Ind	Ind	Ind	Ind	No	Very cloudy but ripples and a few burrows can be identified through the haze. Physical reworking.
SW Ref-5	B	Muddy sand	Yes	Yes	Yes	Yes	Yes	No	No	No	Somewhat cloudy but ripples, a few burrows and a very large burrow can be seen. Tracks over sediment water interface. Periodic physical reworking.
SW Ref-4	B	Muddy sand	Yes	Yes	Yes	Yes	Yes	No	No	No	Cloudy with small ripples, several burrows and a section of crab carapace at lower right. Tubes can be faintly seen.