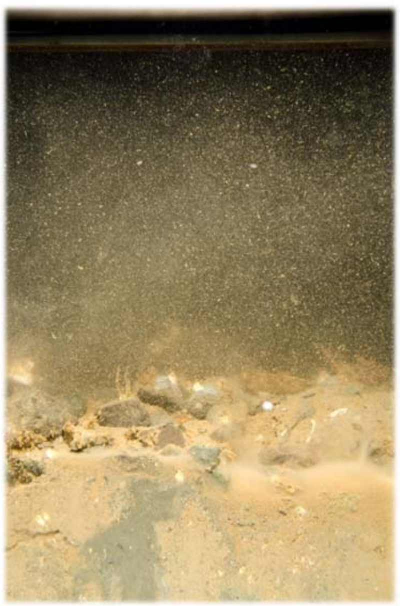
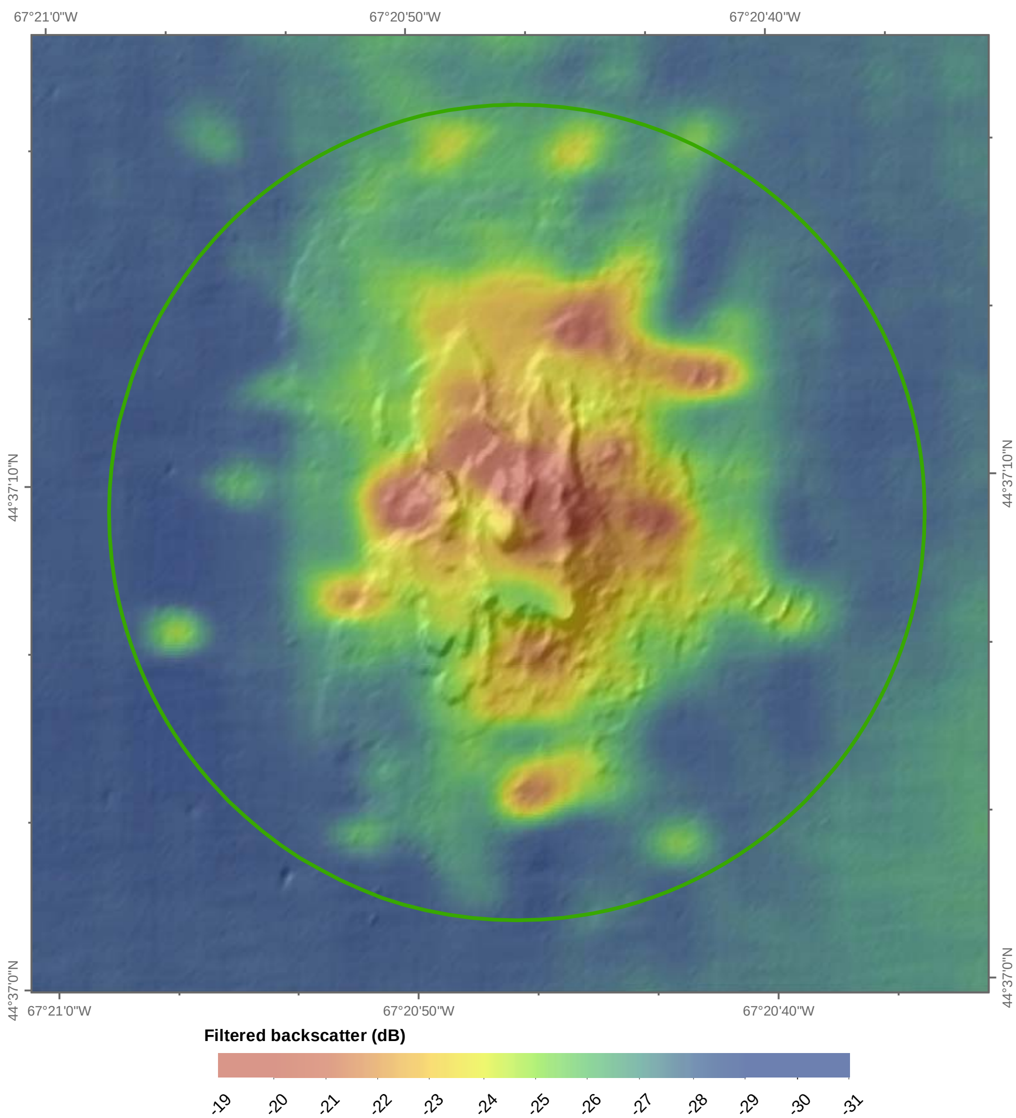
Monitoring Survey at the Machias Bay Disposal Site
October 2012

Disposal Area Monitoring System DAMOS





D A M O S

DISPOSAL AREA MONITORING SYSTEM

Contribution 193
June 2013

US Army Corps of Engineers®
New England District

This report should be cited as:

Hickey, K.; Carey, D. A.; Germano, J. D.; Read, L. B.; Esten, M. E. 2013. Monitoring Survey at the Machias Bay Disposal Site October 2012. DAMOS Contribution No. 193. U.S. Army Corps of Engineers, New England District, Concord, MA, 69 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 2013	FINAL REPORT

4. TITLE AND SUBTITLE
Monitoring Survey at the Machias Bay Disposal Site October 2012

5. FUNDING NUMBERS

6. AUTHOR(S)
Ken Hickey, Drew A. Carey, Joseph D. Germano, Lorraine B. Read, Marie Evans Esten

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Battelle|Environmental Solutions
397 Washington Street
Duxbury, MA 02332

DAMOSVision
215 Eustis Avenue
Newport, RI 02840

8. PERFORMING ORGANIZATION REPORT NUMBER
DV-2013-001

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

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Contribution No. 193

11. SUPPLEMENTARY NOTES
Available from DAMOS Program Manager, Evaluation Branch
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 in 2012 at the Machias Bay Disposal Site (MacBDS) as part of the Disposal Area Monitoring System (DAMOS) Program. The 2012 monitoring effort involved a high-resolution acoustic survey to characterize seafloor topography and dredged material distribution as well as sediment-profile imaging (SPI) and plan-view imaging (PV) surveys to provide additional physical characterization and to assess benthic recolonization. The results of the 2012 surveys were used to document changes at MacBDS since the previous survey in 2002 and the subsequent placement of approximately 64,000 m^3 of dredged material at the site in early 2011.

The high-resolution acoustic survey consisted of multibeam bathymetric, acoustic backscatter, and side-scan sonar data acquisition. The survey was conducted over a square-shaped area that incorporated the entire disposal site. The acoustic survey revealed a small mound of dredged material near the center of the disposal site, slightly offset from the mound created in 2002. The peak of the mound was approximately 4.4 m above the surrounding seafloor and the mound covered an area of approximately 150 × 190 m with a thin apron extending well beyond. The surrounding seafloor was very smooth and homogeneous in slope and texture.

SPI and PV images were collected from MacBDS and two reference areas. Evidence of Stage 3 successional status was present in all replicate images from all survey stations, suggesting that the benthic community at the disposal site had recovered and was equivalent to reference area benthic communities. While the aRPD depths within the disposal site boundary were slightly depressed compared to those found in the ambient areas, evidence of deep, deposit-feeding infauna was present throughout the site, and the aRPD depths were expected to rebound quickly.

In summary, the placement of approximately 64,000 m^3 of dredged material created a mound with the size and extent expected from placement in 20-m water depths. In addition, MacBDS has experienced full recovery of the benthic community in the year and a half since cessation of dredged material placement activities. Given the complete recovery of the benthic infaunal community, it is predicted that the effects from any future disposal operations at MacBDS would be transient and the infaunal community would quickly re-establish itself within a time frame of 12-18 months following completion of disposal operations. Future confirmatory survey work at MacBDS is conditional on the additional placement of a significant amount of dredged material.

14. SUBJECT TERMS DAMOS, Machias Bay Disposal Site, Dredged Material Monitoring, Acoustic Survey, Sediment-Profile/Plan-View Survey

15. NUMBER OF TEXT PAGES: 69

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 MACHIAS BAY DISPOSAL SITE OCTOBER 2012

CONTRIBUTION #193

June 2013

Contract No. W912WJ-12-D-0004
Report No. DV-2013-001

Submitted to:
New England District
U.S. Army Corps of Engineers
696 Virginia Road
Concord, MA 01742-2751

Prepared by:
Drew A. Carey
Ken Hickey
Joseph D. Germano
Lorraine B. Read
Marie Evans Esten

Submitted by:
DAMOSVision
215 Eustis Avenue
Newport, RI 02840

Frontispiece

Bucks Harbor Navigation Project

Bucks Harbor is located in Machiasport, Maine on Machias Bay, about 25 miles southwest of Eastport. Bucks Harbor is formed by an inner and outer harbor and is used by a sizeable commercial fishing fleet and a small number of seasonal recreational craft.

The U.S. Army Corps of Engineer's work in Bucks Harbor consists of an eight-foot-deep anchorage, 11 acres in area, on the western side of the outer harbor. The anchorage extends southeasterly from Sprague and Look Wharf at Bucks Neck towards Bucks Head.

Completed in 1974, the anchorage was constructed under Section 107 of the Corps' Continuing Authorities Program (USACE 2013).

<u>Note on units of this report:</u> As a scientific contribution, information and data are presented in the metric system. However, given the prevalence of English units in the dredging industry of the United States, conversions to English units are provided for the general information in Section 1. A table of common conversions can be found in Appendix D.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

EXECUTIVE SUMMARY

A monitoring survey was conducted in 2012 at the Machias Bay Disposal Site (MacBDS) as part of the Disposal Area Monitoring System (DAMOS) Program. The 2012 monitoring effort involved a high-resolution acoustic survey to characterize seafloor topography and dredged material distribution as well as sediment-profile imaging (SPI) and plan-view imaging (PV) surveys to provide additional physical characterization and to assess benthic recolonization. The results of the 2012 surveys were used to document changes at MacBDS since the previous survey in 2002 and the subsequent placement of approximately 64,000 m^3 of dredged material at the site in early 2011.

The high-resolution acoustic survey consisted of multibeam bathymetric, acoustic backscatter, and side-scan sonar data acquisition. The survey was conducted over a square-shaped area that incorporated the entire disposal site. The acoustic survey revealed a small mound of dredged material near the center of the disposal site, slightly offset from the mound created in 2002. The peak of the mound was approximately 4.4 m above the surrounding seafloor and the mound covered an area of approximately 150 × 190 m with a thin apron extending well beyond. The surrounding seafloor was very smooth and homogeneous in slope and texture.

SPI and PV images were collected from MacBDS and two reference areas. Evidence of Stage 3 successional status was present in all replicate images from all survey stations, suggesting that the benthic community at the disposal site had recovered and was equivalent to reference area benthic communities. While the aRPD depths within the disposal site boundary were slightly depressed compared to those found in the ambient areas, evidence of deep, deposit-feeding infauna was present throughout the site, and the aRPD depths were expected to rebound quickly.

In summary, the placement of approximately 64,000 m^3 of dredged material created a mound with the size and extent expected from placement in 20-m water depths. In addition, MacBDS has experienced full recovery of the benthic community in the year and a half since cessation of dredged material placement activities. Given the complete recovery of the benthic infaunal community, it is predicted that the effects from any future disposal operations at MacBDS would be transient and the infaunal community would quickly re-establish itself within a time frame of 12-18 months following completion of disposal operations. Future confirmatory survey work at MacBDS is conditional on the additional placement of a significant amount of dredged material.

1.0 INTRODUCTION

A monitoring survey was conducted at the Machias Bay Disposal Site (MacBDS) in October 2012 as part of the U.S. Army Corps of Engineers (USACE) New England District (NAE) Disposal Area Monitoring System (DAMOS) Program. DAMOS is a comprehensive monitoring and management program designed and conducted to address environmental concerns surrounding the placement of dredged material at aquatic disposal sites throughout the New England region. An introduction to the DAMOS Program and MacBDS, including brief descriptions of previous dredged material disposal and site monitoring activities, 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 are promptly identified and addressed (Germano et al. 1994). For over 35 years, the DAMOS Program has collected and evaluated disposal site data throughout New England. Based on these data, patterns of physical, chemical, and biological responses of seafloor environments to dredged material disposal activity have been documented (Fredette and French 2004).

DAMOS monitoring surveys fall into two general categories: confirmatory studies and focused studies. Confirmatory studies are designed to test hypotheses related to expected physical and ecological response patterns following placement of dredged material on the seafloor at established, active disposal sites. The data collected and evaluated during these studies provide answers to strategic management questions in determining the next step in the disposal site management process. Focused studies are periodically undertaken within the DAMOS Program to evaluate inactive or historical disposal sites and contribute to the development of dredged material placement and capping techniques. The resulting information is used to guide the management of disposal activities at each site. The 2012 MacBDS investigation was a confirmatory study featuring monitoring of an area that had recently received dredged material.

Two primary goals of DAMOS confirmatory monitoring surveys are to document the physical location and stability of dredged material placed into the aquatic environment and to evaluate the biological recovery of the benthic community following placement of the dredged material. Several survey techniques are employed in order to characterize these responses to dredged material placement. Sequential acoustic monitoring surveys (including bathymetric, acoustic backscatter measurements, and side-scan sonar) are made to characterize the height and spread of discrete dredged material deposits or mounds created at open water sites as well as the accumulation/consolidation of dredged material into confined aquatic disposal (CAD) cells. Sediment-profile imaging (SPI) and plan-view underwater camera photography (referred to as plan-view [PV] imaging) surveys are performed to provide further physical characterization of the material and to support evaluation of seafloor (benthic) habitat conditions and recovery over time. Each type of data collection activity is conducted periodically at disposal sites, and the conditions found after a defined period of disposal activity are compared with the long-term data set at a specific site to determine the next step in the disposal site management process (Germano et al. 1994). Focused DAMOS monitoring surveys may also feature additional types of data collection activities as deemed appropriate to achieve specific survey objectives, such as sub-bottom profiling, towed video, sediment coring, or grab sampling.

1.2 Introduction to the Machias Bay Disposal Site

The Machias Bay Disposal Site (MacBDS) is an infrequently used dredged material disposal site located near the mouth of Machias Bay in eastern Maine (Figure 1-1). MacBDS occupies a 1230 × 1230-m (4040 × 4040-ft) area of seafloor located approximately 1.8 km (1.1 mi) east of Howard Point (Figure 1-2). MacBDS has historically received dredged material from Bucks Harbor situated to the west and the Machias River flowing into Machias Bay to the north (Figure 1-1).

Water depths at MacBDS increase seawardly with a nearly uniform slope from 19.3 m (63.3 ft) in the northwest corner to 26.5 m (86.9 ft) in the southeast corner (Figure 1-3). The only large bottom feature at MacBDS is the historic disposal mound situated near the center of the site (SAIC 2003).

MacBDS was first used for placement of dredged material in 1971 and again in 1974, followed by a hiatus in placement of nearly 40 years. A DAMOS monitoring survey was conducted at MacBDS in 2002 to evaluate the status of the older deposits and as a baseline for future use of the site. In 2011, dredged material was placed at MacBDS and, in 2012, a second DAMOS monitoring survey was conducted. These historic and recent disposal activities and monitoring surveys are briefly described below.

1.3 Historic Dredged Material Disposal Activity

In the 1970s, dredged material from two projects was placed at MacBDS (Table 1-1). In 1971, an estimated total of 5,900 m^3 (7,700 yd^3) of material from a maintenance dredging project for the six-foot channel in the Machias River was placed at MacBDS. In 1974, an estimated total volume of 49,400 m^3 (65,000 yd^3) of material from a maintenance and improvement project in Bucks Harbor was placed at MacBDS (SAIC

2003). There was reportedly no additional dredged material disposal activity from 1974 to 2002 when a baseline DAMOS monitoring survey was conducted at the site.

1.4 Previous MacBDS Monitoring Event

In July 2002, a DAMOS survey was conducted at MacBDS featuring bathymetry, side-scan sonar, and sediment-profile imaging (SAIC 2003). The site had been inactive since 1974, and the 2002 survey sought to document the distribution of historic dredged material and assess benthic community status within the site.

The bathymetric survey results revealed a historic dredged material mound near the center of the site. The mound was roughly conical in shape, approximately 300 m (1000 ft) in diameter and had a maximum height above the seafloor of 2 m (6 ft). No other major physical features were observed within the site. Side-scan sonar analysis (a form of acoustic backscatter recording) resulted in a characterization of site sediments as having relatively low density (SAIC 2003).

The sediment-profile imaging (SPI) survey found that surficial sediments were primarily fine-grained (reddish-tan over gray) sandy silt. The benthic community within the disposal site was found to be similar to that of the reference areas. In both areas, bioturbation activity was relatively low, attributed to the significant sand content and lower temperature of bottom waters (SAIC 2003).

The 2003 monitoring report concluded that the historic mound appeared stable and the benthic community showed no adverse effects. The report recommended that future monitoring be conducted during late summer to early fall when bottom waters were at their warmest to document benthic habitat recovery.

1.5 Recent Dredged Material Disposal Activity

From January through March of 2011, 64,000 m^3 (84,000 yd^3) of dredged material from a Bucks Harbor maintenance and improvement project was placed at MacBDS (Table 1-1). The material was removed using a mechanical dredge and placed at the site using two split-hulled barges, targeting the center of the site for disposal. The dredged material was primarily silt and clay. The locations of individual disposal events for the January through March 2011 disposal period are shown in Figure 1-4.

1.6 2012 Survey Objectives

The 2012 survey was designed to address the following two objectives:

- To characterize the seafloor topography and surficial features in locations where recent disposal activities have occurred and over the full MacBDS by completing a high-resolution acoustic survey, and

- To use SPI and PV imaging to further define the physical characteristics of surficial sediment and to assess the benthic recolonization status (recovery of the bottom-dwelling animals) of the area with recent disposal activity.

Table 1-1.

Estimated Volume of Dredged Material Placed at MacBDS
from June 1971 to March 2011

Project	Disposal Dates	Volume (m^3)	Volume (yd^3)	Reference
Machias River six-foot channel maintenance	June–September 1971	5,900	7,700	SAIC 2003
Bucks Harbor improvement	June–July 1974	49,400	65,000	SAIC 2003
Total Volume from 1971 to 1974		**55,300**	**72,700**	
Bucks Harbor maintenance	January–March 2011	26,344	34,459	USACE 2012
Bucks Harbor improvement	January–March 2011	37,694	49,305	USACE 2012
Total Volume from 2011		**64,038**	**83,764**	
Total		**119,338**	**156,464**	

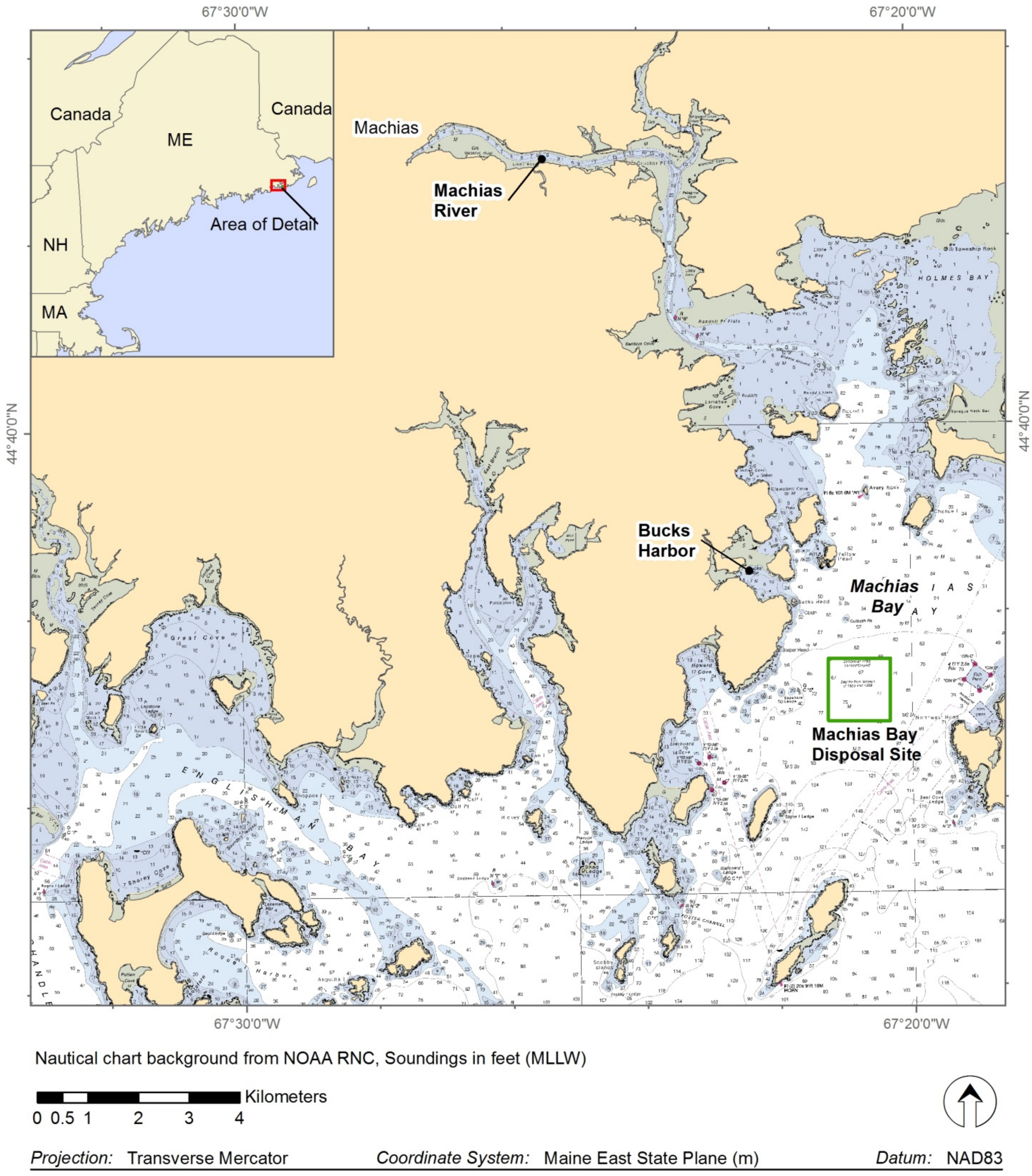


Figure 1-1. Location of the Machias Bay Disposal Site

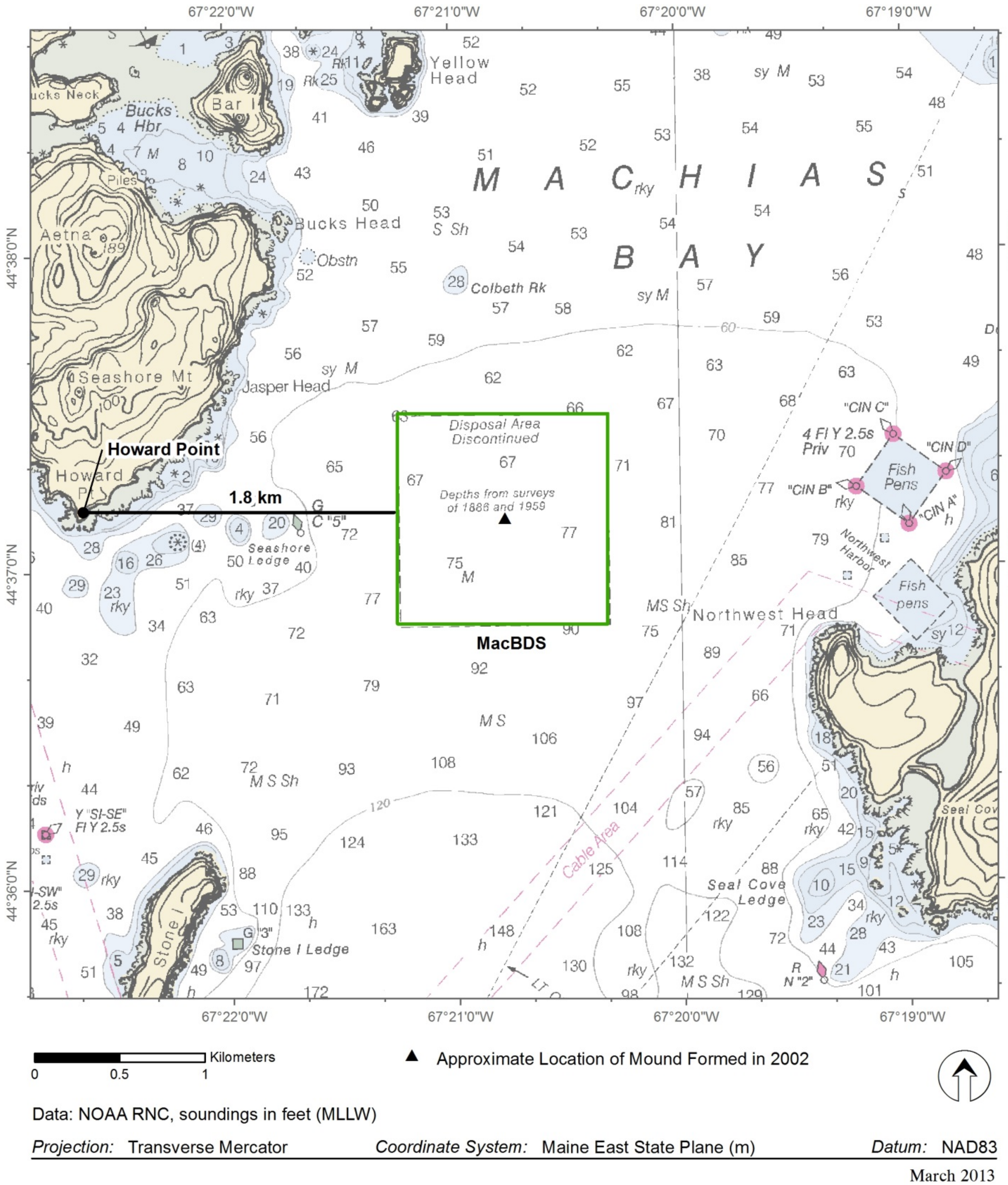


Figure 1-2. MacBDS with site boundary

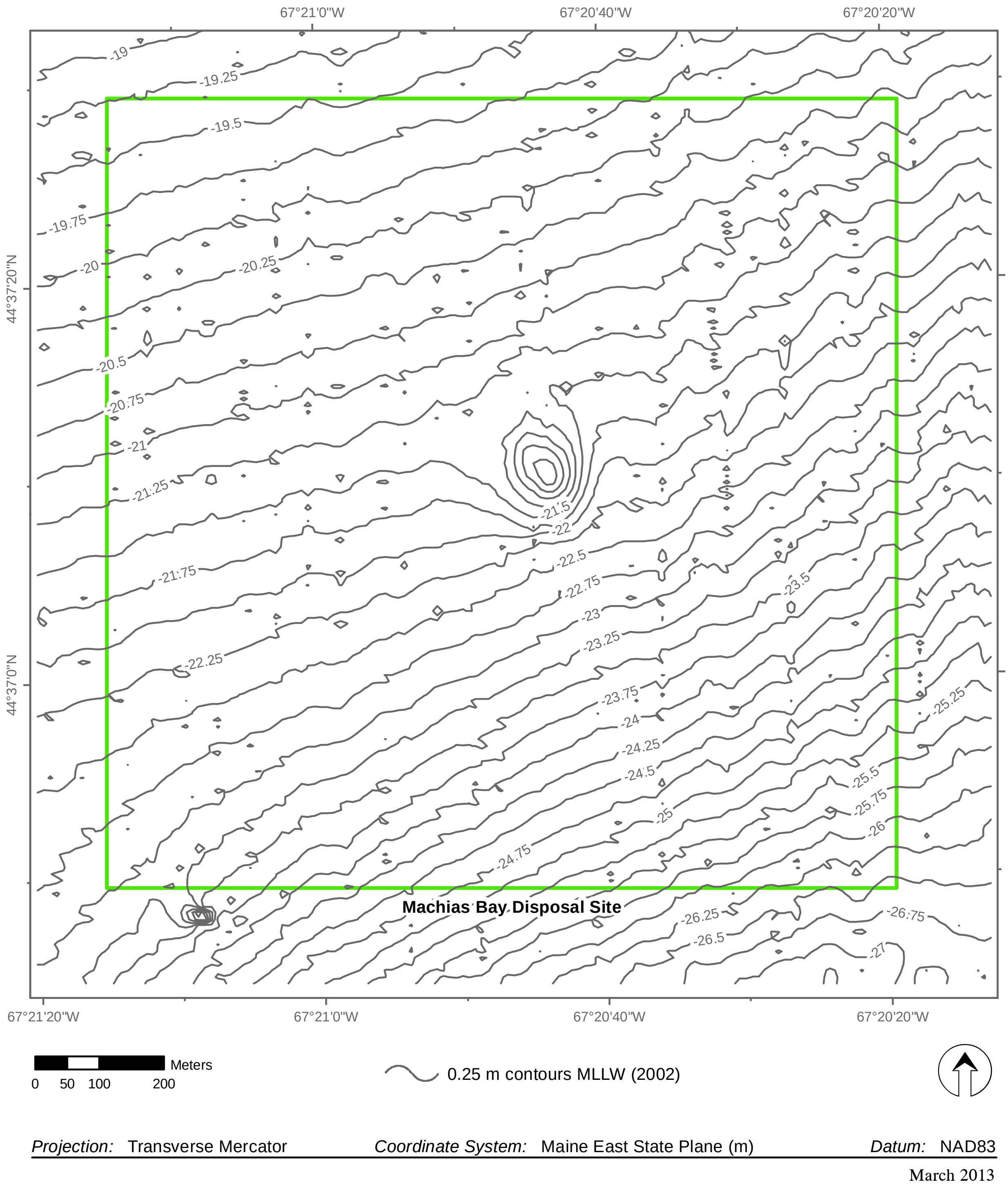


Figure 1-3. Bathymetric contour map of MacBDS based on 2002 survey (SAIC 2003)

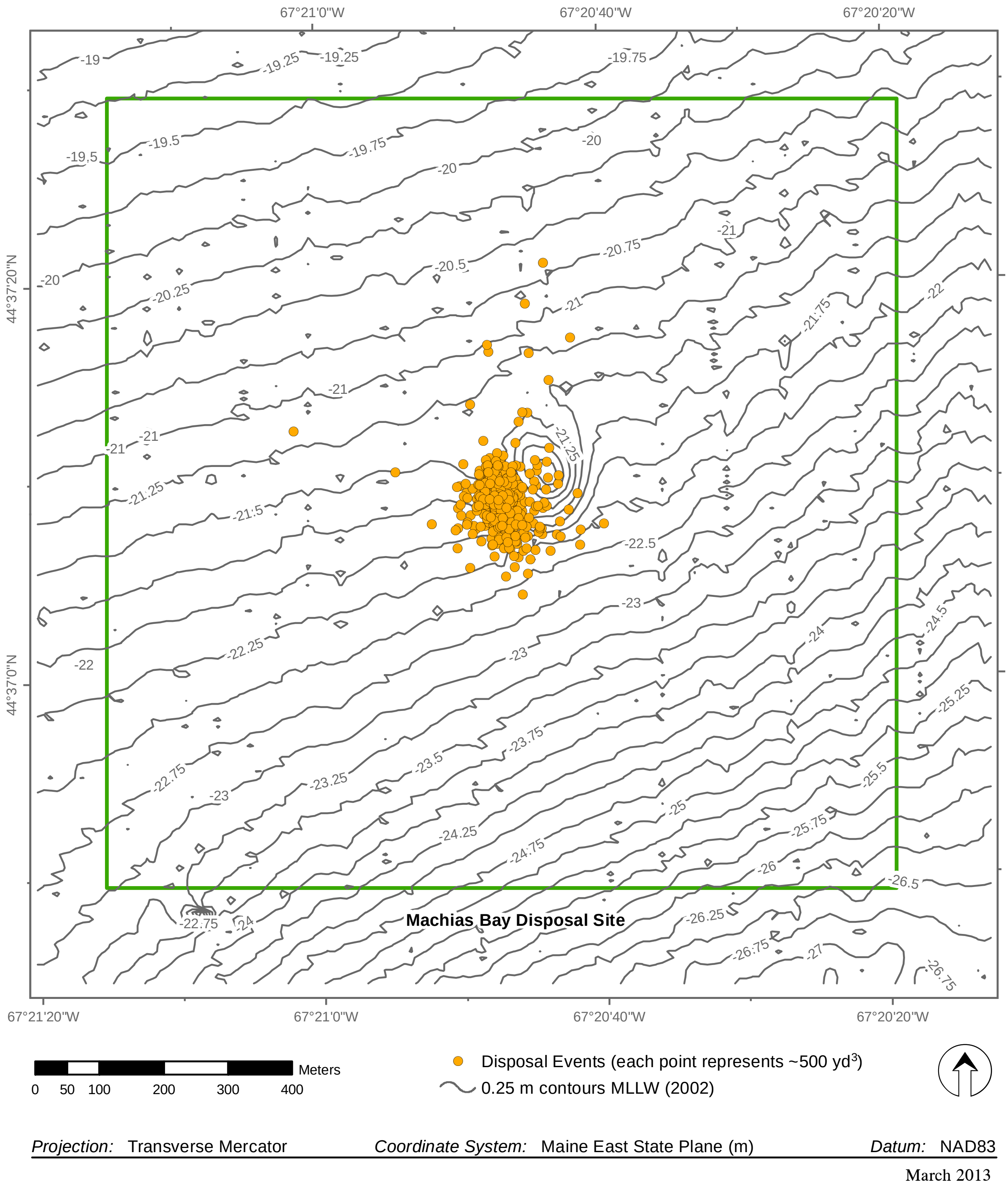


Figure 1-4. Location of disposal events at MacBDS over the period of January to March 2011

2.0 METHODS

The October 2012 survey at MacBDS was conducted by a team of investigators from CR Environmental and Germano & Associates aboard the R/V *Jamie Hanna*. The acoustic survey was conducted on 3 October 2012 to assess dredged material distribution at MacBDS. The SPI and PV imaging survey was conducted on 13 October 2012 to assess benthic conditions at MacBDS.

2.1 Navigation and On-Board Data Acquisition

Navigation for the surveys was accomplished using a Hemisphere 12-channel Differential Global Positioning System (DGPS) capable of receiving U.S. Coast Guard (USCG) Beacon corrections. Trimble DGPS were available as backups. Both systems are capable of submeter horizontal position accuracy. The DGPS was interfaced to a laptop computer running HYPACK MAX® hydrographic survey software. HYPACK MAX® continually recorded vessel position and DGPS satellite quality and provided a steering display for the vessel captain to accurately maintain the position of the vessel along preestablished survey transects and targets.

Redundant vessel heading measurements were acquired using two compass systems, each capable of providing heading measurements accurate to within 0.05° up to 20 times per second. The primary heading device was a SG Brown Meridian Gyrocompass installed in the pilothouse to the port of the vessel's centerline. A dual-antenna Hemisphere VS-100 Crescent Digital compass and DGPS were installed above the pilot house as a backup for the gyrocompass. Both systems were interfaced to HYPACK® acquisition software.

The pulse-per-second (PPS) signals from DGPS were hardware-interfaced to HYPACK MAX® using a translation circuit and provided microsecond level accuracy of data stream time-tagging from each sensor.

2.2 Acoustic Survey

The acoustic survey included bathymetric, backscatter, and side-scan sonar data collection and processing. Bathymetric surveys provide measurements of water depth that, when processed, can be used to map the seafloor topography. The processed data can also be compared with previous surveys to track changes in the size and location of seafloor features. This technique is the primary tool in the DAMOS Program for mapping the distribution of dredged material at disposal sites. Backscatter and side-scan sonar data provide images that support characterization of surficial topography, sediment texture, and roughness.

2.2.1 Acoustic Data Collection

The 2012 multibeam bathymetric survey of MacBDS was conducted on 3 October 2012. Data layers generated by the survey included multibeam bathymetric, sediment acoustic backscatter (beam time-series data), and side-scan sonar data.

The acoustic survey of MacBDS was conducted over a 1,300 × 1,300 m area that included the entire site. The MacBDS acoustic survey included a total of 34 survey lines, spaced approximately 30 m apart and oriented in a north–south direction (Figure 2-1). Seven cross-tie lines, oriented east–west and spanning the survey area, were occupied to assess data quality and the accuracy of tidal corrections (Figure 2-1).

Bathymetric, acoustic backscatter, and side-scan sonar data were collected using a Reson 8101 Multibeam Echo Sounder (MBES). This 240-kHz system forms 101 1.5°-beams distributed equiangularly across a 150° swath. The MBES transducer was mounted amidships to the port rail of the survey vessel using a high-strength adjustable boom, and the primary DGPS antenna was attached to the top of the transducer boom. The transducer depth below the water surface (draft) was checked and recorded at the beginning and end of data acquisition.

The MBES topside processor was equipped with components necessary to export depth solutions, backscatter, and side-scan sonar signals to the HYPACK MAX® acquisition computer via Ethernet communications. HYPACK MAX® also received and recorded navigation data from the DGPS, motion data from a serially interfaced TSS DMS 3-05 motion reference unit (MRU), and heading data from the Meridian and Hemisphere compass systems. Several patch tests were conducted during the survey to allow computation of angular offsets between the MBES system components. The system was calibrated for the speed of sound in the local water body by performing conductivity-temperature-depth (CTD) casts at frequent intervals throughout the survey day with a Seabird SBE-19 Seacat CTD profiler. Additional confirmations of proper calibration, including static draft, were obtained using the “bar check” method, in which a metal plate was lowered beneath the MBES transducer to known depths (e.g., 2.0 and 5.0 m) below the water surface. Bar-check calibrations were accurate to within 0.05 m in tests conducted at the beginning and end of each day.

Water depths over the survey area were recorded in meters and referenced to water levels recorded by an InSitu, Inc. LevelTroll tide gage installed at the fishing pier in Bucks Harbor, located approximately 3.5 km northwest of the survey area. The gage was programmed to record a six-minute series of measurements to support time offset comparison with National Oceanic and Atmospheric Administration (NOAA) tide data.

2.2.2 Bathymetric Data Processing

Bathymetric data were processed using HYPACK HYSWEEP® software. Processing components are described below and included

- Adjustment of data for tide fluctuations
- Correction of ray bending associated with refraction in the water column
- Removal of spurious points associated with water column interference or system errors
- Development of a grid surface representing depth solutions
- Statistical estimation of sounding solution uncertainty
- Generation of data visualization products

Tidal adjustments were accomplished using a Tide Zoning Model (TZM) calculated by NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) specifically for this survey area. The model applied corrections of -6 minutes and height × 0.9 to the six-minute Mean Lower Low Water (MLLW) data series acquired at NOAA's Cutler Ferris Wharf Tide Station (#8411060). The adjusted data were compared to raw tide measurements acquired in Bucks Harbor to verify time and amplitude veracity (Figure 2-2). Preliminary multibeam processing efforts demonstrated that the TZM introduced greater uncertainty than the Bucks Harbor data. The TZM calculated high and low tide MLLW elevations were used to calculate the MLLW elevation of the Bucks Harbor gage.

Correction of sounding depth and position (range and azimuth) associated with refraction due to water column stratification was conducted using a series of five sound-velocity profiles acquired by the survey team. The water column appeared well mixed during the survey, and data artifacts associated with refraction were relatively fine scale.

Data were filtered to accept only beams falling at an angular limit of 50°. Anomalous soundings were flagged or rejected based on the careful examination of data on a sweep-specific basis.

The 240-kHz Reson 8101 MBES system has a published nadir beam width of 1.5° across track and 1.5° along track. Assuming a maximum slant range of 35 m per channel and a maximum beam angle of 50°, the maximum diameter of the beam footprint has been calculated as approximately 1.2 × 1.9 m. Data were reduced to a cell (grid) size of 2.0 × 2.0 m, acknowledging the system's fine range resolution while accommodating beam position uncertainty. This data reduction was accomplished by calculating and exporting the average elevation for each cell in accordance with USACE recommendations (USACE 2002).

Within-cell standard deviations (1-sigma) ranged from 0 to 0.53 m (average 0.02). The average range of cleaned and processed sounding solutions in each 1 m^2 cell was 0.09 m (SD = 0.05 m). The average Root Mean Squared uncertainty at the 95^{th} percentile confidence interval (1.96 - sigma) was 0.04 m. It is noteworthy that the most stringent National Oceanic Service (NOS) and International Hydrographic Organization (IHO) standard for this project depth (Special Order 1A) would call for a 95^{th} percentile confidence interval (95% CI) of 0.30 m. USACE performance standards for this project depth specify a maximum allowable uncertainty of 0.6 m. The MBES data collected for this project are compliant with all applicable performance standards.

Nadir data from the mainstay and cross-tie transects were compared to further refine the uncertainty assessment. Differences between co-located points occupied on perpendicular transects were tabulated and statistically analyzed to assess and report data quality relative to promulgated USACE performance standards. The average difference between 102 co-located points at cross-tie intersections was -0.018 m, indicating that the modified TZM effectively minimized tide bias. The standard deviation of these comparisons was 0.097 m, indicating high repeatability. The 95^{th} percentile accuracy estimate for cross-tie comparisons was calculated per USACE (2002) as 0.19 m, further demonstrating data compliance with promulgated performance standards.

Reduced data were exported in ASCII text format with fields for Easting, Northing, and MLLW elevation (meters). All data were projected to the Maine State Plane (East 1801), North American Datum (NAD83 [metric]). A variety of data visualizations were generated using a combination of IVS3D Fledermaus® (V.7), ESRI ArcMap® (V.10.1), and Golden Software Surfer® (V. 10). Visualizations and data products included

- ASCII databases of all processed soundings including MLLW depths and elevations

- Contours of seabed elevation (25-cm, 50-cm and 1.0-m intervals) in SHP format suitable for plotting using GIS (Geographic Information Systems) and CAD (Computer Aided Design) software

- 3-Dimensional surface maps of the seabed created using 5× vertical exaggeration and artificial illumination to highlight fine-scale features not visible on contour layers (delivered in grid and TIF formats)

- A relief map of the survey area created using 5× vertical exaggeration, delivered in georeferenced TIF format.

2.2.3 Backscatter Data Processing

Backscatter data provide an estimation of surficial sediment texture based on sediment surface roughness and were extracted from cleaned files and converted to Generic Sensor Format (GSF). Mosaics of beam time-series (BTS) backscatter data were created using HYPACK®'s implementation of GeoCoder software developed by scientists at the University of New Hampshire/NOAA Center for Coastal and Ocean Mapping (UNH/NOAA CCOM). A mosaic of unfiltered BTS data was developed and exported in grayscale TIF format. BTS data were also exported in ASCII format with fields for Easting, Northing, and backscatter (dB). A Gaussian filter was applied to backscatter data to minimize nadir artifacts, and the filtered data were used to develop a grid of backscatter values using a 2-m node interval. The grid was delivered in ESRI ASC and GRD formats to facilitate comparison with other data layers.

2.2.4 Side-Scan Sonar Data Processing

The side-scan sonar data were processed using both Chesapeake Technology, Inc. SonarWiz software and HYPACK®'s implementation of GeoCoder software. Individual georeferenced TIF images of each sonar file and georeferenced mosaics with resolutions of 0.1–0.2 m/pixel were generated. The mosaic side-scan sonar data were merged with bathymetric data and formatted for 3D display using Fledermaus® software.

2.2.5 Acoustic Data Analysis

The processed bathymetric grids were converted to rasters, and bathymetric contour lines and acoustic relief models were generated and displayed using GIS. GIS was also used to calculate depth difference grids between the previous bathymetric survey and the 2012 bathymetric dataset. The previous bathymetric survey at MacBDS was conducted in 2002, covering the area of recent disposal activity. The depth difference grids were calculated by subtracting the 2002 survey depth estimates from the 2012 survey depth estimates at each point throughout the grid. The resulting depth differences were contoured and displayed using GIS. Backscatter and side-scan sonar mosaics and filtered backscatter grids were combined with acoustic relief models in GIS to facilitate visualization of relationships between acoustic datasets (images and color-coded grids are rendered with sufficient transparency to allow three-dimensional acoustic relief model to be visible underneath).

2.3 Sediment-Profile and Plan-View Imaging Survey

2.3.1 Sediment-Profile 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 to photograph a cross section of the sediment-water interface. In the 2012 survey at MacBDS, high-resolution SPI images were acquired using a Nikon® D200 digital single lens reflex camera mounted inside an Ocean Imaging® Model 3731 pressure housing system. The pressure housing sat atop a wedge-shaped prism with a front faceplate and a back mirror. The mirror was mounted at a 45° 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 an internal strobe to obtain a cross-sectional image of the upper 15–20 cm of the sediment column (Figure 2-3).

The camera remained on the seafloor for approximately 20 seconds to ensure that a successful image had been obtained. Details of the camera settings for each digital image are available in the associated parameters file embedded in each electronic image file. For this survey, the ISO-equivalent was set at 640, shutter speed was 1/250, f-stop was f9, and storage was in compressed raw Nikon Electronic Format (NEF) files (approximately 9 MB each). Electronic files were converted to high-resolution JPEG (8-bit) format files (3300 × 4900 pixels) using Nikon Capture® NX2 software (Version 2.2.7).

Test exposures of the Kodak® Color Separation Guide (Publication No. Q-13) were made on deck at the beginning and end of the 2012 survey to verify that all internal electronic systems were working to design specifications and to provide a color standard against which final images could be checked for proper color balance. After deployment of the camera at each station, the frame counter was checked to ensure that the requisite number of replicates had been obtained. In addition, a prism penetration depth indicator on the camera frame was checked to verify that the optical prism had actually penetrated the bottom to a sufficient depth. If images were missed or the penetration depth was insufficient, the camera frame stop collars were adjusted and/or weights were added or removed, and additional replicate images were taken. Changes in prism weight amounts, the presence or absence of mud doors, and frame stop collar positions were recorded for each replicate image.

Each image was assigned a unique time stamp in the digital file attributes by the camera's data logger and cross-checked with the time stamp in the navigational system's computer data file. In addition, the field crew kept redundant written sample logs. Images were downloaded periodically to verify successful sample acquisition and/or to assess what type of sediment/depositional layer was present at a particular station. Digital image files were renamed with the appropriate station names immediately after downloading as a further quality assurance step.

2.3.2 Plan-View Imaging

An Ocean Imaging® Model DSC16000 plan-view (PV) underwater camera system with two Ocean Imaging® Model 400-37 Deep Sea Scaling lasers mounted to the DSC16000 was attached to the sediment-profile camera frame and used to collect PV photographs of the seafloor surface; both SPI and PV images were collected during each "drop" of the system. The PV system consisted of a Nikon D-7000 encased in an aluminum housing, a 24 VDC autonomous power pack, a 500 W 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; the scaling lasers projected two red dots that are separated by a constant distance (26 cm) regardless of the field-of-view of the PV system, which can be varied by increasing or decreasing the length of the trigger wire. The field-of-view for the PV images ranged from approximately 0.4 to 1.4 m^2 (Appendix C). 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 PV camera (Figure 2-3). Details of the camera settings for each digital image are available in the associated parameters file embedded in each electronic image file; for this survey, the ISO-equivalent was set at 400. The additional camera settings used were as follows: shutter speed 1/20, f 11, white balance set to flash, color mode set to Adobe RGB, sharpening set to none, noise reduction off, and storage in compressed raw Nikon Electronic Format (NEF) files (approximately 20 MB each). Electronic files were converted to high-resolution JPEG (8-bit) format files (3264 × 4928 pixels) using Nikon Capture® NX2 software.

Prior to field operations, the internal clock in the digital PV system was synchronized with the GPS navigation system and the SPI camera. Each PV image acquired was assigned a time stamp in the digital file and redundant notations in the field and navigation logs. Throughout the survey, PV images were downloaded at the same time as the sediment-profile images after collection and evaluated for successful image acquisition and image clarity.

The ability of the PV system to collect usable images was dependent on the clarity of the water column. To minimize the effects of turbid bottom waters, the bounce trigger cable was shortened to 1.5 m in order to decrease the distance between the camera focal plane and the seafloor. By limiting the distance between the camera lens port and the intended subject, picture clarity was improved. One major drawback to the relatively short trigger cable length and close distance between the PV system and the seafloor was that the field-of-view of the PV system was decreased so that a smaller area of the seafloor was photographed.

2.3.3 SPI and PV Data Collection

Prior to the SPI survey, the 2002 SPI survey results (SAIC 2003) and preliminary October 2012 acoustic survey results were reviewed and analyzed. The area of recent dredged material was estimated to be within a 250-meter diameter area centered over the placement location (Figure 1-4). Within this circle, 18 stations were randomly selected over the defined mound area of recent dredged material placement (Figure 2-4). Two previously monitored reference areas (one to the northeast [NEREF] and one to the southwest [SWREF]) were also surveyed, with six stations randomly selected within each reference area (Figure 2-4). The target SPI/PV station locations are provided in Table 2-1, and actual SPI/PV station replicate locations are provided in Table 2-2.

The SPI/PV survey at MacBDS was conducted on 13 October aboard the R/V *Jamie Hanna*. At each station, the vessel was positioned at the target coordinates and the camera was deployed within a defined station tolerance of 10 m. An effort was made to collect at least four replicate SPI and PV images at each of the stations. The best three images from each station were chosen for analysis (Appendices A and C).

The DGPS described above was interfaced to HYPACK® software via laptop serial ports to provide a method to locate and record target sampling locations. Throughout the survey, the HYPACK® data acquisition system received DGPS data. The incoming data stream was digitally integrated and stored on the PC's hard drive. Actual SPI/PV sampling locations were recorded as target files using this system.

2.3.4 SPI and PV Data Analysis

Computer-aided analysis of the resulting images provided a set of standard measurements to allow comparisons between different locations and different surveys. The DAMOS Program has successfully used this technique for over 30 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites. For a detailed discussion of SPI methodology, see Germano et al. (2011).

Following completion of data collection, the digital images were analyzed using Adobe Photoshop® CS 5 Version 12.1. Images were first adjusted in Adobe Photoshop® to expand the available pixels to their maximum light and dark threshold range. Linear and areal measurements were recorded as number of pixels and converted to scientific units using the Kodak® Color Separation Guide for measurement calibration. Detailed records of all SPI results are included in Appendix A.

2.3.4.1 SPI Data Analysis

Analysis of each SPI image was performed to provide 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. Conversion to other grain size scales is provided in Appendix B. The presence and thickness of disposed dredged material were also assessed by inspection of the images.

Penetration Depth–The depth to which the camera penetrated 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 (aRPD) Depth–The aRPD depth 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 gray. As the particles are buried or moved down by biological activity, they are exposed to reduced oxygen concentrations in subsurface pore waters and their oxic coating slowly reduces, changing color to dark gray or black. When biological activity is high, the aRPD depth increases; when it is low or absent, the aRPD depth decreases. The aRPD depth was measured by assessing 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 which 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 of means of replicate values from each station. The three replicates with the best quality images from each station were chosen for analysis.

2.3.4.2 PV Data Analysis

The PV images provided a much larger field-of-view than the SPI images and provided valuable information about the landscape ecology and sediment topography in the area where the pinpoint “optical core” of the sediment profile was taken. Unusual surface sediment layers, textures, or structures detected in any of the sediment-profile images can be interpreted in light of the larger context of surface sediment features; i.e., is a surface layer or topographic feature a regularly occurring feature and typical of the bottom in this general vicinity or just an isolated anomaly? The scale information provided by the underwater lasers allowed accurate density counts (number per square meter) of attached epifaunal colonies, sediment burrow openings, or larger macrofauna or fish which may have been missed in the sediment-profile cross section. Information on sediment transport dynamics and bedform wavelength were also available from PV image analysis. Analysts calculated the image size and field-of-view and noted sediment type; recorded the presence of bedforms, burrows, tubes, tracks, trails, epifauna, mud clasts, and debris; and included descriptive comments (Appendix C).

2.3.5 Statistical Methods

Statistical analysis was used to aid in the assessment of the benthic recolonization status of the recently formed mound relative to reference conditions. The two SPI parameters which are most indicative of recolonization status, and which also lend themselves to quantitative analysis, are the depth of the aRPD (an indirect measure of the degree of biological reworking of surface sediments) and the infaunal successional stage. For the statistical analysis, the mean value for aRPD depth (based on $n = 3$ replicate images) was utilized, while the maximum value among the three replicates was used as the successional stage rank for each station. The successional stage ranks had possible values between 0 (no fauna present) and 3 (Stage 3); half ranks were also possible for the "in-between" stages (e.g., Stage 1 going to 2 had a value of 1.5).

Traditionally, study objectives have been addressed using point null hypotheses of the form "There is no difference in benthic conditions between the reference area and the disposal mound." An approach using bioequivalence or interval testing is considered to be more informative than the point null hypothesis test of "no difference." In reality, there is always some small difference, and the statistical significance of this difference may or may not be ecologically meaningful. Without an associated power analysis, this type of point null hypothesis testing provides an incomplete picture of the results.

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

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

where d is the difference between the reference area and disposal mound means.

If the null hypothesis is rejected, then it is concluded that the two means are equivalent to 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. Based on historical DAMOS data, δ values of 1 for aRPD depth and 0.5 for successional stage rank (on the 0–3 scale) have been established.

The test of the 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, more typically, on Student's *t*-distribution when sample sizes are small and variances must be estimated from the data. 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, the *t*-distribution can be used to construct a confidence interval around any linear function of means.

In the sampling design utilized in the 2012 SPI/PV survey at MacBDS, there were three distinct areas (two reference areas, and the recent disposal mound), and the difference equations of interest are the linear contrasts of the mean of the two reference means minus the mean on the mound, or

$$[\tfrac{1}{2}\,(\text{Mean}_{\text{NEREF}} + \text{Mean}_{\text{SWREF}}) - (\text{Mean}_{\text{Mound}})]$$

where $\text{Mean}_{\text{Mound}}$ was the mean for the disposal mound stations.

The two reference areas collectively represented ambient conditions, but if there were mean differences among these two areas then pooling them into a single reference group would increase the variance beyond true background variability. The effect of keeping the two reference areas separate has little effect on the grand reference mean (if *n* is equal among these areas), but it maintains the variance as a true background variance for each individual population with its respective mean.

The difference equation, $\hat{d}$, for the comparison of interest was:

$$[\tfrac{1}{2}(\text{Mean}_{\text{NEREF}} + \text{Mean}_{\text{SWREF}}) - (\text{Mean}_{\text{Mound}})] \qquad \text{[Eq.1]}$$

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

$$SE(\hat{d}) = \sqrt{\sum_j \left(S_j^2 c_j^2 / n_j\right)} \qquad \text{[Eq.2]}$$

where:

c_j = coefficients for the j means in the difference equation, $\hat{d}$ [Eq. 1] (i.e., for equation 1 shown above, the coefficients were ½ for each of the 2 reference areas, and -1 for the disposal mound).

S_j^2 = variance for the j^{th} area. If equal variances are assumed, a single pooled residual variance estimate can be substituted for each group, equal to the mean square error from an ANOVA based on all three groups.

n_j = number of replicate observations for the j^{th} area.

The inequivalence null hypothesis was rejected (and equivalence was concluded) if the confidence interval on the difference of means, $\hat{d}$, was fully contained within the interval [−δ , + δ]. Thus the decision rule was to reject H_0 if:

$$D_L = \hat{d} - t_{\alpha,\upsilon} se(\hat{d}) > -\delta \quad \text{and} \quad D_U = \hat{d} + t_{\alpha,\upsilon} se(\hat{d}) < \delta \qquad \text{[Eq. 3]}$$

where:

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

$t_{\alpha,\upsilon}$ = upper $(100\text{-}\alpha)^{th}$ 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 residual variance estimate was used, it was the residual degrees of freedom from an ANOVA on all groups (total number of stations minus the number of groups); if separate variance estimates were used, degrees of freedom were calculated based on the Brown and Forsythe estimation (Zar 1996).

Validity of the normality and equal variance assumptions were tested using Shapiro-Wilk's test for normality on the area residuals ($\alpha = 0.05$) and Levene's test for equality of variances among the three areas ($\alpha = 0.05$). If normality was not rejected but equality of variances was, then a normal t-interval was used with the variance for the difference equation based on separate variances for each group with associated degrees of freedom (i.e., Brown and Forsythe estimation, Zar 1996). If normality was rejected, then bootstrapping was used to construct the confidence interval for the difference equation.

Table 2-1.

MacBDS 2012 Survey Target SPI/PV Station Locations

Target SPI/PV Station Locations			Target Reference Station Locations		
Station	Latitude (N)	Longitude (W)	Station	Latitude (N)	Longitude (W)
1	44° 37.140'	67° 20.706'	NEREF-19	44° 37.509'	67° 19.452'
2	44° 37.113'	67° 20.930'	NEREF-20	44° 37.656'	67° 19.460'
3	44° 37.112'	67° 20.690'	NEREF-21	44° 37.612'	67° 19.292'
4	44° 37.219'	67° 20.785'	NEREF-22	44° 37.714'	67° 19.313'
5	44° 37.116'	67° 20.758'	NEREF-23	44° 37.641'	67° 19.379'
6	44° 37.044'	67° 20.864'	NEREF-24	44° 37.613'	67° 19.473'
7	44° 37.203'	67° 20.731'	SWREF-25	44° 36.351'	67° 21.788'
8	44° 37.201'	67° 20.647'	SWREF-26	44° 36.390'	67° 21.887'
9	44° 37.190'	67° 20.778'	SWREF-27	44° 36.624'	67° 21.907'
10	44° 37.149'	67° 20.954'	SWREF-28	44° 36.546'	67° 21.818'
11	44° 37.036'	67° 20.824'	SWREF-29	44° 36.580'	67° 21.799'
12	44° 37.260'	67° 20.707'	SWREF-30	44° 36.568'	67° 21.744'
13	44° 37.068'	67° 20.904'			
14	44° 37.237'	67° 20.899'			
15	44° 37.123'	67° 20.809'			
16	44° 37.143'	67° 20.874'			
17	44° 37.271'	67° 20.778'			
18	44° 37.068'	67° 20.777'			

Note: Coordinate system NAD83

Table 2-2.

MacBDS 2012 Survey Actual SPI/PV Replicate Locations

SPI/PV Replicate Locations					
Replicate	Latitude (N)	Longitude (W)	Replicate	Latitude (N)	Longitude (W)
1A	44° 37.139'	67° 20.704'	9D	44° 37.188'	67° 20.779'
1B	44° 37.138'	67° 20.706'	10A	44° 37.147'	67° 20.952'
1C	44° 37.137'	67° 20.708'	10B	44° 37.148'	67° 20.952'
1D	44° 37.138'	67° 20.707'	10C	44° 37.147'	67° 20.952'
2A	44° 37.110'	67° 20.929'	10D	44° 37.147'	67° 20.950'
2B	44° 37.114'	67° 20.928'	11A	44° 37.036'	67° 20.827'
2C	44° 37.112'	67° 20.924'	11B	44° 37.036'	67° 20.827'
2D	44° 37.113'	67° 20.929'	11C	44° 37.037'	67° 20.828'
3A	44° 37.113'	67° 20.691'	11D	44° 37.036'	67° 20.828'
3B	44° 37.111'	67° 20.691'	12A	44° 37.260'	67° 20.705'
3C	44° 37.109'	67° 20.690'	12B	44° 37.260'	67° 20.705'
3D	44° 37.110'	67° 20.691'	12C	44° 37.257'	67° 20.702'
4A	44° 37.217'	67° 20.786'	12D	44° 37.256'	67° 20.709'
4B	44° 37.217'	67° 20.789'	13A	44° 37.065'	67° 20.905'
4C	44° 37.216'	67° 20.787'	13B	44° 37.065'	67° 20.902'
4D	44° 37.217'	67° 20.786'	13C	44° 37.067'	67° 20.908'
5A	44° 37.116'	67° 20.756'	13D	44° 37.066'	67° 20.905'
5B	44° 37.116'	67° 20.756'	14A	44° 37.238'	67° 20.898'
5C	44° 37.114'	67° 20.754'	14B	44° 37.235'	67° 20.897'
5D	44° 37.115'	67° 20.756'	14C	44° 37.236'	67° 20.898'
6A	44° 37.044'	67° 20.866'	14D	44° 37.234'	67° 20.898'
6B	44° 37.042'	67° 20.863'	15A	44° 37.119'	67° 20.808'
6C	44° 37.042'	67° 20.865'	15B	44° 37.122'	67° 20.809'
6D	44° 37.042'	67° 20.866'	15C	44° 37.119'	67° 20.812'
7A	44° 37.197'	67° 20.730'	15D	44° 37.119'	67° 20.811'
7B	44° 37.201'	67° 20.735'	16A	44° 37.141'	67° 20.878'
7C	44° 37.201'	67° 20.731'	16B	44° 37.141'	67° 20.875'
7D	44° 37.201'	67° 20.729'	16C	44° 37.139'	67° 20.872'
8A	44° 37.198'	67° 20.651'	16D	44° 37.139'	67° 20.874'
8B	44° 37.199'	67° 20.645'	17A	44° 37.269'	67° 20.779'
8C	44° 37.202'	67° 20.645'	17B	44° 37.269'	67° 20.780'
8D	44° 37.200'	67° 20.644'	17C	44° 37.269'	67° 20.778'
9A	44° 37.187'	67° 20.779'	17D	44° 37.270'	67° 20.778'
9B	44° 37.188'	67° 20.774'	18A	44° 37.064'	67° 20.781'
9C	44° 37.187'	67° 20.776'	18B	44° 37.069'	67° 20.777'
			18C	44° 37.069'	67° 20.777'

Table 2-2. continued

Reference Replicate Locations					
Replicate	Latitude (N)	Longitude (W)	Replicate	Latitude (N)	Longitude (W)
NEREF-19A	44° 37.506'	67° 19.452'	SWREF-25A	44° 36.350'	67° 21.784'
NEREF-19B	44° 37.506'	67° 19.452'	SWREF-25B	44° 36.352'	67° 21.785'
NEREF-19C	44° 37.506'	67° 19.448'	SWREF-25C	44° 36.351'	67° 21.784'
NEREF-19D	44° 37.508'	67° 19.446'	SWREF-25D	44° 36.351'	67° 21.786'
NEREF-20A	44° 37.656'	67° 19.460'	SWREF-26A	44° 36.389'	67° 21.885'
NEREF-20B	44° 37.656'	67° 19.457'	SWREF-26B	44° 36.389'	67° 21.886'
NEREF-20C	44° 37.653'	67° 19.458'	SWREF-26C	44° 36.388'	67° 21.884'
NEREF-20D	44° 37.656'	67° 19.456'	SWREF-26D	44° 36.389'	67° 21.885'
NEREF-21A	44° 37.611'	67° 19.295'	SWREF-27A	44° 36.626'	67° 21.902'
NEREF-21B	44° 37.612'	67° 19.291'	SWREF-27B	44° 36.626'	67° 21.906'
NEREF-22A	44° 37.715'	67° 19.314'	SWREF-27C	44° 36.626'	67° 21.904'
NEREF-22B	44° 37.716'	67° 19.310'	SWREF-27D	44° 36.623'	67° 21.906'
NEREF-22C	44° 37.714'	67° 19.314'	SWREF-28A	44° 36.546'	67° 21.811'
NEREF-22D	44° 37.712'	67° 19.308'	SWREF-28B	44° 36.547'	67° 21.820'
NEREF-23A	44° 37.640'	67° 19.373'	SWREF-28C	44° 36.547'	67° 21.820'
NEREF-23B	44° 37.640'	67° 19.378'	SWREF-28D	44° 36.547'	67° 21.818'
NEREF-23C	44° 37.638'	67° 19.381'	SWREF-29A	44° 36.581'	67° 21.794'
NEREF-23C	44° 37.607'	67° 19.293'	SWREF-29B	44° 36.577'	67° 21.799'
NEREF-23D	44° 37.637'	67° 19.376'	SWREF-29C	44° 36.577'	67° 21.795'
NEREF-23D	44° 37.610'	67° 19.290'	SWREF-29D	44° 36.579'	67° 21.795'
NEREF-24A	44° 37.612'	67° 19.473'	SWREF-30A	44° 36.563'	67° 21.740'
NEREF-24B	44° 37.611'	67° 19.468'	SWREF-30B	44° 36.571'	67° 21.745'
NEREF-24C	44° 37.609'	67° 19.469'	SWREF-30C	44° 36.568'	67° 21.742'
NEREF-24D	44° 37.610'	67° 19.471'	SWREF-30D	44° 36.569'	67° 21.739'

Notes: 1) Coordinate system NAD83
2) This table reflects all attempts to collect replicates at each target station. The three replicates with the best quality images were used for analysis.

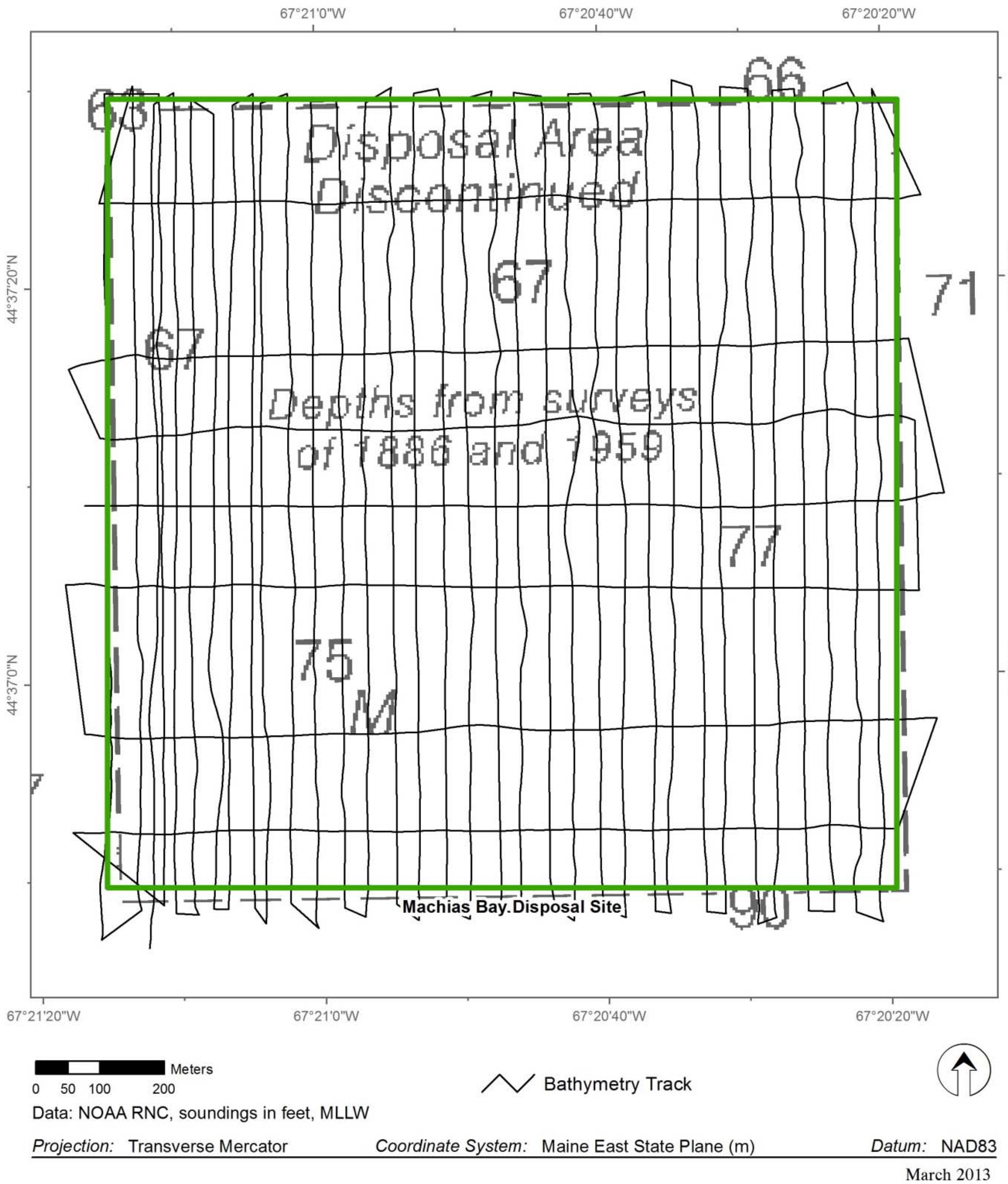


Figure 2-1. MacBDS with bathymetric survey lines indicated

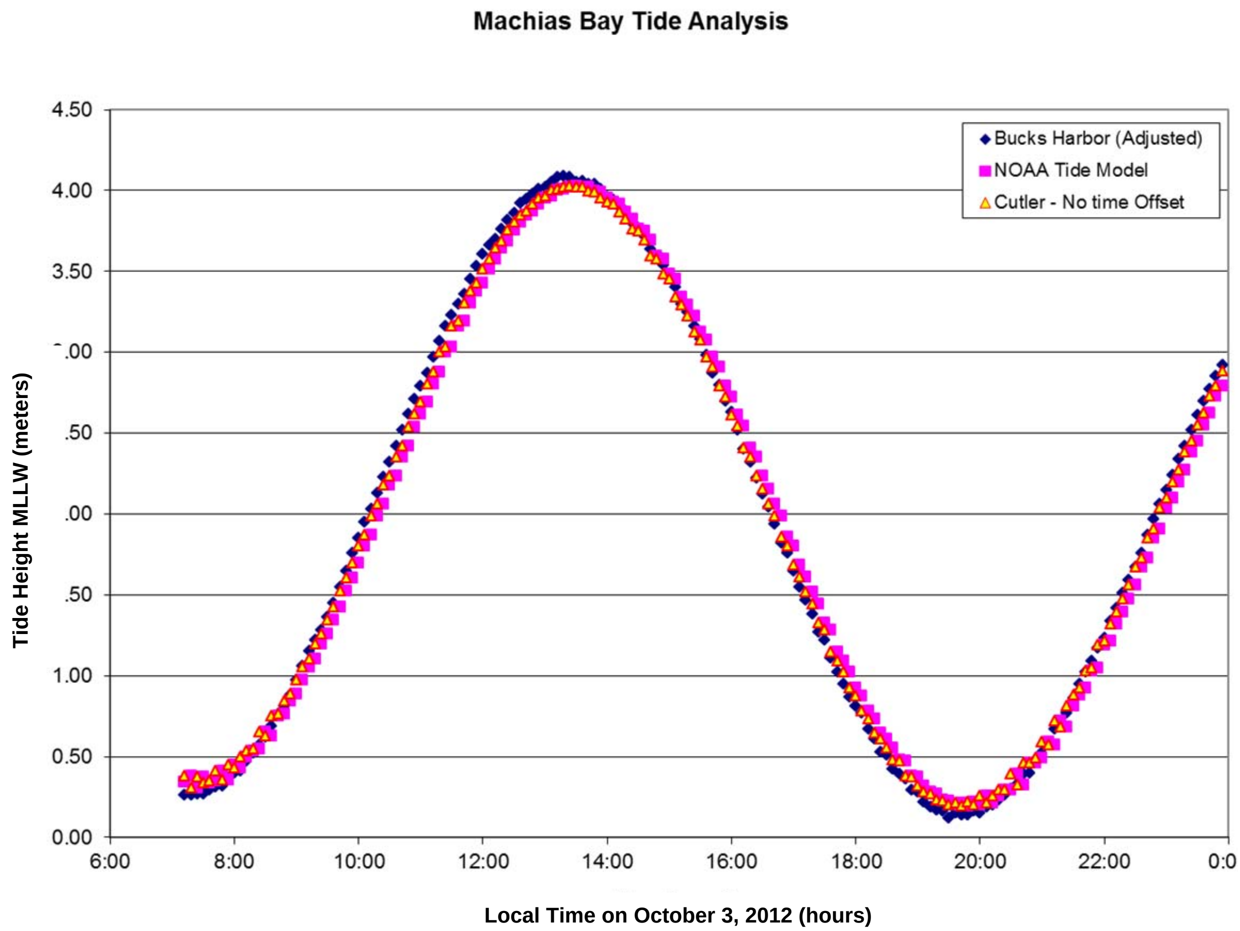


Figure 2-2. Comparison of predicted and measured tidal height adjustments

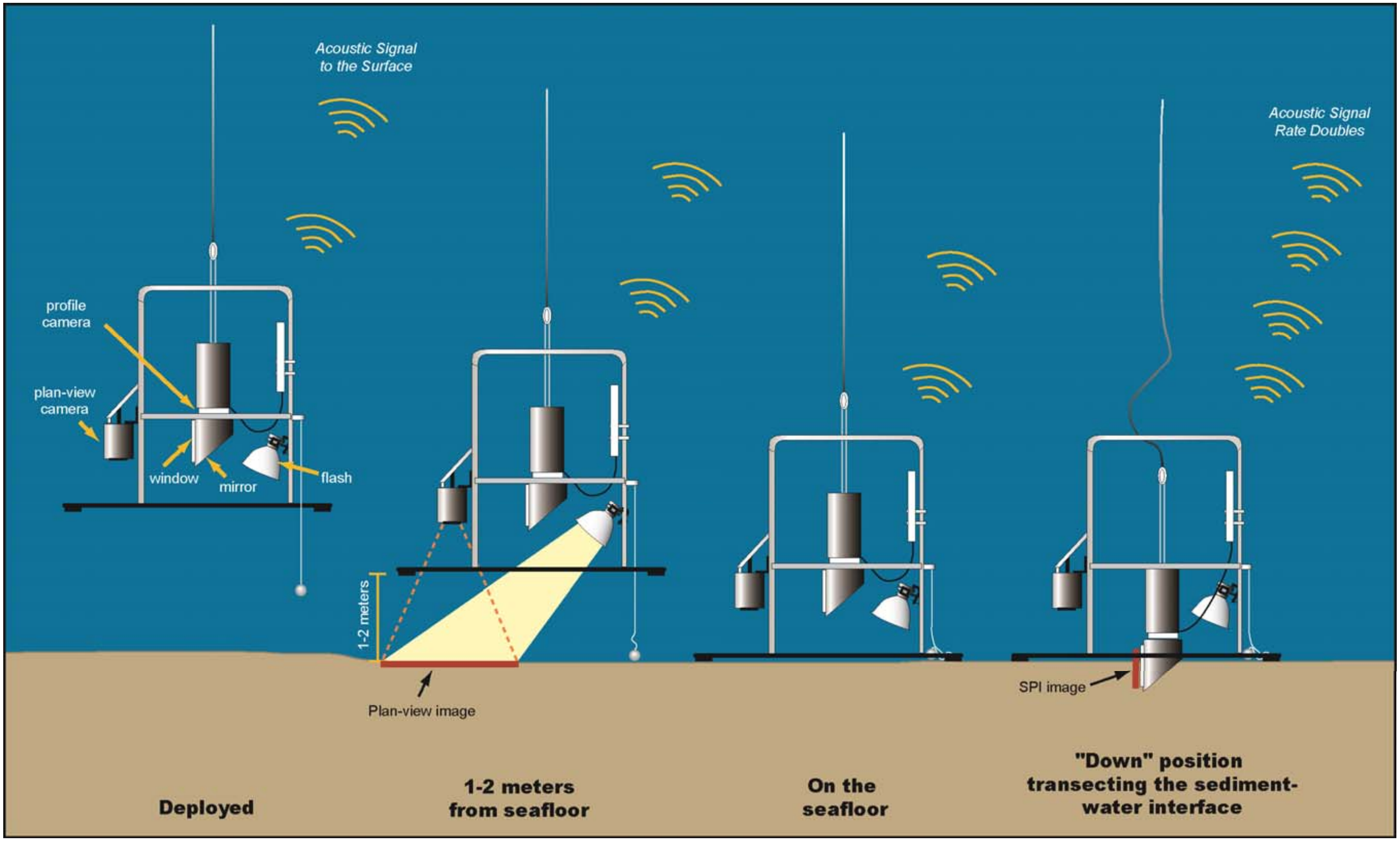


Figure 2-3. Schematic diagram of the SPI/PV camera deployment

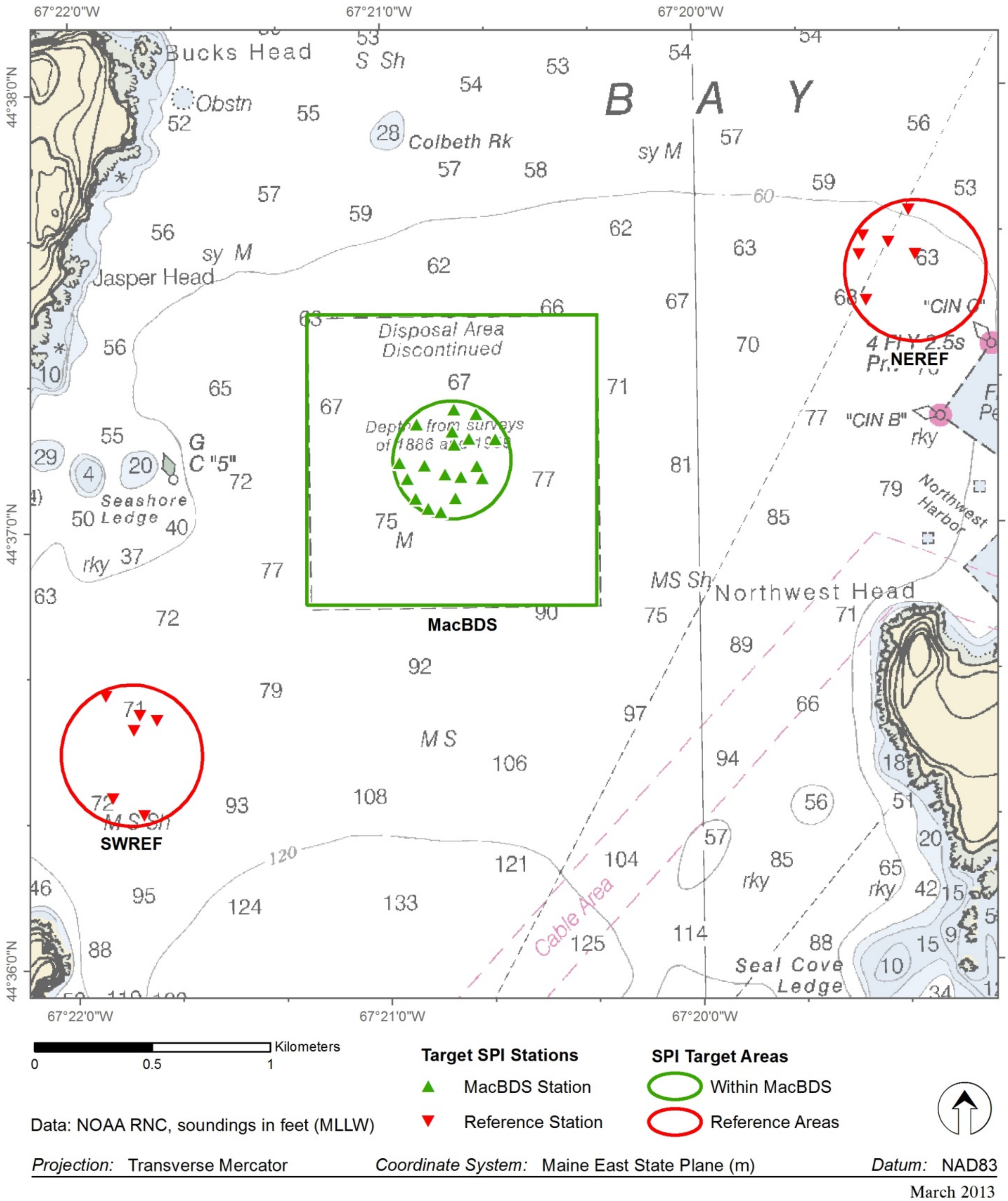


Figure 2-4. MacBDS and reference areas with target sediment-profile image stations indicated

3.0 RESULTS

3.1 Bathymetry

3.1.1 Existing Bathymetry

The bathymetry of MacBDS as surveyed in 2012 revealed a central mound on a gently sloping seafloor (Figure 3-1). The overall site bathymetry was consistent with that of the 2002 survey with water depths ranging from approximately 19.3 m in the northwest corner to 26.5 m in the southeast corner. The seafloor sloped uniformly from northwest to southeast with the exception of one centrally-located disposal mound. The minimum depth over the mound was approximately 17.1 m. The peak of the mound was approximately 4.4 m above the surrounding seafloor. The mound covered an area of approximately 150 × 190 m with an apron extending well beyond, particularly to the northwest and southwest. The planar footprint of the mound (including the apron) was approximately 61,700 m^2. The mound was generally a low-relief feature with a mean side-slope of approximately 2 degrees (angle above horizontal) and a maximum side-slope of 19 degrees located along the eastern side (Figure 3-1).

Multibeam bathymetric data rendered as an acoustic relief model (grayscale with hillshading) provided a more detailed representation of the surface of the mound and site (Figure 3-2). The overall site was noticeably smooth with a few small (<10 m diameter) depressions scattered away from the mound. The mound itself had a distinctive profile with flat terraces to the north and west, a cone-shaped peak, and an irregular slope to the east (Figure 3-2). The eastern margin of the mound had several small (<50 m diameter) oval and semi-circular shaped features attributed to disposal activities.

3.1.2 Acoustic Backscatter

Backscatter imagery of the disposal site provided a clear rendering of the dredged material placed on the seafloor and associated placement features (Figure 3-3). The dredged material over the mound had elevated backscatter distributed in overlapping circular patterns. Surrounding the mound were nine circular features (<50 m in diameter) with elevated backscatter compared to the surrounding sediments. The disposal site had remarkably uniform backscatter with two linear areas of higher backscatter in the northeast corner (Figure 3-3).

3.1.3 Side-Scan Sonar

Side-scan sonar results also provided a clear representation of disposal activity, but with some distinct differences from the backscatter results (Figure 3-4). The side-scan sonar results have a higher resolution and are more responsive to minor surface textural features and slope than the backscatter. The placement area at MacBDS had a very restricted area of stronger return compared to the large area in the backscatter (compare Figures 3-3 and 3-4). The circular disposal impact features were clearer in the backscatter data indicating they were mostly likely formed by slight compositional differences in the dredged material compared to ambient sediments. The side-scan sonar record had numerous small angular targets throughout the disposal site (Figure 3-4). These targets were consistent with lobster traps seen in New England coastal waters on other surveys.

3.1.4 Comparison with Previous Bathymetry

Digital data provided for the 2002 survey consisted of single-beam echo sounder transects spaced approximately 50 to more than 80 m apart, oriented in a north-south direction. Perpendicular cross-tie quality control transects were not available. Data had been "sorted" to an along-transect density of 5 m. This sorting procedure likely introduced a low-magnitude shoal (shallow) bias. The 2002–2012 elevation comparisons suggested a large scale tide-dependent negative (deep) bias of approximately -5 to -15 cm. This bias was taken into account during quantitative analysis of the elevation comparison model.

The bathymetric contour map developed from the 2012 survey data (Figure 3-1) revealed an expanded mound compared to the mound found during the 2002 survey (Figure 1-3). A subtraction of the bottom depths in the 2002 survey from the 2012 depths highlighted the apparent changes in bathymetry since the 2002 survey (Figure 3-5). Expansion of the mound was most pronounced to the west and south of the 2002 apex where the depth decreased (elevation increased) by more than 4 m. The depth measured in 2012 at the location of the apex of the 2002 mound decreased by approximately 30 cm since 2002, which likely represented recent dredged material placed on the older mound (Figure 1-4).

The 2002–2012 depth difference comparison revealed changes ranging from a slight increase in depth to a decrease in depth of approximately 4 m. The small apparent depth increase adjacent to the eastern flank of the 2002 mound was likely a modeling artifact associated with interpolation between transects spaced more than 80 m apart.

The depth difference analysis resulted in a measured volume of 56,600 m^3 of dredged material added to the mound area since the 2002 survey. This volume was consistent with the estimated volume of dredged material (64,000 m^3) placed at MacBDS as part of the Bucks Harbor dredging project between January and March 2011 (Table 1-1). The difference between estimates of volumes placed and volumes measured at the site were within expected ranges associated with mound consolidation and uncertainty in volume estimates given the difference in bathymetric techniques.

3.2 Sediment-Profile and Plan-View Imaging

The primary purpose of the SPI/PV survey at the Machias Bay Disposal Site was to characterize the physical features of the surface sediments and assess the status of benthic recolonization on the disposal mound 19 months after disposal operations had ceased and compare it with conditions at the two reference areas. The 18 stations sampled on the dredged material mound were randomly placed within the area of the recent deposit defined by the multibeam survey results. A station summary of some of the measured parameters from the profile images can be found in Tables 3-1 and 3-2, with a complete set of results in Appendix A (SPI), and Appendix C (PV).

3.2.1 Reference Area Stations

Physical Sediment Characteristics: The sediments at the reference areas, NEREF and SWREF, were either sandy silt/clays or silty very fine sands; there was a higher percentage of sandy stations at SWREF than at NEREF (Figure 3-6). Most of the plan-view images revealed a rather uniform, muddy surface with multiple, small burrow openings and a general lack of small-scale topographic anomalies other than biogenic foraging structures (Figure 3-7). Subsurface sediments in two of the replicate images from Station NEREF-21 had a noticeably higher than normal amount of organic material below the surface oxidized layer (Figure 3-8); the origin of the enhanced organics at this particular location is unknown.

The stops and weights were kept constant and set at their maximum values for all stations during this survey due to the higher sand content and consolidated nature of the sediments. Mean prism penetration at the reference stations ranged from 10.1 to 17.6 cm, with an overall reference area average of 12.4 cm (Figure 3-9). Small scale boundary roughness values had a total range of 1 cm, from a low value of 0.6 to a reference area high value of 1.6 cm; most of these small-scale roughness elements were biogenic in origin (see Figures 3-6 and 3-7 for examples and find details in Appendix A). None of the stations surveyed in either of the two reference areas displayed any evidence of low dissolved oxygen in the overlying water or signs of methane in the subsurface sediments.

Biological Conditions and Benthic Recolonization: Station mean values for the mean aRPD depths at the reference stations ranged from 2.5 to 5.2 cm, with an overall reference area mean of 3.5 cm (Table 3-1; Figure 3-10). Evidence of mature, deposit-feeding infaunal assemblages were found at all the reference stations, with bioturbation depths extending to the camera prism penetration depths at many of the locations (Figure 3-11; Appendix A). The plan-view images revealed the reference areas to be free of any obvious physical or anthropogenic disturbance impacts, thereby maintaining suitable conditions for the continued establishment of Stage 3 successional communities (Rhoads et al. 1978, Rhoads and Germano 1986).

3.2.2 Disposal Site Stations

SPI and PV images were collected at 17 of 18 MacBDS stations. Plan-view images but no profile images were collected at Station 3 (the 18th) because the camera became fouled on a lobster trap which prevented prism penetration. Given the uniformity of conditions at the other 17 stations sampled within the disposal site coupled with weather and schedule constraints, a decision was made to forego re-sampling this one location.

Physical Sediment Characteristics: Similar to the reference areas, the sediments at the disposal site ranged from sandy silt/clays to silty, very fine to medium sand (Figure 3-12); there was a noticeable difference in the range of sediment particle sizes at the disposal site, with stations located on the slopes of the disposal mound having an armored surface of shell fragments (Figure 3-13) or larger pebbles and cobbles (Figure 3-14), a textural feature that was noticeably absent from the reference stations. On the flatter areas of the dredged material deposit, sediments were mostly silty sands with a coarser layer of particles near the sediment surface (Figure 3-15).

Camera prism penetration depths ranged from 9.0 to 16.9 cm (the lowest values on the eastern and southern margin associated with the shells and cobbles mentioned above or with hard sand at Stations 1 and 18), with an overall disposal site mean of 12.2 cm (Table 3-1; Figure 3-16). Boundary roughness values had a slightly greater range of 2.8 cm at the disposal site stations as compared with those from the reference areas, ranging from a low of 0.4 to a maximum of 3.2 cm, with an overall mean disposal site reference value of 1.2 cm. As with the small-scale topographic relief found at the reference areas, most of the values at the disposal site were biogenic in origin (Figure 3-17). There were no locations sampled within the disposal site boundary that showed any evidence of low oxygen in the overlying waters or methane formation from excess organic enrichment in the subsurface sediments.

Biological Conditions and Benthic Recolonization: Station mean values for the aRPD depth at the disposal site ranged from 2.2 to 3.8 cm, with an overall disposal site mean aRPD depth of 2.9 cm (Table 3-1, Figure 3-18). Similar to the reference stations, evidence of mature, deposit-feeding assemblages was found at every station sampled within the disposal site boundary (Appendix A), even at those stations in the center of the deposit where dredged material was thickest (Figure 3-19). The maximum depth of feeding void structures, when present, ranged from 6.2 to 19.2 cm; evidence of burrowing and feeding activities often was seen at the limit of camera prism penetration (Figure 3-20), indicating that resident infauna were bioturbating to depths greater than what were able to be measured in the collected profile images.

3.3 Statistical Comparisons

3.3.1 Mean aRPD Depths

The two reference areas were fairly similar though SWREF had slightly higher mean and variance for the aRPD depth values (Table 3-3, Figure 3-21). Results for the normality test indicate that the area residuals (i.e., each observation minus the area mean) were normally distributed (Shapiro-Wilk's test p-value = 0.51). The assumption of equal variances was rejected by Levene's test ($p = 0.04$) so a separate variance estimate was used to compute the standard error for the difference equation shown in Table 3-4.

The difference between mound and the mean of the reference locations was 0.62 m. The 95% confidence bounds for the Inequivalence test on this difference were [0.17, 1.06]. These bounds were not fully contained within the interval [-1.0, +1.0], which are the limits of what is considered to be ecologically equivalent. Hence, it was concluded that the mound was statistically inequivalent to the mean reference conditions for the aRPD depth endpoint. The observed difference was not statistically within the interval defined by the assumed "ecologically meaningful" δ of 1.0 cm, even though the exceedance of this delta was quite small.

3.3.2 Successional Stage Ranks

No statistical testing was needed for comparing the successional stage ranks among the disposal site and reference areas because there were Stage 3 taxa present at all stations sampled with no variation in station successional stage ranking; all the areas sampled were equivalent from the standpoint of trophic infaunal assemblages.

Table 3-1.

Summary of MacBDS Reference Station Sediment-Profile Imaging Results, October 2012

Station	Grain Size Major Mode (phi)	Station Mean Penetration (cm)	Station Mean Boundary Roughness (cm)	Station Mean aRPD Depth (cm)	Methane Present?	Station Maximum Void Depth (cm)	Highest Successional Stage Present
SWREF-25	>4	17.6	1.4	5.2	No	15.3	Stage 1 on 3
SWREF-26	>4	14.5	1.6	4.4	No	9.5	Stage 1 on 3
SWREF-27	4-3	10.2	1.1	2.9	No	11.5	Stage 1 on 3
SWREF-28	4-3	10.1	0.9	2.6	No	9.2	Stage 1 on 3
SWREF-29	4-3	10.5	0.8	3.3	No	6.3	Stage 1 on 3
SWREF-30	4-3	10.9	1.0	3.6	No	8.6	Stage 1 on 3
NEREF-19	4-3	11.9	0.6	3.0	No	9.5	Stage 1 on 3
NEREF-20	>4	11.1	0.8	3.7	No	6.2	Stage 1 on 3
NEREF-21	>4	11.9	1.0	3.4	No	8.7	Stage 1 on 3
NEREF-22	>4	14.8	0.9	3.6	No	15.5	Stage 1 on 3
NEREF-23	>4	12.1	1.6	3.7	No	11.2	Stage 1 on 3
NEREF-24	>4	12.7	1.1	2.5	No	16.5	Stage 1 on 3
Min	NA	10.1	0.6	2.5	NA	6.2	NA
Max	NA	17.6	1.6	5.2	NA	16.5	NA
Mean*	NA	12.4	1.1	3.5	NA	10.7	NA

*Station means were calculated from three replicates, reference area mean values were calculated as the mean of station means.

Table 3-2.

Summary of MacBDS Mound Sediment-Profile Imaging Results, October 2012

Station	Grain Size Major Mode (phi)	Station Mean Penetration (cm)	Station Mean Boundary Roughness (cm)	Station Mean aRPD Depth (cm)	Methane Present?	Station Maximum Void Depth (cm)	Highest Successional Stage Present
1	4-3	9.4	1.0	2.9	No	8.2	Stage 1 on 3
2	4-3	14.6	0.4	3.8	No	13	Stage 1 on 3
4	>4	16.9	1.5	2.7	No	14.1	Stage 1 on 3
5	4-3	10.3	3.2	2.5	No	8.2	Stage 1 on 3
6	4-3	11.5	0.9	2.6	No	10.2	Stage 1 on 3
7	4-3	9.0	1.3	2.4	No	0	Stage 1 on 3
8	4-3	11.6	1.4	3.7	No	8.9	Stage 1 on 3
9	>4	15.5	2.5	2.2	No	19.2	Stage 1 on 3
10	4-3	10.6	1.2	2.8	No	12.4	Stage 1 on 3
11	4-3	11.9	1.0	2.9	No	0	Stage 1 on 3
12	4-3	11.5	1.2	3.2	No	6.7	Stage 1 on 3
13	4-3	13.2	0.7	3.1	No	12.6	Stage 1 on 3
14	4-3	10.6	1.0	2.8	No	8.4	Stage 1 on 3
15	>4	15.7	1.0	2.5	No	10.9	Stage 1 on 3
16	4-3	16.0	0.8	2.9	No	13.7	Stage 1 on 3
17	4-3	10.5	1.1	3.1	No	0	Stage 1 on 3
18	4-3	9.0	0.8	2.5	No	11.3	Stage 1 on 3
Min	NA	9.0	0.4	2.2	NA	0.0	NA
Max	NA	16.9	3.2	3.8	NA	19.2	NA
Mean*	NA	12.2	1.2	2.9	NA	9.3	NA

*Station means were calculated from three replicates, disposal mound mean values were calculated as the mean of station means.

Table 3-3.

Summary of Station Mean aRPD Depth by Sampling Location

Area	N	Mean aRPD Depth (cm) Mean	Standard Deviation
Reference areas			
NEREF	6	3.3	0.47
SWREF	6	3.7	0.96
Mean:		3.5	
Disposal site			
Mound	17	2.9	0.44

Table 3-4.

Summary Statistics and Results of Bioequivalence Testing for aRPD Depth Values

Difference Equation	Observed Difference ($\hat{d}$)	SE($\hat{d}$)	df for SE($\hat{d}$)	95% Lower Confidence Bound	95% Upper Confidence Bound
All data					
Mean REF - mound	0.62	0.24	8.6	0.17	1.06

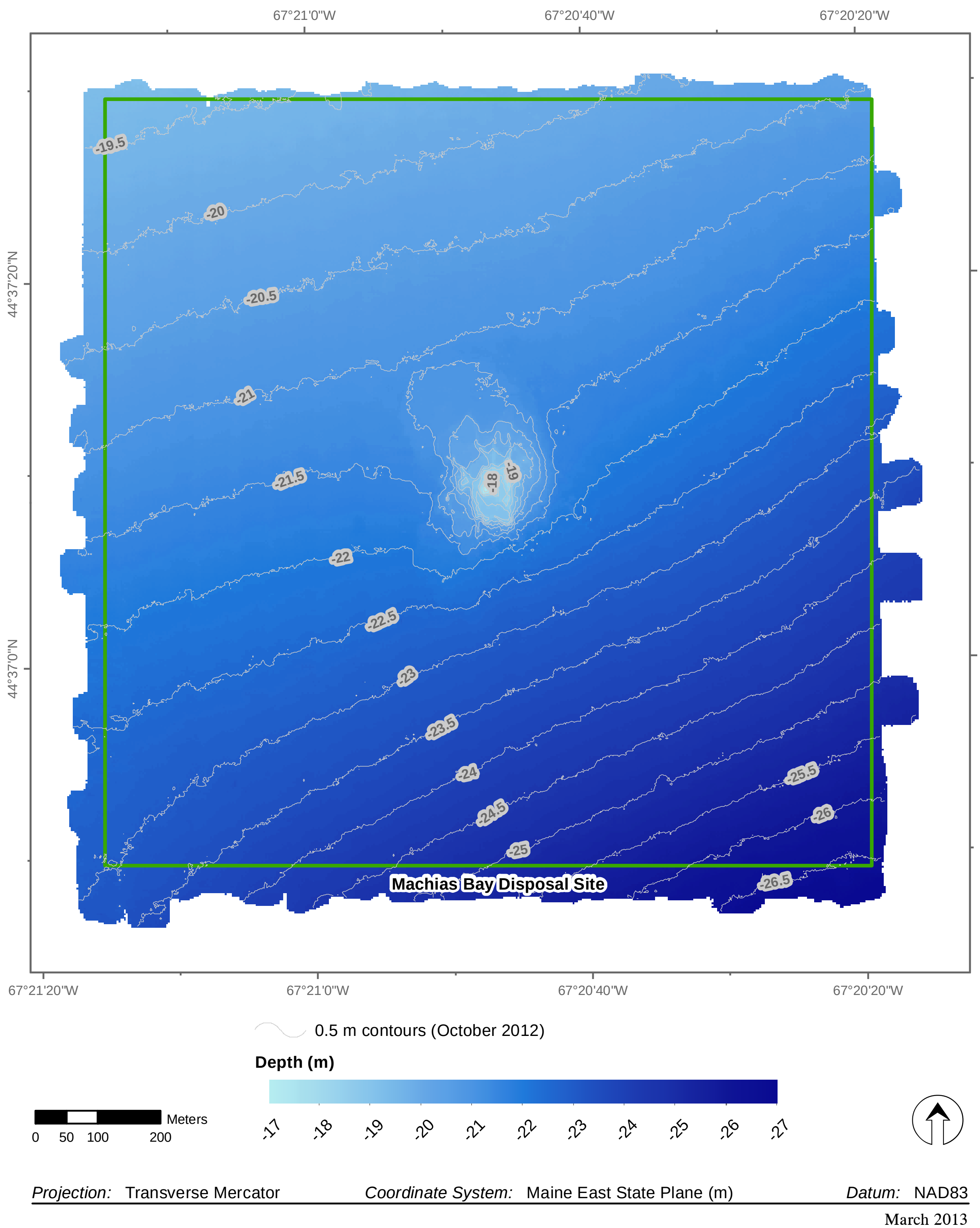


Figure 3-1. Bathymetric contour map of MacBDS – October 2012

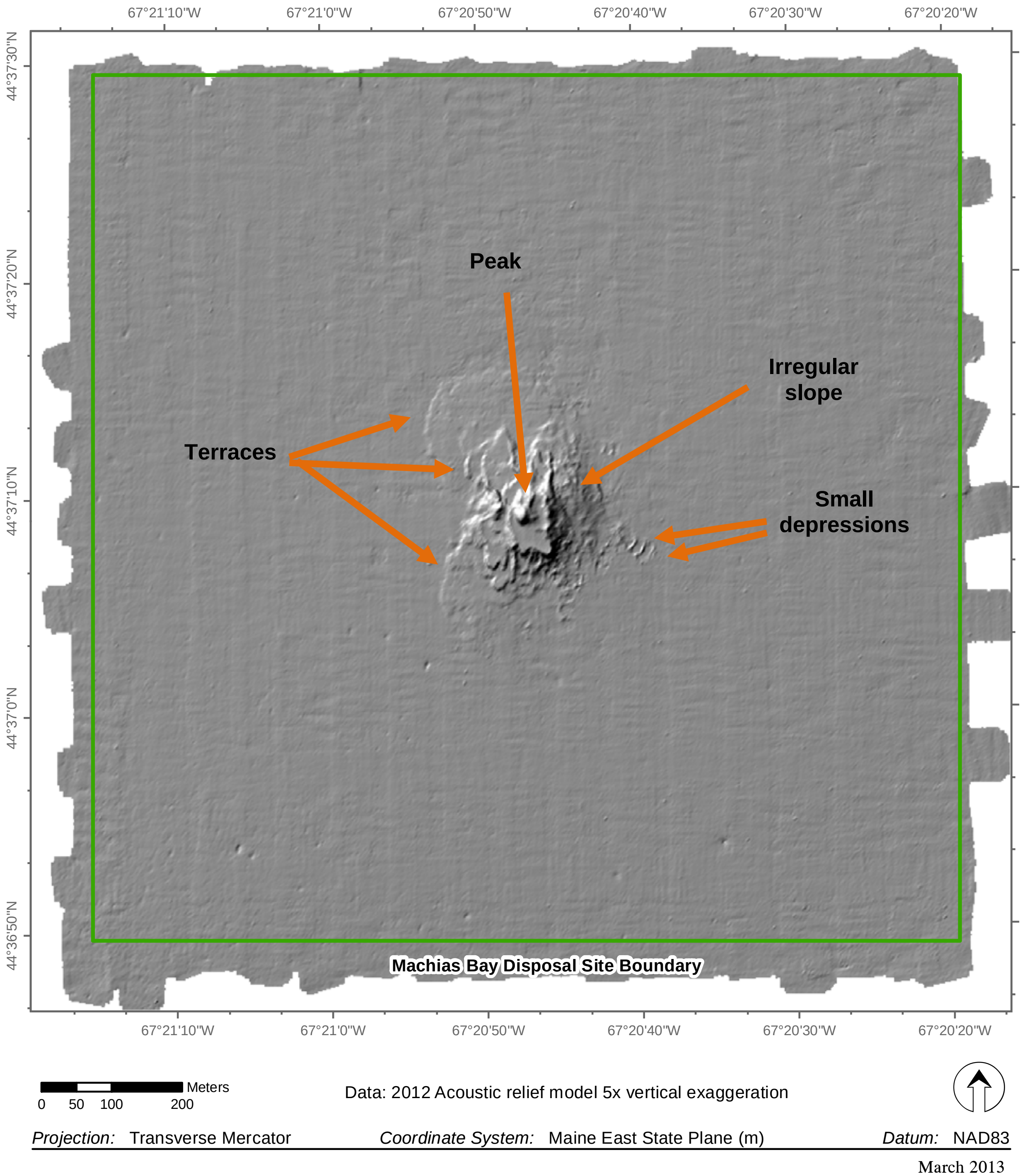


Figure 3-2. Acoustic relief model of MacBDS – October 2012

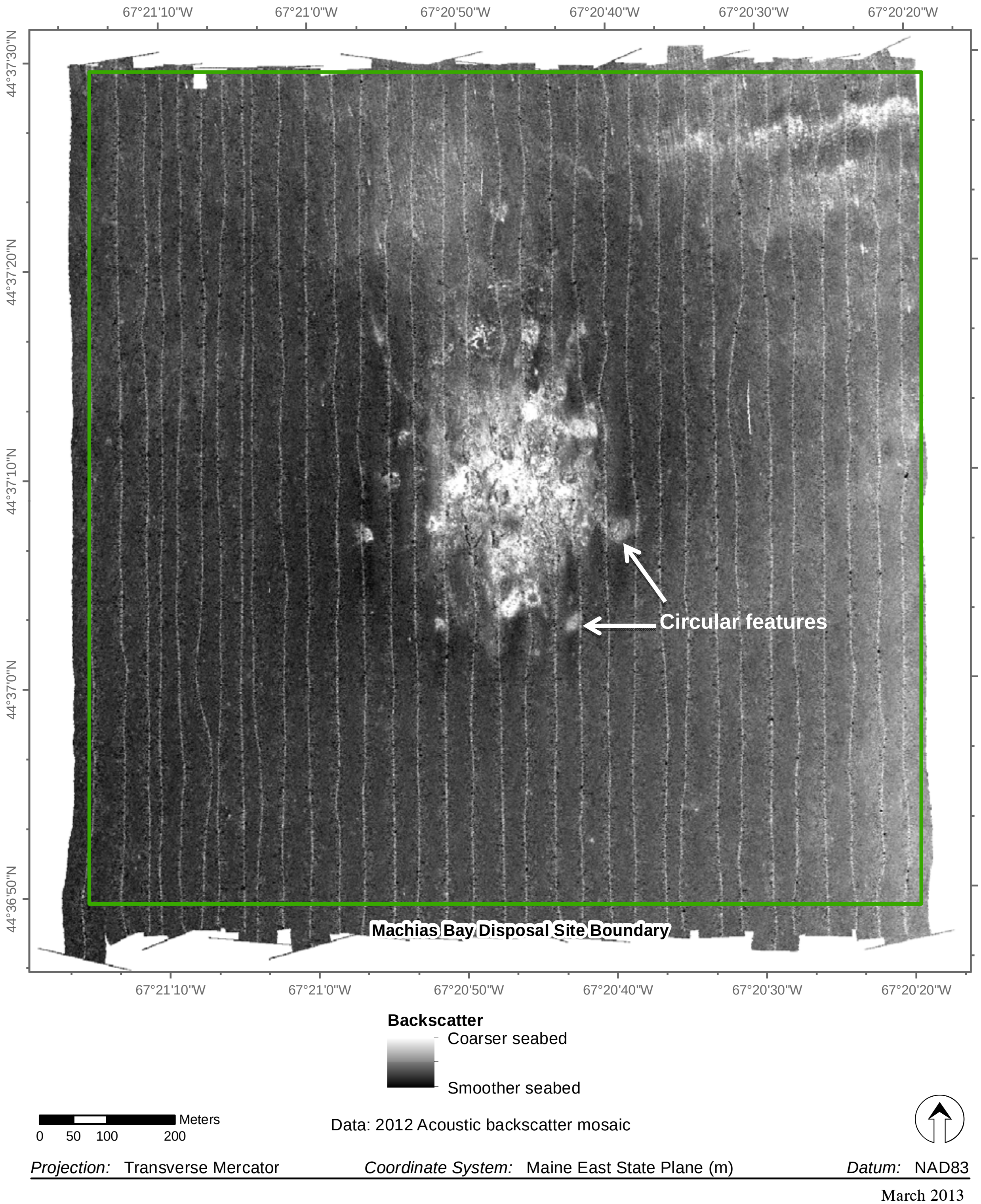


Figure 3-3. Acoustic backscatter of MacBDS – October 2012

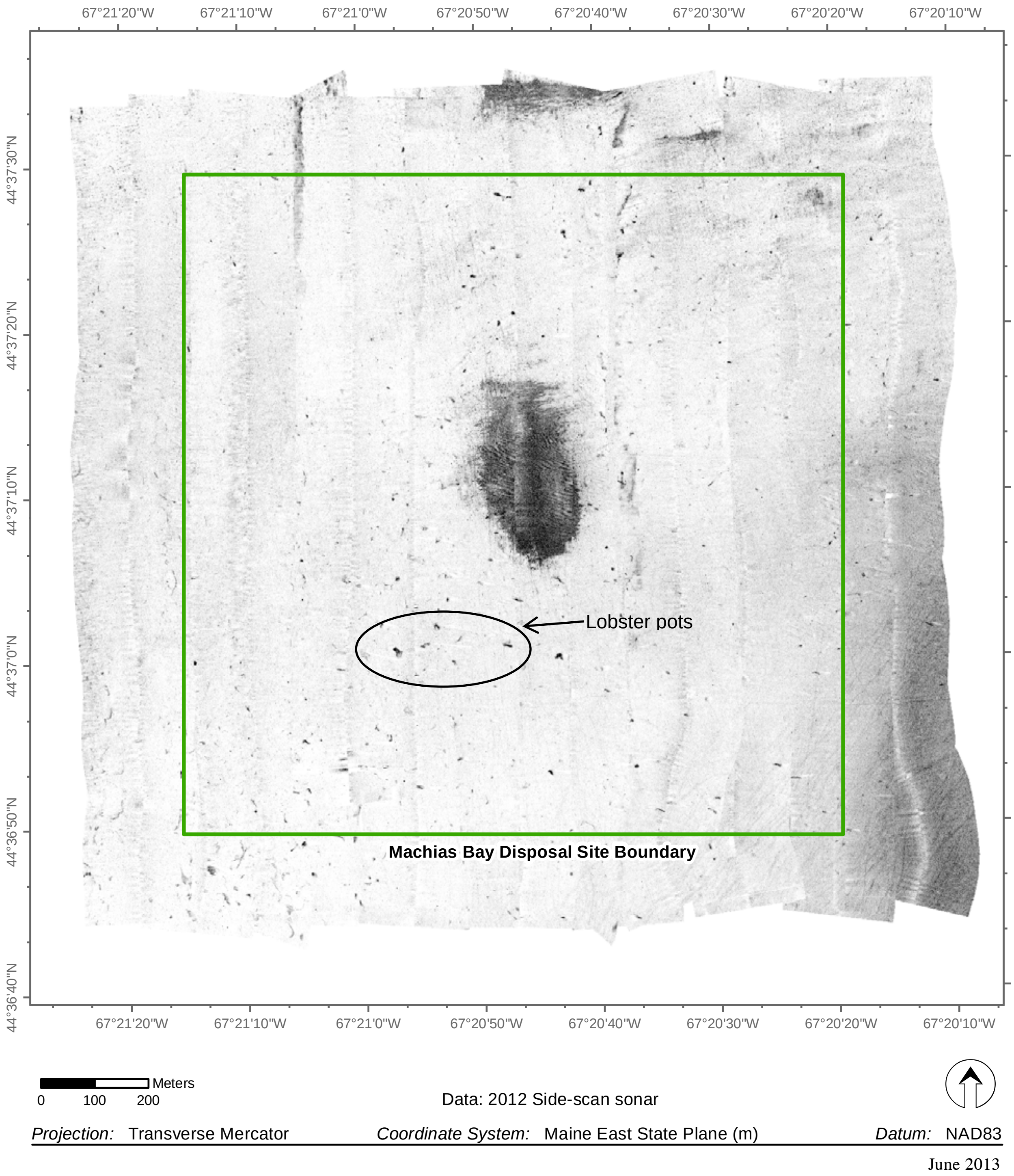


Figure 3-4. Side-scan sonar mosaic of MacBDS – October 2012

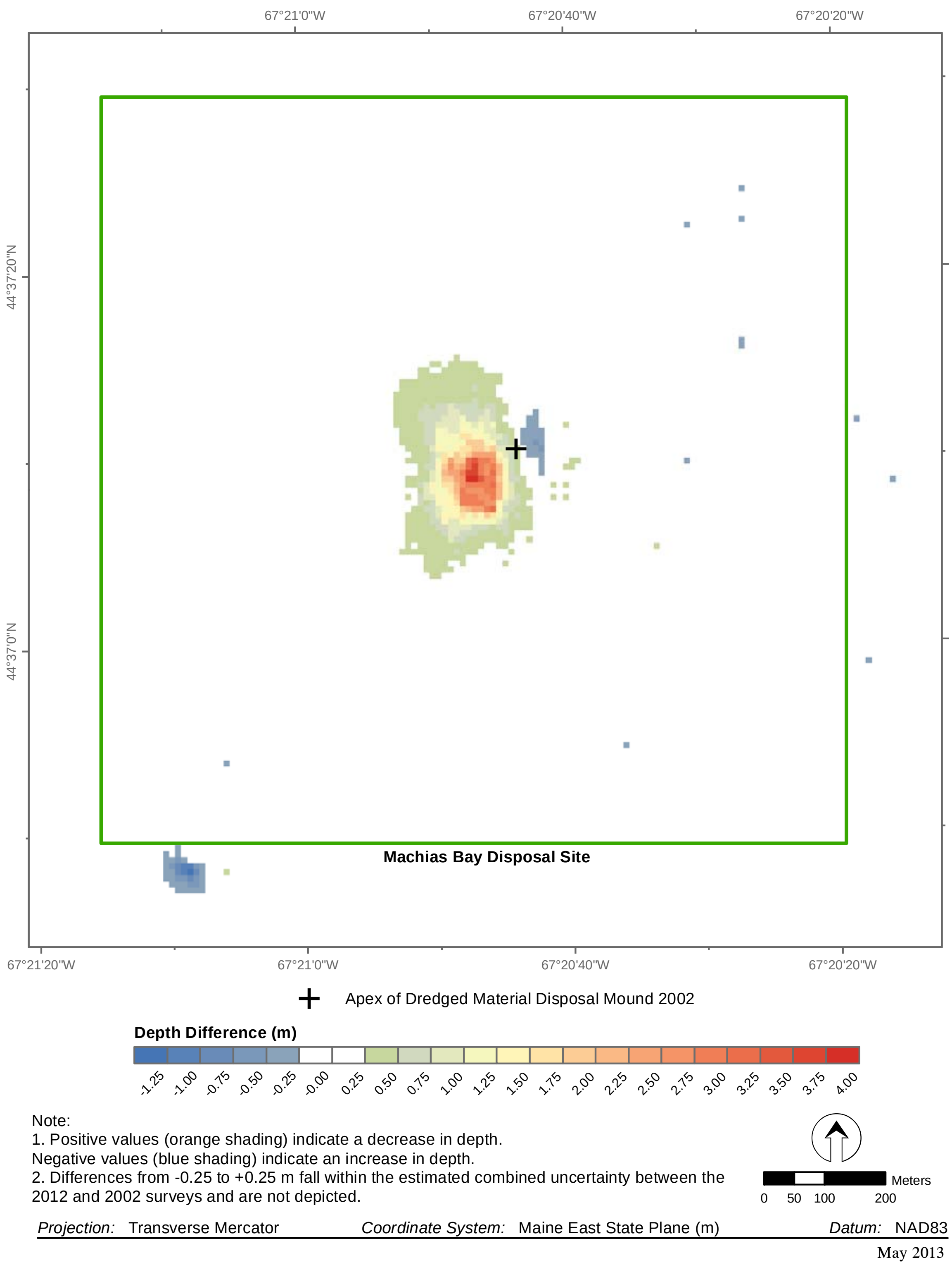


Figure 3-5. Depth difference contour map of MacBDS: July 2002 vs. October 2012

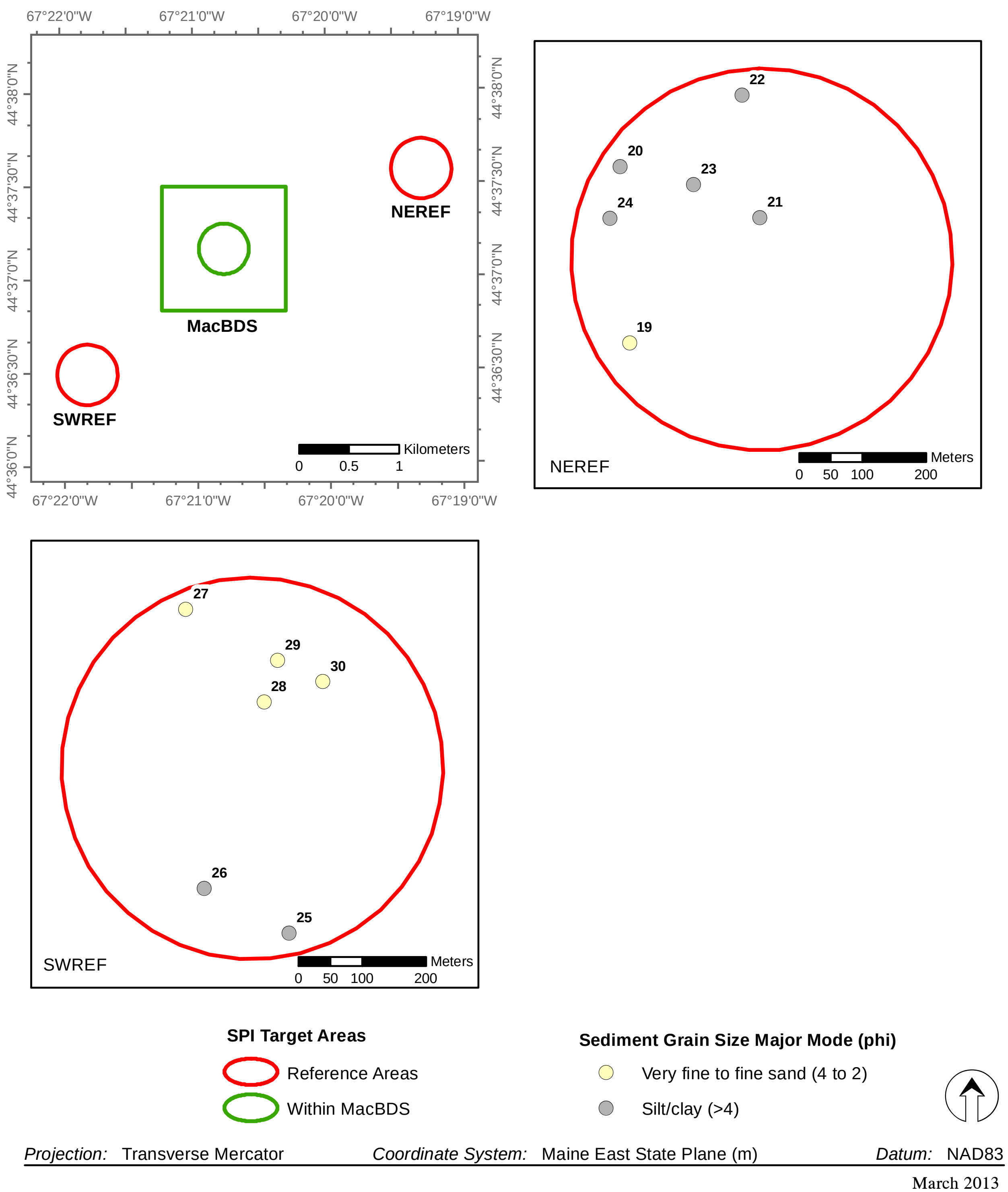


Figure 3-6. Sediment grain size major mode (phi) at reference areas

Figure 3-7. Plan-view image from reference Station SWREF-25 showed a larger foraging depression along the right edge of the image as well as multiple small burrow openings scattered across the sediment surface.

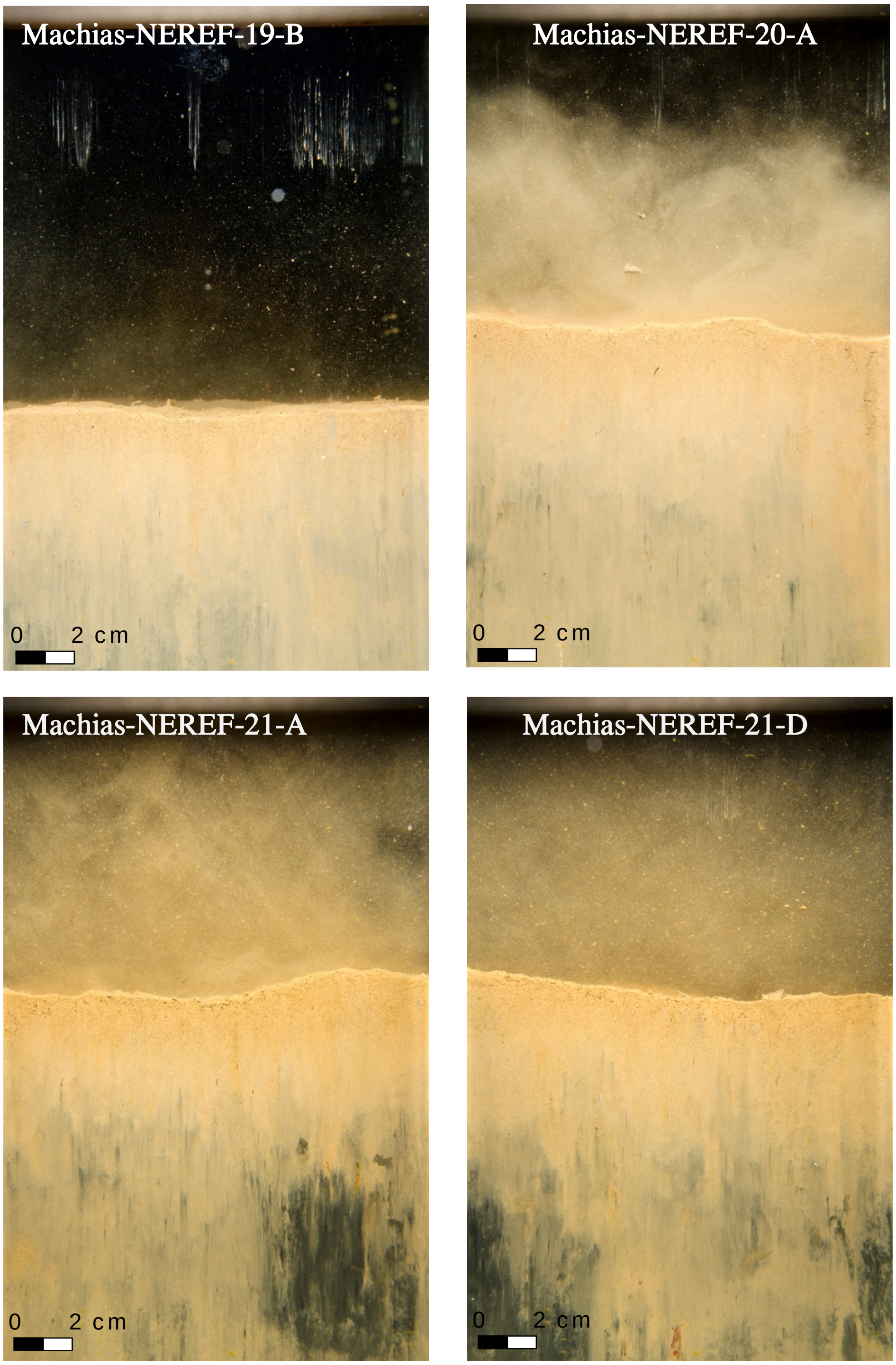
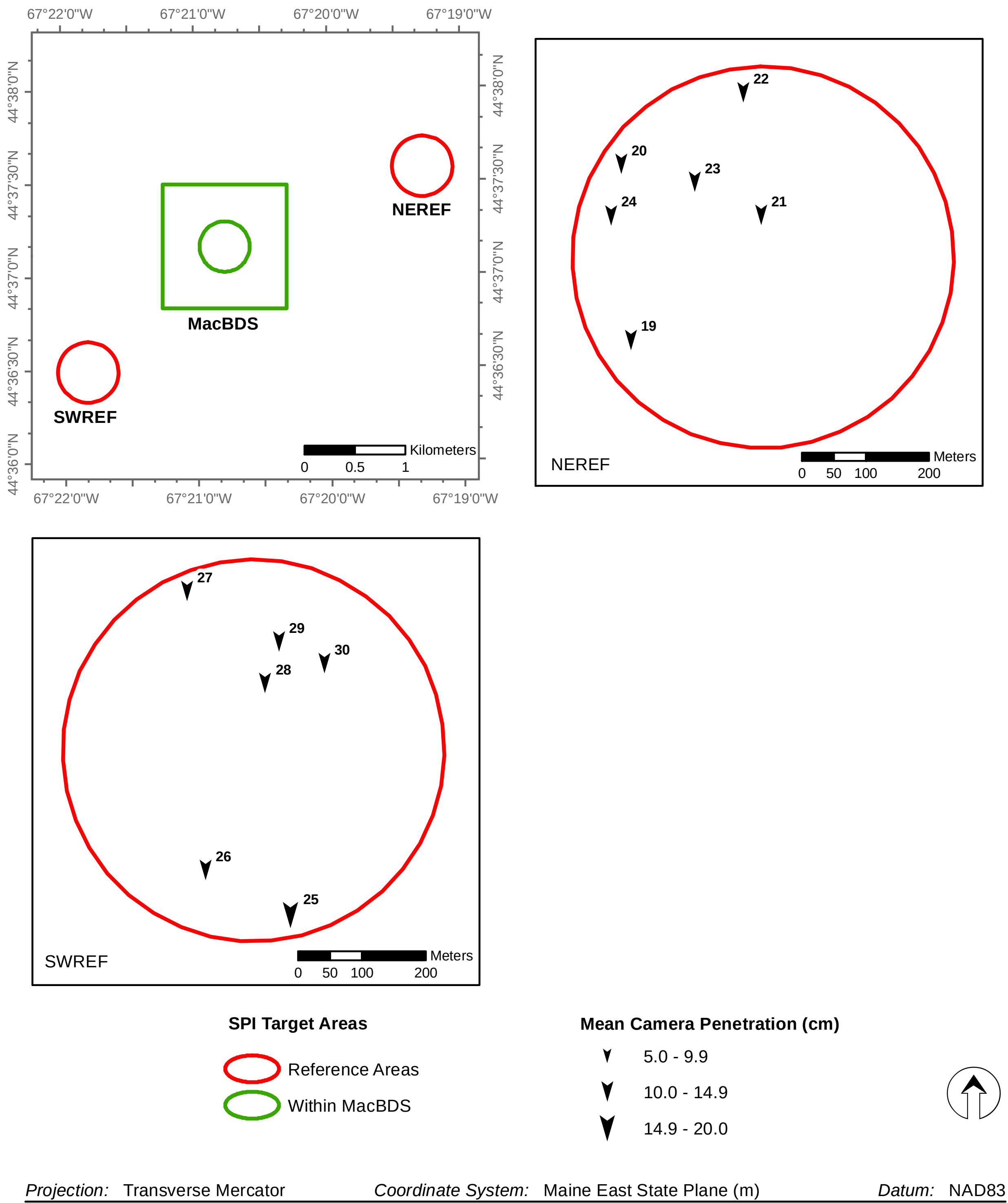
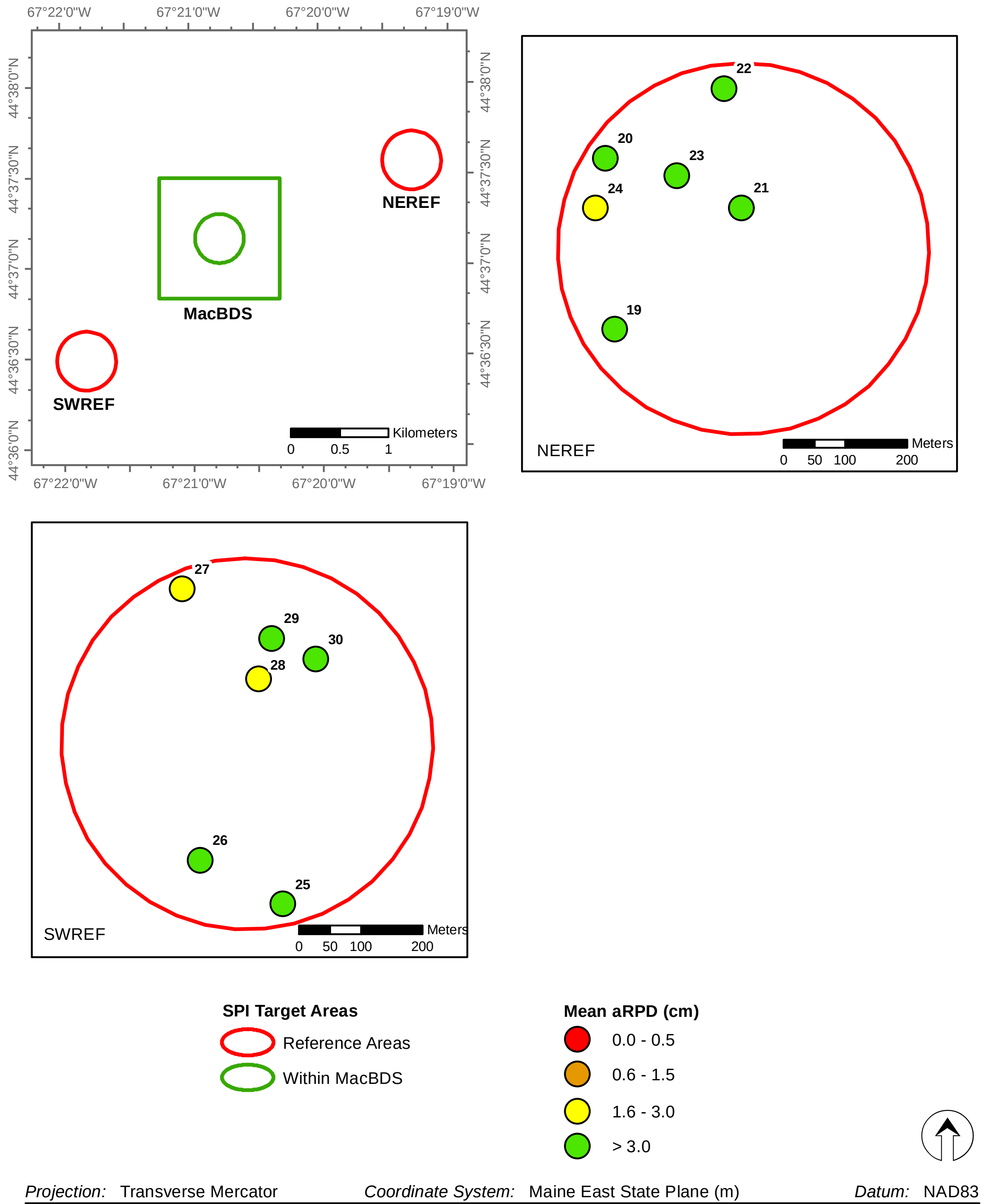


Figure 3-8. Subsurface sediments in two images from reference Station NEREF-21 (bottom) had a lower than normal albedo compared with the subsurface sediments at the other reference stations NEREF-19 and 20, indicative of excess organic loading.



March 2013

Figure 3-9. Mean station camera prism penetration depth (cm) at reference areas



March 2013

Figure 3-10. Average station aRPD depths (cm) at reference areas

Figure 3-11. Sediment-profile image from reference Station NEREF-24 showed burrows and feeding voids (arrows) throughout the entire depth of the cross-sectional image.

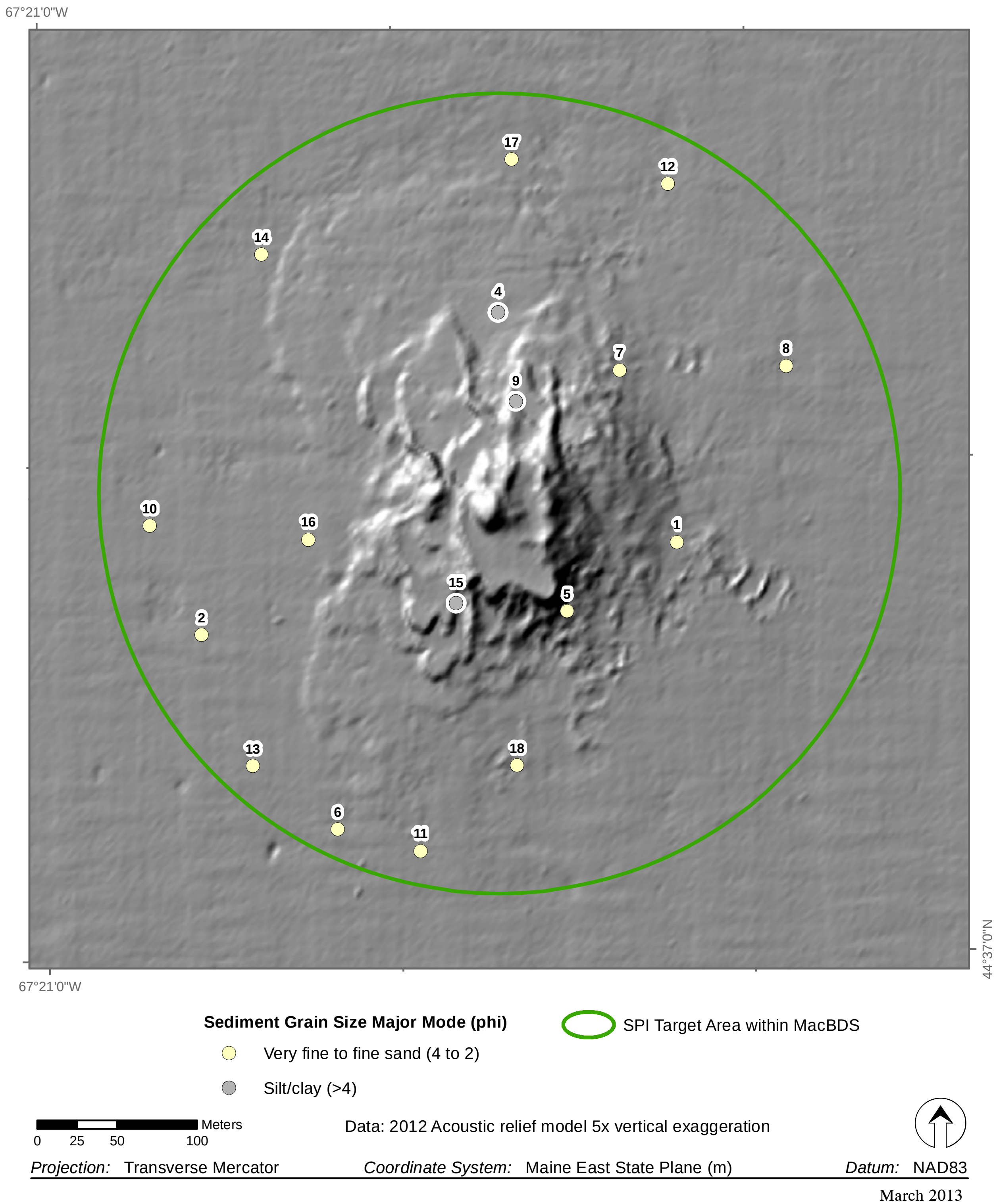


Figure 3-12. Sediment grain size major mode (phi) at MacBDS

Figure 3-13. Plan-view images from Stations 5 (top) and 7 (bottom) on the slopes of the disposal mound showed a surface armoring of shell fragments.

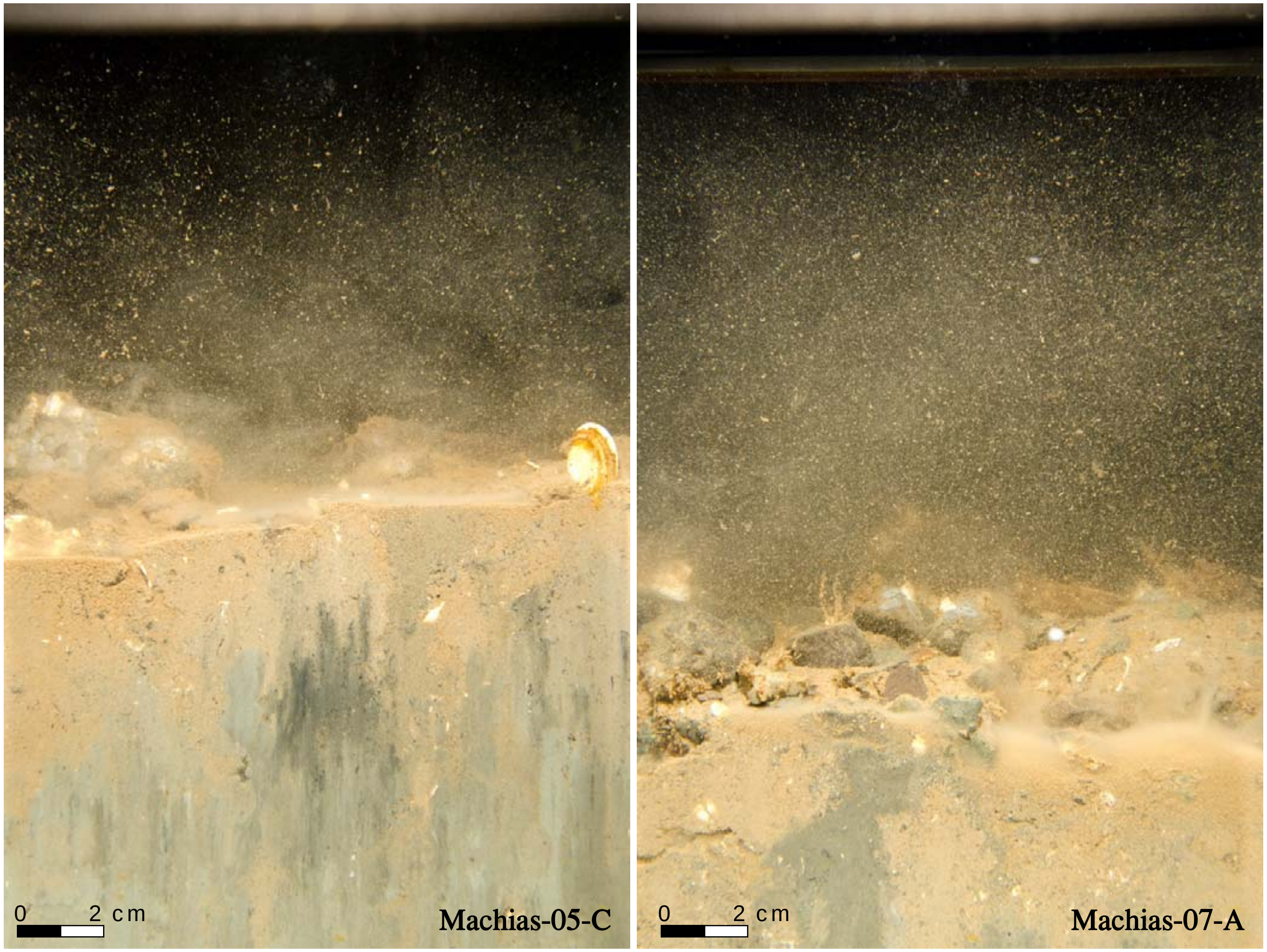


Figure 3-14. Sediment-profile images from Stations 5 (left) and 7 (right) showed larger pebble and cobble particles on the sediment surface of the dredged material mound.

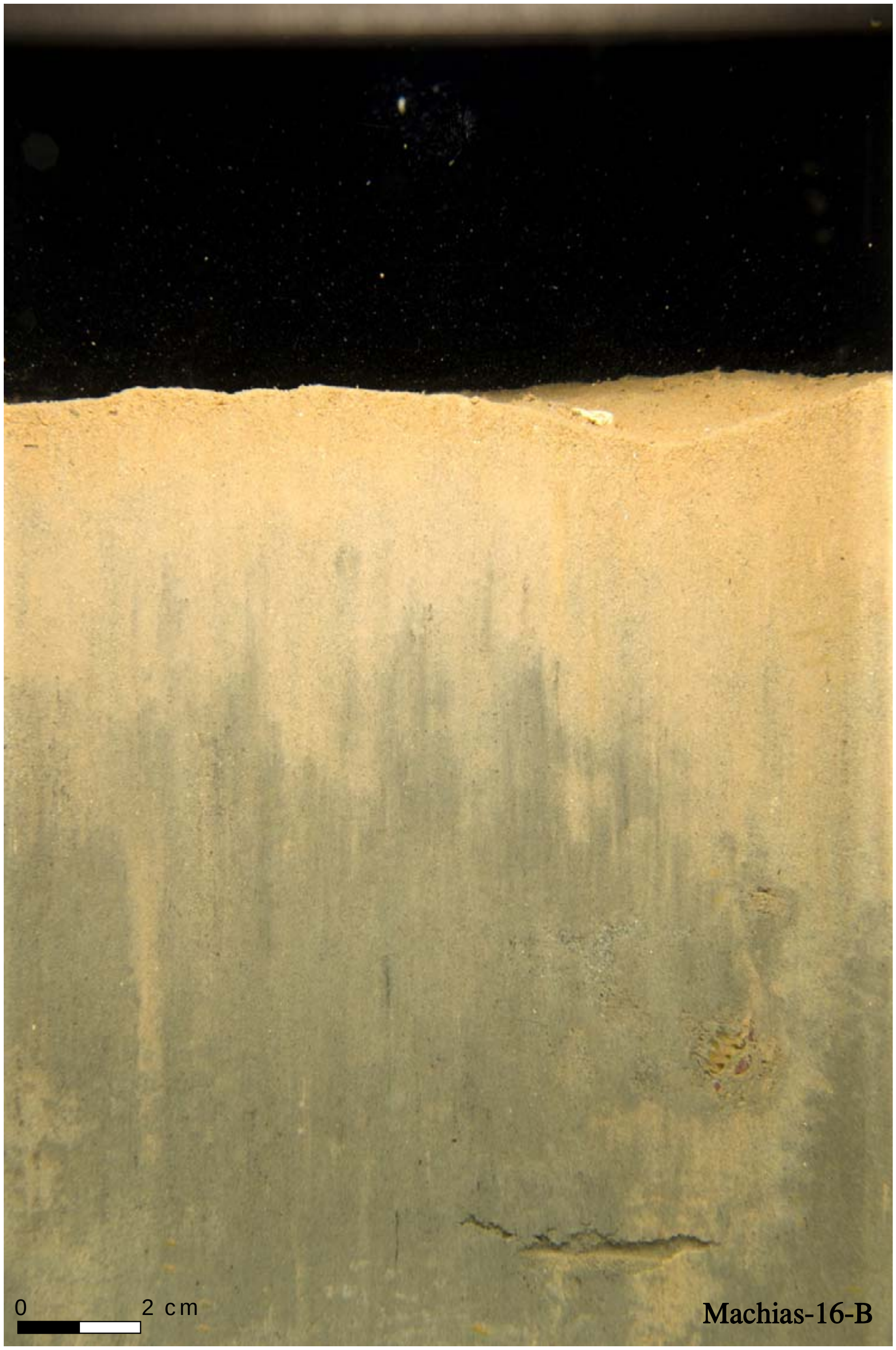


Figure 3-15. Sediment-profile image from Station 16 showed the top 1 cm with a slightly higher percentage of fine to medium sand particles than the underlying silty very fine sand.

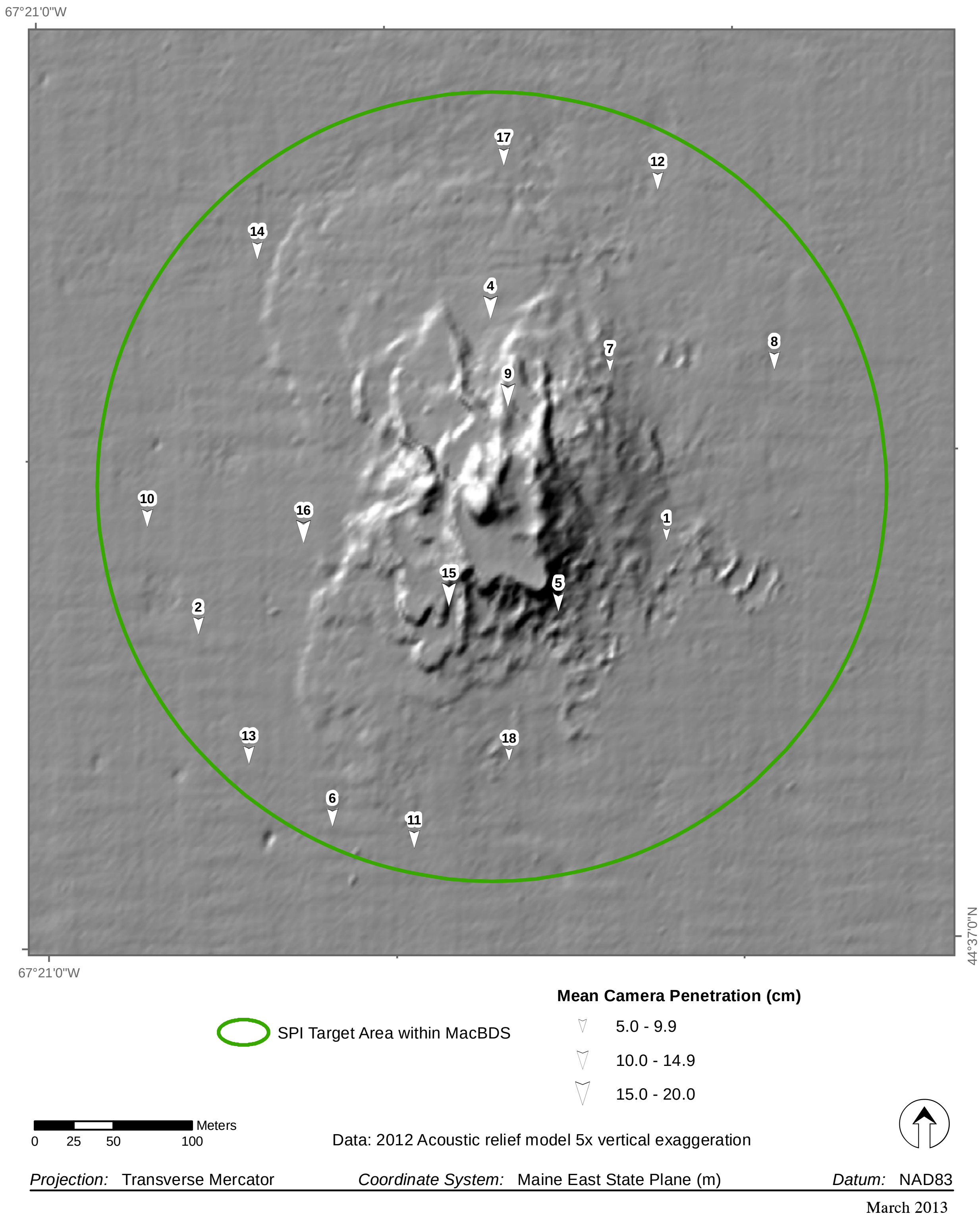


Figure 3-16. Mean station camera prism penetration depth (cm) at MacBDS

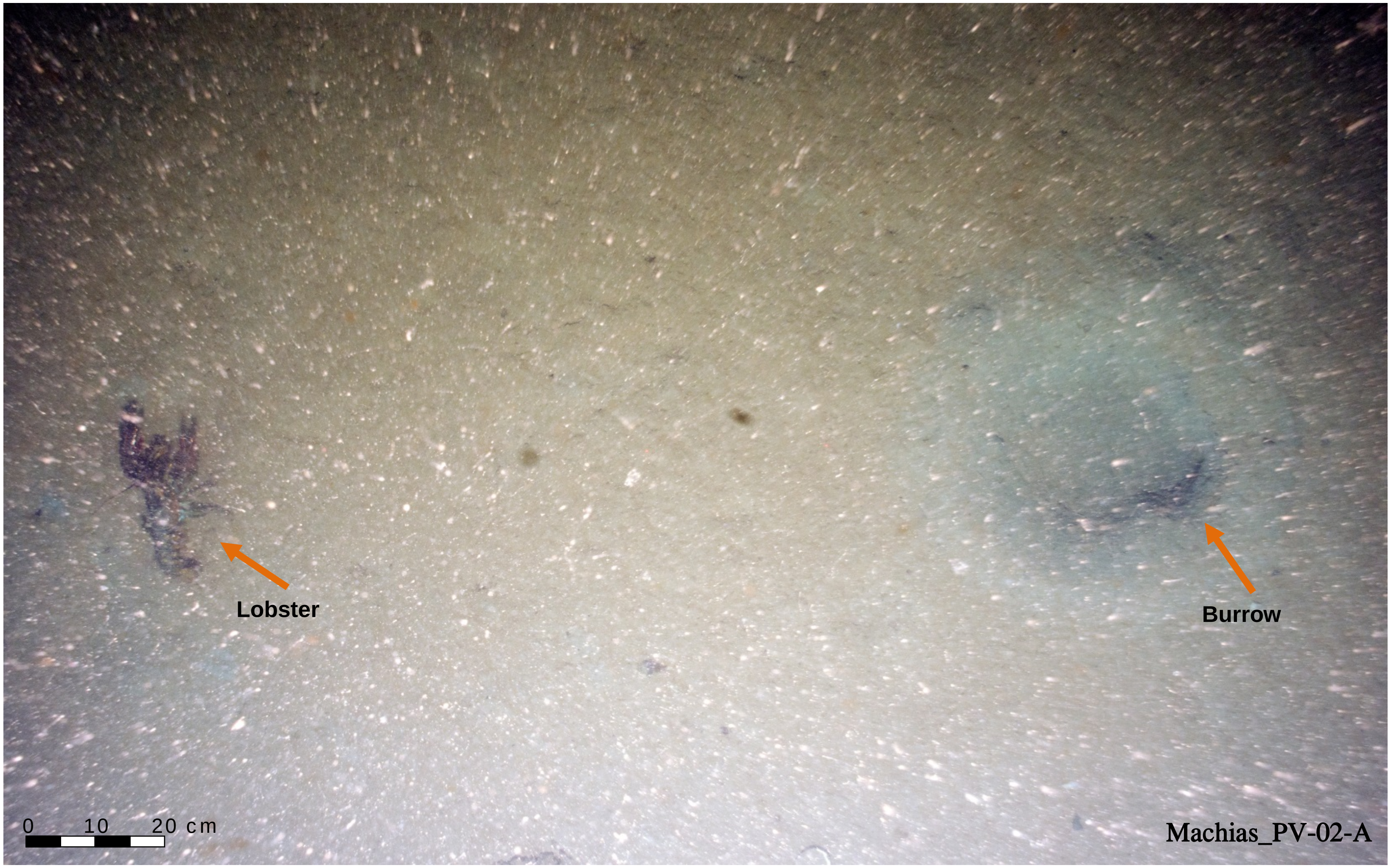


Figure 3-17. Plan-view image from Station 2 showed biogenic relief structures on the right in the form of a lobster burrow and a lobster on the left (arrows). Note: the specks are reflections from suspended material in the water column.

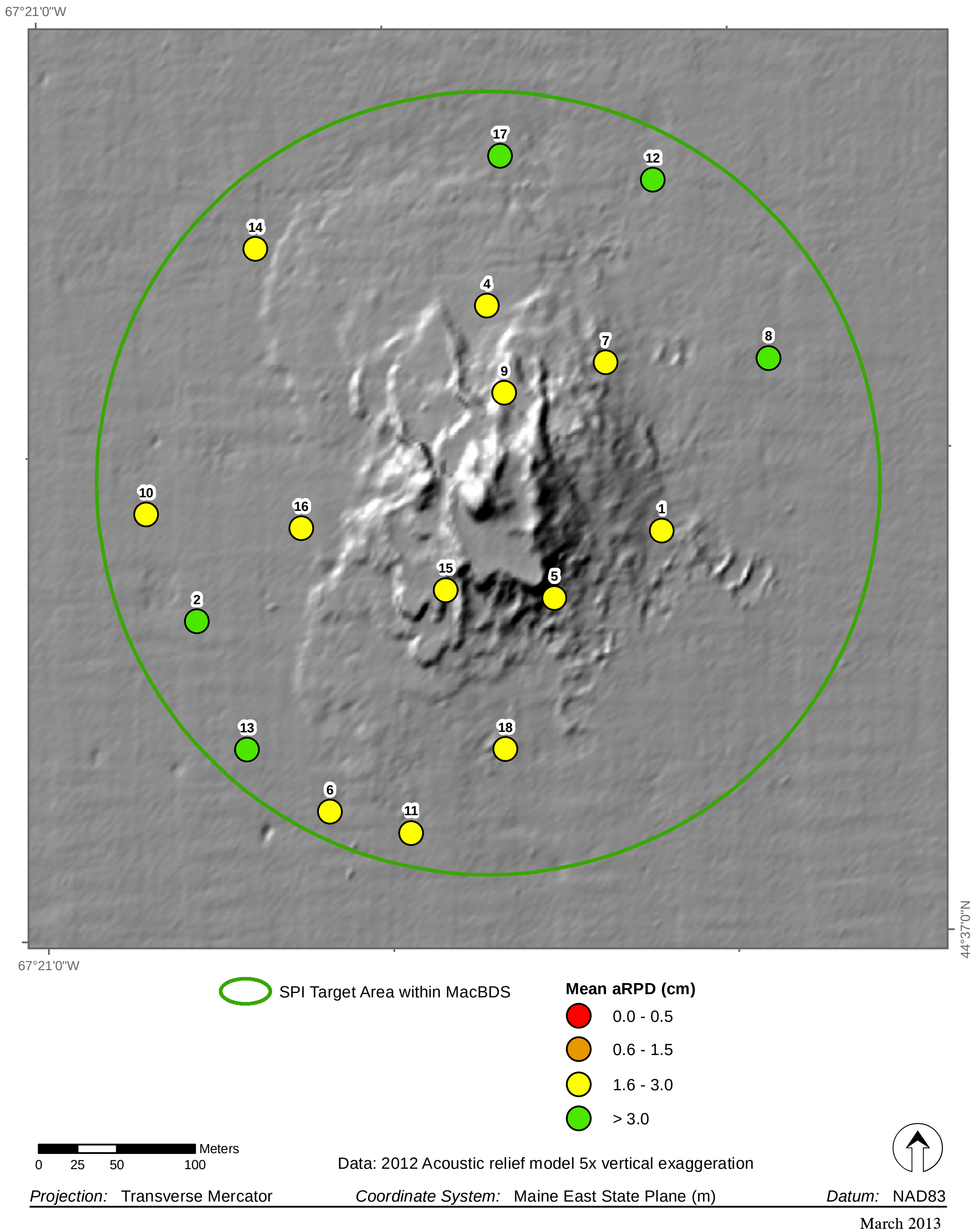


Figure 3-18. Mean station aRPD depths (cm) at MacBDS

Figure 3-19. Sediment-profile image taken near the center of the mound at Station 9 showed evidence of deposit-feeding infauna in the form of oxidized burrows and feeding voids at depth.

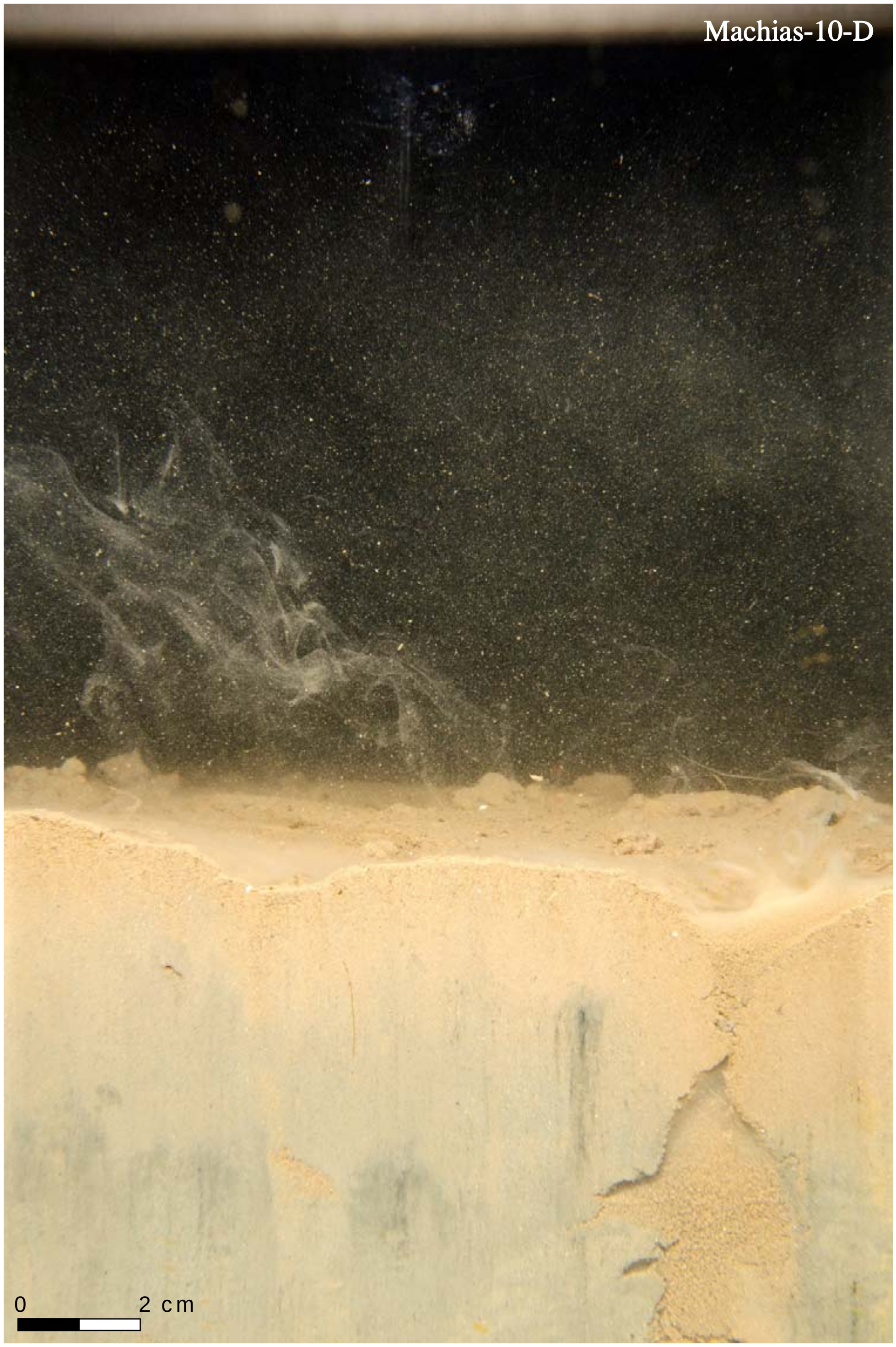


Figure 3-20. Sediment-profile image from Station 10 showed infaunal reworking activities that extended beyond the depth of the camera prism penetration.

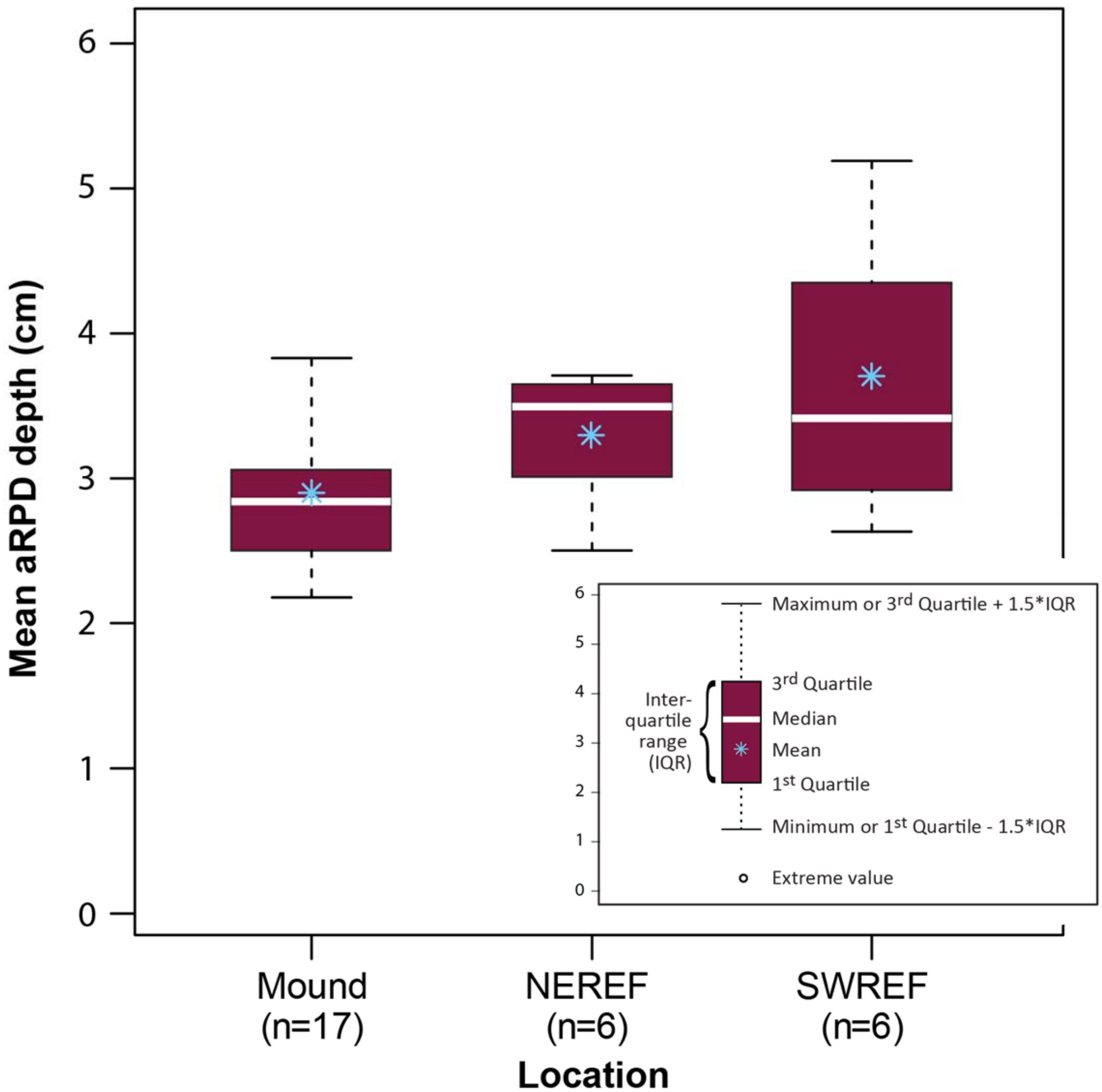


Figure 3-21. Boxplot of distribution of aRPD depth values at MacBDS reference areas and disposal site. Boxplots use ranges and quartiles to display relative differences in medians, dispersion and skewness among areas. These are graphical aids for visualizing the results of statistical tests on normality (contraindicated by lack of symmetry in the box and "whiskers"), and equality of variances (contraindicated by widely disparate ranges between boxplots for different areas).

4.0 DISCUSSION

4.1 Seafloor Topography

The high resolution acoustic survey revealed a tightly-formed mound rising just over 4 m above the surrounding seafloor with a footprint of 150 × 190 m (Figure 3-5). This observation is consistent with expectations resulting from placement of a small amount of dredged material (64,000 m^3) within a relatively closely-spaced series of release locations (Figure 1-4). The surrounding seafloor at the disposal site was uniform in slope and texture which allowed a very clear characterization of the changes in seafloor topography that resulted from placement of dredged material (Figure 3-2). The overall size of the mound was proportional to the volume of material disposed and well within the ranges associated with self-weight consolidation of dredged material after placement. The small-scale topography of the mound (flat terraces, cone-shaped peak and irregular slopes) appeared to reflect some of the heterogeneity of sediments placed at the site (Figure 4-1). The SPI and PV image results recorded compact sands, pebbles, shells, and some cobbles over primarily silt/clay deposits.

4.2 Distribution of Dredged Material

Because the dredged material placement activities at MacBDS have been very limited and the site was fairly homogeneous in sediment texture, acoustic backscatter measurements provided a very clear picture of dredged material distribution (Figure 3-3). When the acoustic backscatter patterns were combined with the acoustic relief model (essentially a simulated three-dimensional surface derived from millions of water depth measurements) the patterns associated with dredged material placement became clear (Figure 4-2). The higher backscatter values were clearly grouped around the disposal mound. The circular and semi-circular patterns in both the backscatter and acoustic relief were consistent with placement impact features observed at other disposal sites in New England (Carey et al. 2012, Valente et al. 2012). Some areas of the mound formed relatively smooth terraces, while other areas had a more uneven slope (Figures 4-1 and 4-2). Processing backscatter into a quantitative set of values (as opposed to a mosaicked image) provided a more general evaluation of the relative properties of the surface sediments across the mound (Figure 4-3). As expected, the highest returns corresponded to those areas of the mound with either rougher surface texture and/or the presence of shells, pebbles, or hard sand (Figures 4-3 and 3-16).

Side-scan sonar results contrasted with the backscatter results (Figure 4-4). The side-scan sonar mosaic had a small ellipsoid pattern of higher returns (about 250 m on the long axis and 125 m on the short axes) but did not have the larger area of intensity seen in the backscatter results (compare Figures 4-2, 4-3 and 4-4). The side-scan sonar returns were not elevated over the southwestern quadrant of the mound or at the locations of disposal impact features seen in the backscatter (Figure 4-4). Side-scan sonar is more responsive to surface texture and slope effects than backscatter collected from snippets. The interpretation of the difference in results was that the side-scan sonar detected a pattern of shells and pebbles seen in the SPI and PV images (Figures 3-13 and 3-14). The backscatter results detected the thin layer of higher water content of dredged material that spread from the placement locations (Figure 3-15).

4.3 Benthic Recolonization

There was clear evidence of the recent dredged material placement activity including aRPD depths within the disposal site boundary that were slightly depressed compared to those found in the ambient areas. However, the benthic community on the disposal mound had fully recovered in the 19 months between completion of placement operations and the 2012 monitoring survey. There were also depositional layers and textural anomalies in the sediment-profile images from the mound that clearly were the result of the placement operations in 2011, but evidence of deep deposit-feeding infauna was present throughout the site (Figure 3-19). While the disposal site and environs are popular locations for commercial lobstering (a high density of lobster buoys were encountered at the site during the 2012 survey), there was no evidence of substantial physical disturbance to the seafloor from commercial bottom trawling at the site. Thus, there was sufficient time for mature infaunal communities to be re-established, even in those locations where the placement created a thick enough deposit to smother the existing infaunal community (Rhoads et al. 1978, Germano et al. 1994, Bolam and Rees 2003). Given the complete recovery of the benthic infaunal community, it is predicted that the effects from any future disposal operations at MacBDS would be transient and the infaunal community would quickly re-establish itself in a time frame of 12–18 months following completion of disposal operations.

It is noteworthy that during the last monitoring survey that took place 10 years previously at this site (SAIC 2003), evidence of Stage 3 infauna were missing from approximately 25% of the disposal site stations and 20% of the reference stations sampled. The 2002 monitoring survey was the first survey performed since the completion of disposal operations 30 years previously, so any lack of mature infaunal assemblages was certainly not due either to disturbance frequency from disposal or insufficient time for recolonization. This type of small-scale variation in infaunal biological communities is often found (Rhoads and Germano 1982) and can be caused by any number of naturally occurring forces (competition, predation, commercial fishing, storm wave orbital energy impacting the bottom, etc.); it is also possible that Stage 3 taxa were present at these locations in the previous survey but not diagnosed because of low population densities (plan-view images were not taken during the 2002 survey; when Stage 3 taxa are in low densities and not intercepted in profile images, their burrow openings are visible in the plan-view images that sample a much larger area than the profile images).

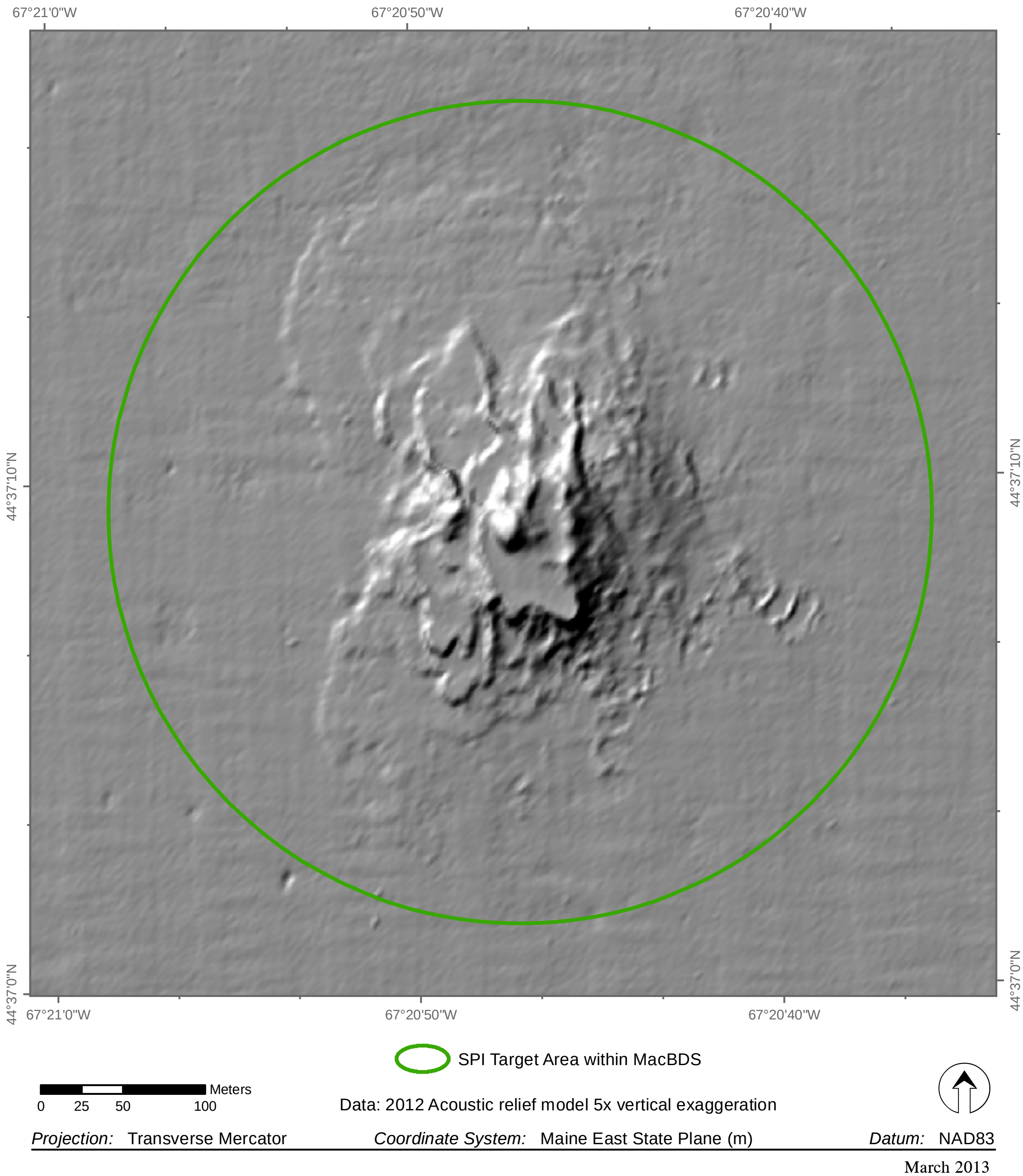


Figure 4-1. Hillshaded acoustic relief model of the mound at MacBDS

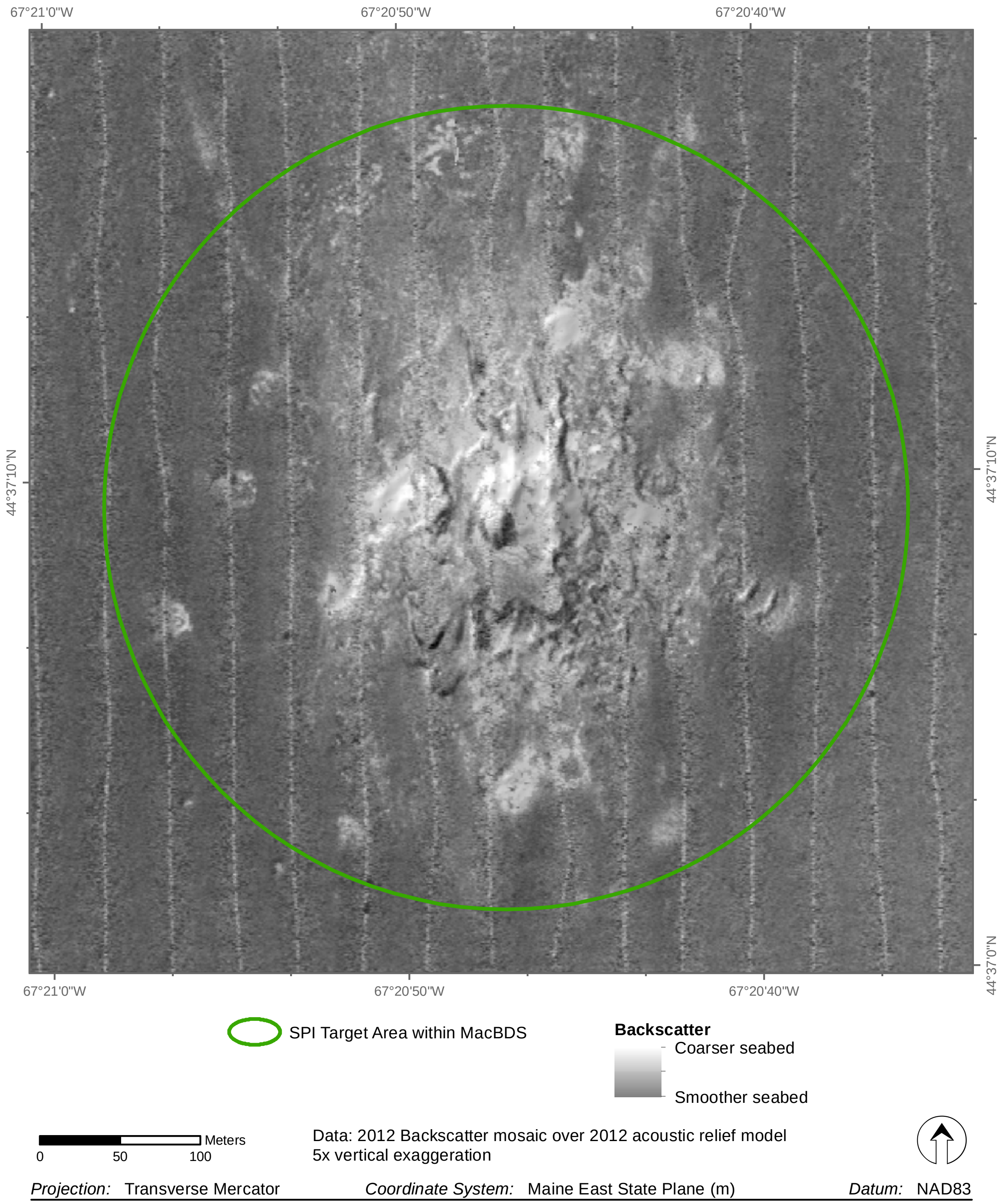


Figure 4-2. Backscatter mosaic over hillshaded acoustic relief model of the mound at MacBDS

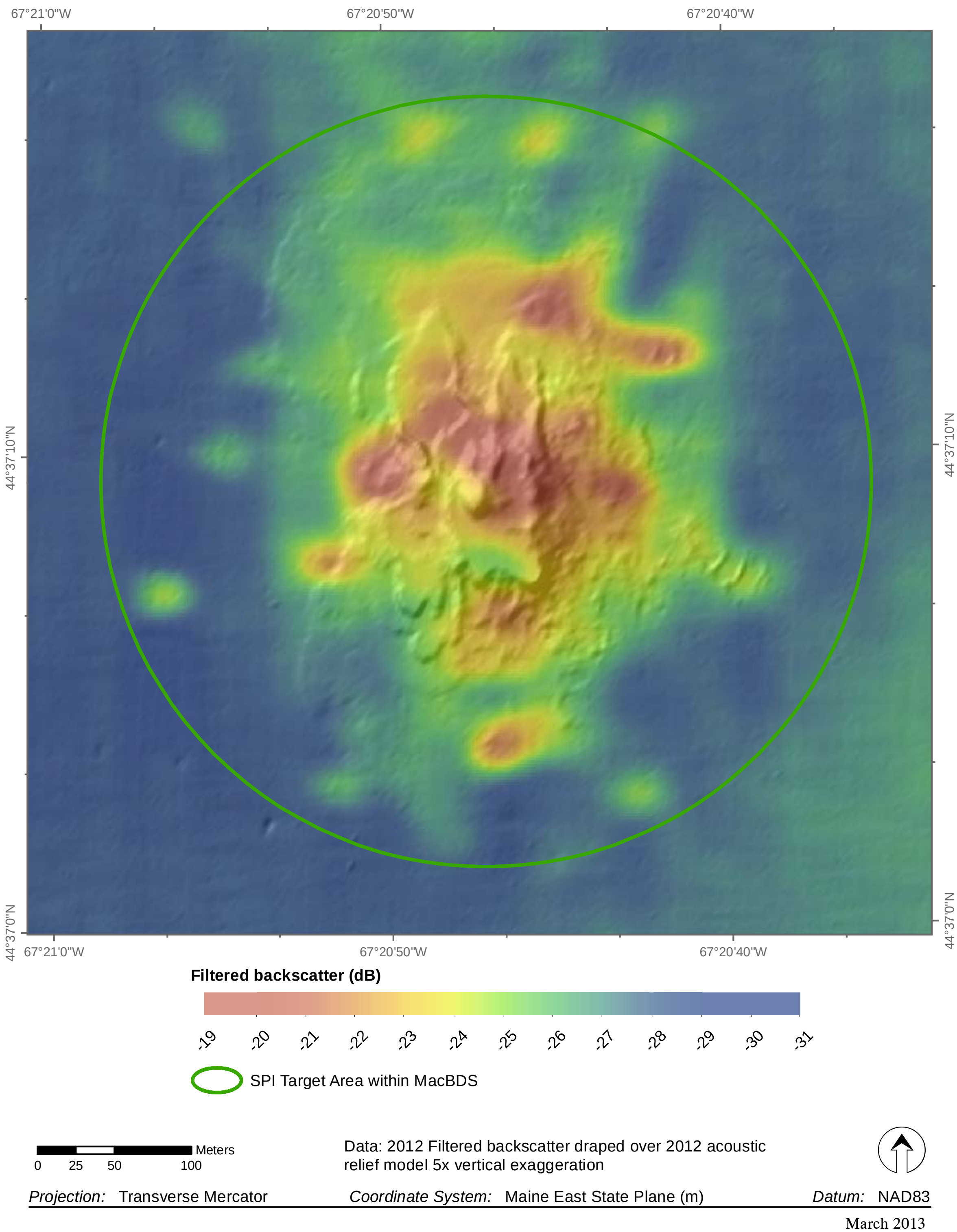


Figure 4-3. Filtered backscatter (quantitative) over hillshaded acoustic relief model of the mound at MacBDS

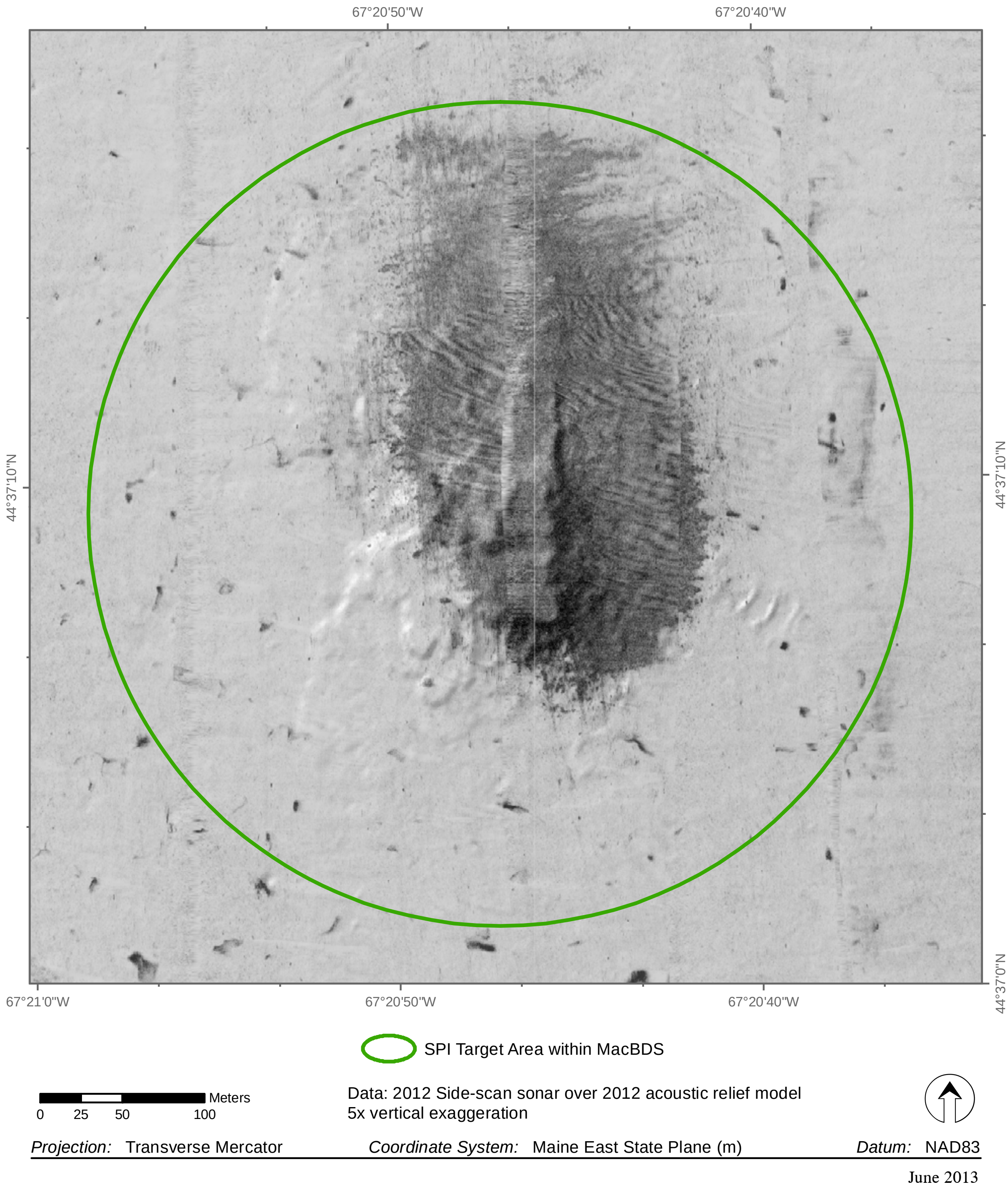


Figure 4-4. Side-scan sonar mosaic over acoustic relief model zoomed to extent of mound at MacBDS - 2012

5.0 CONCLUSIONS AND RECOMMENDATIONS

The combined multibeam bathymetric and SPI/PV surveys performed at MacBDS in October 2012 provided the following findings:

- The dredged material mound formed in 2011 was consistent with the size and extent expected from placement of 64,000 m^3 of dredged material in 20-m water depths.
- The dredged material mound appeared to be stable with no evidence of sediment transport.
- The sediments on the surface of the dredged material mound showed evidence of complete recovery of the benthic community; characteristics were typical of the surrounding seafloor (Stage 3 successional community assemblage).
- The surface sediments on the mound had slightly depressed apparent Redox Potential Discontinuity (aRPD) depths compared to reference area values. Given the presence of a healthy equilibrium deposit-feeding assemblage, it is expected that the aRPD depths on the mound will converge with reference area values within a year.
- The disposal site and reference areas displayed a robust benthic community assemblage with relatively uniform sediment characteristics that made mapping and characterizing dredged material distribution and seafloor condition very straightforward.
- Given the complete recovery of the benthic infaunal community, it is predicted that the effects from any future disposal operations at MacBDS will be transient, and the infaunal community will quickly re-establish itself in a time frame of 12–18 months following completion of disposal operations.

Based on the findings of the 2012 MacBDS survey, the following recommendations are proposed:

R1) High resolution acoustic surveys should be conducted if future dredged material placement activities are performed at the site to monitor the morphology and stability of the existing dredged material mound and the formation of additional deposits.

R2) Given the height of the existing mound above the surrounding bottom (and related water depth), future placement should target a position offset from the existing mound peak (with specific offset determined by the amount of material to be placed).

R3) Benthic recolonization should be monitored with SPI/PV surveys at additional deposits formed as a result of placement activity.

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.

Carey, D. A.; Hickey, K.; Myre, P. L.; Read, L. B.; Esten, M. E. 2012. Monitoring Surveys at the Historical Brenton Reef Disposal Site 2007 & 2009. DAMOS Contribution No. 187. U.S. Army Corps of Engineers, New England District, Concord, MA, 130 pp.

Fredette, T. J.; French, G. T. 2004. Understanding the physical and environmental consequences of dredged material disposal: history in New England and current perspectives. Mar. Pollut. Bull.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 Regions. DAMOS Contribution No. 87. U.S. Army Corps of Engineers, New England Division, Waltham, MA, 67 pp.

Germano, J. D.; Rhoads, D. C.; Valente, R. M.; Carey, D. A.; Solan, M. 2011. The use of sediment-profile imaging (SPI) for environmental impact assessments and monitoring studies: lessons learned from the past four decades. Oceanogr. Mar. Biol. Ann. Rev. 49:235–285.

McBride, G. B. 1999. Equivalence tests can enhance environmental science and management. Aust. New Zeal. J. Stat. 41(1):19–29.

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 benthic community structure: a new protocol. Hydrobiologia 142: 291–308.

Rhoads, D. C.; McCall, P. L.; Yingst, J. Y. 1978. Disturbance and production on the estuarine seafloor. American Scientist 66: 577-586.

SAIC. 2003. Monitoring survey at the Machias Bay Disposal Site July 2002. DAMOS Contribution #141, Report No. SAIC-608, submitted to Regulatory Division, New England District, U.S. Army Corps of Engineers, Concord, MA.

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. Pharmacokinet. Biopharm. 15:657–680.

USACE. 2002. Engineering and Design Hydrographic Surveying. EM1110-2-1003.

USACE. 2012. Request for Proposal for a Task Order under Contract No. W912WJ-12-D-0004 Task Order for the Support of the Disposal Area Monitoring System (DAMOS) Program. Letter from Sheila Winston-Vincuilia, U.S. ACE to Lisa Lefkovitz, Battelle Memorial Institute, August 17, 2012.

USACE. 2013. “Buck’s Harbor Navigation Project.” US Army Corps of Engineers, New England District. http://www.nae.usace.army.mil/Missions/CivilWorks/Navigation/Maine/BucksHarbor.aspx (5 April 2013).

Valente, R. M.; Carey, D. A.; Read, L. B.; Esten, M. E. 2012. Monitoring Survey at the Central Long Island Sound Disposal Site October 2009. DAMOS Contribution No.184. U.S. Army Corps of Engineers, New England District, Concord, MA, 90 pp.

Zar, J. H. 1996. Biostatistical analysis. Third edition. New Jersey: Prentice Hall.

APPENDIX A

SEDIMENT-PROFILE IMAGE ANALYSIS RESULTS FOR MACBDS SURVEY, OCTOBER 2012

Sediment-Profile Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Weights (per side)	Water Depth (ft)	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq. cm)	Mean aRpd (cm)	Mud Clast Number	Mud Clast State
1	C	10/13/2012	10:48:15	16	5	82	14.6	4-3	1	>4	131.4	9.0	8.5	9.4	0.9	biogenic	48.7	3.3	0	
1	D	10/13/2012	10:49:04	16	5	82	14.6	4-3	1	>4	141.7	9.7	9.4	10.4	1.0	biogenic	35.7	2.4	0	
2	A	10/13/2012	10:03:11	16	5	83	14.6	4-3	1	>4	205.1	14.0	13.8	14.3	0.5	biogenic	53.7	3.7	0	
2	B	10/13/2012	10:04:12	16	5	83	14.6	4-3	1	>4	192.5	13.2	13	13.5	0.5	biogenic	46.1	3.2	0	
2	C	10/13/2012	10:05:11	16	5	83	14.6	>4	1	>4	240.5	16.5	16.2	16.5	0.3	biogenic	68	4.7	0	
4	A	10/13/2012	12:05:52	16	5	76	14.6	>4	1	>4	213.7	14.6	13.7	15.8	2.1	biogenic	43	2.9	0	
4	B	10/13/2012	12:06:46	16	5	76	14.6	>4	1	>4	278.4	19.1	18.8	19.4	0.6	biogenic	26	1.8	0	
4	C	10/13/2012	12:07:55	16	5	76	14.6	4 to 3/>4	-2	>4	247.6	17.0	16.1	17.8	1.7	physical	51	3.5	1	oxidized
5	A	10/13/2012	12:36:17	16	5	74	14.6	4-3	1	>4	132.5	9.1	8.6	9.5	0.9	biogenic	53.7	3.7	0	
5	B	10/13/2012	12:37:07	16	5	74	14.6	>4	1	>4	174.7	12.0	8.4	15.3	6.9	physical	21	1.4	3	reduced
5	C	10/13/2012	12:38:00	16	5	74	14.6	4-3	-5	>4	144.2	9.9	9	10.8	1.8	biogenic	34.4	2.4	0	
6	A	10/13/2012	9:46:05	16	5	86	14.6	4-3	1	>4	152.1	10.4	10	11.3	1.3	biogenic	27.8	1.9	0	
6	C	10/13/2012	9:48:00	16	5	86	14.6	4-3	1	>4	167	11.4	11.1	11.9	0.8	biogenic	39.3	2.7	0	
6	D	10/13/2012	9:48:53	16	5	86	14.6	4-3	1	>4	183.4	12.6	12.2	12.8	0.6	biogenic	48.1	3.3	0	
7	A	10/13/2012	11:08:44	16	5	77	14.6	-2	-5	>4	67.4	4.6	4.2	5.5	1.3	physical	26.8	1.8	0	
7	B	10/13/2012	11:10:16	16	5	77	14.6	4 to 3/>4	1	>4	179.9	12.3	11.4	13.4	2.0	biogenic	50.4	3.5	0	
7	D	10/13/2012	11:12:08	16	5	77	14.6	4-3	1	>4	149	10.2	10.2	10.7	0.5	biogenic	29.6	2.0	0	
8	A	10/13/2012	10:53:27	16	5	82	14.6	4-3	1	>4	195.3	13.4	12.8	13.9	1.1	biogenic	53.9	3.7	0	
8	B	10/13/2012	10:54:21	16	5	82	14.6	4-3	1	>4	154.2	10.6	9.7	11.1	1.4	physical	56.8	3.9	0	
8	D	10/13/2012	10:56:14	16	5	82	14.6	4-3	1	>4	159.8	10.9	9.8	11.4	1.6	biogenic	52.4	3.6	0	
9	A	10/13/2012	12:22:55	16	5	69	14.6	>4	1	>4	297.1	20.3	19.6	20.8	1.2	biogenic	22.1	1.5	0	
9	B	10/13/2012	12:23:51	16	5	69	14.6	4-3	1	>4	188.6	12.9	12.3	13.4	1.1	biogenic	29.6	2.0	0	
9	D	10/13/2012	12:26:06	16	5	69	14.6	>4	1	>4	194.9	13.3	10.7	15.8	5.1	biogenic	43.7	3.0	0	
10	A	10/13/2012	10:09:12	16	5	83	14.6	4-3	1	>4	174.8	12.0	11.4	12.4	1.0	biogenic	41.8	2.9	0	
10	C	10/13/2012	10:11:02	16	5	83	14.6	4-3	1	>4	176.3	12.1	11.9	12.2	0.3	biogenic	49.1	3.4	0	
10	D	10/13/2012	10:12:02	16	5	83	14.6	4-3	1	>4	112.1	7.7	6.4	8.7	2.3	biogenic	33.3	2.3	0	
11	A	10/13/2012	9:38:43	16	5	86	14.6	4-3	1	>4	165.2	11.3	10.6	11.7	1.1	biogenic	37.6	2.6	0	
11	B	10/13/2012	9:39:38	16	5	86	14.6	4-3	1	>4	174.5	12.0	11.4	12.7	1.3	biogenic	35.5	2.4	0	

Sediment-Profile Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Weights (per side)	Water Depth (ft)	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq. cm)	Mean aRpd (cm)	Mud Clast Number	Mud Clast State
11	C	10/13/2012	9:40:45	16	5	86	14.6	4-3	1	>4	182.4	12.5	12.3	13	0.7	biogenic	52.5	3.6	0	
12	A	10/13/2012	11:17:20	16	5	78	14.6	4-3	1	>4	168.2	11.5	11	12.2	1.2	biogenic	51.4	3.5	0	
12	C	10/13/2012	11:19:08	16	5	78	14.6	4-3	1	>4	170.3	11.7	11	12.6	1.6	biogenic	46.7	3.2	0	
12	D	10/13/2012	11:20:25	16	5	78	14.6	4-3	1	>4	163.7	11.2	10.9	11.7	0.8	biogenic	41.9	2.9	0	
13	A	10/13/2012	9:55:00	16	5	85	14.6	4-3	1	>4	222.8	15.3	14.7	15.7	1.0	biogenic	51.2	3.5	0	
13	B	10/13/2012	9:55:52	16	5	85	14.6	4-3	1	>4	175.4	12.0	11.6	12.2	0.6	biogenic	42.6	2.9	0	
13	C	10/13/2012	9:58:00	16	5	85	14.6	4-3	1	>4	181.1	12.4	12.1	12.7	0.6	biogenic	43.1	3.0	0	
14	A	10/13/2012	11:31:46	16	5	78	14.6	4-3	1	>4	144.4	9.9	9.4	10.1	0.7	biogenic	36.9	2.5	0	
14	B	10/13/2012	11:32:37	16	5	78	14.6	4-3	1	>4	166.9	11.4	11.1	11.7	0.6	biogenic	39.6	2.7	0	
14	C	10/13/2012	11:33:29	16	5	78	14.6	4-3	1	>4	154.9	10.6	9.5	11.3	1.8	biogenic	46.5	3.2	0	
15	B	10/13/2012	12:30:43	16	5	73	14.6	>4	1	>4	192.6	13.2	12.7	13.4	0.7	biogenic	53	3.6	0	
15	C	10/13/2012	12:31:34	16	5	73	14.6	>4	1	>4	261.8	17.9	17.2	19	1.8	biogenic	15.4	1.1	0	
15	D	10/13/2012	12:32:41	16	5	73	14.6	>4	1	>4	232.1	15.9	15.6	16.1	0.5	biogenic	40.9	2.8	0	
16	A	10/13/2012	11:38:24	16	5	79	14.6	4-3	1	>4	214	14.7	14.3	15.1	0.8	biogenic	40	2.7	0	
16	B	10/13/2012	11:39:44	16	5	79	14.6	4-3	1	>4	224.5	15.4	14.7	15.8	1.1	biogenic	46.1	3.2	0	
16	C	10/13/2012	11:40:53	16	5	79	14.6	4-3	1	>4	263.2	18.0	17.7	18.2	0.5	biogenic	42.7	2.9	0	
17	B	10/13/2012	11:25:03	16	5	78	14.6	4-3	1	>4	127.9	8.8	8.4	9.4	1.0	biogenic	38.9	2.7	4	
17	C	10/13/2012	11:26:00	16	5	78	14.6	4-3	1	>4	168.8	11.6	11.3	12	0.7	biogenic	43	2.9	0	
17	D	10/13/2012	11:26:57	16	5	78	14.6	4-3	1	>4	161.5	11.1	10.2	11.8	1.6	physical	52.1	3.6	3	oxidized
18	A	10/13/2012	9:11:30	15	4	86	14.6	4-3	1	>4	51.1	3.5	3	4	1.0	biogenic	31.8	2.2	0	
18	B	10/13/2012	9:13:26	15	4	86	14.6	4-3	1	>4	171.8	11.8	11.4	12.4	1.0	biogenic	38.4	2.6	0	
18	C	10/13/2012	9:14:30	15	4	86	14.6	4-3	1	>4	172.3	11.8	11.6	12	0.4	biogenic	37.8	2.6	2	oxidized
SWREF-25	B	10/13/2012	14:57:56	16	5	74	14.6	>4	1	>4	285.8	19.6	19.3	19.8	0.5	biogenic	63.2	4.3	0	
SWREF-25	C	10/13/2012	14:59:16	16	5	74	14.6	>4	1	>4	254.4	17.4	15.9	18.9	3.0	physical	88.8	6.1	8	oxidized
SWREF-25	D	10/13/2012	15:00:25	16	5	74	14.6	>4	1	>4	228.7	15.7	15.3	16	0.7	biogenic	75.4	5.2	0	
SWREF-26	A	10/13/2012	14:49:17	16	5	69	14.6	>4	1	>4	202.7	13.9	13.1	14.7	1.6	biogenic	70.9	4.9	0	
SWREF-26	B	10/13/2012	14:50:51	16	5	69	14.6	>4	1	>4	224.6	15.4	14.7	15.9	1.2	biogenic	57.7	4.0	2	oxidized
SWREF-26	C	10/13/2012	14:51:56	16	5	69	14.6	>4	1	>4	208.6	14.3	13	15.1	2.1	biogenic	62.1	4.3	3	reduced
SWREF-27	A	10/13/2012	15:30:29	16	5	66	14.6	4-3	1	>4	134.8	9.2	7.7	9.9	2.2	biogenic	23.1	1.6	0	
SWREF-27	C	10/13/2012	15:32:46	16	5	66	14.6	4-3	1	>4	174.2	11.9	11.7	12.3	0.6	biogenic	61	4.2	0	

Sediment-Profile Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Date	Time	Stop Collar Setting (in)	# of Weights (per side)	Water Depth (ft)	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type	aRPD Area (sq. cm)	Mean aRpd (cm)	Mud Clast Number	Mud Clast State
SWREF-27	D	10/13/2012	15:34:00	16	5	66	14.6	4-3	1	>4	138.7	9.5	9.3	9.9	0.6	biogenic	43.8	3.0	0	
SWREF-28	A	10/13/2012	15:07:18	16	5	69	14.6	4-3	1	>4	158.2	10.8	9.8	11.4	1.6	biogenic	36.9	2.5	3	both
SWREF-28	B	10/13/2012	15:08:37	16	5	69	14.6	4-3	1	>4	140.1	9.6	9.4	9.9	0.5	biogenic	41.5	2.8	0	
SWREF-28	D	10/13/2012	15:10:37	16	5	69	14.6	4-3	1	>4	145.9	10.0	9.6	10.3	0.7	biogenic	36.9	2.5	2	oxidized
SWREF-29	A	10/13/2012	15:22:16	16	5	69	14.6	4-3	1	>4	161.1	11.0	10.9	11.4	0.5	biogenic	55.2	3.8	0	
SWREF-29	B	10/13/2012	15:24:02	16	5	69	14.6	4-3	1	>4	130.4	8.9	8.5	9.3	0.8	biogenic	35.7	2.4	0	
SWREF-29	C	10/13/2012	15:25:01	16	5	69	14.6	4-3	1	>4	167.6	11.5	11	12.1	1.1	biogenic	51.7	3.5	1	reduced
SWREF-30	A	10/13/2012	15:14:17	16	5	70	14.6	4-3	1	>4	172.5	11.8	11.3	12.2	0.9	biogenic	73	5.0	0	
SWREF-30	B	10/13/2012	15:16:39	16	5	70	14.6	4-3	1	>4	151.3	10.4	9.8	10.9	1.1	biogenic	42.8	2.9	0	
SWREF-30	C	10/13/2012	15:17:42	16	5	70	14.6	4-3	1	>4	154.6	10.6	10.1	11	0.9	biogenic	40.5	2.8	0	
NEREF-19	A	10/13/2012	14:15:27	16	5	69	14.6	4-3	1	>4	157.3	10.8	10.6	11.1	0.5	biogenic	40.9	2.8	0	
NEREF-19	C	10/13/2012	14:17:18	16	5	69	14.6	4-3	1	>4	198.4	13.6	13.2	13.9	0.7	biogenic	38.3	2.6	0	
NEREF-19	D	10/13/2012	14:18:37	16	5	69	14.6	4-3	1	>4	167.5	11.5	11.2	11.9	0.7	biogenic	52.8	3.6	0	
NEREF-20	A	10/13/2012	13:51:38	16	5	65	14.6	>4	1	>4	163.4	11.2	10.8	11.6	0.8	biogenic	58.6	4.0	0	
NEREF-20	C	10/13/2012	13:53:44	16	5	65	14.6	>4	1	>4	171.9	11.8	11.4	12.2	0.8	biogenic	51.5	3.5	2	reduced
NEREF-20	D	10/13/2012	13:55:16	16	5	65	14.6	>4	1	>4	152.2	10.4	10.1	11	0.9	biogenic	49.9	3.4	1	reduced
NEREF-21	A	10/13/2012	14:06:20	16	5	65	14.6	>4	1	>4	180.8	12.4	11.8	13	1.2	biogenic	52.5	3.6	0	
NEREF-21	C	10/13/2012	14:08:47	16	5	65	14.6	>4	1	>4	160.3	11.0	10.6	11.2	0.6	biogenic	44.2	3.0	0	
NEREF-21	D	10/13/2012	14:10:29	16	5	65	14.6	>4	1	>4	178.5	12.2	11.9	13	1.1	biogenic	52.8	3.6	2	oxidized
NEREF-22	B	10/13/2012	13:34:55	16	5	63	14.6	>4	1	>4	184.1	12.6	11.9	13.1	1.2	biogenic	47.4	3.2	3	reduced
NEREF-22	C	10/13/2012	13:35:54	16	5	63	14.6	>4	1	>4	239.3	16.4	15.9	16.8	0.9	biogenic	56.5	3.9	0	
NEREF-22	D	10/13/2012	13:36:46	16	5	63	14.6	>4	1	>4	225.6	15.5	15.1	15.7	0.6	biogenic	52.8	3.6	0	
NEREF-23	A	10/13/2012	13:42:38	16	5	65	14.6	>4	1	>4	166.4	11.4	10.2	12.2	2.0	biogenic	43.1	3.0	0	
NEREF-23	B	10/13/2012	13:43:39	16	5	65	14.6	>4	1	>4	195.9	13.4	13.2	14.1	0.9	biogenic	61.3	4.2	0	
NEREF-23	D	10/13/2012	13:46:21	16	5	65	14.6	>4	1	>4	167.8	11.5	10.7	12.5	1.8	biogenic	57.9	4.0	0	
NEREF-24	A	10/13/2012	13:59:49	16	5	66	14.6	>4	1	>4	154.2	10.6	10.4	10.9	0.5	biogenic	32.4	2.2	0	
NEREF-24	C	10/13/2012	14:01:48	16	5	66	14.6	>4	1	>4	153.8	10.5	10.3	11.2	0.9	biogenic	35.2	2.4	0	
NEREF-24	D	10/13/2012	14:02:45	16	5	66	14.6	>4	1	>4	247.3	16.9	16.2	18	1.8	biogenic	42.1	2.9	3	r

Sediment-Profile Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Methane	Low Do?	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
1	C	No	No	Consolidated silty fine sand >pen; light tan oxy lyr over grey@depth; moderate aRPD contrast; several worms@depth; biogenic mounds	1	6.8	8.2	7.5	1 on 3
1	D	No	No	Silty, very fine sand>pen; light tan oxy lyr over grey@depth; moderate aRPD contrast; several worms@depth, evidence of sub-surface burrowing.	0				1 on 3
2	A	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; small burrows upper 1-2 cm; vertical oxy burrow@lower right	0				1 on 3
2	B	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; small burrows upper 1-2 cm; multiple worms@depth	2	3.4	13	8.2	1 on 3
2	C	No	No	Fine-sandy, silt/clay>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; black/reduced sed@depth; small burrows+worms upper 1-2 cm; several worms@depth	0				1 on 3
4	A	No	No	Fine-sandy, silt/clay>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; multiple lrg+small worms@depth; vertical oxy tube/burrow@right w/ biogenic mound above; piece of wood debris@surf center	1	8.2	9	8.6	1 on 3
4	B	No	No	Fine-sandy, silt/clay>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; small worms upper 2-3 cm, evidence of subsurface burrowing	0				1 on 3
4	C	No	No	S/M=upper 3-4 cm is fine sand w/ shell frags over silt/clay@depth; shells+frags+a few pebbles@surf; 1 subsurface void, surface disturbed by previous replicate (see corresponding PV)	1	13.6	14.1	13.9	1 on 3
5	A	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; moderate aRPD contrast; multiple small worms@depth; small piece of larger-bodied worm@left edge	0				1 on 3
5	B	No	No	Silt/clay>pen; light tan oxy layer over mottled grey@depth; sed surf looks physically disturbed=camera base frame artifact; thin aRPD w/ moderate contrast; partial void left+multiple small worms@depth	1	7.9	8.2	8.1	1 on 3
5	C	No	No	Silty, very fine sand>pen; a few pebbles+numerous shells/frags@surf; moderate aRPD contrast; burrow opening@left w/ oxy halo beneath; small worms@depth	0				1 on 3
6	A	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; tunnels/burrows in upper 2-3 cm; dense surf tubes; small deep voids bottom edge; worms@depth	3	9.6	10.2	9.9	1 on 3
6	C	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; tunnels/burrows in upper 2-3 cm; small worms@depth	0				1 on 3
6	D	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; a few tunnels/burrows in upper 1-2 cm; small/thin worms@depth; 1 void	1	9.2	9.4	9.3	1 on 3

Sediment-Profile Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Methane	Low Do?	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
7	A	No	No	Low pen=numerous pebbles over sandy mud; shell frags; epifaunal growth on pebbles; subsurface burrow@left	0				1 on 3
7	B	No	No	Silty fine sand over silt/clay; light tan oxy layer over mottled grey@depth; moderate aRPD contrast; small surf tubes+several small thin worms@depth	0				1 on 3
7	D	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; bio reworking of upper 1 cm; small/thin worms@depth; vertical oxy burrow@right w/ biogenic mound above	0				1 on 3
8	A	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; a few tunnels/burrows in upper 1 cm; worms@depth; partial void@left edge	1	8.6	8.9	8.8	1 on 3
8	B	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; bio reworking of upper 1 cm; several thin worms@depth, evidence of subsurface burrowing	0				1 on 3
8	D	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; worms@depth; vertical oxy burrows@depth	0				1 on 3
9	A	No	No	Sandy silt/clay>pen; moderate aRPD contrast; reduced patches@depth; vertical oxy burrow center+deep void; shell frags adhering to object@surface	1	19	19.2	19.1	1 on 3
9	B	No	No	Silty, very fine sand>pen; moderate aRPD contrast; a few small worms@depth; vertical oxy burrow left of center w/ biogenic mound above	0				1 on 3
9	D	No	No	Sandy silt/clay>pen; moderate aRPD contrast; 1 relatively large (2.5 cm diameter) vertical burrow@center, artifact of camera prism dragging down surface shell or other debris	0				1 on 3
10	A	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; bio reworking of upper 1 cm; a few small/thin worms@depth, evidence of subsurface burrowing	0				1 on 3
10	C	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; partial voids left+2 deep voids bottom edge of image	3	5.6	12.4	9.0	1 on 3
10	D	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; moderate aRPD contrast; 2 vertical oxy burrows w/ surf openings; long thin worm center	1	1.9	2.1	2.0	1 on 3
11	A	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; weak to moderate aRPD contrast; several worms at depth as well as evidence of subsurface burrowing (transected burrow halos)	0				1 on 3
11	B	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; weak to moderate aRPD contrast; surf tubes; small biogenic mounds; bio reworking of upper 1 cm; small reddish cryptic worms	0				1 on 3

Sediment-Profile Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Methane	Low Do?	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
11	C	No	No	Sandy mud over silty sand layering; moderate aRPD contrast;surf tubes; several small cryptic worms@depth	0				1 on 3
12	A	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; weak to moderate aRPD contrast; surf tubes; vertical oxy tubes/burrows; several worms subsurface	0				1 on 3
12	C	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; weak to moderate aRPD contrast; surf tubes; small biogenic mounds; 1 partial void; several red worms@depth	1	6.4	6.7	6.6	1 on 3
12	D	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; weak to moderate aRPD contrast; deep vertical oxy burrow@right; several worms@depth	2	4.9	6.3	5.6	1 on 3
13	A	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; clear DM layering; weak to moderate aRPD contrast; numerous subsurface red worms; tubes+a few stick amphipods@surf	2	11.6	12.6	12.1	1 on 3
13	B	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; weak to moderate aRPD contrast; biogenic mounds; deep voids/burrows; a few worms@depth	2	8.3	10.9	9.6	1 on 3
13	C	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; weak to moderate aRPD contrast; vertical oxy burrow left of center w/ surf opening surrounded by pelletized sed; small worms@depth; biogenic mounds.	4	5.5	12.4	9.0	1 on 3
14	A	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; weak to moderate aRPD contrast; 1 large and several small red subsurface worms; biogenic mounds	1	4.9	5.1	5.0	1 on 3
14	B	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; weak to moderate aRPD contrast; vertical oxy burrows+biogenic mounds; several long thin red worms	0				1 on 3
14	C	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; faint DM layering; weak to moderate aRPD contrast; vertical oxy burrows; several long thin red worms, evidence of subsurface burrowing	1	8.3	8.4	8.4	1 on 3
15	B	No	No	Sandy silt/clay>pen; light tan oxy layer over grey@depth; faint DM layering; weak to moderate aRPD contrast; vertical oxy burrows/tubes; cryptic worms@depth	0				1 on 3
15	C	No	No	Sandy silt/clay>pen; light tan oxy layer over grey@depth; thin aRPD w/ moderate contrast; thick surf tubes+1-2 cryptic shallow worms, ophiuroid arm projecting above SWI at right edge	0				2 going to 3
15	D	No	No	Sandy silt/clay>pen; light tan oxy layer over grey@depth; DM layering; moderate aRPD contrast; large void/burrow; several long thin red worms	1	9.5	10.9	10.2	1 on 3
16	A	No	No	Silty, very fine sand>pen; slightly sandy; light tan oxy layer over grey@depth; moderate aRPD contrast; surf tubes+voids	4	7.8	9	8.4	1 on 3

Sediment-Profile Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Methane	Low Do?	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
16	B	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; moderate aRPD contrast; vertical oxy burrows; deep void/burrow; large bodied org lower right corner	2	7.7	13.7	10.7	1 on 3
16	C	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; moderate aRPD contrast; DM layering?; vertical oxy burrows; small cryptic worms upper 2-3 cm, subsurface burrow edge transected at depth	0				1 on 3
17	B	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; numerous oxy mud clasts on sed surf in farfield; numerous long thin worms@depth	0				1 on 3
17	C	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; weak aRPD contrast; faint DM layering; surf tubes+several small cryptic worms@depth	0				1 on 3
17	D	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; weak aRPD contrast; DM layering; surf tubes+several small cryptic worms@depth, boundary roughness at left edge from previous camera sample	0				1 on 3
18	A	No	No	Low pen=firm /muddy fine sand; a few pebbles@surf; surf tubes	0				ind
18	B	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; weak DM layering=upper 6-7 cm is homogenous silty sand over streaky grey clay w/ patches of fine sand; clay@depth has large megafuanal burrows/voids; several subsurface worms	2	7	11.3	9.2	1 on 3
18	C	No	No	Silty, very fine sand>pen; light tan oxy layer over grey@depth; moderate aRPD contrast; DM layering; vertical oxy burrows w/ extending to sed surface	2	4.8	7.4	6.1	1 on 3
SWREF-25	B	No	No	Sandy silt/clay>pen; moderate aRPD contrast; patches/horizons of black reduced sed@depth; multiple subsurface worms; unusual inventory of organics at depth as compared with disposal site	1	14.7	15.3	15.0	1 on 3
SWREF-25	C	No	No	Sandy silt/clay>pen; weak to moderate aRPD contrast; small patches/horizons of black reduced sed@depth; physical disturbance of sed surf=camera artifact (visible in PV image)	3	4.2	13.1	8.7	1 on 3
SWREF-25	D	No	No	Sandy silt/clay>pen; minor fraction of very fine sand; weak aRPD contrast; small patches/horizons of black reduced sed@depth; 1 partial void; multiple long thin red worms@depth	1	11.4	12.2	11.8	1 on 3
SWREF-26	A	No	No	Sandy silt/clay>pen; weak to moderate aRPD contrast; small patches of dark reduced sed@depth; partial voids; large bodied segmented worm left (possible Maldanid); shallow burrow w/ surf opening; fecal pellets@surf	3	4.5	9.5	7.0	1 on 3
SWREF-26	B	No	No	Sandy silt/clay>pen; minor fraction of very fine sand; weak aRPD contrast; burrow/void complex; biogenic mound@center w/ concentrated patches of fecal pellets	3	4.1	8.9	6.5	1 on 3
SWREF-26	C	No	No	Upper 10 cm is sandy silt/clay overlying muddy very fine sand@depth; wiper clasts; a few worms@depthl surf tubes	0				1 on 3

Sediment-Profile Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Methane	Low Do?	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
SWREF-27	A	No	No	Silty, very fine sand>pen; weak to moderate aRPD contrast; several voids/burrows; surf tubes	4	2.4	7.9	5.2	1 on 3
SWREF-27	C	No	No	Silty, very fine sand>pen; weak aRPD contrast; vertical oxy burrow w/ surf opening; surf tubes; partial void left; somewhat pelletized surface	2	8.5	11.5	10.0	1 on 3
SWREF-27	D	No	No	Silty, very fine sand>pen; weak aRPD contrast; surf tubes; multiple worms@depth; large vertical burrow lower right corner	1	7.3	7.5	7.4	1 on 3
SWREF-28	A	No	No	Silty, very fine sand>pen; weak aRPD contrast; surf tubes; multiple small worms@depth; vertical oxy burrow w/ surf opening@right	0				1 on 3
SWREF-28	B	No	No	Silty, very fine sand>pen; weak aRPD contrast; surf tubes; multiple small worms@depth; multiple subsurface voids/burrows	4	1.8	9.2	5.5	1 on 3
SWREF-28	D	No	No	Silty, very fine sand>pen; weak aRPD contrast; surf tubes; worms@depth; 1 shallow void	1	1.6	1.8	1.7	1 on 3
SWREF-29	A	No	No	Silty, very fine sand>pen; moderate aRPD contrast; somewhat reduced@depth; numerous subsurface worms; biogenic reworking of upper 1 cm; fecal pellets visible@surf	0				1 on 3
SWREF-29	B	No	No	Silty, very fine sand>pen; weak to moderate aRPD contrast; numerous subsurface worms; vertical oxy burrows/tubes; biogenic reworking of upper 1 cm; biogenic mounds	1	5.6	6.3	6.0	1 on 3
SWREF-29	C	No	No	Silty, very fine sand>pen; weak aRPD contrast; numerous subsurface worms; vertical oxy burrows/tubes; biogenic reworking of upper 1 cm	0				1 on 3
SWREF-30	A	No	No	Silty, very fine sand>pen; weak aRPD contrast; numerous subsurface worms; small patches reduced sed@depth; shallow vertical burrows	1	3.1	3.4	3.3	1 on 3
SWREF-30	B	No	No	Silty, very fine sand>pen; weak aRPD contrast; numerous subsurface worms; small patches reduced sed@depth; shallow vertical burrows	1	8.6	8.6	8.6	1 on 3
SWREF-30	C	No	No	Silty, very fine sand>pen; weak aRPD contrast; numerous subsurface worms; vertical oxy burrow extending to surface@left	1	2.1	2.1	2.1	1 on 3
NEREF-19	A	No	No	Silty, very fine sand>pen; weak aRPD contrast; numerous subsurface worms; surf tubes; biogenic mounds	0				1 on 3
NEREF-19	C	No	No	Silty, very fine sand>pen; weak aRPD contrast; numerous subsurface worms+feeding voids; small patches reduced sed@depth	5	3.7	9.5	6.6	1 on 3
NEREF-19	D	No	No	Silty, very fine sand>pen; weak aRPD contrast; numerous subsurface worms; small patches reduced sed@depth; vertical oxy burrow@right; biogenic mounds	2	4.7	5.6	5.2	1 on 3
NEREF-20	A	No	No	Sandy silt/clay>pen; slightly sandier near surface; weak aRPD contrast; numerous subsurface worms; deep vertical oxy burrow w/ surf opening@far right; biogenic mound	1	6	6.2	6.1	1 on 3

Sediment-Profile Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Methane	Low Do?	Comment	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage
NEREF-20	C	No	No	Sandy silt/clay>pen; slightly sandier near surface; weak aRPD contrast; numerous small thin subsurface worms; wiper clasts	0				1 on 3
NEREF-20	D	No	No	Sandy silt/clay>pen; slightly sandier near surface; weak to moderate aRPD contrast; numerous subsurface worms; patches reduced sed@depth; bio reworking of upper 1 cm	0				1 on 3
NEREF-21	A	No	No	Sandy silt/clay>pen; moderate aRPD contrast; patch of black/reduced sed@depth; numerous subsurface worms; partial voids; bio reworking of upper 1 cm	2	6.2	8.3	7.3	1 on 3
NEREF-21	C	No	No	Sandy silt/clay>pen; slightly sandier near surface; weak aRPD contrast; numerous subsurface worms; wiper clasts; vertical oxy burrow left of center; large worm (*Nepthys sp.*) just below surface@left	1	5.6	5.8	5.7	1 on 3
NEREF-21	D	No	No	Sandy silt/clay>pen; weak aRPD contrast but black/reduced sed@depth; numerous small+larger subsurface worms; wiper clasts; partial voids	4	7.3	8.7	8.0	1 on 3
NEREF-22	B	No	No	Sandy silt/clay>pen; weak aRPD contrast; numerous subsurface worms; wiper clasts	0				1 on 3
NEREF-22	C	No	No	Sandy silt/clay>pen; weak to moderate aRPD contrast; patches of black sed@depth; multiple subsurface worms; shallow burrow w/ surf opening@right	1	14.9	15.5	15.2	1 on 3
NEREF-22	D	No	No	Sandy silt/clay>pen; moderate to strong aRPD contrast; horizon of black/sulfidic sed@depth; numerous large+small worms@subsurface; biogenic mounds; appears like DM layering	1	12.2	12.5	12.4	1 on 3
NEREF-23	A	No	No	Sandy silt/clay>pen; weak aRPD contrast; numerous lrg+small subsurface worms; deep void/burrow; biogenic mound; slight pull away@right	3	2.5	11.2	6.9	1 on 3
NEREF-23	B	No	No	Sandy silt/clay>pen; weak aRPD contrast; patches of dark sed@depth; numerous subsurface worms; void/burrow w/ worm body visible within; cluster of fecal pellets@surf@center; biogenic mound	2	8.1	9.8	9.0	1 on 3
NEREF-23	D	No	No	Sandy silt-clay>pen; weak aRPD contrast; numerous subsurface worms; biogenic mound; bio reworking of upper 0.5 cm=pelletized surface	0				1 on 3
NEREF-24	A	No	No	Sandy silt/clay>pen; weak aRPD contrast; numerous subsurface worms; partial voids; vertical oxy burrow@right; surf tubes	2	5.2	8.8	7.0	1 on 3
NEREF-24	C	No	No	Sandy silt/clay>pen; slightly sandier near surface; weak aRPD contrast; biogenic mounds; several large+small worms@depth	0				1 on 3
NEREF-24	D	No	No	Sandy silt/clay>pen; slightly sandier near surface; weak to moderate aRPD contrast; patches of black/reduced sed@depth; numerous subsurface worms; multiple voids/burrows lower left corner; wiper clasts	7	7.1	16.5	11.8	1 on 3

APPENDIX B

GRAIN SIZE SCALE FOR SEDIMENTS

APPENDIX B

Grain Size Scale for Sediments

Phi 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

APPENDIX C

PLAN-VIEW IMAGE ANALYSIS RESULTS FOR MACBDS SURVEY, OCTOBER 2012

Plan-View Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Date	Time	Image width (cm)	Image height (cm)	Field of View imaged (m²)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Trails	Epifauna	Mud Clasts	Debris	Comment
2	A	10/13/2012	10:03:37	200.9	132.8	2.7	silt/clay	n	y	y	y	n	y	n	n	Moderate turbidity; 23 cm lobster; circular depression in sed=most likely biogenic. (lobster burrow)
2	B	10/13/2012	10:04:36	204.7	135.3	2.8	silt/clay	n	y	y	y	n	y	n	n	Moderate to high turbidity; 21 cm lobster=same one as previous? hang weight visible bottom edge
2	C	10/13/2012	10:05:32	204.7	135.2	2.8	silt/clay	n	y	y	y	n	n	n	n	Moderate to high turbidity; hang weight visible bottom of image
3	A	10/13/2012	10:40:27	203.4	134.5	2.7	silt/clay	n	y	y	y	y	n	n	n	Silt/clay w/ dense shell frags; many burrows w/ reduced expelled sediment; hang weight bottom of image
3	C	10/13/2012	10:42:43	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Cannot be analyzed=too turbid to see sed surface
3	D	10/13/2012	10:43:35	203.3	134.3	2.7	silt/clay	n	y	y	ind	ind	n	n	n	Half of image obscured by turbidity; looks like silt/clay w/ dense shell frags
4	A	10/13/2012	12:06:13	195.9	129.4	2.5	silt/clay	n	y	y	n	n	n	n	n	Silt/clay w/ dense shell frags
4	C	10/13/2012	12:08:20	196	129.1	2.5	silt/clay	n	y	y	n	n	n	n	n	Camera footprint visible=same seafloor area imaged as previous rep=silt/clay w/ dense shell frags
4	D	10/13/2012	12:09:31	200.1	132.4	2.6	silt/clay	n	y	y	n	n	y	n	n	Silt/clay w/ dense shell frags+scattered gravel (pebbles) w/ epifauna
5	A	10/13/2012	12:36:40	199.9	132.1	2.6	silt/clay	n	y	y	y	n	y	n	n	Silt/clay w/ dense shell frags+some gravel; 1 crab and 1 shrimp; piece of reddish seaweed lower left corner
5	C	10/13/2012	12:38:26	218.2	144.2	3.1	silt/clay	n	n	y	n	n	y	n	n	Silt/clay w/ dense shell frags; 1 crab; red seaweed fronds lower left corner
5	D	10/13/2012	12:39:22	211.7	140.2	3.0	silt/clay w/ gravel	n	n	y	n	n	y	n	n	Silt/clay w/ dense shell frags+dense gravel; 1 crab; depression made by SPI prism
6	B	10/13/2012	9:47:12	145.6	96.1	1.4	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay w/ numerous burrows+trails/tracks

Plan-View Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Date	Time	Image width (cm)	Image height (cm)	Field of View imaged (m²)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Trails	Epifauna	Mud Clasts	Debris	Comment
6	D	10/13/2012	9:50:14	ind	ind		ind	ind	ind	ind	ind	ind	ind	ind	ind	Cannot be analyzed=too turbid to see sed surface
7	A	10/13/2012	11:09:09	185.7	122.5	2.3	mixed mud+gravel	n	y	y	y	n	y	n	y	Dense gravel and shell frags over sandy mud/muddy sand; crushed aluminum can bottom center; wood debris upper center
7	B	10/13/2012	11:10:41	176.1	116.6	2.1	sandy mud w/ shell frags	n	y	y	y	y	n	n	n	Muddy sand/sandy mud w/ shells and shell frags; plume of sed resuspended by trigger hand weight
7	D	10/13/2012	11:12:33	191.4	126.6	2.4	mixed mud/sand/gravel/shells	n	y	y	y	y	y	n	n	Mix of muddy sand/sandy mud+shells+shell frags+gravel; concentrated patch of gravel lower right corner; crab left of center; furrow from hang weight?
8	C	10/13/2012	10:56:21	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Cannot be analyzed=too turbid to see sed surface
8	D	10/13/2012	10:57:19	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Cannot be analyzed=camera lens too close to sed
9	A	10/13/2012	12:23:20	177.2	116.4	2.1	silt/clay	n	n	y	y	y	y	n	n	Silt/clay w/ scatterred gravel and shells
9	B	10/13/2012	12:24:17	188.4	123.6	2.3	silt/clay	n	y	y	y	y	y	n	n	Silt/clay w/ a very little bit of gravel and shells; epifauna on rocks upper left corner
9	D	10/13/2012	12:26:31	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Difficult to analyze=high turbidity+camera frame disturbance of sed surf=can't see laser dots; looks like mud w/ shell frags
10	A	10/13/2012	10:09:38	201.2	133	2.7	silt/clay	n	y	y	n	n	n	n	n	Moderate turbidity; silt/clay w/ shells+shell frags
10	B	10/13/2012	10:10:27	199.3	131.8	2.6	silt/clay	n	y	y	ind	n	n	n	n	Moderate to high turbidity; looks like mud w/ some shell frags
10	D	10/13/2012	10:12:26	200.7	132.6	2.7	silt/clay	n	y	y	y	y	y	n	n	Silt/clay w/ shell frags; line@sed surf=camera base sled imprint
11	A	10/13/2012	9:39:09	198.7	130.9	2.6	silt/clay	n	y	y	y	y	n	n	n	Silt/clay w/ shell frags

Plan-View Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Date	Time	Image width (cm)	Image height (cm)	Field of View imaged (m^2)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Trails	Epifauna	Mud Clasts	Debris	Comment
11	C	10/13/2012	9:41:08	163.1	107.8	1.8	silt/clay	n	y	y	y	y	n	n	n	Silt/clay w/ shell frags; straight line furrow@sed surf=camera artifact from previous replicate; moderate to high turbidity
11	D	10/13/2012	9:42:05	205.2	135.4	2.8	silt/clay	n	y	y	y	y	y	n	n	Moderate turbidity; silt/clay w/ shell frags
12	A	10/13/2012	11:17:46	196.4	129.2	2.5	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ shell frags; many elongated burrow openings (clam siphons) and trails/tracks.
12	B	10/13/2012	11:18:44	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Cannot be analyzed=missed shot/too turbid to see sed surface
12	C	10/13/2012	11:19:34	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Cannot be analyzed=too turbid to see sed surface
13	A	10/13/2012	9:55:25	203.1	134.1	2.7	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ some shell frags; many burrow openings and trails/tracks; linear trails just above center of image from crabs
13	B	10/13/2012	9:56:16	199.9	131.5	2.6	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ some shell frags; many burrow openings and trails/tracks
13	C	10/13/2012	9:58:24	201.2	132.7	2.7	silt/clay	n	y	y	y	n	n	n	n	Relatively featureless silt/clay w/ some shell frags; lobster burrow opening visible toward top center
14	A	10/13/2012	11:32:11	197.5	130.5	2.6	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ some shell frags; many small burrow openings
14	B	10/13/2012	11:33:03	194.3	128.5	2.5	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ some shell frags; many small burrow openings+tracks
14	C	10/13/2012	11:33:54	192	126.8	2.4	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ some shell frags; many small burrow openings+tracks

Plan-View Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Date	Time	Image width (cm)	Image height (cm)	Field of View imaged (m^2)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Trails	Epifauna	Mud Clasts	Debris	Comment
15	A	10/13/2012	12:30:13	192	126.7	2.4	silt/clay	n	y	y	y	y	y	n	n	Relatively featureless silt/clay w/ some shell frags; many small burrow openings+tracks/trails; 1 fish right; tapered cylindrical tube-like object upper left
15	B	10/13/2012	12:31:09	172.1	113.8	2.0	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ some shell frags; looks like furrow of grey clay w/ patchy veneer of brown silt
15	D	10/13/2012	12:33:06	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Cannot be analyzed=too turbid to see sed surface
16	A	10/13/2012	11:38:50	195.9	129.6	2.5	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ some shell frags; numerous elongated bivalve siphon openings @sed surf, especially upper right quadrant
16	B	10/13/2012	11:40:09	174.5	115.3	2.0	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ some shell frags; many small burrow openings+tracks/trails; seaweed fronds lower right corner; hang weight+wire
16	C	10/13/2012	11:41:17	197.1	129.9	2.6	silt/clay	n	y	y	y	y	ind	n	n	High turbidity=sed surf partially visible in upper left corner; looks like silt/clay; seaweed lower left corner
17	A	10/13/2012	11:24:35	201.3	133.2	2.7	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ some shell frags; numerous elongated bivalve siphon openings @sed surf, especially upper right quadrant
17	B	10/13/2012	11:25:29	201.5	132.9	2.7	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ some shell frags; half of image obscured by turbidity
17	C	10/13/2012	11:26:26	196.1	129.4	2.5	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ some shell frags; numerous elongated bivalve siphone openings@sed surf
18	A	10/13/2012	9:11:53	187.3	123.8	2.3	gravel with sandy mud	n	n	n	n	n	y	n	n	Assorted gravel over silt/clay; strand of *Ulva sp.*@center; epifauna on rocks

Plan-View Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Date	Time	Image width (cm)	Image height (cm)	Field of View imaged (m^2)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Trails	Epifauna	Mud Clasts	Debris	Comment
18	B	10/13/2012	9:13:52	194.1	128	2.5	silt/clay	n	y	y	y	y	n	n	n	Relatively featureless silt/clay w/ some shell frags; numerous burrow openings surrounded by grey expelled sed; numerous tracks/trails
18	C	10/13/2012	9:14:57	197.6	130.6	2.6	silt/clay	n	y	y	y	y	n	n	y	Relatively featureless silt/clay w/ some shell frags; camera frame imprint; appears to be a piece of rusted debris bottom center
SWREF-25	A	10/13/2012	14:57:04	194.3	128.2	2.5	silt/clay	n	y	y	y	y	y	n	n	Soft silt/clay w/ some shell frags; numerous small burrow openings; numerous tracks/trails; epifauna on rock@right
SWREF-25	C	10/13/2012	14:59:40	194.5	128.6	2.5	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay w/ some shell frags; numerous small burrow openings; significant camera frame disturbance=base frame+prism imprints
SWREF-25	D	10/13/2012	15:00:51	191	125.9	2.4	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay w/ some shell frags; numerous small burrow openings
SWREF-26	A	10/13/2012	14:49:43	190.3	125.9	2.4	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay w/ some shell frags; dense small burrow openings+tracks; very dense track upper right corner
SWREF-26	B	10/13/2012	14:51:17	187.6	123.7	2.3	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay w/ some shell frags; dense small burrow openings+tracks
SWREF-26	C	10/13/2012	14:52:21	194.5	128.6	2.5	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay w/ some shell frags; dense small burrow openings+tracks
SWREF-27	A	10/13/2012	15:30:53	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Insufficient light, strobe didn't fire; image cannot be analyzed
SWREF-27	B	10/13/2012	15:32:12	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Insufficient light, strobe didn't fire; image cannot be analyzed
SWREF-27	C	10/13/2012	15:33:11	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Cannot be analyzed=too turbid
SWREF-28	A	10/13/2012	15:07:41	195.2	128.8	2.5	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay w/ some shell frags; dense small burrow openings+some tracks

Plan-View Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Date	Time	Image width (cm)	Image height (cm)	Field of View imaged (m²)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Trails	Epifauna	Mud Clasts	Debris	Comment
SWREF-28	B	10/13/2012	15:09:03	197.5	130.5	2.6	silt/clay	n	y	y	y	y	y	n	n	Soft silt/clay w/ some shell frags; dense small burrow openings+tracks/trails; small piece red algae top center
SWREF-28	D	10/13/2012	15:11:03	197.2	130.1	2.6	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay w/ some shell frags; burrow openings+tracks/trails; image is partially obscured by turbidity
SWREF-29	A	10/13/2012	15:22:41	191.5	126.5		silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay w/ shell frags; dense burrow openings and tracks/trails; 1 small piece *Ulva sp.*
SWREF-29	B	10/13/2012	15:24:27	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Insufficient light, strobe didn't fire; image cannot be analyzed
SWREF-29	C	10/13/2012	15:25:25	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Cannot be analyzed=too turbid
SWREF-30	A	10/13/2012	15:14:43	184.8	121.9	2.3	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; dense burrow openings and very dense tracks/trails; numerous bivalve siphon openings
SWREF-30	B	10/13/2012	15:17:04	194.6	128.8	2.5	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; dense small burrow openings and tracks/trails; 2 large biogenic depressions (most likely lobster burrow openings); *Cerianthid* anemone@right center
SWREF-30	C	10/13/2012	15:18:06	195.5	129.3	2.5	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; many burrows+tracks/trails; some shell frags; mostly small burrows but 1 large one (most likely lobster) top of image
NEREF-19	A	10/13/2012	14:15:51	193.1	127.4	2.5	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; many burrows+tracks/trails; some shell frags
NEREF-19	B	10/13/2012	14:16:47	193.1	127.3	2.5	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay w/ many burrows+tracks; image partially obscured by turbidity
NEREF-19	D	10/13/2012	14:19:02	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Cannot be analyzed=too turbid
NEREF-20	A	10/13/2012	13:52:02	191.8	126.5	2.4	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; many burrows+tracks/trails

Plan-View Image Analysis Results for MacBDS Survey, October 2012

Station	Replicate	Date	Time	Image width (cm)	Image height (cm)	Field of View imaged (m²)	Sediment Type	Bedforms	Burrows	Tubes	Tracks	Trails	Epifauna	Mud Clasts	Debris	Comment
NEREF-20	C	10/13/2012	13:54:09	191.1	126	2.4	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; many burrows+tracks/trails; several elongated burrow openings in lower right corner
NEREF-20	D	10/13/2012	13:55:41	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Cannot be analyzed=too turbid
NEREF-21	B	10/13/2012	14:07:44	192.2	126.9	2.4	silt/clay	n	y	y	y	y	n	n	n	Poor visibility; looks like silt/clay w/ burrows+some shells
NEREF-21	C	10/13/2012	14:09:11	189.8	125.4	2.4	silt/clay	n	y	y	y	y	n	n	n	Poor visibility; many burrows; tracks/trails
NEREF-21	D	10/13/2012	14:10:54	198.8	131.2	2.6	silt/clay	n	y	y	y	y	n	n	n	Poor visibility; burrows+tracks/trails
NEREF-22	A	10/13/2012	13:34:28	193.3	127.6	2.5	silt/clay	n	y	y	y	y	y	n	n	Soft silt/clay; many burrows+tracks/trails; fish at bottom edge to right of trigger hang weight
NEREF-22	B	10/13/2012	13:35:20	194.7	128.6	2.5	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; many burrows+tracks/trails
NEREF-22	C	10/13/2012	13:36:18	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	ind	Cannot be analyzed=majority of image is too turbid; looks like soft silt/clay w/ burrows+tracks on left side of image
NEREF-23	A	10/13/2012	13:43:02	194.9	128.6	2.5	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; many burrows+tracks/trails
NEREF-23	B	10/13/2012	13:44:05	191.1	126.6	2.4	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; many burrows+tracks/trails
NEREF-23	C	10/13/2012	13:45:09	197	130.2	2.6	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; many burrows+tracks/trails; piece of seaweed in lower right corner
NEREF-24	A	10/13/2012	14:00:15	194.9	128.6	2.5	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; many burrows+tracks; burrowing anemone just below right laser dot; some elongated burrow openings (bivalves siphons)
NEREF-24	C	10/13/2012	14:02:11	193.3	128	2.5	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; some shell frags; many burrows+tracks/trails
NEREF-24	D	10/13/2012	14:03:10	196.2	129.4	2.5	silt/clay	n	y	y	y	y	n	n	n	Soft silt/clay; some shell frags; many burrows+tracks/trails, corner of base sled imprint from previous replicate can be seen at top edge of image

APPENDIX D

TABLE OF COMMON CONVERSIONS

APPENDIX D

Table of Common Conversions

Metric Unit Conversion to English Unit		English Unit Conversion to Metric Unit	
1 meter 1 m	3.2808399 ft	1 foot 1 ft	0.3048 m
1 square meter 1 m^2	10.7639104 ft^2	1 square foot 1 ft^2	0.09290304 m^2
1 kilometer 1 km	0.621371192 mi	1 mile 1 mi	1.609344 km
1 cubic meter 1 m^3	1.30795062 yd^3	1 cubic yard 1 yd^3	0.764554858 m^3
1 centimeter 1 cm	0.393700787 in	1 inch 1 in	2.54 cm