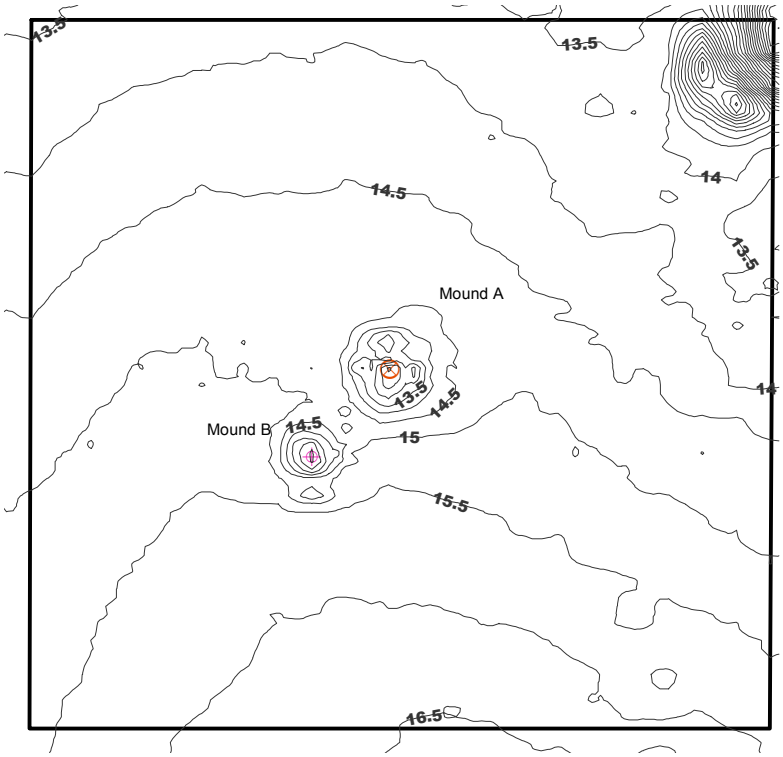
Monitoring Survey at the Tupper Ledge Disposal Site
September 2003

Disposal Area Monitoring System DAMOS



D A M O S

DISPOSAL AREA MONITORING SYSTEM

Contribution 158
September 2004

US Army Corps of Engineers ®
New England District

This report should be cited as:

ENSR. 2004. Monitoring Survey at the Tupper Ledge Disposal Site, September 2003. DAMOS Contribution No. 158. U.S. Army Corps of Engineers, New England District, Concord, MA, 58 pp.

REPORT DOCUMENTATION PAGE

form approved
OMB No. 0704-0188

Public reporting concern for the collection of information is estimated to average 1 hour per response including the time for reviewing instructions, searching existing data sources, gathering and measuring the data needed and correcting and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information including suggestions for reducing this burden to Washington Headquarters Services, Directorate for information Observations and Records, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302 and to the Office of Management and Support, Paperwork Reduction Project (0704-0188), Washington, D.C. 20503.

1. AGENCY USE ONLY (LEAVE BLANK)

2. REPORT DATE
September 2004

3. REPORT TYPE AND DATES COVERED
FINAL REPORT

4. TITLE AND SUBTITLE
Monitoring Survey at the Tupper Ledge Disposal Site September 2003

5. FUNDING NUMBERS

6. AUTHOR(S)
ENSR International, CoastalVision, Germano & Associates, and CR Environmental

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
ENSR International
2 Technology Park Drive
Westford, MA 01886

8. PERFORMING ORGANIZATION REPORT NUMBER
ENSR-9000-340-30B

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

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Contribution No. 158

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

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

12b. DISTRIBUTION CODE

13. ABSTRACT

The Tupper Ledge Disposal Site (TLDS) was monitored as part of the US Army Corps of Engineers New England District Disposal Area Monitoring System (DAMOS) on 1-3 September 2003 and 15 September 2003. The 2003 field effort included bathymetric and sediment-profile imaging (SPI) surveys designed to document changes in seafloor topography, evaluate the physical distribution of dredged material, and assess the benthic recolonization status associated with recent dredged material disposal activity. Disposal site data were compared with nearby reference area data and historical data from the TLDS baseline survey of March 2000 and first TLDS post-disposal survey of August 2001.

Prior to the August 2001 survey, approximately 50,000 m^3 of dredged material was placed at TLDS. Between the August 2001 and August 2003 surveys, an additional 47,000 m^3 of dredged material was placed at TLDS. The 2003 bathymetric survey indicated two distinct mounds at TLDS, Mound A at the center of the site, observed in the August 2001 survey, and Mound B in the southwest quadrant of the site, formed between August 2001 and August 2003. The newer mound had an approximate height of 2.3 m above the surrounding seafloor, with sediment extending approximately 400 to 600 m from the mound center. The SPI survey indicated fairly advanced benthic recolonization, with Stage III assemblages at the majority of the stations and a relatively deep mean RPD depth of 2.2 cm. Although benthic recolonization was more advanced than expected, the appearance of bacterial colonies and sediment striations indicated that the system has been subject to periods of hypoxia or anoxia, potentially associated with the high organic loadings of the dredged material placed at TLDS. Following completion of the Union River dredging operations, it is anticipated that TLDS will not be used for at least five to ten years, allowing for periodic monitoring to better understand these unique sediments.

14. SUBJECT TERMS DAMOS, Tupper Ledge Disposal Site, Dredged Material

15. NUMBER OF TEXT PAGES: 58

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

MONITORING SURVEY AT THE TUPPER LEDGE DISPOSAL SITE SEPTEMBER 2003

CONTRIBUTION #158

September 2004

Report No.
ENSR-9000-340-30B

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

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

Submitted by:
ENSR International
2 Technology Park Drive
Westford, MA 01886
(978) 589-3000

US Army Corps of Engineers®
New England District

TABLE OF CONTENTS

Page

LIST OF TABLES iii
LIST OF FIGURES iv
EXECUTIVE SUMMARY vi

1.0 INTRODUCTION 1
1.1 Overview of the DAMOS Program 1
1.2 Introduction to the Tupper Ledge Disposal Site 2
1.3 Historic Dredged Material Disposal Activity 5
1.4 Previous TLDS Monitoring Events 5
1.5 Recent Dredged Material Disposal Activity 6
1.6 Survey Objectives 6

2.0 METHODS 10
2.1 Navigation and On-Board Data Acquisition 10
2.2 Bathymetry 10
2.2.1 Bathymetric Data Acquisition 10
2.2.2 Bathymetric Data Processing 13
2.2.3 Bathymetric Data Analysis 13
2.3 Sediment-Profile Imaging 14
2.3.1 SPI Data Acquisition 14
2.3.2 SPI Data Analysis 17

3.0 RESULTS 20
3.1 Bathymetry 20
3.1.1 Existing Bathymetry 20
3.1.2 Comparison with Previous Bathymetry 20
3.2 Sediment-Profile Imaging 24
3.2.1 Tupper Ledge Disposal Site 24
3.2.2 Reference Area 39
3.2.3 Comparison with Reference Area Conditions 43
3.2.4 Comparison with Previous Surveys 44

4.0 DISCUSSION 48
4.1 Dredged Material Distribution 48
4.2 Biological Conditions and Benthic Recolonization 49
4.3 Historical Data Interpretation and Conclusions Revisited 51

5.0 CONCLUSIONS 54

6.0 REFERENCES 56

APPENDICES

A DISPOSAL BARGE LOG SUMMARY FOR TLDS – AUGUST 2001 TO SEPTEMBER 2003
B SEDIMENT-PROFILE IMAGE RESULTS FOR TLDS – SEPTEMBER 2003 SURVEY

INDEX

LIST OF TABLES

Page

Table 1-1 Summary of Disposal Activities at TLDS between December 2001 and April 2003 8

Table 2-1 Summary of Field Activities at TLDS in September 2003 11

Table 2-2 TLDS Sediment-Profile Imaging Sampling Locations 15

Table 2-3 Calculation of the SPI Organism-Sediment Index (OSI) 19

Table 3-1 Summary of SPI Results for TLDS Stations, September 2003 28

Table 3-2 Summary of SPI Results for TLDS Reference Stations, September 2003 40

Table 3-3 Comparison of Sediment Biological Conditions for TLDS and Reference Stations in 2001 and 2003 41

LIST OF FIGURES

Page

Figure 1-1 Location of the Tupper Ledge Disposal Site 3

Figure 1-2 TLDS with 2001 depth contours and Mound A indicated 4

Figure 1-3 TLDS with recent dredged material disposal locations indicated 7

Figure 2-1 Bathymetric survey lines at TLDS, September 2003 12

Figure 2-2 SPI sampling locations at TLDS, September 2003..... 16

Figure 3-1 Bathymetric contour map of TLDS, September 2003 21

Figure 3-2 Bathymetric contour map of TLDS, August 2001 22

Figure 3-3 Depth-difference contour map of TLDS 23

Figure 3-4 Sediment-profile images from Station I03 illustrate the low bearing strength and high water content typical of many stations at TLDS. 25

Figure 3-5 Different sediment types resulting from disposal operations found throughout TLDS. 26

Figure 3-6 Sediment-profile image from Station I12 showing abundant wood chips and fibers at depth, a signature characteristic of the dredged material disposed at TLDS. 27

Figure 3-7 Mean apparent RPD depths at TLDS, September 2003..... 30

Figure 3-8 Presence or absence of dredged material in the area of TLDS as detected by sediment-profile imaging in September 2003. 32

Figure 3-9 Sediment-profile image from Station I21 showing the layer of recently deposited dredged material extending beyond the depth of the prism penetration. 33

Figure 3-10 Replicate sediment-profile images from Station I08 show a layer of recently deposited dredged material indicated by wood fibers and reduced particles.. 34

Figure 3-11 Infaunal successional stages at TLDS, September 2003. 35

Page

Figure 3-12 Sediment-profile images showing evidence of Stage III deposit-feeding assemblages from Station I10 and signs of only early biological recolonization at Station I11 36

Figure 3-13 Median OSI values at TLDS, September 2003. Values < +6 generally indicate evidence of recent disturbance. 37

Figure 3-14 Presence/absence of sulfur-reducing bacterial colonies at TLDS. 38

Figure 3-15 Sediment-profile image from Station WREF8 showing alternating light/dark sediment bands, typical of periodic organic sediment deposition or seasonal anoxia. 42

Figure 3-16 Sediment-profile image from Station CREF2 showing a typical cross-sectional profile of undisturbed, ambient sediment with prominent feeding voids made by Stage III taxa. 45

Figure 3-17 Sediment-profile images from Station WREF7 and Station I01 showing similar patterns of light/dark anoxic banding. 46

Figure 4-1 Sediment-profile images showing similar lamination patterns from a seasonally anoxic basin in the Caspian Sea and from TLDS Station WREF5. 50

EXECUTIVE SUMMARY

A monitoring survey was conducted at the Tupper Ledge Disposal Site (TLDS) as part of the Disposal Area Monitoring System (DAMOS). The September 2003 field effort consisted of bathymetric and sediment-profile imaging surveys designed to document changes in seafloor topography, evaluate the physical distribution of dredged material, and assess the recovery of the benthic community relative to ambient sediment conditions.

The Tupper Ledge Disposal Site was selected for dredged material disposal following a baseline survey in March 2000. Between January and April 2001, approximately 50,000 m^3 of dredged material was placed at the center of TLDS, forming Mound A. A monitoring survey in August 2001 indicated inhibited benthic recolonization of the mound, attributed to elevated organic content and high sediment oxygen demand associated with decomposition of the wood particles in the dredged material. Between December 2001 and April 2003, approximately 47,000 m^3 of dredged material was placed in the southwest quadrant of TLDS. All dredged material placed at TLDS originated from the Union River, near Ellsworth, Maine.

The comparison of the 2001 and 2003 bathymetric data indicated the formation of a new mound, Mound B, in the southwest quadrant of TLDS. Mound B was conical in shape, rising approximately 2.3 m above the surrounding seafloor. SPI results confirmed the bathymetric results, indicating the thickest accumulation of dredged material near the point of disposal, and that sediment has spread in a thin apron 400-600 m from the point of disposal. Diagnostic features in many of the 2003 SPI images allowed for the clear distinction between ambient sediments and dredged material, resulting in identification of historic dredged material at locations where it had not previously been reported. A re-examination of the historic SPI images confirmed that the extent of the dredged material was somewhat underreported following the 2001 survey, in which dredged material was not reported at stations outside of the TLDS boundary. The 2003 survey indicated dredged material extended beyond the TLDS boundary in all directions, and extended farthest to the south and west.

Benthic recolonization was more advanced than initially expected, with Stage III assemblages present at the majority of the stations sampled, and no evidence of the azoic conditions that were observed during the 2001 survey. The mean RPD depth at stations within the dredged material footprint was 2.2 cm, considerably higher than that measured in the 2001 survey (0.6 cm), and lower than that measured in ambient sediments (3.1 cm). The high frequency of Stage III infauna observed within the dredged material footprint resulted in a median OSI of +8 (ranging from +4 to +10), compared to the median OSI at the reference stations of +9.5 (ranging from +4 to +11). Benthic recolonization had advanced significantly since the 2001 survey, when the median OSI

within TLDS was +2 (ranging from -8 to +8), when widespread azoic conditions and anoxic banding in the sediments were observed at several stations.

Although OSI values suggested a fairly advanced benthic community, there was persistent evidence in the sediment record that this area has been substantially influenced by the additional organic enrichment of the dredged material placed at this site. Evidence of sulfur-reducing bacterial colonies that develop only during hypoxic conditions was found at 17 stations, all but one located within the dredged material footprint. These bacterial colonies appear when boundary-layer dissolved oxygen concentrations fall into the hypoxic range, between 0-1 mg/L, and their presence in TLDS indicated that the system had experienced a hypoxic event. Banding of light and dark sediments, indicative of periods of anoxia or hypoxia, were observed both within and outside of the dredged material footprint, and provided further evidence of the stressed benthic system. The widespread presence of Stage III infauna indicated that the duration of the hypoxic event was sufficiently short such that the benthic ecosystem was not permanently degraded.

A re-examination of SPI images from the baseline (2000) survey indicated the presence of incipient bacterial colonies at the majority of the stations sampled. This discovery, combined with the size of the disposal site relative to the shape of the embayment and other results from the baseline survey (e.g., high total organic carbon, low flushing rates and a stratified water column), suggested a system susceptible to hypoxic events, particularly when exposed to high organic loadings.

Benthic conditions have improved since 2001, however the persistence of anoxic banding patterns and the presence of the sulfur-reducing bacterial colonies that largely coincide with the presence of dredged material indicated that the system may be vulnerable to hypoxia. TLDS was chosen for dredged material disposal following characterization of four sites along the coast of Maine. Sites were investigated to determine suitability for one-time or short-term dredged material disposal activities (SAIC 2000). TLDS was selected to accommodate small to moderate volumes of sediment to be removed from Union River over one to three years of dredging to maintain access in and out of the harbor for recreational and commercial use. Following completion of the Union River dredging operations, it is anticipated that TLDS will not be used for at least five to ten years. Periodic monitoring during this time will help to better understand the rate of recovery of these unique sediments.

1.0 INTRODUCTION

A monitoring survey was conducted at the Tupper Ledge Disposal Site in September 2003 as part of the U.S. Army Corps of Engineers (USACE) New England District (NAE) Disposal Area Monitoring System (DAMOS). DAMOS is a comprehensive monitoring and management program designed and conducted to ensure environmental protection of open-water disposal sites throughout the New England region. An introduction to the DAMOS program and the Tupper Ledge Disposal Site, including a brief description of previous dredged material disposal activities and previous monitoring surveys at this site, is provided below.

The establishment of disposal site boundaries provide a management area for placement of dredged material on the seafloor. Barge operators are given specific coordinates (and often visible lighted buoys) within these disposal boundaries to navigate to and release their cargo of dredged material. In practice, it is usually expected that placement will occur in a cluster around these target coordinates (or buoys) and that a small portion of dredged material remains in the water column following release. The Clean Water Act Section (404)(b)(1) provides guidelines for the discharge of dredged material and defines the discharge point as the point within the disposal site (including both the bottom surface area and any overlying volume of water) at which the dredged material is released. The Marine Protection, Research, and Sanctuaries Act Section 102 defines the release zone as a locus of points 100 m around the barge from beginning to end of the discharge (40 CFR Section 227.28). Monitoring objectives recognize that the site boundary is a target area for release at the water surface, and that during descent and placement some dredged material may extend across the boundary on the seafloor.

1.1 Overview of the DAMOS Program

For over 25 years, the USACE NAE has collected and evaluated disposal site data throughout New England. Patterns of physical, chemical, and biological responses of seafloor environments to dredged material disposal activity have been documented based on these data. The DAMOS Program features a tiered management protocol designed to ensure that any potential adverse environmental impacts associated with dredged material disposal activities are promptly identified and addressed (Germano et al. 1994). Monitoring surveys are designed to collect data that will allow evaluation of the environmental status of each disposal site relative both to conditions at the site after recent disposal of dredged material and to conditions observed in nearby reference areas unaffected by disposal activities. The results of each monitoring survey are evaluated to determine the next step in the process of managing each specific disposal site.

DAMOS monitoring surveys are designed to test hypotheses related to expected physical and ecological response patterns following placement of dredged material on the seafloor. Typical DAMOS surveys include bathymetric measurements and sediment-profile imaging (SPI). Sequential bathymetric measurements are made to determine the location and accumulation or loss of dredged material placed at a given site. SPI surveys are performed to support evaluation of benthic habitat conditions. DAMOS monitoring surveys may also feature additional types of data collection activities, such as side-scan sonar or sediment coring, as deemed appropriate to achieve specific survey objectives. The longevity of the DAMOS Program and the periodic nature of the monitoring have resulted in a long-term record for many of the disposal sites.

1.2 Introduction to the Tupper Ledge Disposal Site

The Tupper Ledge Disposal Site (TLDS) is an infrequently used dredged material disposal site located in the waters of eastern Maine (Figure 1-1). TLDS is situated in Union River Bay approximately 5 km south of Ellsworth, Maine, and is within 20 km of Maine's scenic Acadia National Park. Union River Bay drains the Union River and is connected to Blue Hill Bay and the Gulf of Maine to the south. Within Union River Bay, TLDS is situated relatively close to the surrounding coast; to the west, north, and east, the site is roughly 1500 m from the shoreline. TLDS is defined as a 500 x 500 m area on the seafloor centered at 44° 28.256' N, 68° 26.664' W (NAD 83).

TLDS is characterized by a gently sloping seafloor. Water depths along the northern edge of the study area are approximately 14.5 m Mean Lower Low Water (MLLW), sloping down to depths of 16 m MLLW along the southern boundary of the study area (Figure 1-2). A small depression with a maximum depth approximately 4 to 5 m deeper than surrounding waters was detected in the northeast corner of the study area (SAIC 2002). The depression is located adjacent to the rock outcrop known as Tupper Ledge, and was likely formed by water flow around the outcrop (SAIC 2002). Within the disposal site, water depths range from 14.25 m MLLW in the north to 15.5 m MLLW in the south. A disposal mound (designated as Mound A in this report, see Figure 1-2) was identified at the center of the site, extending 2–3 m above the surrounding seafloor (SAIC 2002).

TLDS was chosen for dredged material disposal following characterization of four sites along the coast of Maine. Sites were investigated to determine suitability for one-time or short-term dredged material disposal activities (SAIC 2000). TLDS was selected to accommodate small to moderate volumes of sediment to be removed from Union River over one to three years of dredging to maintain access in and out of the harbor for

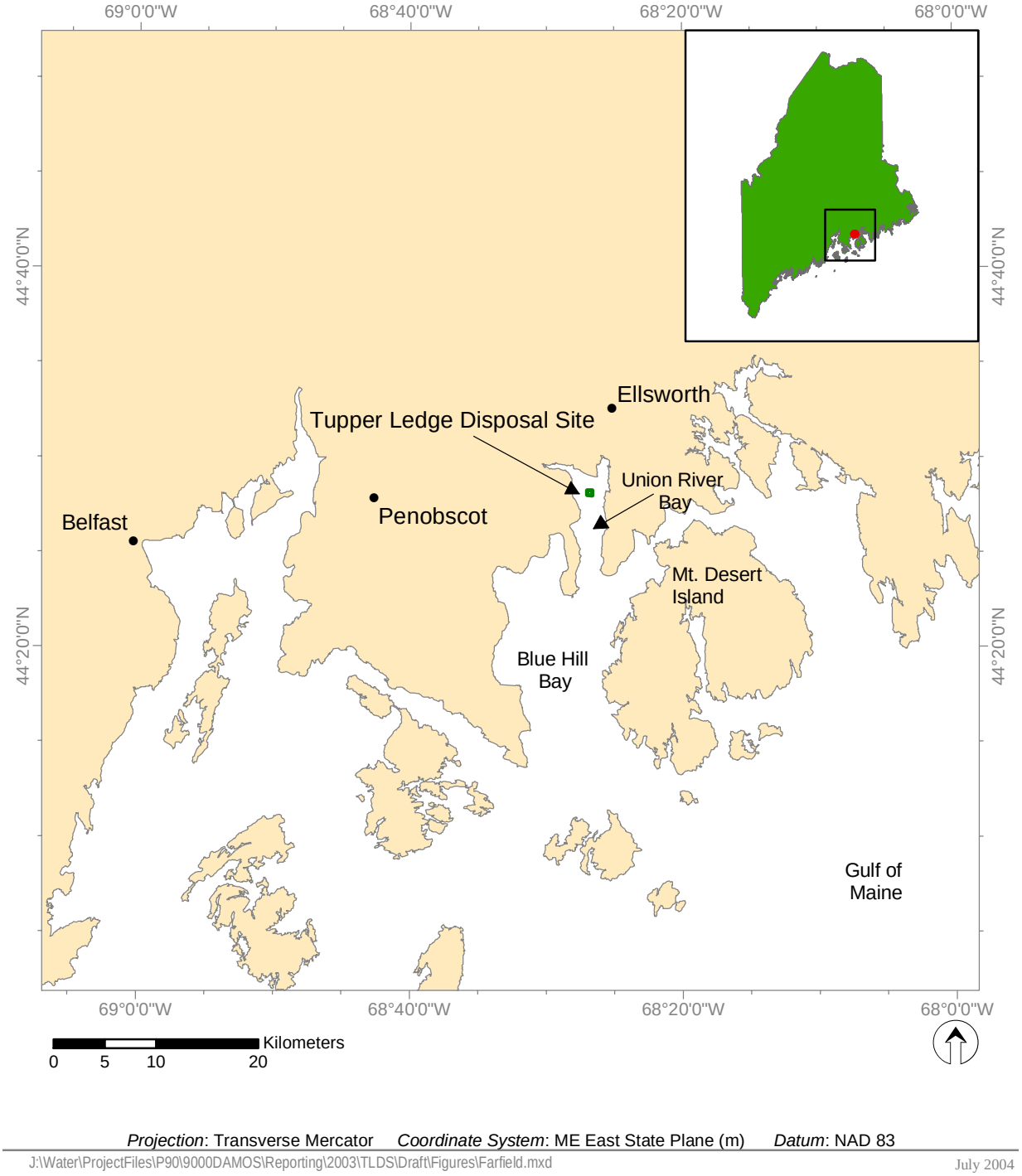
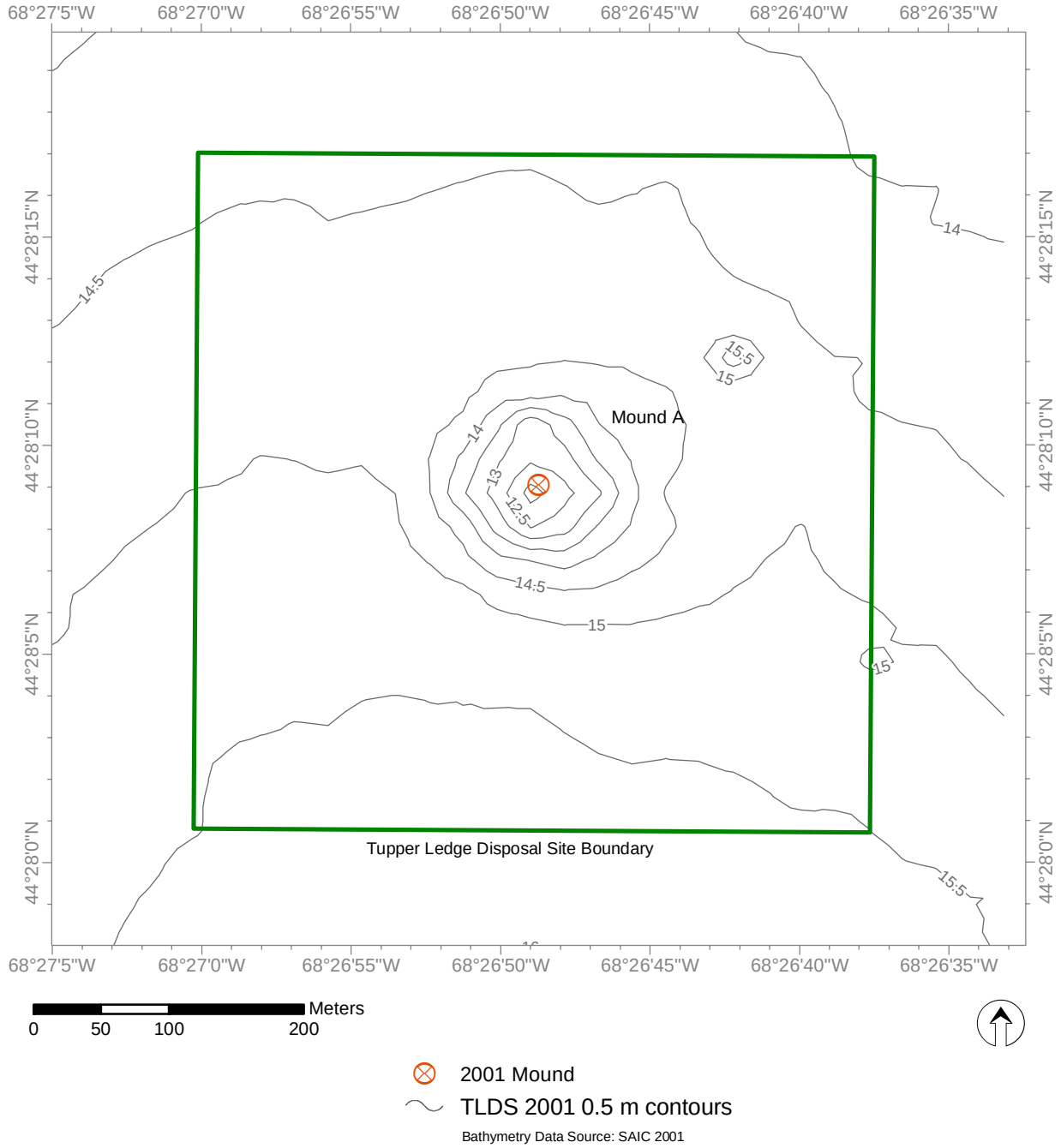


Figure 1-1 Location of the Tupper Ledge Disposal Site



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

J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2003\TLDS\Draft\Figures\Mounds.mxd July 2004

Figure 1-2 TLDS with 2001 depth contours and Mound A indicated

recreational and commercial use. Following completion of the Union River dredging operations, it is anticipated that TLDS will not be used for at least five to ten years.

1.3 Historic Dredged Material Disposal Activity

Historic dredged material disposal activity began in the late 1800s, when material removed from the Union River Federal Channel was placed at the location of the current TLDS. Historic disposal last occurred in 1911 (USACE 2000). TLDS was selected as a disposal site for recent projects in 2000. From January to April 2001, approximately 50,000 m^3 of dredged material from the Union River Federal Navigation Channel was placed at TLDS, forming Mound A (SAIC 2002).

1.4 Previous TLDS Monitoring Events

A baseline survey of the TLDS area was conducted in March 2000 to determine suitability for potential site selection (SAIC 2000). The survey included bathymetry, sediment-profile imagery, sediment grab samples, and physical oceanographic measurements. Sediment-profile images were collected at nine stations and grab samples for analysis of PAHs, PCBs, pesticides, trace metals, total organic carbon, moisture content, and grain size were collected at three of these locations. Physical oceanographic measurements included the deployment of an acoustic current meter at the center of the site to measure near-bottom velocities and several deployments of mid-water and surface-water drifters to characterize water column and surface currents. Current measurements were recorded during a spring tidal cycle when near-maximum values were expected.

The 2000 survey confirmed the depositional nature of the area and recommended suitability of the site for disposal (SAIC 2000). Sediments had a high silt/clay content and high TOC, characteristic of a depositional environment with high loading of organic debris. Sediment chemistry revealed background concentrations typical of coastal Maine, with no contraindications to the establishment of a disposal site. SPI results were consistent with sediment chemistry and geotechnical results, showing organic-rich, fine-grained sediments at the site. The benthic community showed indications of a moderately disturbed to undisturbed environment.

Physical oceanographic measurements showed low current velocities and an apparent stratification in the water column. Near-bottom velocities averaged approximately 6 $cm \cdot s^{-1}$ during the flood tide and 3 $cm \cdot s^{-1}$ during the ebb tide, with maximum velocities of 10 $cm \cdot s^{-1}$ and 6 $cm \cdot s^{-1}$ during the flood and ebb tide, respectively. Drifter deployments indicated a two-layer flow resulting from distinct water masses: the

colder, saline waters of the Gulf of Maine flow under the freshwater discharge from Patten Bay and Union River, resulting in a stratified water column (SAIC 2000).

A second survey was conducted in August 2001 following initial disposal at TLDS. Survey activities included bathymetry and sediment-profile imagery to detect changes in seafloor topography, delineate the spatial distribution of dredged material, and assess the benthic recolonization status following disposal activity. The 2001 survey results indicated that benthic recolonization over the new disposal mound was apparently inhibited, with azoic conditions (i.e., absence of visible macrofaunal life) found at many stations in lieu of the expected early colonizing community (i.e., Stage I). The slower-than-expected benthic recovery was attributed to the elevated organic content and high sediment oxygen demand (SOD) associated with decomposition of wood particles in the dredged material (SAIC 2002).

1.5 Recent Dredged Material Disposal Activity

Recent disposal activity (between December 2001 and April 2003) placed approximately 47,000 m^3 of dredged material (based on scow estimates) in the southwest quadrant of TLDS, at the location of Mound B (Figure 1-3, Table 1-1). This sediment was dredged from the Union River, Ellsworth, Maine.

1.6 Survey Objectives

The September 2003 survey at TLDS was designed to document changes in seafloor topography, to assess benthic recolonization status in response to recent dredged material disposal activity, and to monitor continued recovery of older dredged material disposal areas relative to nearby reference areas and previous survey results.

The design of the September 2003 survey allowed assessment of the following expectations:

- The 47,000 m^3 of sediment placed in the southwest quadrant of TLDS since the August 2001 survey will have resulted in a discrete disposal mound.

- Benthic recolonization will appear slow, based on the disposal of comparable amounts of material similar to that placed earlier (i.e., elevated organic content, high SOD from decomposing wood chips). Benthic habitat recovery will exhibit the following:

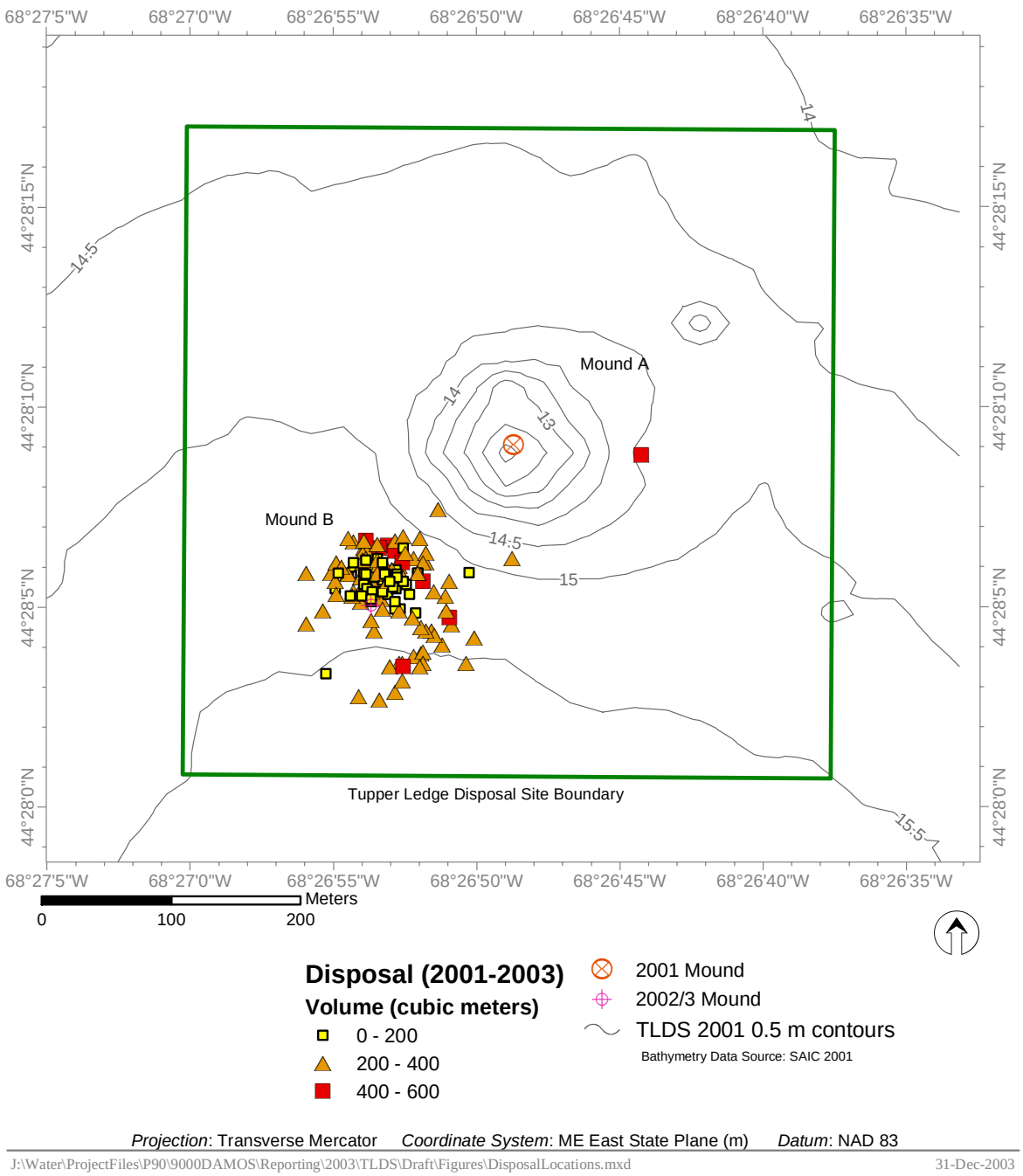


Figure 1-3 TLDS with recent dredged material disposal locations indicated

Table 1-1

Summary of Disposal Activities at TLDS between December 2001 and April 2003

Source Project	Estimated Scow Volume Disposed (m^3)
Union River – City of Ellsworth	15,062
Union River – COE Federal Navigation Project	32,345
Total	47,407

- Stage I or Stage II assemblages will be present at all stations; however, given the initial degraded conditions at the site in August 2001 and the high SOD of the dredged material, Stage III assemblages will not be as common or abundant within the disposal site as at the reference stations.

- Azoic conditions will not be observed at the site because the length of time over which the (approximately) same volume was placed was four times greater than the time frame over which it was placed in 2001: 51,000 m^3 over 4 months prior to the 2001 survey versus 47,000 m^3 over 16 months prior to the 2003 survey. Both surveys took place four months after the last disposal of dredged material at the site.

2.0 METHODS

The September 2003 survey at TLDS was performed by ENSR International, CR Environmental, and Germano & Associates. The survey was performed on 1–3 and 15–16 September 2003 and included bathymetry and sediment-profile imaging (SPI). Field activities are summarized in Table 2-1, and an overview of the methods used to collect survey data as well as methods used to process and analyze the data is provided below. A detailed description of methodology and related terminology can be found in ENSR (2004).

2.1 Navigation and On-Board Data Acquisition

Positional data, comprised of horizontal positioning (x- and y-dimensional data) and time (t-dimensional data), were collected using a Trimble AG 132 Differential Global Positioning System (DGPS). This system received and processed satellite and land-based beacon data and provided real-time vessel position, typically to sub-meter accuracy. Coastal Oceanographics, Inc.'s HYPACK® hydrographic survey software was used to acquire, integrate, and store all positional data from the DGPS as well as bathymetric and station data. The HYPACK® software also displayed real-time vessel position, bathymetric data, and SPI stations over an electronic chart of the study area, thus enabling survey scientists to review and evaluate survey data on a real-time basis.

2.2 Bathymetry

Bathymetry 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.

2.2.1 Bathymetric Data Acquisition

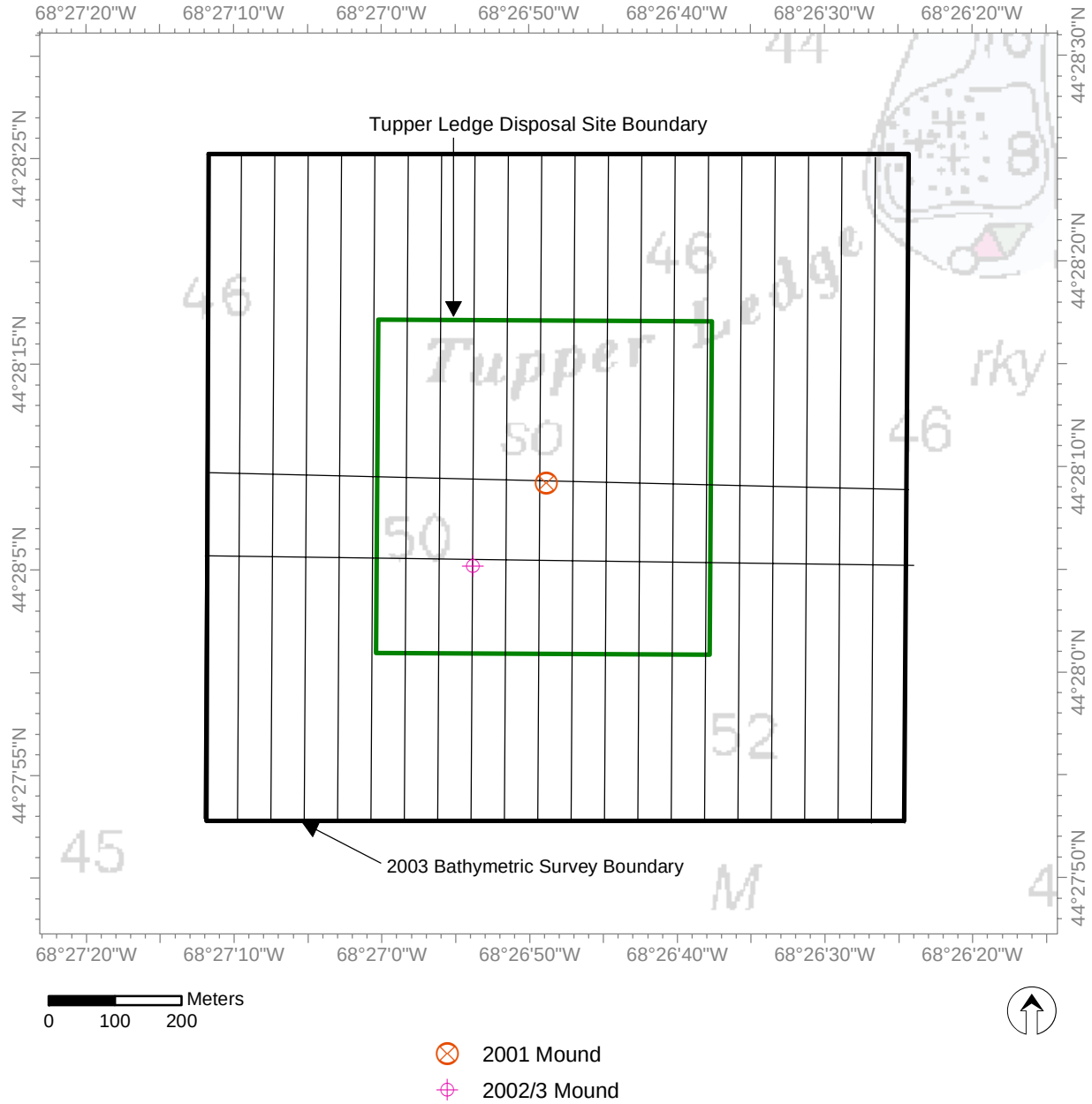
The 2003 bathymetric survey was conducted over a 1000 x 1000 m area, duplicating the 2001 study area (Figure 2-1). The survey was conducted on 15 September 2003 aboard the *R/V Cyprinodon*. A total of 22 survey lines, each 50 m apart, were occupied (Figure 2-1). In addition, two perpendicular cross-tie lines were occupied to assess data quality.

The bathymetric survey was conducted using an Ocean Data Equipment Corporation (ODEC) MF500 precision echo sounder outfitted with a narrow (3°) beam,

Table 2-1

Summary of Field Activities at TLDS in September 2003

Survey Type	Date	Summary
Bathymetric	15 September 2003	Area: 1000 x 1000 m Lines: 22 Spacing: 50 m
Sediment-Profile Imaging	1–3 September 2003	Stations: 50 25 inner 11 outer 14 reference



Individual survey lines with 50 meter spacing
Horizontal crossing lines provided quality assurance

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

J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2003\TLDS\Draft\Figures\BathyLines.mxd 31-Dec-2003

Figure 2-1 Bathymetric survey lines at TLDS, September 2003

200-kHz transducer. The accuracy of this system was approximately 0.1% of the water depth, or approximately 1.5 cm in the waters of TLDS. The system was calibrated at the dock prior to the survey. In addition, local measurements of temperature and salinity were taken *in situ* using a Seabird Instruments, Inc. SEACAT-19 CTD. Local tidal water level data were recorded at a project benchmark established by a ME-Registered Land Surveyor on Newbury Neck on the western shore of Union River Bay using a pressure transducer (InSitu, Inc. Mini-Troll®). These ancillary measurements were used to process the bathymetric data.

2.2.2 Bathymetric Data Processing

The bathymetric data were processed using the HYPACK® software program and included corrections for tidal conditions, local speed of sound, acquisition system latency, and spurious data points. Tidal correction consisted of transforming the raw measurements of depth below the transducer to seafloor elevation measurements relative to Mean Lower Low Water (MLLW) using the locally collected tidal elevation data. The speed of sound during performance of the survey was calculated from local temperature and salinity measurements and used to correct the bathymetric data. Corrections were applied for acquisition system latency to account for positional errors related to small time delays between the actual DGPS and echo sounder measurements and the digital recording. The bathymetric data were also reviewed for spurious data points (clearly unrealistic measurements resulting from signal interference), and these points were removed.

2.2.3 Bathymetric Data Analysis

Bathymetric data were analyzed to gain a better understanding of the existing conditions at the site and for comparison with previous surveys to document changes in seafloor topography. For this survey, the corrected bathymetric data were analyzed using a combination of the contouring and surface plotting software program, Surfer® 8.0 and the GIS-based software package ArcView® 8.3. Using Surfer®, the processed TLDS 2003 data were gridded to a cell size of 25 m^2, consistent with the bathymetric grid created for the previous (August 2001) survey (SAIC 2002). Once gridded, bathymetric contour lines were displayed using ArcView®.

Surfer® was also used to calculate a depth difference grid based on the August 2001 and the September 2003 bathymetric data sets. This grid was calculated by subtracting interpolated depth estimates of September 2003 from the August 2001 depth estimates at each point throughout the grid. The resulting depth differences were contoured and displayed using ArcView®.

2.3 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 an underwater frame/camera system that can photograph a cross section of the sediment-water interface. Computer-aided analysis of the resulting images provides a set of standard measurements that can be compared between different locations and different surveys. The DAMOS Program has successfully used this technique for over 20 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites.

2.3.1 SPI Data Acquisition

Fifty stations were occupied in the 2003 TLDS SPI survey (Table 2-2, Figure 2-2). A square grid of 25 stations (denoted as inner stations in Table 2-2) within the 500 × 500 m disposal site boundary, plus an additional eight stations (denoted as outer stations in Table 2-2) located outside the site boundary, were sampled. These 33 stations were sampled previously in August 2001 (SAIC 2002). Note that stations initially designated as reference stations were reclassified as outer stations following detection of dredged material in the SPI analysis (See discussion in Section 3.2.2).

Seventeen additional stations to the east, west, and south of the disposal site were sampled to provide a basis of comparison between sediment conditions at TLDS and ambient sediment conditions in Union River Bay (Figure 2-2). In the 2001 survey, two reference areas (WREF and EREF) were established approximately 1 km south of the TLDS study area and, within each reference area, four sampling locations were randomly selected and occupied. In the 2003 survey, these eight randomly selected stations were occupied within these two reference areas, and nine additional reference stations were occupied to clarify ambiguities from the 2001 survey about the extent of dredged material outside the site boundaries as well as to support evaluation of reference conditions in the area. These 17 stations were designated as reference (nine stations) or outer disposal site (eight stations) based on the 2003 survey results, and grouped accordingly in this report.

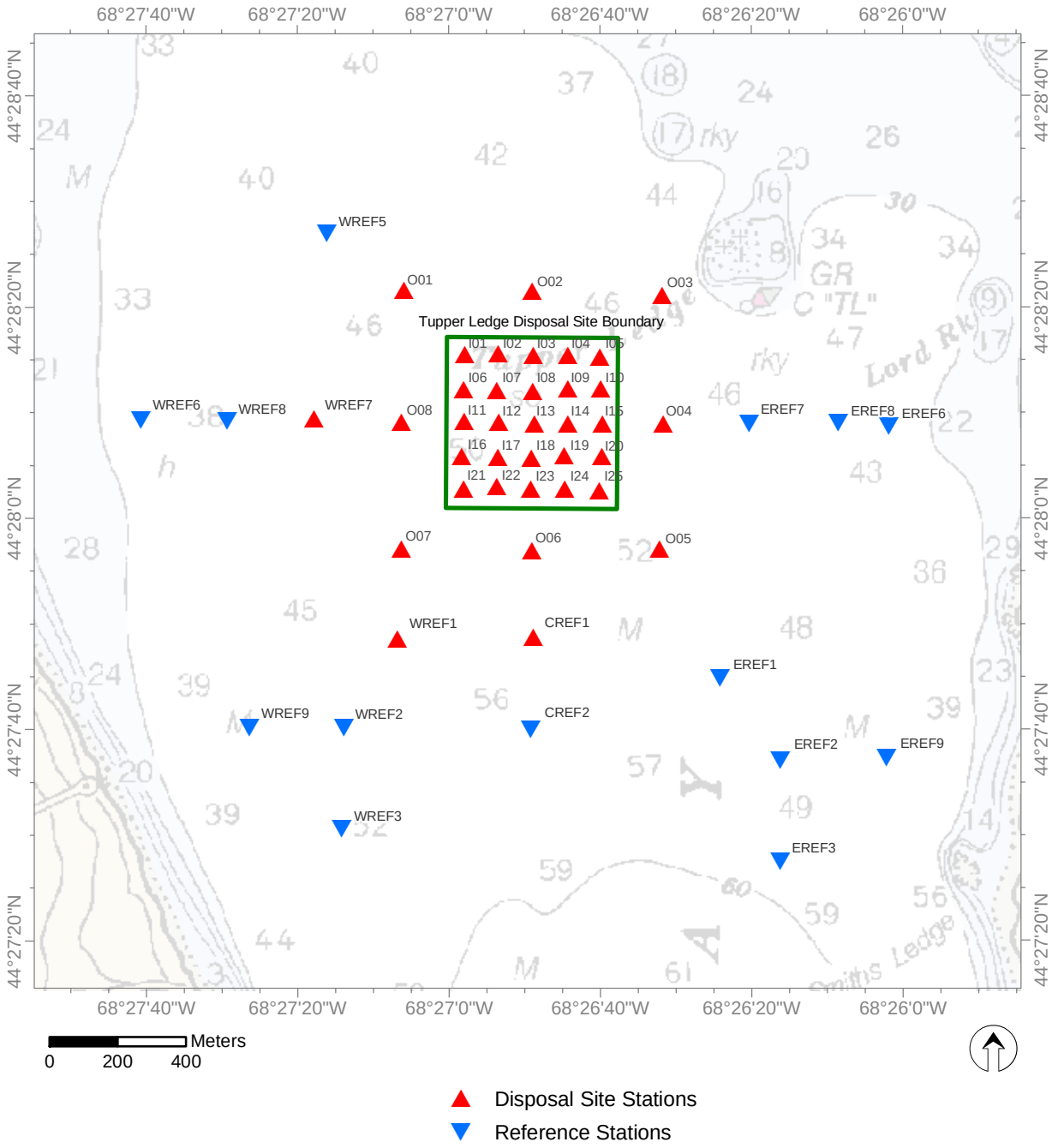
The SPI survey was performed on 1–3 September 2003 aboard the *F/V Susan & Caitlin*. At each station, the vessel was positioned at the target coordinates and the three replicates were collected within a defined station tolerance of 10 m. Three replicate sediment-profile images were collected at each of the 50 stations for characterization of small-scale variability.

Table 2-2

TLDS Sediment-Profile Imaging Sampling Locations

Area	Station	Latitude (N)	Longitude (W)	Area	Station	Latitude (N)	Longitude (W)
Inner	I01	44° 28.257'	68° 26.967'	Outer	O01	44° 28.356'	68° 27.101'
	I02	44° 28.257'	68° 26.891'		O02	44° 28.354'	68° 26.815'
	I03	44° 28.256'	68° 26.816'		O03	44° 28.353'	68° 26.529'
	I04	44° 28.256'	68° 26.740'		O04	44° 28.149'	68° 26.531'
	I05	44° 28.256'	68° 26.665'		O05	44° 27.949'	68° 26.533'
	I06	44° 28.203'	68° 26.967'		O06	44° 27.950'	68° 26.819'
	I07	44° 28.203'	68° 26.892'		O07	44° 27.952'	68° 27.105'
	I08	44° 28.202'	68° 26.816'		O08	44° 28.151'	68° 27.103'
	I09	44° 28.202'	68° 26.741'		CREF1	44° 27.812'	68° 26.816'
	I10	44° 28.202'	68° 26.665'		WREF1	44° 27.809'	68° 27.115'
	I11	44° 28.151'	68° 26.968'		WREF7	44° 28.156'	68° 27.300'
	I12	44° 28.150'	68° 26.892'	Reference	CREF2	44° 27.670'	68° 26.816'
	I13	44° 28.150'	68° 26.817'		EREF1	44° 27.747'	68° 26.401'
	I14	44° 28.150'	68° 26.741'		EREF2	44° 27.620'	68° 26.267'
	I15	44° 28.149'	68° 26.666'		EREF3	44° 27.456'	68° 26.272'
	I16	44° 28.097'	68° 26.968'		EREF6	44° 28.141'	68° 26.028'
	I17	44° 28.096'	68° 26.893'		EREF7	44° 28.149'	68° 26.340'
	I18	44° 28.096'	68° 26.817'		EREF8	44° 28.146'	68° 26.140'
	I19	44° 28.096'	68° 26.742'		EREF9	44° 27.622'	68° 26.036'
	I20	44° 28.095'	68° 26.666'		WREF2	44° 27.668'	68° 27.234'
	I21	44° 28.048'	68° 26.969'		WREF3	44° 27.511'	68° 27.236'
	I22	44° 28.048'	68° 26.893'		WREF5	44° 28.445'	68° 27.270'
	I23	44° 28.047'	68° 26.818'		WREF6	44° 28.156'	68° 27.679'
	I24	44° 28.047'	68° 26.742'		WREF8	44° 28.155'	68° 27.488'
	I25	44° 28.047'	68° 26.667'		WREF9	44° 27.670'	68° 27.440'

Note: All coordinates NAD83



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

J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2003\TLDS\Draft\Figures\SPILocations.mxd 31-Dec-2003

Figure 2-2 SPI sampling locations at TLDS, September 2003. Note that several stations initially designated as reference were reclassified as outer stations following SPI analysis.

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

2.3.2 SPI Data Analysis

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

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

Penetration Depth—The depth to which the camera penetrates into the seafloor was measured to provide an indication of the sediment density or bearing capacity.

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. Computer image-analysis software was used to calculate the roughness measure. Analysis also included interpretation of the source (biological or physical) of the roughness.

Apparent Redox Potential Discontinuity (RPD) Depth—RPD provides a measure of the oxygen conditions within sediment pore waters. The RPD 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 what types of species or organism-related activities were apparent in the images.

Organism-Sediment Index (OSI)—OSI is a summary parameter incorporating the apparent mean RPD depth, successional stage, and presence of methane or low oxygen. This index is a convenient summary statistic to map disturbance gradients in benthic habitats (Revelas et al. 1987; Table 2-3).

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

Table 2-3

Calculation of the SPI Organism-Sediment Index (OSI)

Parameter	Index Value
A. Mean RPD Depth (choose one)	
0.00 cm	0
0.01 – 0.75 cm	1
0.76 – 1.50 cm	2
1.51 – 2.25 cm	3
2.26 – 3.00 cm	4
3.01 – 3.75 cm	5
> 3.75 cm	6
B. Successional Stage (choose one)	
Azoic	-4
Stage I	1
Stage I – II	2
Stage II	3
Stage II – III	4
Stage III	5
Stage I on III	5
Stage II on III	5
C. Chemical Parameters (choose all that apply)	
Methane Present	-2
No/Low Dissolved Oxygen	-4

Calculation of Organism-Sediment Index (OSI)
OSI = Total of above indices (A+B+C)
Range of possible OSI values is -10 to +11

3.0 RESULTS

3.1 Bathymetry

3.1.1 Existing Bathymetry

The September 2003 bathymetric survey results for TLDS were consistent with earlier surveys, showing a seafloor sloping towards the south and with water depths ranging from 14.5 m MLLW in the north to 16 m MLLW in the south (Figure 3-1). Two disposal mounds were evident: one (designated Mound A in this report), in the center of the site, was previously observed in the 2001 survey, and a second mound (designated Mound B) was located to the southwest of the original mound.

Both of the disposal mounds were roughly conical in shape. The diameter of Mound A was approximately 150 m, with an average side slope of 3%, suggesting that the mound was stable in configuration. The minimum water depth at the apex of Mound A was approximately 12.9 m MLLW, and the mound rose approximately 1.6 m above the surrounding seafloor. The diameter of Mound B was approximately 120 m, with an average side slope of 5%. The apex of Mound B was at approximately 13 m MLLW, and rose approximately 2.3 m above the surrounding seafloor.

3.1.2 Comparison with Previous Bathymetry

The bathymetric contour map developed from the 2003 survey data (Figure 3-1) revealed bathymetric features similar to those found in 2001 (Figure 3-2 and SAIC 2002), with the exception of the new disposal mound. The depth difference map between the 2001 and 2003 bathymetric data revealed two features at the location of the two disposal mounds in the center of TLDS (Figure 3-3). At Mound A, the older mound, water depths appeared greater in the recent survey, indicating consolidation of the central portion of the mound. Up to 0.5 m of consolidation appears to have occurred over this mound (not unusual in high water content muds during loading from disposal). The formation of Mound B, the new mound, is evident in the depth difference map, with an increase in seafloor elevation up to 2.3 m between the two surveys.

Other features that appear in the depth difference map (and potentially some of the apparent consolidation over Mound A) were probably small-scale survey artifacts, rather than actual bathymetric differences between the two surveys. These apparent differences might be attributed to small differences in track lines between surveys as well as differences in bathymetric data processing methodology (e.g., the application of tidal correction data and/or data interpolation methodology).

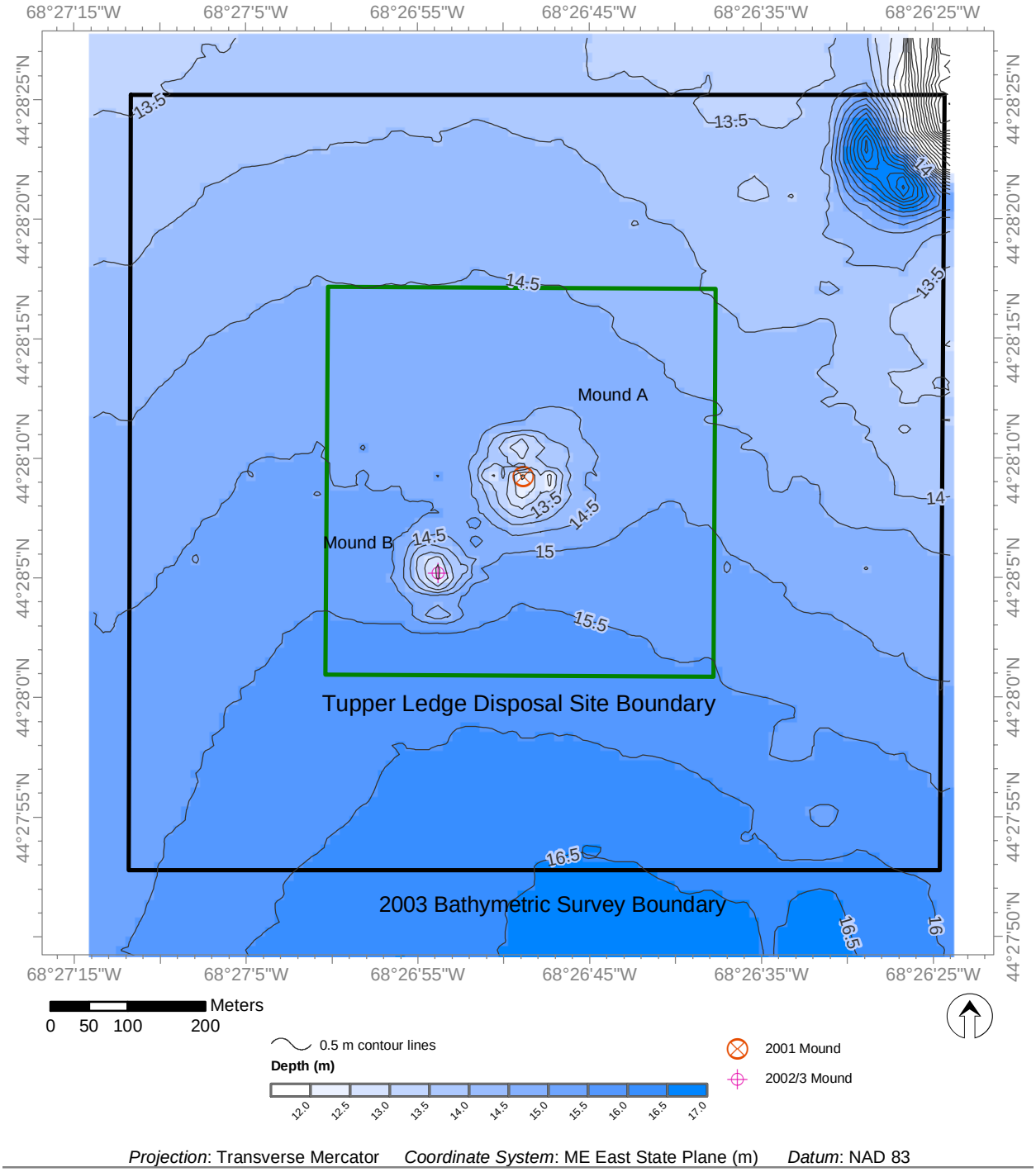


Figure 3-1 Bathymetric contour map of TLDS, September 2003

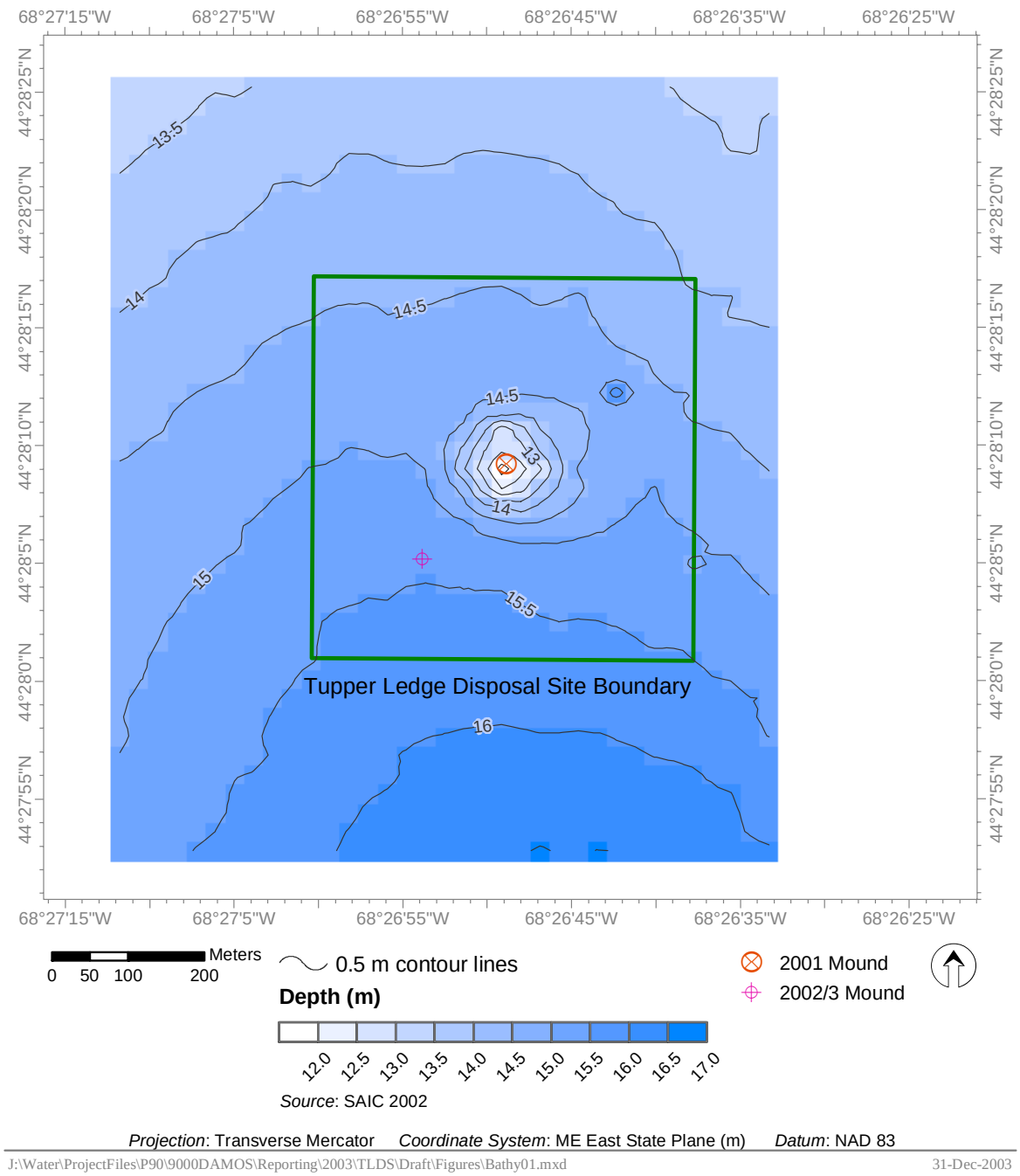


Figure 3-2 Bathymetric contour map of TLDS, August 2001

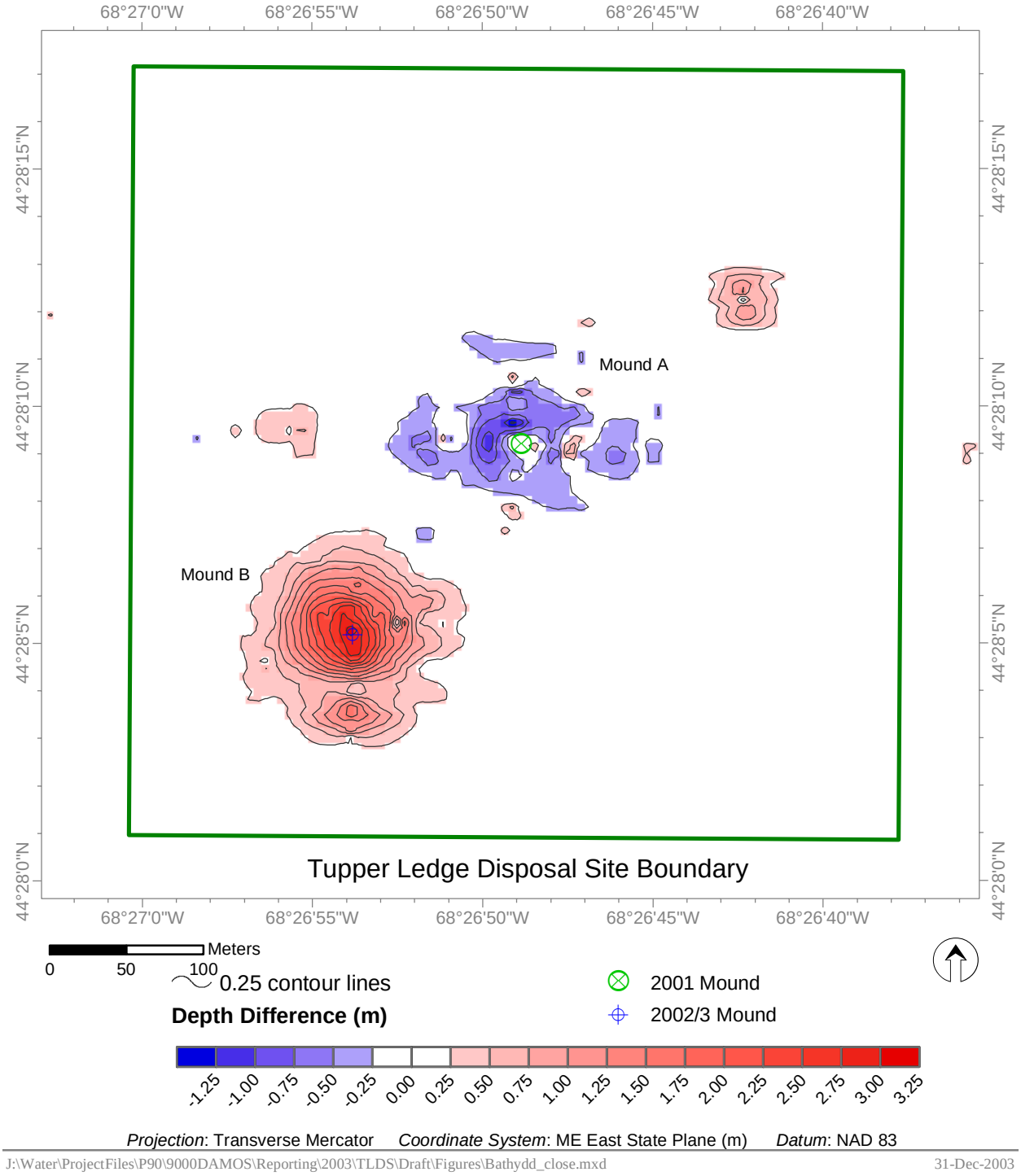


Figure 3-3 Depth-difference contour map of TLDS: August 2001 vs. September 2003

3.2 Sediment-Profile Imaging

The SPI survey results were used to delineate the spatial extent of the disposed dredged material that could not be detected by the bathymetric survey, as well as to monitor the recovery and status of the infaunal community. The full analytical results are presented in Appendix B.

3.2.1 Tupper Ledge Disposal Site

Sediment Physical Characteristics

The sediments at all except two stations within the disposal site boundary were fine-grained, low-shear-strength, silt/clay muds with a major mode of >4 phi (Appendix B). The primary distinguishing features of these sediments was high water content and low bearing strength. The sediment-profile camera prism over-penetrated the seafloor at many of the locations on the initial sampling round, making it necessary to fit the camera with mud doors and place the stop collars at a minimal setting in order to get useful images (Figure 3-4). Relatively hard bottom was encountered at two stations within the disposal site, I13 and I17: Station I13 had a hard cohesive clay on the sediment surface, while Station I17, at the center of the new dredged material mound, had cobble and rocks (Figure 3-5).

The total range of sediment grain size at stations within the disposal site varied between a minimum of >4 phi (coarse silt and finer) and a maximum of 0 phi (medium sand); however, many of the larger sized particles found at the majority of the stations were not sand particles, but wood chips and fibers (Figure 3-6). The presence of wood chips in the disposed material was noted in the last survey performed at the site (SAIC 2002) and was expected based on the pre-dredging sediment characterization (USACE 2000).

Small-scale boundary roughness varied from 0.2 to 5.2 cm, and was evenly split between topography caused by biological processes and that caused by physical disturbances (Appendix B). The depth of the apparent RPD at stations within the disposal site ranged from a little over 1 cm to almost 4 cm, with an overall site average of 2.22 cm (Appendix B; Table 3-1; Figure 3-7); the largest apparent RPD values within the disposal site were found at Stations I11, I12, and I16, just northwest of the recently formed Mound B.

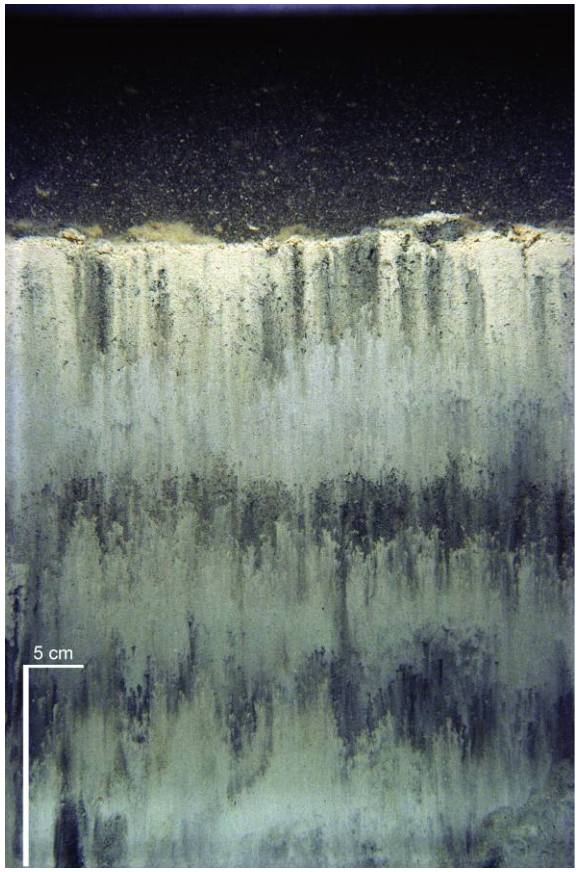
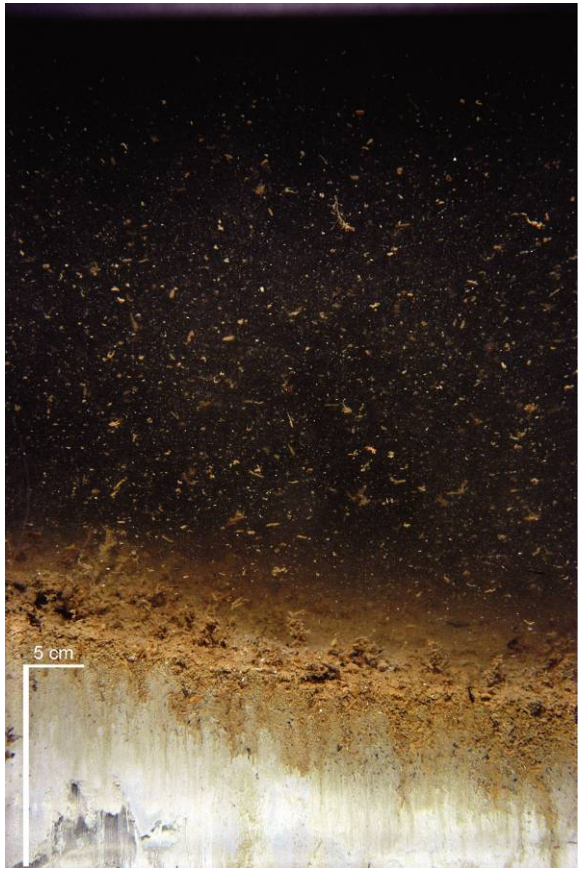


Figure 3-4 Sediment-profile images from Station I03 illustrate the low bearing strength and high water content typical of many stations at TLDS. The image on the left shows over-penetration of the camera prism when the instrument was initially deployed; the image on the right was taken the next day using mud doors to increase the camera's bearing surface. Both images show multiple depositional intervals from recent disposal activities.



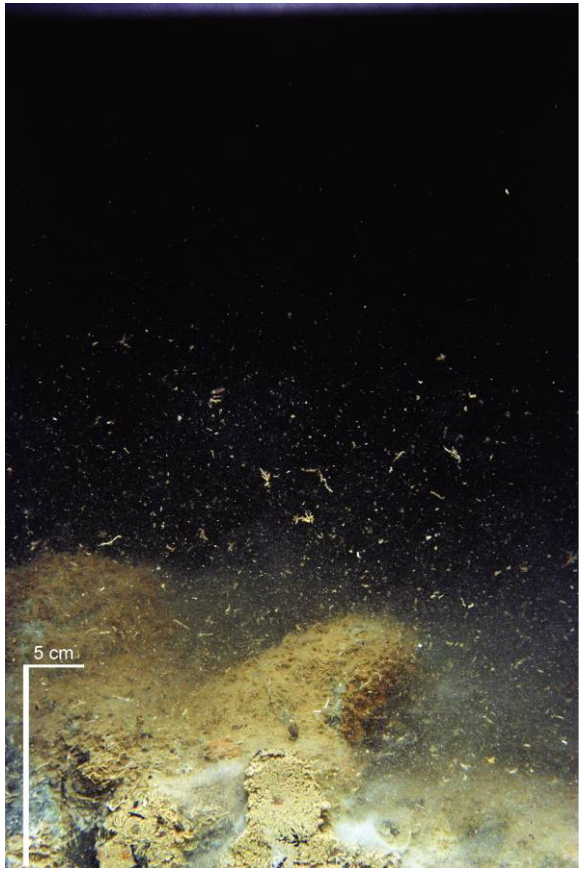


Figure 3-5 Different sediment types resulting from disposal operations were found throughout TLDS. Consolidated clays at I13 (left) and rocks at I17 (right) were seen at the sediment surface.

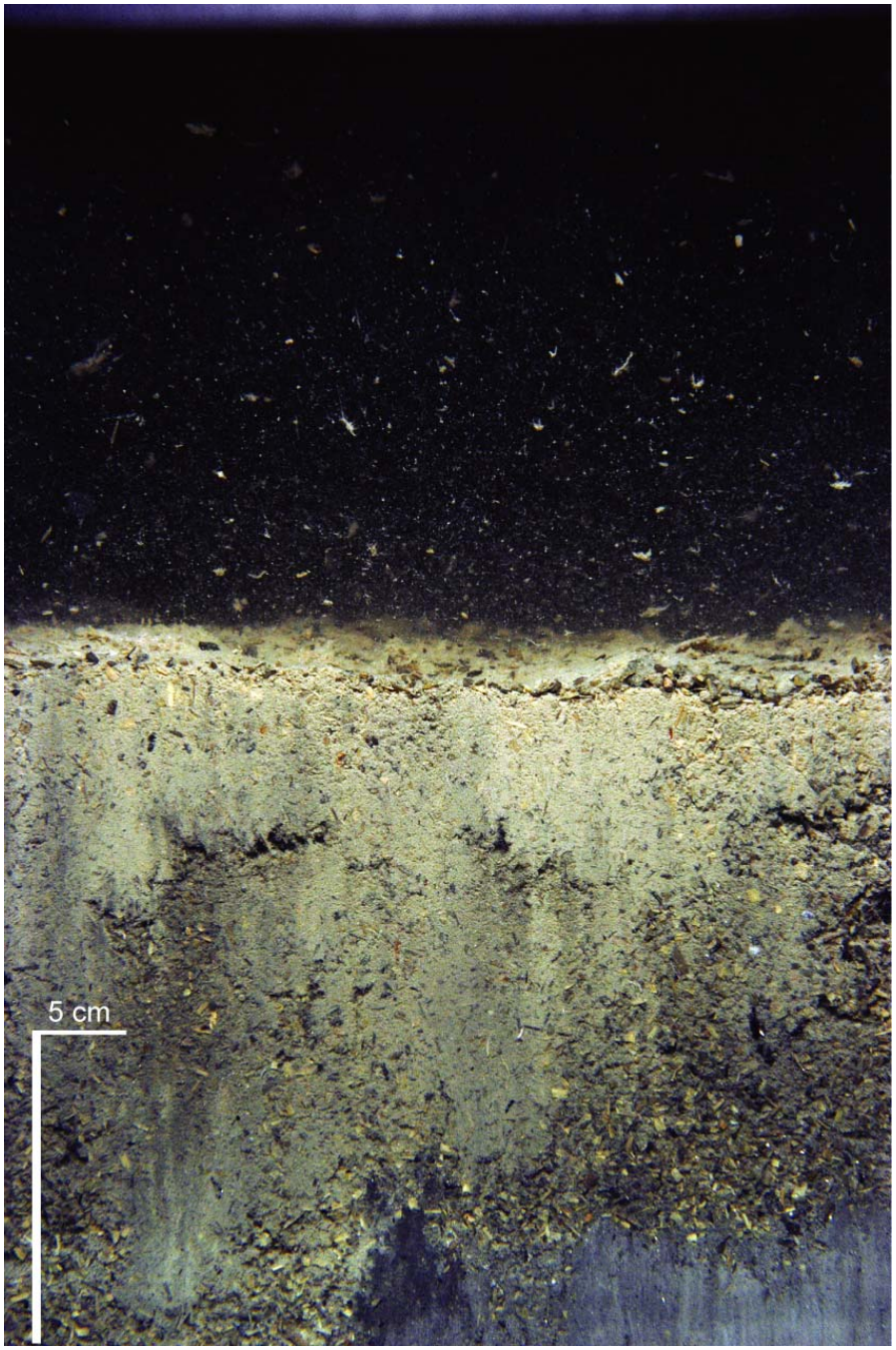


Figure 3-6 Sediment-profile image from Station I12 showing abundant wood chips and fibers at depth, a signature characteristic of the dredged material disposed at TLDS. The variation in particle size range noted in Appendix B is largely due to the presence of wood material in the dredged sediments.

Table 3-1

Summary of SPI Results for TLDS Stations, September 2003

Area	Station	Mean Prism Penetration Depth (cm)	Grain Size Major Mode (phi)	Mean RPD Depth (cm)	Successional Stages present (no. of replicates)	Median OSI	Mean Total DM Thickness (cm)	Mean Recent DM Thickness (cm)	Bacteria Present?
Inner	I 01	15.69	>4	1.27	I (1), III (1), I on III (1)	7	10.11	4.42	No
	I 02	20.49	>4	2.71	I (1), III (1), I on III (1)	9	9.22	7.63	Yes
	I 03	15.54	>4	1.20	I (1), I on III (2)	7	11.30	4.85	Yes
	I 04	17.54	>4	2.41	I on III (1), III (2)	9	10.41	4.85	No
	I 05	19.98	>4	1.13	II (1), III (1), I on III (1)	7	7.67	0.63	No
	I 06	15.40	>4	2.01	I on III (3)	9	>15.4	7.66	Yes
	I 07	11.85	>4	2.38	I (1), I on III (2)	7	>11.85	9.23	No
	I 08	15.35	>4	1.65	I on III (3)	8	>15.35	>15.35	Yes
	I 09	19.31	>4	2.73	I on III (3)	9	14.20	12.53	No
	I 10	16.28	>4	1.28	I (1), I on III (2)	7	>14.28	8.83	No
	I 11	9.73	>4	3.29	I (1), 1-II (2)	6	>9.73	>9.73	Yes
	I 12	11.44	>4	3.90	I (1), II (1), II-III (1)	8	>11.44	>11.44	Yes
	I 13	1.70	>4	1.87	I on III (1), Ind. (2)	8	>5.10	0.00	No
	I 14	16.60	>4	1.69	I on III (3)	8	>16.60	13.42	Yes
	I 15	19.50	>4	2.02	I on III (3)	8	5.67	2.47	No
	I 16	7.14	>4	3.42	I (1), I on III (2)	10	>7.14	>7.14	Yes
	I 17	1.42	4-3	2.77	I on III (1), Ind. (2)	9	>4.27	0.00	No
	I 18	19.71	>4	2.53	I on III (2), III (1)	9	>14.93	8.57	Yes
	I 19	20.35	>4	2.42	I on III (1), III (2)	9	18.00	5.95	Yes
	I 20	18.71	>4	2.76	I on III (3)	10	8.29	4.96	No
	I 21	18.36	>4	2.33	I on III (2), III (1)	9	>18.36	>16.34	No
	I 22	12.71	>4	1.86	II (1), I on III (2)	8	>12.71	>12.71	Yes
	I 23	20.67	>4	2.35	I on III (1), III (1), Ind. (1)	9	13.79	4.46	Yes

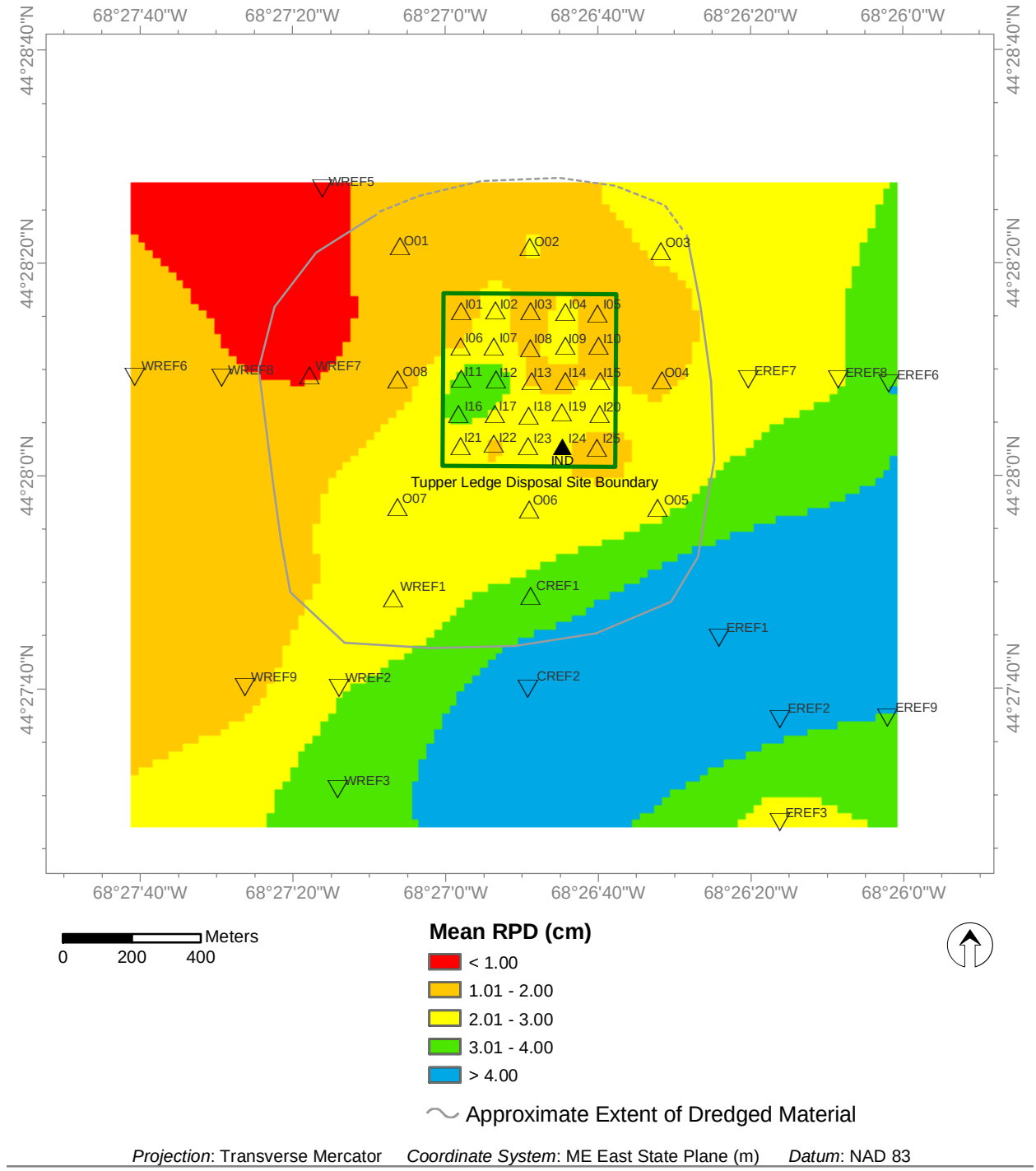
DM: Dredged Material; NA: Not applicable; Ind: Indeterminate

Table 3-1, continued

Summary of SPI Results for TLDS Stations, September 2003

Area	Station	Mean Prism Penetration Depth (cm)	Grain Size Major Mode (phi)	Mean RPD Depth (cm)	Successional Stages present (no. of replicates)	Median OSI	Mean Total DM Thickness (cm)	Mean Recent DM Thickness (cm)	Bacteria Present?
	I 24	20.72	>4	Ind.	I-II (1), III(1), I on III (1)	Ind.	9.82	Ind.	No
	I 25	20.09	>4	1.41	I on III (1), III (2)	7	9.97	2.27	No
Outer	O 01	13.64	>4	1.35	I (1), III (2)	8	5.63	5.63	Yes
	O 02	14.30	>4	2.04	I (3)	4	10.01	6.81	Yes
	O 03	11.69	>4	2.13	I (1), I on III (2)	8	0.89	0.89	No
	O 04	18.08	>4	1.84	I on III (3)	8	0.84	0.84	No
	O 05	13.98	>4	2.76	II (2), III (1)	8	7.86	6.17	No
	O 06	14.72	>4	2.48	I on III (3)	9	6.25	4.69	No
	O 07	15.10	>4	2.97	I (2), I on III (1)	6	6.13	4.85	No
	O 08	11.53	>4	1.42	I (1), III (1), Ind. (1)	5.5	9.45	4.24	No
	CREF1	16.13	>4	3.22	I on III (2), III (1)	9	4.55	3.23	No
	WREF1	14.88	>4	2.09	III (2), I on III (1)	9	2.45	2.45	Yes
	WREF7	15.13	>4	0.94	III (1), I on III (2)	7	6.22	4.50	Yes
Avg.		15.15		2.19		NA			
Median		NA		NA		8			
Min		1.42		0.94		4			
Max		20.72		3.90		10			

DM: Dredged Material; NA: Not applicable; Ind: Indeterminate



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

J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2003\TLDS\Draft\Figures\SPI_RPD.mxd 31-Dec-2003

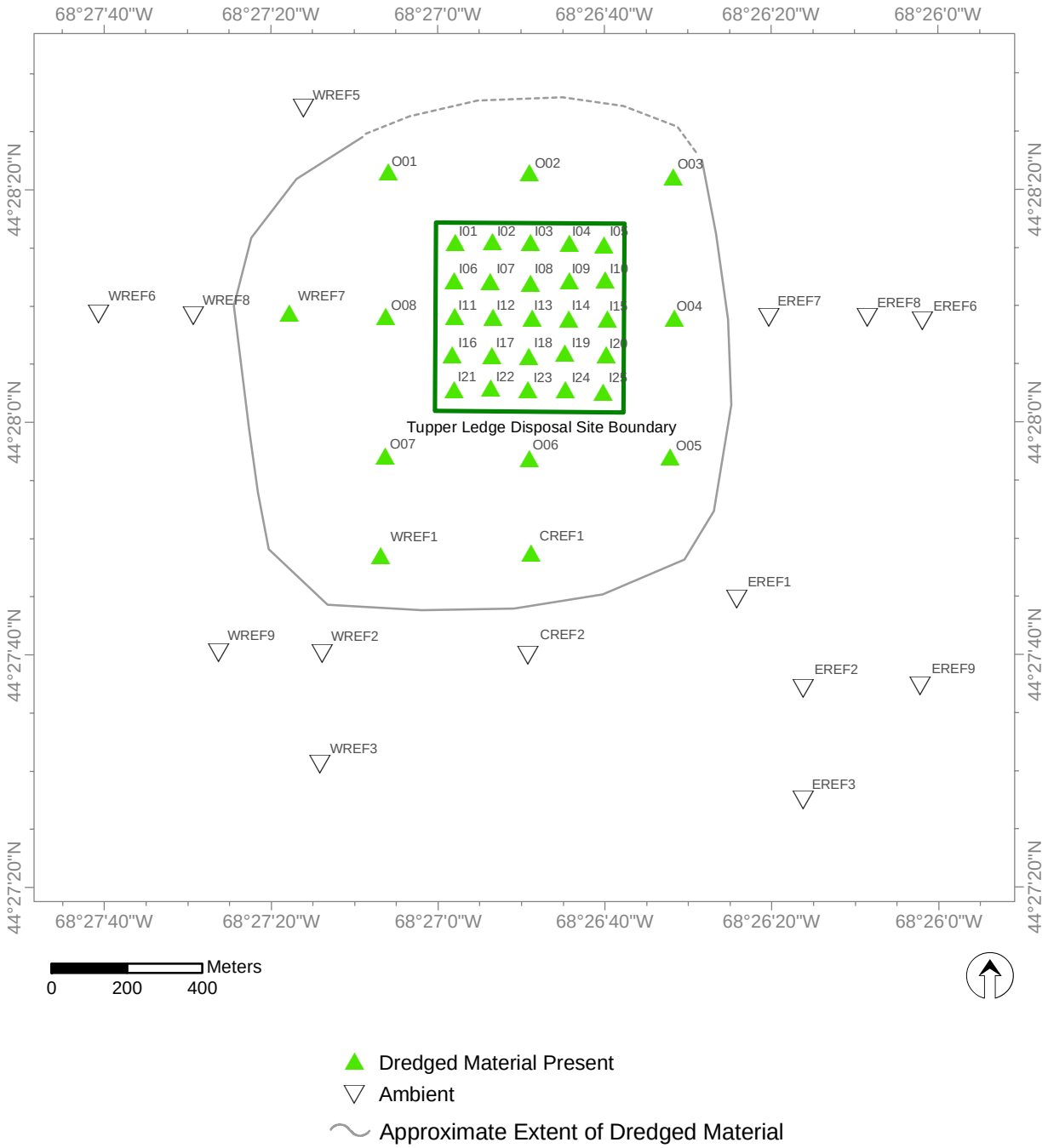
Figure 3-7 Mean apparent RPD depths at TLDS, September 2003.

Dredged material at TLDS has spread out anywhere from 200 to 400 m beyond the disposal site boundary (Figure 3-8). While the presence of dredged material was fairly easy to confirm at stations within the disposal site boundaries because of the presence of either anomalous sediment types (Figure 3-5) or wood chips and fibers (Figure 3-9), its signature was less distinguishable at stations outside the disposal site. Thin (<10 cm) layers of dredged material were found outside the disposal site; in the SPI images, these layers were similar in appearance to the dark sedimentary intervals caused by the apparent occurrence of periodic anoxia in the region (Figure 3-4). In addition to the presence of wood particles, the other feature of the dredged material that helped to distinguish it from the dark, subsurface laminations of muds with high sediment-oxygen demand (SOD) was the presence just below the oxidized surface layer of small, reduced organic pockets/particles of sediment that had the appearance of coarse black pepper. This "coarse pepper" feature of degradation-resistant particles was present in all images with fine-grained dredged material taken inside the disposal site (Figure 3-10), and gradually tapered off with increasing distance from the disposal site boundary. Dredged material sedimentary intervals could thus be distinguished from the reduced sedimentary intervals caused by low oxygen conditions in the ambient sediment.

Biological Conditions and Benthic Recolonization Status

Evidence of mature infaunal communities was found throughout the disposal site (Figure 3-11) despite the recent deposit of dredged material and evidence of hypoxic or anoxic conditions occurring in the recent past,. Deposit-feeding (Stage III) taxa were present in at least one replicate image at all stations sampled within the site boundary, except Station I11 (Figure 3-12), and Station O02 to the north of the site boundary (both stations had dredged material present).

The prevalence of mature infaunal assemblages throughout the site was also reflected in the distribution of OSI values (Figure 3-13); median values at all stations within the disposal site boundary were +7 or above, with the exception once again of Station I11 (the shallow RPD values and early successional stage status depressed OSI values at this location). Another indicator of the quality of benthic habitat conditions at the site was the presence of sulfur-reducing bacterial colonies (*Beggiatoa* or *Thiobacilli*; Figure 3-12); evidence of these bacterial colonies, which occur only in low-oxygen conditions, was found at 12 stations within the disposal site (Figure 3-14). Detection of sulfur-reducing colonies requires careful examination of high-resolution images, as they can easily be missed during routine analysis. The presence of high sediment oxygen demand (SOD) layers near the surface is often an indicator for the presence of sulfur-reducing bacterial colonies.



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

J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2003\TLDS\Draft\Figures\SPI_TDM.mxd 31-Dec-2003

Figure 3-8 Presence or absence of dredged material in the area of TLDS as detected by sediment-profile imaging in September 2003.

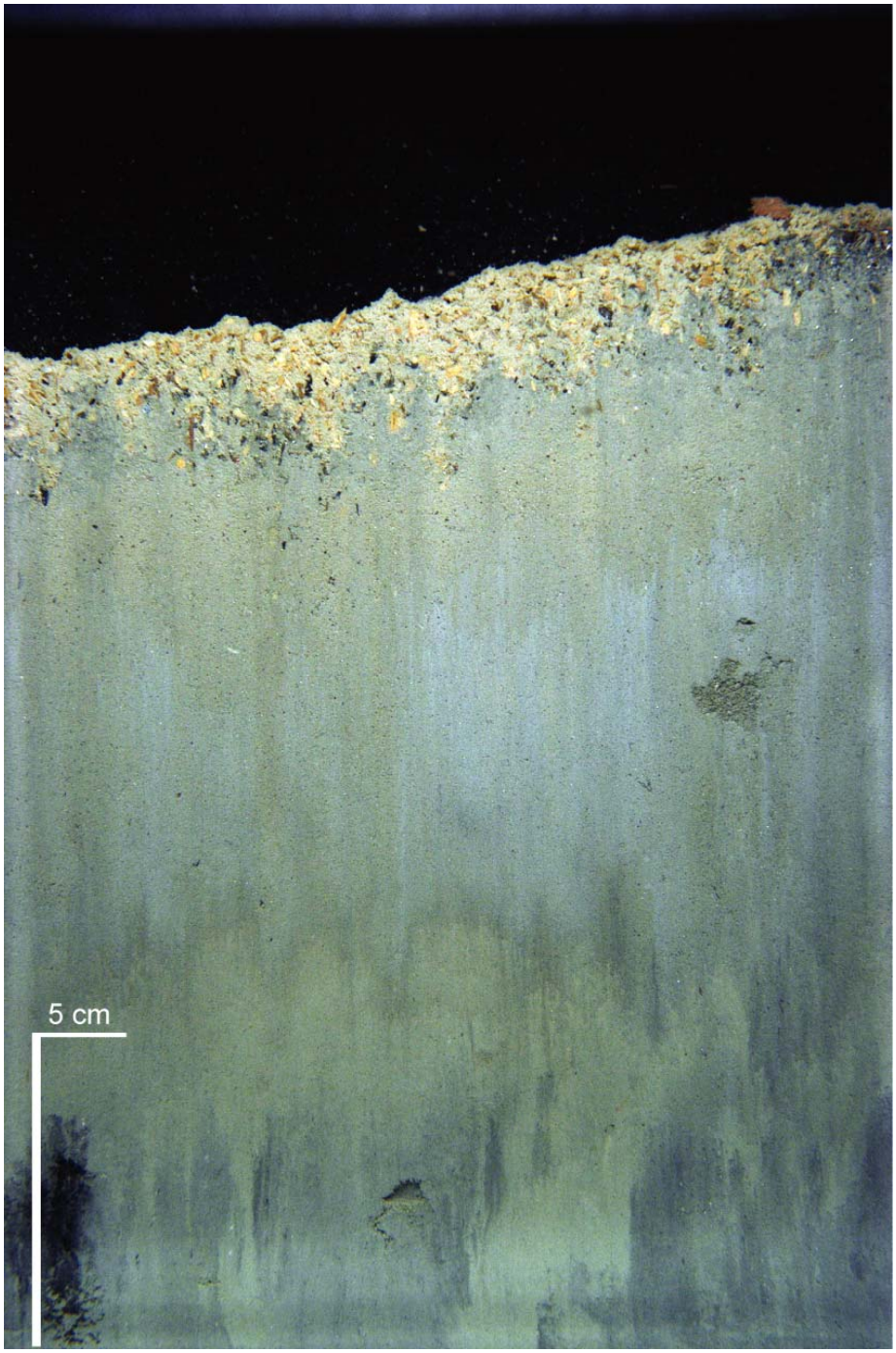


Figure 3-9 Sediment-profile image from Station I21 showing the layer of recently deposited dredged material extending beyond the depth of the prism penetration. Note the diagnostic feature of wood chips and fibers at the sediment surface.

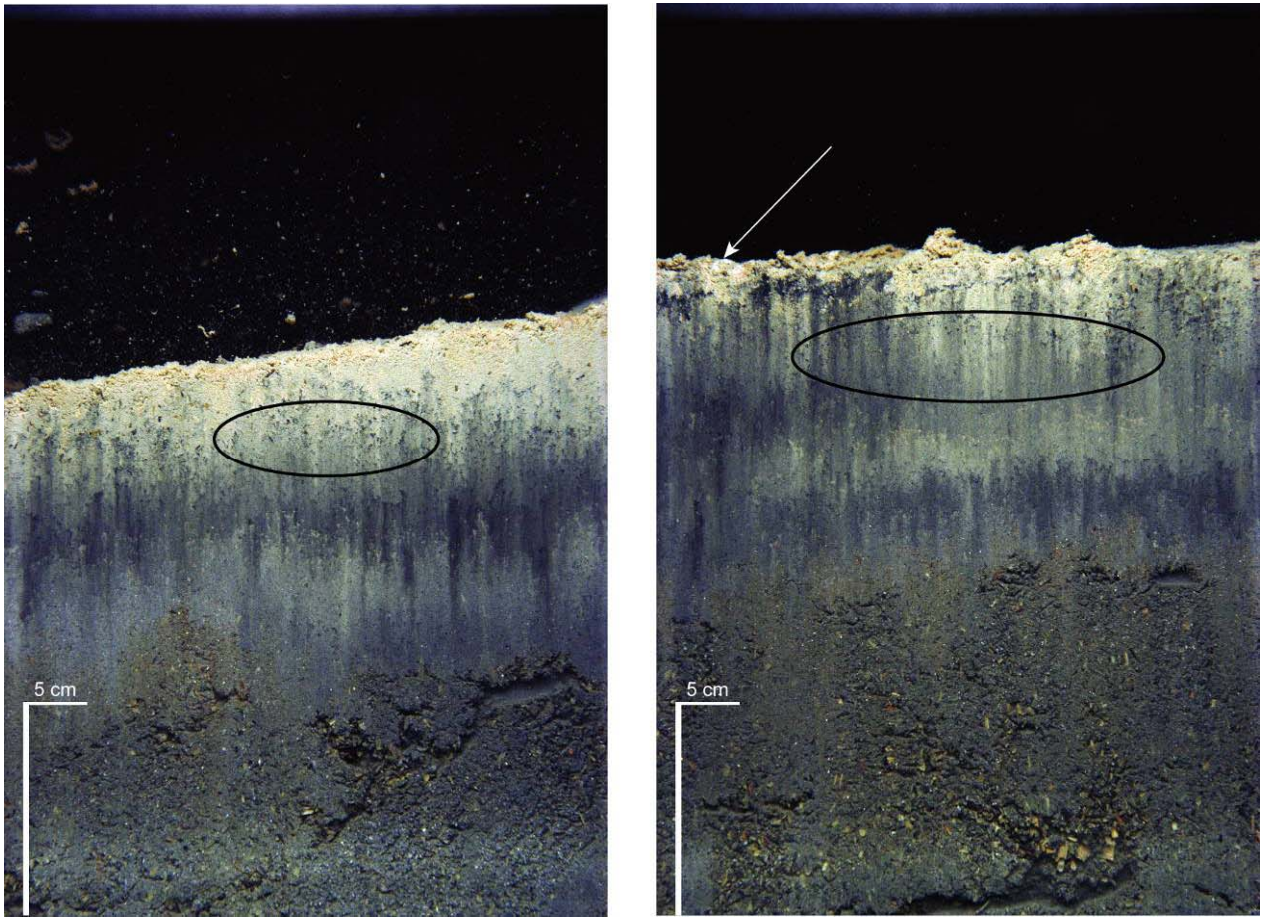
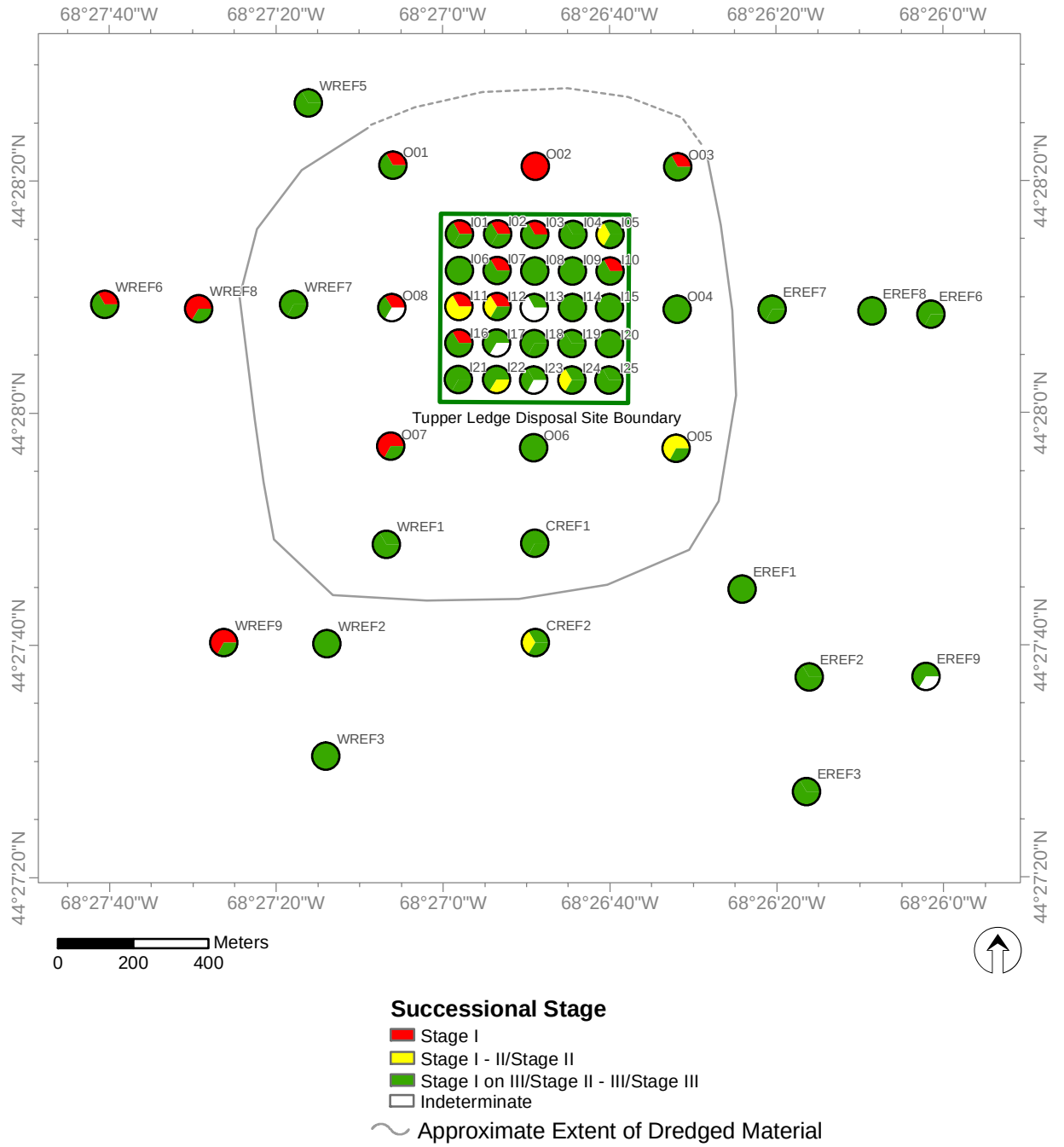


Figure 3-10 Replicate sediment-profile images from Station I08 show a layer of recently deposited dredged material indicated by wood fibers and reduced particles. The dredged material exceeds the camera prism penetration depth. The diagnostic signature of this allochthonous deposit includes wood fibers and clusters of individual, reduced particles (ellipse). Note the presence of the white colony of sulfur-reducing bacteria (arrow) on the sediment surface in the image on the right.



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

J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2003\TLDS\Draft\Figures\SPI_stage.mxd 31-Dec-2003

Figure 3-11 Infaunal successional stages at TLDS, September 2003.

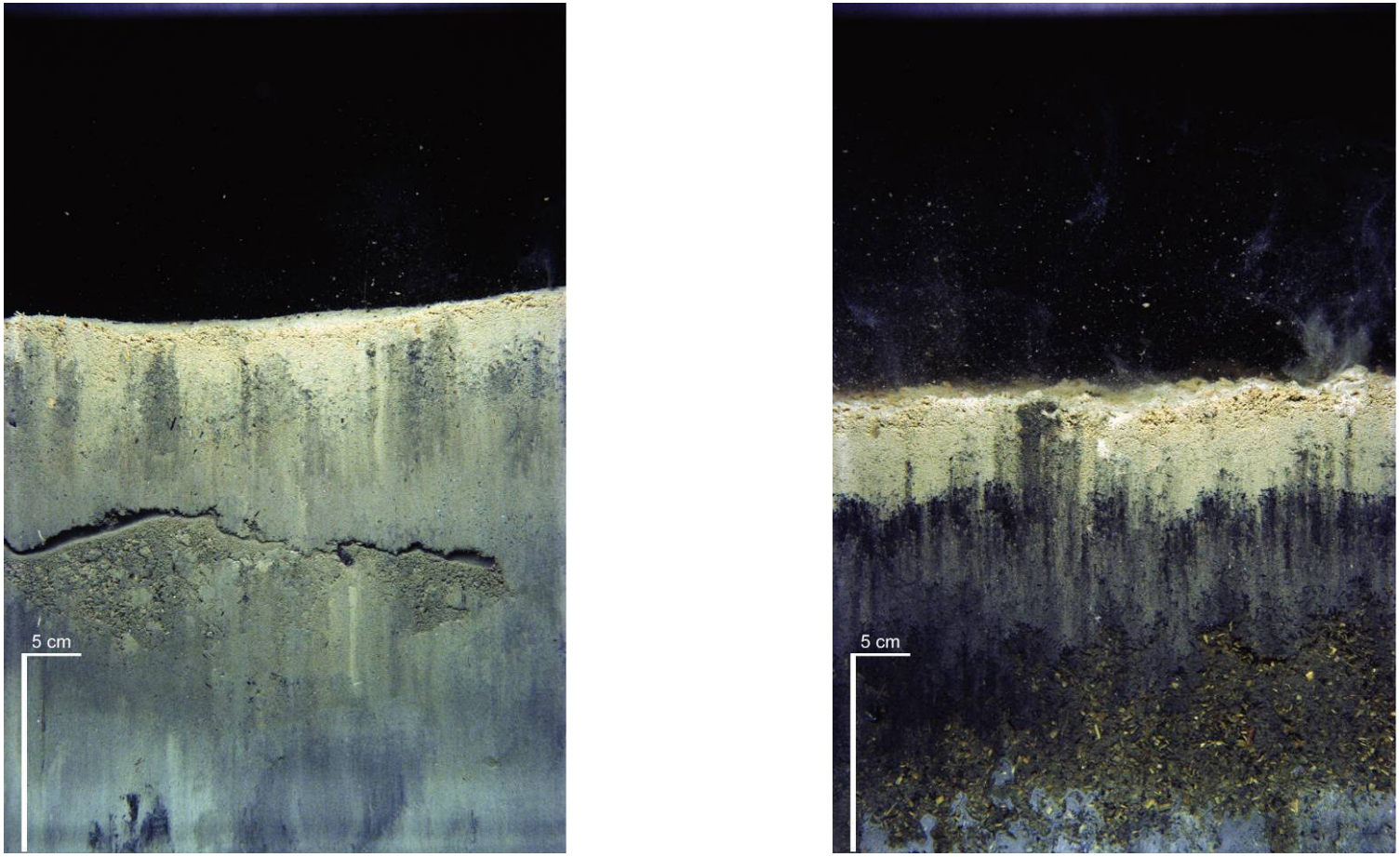
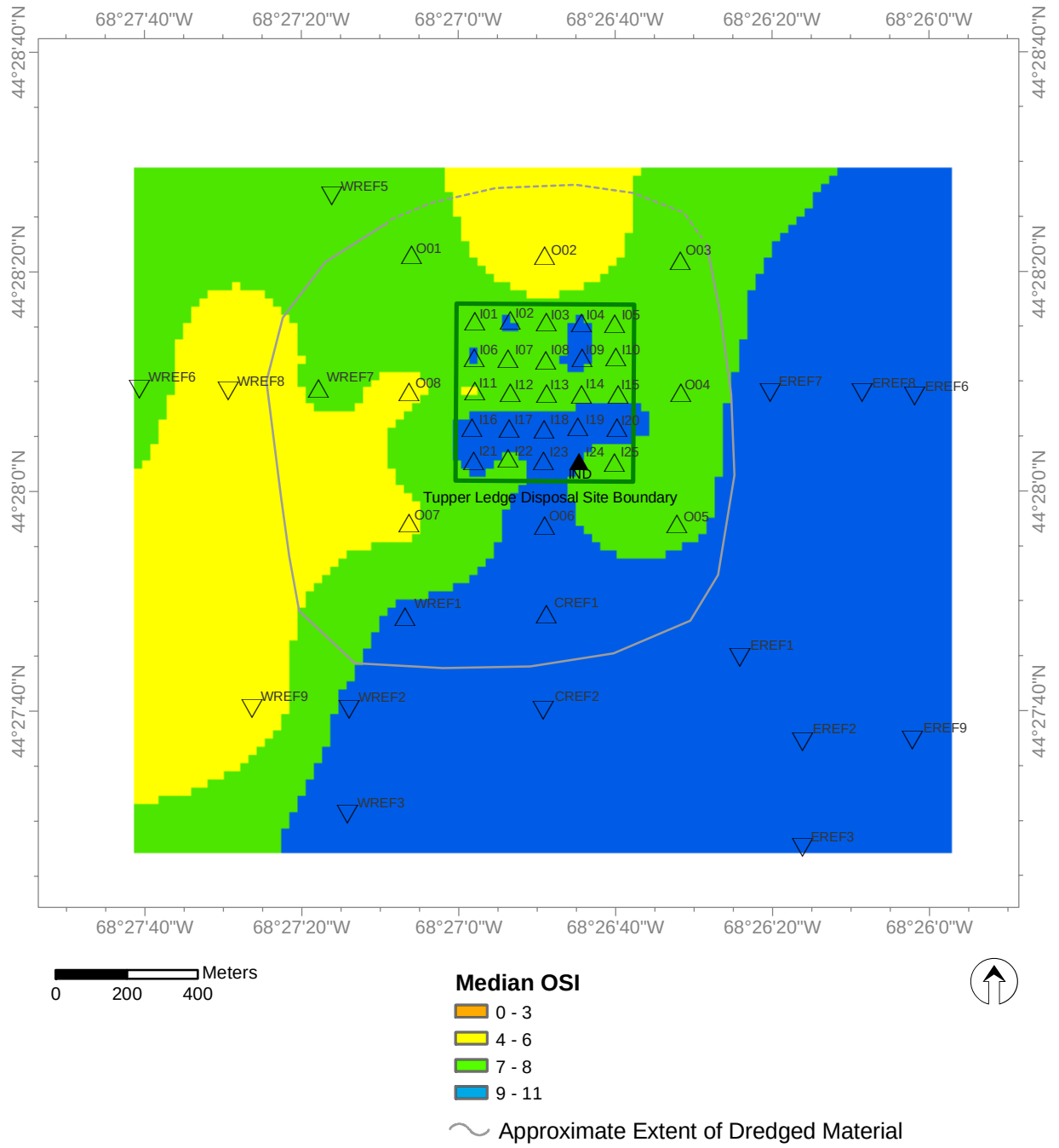


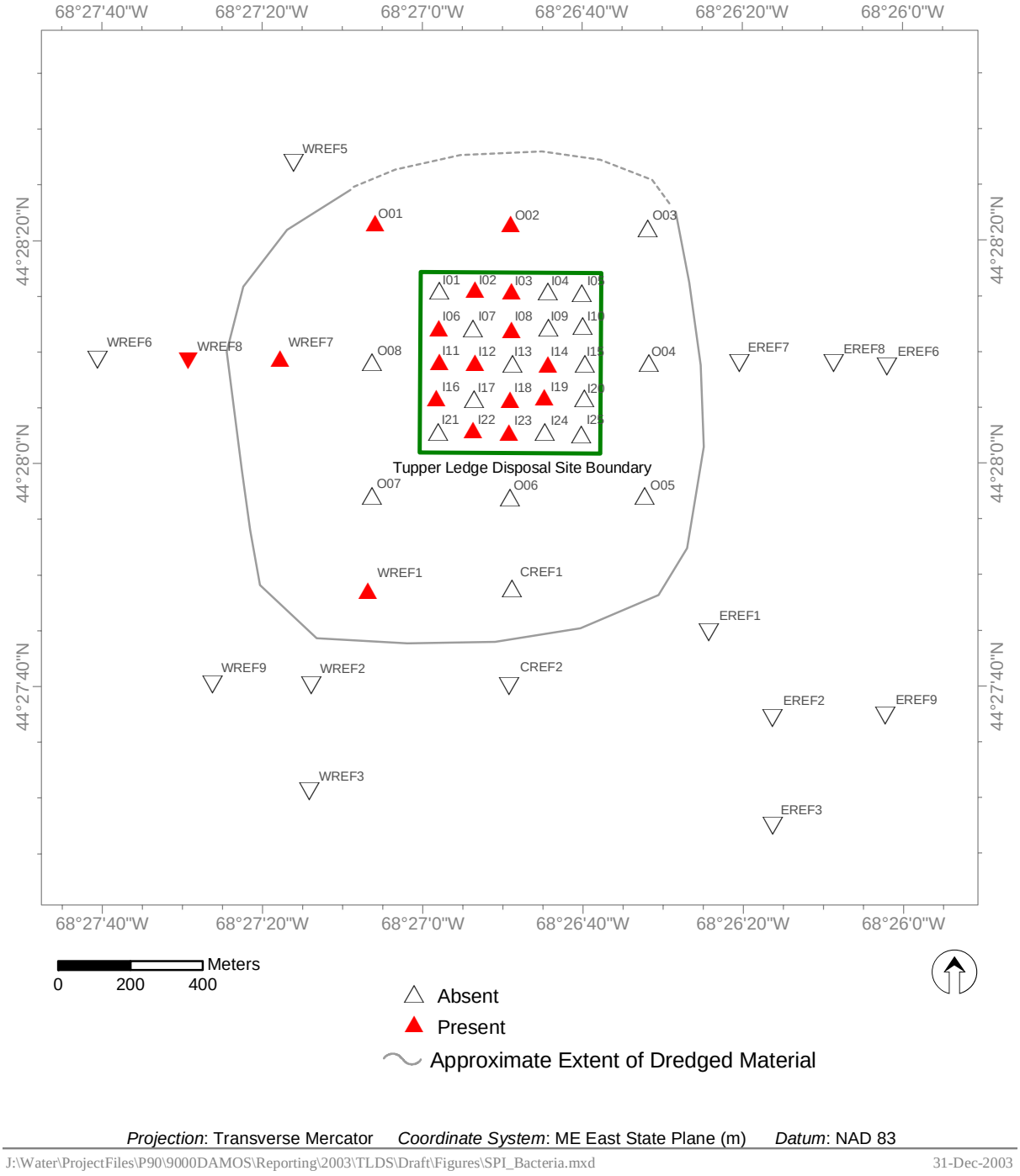
Figure 3-12 Sediment-profile images showing evidence of Stage III deposit-feeding assemblages from Station I10 and signs of only early biological recolonization at Station I11. Stage III assemblages were found at most stations within the disposal site boundaries, as shown in this profile image from Station I10 (left). Station I11 (right) only showed signs of early biological recolonization, with a Stage I assemblage present as well as *Beggiatoa* colonies (white patches) at the sediment-water interface.



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

J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2003\TLDS\Draft\Figures\SPI_OSI.mxd 31-Dec-2003

Figure 3-13 Median OSI values at TLDS, September 2003. Values $\leq +6$ generally indicate evidence of recent disturbance.



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

J:\Water\ProjectFiles\P90\9000DAMOS\Reporting\2003\TLDS\Draft\Figures\SPI_Bacteria.mxd 31-Dec-2003

Figure 3-14 Presence/absence of sulfur-reducing bacterial colonies at TLDS. At those stations where presence is indicated, bacterial colonies were evident in one or more replicate images (see Appendix B for details).

3.2.2 Reference Area

Even though a total of 17 stations were designated as reference stations prior to the survey, not all of these stations were found to be representative of ambient conditions. As discussed above, given the uncertainties reported in the previous survey (SAIC 2002) about the presence or absence of dredged material, stations were arranged in linear transects outside the disposal site to identify the spatial extent of dredged material on the seafloor. Dredged material was present at three of the 17 locations originally expected to represent reference conditions (WREF1, WREF7, CREF1; Figure 3-8). Therefore, these three stations were excluded from the pool of reference data, and were considered "outer" stations in the analysis and presentation of the results. For the purpose of describing the status of ambient sediments or for comparing disposal site characteristics with reference or ambient conditions, only data from the 14 stations without dredged material were considered. This approach (i.e., defining reference locations based on results) is appropriate only during the reconnaissance phase of disposal site monitoring. Evidence of regional stress from periodic anoxic events makes it acceptable in this survey in order to maximize information on ambient conditions around the disposal site. Detailed information about the images from all stations can be found in Appendix B.

Sediment Physical Characteristics

The ambient sediments that were not affected by dredged material disposal had the same general geotechnical properties as sediments inside the disposal site: fine-grained, high water content, low shear strength muds (major mode >4 phi). Sediments at the ambient stations had a total grain size range from medium sand (1 phi) to coarse silt and finer (>4 phi), with the majority of stations falling in the category of well-sorted muds ranging from 3 phi to >4 phi (Appendix B).

Small-scale boundary roughness values ranged from 0.32 to 4.8 cm (Appendix B), with the majority of images (>70%) having roughness elements caused by biogenic activity. The range of mean apparent RPD values extended from 0.81 to 6.01 cm (Table 3-2), with an overall ambient station average of 3.06 cm (Figure 3-7; Table 3-3; Appendix B). The thickest layers of oxidized sediments were found to the south and southeast of the disposal site in a cluster of three stations (CREF2, EREF1, EREF2; Figure 3-7).

There were numerous occurrences of alternating dark/light laminar sediment banding at the reference stations; these alternating high- and low-reflectance sedimentary intervals could easily be mistaken for dredged material layers because of their similar appearance (Figure 3-15; comment field in Appendix B). However, upon closer

Table 3-2

Summary of SPI Results for TLDS Reference Stations, September 2003

Area	Station	Mean Prism Penetration Depth (cm)	Grain Size Major Mode (phi)	Mean RPD Depth (cm)	Successional Stages present (no. of replicates)	OSI Station Median	Mean Total DM Thickness (cm)	Mean Recent DM Thickness (cm)	Bacteria Present?
Central	CREF2	14.33	>4	4.97	II (1), III (1), I on III (1)	10	0.00	0.00	No
East	EREF1	18.93	>4	6.01	III (3)	11	0.00	0.00	No
	EREF2	17.74	>4	4.36	I on III (1), III (2)	11	0.00	0.00	No
	EREF3	18.43	>4	2.45	I on III (1), III (2)	9	0.00	0.00	No
	EREF6	15.84	>4	4.00	I on III (2), III (1)	10	0.00	0.00	No
	EREF7	12.53	>4	2.60	I on III (2), III (1)	9	0.00	0.00	No
	EREF8	15.11	>4	2.88	I on III (3)	10	0.00	0.00	No
	EREF9	14.99	>4	3.97	I on III (2), Ind. (1)	10.5	0.00	0.00	No
West	WREF2	18.74	>4	2.93	I on III (3)	9	0.00	0.00	No
	WREF3	17.88	>4	3.70	I on III (3)	10	0.00	0.00	No
	WREF5	13.76	>4	0.81	III (2), I on III (1)	7	0.00	0.00	No
	WREF6	14.78	>4	1.42	I (1), I on III (2)	8	0.00	0.00	No
	WREF8	14.84	>4	1.08	I (2), III (1)	4	0.00	0.00	Yes
	WREF9	18.72	>4	1.62	I (2), III (1)	5	0.00	0.00	No
Avg.		16.19		3.06		NA			
Median		NA		NA		9.5			
Min.		12.53		0.81		4			
Max.		18.93		6.01		11			

DM: Dredged Material; NA: Not applicable; Ind: Indeterminate

Table 3-3

Comparison of Sediment Biological Conditions for
TLDS and Reference Stations in 2001 and 2003

Area	Year	Average RPD, In cm (range)	Median OSI value (range)
TLDS	2001	0.60 (0 to 1.81)	+2 (-8 to +8)
	2003	2.19 (0.94 to 3.90)	+8 (+4 to +10)
Reference	2001	1.22 (0.59 to 1.56)	+7 (+1 to +7)
	2003	3.06 (0.81 to 6.01)	+9.5 (+4 to +11)

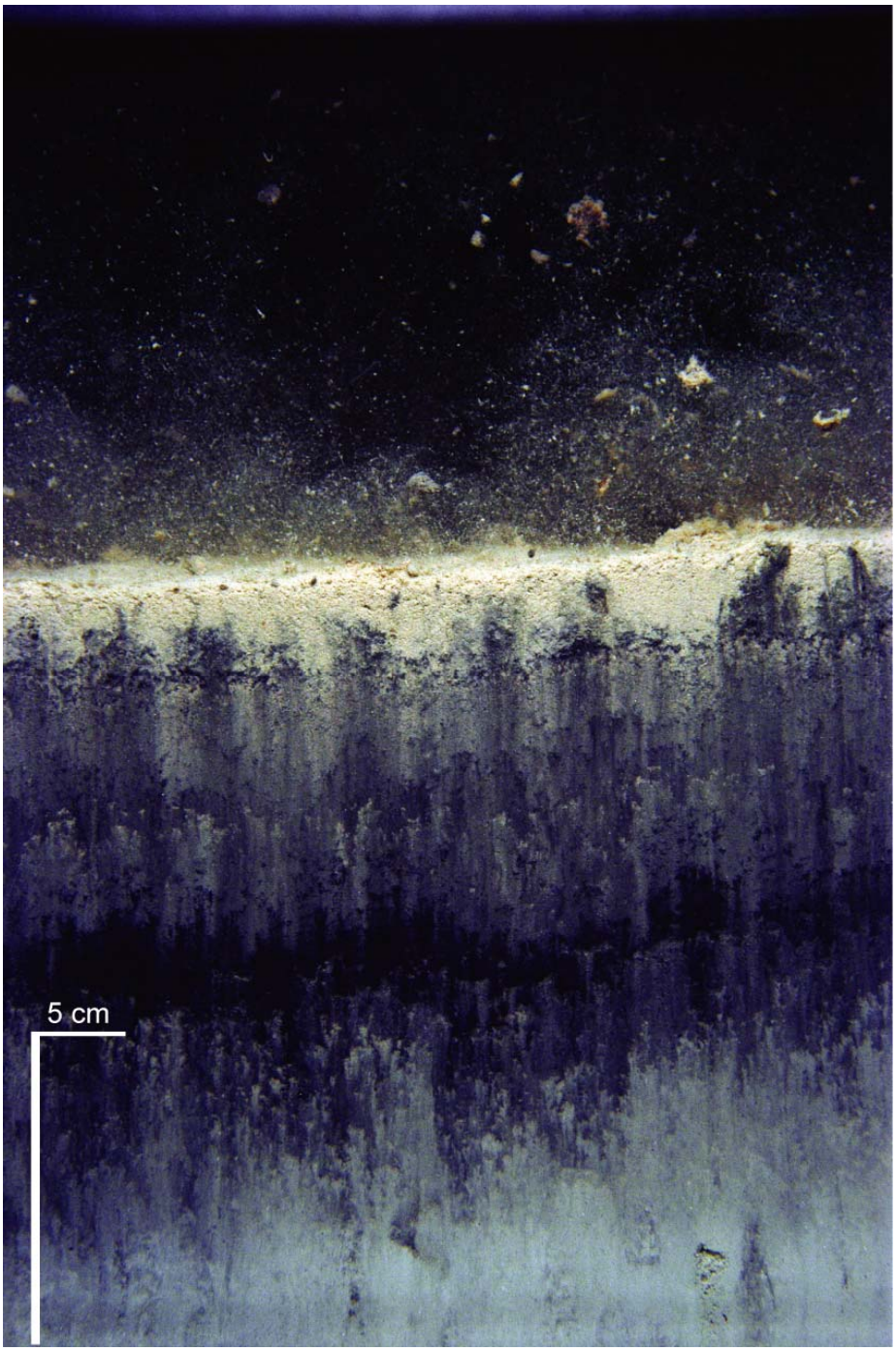


Figure 3-15 Sediment-profile image from Station WREF8 showing alternating light/dark sediment bands, typical of periodic organic sediment deposition or seasonal anoxia.

examination, these striations and reduced, sulfidic sediments did not have the diagnostic signatures of the disposal site material (wood chips, reduced coarse-pepper-sized organic particles) and therefore were either due to natural source input (Union River suspended sediments or run-off from nearby shorelines) or, more likely, seasonal episodes of hypoxia or anoxia.

Biological Conditions and Benthic Recolonization Status

Mature, deposit-feeding communities (Stage III assemblages) were common and present in at least one image at all reference stations (Figure 3-11; Figure 3-16), with nine of the 14 stations having Stage III assemblages present in all three replicate images. Median OSI values ranged from 4 to 11 (Table 3-2; Figure 3-13), with WREF 8 (Figure 3-15) having the lowest value due to the relatively shallow RPD values and prevalence of Stage I communities. The highest median OSI values were generally found to the east and south of the disposal site, while those to the west and north of the site (Figure 3-8), did not exceed a value of +8 (Figure 3-13).

Evidence of sulfur-reducing bacteria was found at Station WREF8 (Figure 3-14), which was somewhat noteworthy as this was the only station where bacterial colonies were present and dredged material was not. A re-examination of 2000 and 2001 sediment-profile images from TLDS revealed that the same type of bacterial colony was present in profile images both inside and outside the disposal site boundary, but they were neither recognized nor reported (SAIC 2000, 2002). (Note: Without microscopic examination we cannot state with certainty that the bacterial colonies seen in the sediment-profile images are indeed the genus *Beggiatoa*, but we can state with certainty that they are in the same family of sulfur-reducing bacteria that appear only in hypoxic or anoxic conditions. Their diagnostic morphology has been documented in numerous other sediment-profile imaging surveys, e.g., Karakassis et al. 2002; Nilsson & Rosenberg 1997; Rosenberg et al. 2001).

3.2.3 Comparison with Reference Area Conditions

The sediments in areas with dredged material had the same grain-size major mode (all fine-grained muds) and geotechnical properties as sediments in the ambient or reference areas. The range of particle size was somewhat greater in areas with dredged material due to the heterogeneity of the disposed sediments, with a total grain size range from very coarse sand (0 phi) to silt and clay (>4 phi). Although the grain-size major mode of both the reference area stations and the TLDS stations was >4 phi, a greater range of grain sizes was observed at more of the TLDS stations. Alternating light/dark

laminations in the cross-sectional profiles were present in images from both within and outside of the disposal site (Figure 3-17).

The average apparent RPD was relatively deep at all stations, but greater at stations outside the dredged material footprint than inside (3.1 and 2.2 cm overall mean, respectively, Figure 3-7), probably due to the higher sediment-oxygen demand (SOD) of the organically enriched dredged material. However, the successional status was fairly similar at stations both on and off the dredged material (Figure 3-11). Mature, deposit-feeding taxa were present at all stations except one (Station O02). While the median OSI was slightly greater at reference stations because of the significantly deeper RPD values, stations on the dredged material also exhibited high OSI values (Table 3-3) because of this advanced successional stage status.

In addition to the difference in apparent RPD values, the other noticeable difference in sediment quality between ambient sediment and dredged material was the location of areas with colonies of sulfur-reducing bacteria (Figure 3-14). These indicators of low-oxygen stress were found only at those stations with dredged material present (the one exception was Station WREF8). Thus, although conditions were slightly degraded within the dredged material footprint as measured by apparent RPD depth and the presence of sulfur-reducing bacteria, the biological community appeared to be fairly resilient given the ubiquitous presence of deposit-feeding fauna throughout the entire site.

3.2.4 Comparison with Previous Surveys

Two previous surveys were carried out at TLDS, the initial baseline survey in March 2000 (SAIC 2000) and the first-year monitoring survey in August 2001 (SAIC 2002). In both surveys, the presence of soft, fine-grained sediments with high water content were noted, similar to the findings in this most recent survey. Both the 2001 and 2003 surveys required the use of the mud doors on the profile camera to prevent prism over-penetration.

The initial baseline survey occupied only nine stations in a 3 x 3 grid over what would become the disposal site and documented an average site value of 2.7 cm for the apparent RPD depth. There was a combination of both Stage I and Stage I on III assemblages present throughout the site before any dredged material was disposed. The OSI values ranged from +5 to +9, with an overall site average of +6.

Conditions at the site deteriorated after the first year of disposal operations, during which approximately 51,000 m^3 of dredged material was placed. The 2001 survey, carried out four months following the last disposal operation, documented poor infaunal

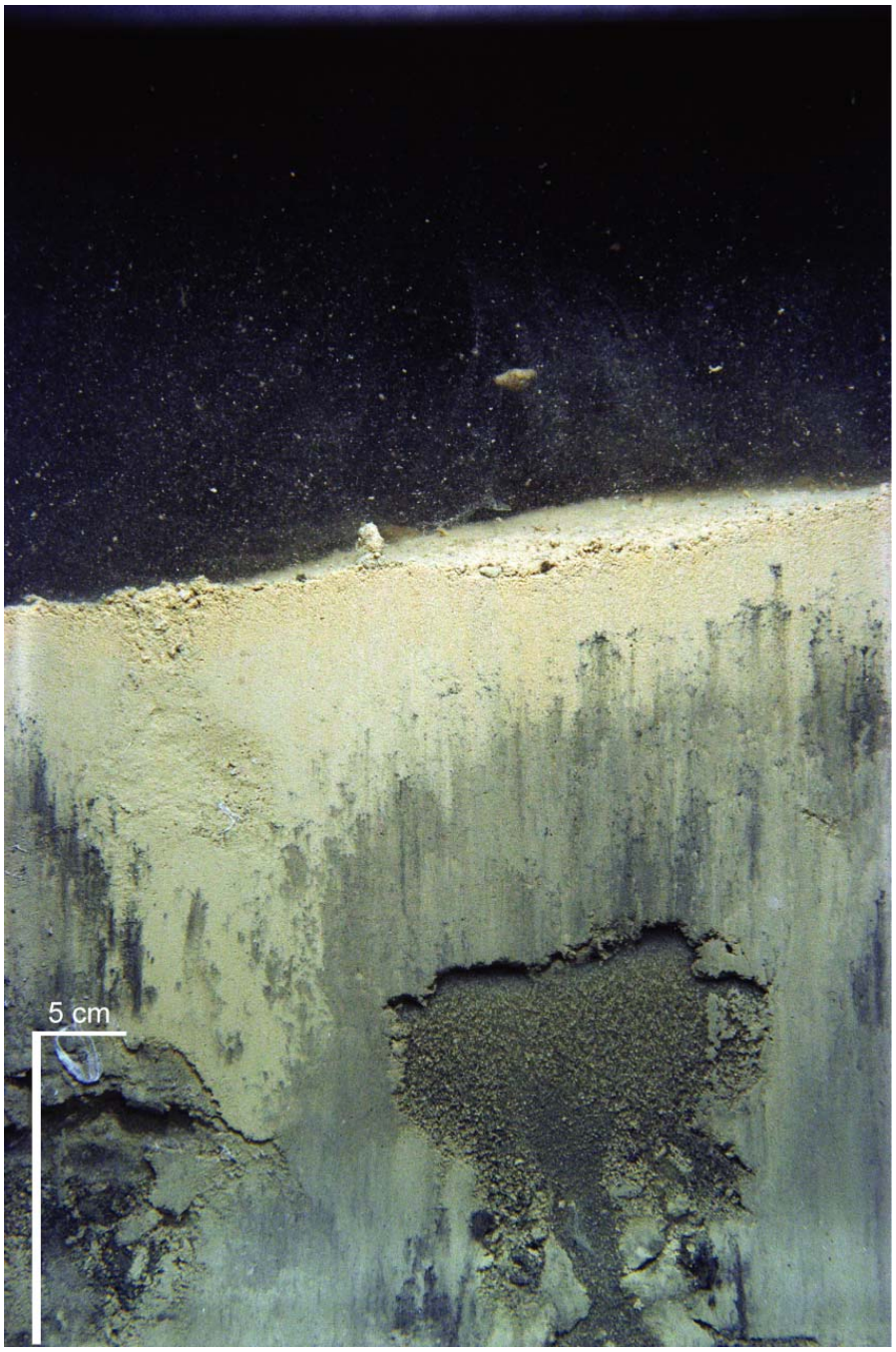
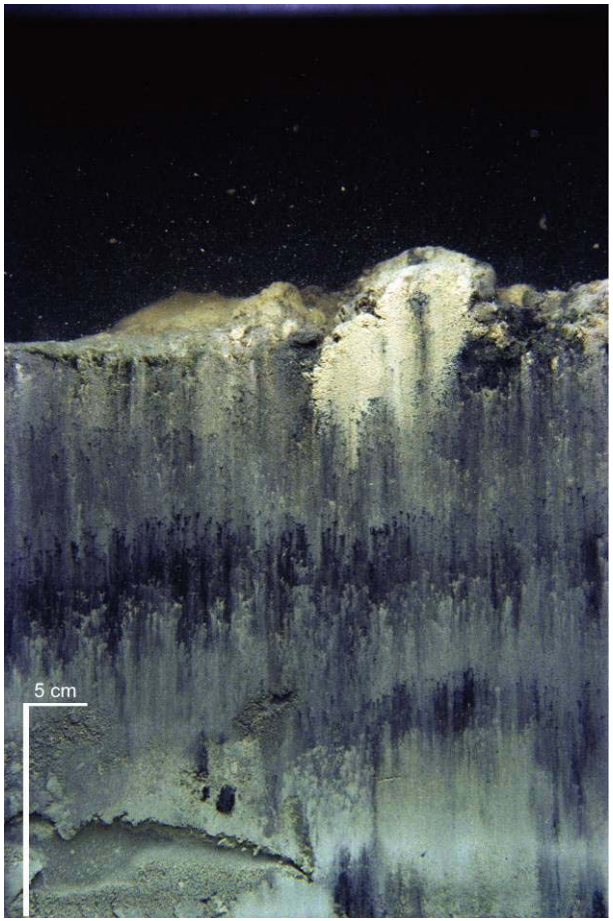


Figure 3-16 Sediment-profile image from Station CREF2 showing a typical cross-sectional profile of undisturbed, ambient sediment with prominent feeding voids made by Stage III taxa.



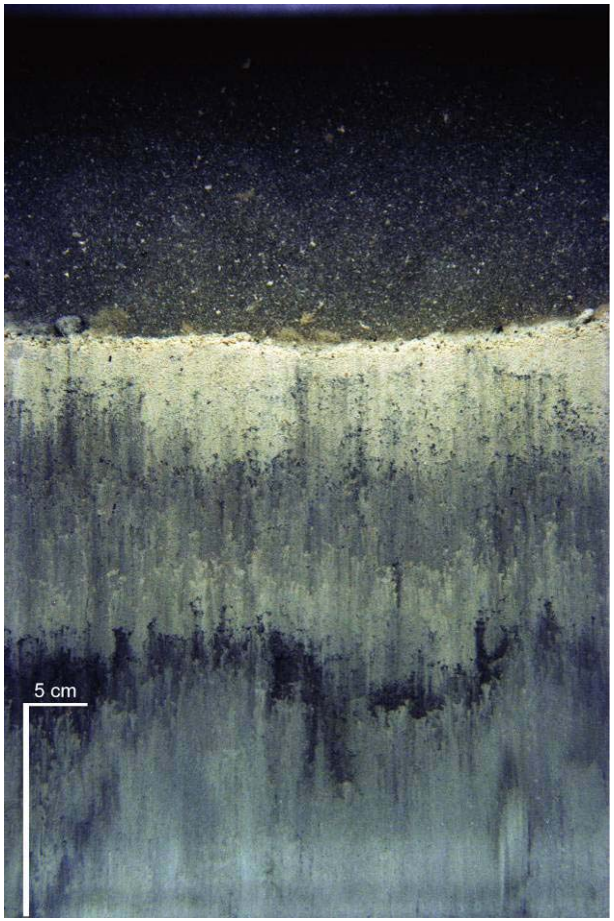


Figure 3-17 Sediment-profile images from Station WREF7 (left) and Station I01 (right) showing similar patterns of light/dark anoxic banding. Note the characteristic "coarse black pepper" particles of reduced sediment in the dredged material in the image on the right.

recolonization, azoic conditions at many stations, reduced sediment at the surface of many stations indicating low oxygen conditions, and very low apparent RPD values both inside and outside the site (Table 3-3). As seen in the 2003 survey, the presence of wood particles was noted in the dredged material. OSI values had fallen dramatically since the baseline survey (Table 3-3), with a site median value of +1 within the disposal site boundary, +3 at the outer stations, and +7 at the reference stations. Bands or horizons of reduced sediment were found in over half the images and were attributed to organic enrichment from spring runoff or sporadic phytoplankton blooms (SAIC 2002; p. 42).

Since the 2001 survey, approximately 47,000 m^3 of additional material has been placed at the site, and, as in 2001, a survey was carried out 4 months after cessation of disposal operations. The footprint of dredged material is much larger than reported in the 2001 survey, as dredged material was detected at all of the outer stations. It is expected that the thin apron of dredged material was larger than before, given that additional material was deposited at the site and in a different quadrant inside the site boundary. While evidence of organic enrichment and hypoxic/anoxic stress still existed at the site, benthic habitat conditions (apparent RPD depth, infaunal successional status, and OSI values) markedly improved since the last survey (Table 3-3).

4.0 DISCUSSION

The primary objectives of the September 2003 survey at TLDS were to document any changes in dredged material distribution and bathymetry and to assess the status of benthic recolonization at the site relative to reference area conditions and previous surveys. Since the 2001 survey, 47,000 m^3 of dredged material was disposed in the southwest quadrant of TLDS. Seafloor topography, sediment distribution and benthic recolonization at TLDS were characterized with bathymetric and SPI surveys in 2001 and 2003. Bathymetric and SPI surveys performed in 2000 provided pre-disposal reference conditions for comparison.

4.1 Dredged Material Distribution

The differences in bathymetry between the 2001 and 2003 surveys (Figure 3-3) provided clear evidence for the formation of a new mound (Mound B) in the southwest quadrant of the site. The sediment-profile images from the vicinity of Mound B and the older Mound A showed anomalous sediment types (over-consolidated clays, rocks) that are typical of heterogeneous deposits of dredged material. Anecdotal reports from the local harbormaster (R. Heckman, Ellsworth Harbormaster, personal communication) warned us to expect deposits of rocks at the site from the recent disposal activities, and rocks were indeed found at one station (I17) on Mound B.

The thickest accumulations were detected by the acoustic imaging, while the thinner layers of dredged material in the surrounding deposit apron were detected by sediment-profile imaging; this is consistent with the results of previous DAMOS surveys throughout New England where a combination of precision bathymetry and sediment-profile imaging was used to map the dredged material footprint (Germano 1983; Germano & Rhoads 1984; Rhoads and Germano 1990; SAIC 1988; 1990a; 1990b; 1990c; 1994). Dredged material extended deeper than the camera prism penetrated at the cluster of stations surrounding both Mounds A and B (Stations I08, I11-I13, I16-17, and I 21-22), and had spread in a thin pancake layer uniformly around the disposal site immediately adjacent to the site boundary (dredged material was detected at all outer stations; Figure 3-8). It also extended a little farther to the south and west of the ring of outer stations because of the relocation of the disposal point to the southwest quadrant of the site for the most recent round of sediment deposits.

Rather substantial differences were noted for the distribution of dredged material between the 2001 survey (Figure 3-12 in SAIC 2002) and this most recent survey (Figure 3-8, this report). Diagnostic features of dredged material, including the increased presence of wood particles and the coarse pepper-sized reduced sedimentary particles,

were observed in several images and allowed us to distinguish between recent and historical layers of material (Table 3-1) at stations where no dredged material was reported earlier (e.g., all the outer stations). These diagnostic features of dredged material were observed in the re-examination of the historical sediment-profile slides and indicated that the presence of dredged material was somewhat under-reported in 2002. However, the spread of a thin apron of material 400–600 m from the disposal point is well within the range one would expect from unconfined disposal of fine-grained material in these water depths (Germano and Rhoads 1984; McDowell et al 1994; Germano 2003).

4.2 Biological Conditions and Benthic Recolonization

The infaunal community at TLDS has made a dramatic recovery, compared with the poor biological conditions and arrested benthic community recolonization reported after the last survey (SAIC 2002), despite the continued disposal of material at the site. All stations within the disposal site showed evidence of diverse biological invertebrate assemblages, consisting of both opportunistic taxa (Stage I fauna) as well as mature, deposit-feeding invertebrates (Stage III fauna), resulting in a Stage I on III designation in at least one image from almost every station (Table 3-1). Station I11 was the notable exception with only Stage I and II fauna present, which corresponded to the biological recovery condition that had been predicted for the majority of the site based on previous results. The high frequency of Stage III fauna at most of the stations sampled (Figure 3-11; only two stations without Stage III fauna) combined with the similarly high median OSI values over most of the site (Figure 3-13; only six stations with OSI values $< +6$) would seem to indicate that recovery is well underway and within management guidelines (Germano et al. 1994). However, evidence of hypoxia both within and surrounding the disposal site suggests that disposal of organically enriched dredged material has put an adverse stress on the ecosystem,.

The prime indicator that this area was suffering from hypoxic conditions was the presence of the *Beggiatoa* or *Beggiatoa*-like bacterial colonies. Sulfur-reducing bacterial colonies appear when boundary-layer dissolved oxygen concentrations drop into the hypoxic range between 0 and 1 ml/L (Rosenberg and Diaz 1993). The presence of these bacterial colonies is evidence that this area had gone hypoxic or anoxic, and confirms that the alternating light/dark banding patterns observed in the sediments were not directly the result of dredged material deposits but instead were caused by sustained stress from low oxygen (a condition not observed in the baseline survey). Sediment-profile surveys in basins undergoing seasonal anoxia in the Caspian Sea have produced images with lamination patterns similar to those found at TLDS (Figure 4-1). The occurrence of the bacterial colonies in the post-disposal surveys largely coincided with locations where dredged material was present (16 of 17 occurrences, see Figure 3-14), suggesting that the

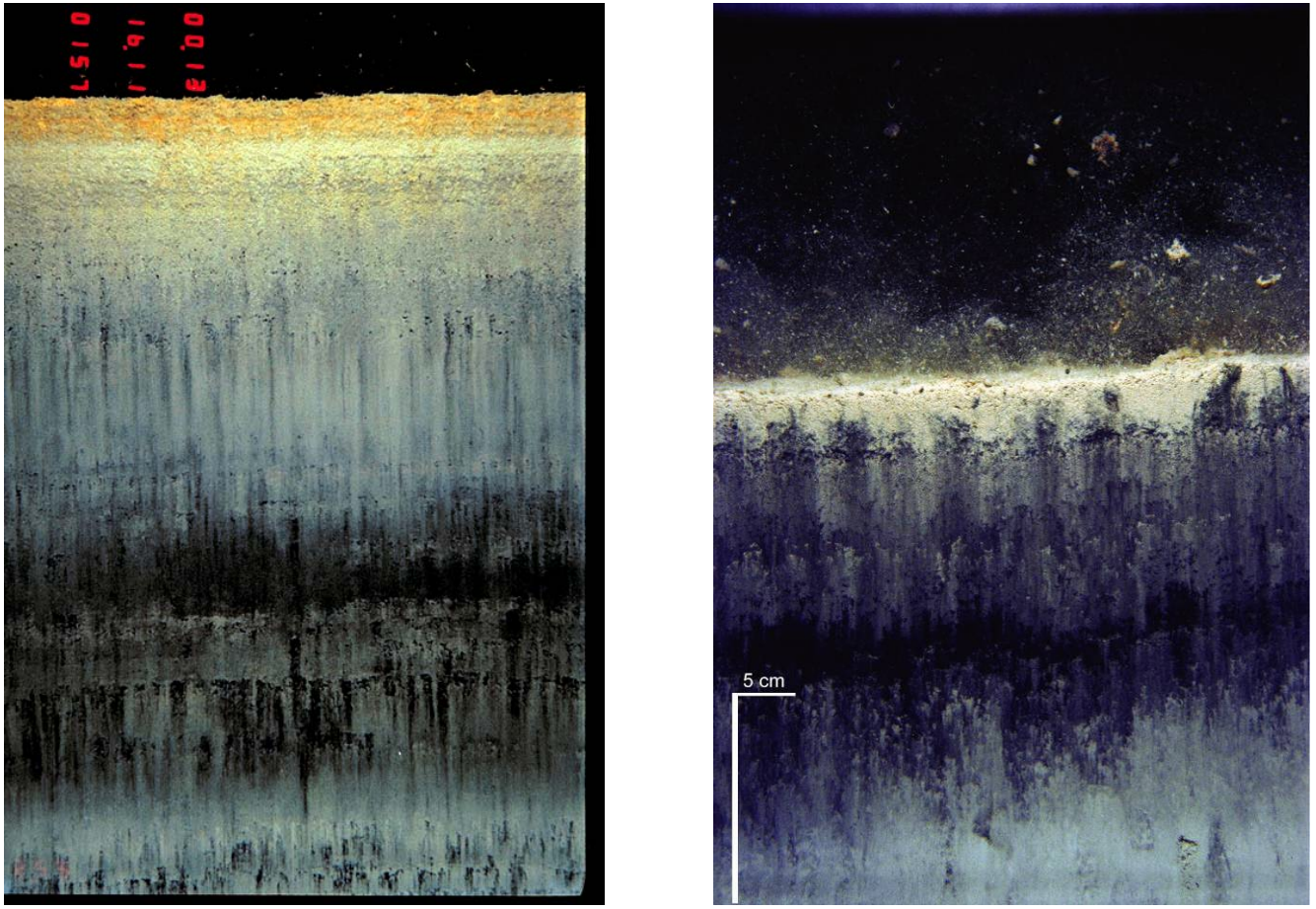


Figure 4-1 Sediment-profile images showing similar lamination patterns from a seasonally anoxic basin in the Caspian Sea (left, Germano and Associates 2003) and from TLDS Station WREF5 (right). The bands of reduced sediment are produced during periods when dissolved oxygen disappears in the benthic boundary layer and overlying water.

organically enriched dredged material likely drove the boundary layer conditions to hypoxic levels with associated anoxic conditions outside the footprint, reflected in the light/dark banding patterns.

Once an area starts to experience seasonal anoxia or hypoxia, the implications for benthic community structure and ecosystem energy cycling can be quite dramatic (Diaz and Rosenberg 1995). Long periods of hypoxia may result in remineralization of a large proportion of the organic carbon by the anaerobic microbial population (e.g., *Beggiatoa*), with subsequently less energy available to support benthic recruitment with the return of normal oxygen concentrations in the water column. However, short duration hypoxic events favor recolonization by macrobenthos over microbes, and the benthic community is able to recover, as was evidently the case at TLDS (note the increased presence of Stage III fauna in the 2003 survey).

4.3 Historical Data Interpretation and Conclusions Revisited

The sediment-profile images from TLDS were a particularly challenging dataset to interpret because of the widespread occurrence of alternating layers of oxidized and reduced sediment in the cross-sectional profiles. An initial scan of the images could easily leave one with the impression that the dredged material distribution was much greater than it actually was, because the alternating light/dark sediment horizons look very similar to depositional intervals commonly found within disposal sites after repeated deposits of dredged material. Two key features were identified in the 2003 SPI images that allowed us to better characterize conditions at TLDS:

(1) Sedimentary textural features that were diagnostic of the dredged material (wood fibers and small, reduced, coarse-pepper-sized black particles just at the redox boundary) which allowed us to distinguish dredged material layers from anoxic banding layers; and

(2) Small colonies of *Beggiatoa* (or a similar genus of sulfur-reducing bacteria), which are indicative of hypoxic or anoxic conditions and were present in half of the images taken within TLDS.

The identification of these features and the realization that disposal of dredged material might have caused the area of seafloor both within and around the disposal site to experience periods of anoxia (enough to produce the diagnostic banding patterns in the sediment), led to a reexamination of sediment-profile images collected in 2000 and 2001 to more fully understand the benthic conditions at TLDS. The examination of the

historical images was critical to diagnosing what was happening at the site this year and to developing a set of conclusions and recommendations for TLDS going forward.

The baseline survey (SAIC 2000) noted the presence of extremely soft sediments with high water content and patches of reduced sediments at depth. Even though the average apparent RPD value for the area was 2.7 cm, OSI values were somewhat depressed for an undisturbed area and ranged from only +5 to +9; the average OSI (+6) was right on the cusp of the value considered indicative of disturbed habitats. Reexamination of the baseline SPI images in light of the more recent observations indicated the presence of incipient colonies of *Beggiatoa* at several of the stations. Apparently the seafloor was experiencing very short and episodic periods of low oxygen, but the periods were not long enough to produce the diagnostic sedimentary laminations found in seasonally anoxic basins (Figure 4-1). Baseline conditions indicated a site ideal for containment of any disposed material (this is a low-energy, depositional site), however the physical shape of the embayment, low flushing rates, relatively high sediment TOC (3.67%), stratified water conditions, and incipient *Beggiatoa* colonies indicated conditions ideal for promoting and maintaining hypoxic or anoxic conditions should large volumes of additional organic matter repeatedly arrive in the system.

The first survey following disposal of the initial 51,000 m^3 of dredged material recognized deteriorating conditions at the site. The post-disposal survey report (SAIC 2002) notes that:

> Benthic recolonization over the surface of the new disposal mound at TLDS was slower than expected, as azoic conditions (i.e., absence of visible macrofaunal life) were found at a significant number of stations in lieu of the expected early colonizing community (i.e., Stage I). The inhibited recolonization of the mound was attributed to the elevated organic content and high sediment oxygen demand associated with decomposition of the wood particles in the dredged material. Benthic habitat conditions were determined to be highly degraded over the disposal mound at TLDS, due to the widespread anoxic conditions in the sediment and associated poor infaunal recolonization.

The severely degraded conditions within the disposal site suggested that disposal of this organically enriched material was producing hypoxic/anoxic conditions. Results from the post-disposal survey provided evidence of degradation that included average apparent RPD depths at inside and outside stations being less than 1 cm, azoic conditions at 11 out of 25 disposal stations and one outer station four months after disposal operations had ceased (dense populations of opportunists usually appear in the spring and summer within 1–2 weeks following disturbance), and the appearance of anoxic banding in the sediments

in half of the stations outside the site. A re-examination of the original slides from the 2001 survey revealed the presence of sulfer-reducing bacterial colonies at 11 stations (I01, I03, I04, I06, I09, I11, I16, I20, I21, O05, and EREF4). It is likely that the introduction of organic-rich dredged material stimulated sufficiently high sediment oxygen demand to affect the entire sub-basin, including the reference areas.

In 2003, unlike the 2001 post-disposal survey, azoic conditions were not present in any areas of the site, and, in fact, Stage III taxa had recolonized most of the area both within and outside the disposal site (Figure 3-11). The apparent RPD depths and OSI values were much greater than before (Table 3-3), and it appears the system has improved from 2001 conditions. Despite additional disposal of organic-rich material, the point where SOD prevents recolonization and recovery of the benthic community has not been reached. This "point of no return" occurs when sediment organic loads are so high that organic carbon is being completely remineralized by the microbial population, and even with the return of normal oxygen concentrations in the water column, sufficient energy is not available to support benthic recruitment. However, the persistence of anoxic banding patterns in many of the images and the combined presence of the *Beggiatoa* colonies largely coinciding with the presence of dredged material indicate that this could be an area at risk. Significant further stress from additional organically enriched material from the Union River area could increase the chance of severe or long-term degradation of local seafloor conditions from prolonged periods of hypoxia or anoxia.

5.0 CONCLUSIONS

The September 2003 survey was performed to provide post-disposal bathymetric and SPI data at TLDS, including the older Mound A formed by disposal of 51,000 m^3 of dredged material deposited between January and April 2001 and the newer Mound B formed by disposal of 47,000 m^3 of dredged material deposited between December 2001 and April 2003. Survey data also served to refine the extent of dredged material and establish suitable reference areas.

The 2003 survey was designed to assess the following specific expectations:

- The 47,000 m^3 of sediment placed in the southwest quadrant of TLDS since the August 2001 survey will result in a discrete disposal mound.

- Benthic recolonization will appear slow, based on the disposal of comparable amounts of material similar to that placed earlier (i.e., elevated organic content, high SOD from decomposing wood chips). Benthic habitat recovery will exhibit the following:

    - Stage I or Stage II assemblages will be present at all stations, however, given the initial degraded conditions at the site in August 2001 and the high SOD of the dredged material, Stage III assemblages will not be as common or abundant within the disposal site as at the reference stations.

    - Azoic conditions will not be observed at the site because the length of time over which the (approximately) same volume was placed was four times greater than the time frame over which it was placed in 2001: 51,000 m^3 over four months prior to the 2001 survey versus 47,000 m^3 over 16 months prior to the 2003 survey. Both surveys took place four month after the last disposal of dredged material at the site.

Following the disposal of approximately 47,000 m^3 of additional dredged material at Tupper Ledge Disposal Site from Union River, a new disposal mound has formed as expected within the site boundaries. Around this mound, dredged material is also spread out in a thin apron at least 200 m in all directions from the site boundary, with additional spreading to the west and south of the site. The sediment-profile images confirmed that the disposed material was primarily organic-rich, fine-grained sediments with evidence of wood chips and fibers from the historical sawmill operations in the Union River.

Benthic recolonization was more advanced than initially expected, with Stage III assemblages present at the majority of stations sampled; unlike the last post-disposal survey, no evidence of azoic conditions was found at any location. While benthic habitat conditions had improved dramatically since the last survey, with median OSI values above +6 at the majority of stations, there was persistent evidence in the sediment record that this area has been stressed from the additional organic enrichment resulting from dredged material being placed at the site. Evidence of sulfur-reducing bacterial colonies, which develop only during hypoxic or anoxic conditions, was found at 17 stations (16 within the dredged material footprint), while sedimentary evidence of prolonged anoxic conditions (alternating oxidized/reduced laminar horizons) was found at many stations both within and outside the disposal footprint.

Based on the findings of the 2003 TLDS survey, the following recommendations are offered:

R1) TLDS should be monitored periodically until disposal site conditions approach ambient (i.e., reference area) conditions. Specifically, in addition to standard SPI parameters, the presence of sulfur-reducing bacterial colonies and sediment banding (alternating oxidized/reduced laminar horizons) should be monitored throughout Union River Bay. Reference areas should be established to the north, south, west, and east at least 200 m away from the nearest detectable dredged material and surveyed with randomized sampling within a defined area. Additional reconnaissance stations can be established along transects from the disposal site to evaluate gradients in benthic conditions due to disposed material.

R2) Following the completion of the presently on-going dredging projects, the potential for more severe impacts at and around the site should be carefully evaluated prior to future use of TLDS.

6.0 REFERENCES

Diaz, R.J.; Rosenberg, R. 1995. Marine benthic hypoxia: A review of its ecological effects and the behavioural responses of benthic macrofauna. Oceanogr Mar Bio: an Annual Review 33: 245–303.

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

Germano, J.D. 1983. High resolution sediment profiling with REMOTS® camera system. Sea Technol. 24:35-41.

Germano, J.D. 2003. Designing borrow pit CAD sites: Remember Newton's Third Law! In: Randall, R.E., ed. Proceedings of the Western Dredging Association Twenty-Third Technical Conference. June 10–13, 2003, Chicago, Illinois. CDS Report No. 376. Center for Dredging Studies, College Station, TX. pp. 302–312.

Germano & Associates. 2003. Sediment-profile imaging survey at Oguz Oil Platforms, Caspian Sea, September 2002. Report to Battelle Ocean Sciences.

Germano, J.D.; Parker, J.; Charles, J. 1994. Monitoring Cruise at the Massachusetts Bay Disposal Site, August 1990. DAMOS Contribution No. 92. U.S. Army Corps of Engineers, New England Division, Waltham, MA, 51 pp.

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

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

Karakassis, I.; Tsapakis, M.; Smith, C.J.; Rumohr, H. 2002. Fish farming impacts in the Mediterranean studied through sediment profiling imagery. Mar-Ecol Prog. Ser. 227:125-133.

McDowell, S.; May, B.; Pabst, D. 1994. The dioxin capping project at the NY Mud Dump Site. In: McNair, E.C., ed. Dredging '94: Proceedings of the Second International Conference on Dredging and Dredged Material Placement, ASCE/November 13–16, 1994, Lake Buena Vista, FL, pp. 1270–1277.

Nilsson, H.C.; Rosenberg, R. 1997. Benthic habitat quality assessment of an oxygen stressed fjord by surface and sediment profile images. J. Marine Syst. 11:249-264.

Revelas, E.C.; Germano, J.D.; Rhoads, D.C. 1987. REMOTS® Reconnaissance of benthic environments. Coastal Zone '87: Proceedings of the Conference, WW Div/ASCE/May 26–29, Seattle, WA, pp. 2069–2083.

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.; Germano, J.D. 1990. The use of REMOTS® imaging technology for disposal site selection and monitoring. In: Demars, K.; Chaney, R. eds. Geotechnical Engineering of Ocean Waste Disposal, ASTM Symposium Volume, January, 1989. Orlando, FL. pp. 50-64.

Rosenberg, R.; Diaz, R. J. 1993. Sulphur bacteria (Beggiatoa spp.) mats indicate hypoxic conditions in the Inner Stockholm Archipelago. Ambio 22:22–36.

Rosenberg, R.; Nilsson, H.C.; Diaz, R.J. 2001. Response of benthic fauna and changing sediment redox profiles over a hypoxic gradient. Estuar. Coast. Shelf S. 53: 343-350.

SAIC. 1988. Monitoring Surveys at the Foul Area Disposal Site, February 1987. DAMOS Contribution No. 64. U.S. Army Corps of Engineers, New England Division, Waltham, MA, 12 pp.

SAIC. 1990a. Monitoring Cruise at the New London Disposal Site, July 1987. DAMOS Contribution No. 66. U.S. Army Corps of Engineers, New England Division, Waltham, MA, 17 pp.

SAIC. 1990b. Monitoring Cruise at the Western Long Island Sound Disposal Site, November 1987. DAMOS Contribution No. 74. U.S. Army Corps of Engineers, New England Division, Waltham, MA, 90 pp.

SAIC. 1990c. Monitoring Cruise at the Massachusetts Bay Disposal Site, November 1988 - January 1989. DAMOS Contribution No. 73. U.S. Army Corps of Engineers, New England Division, Waltham, MA, 43 pp.

SAIC. 1994. Monitoring cruise at the Massachusetts Bay Dispsoal Site, August 1990. DAMOS Contribution #92.

SAIC. 2000. Survey of a proposed disposal site near Tupper Ledge in Union River Bay, Maine. Report to the US Army Corps of Engineers, New England Division, Contract No. DACW33-00-D-0001, Work Order 2, Task 2. SAIC Report Number 490, December 15, 2000.

SAIC. 2002. Monitoring Survey at the Tupper Ledge Disposal Site, August 2001. DAMOS Contribution No. 137 (SAIC Report No. 570). U.S. Army Corps of Engineers, New England Division, Concord, MA.

U.S. Army Corps of Engineers. 2000. Union River Ellsworth and Surry, Maine, Environmental Assessment Finding of No Significant Impact and Section 404(b)(1) Evaluation for Maintenance Dredging. Prepared by New England District, Concord, MA.

Appendix A

Disposal Barge Log Summary for TLDS
August 2001 to September 2003

Project Name: UNION RIVER
Permittee: CITY OF ELLSWORTH
Permit Number: 199803108

Disposal Date	Volume Disposed (yd^3)	Volume Disposed (m^3)	Disposal Latitude	Disposal Longitude	Distance from Buoy	Direction from Buoy
1/25/2002	200	153	44.46833	-68.44833	20ft	W
1/26/2002	200	153	44.46833	-68.44833	10ft	W
1/27/2002	200	153	44.46833	-68.44833	10ft	W
1/29/2002	180	138	44.46833	-68.44817	10ft	N
1/30/2002	140	107	44.46833	-68.44833	10ft	N
12/19/2001	220	168	44.46833	-68.44833		
12/25/2001	180	138	44.46833	-68.44783		
12/29/2001	250	191	44.46833	-68.44783		
12/31/2001	250	191	44.46833	-68.44733		
1/2/2002	250	191	44.46833	-68.44817		
1/4/2002	260	199	44.46833	-68.44850	20 FT	NW
1/6/2002	275	210	44.46833	-68.44867	10 FT	W
1/6/2002	275	210	44.46833	-68.44783	10 FT	E
1/8/2002	300	229	44.46833	-68.44833	10 FT	NW
1/9/2002	300	229	44.46833	-68.44833	10 FT	W
1/10/2002	300	229	44.46833	-68.44833	20 FT	W
1/11/2002	300	229	44.46833	-68.44833	5 FT	W
1/12/2002	280	214	44.46833	-68.44850	25 FT	W
1/12/2002	300	229	44.46833	-68.44833	20 FT	W
1/15/2002	275	210	44.46833	-68.44783	10 FT	E
1/18/2002	300	229	44.46833	-68.44833	10 FT	W
1/17/2002	200	153	44.46833	-68.44833	10 FT	W
1/19/2002	180	138	44.46833	-68.44833	20 FT	NW
1/21/2002	225	172	44.46833	-68.44833	20 FT	NW
1/22/2002	185	141	44.46833	-68.44833	10 FT	S
11/26/2002	300	229	44.46828	-68.44814	40	N
11/27/2002	200	153	44.46827	-68.44805	40	S
12/1/2002	200	153	44.46825	-68.44830	40	W
12/2/2002	200	153	44.46837	-68.44845	66	NW
12/3/2002	200	153	44.46850	-68.44797	30	NE
12/4/2002	220	168	44.46830	-68.44814	6	E
12/6/2002	280	214	44.46833	-68.44820	20	N
12/8/2002	300	229	44.46828	-68.44805	10	E
12/9/2002	280	214	44.46830	-68.44808	40	E
12/10/2002	260	199	44.46833	-68.44827	20	N
12/11/2002	260	199	44.46830	-68.44815	10	NE
12/12/2002	200	153	44.46818	-68.44817	20	SE
12/14/2002	200	153	44.46808	-68.44800	45	SE
12/15/2002	220	168	44.46825	-68.44804	5	E
12/16/2002	240	183	44.46824	-68.44805	15	E
12/17/2002	240	183	44.46833	-68.44838	65	WNW
12/18/2002	240	183	44.46838	-68.44832	40	N
1/13/2003	250	191	44.46830	-68.44833		
1/14/2003	230	176	44.46832	-68.44822		
1/15/2003	230	176	44.46820	-68.44817	25	SE
1/29/2003	230	176	44.46830	-68.44818	16	NE
1/31/2003	250	191	44.46825	-68.44805	30	E
2/1/2003	230	176	44.46828	-68.44817		
12/20/2002	250	191	44.46835	-68.44817	20	NE
12/21/2002	200	153	44.46808	-68.44805	40	SSE
12/22/2002	280	214	44.46818	-68.44833	30	SW
12/23/2002	200	153	44.46833	-68.44832	10	NW
12/24/2002	200	153	44.46832	-68.44822		

Project Name: UNION RIVER (Continued)
Permittee: CITY OF ELLSWORTH
Permit Number: 199803108

Disposal Date	Volume Disposed (yd^3)	Volume Disposed (m^3)	Disposal Latitude	Disposal Longitude	Distance from Buoy	Direction from Buoy
12/27/2002	300	229	44.46832	-68.44818		
12/28/2002	250	191	44.46818	-68.44812	20	SW
12/29/2002	250	191	44.46813	-68.44805	60	SE
12/30/2002	240	183	44.46825	-68.44794	60	E
1/1/2003	230	176	44.46813	-68.44828	40	SW
1/3/2003	220	168	44.46822	-68.44832	10	SW
1/6/2003	260	199	44.46825	-68.44812	12	E
1/7/2003	220	168	44.46842	-68.44833	40	NNW
1/8/2003	150	115	44.46832	-68.44814	20	NE
1/9/2003	220	168	44.46825	-68.44807	20	E
1/10/2003	240	183	44.46820	-68.44817	15	SE
1/11/2003	260	199	44.46822	-68.44804	10	E
1/12/2003	250	191	44.46833	-68.44817		
2/4/2003	220	168	44.46820	-68.44827		
2/5/2003	240	183	44.46840	-68.44817	50	N
2/6/2003	240	183	44.46825	-68.44808	20	E
2/8/2003	220	168	44.46830	-68.44825		
4/5/2003	230	176	44.46840	-68.44845	30 ft	NW
4/6/2003	240	183	44.46832	-68.44815		
4/7/2003	220	168	44.46827	-68.44797	25 ft	E
4/9/2003	220	168	44.46817	-68.44848		
4/11/2003	200	153	44.46833	-68.44835	20 ft	NW
4/14/2003	160	122	44.46832	-68.44803	20 ft	NE
4/15/2003	300	229	44.46833	-68.44822		
4/16/2003	280	214	44.46827	-68.44812		
4/17/2003	100	76	44.46817	-68.44837		
4/19/2003	250	191	44.46815	-68.44828	10 ft	SW
4/21/2003	220	168	44.46832	-68.44833		
4/22/2003	200	153	44.46832	-68.44815		
4/23/2003	180	138	44.46823	-68.44807	10 ft	E
4/25/2003	175	134	44.46830	-68.44803	15 ft	E
4/27/2003	100	76	44.46827	-68.44810		
Total Dredged Material Volume	19,700	15,062				

Project Name: UNION RIVER, ELLSWORTH, ME
Permittee: COE-ELLSWORTH ME
Permit Number: 2001C0002

Disposal Date	Volume Disposed (yd^3)	Volume Disposed (m^3)	Disposal Latitude	Disposal Longitude	Distance from Buoy	Direction from Buoy
2/5/2002	600	459	44.46852	-68.44812	21ft	NE
2/6/2002	500	382	44.46837	-68.44804	20ft	N
2/8/2002	450	344	44.46833	-68.44800	30ft	E
2/9/2002	450	344	44.46827	-68.44752	20ft	E
2/10/2002	525	401	44.46848	-68.44805	50ft	NW
2/11/2002	575	440	44.46827	-68.44778	30ft	E
2/12/2002	300	229	44.46877	-68.44763	100ft	N
2/13/2002	500	382	44.46783	-68.44759	180ft	ENE
2/15/2002	500	382	44.46817	-68.44756	75ft	SW
2/16/2002	400	306	44.46838	-68.44801	50ft	NW
2/18/2002	450	344	44.46777	-68.44780	50ft	S
2/19/2002	375	287	44.46788	-68.44728	100ft	SE
2/20/2002	400	306	44.46797	-68.44750	100ft	SE
2/23/2002	400	306	44.46770	-68.44801	75ft	S
2/24/2002	480	367	44.46770	-68.44736	100ft	S
2/25/2002	421	322	44.46843	-68.44787	100ft	NE
2/26/2002	485	371	44.46842	-68.44822	75ft	W
2/27/2002	516	395	44.46837	-68.44815	50ft	WNW
2/28/2002	600	459	44.46802	-68.44752	75ft	SE
3/1/2002	600	459	44.46850	-68.44820	75ft	NW
3/2/2002	520	398	44.46840	-68.44775	100ft	E
3/4/2002	421	322	44.46775	-68.44787	25ft	SW
3/5/2002	470	359	44.46778	-68.44778	75ft	S
3/6/2002	421	322	44.46850	-68.44835	35ft	WNW
3/7/2002	421	322	44.46847	-68.44775	75ft	NW
3/11/2002	421	322	44.46807	-68.44875	75ft	SW
3/12/2002	421	322	44.46853	-68.44828	75ft	W
3/13/2002	421	322	44.46838	-68.44830	75ft	NW
3/14/2002	325	248	44.46750	-68.44805	75ft	W
3/15/2002	390	298	44.46793	-68.44770	50ft	SE
3/16/2002	300	229	44.46770	-68.44798	75ft	W
3/17/2002	400	306	44.46768	-68.44810	100ft	S
3/18/2002	516	395	44.46832	-68.44825	25ft	W
3/19/2002	475	363	44.46835	-68.44817	25ft	W
3/20/2002	516	395	44.46848	-68.44832	50ft	W
3/21/2002	490	375	44.46835	-68.44808	25ft	W
3/22/2002	490	375	44.46770	-68.44778	75ft	SSW
3/25/2002	490	375	44.46768	-68.44781	50ft	SW
3/26/2002	550	421	44.46768	-68.44797	75ft	W
3/27/2002	325	248	44.46847	-68.44836	75ft	W
3/28/2002	400	306	44.46758	-68.44798	75ft	SW
3/29/2002	421	322	44.46855	-68.44805	50ft	E
4/2/2002	421	322	44.46807	-68.44755	75ft	N
4/3/2002	475	363	44.46843	-68.44823	50ft	E
4/4/2002	475	363	44.46790	-68.44767	50ft	E
4/5/2002	450	344	44.46858	-68.44797	50ft	E
4/6/2002	475	363	44.46840	-68.44778	75ft	W
4/8/2002	475	363	44.46857	-68.44781	100ft	E
4/9/2002	475	363	44.46855	-68.44845	75ft	W
4/10/2002	450	344	44.46745	-68.44820	100ft	W
4/11/2002	475	363	44.46840	-68.44832	50ft	W
4/12/2002	530	405	44.46855	-68.44833	75ft	W
4/13/2002	516	395	44.46853	-68.44822	50ft	W
4/14/2002	325	248	44.46747	-68.44840	100ft	W

Project Name: UNION RIVER, ELLSWORTH, ME (Continued)
Permittee: COE-ELLSWORTH ME
Permit Number: 2001C0002

Disposal Date	Volume Disposed (yd^3)	Volume Disposed (m^3)	Disposal Latitude	Disposal Longitude	Distance from Buoy	Direction from Buoy
4/15/2002	535	409	44.46840	-68.44798	25ft	W
4/16/2002	516	395	44.46857	-68.44850	25ft	W
4/17/2002	516	395	44.46793	-68.44775	25ft	SSW
4/18/2002	450	344	44.46795	-68.44780	75ft	
4/19/2002	470	359	44.46840	-68.44862	100ft	W
2/15/2002	600	459	44.46915	-68.44566	50ft	SW
Total Dredged Material Volume	27,760	21,224				

Project Name: UNION RIVER
Permittee: COE-ELLSWORTH ME
Permit Number: 2002C0026

Disposal Date	Volume Disposed (yd^3)	Volume Disposed (m^3)	Disposal Latitude	Disposal Longitude	Distance from Buoy	Direction from Buoy
11/7/2002	75	57	44.46820	-68.44818	50	N
11/7/2002	200	153	44.46818	-68.44791	50	E
11/5/2002	140	107	44.46822	-68.44863		
11/12/2002	290	222	44.46827	-68.44820		
11/13/2002	300	229	44.46793	-68.44825	100	
11/14/2002	200	153	44.46805	-68.44785	100	S
11/15/2002	300	229	44.46820	-68.44767	200	N
11/20/2002	375	287	44.46833	-68.44833	50	
11/21/2002	300	229	44.46847	-68.44795	100	E
11/21/2002	312	239	44.46802	-68.44788	100	SE
11/22/2002	250	191	44.46835	-68.44804	100	NE
11/25/2002	312	239	44.46832	-68.44825	50	N
11/26/2002	125	96	44.46827	-68.44820	50	E
11/26/2002	194	148	44.46763	-68.44872	50	EW
11/27/2002	312	239	44.46855	-68.44835	50	NE
11/27/2002	312	239	44.46832	-68.44850		
12/2/2002	300	229	44.46827	-68.44863		
12/2/2002	300	229	44.46840	-68.44836		
12/3/2002	300	229	44.46827	-68.44822		
12/3/2002	300	229	44.46830	-68.44836		
12/3/2002	312	239	44.46828	-68.44828		
12/4/2002	312	239	44.46833	-68.44891		
12/4/2002	312	239	44.46818	-68.44833		
12/4/2002	225	172	44.46843	-68.44822		
12/4/2002	312	239	44.46843	-68.44833		
12/5/2002	312	239	44.46838	-68.44830		
12/5/2002	312	239	44.46800	-68.44828		
12/6/2002	312	239	44.46838	-68.44814		
12/9/2002	312	239	44.46837	-68.44822		
12/9/2002	312	239	44.46833	-68.44833		
12/9/2002	150	115	44.46820	-68.44828		
12/10/2002	312	239	44.46830	-68.44797		
12/10/2002	312	239	44.46820	-68.44845		
12/10/2002	312	239	44.46843	-68.44691		
12/11/2002	312	239	44.46842	-68.44822		
12/11/2002	312	239	44.46798	-68.44891		
12/11/2002	312	239	44.46837	-68.44857		
12/12/2002	312	239	44.46813	-68.44838		
12/12/2002	312	239	44.46830	-68.44810		
12/12/2002	312	239	44.46835	-68.44808		
12/13/2002	312	239	44.46842	-68.44836		
12/13/2002	312	239	44.46815	-68.44818		
12/16/2002	312	239	44.46824	-68.44836		
12/16/2002	312	239	44.46817	-68.44846		
12/16/2002	312	239	44.46820	-68.44827		
12/17/2002	312	239	44.46824	-68.44830		
12/17/2002	312	239	44.46830	-68.44838		
12/17/2002	312	239	44.46818	-68.44862		
12/19/2002	50	38	44.46833	-68.44860		
12/20/2002	225	172	44.46825	-68.44835		
12/23/2002	312	239	44.46807	-68.44801		
12/24/2002	275	210	44.46808	-68.44817		
Total Dredged Material Volume	14,546	11,121				

Appendix B

Sediment-Profile Image Results for TLDS September 2003 Survey

Table B-1
Grain Size Scale for Sediments

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

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
CREF 1	A2	9/3/03	13:58:53	>4	>4 to 2	241.29	16.53	15.54	17.37	55.91	3.83	2.41	4.54	>20	O & R	N	1.83	P	No	74.57	5.11	74.57	5.11	N	Tan to gray, soft silt. Thin layer of black DM near SWI. Surface covered with mudclasts, most oxidized. Small void in lower left. Old Dm present too, and not included in the DM measurement.	1	11.09	11.75	11.42	Stage III	11
CREF1	B2	9/3/03	13:59:42	>4	>4 to 2	250.10	17.13	15.09	20.20	43.32	2.97	1.49	4.23	0	-	N	5.11	P	No	0.00	0	0.00	0	N	Tan to light gray silt. Large voids at right and oxidized sediment around shallow void and tear. High surface relief from biogenic mound. Organic sediment near SWI discontinuous and may be reworked DM.	2	7.69	>19.83	13.76	Stage I on III	9
CREF1	C2	9/3/03	14:01:57	>4	>4 to 3	215.20	14.74	14.43	15.09	41.68	2.86	1.89	3.80	1	R	N	0.66	B	No	124.53	8.53	67.12	4.6	N	Recent deposition which is interpreted to be both new and older DM over mottled olive-gray silt. Voids in lower right. Fine tubes and floccs at SWI. Organic particles in upper depositional layer which is measured as recent DM. Black mudclast (artifactual) at right SWI.	1	11.63	12.49	12.06	Stage I on III	9
I01	D2	9/3/03	10:52:46	>4	>4 to 2	205.83	14.10	13.71	14.66	25.76	1.76	1.03	2.29	2	O & R	N	0.94	P	No	126.60	8.67	80.26	5.5	N	Layered tan to gray to black silt. Top set of layers is recent DM whose bottom contact is upper portion of the faint relict RPD 4-6 cm below the SWI. Scattered organic particles in upper, new DM layer. Partial top-down recolonization. Fecal matter at SWI.3 distinct 2+ Dm layers in total DM package. Lower contact of old DM is bottom of black sediment band. The profile also shows features consistent with periodic anoxia. The distribution of distinct organic particles in the upper sediment column is consistent with DM deposition analogous to the DM seen at the center of the site.	0	0.00	0.00	0.00	Stage I	4
I01	E2	9/3/03	10:53:29	>4	>4 to 2	246.27	16.87	16.52	17.37	13.14	0.90	0.46	1.34	1	O	N	0.86	P	No	161.22	11.04	48.14	3.3	N	Gray, layered DM with thinly developed RPD. Both old and new DM with new DM being the topmost discrete layer of black sediment. Two large active voids at right within the old DM layer. RPD deepest above voids. Distinct small organic particle in surfial DM layer.	2	6.20	10.60	8.40	Stage I on III	7

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
I01	F2	9/3/03	10:54:21	>4	>4 to 2	235.33	16.12	15.34	17.00	16.69	1.14	0.34	1.74	3	R	N	1.66	P	No	155.15	10.63	65.30	4.47	N	Gray layered DM. Total Dm marked by lower contact of continuouis black band of sediment 2/3 down the frame. Recently depostied DM is lighter gray and has subtle contact with relict RPD 3-5 cm below the SWI. Large active void at right that is at old DM native contact. Large reduced mudclast at left SWI.	1	10.89	14.11	12.50	Stage III	7
I02	A1	9/2/03	15:22:17	>4	>4 to 2	300.19	20.56	20.26	20.77	39.50	2.71	1.94	2.97	0	-	N	0.51	B	No	104.92	7.19	104.92	7.19	Y	Recently deposited dark gray DM over light gray silt. DM/relict RPD contact easily seen. Two prominent active voids in center and lower left. Sediment below recent DM may have some older Dm but distinct signature is not there. RPD thickest above voids; slight trace of Beggiatoa colonies	2	7.74	17.06	12.40	Stage I on III	9
I02	B1	9/2/03	15:23:04	>4	>4 to 2	308.66	21.14	>21.12	>21.12	IND	IND	IND	IND	IND	-	N	IND	IND	No	129.01	8.84	129.01	8.84	N	Recently deposited DM over olive to gray silt. Overpenetrated slightly. Dm estimates are minimums. Void in mid right small and center. Both voids are sediment filled. Possible 2 cm thick layer of old DM below topmost relict RPD though this band of darker sediment is discontinuous.	2	>10.57	>13.11	11.84	Stage III	IND
I02	C1	9/2/03	15:23:53	>4	>4 to 2	288.48	19.76	18.51	20.83	IND	IND	IND	IND	0	-	N	2.31	P	No	169.94	11.64	100.43	6.88	N	Gray recently deposited Dm over older olive-gray DM over light gray silt/clay. Middle Dm layer is exceptionally fluid and is interpeted to be old DM. Surface disrupted from previous sampling. Two relict RPD present (new/old DM and old DM/native). Small organic particles in new DM.	0	0.00	0.00	0.00	Stage I	IND
I03	B1	9/2/03	15:29:18	>4	>4 to 2	304.29	20.84	20.26	21.03	IND	IND	IND	IND	0	-	N	0.77	P	No	146.26	10.02	38.03	2.6	N	OP. Layered DM with to 1-3 cm dark layer being recently deposited DM and Upper layer (top 8-10 cm) being older DM. Relict RPD easily discrnible between olf DM and native sediment. RPD disrupted but appears thin. Small organic particles in recent DM. Void is in lower left, is sediment filled and appears relict. Sediment in void is olive - not tan -similar to the relict RPD hue.	1	16.40	17.00	16.70	Stage I	IND

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
I03	D2	9/3/03	11:07:17	>4	>4 to 2	183.74	12.58	11.94	13.66	21.26	1.46	0.91	1.80	2	O	N	1.71	P	No	183.74	> 12.58	63.81	4.37	N	Layered Dm >P. Recent Dm is uppermost black layer and RPD. Two distinct relict RPD seens and DM is lyered on the 3-5 cm scale. Burrow structure in lower left and along left edge of image	1	5.92	12.17	9.04	Stage I on III	7
I03	E2	9/3/03	11:10:52	>4	>4 to 2	235.13	16.10	15.86	16.49	13.73	0.94	0.23	1.37	3	O	N	0.63	P	No	190.71	13.06	41.88	2.87	N	Layered gray and black DM. Three relict RPD discernible. Backfilled void in lower right corner. Total DM measured to to of bottommost relict RPD, although there may be be DM below the lower relict RPD it is not visible and out of frame of view. Rep B (overpenetrated) did not show any DM at great depth. Recent DM is topmost black layer and RPD. Note the presence of organic particles in the recent DM similar to other reps and stations.	1	13.83	15.51	14.67	Stage I on III	7
I03	G2	9/3/03	11:13:57	>4	>4 to 2	184.19	12.62	11.60	13.23	17.41	1.19	0.60	1.54	0	-	N	1.63	P	No	139.47	9.55	139.47	9.55	Y	Dark gray to black silty DM over gray silt. All DM is recentrly depsoited as there is no stratification within the DM unit. Small organic particles in upper part of the DM unit. Thinly developed RPD. Different from previos reps but simiar to upper portion of Rep B. Start of Beggiatoa colonies as surface (few small isolated strand/clumps scattered over SWI).	0	0.00	0.00	0.00	Stage I	3
I04	A2	9/2/03	15:35:06	>4	>4 to 3	208.07	14.25	13.66	14.95	38.00	2.60	2.20	2.94	0	-	N	1.29	P	No	51.09	3.5	51.09	3.5	N	Tan RPD and some faint, black recently deposited DM overlying homogeneous gray silt/clay with two voids in the center of the frame. Recent DM layer is almost fully obliterated by bioturbation and extends slight deeper than the RPD. Relict olive-hued RPD just slightly below present RPD. Small organic particles in thin slivers of black sediment and the RPD similar to the recent DM observed at Stations IO1-3.	2	9.37	10.57	9.97	Stage I on III	9

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
I04	B2	9/2/03	15:35:50	>4	>4 to 3	289.12	19.80	19.49	20.43	21.77	1.49	0.83	2.06	0	-	N	0.94	B	No	224.02	15.34	68.23	4.67	N	Recent gray to black Dm over thick layer of older DM and native sediments. Old DM/native contact is the relict RPD above the void at the bottom of the frame. Bottom of recent DM layer is the basal contact of the uppermost black sediment band. Old Dm has been reworked and depleted of organics but relict RPD remains. Nice Pic. Thinly developed RPD.	2	10.60	19.51	15.06	Stage III	7
I04	C2	9/2/03	15:36:36	>4	>4 to 3	271.12	18.57	17.89	19.11	45.88	3.14	2.12	3.60	0	-	N	1.23	P	No	181.07	12.4	92.96	6.37	N	Layer of reworked recent DM over older Dm over native gray silt. Old DM is very fluid and has fluid deformation features from prism penetration. Void in mid right and lower left. Mid right void is active. Two relict RPDs.	2	8.29	14.97	11.63	Stage III	10
I05	A2	9/2/03	15:42:14	>4	>4 to 3	298.62	20.45	19.77	20.77	18.14	1.24	0.71	2.00	0	-	N	1.00	B	No	27.72	1.9	27.72	1.9	N	Thin layer of black recent DM over very solft, water rich mottled olive to gray native sediment. Native sediment riddled with active voids. Several small tubes at SWI. Organics in top portion of sediment colmn and are realted to DM. Possible older DM 2-4 cm below fresh DM but signature, other than organic particles is obscured.	8	9.69	16.89	13.29	Stage I on III	7
I05	B2	9/2/03	15:42:57	>4	>4 to 3	280.27	19.20	18.26	20.09	11.13	0.76	0.37	1.03	7	R	N	1.83	P	No	188.00	12.88	Trace	0	N	Old Dm over hray silt. Relict RPD Visible at bottom of dark gray band. Old Dm very water rich. Trace new Dm with the distinct organic particles in the upper sediment column. Reduced mudclasts in SWI background.	0	0.00	0.00	0.00	Stage II	5
I05	C2	9/2/03	15:43:41	>4	>4 to 3	296.46	20.30	19.26	21.20	20.06	1.37	0.69	2.11	2	R	N	1.94	P	No	120.32	8.24	Trace	0	N	Old Dm with trace new DM overlying mottled gray silt. Large void in lower center and smaller voids in upper right. Organic particles in upper sediment column. Assuming the top layer is mostly old DM fue to the light gray homogeneous texture and the presence of some small organic particles.	4	5.94	15.92	10.93	Stage III	7

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
I06	D2	9/3/03	10:58:46	>4	>4 to 2	223.58	15.31	14.63	15.83	37.01	2.54	0.86	2.97	0	-	N	1.20	B	No	223.58	> 15.31	84.89	5.81	N	New DM with small organic particles ovewrlying layered old Dm with several relict RPDs. All Dm layers are laminar and 3-5 cm in thickness. Entire slide composed of DM. Rep A is OP'd and has DM to nearly the bottom of the frame. Two small voids/burrows in uppermost relict RPD.	2	6.11	7.14	6.63	Stage I on III	9
I06	E2	9/3/03	10:59:39	>4	>4 to 3	225.92	15.47	14.66	16.29	11.91	0.82	0.61	1.26	1	O	N	1.63	P	No	225.92	> 15.47	154.03	10.55	Y	Thick layer of black, fresh DM over older dark gray DM. Thin RPD. Reduced void at left but appears to be active. Strong contact between new and old DM. Beggiatoa cluster in center at SWI	1	3.69	6.06	4.88	Stage I on III	7
I06	F2	9/3/03	11:00:24	>4	>4 to 2	225.10	15.42	14.91	15.80	38.94	2.67	1.74	3.52	3	R	N	0.89	P	No	225.10	> 15.42	96.62	6.62	N	New DM over old light gray and black DM. Two relict RPDs. Fresh DM has abundant organic particles in the upper portion of the layer. Void at lower contact of new DM and uppermost relict RPD. Persistent layering suggesting slow bioturbation.	1	5.03	6.17	5.60	Stage I on III	9
I07	D2	9/3/03	11:03:03	>4	>4 to 2	169.62	11.62	11.40	12.17	41.87	2.87	2.23	3.06	0	-	N	0.77	B	No	169.62	> 11.62	131.90	9.03	N	Black to tan very organic new DM over gray to black old DM. Relict RPD near bottom of frame. Void/burrow at left. Thick RPD with abundant small tubes and fecal material. Upper portion of the new DM layer is enriched in terrestrial organic (detritus) particles. Note that the OP'd pics from Reps 1-3 show DM deposits on the order of 16+ cm.	1	6.20	7.00	6.60	Stage I on III	9
I07	E2	9/3/03	11:03:51	>4	>4 to 1	146.19	10.01	9.37	10.71	20.31	1.39	0.94	2.34	1	O	N	1.34	B	No	146.19	> 10.01	146.19	> 10.01	N	Fresh Dm that has two layers. Top layer black and has distinct organic particle/pulp component. Lower part gray silt/clay with minor organic particles. Thinly developed RPD.	0	0	0	0.00	Stage I on III	7
I07	F2	9/3/03	11:04:41	>4	>4 to 2	203.38	13.93	13.49	14.17	41.90	2.87	2.12	3.34	6	R	N	0.69	P	No	203.38	> 13.93	126.20	8.64	N	Thick layer of new DM over gray DM . Two relict RPDs. Laminar Dm deposites. Upper portion of new DM has abundant organic particles (terrestrial lignitic debris). Several rounded reduced mudclasts at the SWI. DM>P.	0	0	0	0.00	Stage I	5

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
I08	A2	9/2/03	14:53:25	>4	>4 to 1	200.98	13.77	12.51	14.91	26.90	1.84	1.14	2.46	0	-	N	2.40	P	No	200.98	> 13.77	200.98	> 13.77	N	Layered recent DM, relict RPD poorly developed. 6 cm of mixed sediment and pulp at bottom of frame. Small organic particles near SWI similar to other DM seen thus far. Void in upper right pulp layer and appears inactive.	1	8.57	9.20	8.89	Stage I on III	8
I08	B2	9/2/03	14:47:09	>4	>4 to 0	237.23	16.25	15.63	16.69	33.51	2.29	2.03	2.66	0	-	N	1.06	P	No	237.23	> 16.25	237.23	> 16.25	N	Layered recent DM. 10.7 cm of pulp at bottom of frame. Oranically loaded. Small organic particles in upper portion of the sediment column. Very faint relict RPD suggesting very little time between successive disposal events and the evaluation that all DM present is recent.	0	0	0	0.00	Stage I on III	9
I08	C2	9/2/03	14:58:00	>4	>4 to 0	233.94	16.02	15.66	16.40	12.06	0.83	0.40	1.20	2	O	N	0.74	B	No	233.94	> 16.02	233.94	> 16.02	Y	Very similar to reps A and B. >8.3 cm of pulp at bottom of frame. Thin RPD. Broken tubes at SWI,Beggiatoa clusters starting to form on surface	2	7.44	16.40	11.92	Stage I on III	7
I09	A2	9/2/03	14:46:38	>4	>4 to 1	303.58	20.79	20.29	21.00	42.86	2.94	2.57	3.23	0	-	N	0.71	B	No	210.21	14.4	175.23	12	N	New DM/old DM/native or old DM. Bottom of new DM material (2 layers) is the bottom of the browninsh pulp unit. Small distinct DM old layer is under pulp layer. Deep RPD and small organic particles in the upper portion of the newer DM layer.	0	0	0	0.00	Stage I on III	9
I09	B2	9/2/03	14:47:28	>4	>4 to 1	268.22	18.37	17.11	20.74	36.69	2.51	1.53	3.20	0	-	N	3.63	B	No	185.63	12.71	185.63	12.71	N	Recent DM over gray silt. Pulp layer at bottom contact of recent DM. Prominent burrow in center and void below. Abundant snmall organic particles in the upper sediment column.	1	4.17	5.60	4.89	Stage I on III	9
I09	C2	9/2/03	14:50:01	>4	>4 to 1	273.95	18.76	17.86	19.54	40.17	2.75	1.83	3.46	0	-	N	1.69	B	No	226.21	15.49	187.80	12.86	N	Recnt DM/old DM/gray silt/ Bottom contact between recent and old DM is bottom part of pulp layer. Recent Dm loaded with small organic particles and pulp. Faint relict RPD between pulp and band of black sediment.	3	5.11	16.40	10.76	Stage I on III	9
I10	A2	9/2/03	14:35:27	>4	>4 to 3	203.52	13.94	13.51	14.60	19.61	1.34	0.72	1.60	0	-	N	1.09	B	No	203.52	> 13.94	203.52	> 13.94	N	DM>P. Texturally, sediment has DM features with some light clays distributed in lower sediment column. Very large prominent void in center of frame. Few very fine tubes at SWI.	1	4.80	7.80	6.30	Stage I on III	7
I10	B2	9/2/03	14:36:17	>4	>4 to 2	217.46	14.89	14.63	15.09	12.96	0.89	0.46	1.60	0	-	N	0.46	B	No	129.44	8.87	68.47	4.69	N	Recent DM - dark gray over old DM -relict RPD and clots of light gray clay over gray silt. Void in left center. Fecal material at SWI. Old dm very thin layer.	1	5.91	8.14	7.03	Stage I on III	7

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
I10	C2	9/2/03	14:37:07	>4	>4 to 3	292.25	20.02	19.63	20.29	23.29	1.60	1.03	1.97	0	-	N	0.66	B	No	292.25	> 20.02	114.94	7.87	N	Layered recent and old DM over gray silt. Broad zone of relict RPD and old DM with two relict RPDs observable. Fine organics in upper sediment column.	0	0	0	0.00	Stage I	4
I11	A2	9/2/03	13:57:21	>4	>4 to 1	172.01	11.78	11.46	12.34	33.13	2.27	0.97	2.80	0	-	N	0.89	B	No	172.01	> 11.78	172.01	> 11.78	Y	Layered recent DM with a distinct pulp layer and a distinct gray cohisive clay layer. Tubes and start of fibrous Beggiatoa mats at SWI. Organic.	0	0	0	0.00	Stage I	5
I11	B2	9/2/03	13:58:46	>4	>4 to 1	104.17	7.13	6.60	7.60	36.91	2.53	1.80	3.29	0	-	N	1.00	B	No	104.17	> 7.13	104.17	> 7.13	Y	Organic recent DM with high degree of pulp and organic fibers with start of bacterial colony -- incipient anoxic conditions. Small tubes at SWI and some fiber fragments.	0	0	0	0.00	Stage I-II	6
I11	C2	9/2/03	13:59:39	>4	>4 to 1	150.07	10.28	9.86	10.63	74.16	5.08	4.57	4.97	0	-	N	0.77	B	No	150.07	> 10.28	150.07	> 10.28	N	Organic recent DM with high degree of pulp and organic fibers. Small tubes at SWI and some fiber fragments. Cohesive, refractory clay clast at bottom of frame. Chaotic fabric in subsurface. Thick, partly depositional RPD.	0	0	0	0.00	Stage I-II	8
I12	A2	9/2/03	14:06:53	>4	>4 to 0	136.76	9.37	8.80	9.63	51.98	3.56	1.86	4.23	0	-	N	0.83	B	No	136.76	> 9.37	136.76	> 9.37	Y	Organic recent DM with high degree of organic fibers and distinct pulp layer. Thick, partly depositional RPD, incipient Beggiatoa colony formation	0	0	0	0.00	Stage I	6
I12	B2	9/2/03	14:08:13	>4	>4 to 0	163.67	11.21	10.77	11.60	80.54	5.52	3.09	7.27	0	-	N	0.83	B	No	163.67	> 11.21	163.67	> 11.21	Y	Organic recent DM with high degree of organic fibers and distinct pulp layer. Thick, partly depositional RPD. Colonial bacterial strands at SWI	0	0	0	0.00	Stage II	9
I12	C2	9/2/03	14:09:11	>4	>4 to 0	200.75	13.75	13.52	14.06	38.52	2.64	1.74	3.26	0	-	N	0.54	B	No	200.75	> 13.75	200.75	> 13.75	Y	Organic recent DM with high degree of organic fibers and distinct pulp layer. Thick, partly depositional RPD, incipient Beggiatoa colony formation	0	0	0	0.00	Stage II-III	8
I13	A2	9/2/03	14:12:44	>4	>4 to 3	74.49	5.10	4.17	6.54	27.30	1.87	0.63	2.46	0	-	N	2.37	P	No	74.49	> 5.1		0	N	Hard cohesive gray clay with tan detritus coating. Abundant tubes at SWI and dense fecal material.	1	3.74	5.86	4.80	Stage I on III	8
I13	B2	9/2/03	14:15:42	IND	Ind.	0.00	0.00	0.00	0.00	IND	IND	IND	IND	IND	IND	N	0.00	NA	No	IND	IND		0	N	Hard bottom . No penetration.	IND	IND	IND	IND	IND	IND
I13	C2	9/2/03	14:16:40	IND	Ind.	0.00	0.00	0.00	0.00	IND	IND	IND	IND	IND	IND	N	0.00	NA	No	IND	IND		0	N	Hard bottom . No penetration.	IND	IND	IND	IND	IND	IND
I14	A2	9/2/03	14:21:43	>4	>4 to 1	227.37	15.57	14.74	16.17	27.42	1.88	0.97	2.99	0	-	N	1.43	P	No	227.37	> 15.57	227.37	> 15.57	Y	Recent DM with distinct pulp layer. Very dark sediment at bottom of frame. Fain relic RPD in upper sediment column. Beggiatoa formation starting at surface	2	3.11	13.37	8.24	Stage I on III	8

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
I14	B2	9/2/03	14:22:42	>4	>4 to 1	210.02	14.38	13.97	14.63	33.45	2.29	0.80	3.03	0	-	N	0.66	B	No	210.02	> 14.38	210.02	> 14.38	N	Recent DM with distinct pulp layer. Very dark sediment at bottom of frame. Fain relict RPD in upper sediment column. Void in upper left and upper right. Abundant fecal matter at SWI.	3	4.09	7.17	5.63	Stage I on III	9
I14	C1	9/2/03	14:24:39	>4	>4 to 1	289.89	19.86	17.34	21.11	13.10	0.90	0.00	1.63	0	-	N	3.77	P	No	289.89	> 19.86	150.29	10.29	N	Layered DM that is exceptionally rich in pulp. Lighter colored upper layeres are interpreted to be recent and lower dark gray to olive pulp layer is thought to be old. Division may be arbitrary. Stage 3 burrows at depth	0	0	0	0.00	Stage I on III	7
I15	A2	9/2/03	14:27:55	>4	>4 to 2	281.63	19.29	19.03	19.63	38.71	2.65	1.66	3.60	0	-	N	0.60	B	No	123.98	8.49	48.90	3.35	N	Layered old and new DM. Two relict RPDs. Voids at left and lowe left. And old voids/bioturbation at center of frame at lower relict RPD.	2	9.72	17.26	13.49	Stage I on III	9
I15	B2	9/2/03	14:28:48	>4	>4 to 2	301.27	20.63	20.09	21.11	24.42	1.67	0.77	2.00	0	-	N	1.03	P	No	30.18	2.07	30.18	2.07	N	Thin layer of recent DM over gray to ilive very soft silt/clay. Large void in lower right. Upper recent DM denoted by the presence of fime orgainc particles and faint black sediment immediately below the RPD.	1	14.86	16.95	15.90	Stage I on III	8
I15	C2	9/2/03	14:31:17	>4	>4 to 1	271.18	18.57	18.06	19.03	25.37	1.74	1.14	2.09	0	-	N	0.97	B	No	94.26	6.46	29.18	2	N	Thin layer of recent DM that has basal black sediment over gray older DM which is defined at the lower contact by a band of tan-green pulp over gray soft silt. Active void in center and lower left. Fine tubes and fecal strings at SWI.	2	7.03	13.12	10.07	Stage I on III	8
I16	A2	9/2/03	13:20:32	>4	>4 to 2	39.40	2.70	0.69	5.97	IND	IND	IND	IND	0	-	N	5.29	P	No	39.40	> 2.7	39.40	> 2.7	Y	Furrow in sediment. Abundant floccs on surface. Sliver at left indicates DM >P. Some tubes on SWI with Beggiatoa formation starting	0	0	0	0.00	Stage I	IND
I16	B2	9/2/03	13:21:20	>4	>4 to 1	128.85	8.83	7.89	9.37	51.90	3.55	0.69	4.77	3	O	N	1.49	P	No	128.85	> 8.83	128.85	> 8.83	N	Very organic recent DM with thick depositional RPD. Abundant pulp fragments interspersed throughout sediment column. Large mudclast in backgorund. Small active void in upper right.	1	3.92	4.57	4.24	Stage I on III	10
I16	C2	9/2/03	13:22:19	>4	>4 to 1	144.59	9.90	8.34	11.80	47.95	3.28	0.89	4.19	0	-	N	3.46	B	No	144.59	> 9.9	144.59	> 9.9	Y	Very organic recent DM with thick depositional RPD. Abundant pulp fragments interspersed throughout sediment column. Disruption of RPD at right. Pocket of pulp in lower left. Tubes and fecal strings at SWI; Beggiatoa colonies starting to form on SWI	0	0	0	0.00	Stage I on III	10

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
I17	A2	9/2/03	13:08:09	IND	Ind.	0.00	0.00	0.00	0.00	IND	IND	IND	IND	IND	IND	N	0.00	NA	No	IND	IND		0	N	Hard bottom . No penetration. Tubes and detritus in background and mantling hard object which are presumably rocks.	IND	IND	IND	IND	IND	IND
I17	E2	9/3/03	15:11:49	IND	Ind.	0.00	0.00	0.00	0.00	IND	IND	IND	IND	IND	IND	N	0.00	NA	No	IND	IND		0	N	Hard bottom . No penetration. Tubes and detritus in background and mantling hard object which are presumably rocks.	IND	IND	IND	IND	IND	IND
I17	F2	9/3/03	15:12:50	4-3	>4 to 1	62.35	4.27	3.57	5.20	40.51	2.77	1.29	3.14	0	-	N	1.63	P	No	62.35	> 4.27		0	N	Bedform. Very silty very fine sand. Cohesive clay DM at left but smeared. Tubes on bedform and mixed pulp in sediment column.	0	0	0	0.00	Stage I on III	9
I18	A2	9/2/03	13:00:58	>4	>4 to 1	292.18	20.01	19.54	20.37	39.61	2.71	1.66	2.63	0	-	N	0.83	B	No	292.18	> 20.01	139.09	9.53	Y	New DM over old DM. Two layers in the new DM unit. Pulp in both old and new DM. Old void in bottom right. Organic; Beggiatoa formation starting at SWI	1	14.31	14.83	14.57	Stage I on III	9
I18	B2	9/2/03	13:01:49	>4	>4 to 1	280.12	19.19	18.09	20.91	IND	IND	IND	IND	0	-	N	2.83	P	No	70.96	4.86	70.96	4.86	N	Recent DM over saturated, plastic gray silt with linear band of black organic sediment clots near bottom of frame. Possible DM but discontinuous. Surface disrupted. One active small void in lower right. Other voids appear inactive. Unusual.	4	12.54	17.43	14.99	Stage III	IND
I18	C2	9/2/03	13:02:42	>4	>4 to 1	291.04	19.93	18.57	20.51	34.18	2.34	1.57	2.69	0	-	N	1.94	P	No	291.04	> 19.93	165.14	11.31	Y	Very similar to Rep A in terms of strata. Abundant laminar bands of pulp; Beggiatoa present	1	15.87	16.15	16.01	Stage I on III	9
I19	A2	9/2/03	12:52:04	>4	>4 to 1	277.02	18.97	18.46	19.40	35.32	2.42	0.57	2.95	0	-	N	0.94	B	No	277.02	> 18.97	108.66	7.44	N	New Dm over old DM. Bottom contact of recent DM is relict RPD just above clots of pulp in the center of the frame. Two voids at the left of frame and two small tubes at SWI.	2	6.34	11.49	8.91	Stage I on III	9
I19	B1	9/2/03	12:52:54	>4	>4 to 1	307.21	21.04	20.80	>21.09	IND	IND	IND	IND	IND	IND	N	IND	NA	No	307.21	> 21.04	107.31	7.35	Y	Black new DM over old olive, pulp rich DM. Distinct RPD in upper-mid sediment column is contact between recent and older DM. Void in upper center and left-center of sediment column. Beggiatoa dragged down in upper surface layer, so definitely present	2	7.63	11.37	9.50	Stage III	IND
I19	C1	9/2/03	12:53:53	>4	>4 to 1	>21.03	>21.03	>21.03	>21.03	IND	IND	IND	IND	IND	IND	N	IND	NA	No	204.21	13.99	44.55	3.05	Y	OP. New DM over older DM with pulp over native. Large voids in native sediment in lower left. Bright upp relict RPD ids contact between recent and older DM; Beggiatoa strands also dragged down in upper layer, so colonies are present here	3	>7.09	>19.66	13.38	Stage III	IND

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
I20	A2	9/2/03	12:41:14	>4	>4 to 3	283.14	19.39	19.06	19.71	47.01	3.22	2.54	3.40	0	-	N	0.66	B	No	153.22	10.49	56.09	3.84	N	Recent DM and some older DM in laminar deposits over uniform gray silt. Large void in lower right. Scattered organic particles and pulp in upper sediment column. Several fine tubes and some fecal string at SWI.	1	18.03	18.63	18.33	Stage I on III	10
I20	B2	9/2/03	12:42:05	>4	>4 to 3	251.53	17.23	16.29	18.49	54.68	3.74	2.20	5.80	0	-	N	2.20	B	No	Trace	IND	Trace	0	N	Tan soft silt with prominent depression at center SWI from large macrofaunal burrow. Minor organic particulates in upper sediment column which denotes the trace DM. Discrete deposits of DM are either not present or have been obscured by bioturbation/RPD, {Patch of organic sediment at right but is discontinuous	0	0	0	0.00	Stage I on III	10
I20	C2	9/2/03	12:42:58	>4	>4 to 3	284.76	19.50	18.54	19.94	19.00	1.30	0.71	1.37	0	-	N	1.40	P	No	88.74	6.08	88.74	6.08	N	Tan to gray soft silt/clay. Thin layer of DM at top whose lower contact is denoted by black band of sediment. Relict RPD underlies this sediment. Unclear whether this is new or old DM. Large fleshy polychaete in lower left. Several small tubes and fecal material at SWI.	0	0	0	0.00	Stage I on III	7
I21	A2	9/2/03	11:28:19	>4	>4 to 1	255.51	17.50	16.14	18.74	17.67	1.21	0.61	1.77	0	-	N	2.60	P	No	255.51	> 17.5	166.95	11.43	N	Tan to gray, layered silt. DM >P. Thin RPD with organic and pulp fragments near SWI. Active voids in upper right and lower mid frame. Relict RPD just below SWI and 2/3 down frame. Recent DM measured from lower relict RPD to SWI. Rep B is OP and has DM >P and sediment below lower relict RPD is considered DM. Nice pic.	2	6.40	14.74	10.57	Stage III	7
I21	D2	9/2/03	12:16:16	>4	>4 to 1	272.37	18.66	17.63	19.63	42.58	2.92	2.17	3.37	0	-	N	2.00	B	No	272.37	> 18.66	272.37	> 18.66	N	Layered tan to gray to black organic silt. Distinct pulp layer 5.8 to 8.7 cm below SWI. Lack of distinct relict RPD suggests that entire sediment column is recently or successively deposited layers of DM. Burrow in center of frame. Small tubes at SWI. Layering is distinct and striking.	1	10.32	13.20	11.76	Stage I on III	9

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
I21	E1	9/2/03	12:16:50	>4	>4 to 1	276.30	18.92	18.60	19.14	41.83	2.87	2.26	3.17	0	-	N	0.54	P	No	276.30	> 18.92	276.30	> 18.92	N	Layered tan to gray to black dredged material. Thick band of pulp 6.1 to 10.9 cm below SWI. No relict RPD that appeared to be stable for a period of time, suggesting that all DM is recent or recently successively deposited. Void at mid right and lower center. Few small tubes at SWI. Similar to D1. MC at surface artifacts of sampling.	2	12.43	16.06	14.24	Stage I on III	9
I22	D2	9/2/03	12:06:56	>4	>4 to 1	178.91	12.25	12.06	12.51	25.14	1.72	0.94	2.17	3	O	N	0.46	P	No	178.91	> 12.25	178.91	> 12.25	Y	Dark gray to black recently deposited DM. Few small tubes at SWI and some fecal material. Start of incipient beggiatoa at left SWI. Thick accumulation of mixed silt and pulp at bottom of frame. High SOD. Worm in lower right quadrant against camera faceplate. Burrows	0	0	0	0.00	Stage I on III	8
I22	E2	9/2/03	12:07:47	>4	>4 to 1	187.98	12.87	12.51	13.57	29.21	2.00	0.61	2.63	6	3O & 3R	N	1.06	P	No	187.98	> 12.87	187.98	> 12.87	Y	Dark gray to black recently deposited DM. Few small tubes at SWI and some fecal material. Thick accumulation of mixed silt and pulp at bottom of frame. High SOD. Both natural and artifactual mudclasts at SWI. RPD appears partly depositional., Beggiatoa starting on SWI. Burrows	0	0	0	0.00	Stage I on III	8
I22	F2	9/2/03	12:11:00	>4	>4 to 1	189.66	12.99	12.91	13.11	27.26	1.87	0.94	1.89	0	-	N	0.20	B	No	189.66	> 12.99	189.66	> 12.99	Y	Dark gray to black recently deposited DM. Incipient beggiatoa at SWI. Thick accumulation of mixed silt and pulp. Very high SOD. Few small tubes at SWI. Similar to reps D and E.	0	0	0	0.00	Stage II	6
I23	A2	9/2/03	11:59:06	>4	>4 to 2	289.83	19.85	19.14	20.60	34.28	2.35	0.89	3.00	0	-	N	1.46	B	No	175.71	12.03	77.76	5.33	Y	Layered recently deposited and older DM over native gray silt. Holothurian in lower center of frame and this is measured as void. Recently deposited DM is defined at bottom by organic particle/pulp band over a distinct relict RPD. Another distinct relict RPD is 2/3 down the frame and demarcates old DM from presumed native sediment. Whitish material at far left SWI is beggiatoa or thiobacilli cluster	1	15.20	16.51	15.86	Stage I on III	9

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
I23	B1	9/2/03	12:01:16	>4	>4 to 2	307.32	21.05	>21	>21	IND	IND	IND	IND	IND	IND	N	IND	IND	No	164.63	11.28	49.28	3.37	N	Overpenetrated. Layered new and old DM over native silt. Recently deposited DM is demarcated at its lower bound by organic particles/pulp. Older DM consists of light gray silt underlain by an organic layer and a relict RPD. Sediment in lower half of frame appears native and is mottled tan/olive/gray.	0	0	0	0.00	IND	IND
I23	C1	9/2/03	12:02:10	>4	>4 to 2	308.04	21.10	>21.09	>21.09	IND	IND	IND	IND	IND	IND	N	IND	IND	No	263.63	18.06	68.24	4.67	N	Overpenetrated. Recently deposited DM over older DM over presumably native. Recent DM demarcated by organic particle/pulp layer. Older DM is layered gray and black, organic silt. Void at right.	1	>10.03	>11.80	10.92	Stage III	IND
I24	A1	9/2/03	12:25:46	>4	>4 to 3	302.00	20.68	19.89	21.11	IND	IND	0.29	1.63	IND	IND	N	1.23	B	No	140.47	9.62	IND	IND	N	Dredged material - gray and black-, over mottled olive-gray and gray silt. Slightly overpenetrated in upper right. Some layering in DM, and upper portion of sediment column near SWI enriched in organic particles.	0	0	0	0.00	Stage I-II	IND
I24	B1	9/2/03	12:30:27	>4	>4 to 3	308.66	21.14	>21.06	>21.06	IND	IND	IND	IND	IND	IND	N	IND	IND	No	150.86	10.33	IND	IND	N	Overpenetrated. Soft, layered DM over native silt. Bottom of DM is Medium to dark gray silt layer/ Large, active void at bottom of DM layer and small void to the right of large void. Bioturbation is starting to obscure DM signature.	2	>7.74	>13.66	10.70	Stage III	IND
I24	C1	9/2/03	12:31:19	>4	>4 to 3	296.81	20.33	19.29	20.86	IND	IND	1.40	2.60	0	-	N	1.57	B	No	139.00	9.52	IND	IND	N	Dark and light gray DM over mottled light olive gray and tan silt. Very fluid mud subsurface. Large gray artifact at upper left that obscures RPD and portion of dredged material. Three small voids, two in lower mid-left and one upper right of frame. Tube at upper right SWI.	3	8.37	14.09	11.23	Stage I on III	IND
I25	A1	9/2/03	12:34:52	>4	>4 to 2	308.15	21.11	>21.11	>21.11	IND	IND	IND	IND	IND	IND	N	IND	IND	No	205.24	14.06	IND	IND	N	Overpenetrated. Layered dredged material over olive-gray native silt. Minimally three layers of DM. Cannot discern the extent of recent vs. older DM. Large active void/burrow in upper center of frame.	1	>1.51	>3.60	5.11	Stage III	IND

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
I25	B2	9/2/03	12:35:57	>4	>4 to 3	264.93	18.15	17.97	18.31	9.07	0.62	0.43	1.11	0	-	N	0.34	B	No	98.51	6.75	26.57	1.82	N	Thin layer of recently deposited DM over older DM over bioturbated olive to gray native sediment. Several active voids with oxidized sediment. Many very small fine tubes at SWI. Two distinct relict RPDs: one under the present RPD/SWI interface and one 1/3 down the frame. Nice pic.	4	6.94	15.75	11.35	Stage I on III	6
I25	C1	9/2/03	12:36:44	>4	>4 to 2	306.90	21.02	20.74	21.11	32.09	2.20	1.49	2.31	0	-	N	0.37	B	No	132.78	9.09	39.73	2.72	N	Thin layer of recently deposited DM over older DM over bioturbated olive to gray native sediment. Two active voids with oxidized sediment. Recent DM marked by the presence of discrete dark, organic particles. Two distinct layers in the older DM unit. Voids at the base of the relict RPD denoting the start of native sediment. Slight overpenetration in the upper right portion of the frame.	2	9.60	11.77	10.69	Stage III	8
O01	A2	9/3/03	10:31:25	>4	>4 to 3	231.47	15.85	14.57	16.66	22.43	1.54	0.52	1.94	2	R	N	2.09	P	No	36.04	2.47	36.04	2.47	N	Layered with top layer having DM based on the presence of discrete organic particles. Only very thin top layer interpreted to be recent. Void in upper center and two voids near bottom of frame. Nice shot of layering. Sediment column shows evidence of periodic low DO/anoxia which is also superimposed on DM signature.	3	4.06	13.91	8.99	Stage III	8
O01	B2	9/3/03	10:32:17	>4	>4 to 3	215.79	14.78	14.43	15.09	26.85	1.84	0.92	2.77	5	R	N	0.66	P	No	60.50	4.14	60.50	4.14	N	Thin layer of dark gray to black recent DM over gray, more clay-rich sediment. Large void in right center of frame with oxidized halo. Reduced mudclasts at the SWI appear artifactual. Nice contact between DM and underlying sediment. Distinct organic particles in DM layer.	1	6.43	10.86	8.64	Stage III	8

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
O01	C2	9/3/03	10:33:02	>4	>4 to 2	150.21	10.29	10.03	10.43	9.92	0.68	0.00	0.89	4	R	N	0.40	P	No	150.21	> 10.29	150.21	> 10.29	Y	DM>P. All dm may be recent DM. Any distinction is difficult between recent/old. Very dark and organic at right of frame. Whitish wisps at SWI may be incipient beggiatoa. Right of frame slightly disrupted in terms of fabric. Abundant organic material in lower right based on sediment parting features. The presence of layered organic material/pulp is indicative of DM presence. Very low DO/anoxia signature.	0	0	0	0.00	Stage I	2
O02	A2	9/3/03	11:51:57	>4	>4 to 3	188.45	12.91	12.60	13.09	28.85	1.98	1.09	2.49	1	O	N	0.49	B	No	99.79	6.83	99.79	6.83	N	Layered tan to gray to black DM. Layering is very distinct and contacts are continuous across frame. Small tube at left SWI. Recent DM is measured as the sediment above the relict RPD in the middle of the sediment column and the sediment above this relict RPD contains scattered organic particles or organics in linear bands across the frame. Evidence of historic and periodic low DO/anoxia.	0	0	0	0.00	Stage I	4
O02	B2	9/3/03	11:52:45	>4	>4 to 3	266.93	18.28	16.54	19.63	37.41	2.56	0.75	3.46	2	O	N	3.09	P	No	266.93	> 18.28	126.76	8.68	N	DM >P. Layered tan to gray to black DM. Layering is very distinct and contacts are continuous across frame. Recent DM is measured as the sediment above the relict RPD in the middle of the sediment column. Dark black band of very organic sediment below relict RPD. Mud appears to be very water-rich based on texture. Recent DM has scattered organic particles or organic particles in linear bands, suggesting DM. High surface relief appears to be natural.	0	0	0	0.00	Stage I	5
O02	C2	9/3/03	11:55:01	>4	>4 to 3	170.82	11.70	11.57	11.94	23.12	1.58	0.43	1.77	2	R	N	0.37	P	No	71.95	4.93	71.95	4.93	Y	Layered black and gray silt/clay with very thinly developed RPD. Reduced mud clast at SWI. Laminar band of DM near SWI. The DM contains distinct and discrete organic particles. The layers in the picture are intact suggesting little bioturbation. Possible incipient beggiatoa at SWI. Sediment column has record of period low DO/anoxia.	0	0	0	0.00	Stage I	4

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
O03	A2	9/3/03	11:59:47	>4	>4 to 3	188.64	12.92	12.54	13.11	24.72	1.69	0.91	1.77	1	O	N	0.57	B	No	38.88	2.66	38.88	2.66	N	Very thin layer of recent deposition, presumably DM, over gray silt. Thin band of dark sediment laden with organic particles separates present RPD from relict, olive-hued RPD. Void with some oxic halo in lower left. Few small tubes at SWI.	1	7.83	8.60	8.21	Stage I on III	8
O03	D2	9/3/03	12:18:46	>4	>4 to 3	192.19	13.16	13.03	13.40	31.90	2.18	1.26	2.60	1	O	N	0.37	B	No	0.00	0	0.00	0	N	Tan RPD with a band of olive sediment underneath RPD over mottled gray silt. If there is recent deposition it is obscured by present RPD. Voids in far left, lower left and lower right. Several intact and broken tubes at the SWI.	3	5.51	12.20	8.86	Stage I on III	8
O03	F2	9/3/03	12:22:30	>4	>4 to 3	131.07	8.98	8.71	9.29	36.84	2.52	0.83	3.26	0	-	N	0.57	B	No	0.00	0	0.00	0	N	Tan RPD overlying gray silt. Small sediment filled void at lower right. No oxidized sediment in void and appears relict. Few small tubes and some fecal string and broken tubes at SWI. Subsurface sediment is strikingly featureless.	1	5.74	6.20	5.97	Stage I	5
O04	A2	9/3/03	17:42:29	>4	>4 to 3	214.73	14.71	13.71	15.37	17.41	1.19	0.37	1.94	0	-	N	1.66	P	No	0.00	0	0.00	0	N	Three distinct units of sediment: one that consists of the RPD and an underlying band of gray sediment. Second unit is a band of olive-gray sediment (relict RPD) and the underlying band of dark gray sediment, Lastly there is a patch of gray sediment at bottom. The sediment from the relict RPD downward was interpreted to be old deposition. Large polychaete at right. The void # and min and max depths refer to the polychaete presence rather than an actual feeding void. Very thin, near-diffusional RPD.	1	4.94	8.00	6.47	Stage I on III	7
O04	B2	9/3/03	17:43:14	>4	>4 to 3	300.84	20.60	20.37	20.66	37.19	2.55	1.77	2.77	0	-	N	0.29	B	No	0.00	0	0.00	0	N	Water rich, mottled olive to gray to black silt/clay. Fluidization features. Subtle layering present but appears unrealted to DM disposal due to the absence of discrete organic particles. Several active voids with the majority of voids occurring in the dark gray/black organic-rich portion of the sediment column.	4	3.23	18.29	10.76	Stage I on III	9

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
O04	C2	9/3/03	17:43:53	>4	>4 to 3	276.16	18.91	18.51	19.34	25.88	1.77	0.89	2.23	10	O	N	0.83	P	No	36.79	2.52	36.79	2.52	N	Stratigraphically, very similar to Rep B but with thin layer of recent DM over mottled and fluid native sediment. Two large prominent voids at left. Native sediment shows mottling whereas the DM (or recent deposition) is texturally homogeneous and contains discrete organic particles immediately below the RPD.	2	8.80	14.17	11.49	Stage I on III	8
O05	A2	9/3/03	13:26:59	>4	>4 to 3	202.36	13.86	13.46	14.71	23.98	1.64	0.74	2.66	5	O	N	1.26	P	No	126.65	8.67	52.58	3.6	N	Dm over native. Thin layer of recent over older DM. Recent has faint band of dark sediment under RPD as lower bound whereas the old DM has a 1-2cm thick band of dark gray to black sediment as its lower bound. Oxidized void at lower left center.	1	10.09	10.63	10.36	Stage III	8
O05	B2	9/3/03	13:27:50	>4	>4 to 3	196.05	13.43	11.83	15.37	40.54	2.78	0.71	3.06	3	R	N	3.54	P	No	79.87	5.47	79.87	5.47	N	DM over native. Dm is marked at lower bound by a 1-2cm band of dark gray to black sediment. Cannot discern new from old DM. Planktonic detritus in RPD. Native sediment mottled.	0	0	0	0.00	Stage II	7
O05	C2	9/3/03	13:28:46	>4	>4 to 3	213.94	14.65	12.31	18.37	56.30	3.86	2.23	4.97	5	O	N	6.06	P	No	137.68	9.43	137.68	9.43	N	Layer of dark gray silt over light gray silt. Thick RPD and high slope across frame. Mudclasts in background. Layering is faint. Cannot discern old from new DM. Tubes at right SWI.	0	0	0	0.00	Stage II	9
O06	A2	9/3/03	13:49:17	>4	>4 to 3	227.83	15.60	14.80	16.11	31.13	2.13	1.12	2.91	1	R	N	1.31	P	No	88.37	6.05	88.37	6.05	N	DM or recent deposition over mottled gray silt (native). Layer appears to be DM and dark gray to black. Large reduced MC at SWI. Small void in upper left center. Some scattered organic particles in DM layer. Tubes and fecal strings at SWI. Nice contact between DM and native.	1	5.40	5.91	5.66	Stage I on III	8

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
O06	B2	9/3/03	13:51:41	>4	>4 to 3	193.07	13.22	12.71	13.77	43.06	2.95	1.60	3.17	0	-	N	1.06	B	No	50.43	3.45	50.43	3.45	N	Faint DM over native gray silt. DM or recent deposition is denoted by thin band of dark organic particles and a partially obscure relict RPD below the present RPD. Abundant very small, fine tubes at SWI. Cannot distinguish DM/deposition history due the faintness of the signature. No feeding voids, but worms at depth against faceplate and large burrow opening at surface just beyond plane of prsim penetration. The mixture of reduced sediments and oxidized, bioturbated sediment within the RPD suggest strong sediment-oxyben demand of the organics within the DM.	0	0	0	0.00	Stage I on III	9
O06	C2	9/3/03	13:52:38	>4	>4 to 3	223.85	15.33	14.43	16.57	34.42	2.36	1.66	2.69	1	R	N	2.14	P	No	134.77	9.23	66.65	4.56	N	Two distinct DM couplets of RPD/dark gray to black sediment, Upper layer is measured as recent DM. Artifactual black MC at left SWI. Voids in center and lower left of frame. Relict void at right center. Several tubes at SWI. Very nice stratigraphy in terms of DM lamination preservation. Both dark layers have scattered organic particles with the uppermost DM layer containg the greater concentration of organic particles. Possible historical/periodic low DO/anoxia.	3	6.83	13.09	9.96	Stage I on III	9
O07	E2	9/3/03	10:00:58	>4	>4 to 3	213.34	14.61	14.31	14.91	33.39	2.29	1.26	3.54	2	1 O & 1 R	N	0.60	B	No	68.73	4.71	68.73	4.71	N	Distinct recent DM layer consisting of an RPD and underlying band of dark gray to black sediment with discrete organic particles. Large oxidized MC at right and small reduced MC at left SWI. The overpenetrated Reps A,B,and C all show that mottled native sediment begins after the recent deposition couplet. Evidence of anoxia/low DO in the upper sediment column in terms of buried relict RPDs. The overpenetrated reps show, in the deepest portions of the sediment column, typical, relict mottled native silts without laminations associated with anoxia.	0	0	0	0.00	Stage I	5
O07	F2	9/3/03	10:01:46	>4	>4 to 3	205.20	14.05	13.06	14.66	44.64	3.06	2.63	3.66	0	-	N	1.60	P	No	58.41	4	58.41	4	N	Similar to Rep E2 but stratigraphy is less distinct and RPD obscures recent layer at left.	0	0	0	0.00	Stage I	6

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
O07	G2	9/3/03	10:02:32	>4	>4 to 3	242.90	16.64	16.34	17.03	52.20	3.58	2.63	3.97	1	O	N	0.69	B	No	141.52	9.69	85.08	5.83	N	Two distinct DM layers. Top layer measured as recent. Void in center of frame at Old DM relict RPD. Large oxidized MC in left background. Subsurface sediment appears water rich and has fluidization features. Thick RPD. Recent DM has been a consistently dark layer at this station. Both dark bands have a few scattered organic particles suggesting DM.	1	6.94	8.49	7.71	Stage I on III	10
O08	D2	9/3/03	10:06:33	>4	>4 to 2	206.29	14.13	13.77	14.32	17.60	1.21	0.54	1.74	1	R	N	0.54	B	No	123.05	8.43	54.19	3.71	N	Three distinct DM layers. Topmost recent layer has band of dark gray to black sediment. Middle band has a very thin faint relict RPD and lower DM layer has very distinct relict RPD underlain by a thin continuous band of black sediment. Topmost, recent DM layer flecked with organic particles. Signature of periodic low DO/anoxia superimposed on DM signature.	0	0	0	0.00	Stage I	3
O08	E2	9/3/03	10:07:23	>4	>4 to 3	82.98	5.68	3.83	10.77	IND	IND	IND	IND	3	R	N	6.94	P	No	IND	IND	IND	IND	N	Silt. Disturbed from previous sampling.	0	0	0	0.00	IND	IND
O08	F2	9/3/03	10:08:12	>4	>4 to 3	215.74	14.78	14.40	14.80	23.98	1.64	0.97	2.83	0	-	N	0.40	B	No	152.77	10.46	69.75	4.78	N	Two distinct DM layers. Upper layer measured as recent and has band of medium gray sediment overlying the relict RPD of the lower DM layer. Lower DM layer is marked by the present of a thick dark gray to black sediment layer. Large void complex at the New/Old DM interface. Discrete organic particles in both DM layers.	1	2.80	5.64	4.22	Stage III	8
WREF1	B1	9/2/03	16:45:49	>4	>4 to 3	303.60	20.79	20.09	21.23	39.40	2.70	2.00	3.83	0	-	N	1.14	B	No	48.11	3.3	48.11	3.3	Y	Bioturbated DM over mottled native silt. Distinct relict RPD in middle of frame as well as a discontinuous band of black sediment immediately overlying the relict RPD. Some reduced sediment near the SWI at left and possible incipient beggiatoa at left and center SWI. Large void/burrow near surface and oxidized sediment-filled void at center. Unusual. Very thin layer encompassing the RPD and reduced, black organic sediment immediately below RPD is interpreted to DM based on the presence of discrete organic particles.	2	2.03	14.09	8.06	Stage I on III	9

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
WREF1	D2	9/3/03	9:35:41	>4	>4 to 3	158.69	10.87	9.91	11.80	36.84	2.52	0.90	3.83	4	3O & 1R	N	1.89	P	No	44.63	3.06	44.63	3.06	N	DM or recent deposition over gray silt. Void at bottom center of frame. Clear layering although sediment does not appear as organically loaded as other stations. Band of organic particles immediately below or within RPD that is considered to be the lower bound of DM.	1	7.80	11.09	9.44	Stage I on III	9
WREF1	E2	9/3/03	9:36:26	>4	>4 to 2	193.42	13.25	12.60	13.74	34.42	2.36	0.94	3.29	5	O	N	1.14	B	No	50.19	3.44	50.19	3.44	N	DM. Bottom of the sediment column is possibly native sediment and measured as such. Large void complex running from center to lower right. Several mudclasts at SWI. Thin band bounded at bottom by continuous trace of black sediment is measured as recent DM/deposition. A distinct band of discrete organic particles can be seen under the RPD and this is the lower limit of DM. Reduced sediment being brought to surface above void/burrow. Some dark sediment near SWI at right .	2	1.20	9.40	5.30	Stage III	9
WREF1	F1	9/3/03	9:37:01	>4	>4 to 2	213.48	14.62	14.14	15.34	11.68	0.80	0.26	1.29	0	-	N	1.20	B	No	0.00	0	0.00	0	N	Recent deposition over gray silt. Two prominent voids at right that are likely from the same animal. Very thin RPD with clear definition at far left and far right. Clear contact for recent deposition. Faint signature of periodic past anoxia, although events due not appear extreme based on the reflectance of the sediment column.	2	5.86	14.09	9.97	Stage III	7
WREF7	A2	9/2/03	17:24:01	>4	>4 to 3	292.51	20.03	18.97	20.63	16.93	1.16	0.63	1.60	0	-	N	1.66	B	No	116.60	7.99	41.29	2.83	N	Three layers of recent deposition presumably DM, that are marked by RPD/relict RPD and gray/black sediment couplets. The dark layers in the upper sediment column contain discrete organic particles consistent with DM, and are especially apparent in the uppermost layer. The majority of subsurface sediment is mottled and water rich suggesting native. RPD thin. Void in lower left.	1	13.83	14.77	14.30	Stage I on III	7

Table B-2
Sediment-Profile Image Results for Inner and Outer Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
WREF7	D2	9/3/03	10:14:34	>4	>4 to 3	213.23	14.60	13.80	15.91	4.34	0.30	0.00	1.66	1	O	N	2.11	P	No	93.02	6.37	93.02	6.37	Y	Layered gray and black silt/DM with periodic anoxia. RPD exists only and a mudclast and beggiatoa at the SWI. Very unusual. Although there are large voids in the lower left corner of frame, there is minimal evidence of bioturbation - unless anoxia is the controlling factor on hue and overprints bioturbated sediment. Discrete organic particles in upper portion of the sediment column.	3	8.43	13.48	10.96	Stage III	6
WREF7	G2	9/3/03	11:42:49	>4	>4 to 3	156.82	10.74	10.23	11.20	19.99	1.37	0.69	1.63	0	-	N	0.97	B	No	62.86	4.31	62.86	4.31	N	Layered gray and black silt. Appears to be new and old DM. Evidence of anoxic lamination in recent DM. Voids at right and small tubes at SWI in left background.	2	3.83	10.00	6.91	Stage I on III	7

Table B-3
Sediment-Profile Image Results for Reference Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
CREF2	A1	9/3/03	14:07:10	>4	>4 to 2	221.95	15.20	14.46	15.86	69.39	4.75	3.20	4.43	2	O	N	1.40	P	No	0.00	0	0.00	0	N	Layered gray and tan silt. Upper layer appears to be organically enriched. Disruption of SWI . Voids with oxidized sediments throughout sediment column. Does not appear to be DM, but may reflect low DO conditions.	6	3.83	15.69	9.76	Stage III	11
CREF2	B2	9/3/03	14:10:00	>4	>4 to 1	188.78	12.93	12.11	14.11	50.28	3.44	1.37	5.71	>10	O	N	2.00	P	No	0.00	0	0.00	0	N	Organic, gray to olive silt with well-defined RPD. Two large voids in subsurface and biogenically reworked sediment at the SWI. Possibble relict RPD in area of voids.	2	6.37	11.29	8.83	Stage I on III	10
CREF2	C2	9/3/03	14:11:23	IND	Ind.	0.00	0.00	0.00	0.00	IND	IND	IND	IND	IND	IND	N	0.00	NA	No	IND	IND	IND	IND	N	Water shot no penetration.	IND	IND	IND	IND	IND	IND
CREF2	D2	9/3/03	14:14:23	>4	>4 to 2	216.72	14.84	14.71	15.03	98.02	6.71	4.23	8.43	1	O	N	0.32	B	No	0.00	0	0.00	0	N	Tan to gray layered silt with new deposit overlying older deposit with relict, olive rpd separating. Deep RPD and biogenically reworked. Tube at SWI. Very enriched in organics and sulfide reduction producing black banding under RPD.	0	0.00	0.00	0.00	Stage II	9
EREF1	B1	9/2/03	15:53:46	>4	>4 to 2	306.49	20.99	20.63	21.11	90.85	6.22	4.80	8.37	0	-	N	0.49	B	No	0.00	0	0.00	0	N	Tan to dark gray silt. Thick RPD and two oxidized voids in lower center and left. Subsurface sediment is very organic and reduced and mottled - not likely old DM.	2	15.31	19.37	17.34	Stage III	11
EREF1	C1	9/2/03	15:54:39	>4	>4 to 3	>21.17	>21.17	>21.17	>21.17	IND	IND	IND	IND	0	-	N	IND	IND	No	0.00	0	0.00	0	N	Overpenetrated. RPD >6.6 cm but SWI not present. Two oxidized voids. Clot of reduced sediment at left. High porosity silt.	2	>10.60	>16.49	13.54	Stage III	IND
EREF1	D2	9/3/03	14:29:39	>4	>4 to 3	213.53	14.62	14.20	14.89	84.61	5.79	4.60	6.54	>10	O	N	0.69	B	No	0.00	0	0.00	0	N	Tan to gray silt. Surface looks recently disturbed with diffusional contact. Mottled/patchy organic sediment at depth. Small void/burrow at lower right.	1	10.49	10.98	10.73	Stage III	11
EREF2	A2	9/2/03	15:59:39	>4	>4 to 3	265.97	18.22	16.91	19.17	80.57	5.52	4.32	5.97	1	O	N	2.26	B	No	0.00	0	0.00	0	N	Soft, tan to gray silt/clay. Deep RPD. Mottled, bigentically reworked subsurface sediment. Biogenic mound at right. Several oxidized voids in right center and shallow void upper left and burrow lower left. Highly bioturbated.	5	2.37	17.54	9.96	Stage I on III	11

Table B-3
Sediment-Profile Image Results for Reference Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
EREF2	C1	9/2/03	16:02:55	>4	>4 to 3	302.69	20.73	20.20	21.11	51.74	3.54	2.86	4.86	0	-	N	0.91	B	No	0.00	0	0.00	0	N	Very soft, tan to gray silt. Voids in upper left, center, and lower left. Organically mottling of subsurface sediment. Slight cake-better texture -water rich. Unusual patch of relict oxidized sediment at lower right. Patch of organic sediment near SWI. Does not appear to be DM but instead organically enriched native sediment. Thin band of reduced sediment in RPD which may indicate a short period of low DO conditions.	3	3.60	17.69	10.64	Stage III	10
EREF2	D2	9/3/03	14:35:41	>4	>4 to 2	208.34	14.27	13.54	14.77	58.48	4.01	2.97	5.77	0	-	N	1.23	B	No	0.00	0	0.00	0	N	Tan to gray silt with organics immediately under the RPD. Possible DM, but not enough supporting evidence but may also be farfield organic input or alternatively the record of a brief low DO period. Oxidized void in lower right. Biogenic mound in cener of SWI.	1	11.63	13.09	12.36	Stage III	11
EREF3	A2	9/2/03	16:16:27	>4	>4 to 2	280.16	19.19	17.23	20.34	36.57	2.50	1.17	4.80	0	-	N	3.11	B	No	0.00	0	0.00	0	N	Tan to gray, very soft silt. Thin RPD at SWI underlain by continuous or mixed-continuous band of black organic sediment. Biogenic depression at left - mound at right. Three voids with oxidized sediment - one under depression and two under mound - all active. Very fine tubes at SWI in background - secondary productivity around depression. Dark sediment may be interpreted to be thin DM but more likely due to low-DO conditions	3	9.80	15.40	12.60	Stage I on III	9
EREF3	B1	9/2/03	16:17:02	>4	>4 to 2	>21.11	>21.11	>21.11	>21.11	IND	IND	7.14	10.54	0	-	N	IND	IND	No	0.00	0	0.00	0	N	Very soft, tan to gray silt. Overpenetrated. Void at right. Mottled organics in subsurface sediment. Water-rich.	1	>7.69	>10.29	8.99	Stage III	IND
EREF3	E2	9/3/03	14:54:34	>4	>4 to 3	218.73	14.98	14.26	15.86	34.84	2.39	0.63	3.80	4	O	N	1.60	P	No	0.00	0	0.00	0	N	Tan to dark gray silt. Appears to be organic input into upper sediment column with possible periodic low DO conditions. Relict RPD visible. Subsurface sediment is also medium to dark gray, organic, and riddles with oxidized voids/burrows. Unusual fabric. Clearly disturbed and recolonized. Thin band of dark gray to black sediment within and immediately under RPD suggests low DO.	5	9.09	15.21	12.15	Stage III	9

Table B-3
Sediment-Profile Image Results for Reference Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
EREF6	A1	9/3/03	13:37:10	>4	>4 to 2	250.46	17.15	16.51	17.49	30.55	2.09	1.95	3.40	0	-	N	0.97	B	No	0.00	0	0.00	0	N	Tan to dark gray, layered, organic, silt. Relict RPD halfway down frame and at bottom of frame. Prominent burrow/void in right center to depth of penetration and expulsion of reduced sediment to SWI. Top layer interpreted to be recent episodic input of organic rich sediment coupled with periodic low DO conditions. No textural or sedimentary fabric features to indicate allochthonous sediment input such as DM.	1	2.83	17.37	10.10	Stage III	8
EREF6	B2	9/3/03	13:38:09	>4	>4 to 2	162.52	11.13	10.83	11.54	51.83	3.55	2.77	4.14	0	-	N	0.71	B	No	0.00	0	0.00	0	N	Tan to gray, organic silt with patch of organically enriched, black sediment at left. Active voids in center of sediment column and fine tubes and floccs at SWI. Very different from Rep A.	2	5.74	7.46	6.60	Stage I on III	10
EREF6	C2	9/3/03	13:38:58	>4	>4 to 3	280.72	19.23	16.40	21.20	92.67	6.35	4.00	7.86	17	O & R	N	4.80	P	No	0.00	0	0.00	0	N	Soft, organic, tan to gray silt. Two active voids at far right. Abundant small (<1cm) oxidized and reduced mudclasts at SWI. Mottled organic subsurface sediment. Few broken small tubes at SWI.	2	10.38	11.35	10.87	Stage I on III	11
EREF7	A2	9/3/03	12:28:06	>4	>4 to 3	188.27	12.89	12.51	13.17	33.81	2.32	0.51	3.23	1	O	N	0.66	B	No	0.00	0	0.00	0	N	Tan to gray silt without distinct layering. Void at center and left of sediment column. RPD at right appears diffusional and becomes thicker above voids. Small biogenic mounding above voids.	3	6.80	11.83	9.32	Stage I on III	9
EREF7	D1	9/3/03	12:59:21	>4	>4 to 2	187.64	12.85	12.60	12.97	32.64	2.24	0.72	3.46	0	-	N	0.37	B	No	0.00	0	0.00	0	N	Organic, tan to gray silt/clay. Void complex at right and void/burrow at lower left edge. Subsurface sediment is mottled with organics and has faint layering. Reduced subsurface sediment being expelled from right void complex.	4	2.40	10.71	6.56	Stage III	8
EREF7	E2	9/3/03	13:03:02	>4	>4 to 3	172.73	11.83	11.54	12.06	47.59	3.26	1.20	4.06	4	O	N	0.51	B	No	0.00	0	0.00	0	N	Organic, tan to gray silt/clay. Three voids/ void complexes in middle of sediment column. Abundant floccs and fecal material at SWI and in water column. Subsurface sediment is organic and mottled.	3	5.63	7.57	6.60	Stage I on III	10
EREF8	A2	9/3/03	13:09:09	>4	>4 to 3	168.25	11.52	11.14	12.00	49.35	3.38	3.00	4.29	0	-	N	0.86	P	No	0.00	0	0.00	0	N	Organic, tan to gray silt/clay. Faint banding from organi/sediment input. Does not appear to be DM. Void with reduced sediment in lower left. Fecal strings at SWI and in water column.	1	7.23	9.80	8.52	Stage I on III	10

Table B-3
Sediment-Profile Image Results for Reference Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
EREF8	B2	9/3/03	13:10:01	>4	>4 to 3	246.18	16.86	16.43	17.14	46.57	3.19	2.17	3.57	7	O & R	N	0.71	B	No	0.00	0	0.00	0	N	Organic, tan to dark gray silt/clay with large active void at right. Possible relict RPD 9.4 cm below SWI. Obvious organic/sediment input. Does not appear to be DM. Small MC at SWI and small tube in left center.	1	7.11	8.57	7.84	Stage I on III	10
EREF8	C2	9/3/03	13:12:07	>4	>4 to 3	247.53	16.95	16.29	17.23	30.23	2.07	0.54	3.20	0	-	N	0.94	B	No	0.00	0	0.00	0	N	Tan silt over gray silt over very dark gray, organically enriched sediment. Large void at bottom left of frame that has an oxidized halo. Floccs and a few fine tubes at the SWI. Possible layering in the upper sediment column but is indistinct.	1	12.60	15.31	13.96	Stage I on III	8
EREF9	B1	9/2/03	16:07:48	>4	>4 to 2	305.61	20.93	20.49	21.20	54.35	3.72	2.63	5.75	0	-	N	0.71	B	No	0.00	0	0.00	0	N	Very soft, tan to gray, organic, silt/clay. Feacal material at SWI and small tube. Void in upper right and large active void complex in lower left. Mottled organic sediment under RPD.	2	2.97	18.60	10.79	Stage I on III	10
EREF9	D2	9/3/03	14:40:41	>4	>4 to 3	197.34	13.52	13.17	13.91	61.46	4.21	2.83	4.60	1	R	N	0.74	P	No	0.00	0	0.00	0	N	Tan to dark gray silt/clay with band of black sediment immediately under RPD. This layer does not appear to be DM but may be other organic sediment input or a record of low DO/anoxia.. Olive relict RPD underlies black band in most of frame. Void/burrow with oxidized sediment at very bottom left. Reduced mudclast in center of frame.	1	12.31	13.43	12.87	Stage I on III	11
EREF9	F2	9/3/03	14:44:26	>4	>4 to 3	153.45	10.51	9.77	11.09	IND	IND	IND	IND	IND	IND	N	1.31	P	No	IND	IND		0	N	Disturbed from sampling and camera pulled out during deployment.	IND	IND	IND	IND	IND	IND
WREF1	B1	9/2/03	16:45:49	>4	>4 to 3	303.60	20.79	20.09	21.23	39.40	2.70	2.00	3.83	0	-	N	1.14	B	No	48.11	3.3	48.11	3.3	Y	Bioturbated DM over mottled native silt. Distinct relict RPD in middle of frame as well as a discontinuous band of black sediment immediately overlying the relict RPD. Some reduced sediment near the SWI at left and possible incipient beggiatoa at left and center SWI. Large void/burrow near surface and oxidized sediment-filled void at center. Unusual. Very thin layer encompassing the RPD and reduced, black organic sediment immediately below RPD is interpreted to DM based on the presence of discrete organic particles.	2	2.03	14.09	8.06	Stage I on III	9

Table B-3
Sediment-Profile Image Results for Reference Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
WREF2	A2	9/2/03	16:35:47	>4	>4 to 3	301.22	20.63	20.37	20.80	54.74	3.75	3.23	4.29	0	-	N	0.43	B	No	0.00	0	0.00	0	N	Depositional layer over fluid, mottle olive to gray silt. Void-oxidized sediment filled-at right. Several fine small tubes at SWI. Depositional layer is being reworked and does not appear to be recent. Thick RPD. Subsurface sediment shows banding that is likely related to periodic low DO events.	1	5.34	8.09	6.71	Stage I on III	10
WREF2	B2	9/2/03	16:36:32	>4	>4 to 3	276.67	18.95	18.17	19.46	37.38	2.56	1.92	3.03	0	-	N	1.29	B	No	0.00	0	0.00	0	N	Depositional layer over fluid, mottled olive to gray silt. Several fine small tubes at SWI. Depositional layer is being reworked and does not appear to be recent. Active sediment-filled void at lower right. Depositional layer denoted by dark band of sediment. Olive relict RPD can be seen below dark band of sediment. Subsurface sediment shows banding that is likely related to periodic low DO events.	1	16.09	17.20	16.64	Stage I on III	9
WREF2	E2	9/3/03	9:28:27	>4	>4 to 3	243.00	16.64	15.92	17.54	36.15	2.48	1.43	3.49	0	-	N	1.63	B	No	0.00	0	0.00	0	N	Very unusual. Homogeneous gray silt/clay/relict RPD-olive-, over dark gray and black silt. Unclear what the depositional history is. Obviously there has been sediment input due to the relict RPD but the light gray homogeneous sediment is atypical of recently deposited layers seen elsewhere in the survey area, Two void, mid-right and lower left. Dense tubes at the SWI. The two thin dark bands are likely relict artifacts of DO anoxia events.	2	10.74	16.32	13.53	Stage I on III	9
WREF3	A1	9/2/03	16:27:40	>4	>4 to 3	301.06	20.62	20.06	21.06	51.82	3.55	2.09	4.97	0	-	N	1.00	B	No	0.00	0	0.00	0	N	Soft, bioturbated tan to gray silt. Possible relict RPD in mid frame, but is discontinuous. Active void in far lower right corner. Abundant small tubes at the SWI.	1	20.51	21.03	20.77	Stage I on III	10
WREF3	B1	9/2/03	16:28:28	>4	>4 to 3	304.88	20.88	20.46	21.11	58.87	4.03	3.69	4.86	0	-	N	0.66	B	No	0.00	0	0.00	0	N	Very soft, water-rich tan to gray silt. Faint possible layering. Most of subsurface sediment is olive gray and mottled. Several small, fine tubes at SWI, edge of void at mid right edge of image. The faint possible layering is 12.1 cm below the SWI, and if it was layering due to deposition, it is not recent based on the obscurity of contacts.	1	6.80	7.52	7.16	Stage I on III	11

Table B-3
Sediment-Profile Image Results for Reference Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
WREF3	D2	9/3/03	9:15:38	>4	>4 to 3	177.01	12.12	11.51	12.80	51.52	3.53	1.63	5.03	0	-	N	1.29	B	No	0.00	0	0.00	0	N	Depositional layer over gray silt. Continuous, invaginated band of black sediment marks the bottom contact of the depositional layer. Void in upper center. Fecal pellets and a few fine tubes at SWI. Thick RPD. Material does not look like recent deposition.	1	4.17	5.09	4.63	Stage I on III	10
WREF5	A2	9/3/03	11:24:01	>4	>4 to 3	199.67	13.68	13.34	13.94	17.85	1.22	0.09	2.06	0	-	N	0.60	B	No	0.00	0	0.00	0	N	Dark gray to black recent sediment over layered older sediment. Thinly developed RPD and high SOD. Void in upper left, lower center, and far right. Nice pic. There appears to be both periodic deposition and periodic anoxia events. Classic signature of anoxia.	4	2.74	9.97	6.36	Stage I on III	7
WREF5	B2	9/3/03	11:24:48	>4	>4 to 3	216.78	14.85	14.06	15.57	5.80	0.40	0.20	0.63	0	-	N	1.51	P	No	0.00	0	0.00	0	N	Very thin RPD. Several layers and couplets in upper sediment column. Sediment shows features that are consistent with periodic anoxia (thin, alternating, dark and light layers), Appear to be both deposition and anoxia events.	2	13.09	15.20	14.14	Stage III	6
WREF5	E2	9/3/03	11:28:50	>4	>4 to 3	186.40	12.77	12.31	13.49	11.62	0.80	0.34	1.14	0	-	N	1.17	B	No	0.00	0	0.00	0	N	Deposition and periodic anoxia. Classic signature of anoxia, but need deposition due to the thickness of the banding and the lack of bioturbation. Active void in lower right. Fascinating.	1	11.54	12.03	11.79	Stage III	7
WREF6	A2	9/3/03	11:35:51	>4	>4 to 3	234.87	16.09	15.46	16.34	28.58	1.96	1.00	2.66	1	R	N	0.89	B	No	0.00	0	0.00	0	N	Recent deposition and possibly anoxia over gray silt. Appears to be some sediment input although it lacks the discrete organic particles associated with DM from the site. Several voids on left side of frame. Tube at left SWI. Layered.	5	3.77	14.89	9.33	Stage I on III	8
WREF6	B2	9/3/03	11:36:46	>4	>4 to 3	209.09	14.32	13.94	14.74	30.05	2.06	1.37	2.63	0	-	N	0.80	B	No	0.00	0	0.00	0	N	Layered with relict RPD in middle of sediment column. There also appears to be some signs of periodic anoxia also in terms of the fabric and hue changes within individual strata. Red algae at SWI. Burrow from surface to lower right. Interesting picture, good image to contrast with WREF5_E2.	1	0.00	13.48	6.74	Stage I on III	8

Table B-3
Sediment-Profile Image Results for Reference Stations at TLDS

Station	Rep	Date	Time	GrnSize Major Mode (phi)	GrnSize Range	Penetration Area (sq. cm)	Penetration Mean (cm)	Penetration Min (cm)	Penetration Max (cm)	RPD Area (sq. cm)	RPD Mean (cm)	RPD min (cm)	RPD max (cm)	# Mud Clasts	Mud Clast State (Ox or Reduced)	Methane	Boundary Rough (cm)	BR Process (phys/bio)	Low DO?	Total DM area (sq. cm)	Total DM Mean Depth (cm)	New DM Area (sq. cm)	New DM Mean Depth (cm)	Bacteria present?	Comments	# Feeding Voids	Feeding Void Min Depth (cm)	Feeding Void Max Depth (cm)	Feeding Void Mean Depth (cm)	Successional Stage	OSI
WREF6	C2	9/3/03	11:37:33	>4	>4 to 3	203.36	13.93	11.86	15.26	3.67	0.25	0.00	0.97	0	-	N	3.40	B	No	0.00	0	0.00	0	N	Recent deposition over medium gray silt. Recent deposition is medium to dark gray. RPD discontinuous and upper portion of the sediment column shows microlamination consistent with periodic anoxia. Bioturbated, reduced sediment at left. High SOD and very unusual in terms of sedimentary fabric.	0	0	0	0.00	Stage I	2
WREF8	D2	9/3/03	10:21:15	>4	>4 to 3	219.92	15.06	14.83	15.49	7.71	0.53	0.18	0.80	0	-	N	0.66	B	No	0.00	0	0.00	0	Y	Periodic anoxia - classic signature. Diffusional RPD and three distinct relict RPD in sediment column. Highly organic. Some beggiatoa near surface. Fascinating and rare image showing both depositional layering with clear anoxic overprinting.	2R	4.43	8.11	6.27	Stage I	2
WREF8	E2	9/3/03	10:22:10	>4	>4 to 3	232.32	15.91	15.71	16.31	30.20	2.07	1.69	2.43	1	R	N	0.60	B	No	0.00	0	0.00	0	N	Layered gray and black silt. Evidence of multiple depositional events and periodic anoxia. Organic particles scattered and not present in large quantity or in any syntactical realtionship with the sediment strata. Rounded reduced MC at left SWI. Fine tubes in background .	0	0	0	0.00	Stage I	4
WREF8	F2	9/3/03	10:25:09	>4	>4 to 3	197.87	13.55	12.97	14.00	9.57	0.66	0.29	1.09	5	R	N	1.03	P	No	0.00	0	0.00	0	N	Layered gray and black silt. Anoxia event overprinting. Void in lower center of frame. In some portions of the SWI the RPD is diffusional.	1	8.26	10.20	9.23	Stage III	6
WREF9	A1	9/3/03	16:51:05	>4	>4 to 3	294.34	20.16	18.80	21.26	16.13	1.10	0.66	1.54	0	-	N	2.46	P	No	0.00	0	0.00	0	N	Very soft, water-rich, faintly layered light gray to olive silt. Layering based on slight hue change and the change in porosity along a laminar contact. Fine tubes at left SWI. Appears to depositional layer.	0	0	0	0.00	Stage III	7
WREF9	B1	9/3/03	16:51:49	>4	>4 to 3	303.71	20.80	20.43	21.09	16.37	1.12	0.40	1.46	0	-	N	0.66	B	No	0.00	0	0.00	0	N	Very similar to Rep A.	0	0	0	0.00	Stage I	3
WREF9	C2	9/3/03	16:52:49	>4	>4 to 3	221.74	15.19	13.86	16.63	38.58	2.64	1.23	3.20	0	-	N	2.77	P	No	0.00	0	0.00	0	N	Disturbed at left side of frame; appears to be fluidized fecal pellets. Possible layering but disturbance obscures it at left.	0	0	0	0.00	Stage I	5

INDEX

anoxia, ix, 40, 51, 52, 58, 60, 62, 67
azoic, 18, 28, 63
bacteria, 37, 38, 49
Bacteria, 43, 52, 55, 60, 66
barge, 10
baseline, viii, ix, 14, 55, 56, 58, 61
bathymetry, 14, 15, 19, 29, 57
Beggiatoa, 40, 45, 52, 58, 60, 61, 62, 66
benthos, 26
Blue Hill Bay, 11
boundary roughness, 26, 33, 48
carbon, ix, 14, 60, 62
Caspian Sea, 58, 59, 65
density, 26
deposition, 51
disposal site
  Tupper Ledge (TLDS), viii, 10, 11, 12, 33, 63, 67
dissolved oxygen (DO), ix, 58, 59
Ellsworth, viii, 11, 15, 17, 57, 67
Federal Navigation Channel, 14
feeding void, 53
grain size, 14, 26, 33, 37, 38, 48, 49, 52
Gulf of Maine, 11, 15
habitat, 11, 15, 40, 56, 61, 63, 64, 66
hypoxia, ix, 52, 58, 60, 62, 65
hypoxic, ix, 40, 52, 56, 58, 60, 61, 64, 66
methane, 27, 28
Mound A, viii, 11, 13, 14, 29, 57, 63
Mound B, viii, 15, 29, 33, 57, 63
Organism-Sediment Index (OSI), 27, 28
reference area, 10, 15, 23, 48, 52, 57, 62, 63, 64
rock outcrop, 11
RPD, viii, 26, 27, 28, 33, 37, 38, 39, 40, 48, 49, 50, 52, 55, 56, 61, 62
sediment
  clay, 14, 33, 52
  cobble, 33
  sand, 33, 48, 52
  silt, 14, 33, 48, 52
sediment-profile camera, 33
sediment-profile imaging, viii, 11, 14, 15, 19, 23, 26, 34, 36, 41, 42, 43, 45, 51, 52, 53, 54, 57, 59, 60, 63, 65, 66
side-scan sonar, 11
successional stage, 26, 27, 28, 37, 38, 40, 44, 49, 55
temperature, 22
tide, 14
topography, viii, 15, 19, 22, 33, 57
Union River, viii, ix, 11, 14, 15, 17, 22, 23, 52, 62, 63, 64, 67