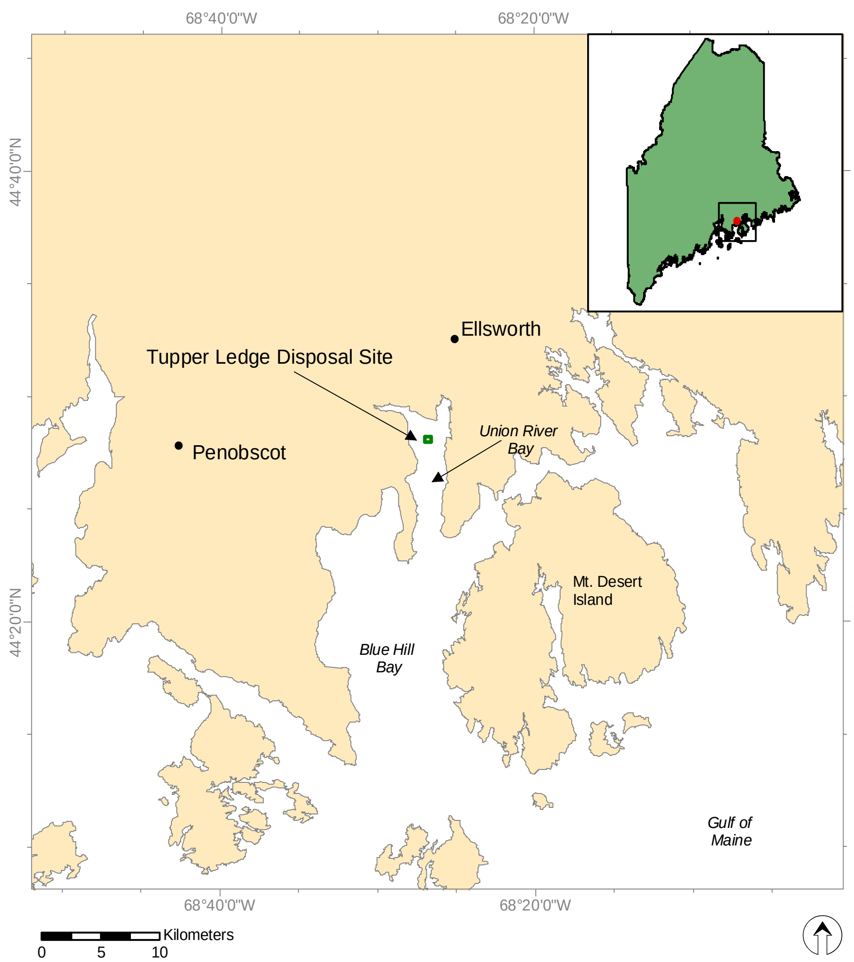
Monitoring Survey at the Tupper Ledge Disposal Site
Union River Bay, Maine
July/September 2005

Disposal Area Monitoring System DAMOS



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

The TLDS is an infrequently used dredged material disposal site located in the waters of eastern Maine, specifically in upper Union River Bay, approximately 5 km (3 miles) south of Ellsworth, Maine. Union River Bay drains the Union River and is connected to Blue Hill Bay and the Gulf of Maine to the south. The last disposal activity at TLDS occurred during April 2003 and a prior survey of the disposal site was conducted in September 2003. The 2003 survey found a new disposal mound (Mound B) and that the benthic recolonization was fairly advanced, but the presence of sulfur-reducing bacterial colonies and sediment banding indicated some organic enrichment and hypoxia. The 2005 bathymetry and SPI surveys were conducted to further evaluate and monitor the recovery of the site.

The bathymetric survey was initiated on 18 July 2005 aboard the R/V *Seahawk* and completed on 19 July 2005. Water depths at TLDS ranged from 12 to 15.5 meters (39-51 feet). Two disposal mounds were evident at TLDS. The deepest portion of the survey area was located northeast of the site where depths reached 18 meters (59 feet). Adjacent to this area was the shallowest point, which rose to about 3 meters (9.8 feet) below the water surface. Up to 0.5 meters (1.6 feet) of consolidation appears to have occurred over the disposal mounds.

The sediment-profile imaging survey was initiated 8 September 2005 aboard the *F/V Shanna Rose* and completed 9 September 2005. All the sediments at the disposal site stations were composed of high water content, low shear strength, fine-grained muds ($\geq 4\ \Phi$). Small-scale boundary roughness at the sediment surface ranged from 0.6 to 3.5 cm and the majority (75%) of the small-scale topographic roughness features was caused by burrowing/feeding activities of the resident macrofauna resulting in burrow openings or mounds/pits at the sediment-water interface.

Union Bay, including the Tupper Ledge Disposal Site, is still undergoing periodic hypoxia/anoxia events. Evidence for these hypoxic/anoxic periods included the persistence of laminated sediments in the reference areas, relatively shallow apparent RPD values, and the relatively small distances below the sediment-water interface at which the sub-surface laminations were detected.

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EXECUTIVE SUMMARY

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

The TLDS is an infrequently used dredged material disposal site located in the waters of eastern Maine, specifically in upper Union River Bay, approximately 5 km (3 miles) south of Ellsworth, Maine. [The NAD83 coordinates for TLDS are: Center: -68.4469, 44.4692; NW: -68.4501, 44.4714; SW: -68.4501, 44.4669; SE: -68.4438, 44.4669; NE: -68.4438, 44.4714.] Union River Bay drains the Union River and is connected to Blue Hill Bay and the Gulf of Maine to the south. The last disposal activity at TLDS occurred during April 2003 and a prior survey of the disposal site was conducted in September 2003. The 2003 survey found a new disposal mound (Mound B) and that the benthic recolonization was fairly advanced, but the presence of sulfur-reducing bacterial colonies and sediment banding indicated some organic enrichment and hypoxia. The 2005 bathymetry and SPI surveys were conducted to further evaluate and monitor the recovery of the site.

The bathymetric survey was initiated on 18 July 2005 aboard the R/V *Seahawk* and completed on 19 July 2005. Water depths at TLDS ranged from 12 to 15.5 meters (39-51 feet). Two disposal mounds were evident at TLDS. The deepest portion of the survey area was located northeast of the site where depths reached 18 meters (59 feet). The shallowest point, outside the site, rose to about 3 meters (9.8 feet) below the water surface across a shoal in the northeast corner of the survey area. Up to 0.5 meters (1.6 feet) of consolidation appears to have occurred over the disposal mounds.

The sediment-profile imaging survey was initiated 8 September 2005 aboard the *F/V Shanna Rose* and completed 9 September 2005. All the sediments at the disposal site stations were composed of high water content, low shear strength, fine-grained mud ($\geq$ 4 Φ). Small-scale boundary roughness at the sediment surface ranged from 0.6 to 3.5 cm and the majority (75%) of the small-scale topographic roughness features was caused by burrowing/feeding activities of the resident macrofauna resulting in burrow openings or mounds/pits at the sediment-water interface.

The dredged material present at all stations within the disposal site boundary was characterized by the presence of either high water-content reduced mud, a chaotic cross-sectional fabric with consolidated blue clay, the presence of wood chips, or rock and cobble. While there was no evidence of low dissolved oxygen in the overlying water or subsurface methane generation at the time of the survey, subsurface laminations indicative of past

hypoxic or anoxic events could still be detected at many of the stations surveyed at both disposal site and reference areas.

The mean apparent RPD values at the stations with past evidence of dredged material ranged from 0.7 to 2.8 cm. Only one station (I22) had evidence of any sulfur reducing bacterial colonies of *Beggiatoa* (occur only in low oxygen conditions) present at the sediment surface. This station and eleven others from the disposal site and five stations outside the disposal site had evidence of sulfur reducing bacteria in the 2003 survey (ENSR, 2004). Only four stations (Stations O-01, O-02, I17, and I21) of all those with dredged material present, had no evidence of any Stage 3 taxa (head-down, deposit-feeding invertebrates). Station I17 had rocks covered by a mantling of mud particles so camera penetration was poor at this location and no determination of infaunal successional stage could be made. Evidence of infaunal deposit feeding activities to depths greater than 10 cm was found at approximately half of the stations surveyed within the disposal site, with structures ranging from subsurface megafaunal burrows to feeding voids and vertical burrow structures.

The objective of the SPI survey was to assess the benthic community status within the site relative to reference conditions. Bioequivalence or interval testing was used with a null hypothesis that presumes the difference between the reference area and disposal mound is great (inequivalence). The test indicated that the true difference between the mean RPD values from the reference areas and mean RPD values from the disposal site was within 1 RPD unit (cm), and therefore the group means were equivalent within our definition of "ecologically meaningful". The test also found the true difference between the successional stage rank values from the reference areas and disposal mounds was within 1 unit, and therefore the group means were equivalent within our definition of "ecologically meaningful".

Union Bay, including the Tupper Ledge Disposal Site, is still undergoing periodic hypoxia/anoxia events. Evidence for these hypoxic/anoxic periods included the persistence of laminated sediments in the reference areas, relatively shallow apparent RPD values, and the relatively small distances below the sediment-water interface at which the sub-surface laminations were detected.

1.0 INTRODUCTION

A monitoring survey was conducted at the Tupper Ledge Disposal Site in July and September 2005 as part of the U.S. Army Corps of Engineers (USACE) New England District (NAE) Disposal Area Monitoring System (DAMOS). DAMOS is a comprehensive monitoring and management program designed and conducted to address environmental concerns associated with use of open-water disposal sites throughout the New England region. An introduction to the DAMOS Program and the Tupper Ledge Disposal Site, including a brief description of previous dredged material disposal activities and previous monitoring surveys at this site, is provided below.

1.1 Overview of the DAMOS Program

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

The DAMOS monitoring surveys are designed to test hypotheses related to expected physical and ecological response patterns following placement of dredged material on the seafloor at established disposal sites. 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 preformed to support evaluation of benthic habitat conditions.

1.2 Introduction to the Tupper Ledge Disposal Site

The Tupper Ledge Disposal Site (TLDS) is an infrequently used dredged material disposal site defined as a 500 x 500 meter (1640 x 1640 feet) area on the seafloor located in the waters of eastern Maine (Figure 1-1). TLDS is located in Union River Bay, approximately 5 km south of Ellsworth, Maine. Coordinates for TLDS (NAD83) are: Center: -68.4469, 44.4692; NW: -68.4501, 44.4714; SW: -68.4501, 44.4669; SE: -68.4438, 44.4669; NE: -68.4438, 44.4714. The center coordinates cited in the previous DAMOS report (SAIC 2002) were incorrectly reported. Those coordinates were based on the initial proposed center coordinates prior to any surveying at the site. Following the first bathymetric survey at the site a decision was made by the New England District to shift the site to the southwest to avoid the ledge area in the northeast. This change in site location was not reflected in the coordinates cited in SAIC (2002), although the graphic presentations in that report are centered on the -68.4469, 44.4692 location.

Tupper Ledge is influenced by freshwater inflow from Patten Bay and the Union River. 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, approximately 1500 meters (4921 feet) from land to the north, east and west.

During the 1800's Ellsworth was a major center for shipbuilding and lumber production. During the late 1800s and early 1900s disposal of dredged materials (shoal material, mill waste, and boulders) from maintenance dredging of the Union River area was placed at Tupper Ledge. Evidence of sawdust was found in the sediments at Tupper Ledge in samples taken decades after the last known disposal activity at the site (USACE 2000).

TLDS is characterized by a gently sloping seafloor. Water depths along the northern edge of the disposal site are approximately 14.5 meters (48 feet) Mean Lower Low Water (MLLW), sloping down to a depth of approximately 15.5 meters (51 feet) MLLW along the southern boundary of the disposal site. Two disposal mounds were evident at TLDS during the 2003 survey: Mound A, approximately 150 meters (492 feet) in diameter and 2.5 meters (8.2 feet) in height, was located in the center of the site and Mound B, approximately 120 meters (394 feet) in diameter and 2.5 meters (8.2 feet) in height, was located to the southwest. A small depression with a depth of approximately 19 meters (62 feet) was located northeast of the site, adjacent to the rock outcrop known as Tupper Ledge (ENSR 2004).

1.3 Recent TLDS Disposal Activity and Monitoring Events

TLDS was selected as a disposal site in 2000 to accommodate small to moderate volumes of sediment removed from the Union River. From January to April 2001, approximately 50,000 m^3 (65,398 cy^3) of dredged material from the Union River Federal Navigation Channel project was placed at TLDS, forming Mound A (SAIC 2002). Disposal activity between December 2001 and April 2003 from the Federal Navigation Project and the city of Ellsworth, resulted in the placement of approximately 47,000 m^3 (61,474 cy^3) of material from the Union River, to form Mound B. No further disposal activity has been recorded at TLDS since the previous survey in September 2003.

A baseline survey of the TLDS area was conducted by SAIC in March 2000 to determine the suitability of reactivating the site for the Federal maintenance dredging. The survey included bathymetry, sediment-profile imagery, sediment grab samples, and physical oceanographic measurements. The 2000 survey confirmed the depositional nature of the

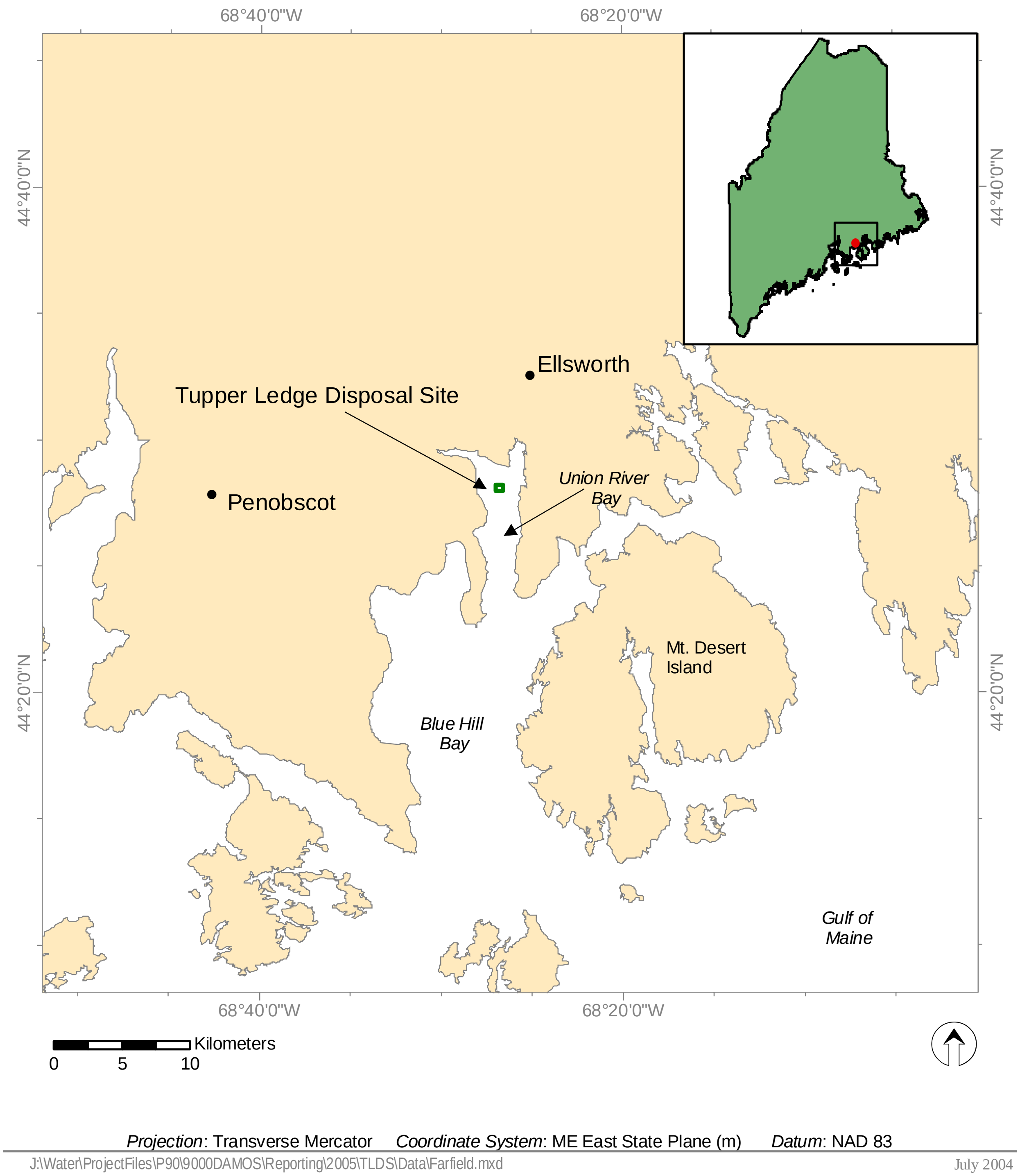

Figure 1-1. Location of the Tupper Ledge Disposal Site

area and recommended suitability of the site for disposal of dredged material.

A second survey was conducted August 2001 following initial disposal at TLDS. Survey activities included bathymetry and sediment-profile imagery to detect changes in seafloor topography, delineate spatial distribution of dredged material, and assess the benthic recolonization status following disposal activity. The 2001 bathymetric survey indicated the formation of Mound A in the center of the site. The SPI results indicated that benthic recolonization over the new disposal mound was apparently inhibited, with azoic conditions found at many stations in lieu of the expected early colonizing community. 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).

A third survey of TLDS was conducted September 2003 to document changes in seafloor topography, to assess benthic recolonization status in response to additional dredged material disposal activity, and to monitor the continued recovery of older dredged material disposal mound relative to nearby reference areas and previous survey results (ENSR 2004). A new disposal mound (Mound B) was evident from the 2003 bathymetric survey results. Mound B was approximately 2.5 meters (8.2 feet) in height and located to the southwest of Mound A. The infaunal community at TLDS was deemed to have made a dramatic recovery, compared with the poor biological conditions and slowed recolonization reported from the 2001 survey. All stations within the disposal site showed evidence of diverse biological invertebrate assemblages, consisting of both opportunist taxa as well as mature, deposit-feeding invertebrates. However, evidence of hypoxia both within and surrounding the disposal site suggested that disposal of organically enriched dredged material had stressed the system.

1.4 Survey Objectives

The Tupper Ledge Disposal Site was previously surveyed in September 2003 (ENSR 2004) and although benthic recolonization was fairly advanced, the presence of sulfur-reducing bacterial colonies and sediment banding indicated some organic enrichment and hypoxia. The 2005 bathymetry and SPI surveys were conducted to further evaluate and monitor the recovery of the site.

The objectives of the 2005 TLDS survey were to (1) document the distribution of dredged material and disposal mound morphology within Tupper Ledge Disposal Site using single-beam bathymetry and (2) assess the benthic recolonization status and indicators of hypoxia of the TLDS seafloor using sediment-profile imaging.

2.0 METHODS

A team of investigators from ENSR International, CR Environmental, and Germano and Associates performed the 2005 surveys at TLDS. The bathymetric survey was conducted 18-19 July 2005 to document the distribution of dredged material within TLDS. The sediment-profile imaging survey was conducted 8-9 September 2005 to assess the benthic status of TLDS.

2.1 Navigation and Data Acquisition

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

2.2 Bathymetry

The 2005 single-beam bathymetric survey was conducted over a 1000 x 1000 meter (3281 x 3281 feet) area, duplicating the 2003 and 2001 study areas (Figure 2-1). The survey was initiated on 18 July 2005 aboard the R/V *Seahawk* and completed on 19 July 2005. A total of 43 survey lines, each 25 meters (82 feet) apart, were occupied as part of the survey. Additional tie-lines were occupied perpendicular to the main survey lines to assess data quality.

2.2.1 Bathymetric Data Acquisition and Processing

The bathymetric data were collected using an Ocean Data Equipment Corporation (ODEC) MF500 precision echo sounder outfitted with a narrow (3°) beam 200-kHz transducer. The accuracy of this system was approximately 0.1% of the water depth, or approximately 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 using an In-situ® Troll 9000. Bathymetric data were recorded by means of a high-resolution trace on a thermal printer in addition to the digital data stored within Hypack®. Hypack® managed data acquisition and storage of data from the echosounder and the Trimble DGPS. In addition, Hypack® recorded depth, heading, position, and time along each survey transect line. Water depths were recorded in feet and referenced to a MLLW (mean lower low water) vertical datum based on local tidal water level data recorded at a project benchmark established on the western shore of Union River Bay using an In-Situ, Inc. Mini-Troll® pressure transducer. Once processed, the water depth data were converted to meters.

2.2.2 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 the contouring and surface plotting functionality of the GIS-based software package ArcInfo® 9.1. The processed TLDS 2005 data were gridded to a cell size of 12.9 x 12.9 meters, consistent with the bathymetric grid created for the previous (September 2003) survey. Once gridded, bathymetric contour lines were displayed using ArcInfo 9.1®.

ArcInfo 9.1® was used to calculate a depth difference grid based on the September 2003 and the July 2005 bathymetric data sets. This grid was calculated by subtracting interpolated depth estimates of July 2005 from the September 2003 depth estimates at each point throughout the grid. The resulting depth differences were contoured and displayed using ArcInfo 9.1®.

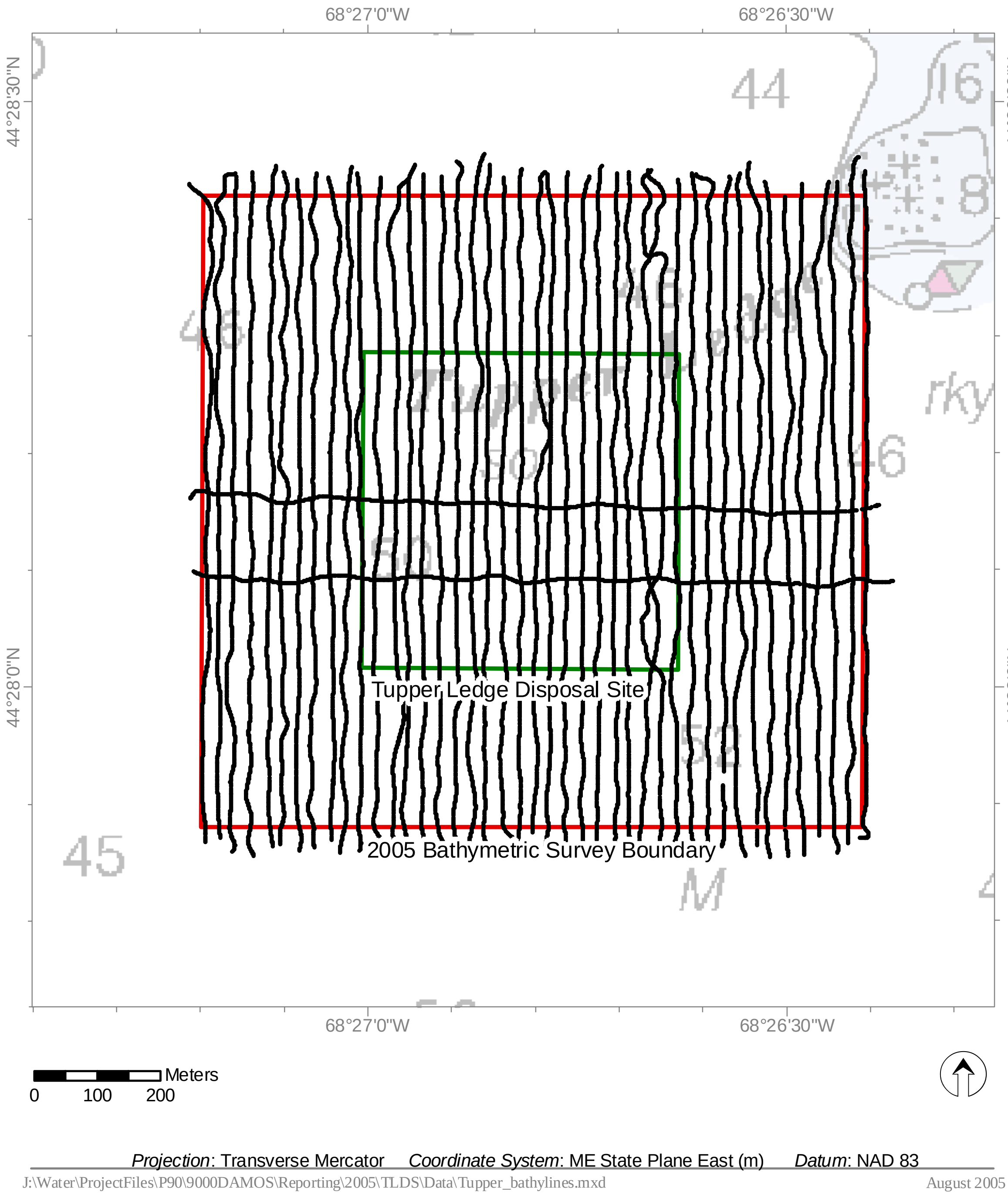

Figure 2-1. TLDS with bathymetric survey boundary and survey lines indicated

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 deploying an underwater camera system that photographs a cross section of the sediment-water interface. Computer-aided analysis of the resulting images provides a set of standard measurements that can be compared between different locations and different surveys. The DAMOS Program has successfully used this technique for over 20 years to map the distribution of disposed dredged material and to monitor benthic recolonization at disposal sites. A detailed discussion of SPI methodology and terminology can be found in the Muscongus Bay monitoring survey report (ENSR et al 2007).

2.3.1 SPI Data Acquisition

The 2005 sediment-profile imaging survey design included 45 stations: 25 stations located within the disposal site, 5 stations located just outside the disposal site, and 15 stations located within three reference areas (Table 2-1, Figure 2-2). The 25 stations located within TLDS were the same stations occupied during the 2003 survey. The five stations located outside of TLDS were stations in which sulfur-reducing bacterial colonies were observed in 2003. As part of the 2005 survey, three reference areas were surveyed, east of the disposal site (EREF), west of the disposal site (WREF), and northwest of the disposal site (NWREF), to provide a basis of comparison between TLDS sediment conditions and the ambient sediment conditions in Union River Bay. The east and west reference areas were previously established during the August 2001 survey while the northwest reference area was established as part of the 2005 survey. Five stations were randomly selected within a 300 meter (984 feet) radius of each of the three reference areas.

The sediment-profile imaging survey was initiated 8 September 2005 aboard the F/V *Shanna Rose* and completed 9 September 2005. At each station, the vessel was positioned at the target coordinates, and the camera was deployed within a defined station tolerance of 10 meter (32.8 feet). Three replicate SPI images were collected at each of the 45 stations.

The SPI system consisted of a metal frame, a Benthos Model 3731 pressure housing, a prism chamber, a Nikon digital camera, and a Benthos Model 2216 Deep Sea Pinger. The camera was mounted inside the pressure housing and sat atop a wedged-shaped prism with a front faceplate and back mirror. The mirror was mounted at a 45-degree angle to reflect the profile of the sediment-water interface. As the prism penetrated the seafloor, a trigger activated a time-delay circuit that fired the internal strobe to obtain a cross-sectional image of the upper 20 cm of the sediment column. The pinger was attached to the camera

Table 2-1

TLDS Sediment-Profile Image Target Sampling Locations

Area	Station	Latitude (N)	Longitude (W)	Area	Station	Latitude (N)	Longitude (W)
TLDS Inner	I01	44° 28.254'	68° 26.964'	TLDS Outer	O01	44° 28.356'	68° 27.096'
	I02	44° 28.254'	68° 26.886'		O02	44° 28.350'	68° 26.814'
	I03	44° 28.254'	68° 26.814'		OWREF7	44° 28.158'	68° 27.294'
	I04	44° 28.254'	68° 26.736'		OWREF8	44° 28.152'	68° 27.486'
	I05	44° 28.254'	68° 26.664'		OWREF1	44° 27.804'	68° 27.114'
	I06	44° 28.200'	68° 26.964'	Reference	WREF-1	44° 27.690'	68° 27.168'
	I07	44° 28.200'	68° 26.892'		WREF-2	44° 27.750'	68° 27.342'
	I08	44° 28.200'	68° 26.814'		WREF-3	44° 27.612'	68° 27.054'
	I09	44° 28.200'	68° 26.736'		WREF-4	44° 27.666'	68° 27.114'
	I10	44° 28.200'	68° 26.664'		WREF-5	44° 27.600'	68° 27.282'
	I11	44° 28.146'	68° 26.964'		NWREF-1	44° 28.806'	68° 27.420'
	I12	44° 28.146'	68° 26.892'		NWREF-2	44° 28.68'	68° 27.414'
	I13	44° 28.146'	68° 26.814'		NWREF-3	44° 28.686'	68° 27.492'
	I14	44° 28.146'	68° 26.736'		NWREF-4	44° 28.788'	68° 27.312'
	I15	44° 28.146'	68° 26.664'		NWREF-5	44° 28.638'	68° 27.516'
	I16	44° 28.092'	68° 26.964'		EREF-1	44° 27.630'	68° 26.340'
	I17	44° 28.092'	68° 26.892'		EREF-2	44° 27.456'	68° 26.298'
	I18	44° 28.092'	68° 26.814'		EREF-3	44° 27.762'	68° 26.214'
	I19	44° 28.092'	68° 26.742'		EREF-4	44° 27.708'	68° 26.136'
	I20	44° 28.092'	68° 26.664'		EREF-5	44° 27.552'	68° 26.382'
	I21	44° 28.044'	68° 26.964'				
	I22	44° 28.044'	68° 26.892'				
	I23	44° 28.044'	68° 26.814'				
	I24	44° 28.044'	68° 26.742'				
	I25	44° 28.044'	68° 26.664'				

Notes: Coordinate system NAD83

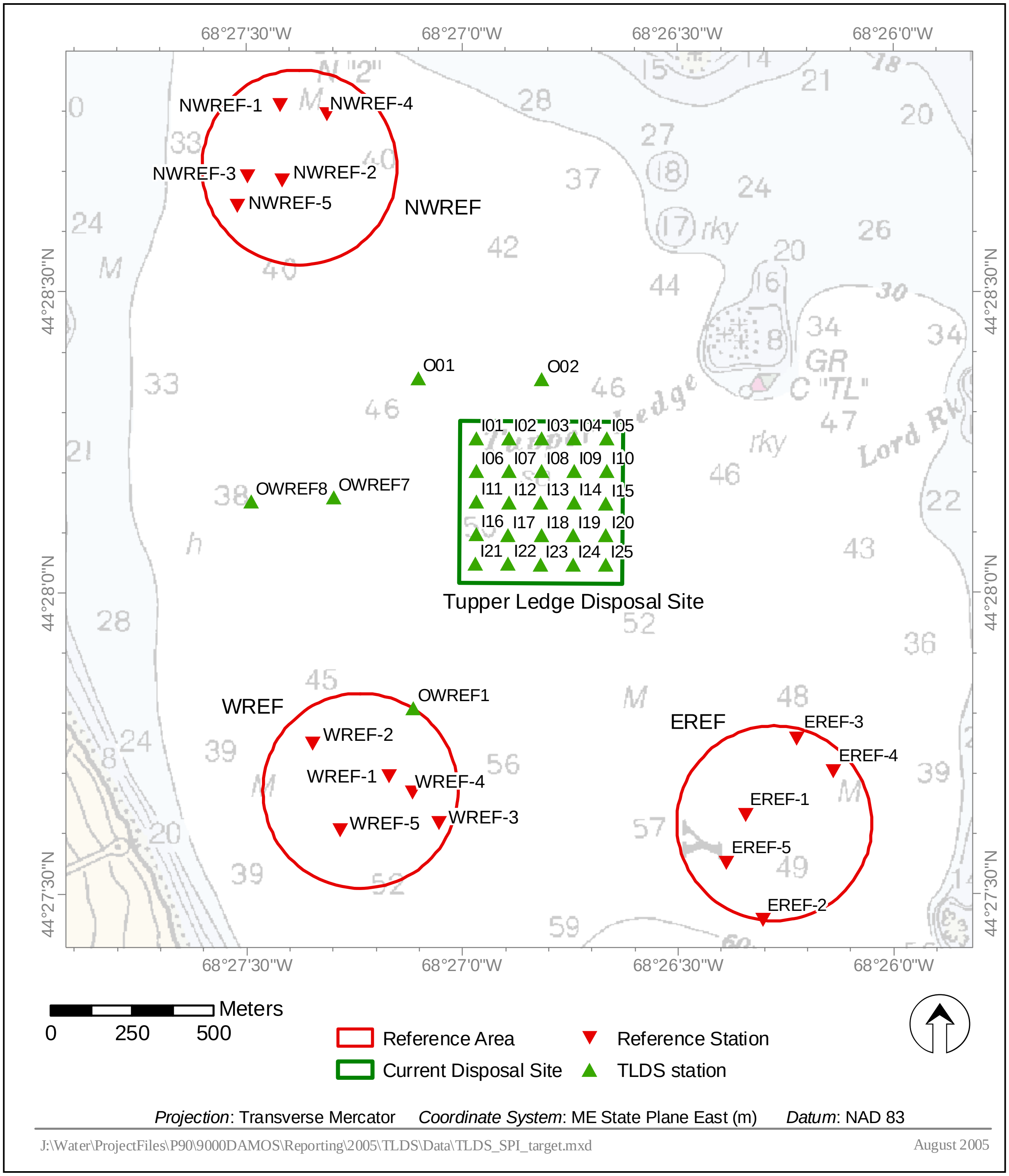

Figure 2-2. TLDS with target sediment-profile image stations indicated

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 A. The presence and thickness of disposed dredged material was also assessed by inspection of the images.

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

Surface Boundary Roughness: Surface boundary roughness is a measure of the vertical relief of features at the sediment-water interface in the sediment-profile image. Surface boundary roughness was determined by measuring the vertical distance between the highest and lowest points of the sediment-water interface. The surface boundary roughness (sediment surface relief) measured over the width of sediment-profile images typically ranges from 0 to 4 cm, and may be related to physical structures (e.g., ripples, rip-up structures, mud clasts) or biogenic features (e.g., burrow openings, fecal mounds, foraging depressions). Biogenic roughness typically changes seasonally and is related to the interaction of bottom turbulence and bioturbational activities.

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

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

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

2.4 Statistical Analysis

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

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

H_0: $d \leq -\delta$ or $d \geq \delta$ (presumes the difference is great)

H_A: $-\delta < d < \delta$ (requires proof that the difference is small)

Where d is the difference between reference mean and a site mean. If the null hypothesis is rejected, then we conclude that the two means are not different from one another within $\pm\delta$ units. The size of δ should be determined from historical data and/or best professional judgment to identify a maximum difference that is within background variability/noise and is therefore not ecologically meaningful.

The two key SPI parameters that are the best indicators of benthic community status are the mean depth of the RPD and the infaunal successional stage. While the RPD data are easily inserted into the formulae used for interval testing, the successional stage classification must be converted to a numerical value. This is relatively straightforward using the ordinal (ranked) classifications that have been established for calculating the Organism-Sediment Index (Rhoads and Germano 1982, 1986) in historical DAMOS reports.

Table 2-2

Rank Determination for Infaunal Successional Stages (SS)

Rank	**Successional Stage**
1	Stage 1
2	Stage 1 - 2
3	Stage 2
4	Stage 2 - 3
5	Stage1 on 3 or Stage 2 on 3
n/a	n/a = Indeterminate

For each replicate image, the successional stage (SS) was converted to a rank base on the above table (Table 2-2). The mean of the ranks among replicates was used in the analyses comparing station values across areas. Based on a review of historical data, δ values of 1 for both RPD and SS rank were used for the interval testing.

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

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

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

The 2005 data consisted of three distinct reference areas with five stations at each reference area. There were 30 stations in the vicinity of TLDS; 29 of these were included as mound stations because they had dredged material present during the 2003 survey. The station omitted (OW Ref-08) was not included in any statistical analyses because it was neither within the disposal area in 2003, nor within any of the focused reference sites. At each of the stations, there were results for three replicate drops of the SPI camera. The three replicate camera observations were averaged to get one observation per station.

In this sampling design, there are actually four distinct areas, three of which are categorized as reference locations, so the difference equation of interest is defined as the average of the three reference means minus the mound mean, or

$$[\tfrac{1}{3}(\text{Mean}_{\text{EREF}} + \text{Mean}_{\text{SREF}} + \text{Mean}_{\text{SWREF}}) - \text{Mean}_{\text{Mound}}]$$

The three reference areas collectively represent ambient conditions, but if there are mean differences among these three areas then pooling them into a single reference group will increase the variance beyond true background variability. The effect of keeping the three reference areas separate has no effect on the grand reference mean (when n is equal among these areas) but it will maintain the variance as a true background variance for each individual population with a constant mean. If the three reference areas have similar means and variances, then they may be pooled for a simpler test on the difference between 15 reference and 29 mound stations.

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

$$\tfrac{1}{3}(\text{Mean}_{\text{EREF}} + \text{Mean}_{\text{SREF}} + \text{Mean}_{\text{SWREF}}) - \text{Mean}_{\text{SITE}} \quad \textbf{\textit{or}} \quad \text{Mean}_{\text{Pooled Refs}} - \text{Mean}_{\text{SITE}}$$

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

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

Where:

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

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

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

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

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

Where:

$\hat{d}$ = observed difference in means between the Reference and Mound

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

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

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

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

3.0 RESULTS

3.1 Bathymetry

3.1.1 Existing Bathymetry

Figure 3-1 presents the TLDS bathymetric data. Water depths at TLDS ranged from approximately 12 meters (39 feet) to 15.5 meters (51 feet). Two disposal mounds were evident at TLDS: Mound A, in the center of the site and Mound B in the southwest quadrant of the site. The minimum depth over Mound A was approximately 12 meters (39 feet) while the minimum depth over Mound B was approximately 12.5 meters (41 feet). The deepest portion of the survey area was located northeast of the site, where depths reached 19 meters (62 feet). Adjacent to the deepest portion of the survey area was the shallowest point, which rose to about 3 meters (9.8 feet) below the water surface. Vertical datum used was mean lower low water (MLLW).

3.1.2 Comparison with Previous Bathymetry

The bathymetric contour map developed from the 2005 survey data (Figure 3-1) revealed bathymetric features similar to those found in 2003 (Figure 3-2). A subtraction of the depths in 2003 from the depths in 2005 displays spatial changes in bathymetry after the 2003 disposal activity (Figure 3-3). At both Mound A and Mound B, the water depths appeared greater in the recent survey, indicating consolidation of the central portion of the mounds. Up to 0.5 meters (1.6 feet) of consolidation appears to have occurred over the mounds (not unusual in high water content dredged material after disposal).

Other features that appear in the depth difference map 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).

3.2 Sediment-Profile Imaging

The intent of the SPI survey was not to delineate the distribution of dredged material, but to assess sediment conditions and the recolonization status of the disposal site and on the ambient seafloor. All SPI results can be found in Appendix A and are summarized in Table 3-1. Soft sediments required the use of mud doors on the SPI camera for all stations surveyed at the site (both disposal site and reference site); no lead weights were used in the camera, and the stop collars were placed at a minimal setting (Appendix A).

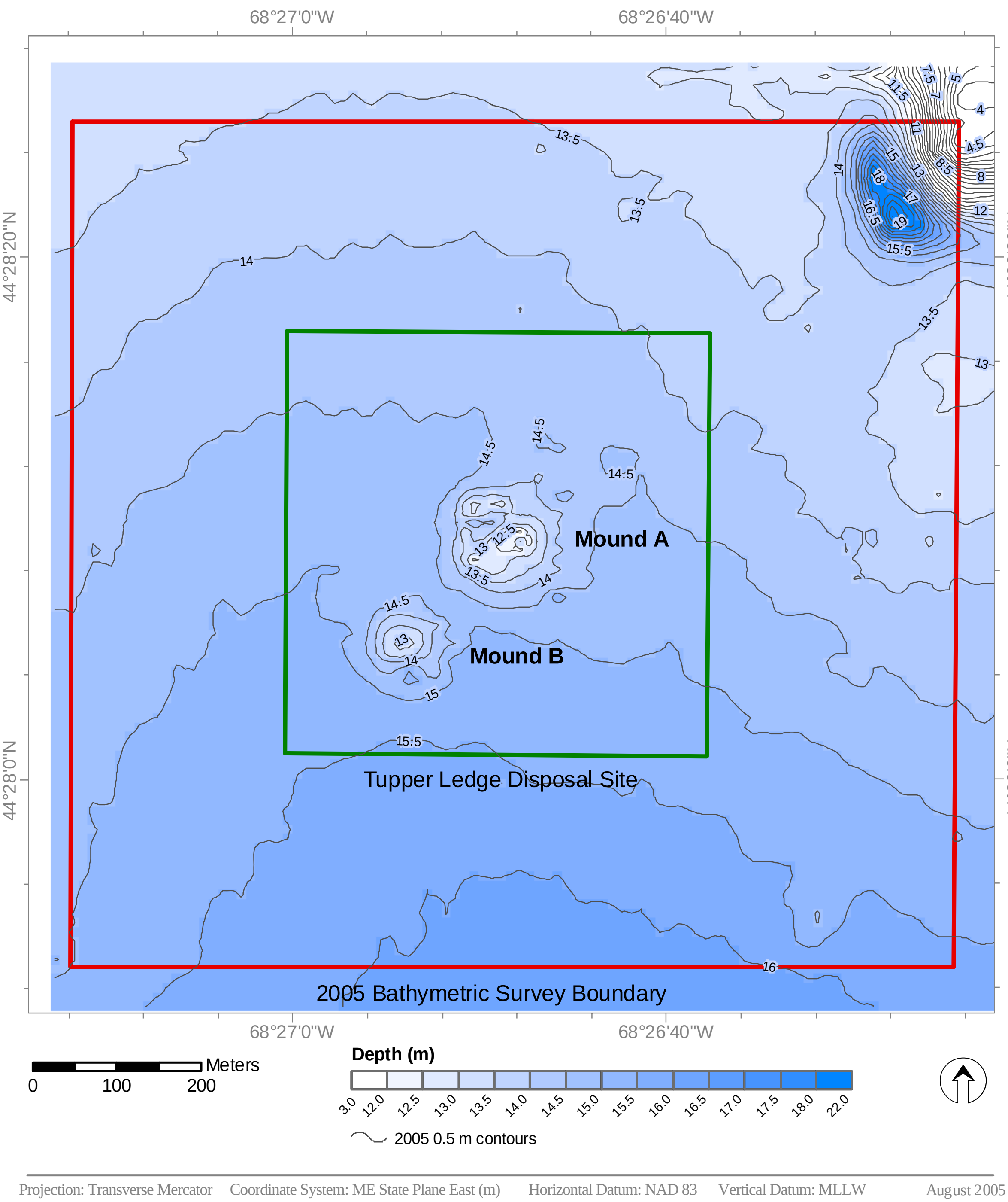

Figure 3-1. Bathymetric contour map of TLDS – July 2005

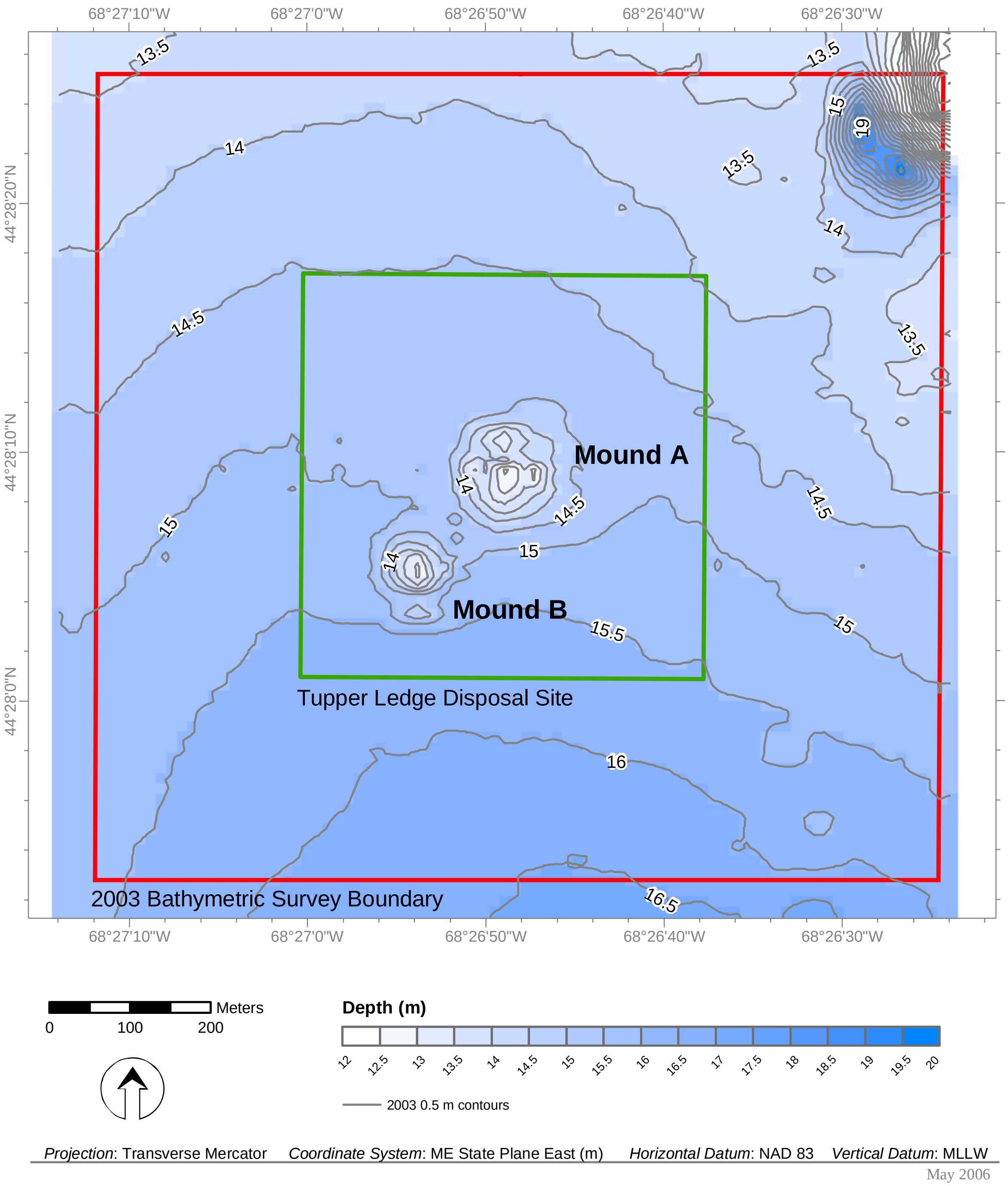

Figure 3-2. Bathymetric contour map of TLDS – September 2003

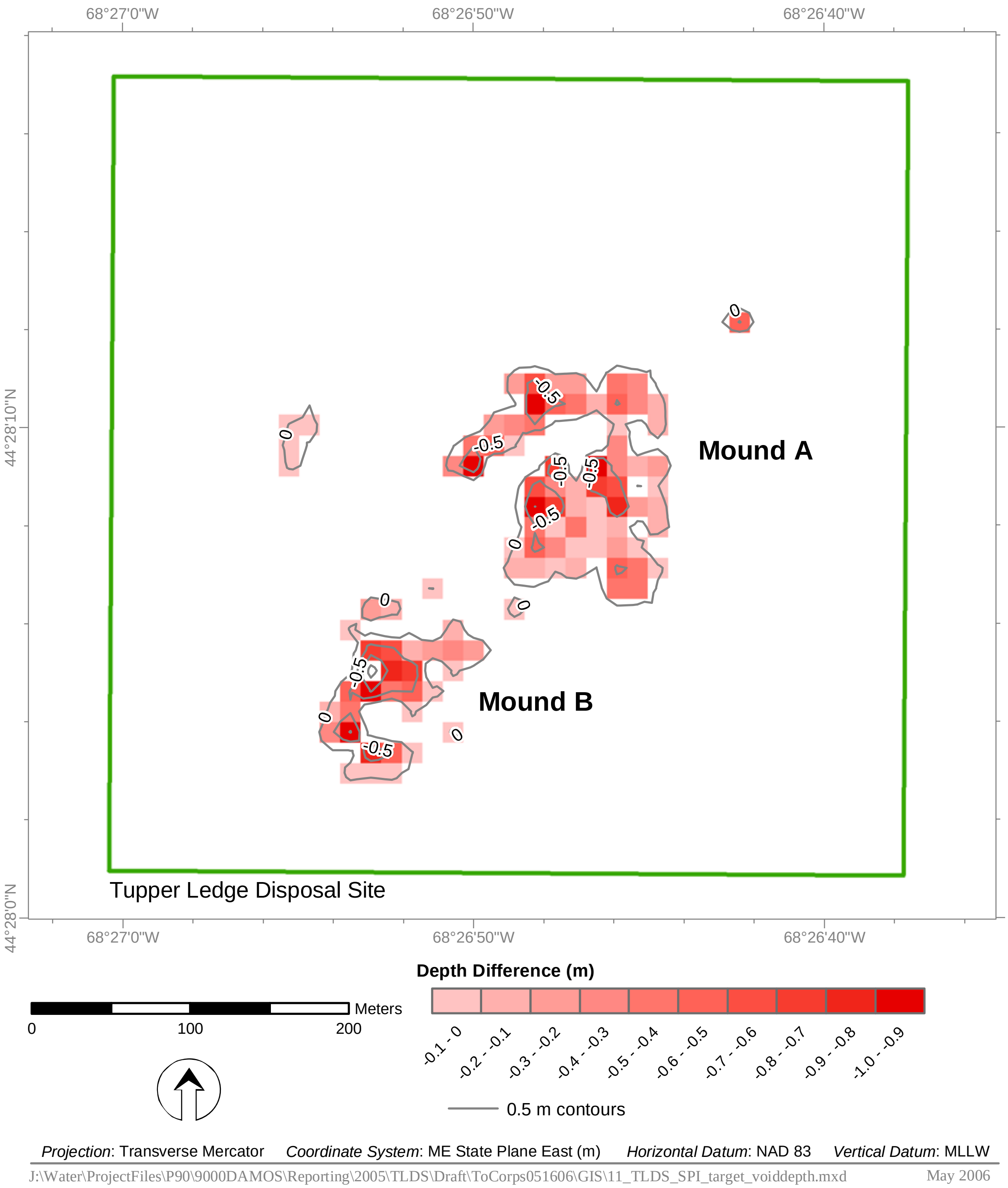

Figure 3-3. Depth-difference contour map of TLDS: September 2003 vs. July 2005

3.2.1 Tupper Ledge Disposal Site: Physical Sediment Characteristics

The sediments at the Tupper Ledge Disposal Site were uniformly all high water content, low shear strength, fine-grained mud ($\geq$ 4 Φ; Table 3-1). While prism penetration varied between 2.6 to 17.7 cm (Table 3-1, Figure 3-4), the one notable location as far as differences in sediment type/shear strength was Station I17 (Figure 3-5); large cobble and rocks were placed at this area, so even though the sediment appeared to be mostly fine-grained (due to a mantling of mud particles over the rocks), prism penetration was minimal.

Evidence of dredged material was found at all disposal area stations and two stations outside of the disposal site (O01 and O02) (Figure 3-6). Dredged material thickness ranged from as little as 2.58 cm (I19) to 15.35 cm (I15), with an average of 10.55 cm including only those stations with dredged material present. Mud clasts were present on the sediment surface in images from practically every station (Appendix A; Figure 3-7); however, these were all due to sampling artifacts from using the mud doors on the camera (cohesive mud will cling to the underside of the steel channel used for the camera base and on the underside of the doors) and no significance was attached to their presence as far as indicators of sediment transport at the site. Small-scale boundary roughness at the sediment surface ranged from 0.6 to 3.5 cm, with an overall disposal site average roughness value of 1.5 cm (Table 3-1); the majority (75%) of the small-scale topographic roughness features was caused by burrowing/feeding activities of the resident macrofauna resulting in burrow openings or mounds/pits at the sediment-water interface.

The dredged material present at all stations within the disposal site boundary was characterized by the presence of either high water-content reduced mud (Figure 3-8), a chaotic cross-sectional fabric with consolidated blue clay (Figure 3-9), the presence of wood chips (Figure 3-10), or disposed rock and cobble (Figure 3-5). While there was no evidence of low dissolved oxygen in the overlying water at the time of the survey, or subsurface methane generation, subsurface laminations indicative of past hypoxic or anoxic events observed in the previous survey could still be detected at many of the stations in 2005 (Figure 3-11).

Table 3-1

Summary of SPI Results for TLDS Stations, September 2005

Reference Stations									
Station	**Grain Size Major Mode (phi)**	**Station Average Penetration (cm)**	**Station Average Boundary Roughness (cm)**	**Station Average RPD (cm)**	**Methane Present?**	**Evidence of past anoxic events Present?**	**Station Average DM thickness (cm)**	**Station Maximum Void Depth (cm)**	**Highest Successional Stage Present**
EREF-01	>4	14.36	1.27	1.73	NO	No	-	13.65	Stage 3
EREF-02	>4	14.91	1.71	1.62	NO	Yes	-	14.26	Stage 3
EREF-03	>4	12.27	1.28	1.41	NO	No	-	0.00	Stage 3
EREF-04	>4	14.34	1.23	1.40	NO	Yes	-	12.35	Stage 1 on 3
EREF-05	>4	14.24	1.13	1.57	NO	Yes	-	12.69	Stage 1 on 3
NWREF-01	>4	13.74	1.76	1.26	NO	Yes	-	11.78	Stage 3
NWREF-02	>4	13.84	1.54	1.13	NO	Yes	-	10.43	Stage 1 on 3
NWREF-03	>4	13.29	1.76	1.09	NO	Yes	-	13.53	Stage 1 on 3
NWREF-04	>4	15.62	1.11	1.20	NO	Yes	-	15.56	Stage 1 on 3
NWREF-05	>4	12.78	1.46	0.79	NO	Yes	-	8.29	Stage 1 on 3
WREF-01	>4	13.93	3.39	1.82	NO	No	-	13.81	Stage 1 on 3
WREF-02	>4	12.92	2.03	1.56	NO	Yes	-	12.12	Stage 1 on 3
WREF-03	>4	13.30	2.26	1.48	NO	Yes	-	14.21	Stage 1 on 3
WREF-04	>4	12.90	1.42	1.50	NO	Yes	-	11.02	Stage 1 on 3
WREF-05	>4	14.83	0.83	1.56	NO	Yes	-	8.68	Stage 1 on 3
Average	NA	13.82	1.61	1.41	NA	NA	-	11.49	NA
Minimum	NA	12.27	0.83	0.79	NA	NA	-	0.00	NA
Maximum	NA	15.62	3.39	1.82	NA	NA	-	15.56	NA

Table 3-1, Continued

Summary of SPI Results for TLDS Stations, September 2005

Disposal Site

Station	Grain Size Major Mode (phi)	Station Average Penetration (cm)	Station Average Boundary Roughness (cm)	Station Average RPD (cm)	Methane Present?	Evidence of past anoxic events Present?	Station Average DM thickness (cm)	Station Maximum Void Depth (cm)	Highest Successional Stage Present
O-01	>4	12.65	1.67	1.43	NO	Yes	> 12.65	0.00	Stage 1 -> 2
O-02	>4	7.76	1.32	1.30	NO	Yes	> 7.76	0.00	Stage 1 -> 2
OWREF-01	>4	15.85	2.63	1.94	NO	Yes	-	16.30	Stage 3
OWREF-07	>4	13.59	0.61	0.96	NO	Yes	-	11.90	Stage 1 on 3
OWREF-08	>4	15.87	2.41	1.28	NO	Yes	-	18.30	Stage 1 on 3
I-01	>4	13.06	0.96	1.22	NO	Yes	4.86	11.42	Stage 1 on 3
I-02	>4	12.47	0.99	1.30	NO	Yes	11.07	8.63	Stage 1 on 3
I-03	>4	12.41	1.53	1.27	NO	Yes	9.47	8.54	Stage 1 on 3
I-04	>4	11.70	0.73	1.38	NO	Yes	9.01	8.65	Stage 1 on 3
I-05	>4	10.21	1.09	1.41	NO	No	> 10.21	10.83	Stage 1 on 3
I-06	>4	13.16	1.65	1.19	NO	Yes	11.06	12.94	Stage 1 on 3
I-07	>4	11.46	1.29	1.30	NO	Ind	> 11.46	11.56	Stage 1 on 3
I-08	>4	9.52	1.25	1.33	NO	No	> 9.52	10.09	Stage 1 on 3
I-09	>4	11.18	1.11	1.18	NO	No	> 11.18	9.70	Stage 1 on 3
I-10	>4	11.04	2.47	1.04	NO	No	> 11.04	11.47	Stage 1 on 3
I-11	>4	9.95	1.79	1.46	NO	No	> 9.95	7.75	Stage 1 on 3
I-12	>4	9.53	1.33	1.26	NO	No	> 9.53	6.93	Stage 1 on 3
I-13	>4	10.45	1.96	2.80	NO	No	> 10.45	15.22	Stage 1 on 3
I-14	>4	14.58	1.96	1.36	NO	Yes	> 14.58	15.36	Stage 1 on 3
I-15	>4	17.67	1.11	1.29	NO	Yes	15.35	18.97	Stage 1 on 3
I-16	>4	15.08	1.21	1.86	NO	No	> 15.08	8.26	Stage 1 on 3
I-17	>4	2.58	2.31	0.67	NO	No	> 2.58	0.00	Indeterminate
I-18	>4	10.78	1.06	1.58	NO	No	> 10.78	9.25	Stage 1 on 3
I-19	>4	12.72	1.46	1.30	NO	Ind	> 12.72	14.10	Stage 1 on 3

Table 3-1, Continued

Summary of SPI Results for TLDS Stations, September 2005

Station	Grain Size Major Mode (phi)	Station Average Penetration (cm)	Station Average Boundary Roughness (cm)	Station Average RPD (cm)	Methane Present?	Evidence of past anoxic events Present?	Station Average DM thickness (cm)	Station Maximum Void Depth (cm)	Highest Successional Stage Present
I-20	>4	12.79	1.03	1.51	NO	No	> 12.79	8.15	Stage 1 on 3
I-21	>4	7.19	3.53	1.76	NO	No	> 7.19	0.00	Stage 2
I-22	>4	10.11	0.75	1.87	NO	No	> 10.11	10.07	Stage 1 on 3
I-23	>4	9.39	2.69	1.56	NO	Ind	> 9.39	9.33	Stage 1 on 3
I-24	>4	13.33	1.16	1.69	NO	No	10.62	14.35	Stage 1 on 3
I-25	>4	14.48	0.85	1.64	NO	Yes	> 14.48	12.55	Stage 1 on 3
Average	NA	11.75	1.53	1.44	NA	NA	-	10.02	NA
Minimum	NA	2.58	0.61	0.67	NA	NA	-	0.00	NA
Maximum	NA	17.67	3.53	2.80	NA	NA	-	18.97	NA

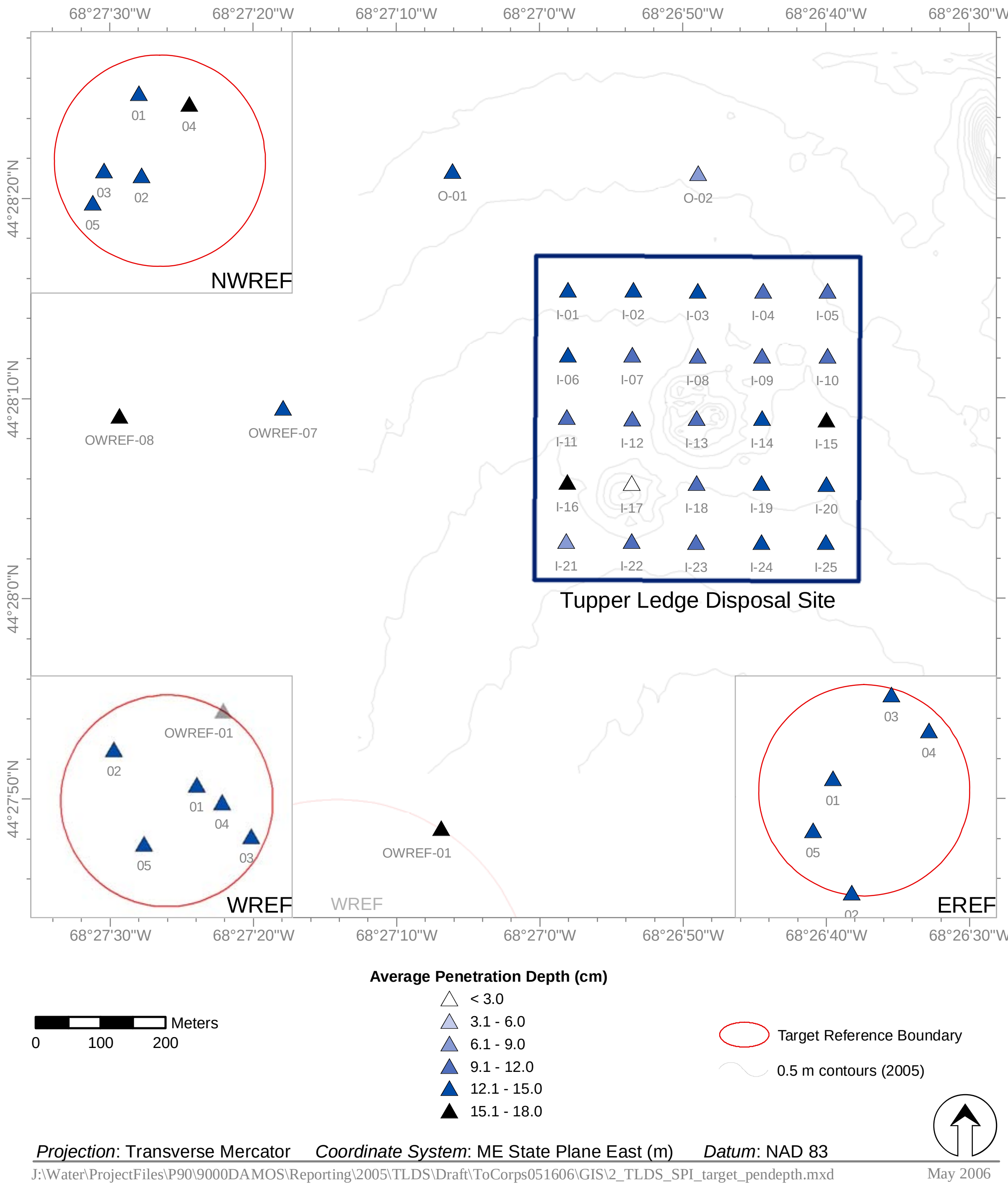

Figure 3-4. Spatial distribution of average camera prism penetration depth (cm) at the Tupper Ledge Disposal Site

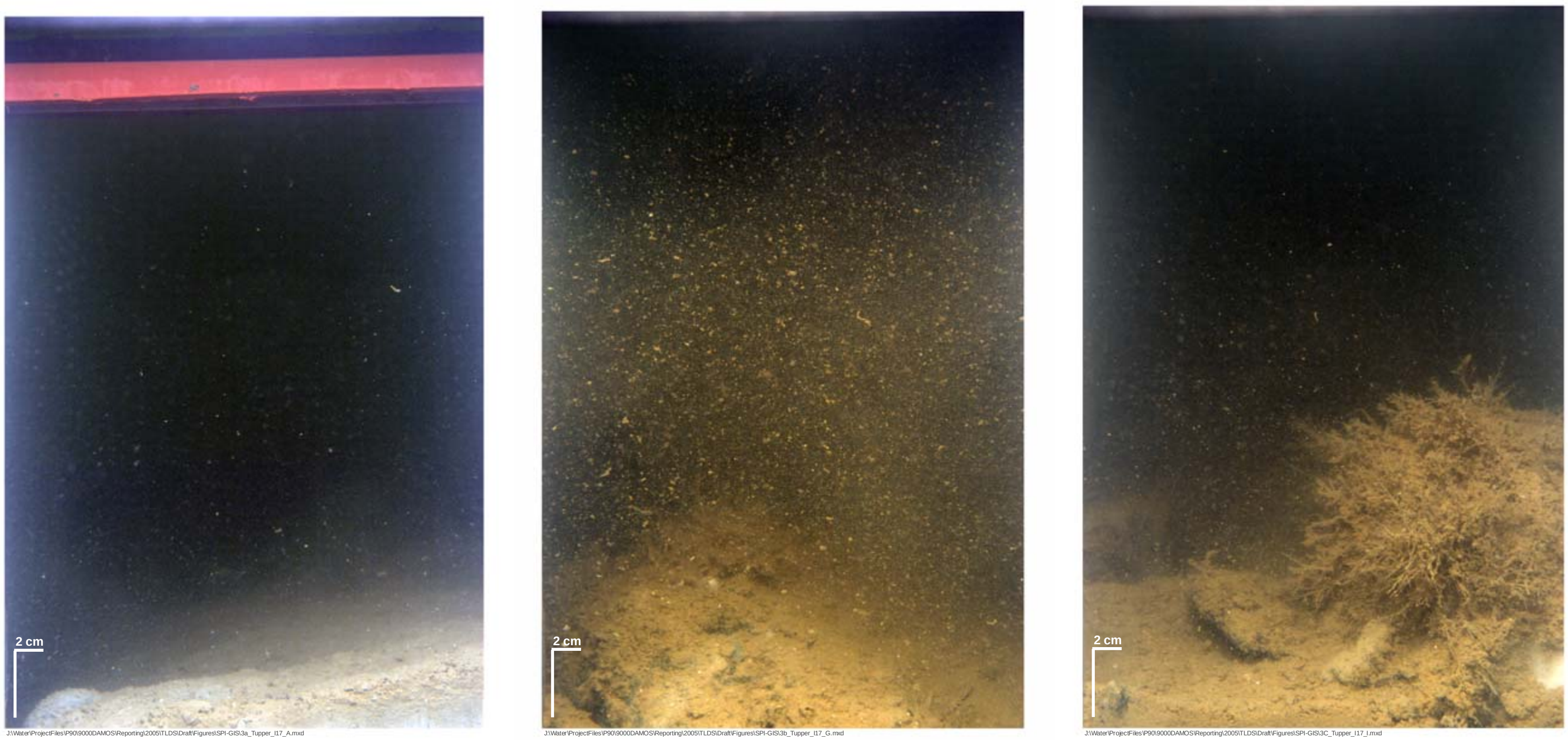

Figure 3-5. Despite the appearance of fine-grained sediments at Station I17, the silt-clay particles are mantling an underlying foundation of cobbles and rocks

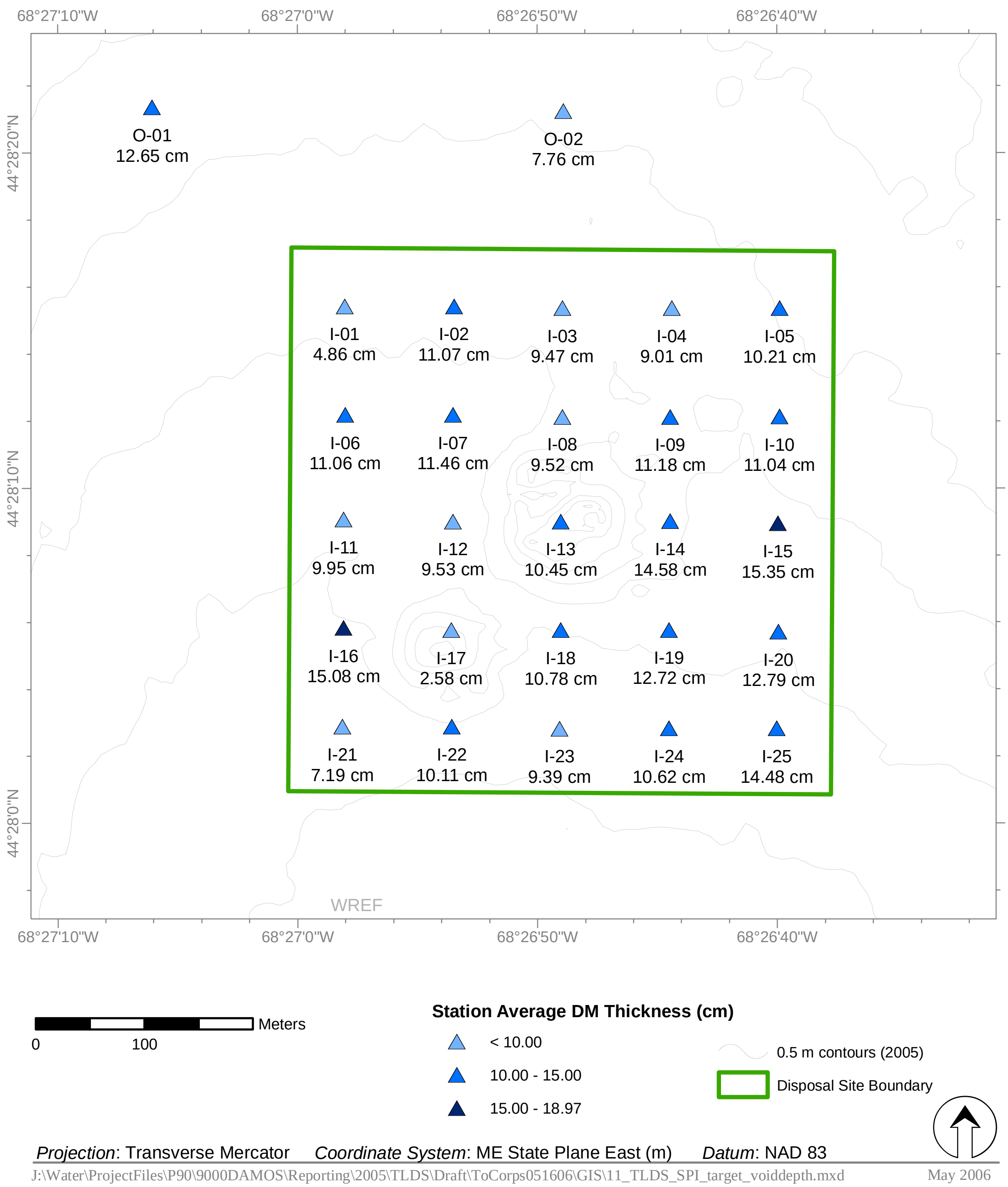

Figure 3-6. Areas with dredged material in the TLDS area as detected by sediment-profile imaging and the dredged material thickness recorded by this imaging in September 2005

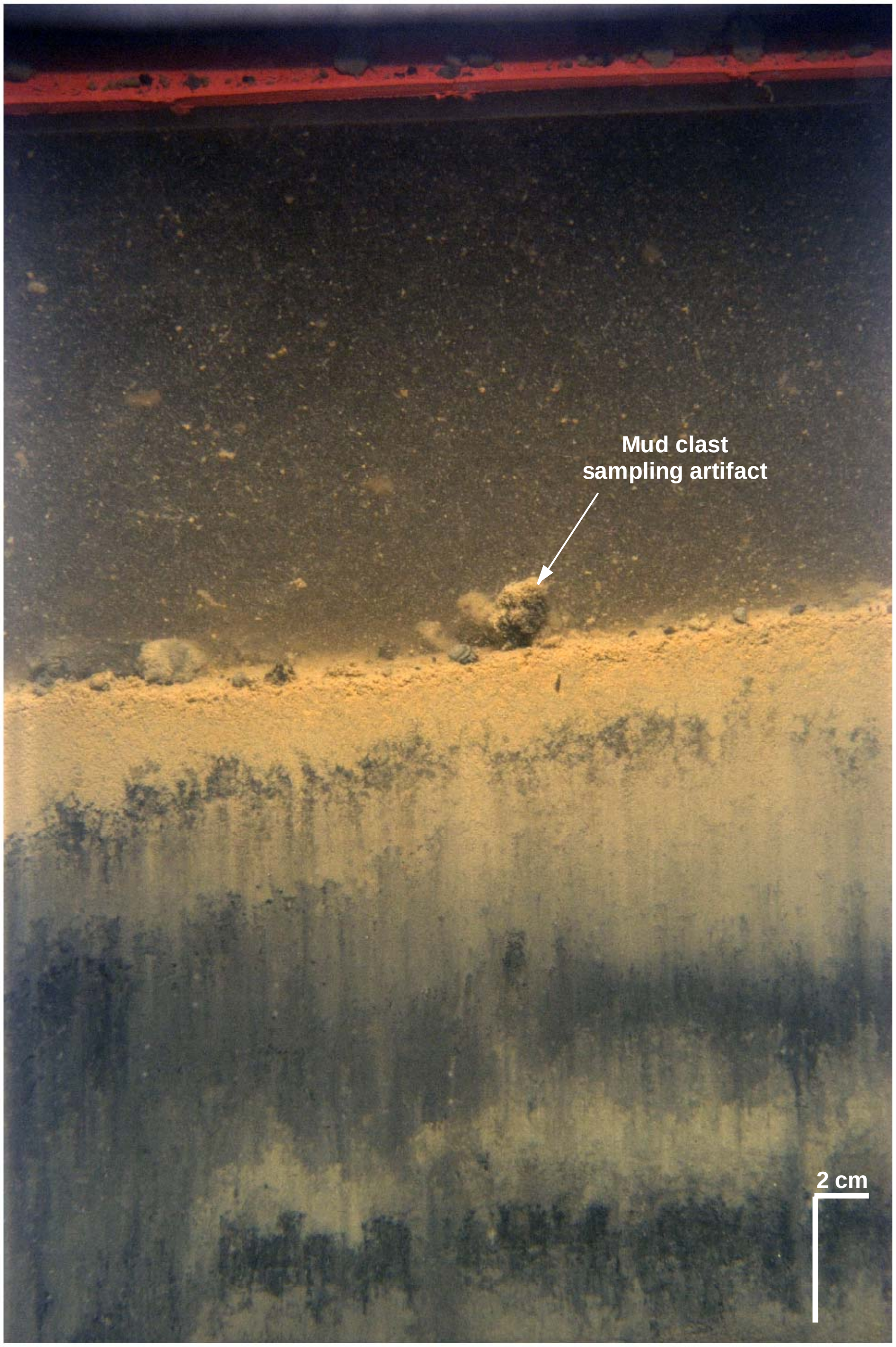

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Figure 3-7. The mud clasts seen at the sediment surface in this profile image from Station I02 are typical of those seen in the majority of the images and are sampling artifacts created by use of the mud doors on the camera frame

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Figure 3-8. The dredged material in this profile image from Station I02 is readily recognized by the highly-reduced nature of the subsurface sediments, reflecting the high organic content of the disposed mud

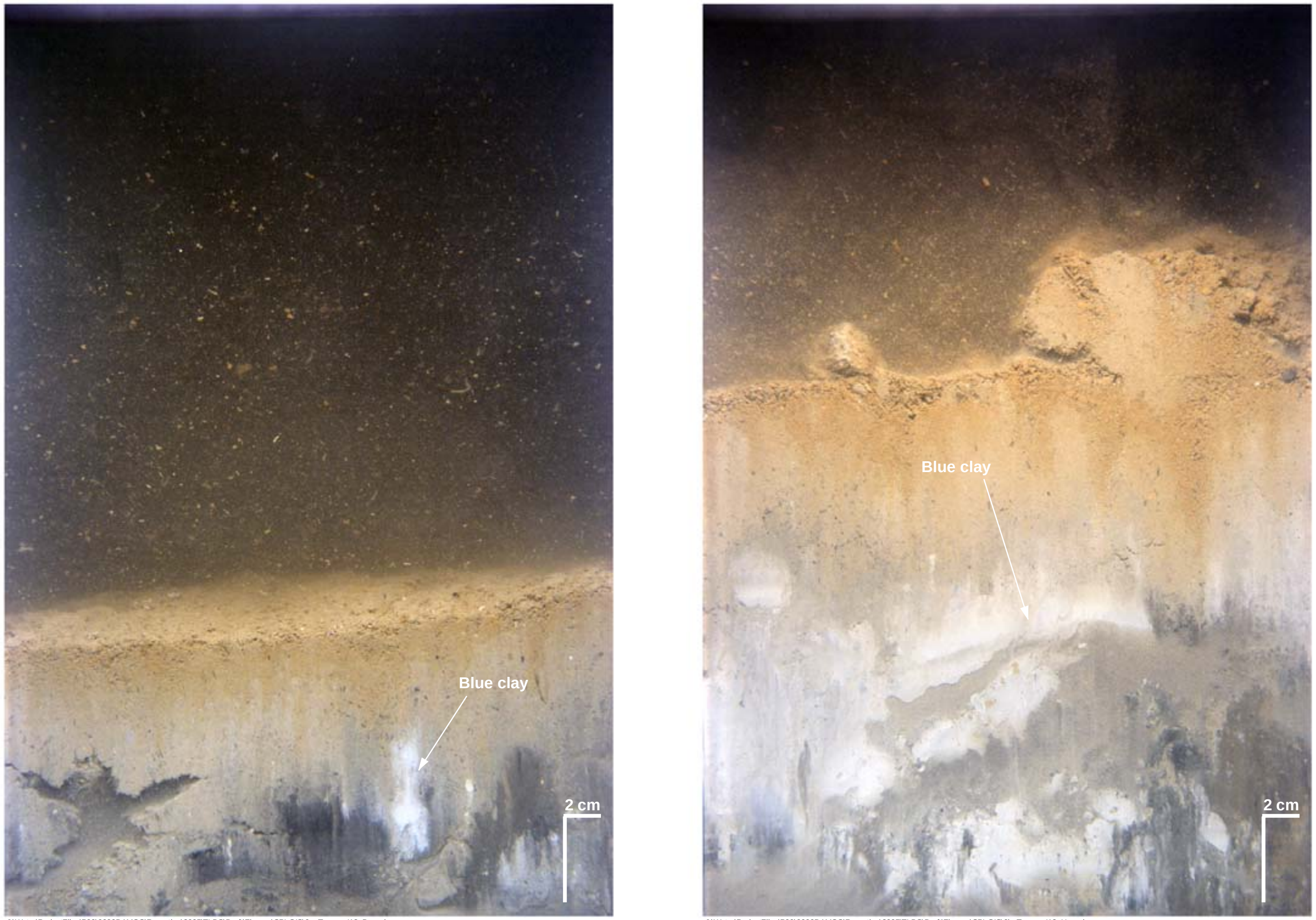

Figure 3-9. Another typical diagnostic characteristic of dredged material at Tupper Ledge is the presence of subsurface consolidated clasts/lumps of blue clay as seen in these profile images from Station I13

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Figure 3-10. One quite common diagnostic feature of disposed sediment at the Tupper Ledge Disposal Site was the presence of wood chips and fibers, as can be seen in this profile image from Station I16

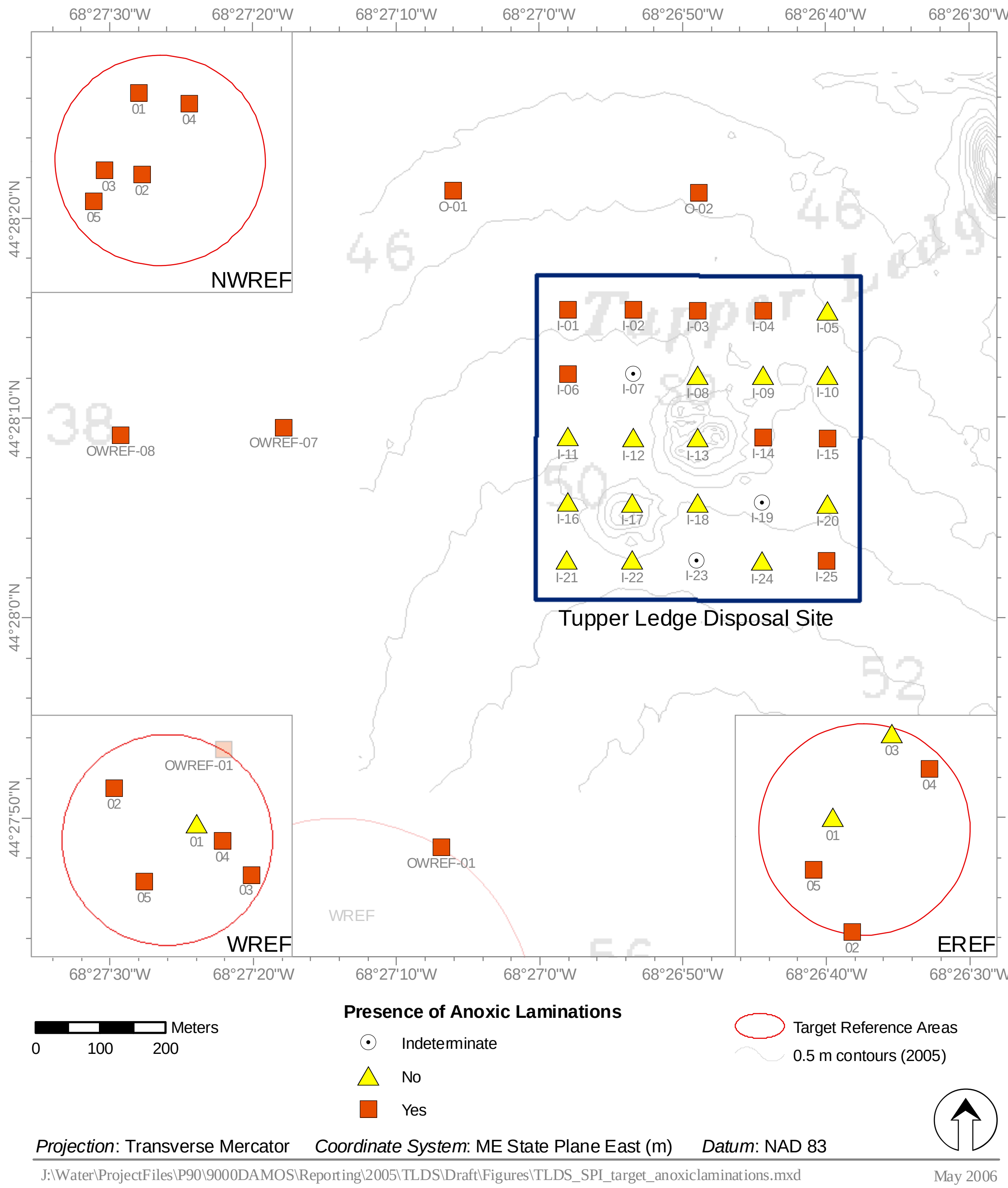

Figure 3-11. Map showing the locations where subsurface sediment laminations indicative of past seasonal hypoxic or anoxic events were present

3.2.2 Biological Conditions and Benthic Recolonization

The mean apparent RPD values at the stations with past evidence of dredged material present (the 25 within the site boundaries plus the five outside stations) ranged from 0.7 to 2.8 cm, with an overall site average of 1.4 cm (Table 3-1, Figure 3-12). In stark contrast to the last survey at this site in 2003, only one station (I22) had evidence of any sulfur reducing bacterial colonies of *Beggiatoa* present at the sediment surface (these colonies only occur in low oxygen conditions).

Of the stations with dredged material present, there were only 4 (Stations O-01, O-02, I17, and I21) that had no evidence of any Stage 3 taxa (Table 3-1, Figure 3-13). No determination of infaunal successional stage could be made at Station I17 because of the poor camera penetration at this particular location. Evidence of infaunal deposit feeding activities to depths greater than 10 cm was found at approximately half of the stations surveyed within the disposal site (Figure 3-14), with structures ranging from subsurface megafaunal burrows (Figure 3-15) to feeding voids and vertical burrow structures (Figure 3-16).

3.2.3 Reference Areas Physical Sediment Characteristics

Similar to the stations within the disposal site, the native sediments on the seafloor outside of the disposal site also had a grain-size major mode of $\geq 4\ \Phi$ with a similar high water content and low shear strength. Prism penetration was fairly uniform at the reference area stations, with values ranging from 12.3 to 15.6 cm (Table 3-1, Figure 3-4). Similar to the disposal site, small scale boundary roughness was primarily caused by biogenic processes (in 73% of the replicate images) and ranged from 0.8 to 3.4 cm. Mud clast artifacts were present in most of the reference area images because of the cohesive quality of the mud and due to the use of the doors on the base sled of the camera.

While there was no evidence of subsurface methane generation or low dissolved oxygen in the overlying water, anoxic laminations were present at all but 3 of the reference area stations (Figure 3-11). The sediments at all of the stations in the NWREF area were particularly notable as far as the quality and appearance of the sub-surface sediments (Figure 3-17); the anoxic laminations in the sediments from this area were thicker and more pronounced than those at the stations in the other reference areas, having the same darker, light reflectance as the subsurface sediments at many of the disposal site stations.

3.2.4 Biological Conditions

The mean apparent RPD depth values at reference area stations were also fairly low and ranged from 0.8 to 1.8 cm, with an overall reference area average of 1.4 cm. No evidence of *Beggiatoa* was found at any of the reference area stations, and Stage 3 taxa were present at all reference stations surveyed (Figure 3-13, Table 3-1). Evidence of infaunal deposit feeding activities to depths greater than 10 cm was found at four out of the five

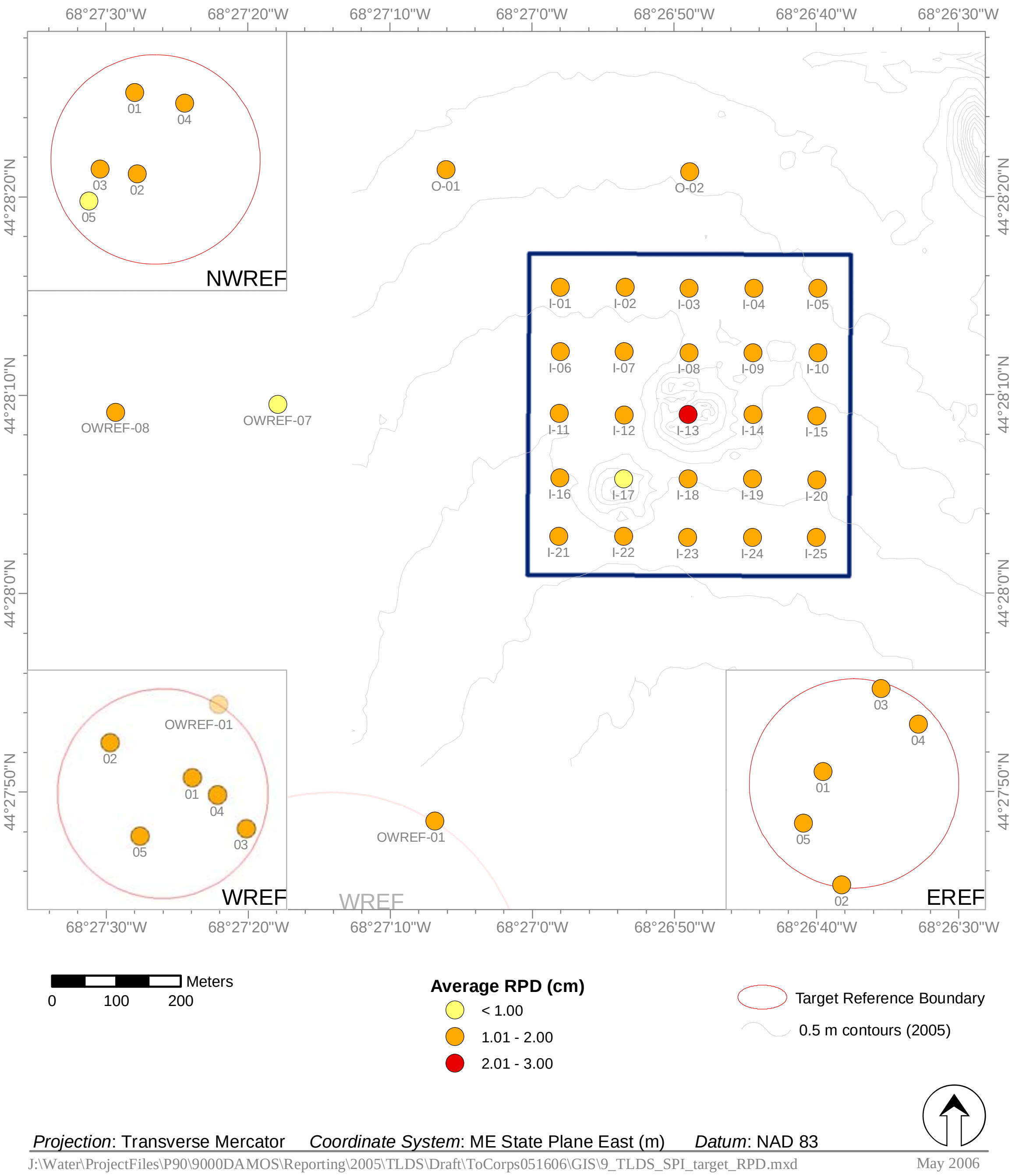

Figure 3-12. Distribution of station-averaged mean apparent RPD depth (cm) at the Tupper Ledge Disposal Site

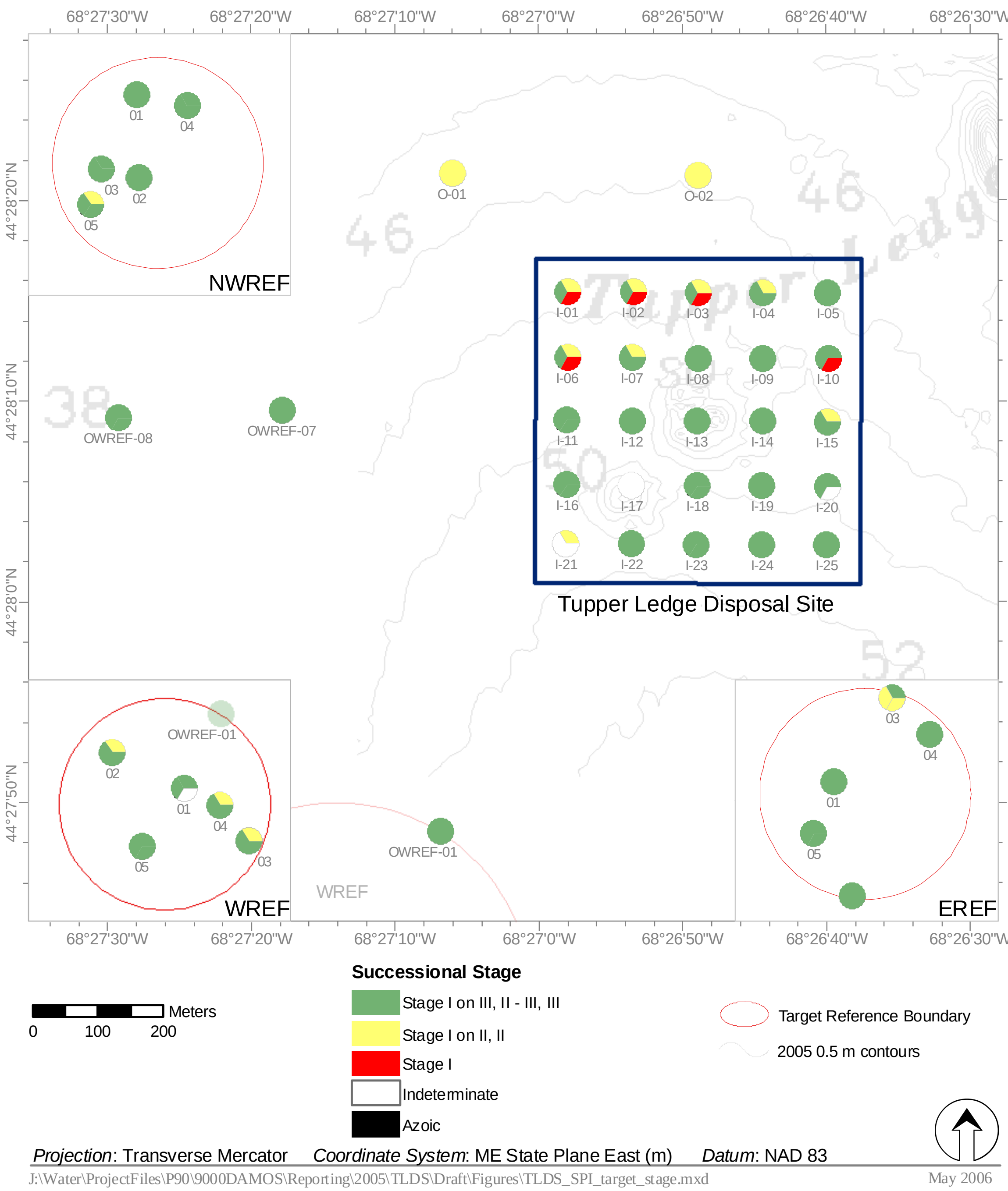

Figure 3-13. Distribution of infaunal successional stages at the Tupper Ledge Disposal Site

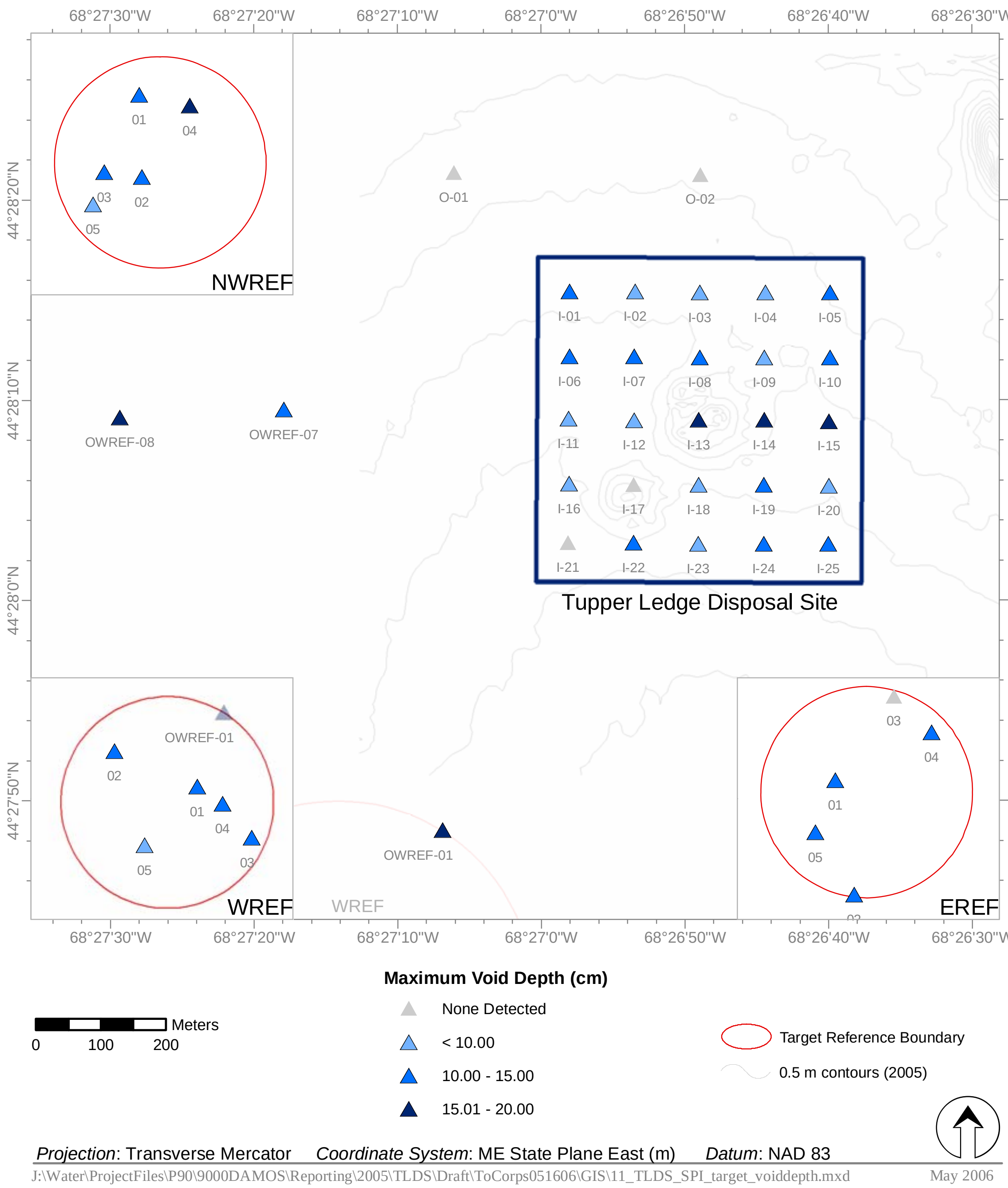

Figure 3-14. Distribution of maximum infaunal feeding void/burrow depth (cm) at the Tupper Ledge Disposal Site

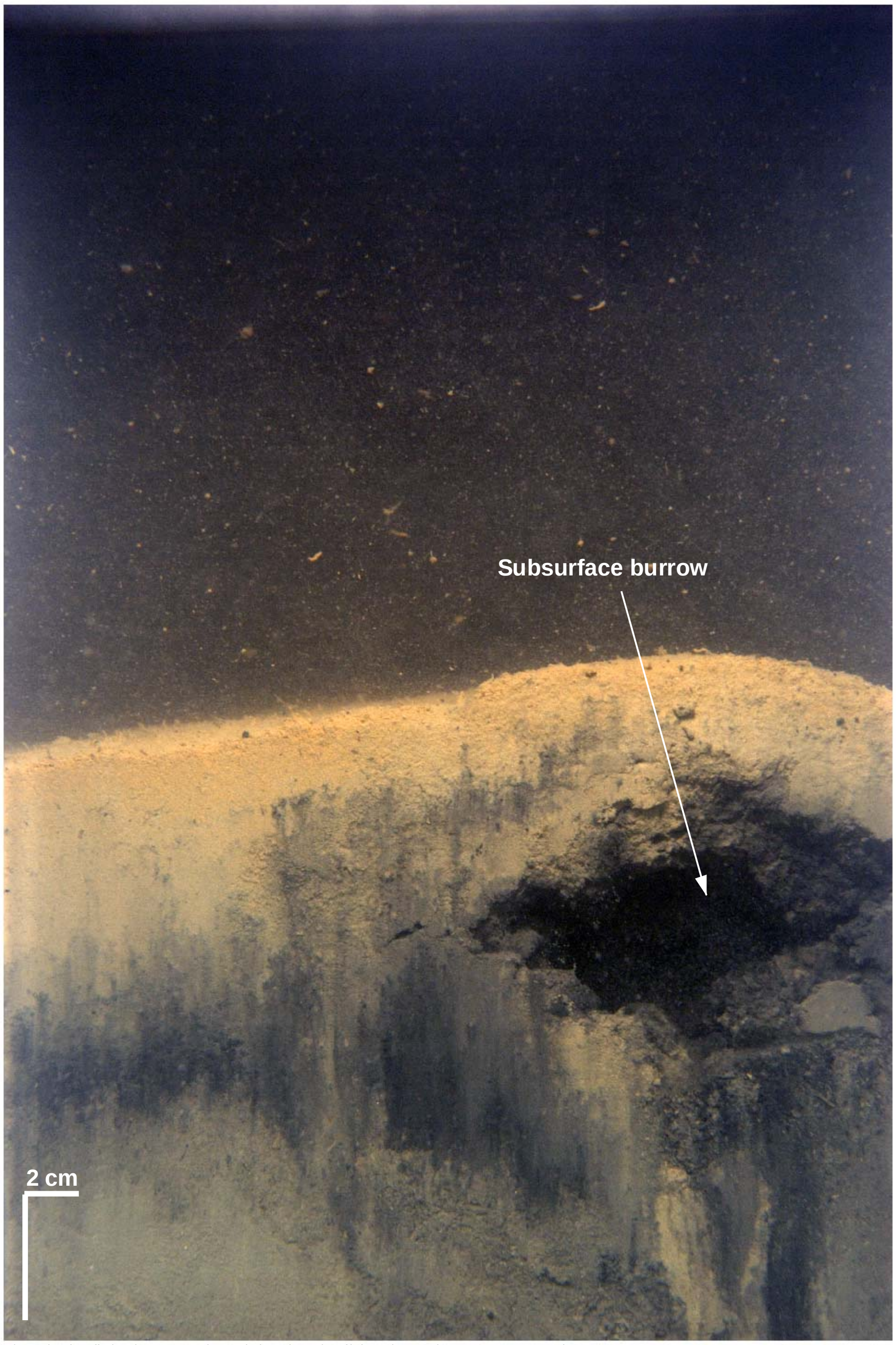

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Figure 3-15. This profile image from Station I19 shows a large subsurface burrow most likely created by a burrowing arthropod (crab or lobster)

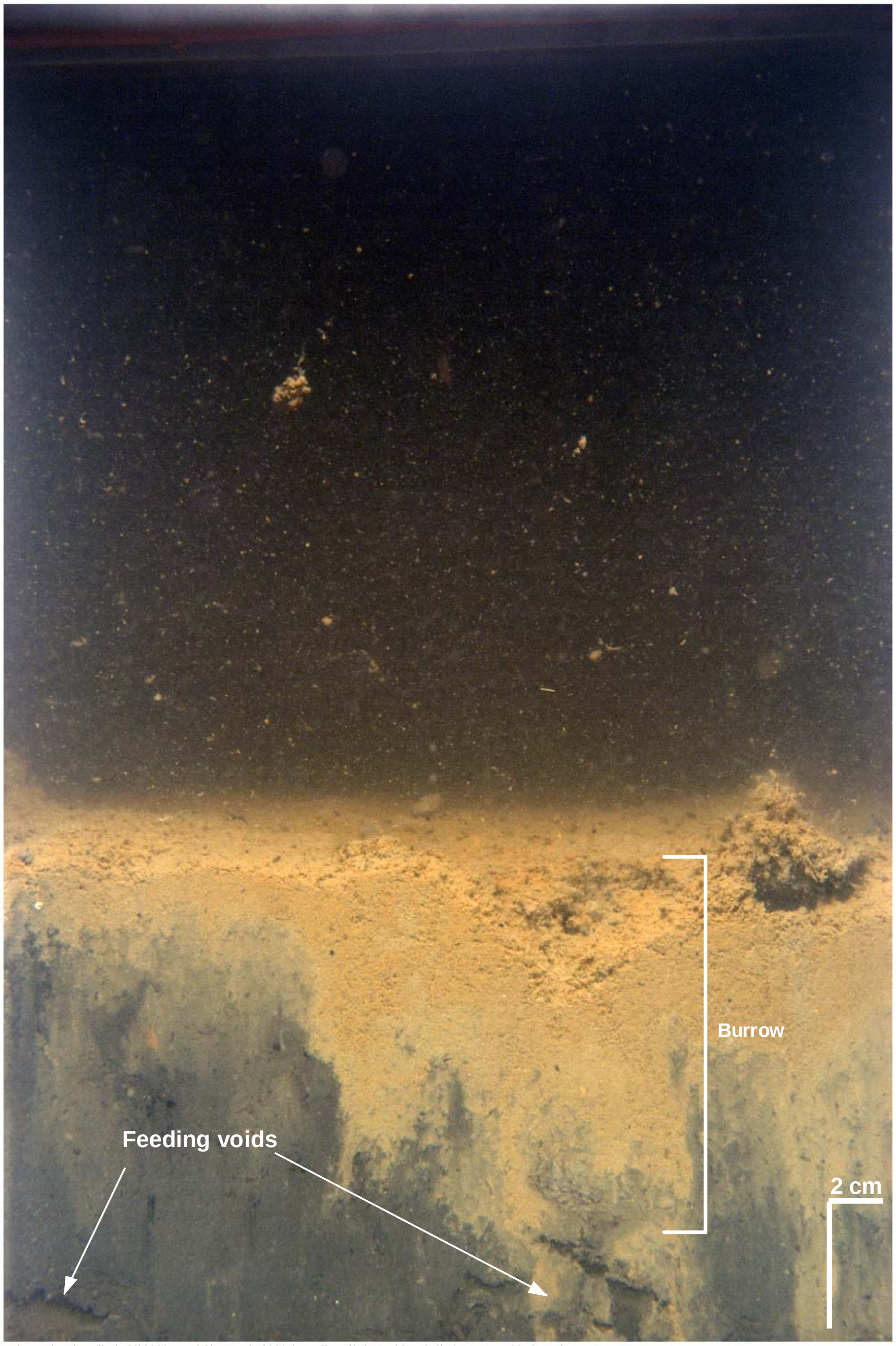

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Figure 3-16. This profile image from Station I08 shows the top of a feeding void or gallery at the bottom of a vertical burrow connected to the sediment surface

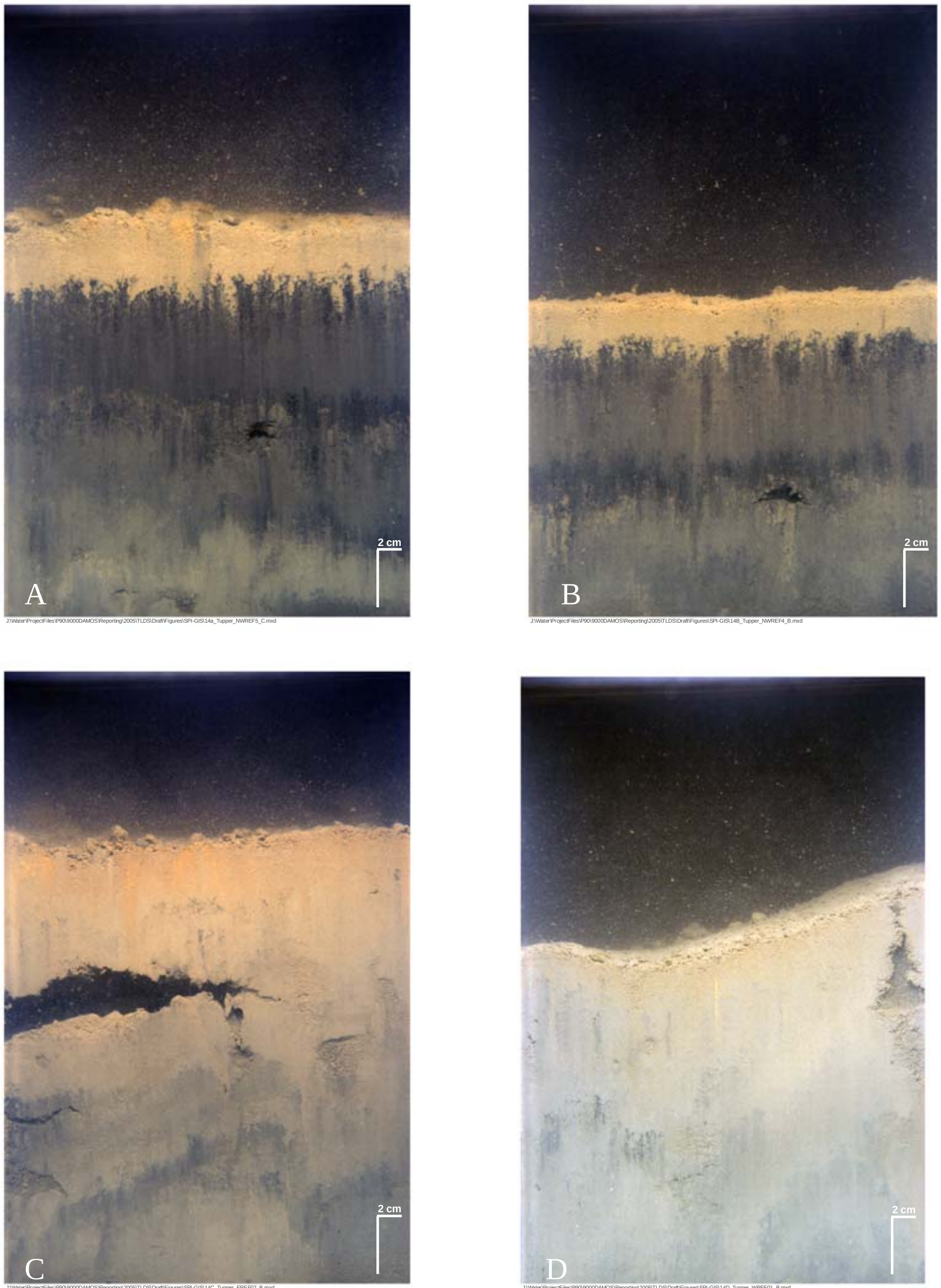

Figure 3-17. The anoxic laminations in the profile images from NWREF stations were generally more pronounced and distinct than those found at stations in the other reference areas

A). Station NWREF 5 B). Station NWREF 4
C). Station EREF02 D). Station WREF 01

stations in each of the three reference areas (Figure 3-14); the particle advection by bioturbating infauna at many of the reference stations was responsible for homogenizing and disrupting the sub-surface laminations caused by past seasonal hypoxic/anoxic events (Figure 3-18).

3.2.5 Comparison Between Disposal Site and Reference Areas

Mean RPD Variable

The three reference areas showed some small differences in mean values (Table 3-2, Figure 3-16) with NWREF having a lower mean than the other two. The maximum difference among reference locations was only 0.48 cm (1.58 to 1.10 cm), but the standard deviations within reference areas were small (from 0.14 to 0.18). Pooling stations across reference areas with different means will increase the estimate of residual variability beyond the true residual variability. Consequently, the reference areas were treated separately in the following analysis.

Table 3-2

Summary of Station Means by Sampling Location

		Mean RPD (cm)		**SS rank**	
Area	**N**	**Mean**	**Stdev**	**Mean**	**Stdev**
Reference Locations					
EREF	5	1.55	0.14	4.6	0.72
NWREF	5	1.10	0.18	4.7	0.60
WREF	5	1.58	0.14	4.5	0.38
Mean:		1.41		4.6	
Tupper Ledge Mound					
	29	1.44	0.38	4.2	1.06

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Figure 3-18. The bioturbational activities of Stage 3 infauna as seen in this example profile image from Station WREF03 were responsible for homogenizing the sub-surface anoxic strata at many of the reference stations

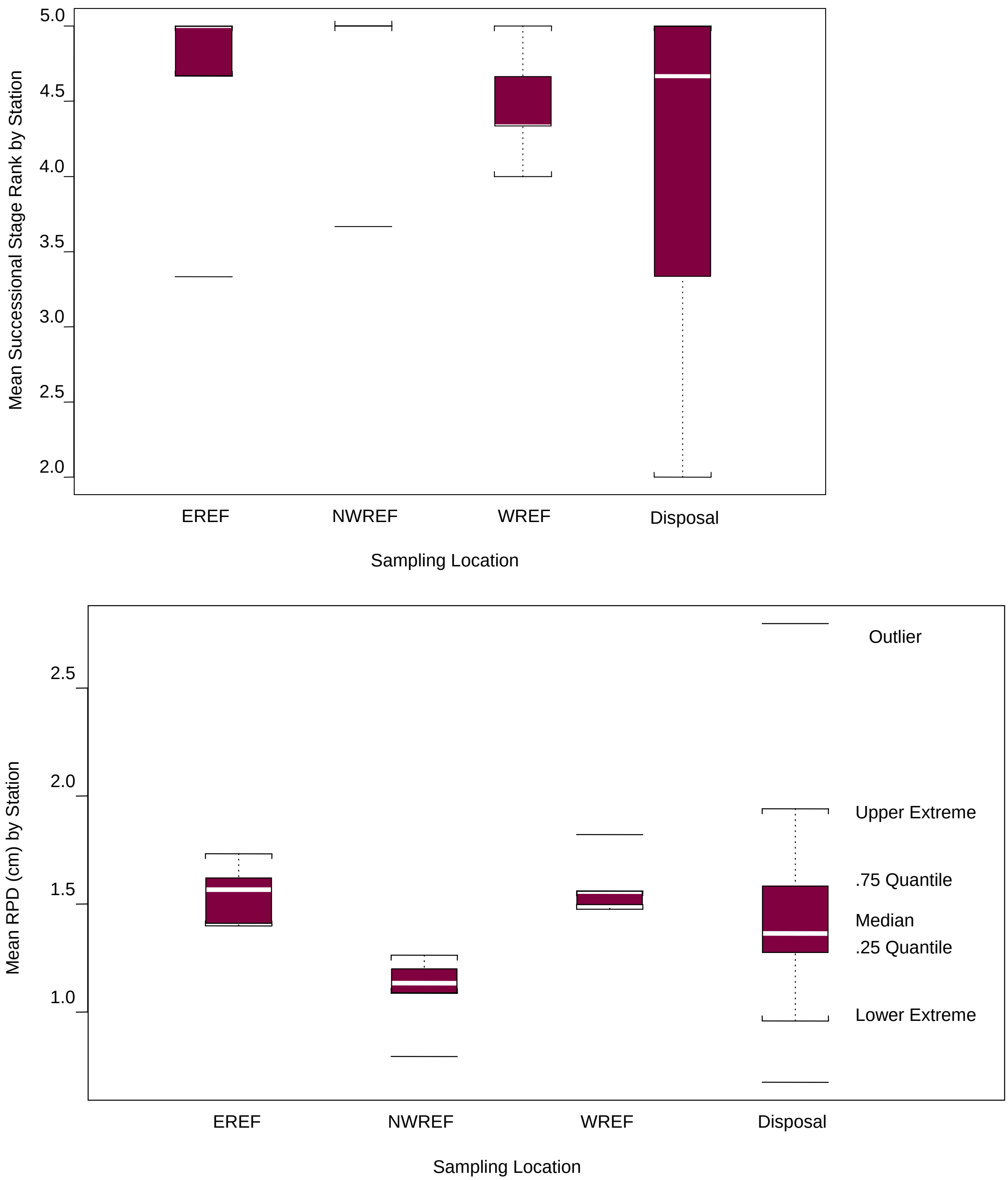

Figure 3-19. Boxplots showing distribution of station mean Successional Stage rank and RPD values for 2005 Tupper Ledge survey

Results for the normality test indicated that normality of the area residuals (i.e., each observation minus the area mean) was rejected by the Shapiro-Wilk's test ($p < 0.001$). This was due to a single influential data point from Mound station I-13; otherwise the distribution was symmetric and normality was not rejected (Shapiro-Wilk's $p = 0.22$). The result of including this station was to increase the variance and reduce the power of the test. Because we had no reason to exclude this station, we considered it a valid data point and used it in the analysis. The assumption of equal variances was not rejected by Levene's test ($p=0.26$) so a pooled variance estimate was used to compute the variance for the difference equation (Table 3-3).

Table 3-3

Summary Statistics and Results of Bioequivalence Testing for RPD Values

Difference Equation	Observed Difference ($\hat{d}$)	SE($\hat{d}$)	df for SE($\hat{d}$)	95% Lower Confidence Bound	95% Upper Confidence Bound
Ref – Mound	-0.04	0.10	40	-0.21	0.14

The specified δ value of ±1 was outside of the 95% lower and upper confidence bounds for the observed difference, even with the inflated variance from the extreme value. This indicates that the true difference between the mean RPD values from the reference areas and mean RPD values from the disposal site was within 1 RPD units, and therefore the group means were equivalent within our definition of "ecologically meaningful".

Successional Stage Rank Variable

The three reference areas had similar Successional Stage (SS) rank values both in terms of mean and range (Table 3-2, Figure 3-16, see Section 2-4 and Table 2-2 on how ranks were determined). The maximum difference among mean rank values was 0.2 which was well within the background variability (standard deviations ranged from 0.38 to 0.72). Pooling the reference areas for this endpoint increased the power for our estimate of Reference group mean and variance.

The residuals for the mound and pooled reference data were left-skewed, with nearly half the values at or near the maximum rank value of 5. No normalizing transformation exists for these left-skewed data. A non-parametric confidence interval was constructed on the difference between the reference mean and the mound mean using a bootstrap-*t* interval (Lunneborg 2000; Manly 1997) (See methods in Appendix B). Note that the bootstrap-*t* approach as applied assumes separate means and variances, so Levene's test for homogeneity of variances between the two groups was not required.

Table 3-4

Summary Statistics and Results of Bioequivalence Testing for SS Rank Values.

Difference Equation	**Observed Difference (*d*)**	***SE(d)***	**95% Lower Confidence Bound using bootstrap-t**	**95% Upper Confidence Bound using bootstrap-t**
Ref – Mound	0.40	0.24	-0.02	0.78

The specified δ value of 1 is not within the 95% lower and upper confidence bounds for the observed difference. This indicates that the true difference between the Successional Stage rank values from the reference areas and disposal mounds was within 1 unit, and therefore the group means are equivalent within our definition of "ecologically meaningful".

Comparison between 2003 and 2005

A comparison was made between results from 2003 and 2005 for 29 stations [the 25 "inner disposal site" stations plus the additional four stations that had dredged material present in 2003 (i.e., O-01, O-02, OWREF-01, OWREF-07)] for both the mean RPD and successional stage rank values (Figure 3-20). Slight skewness in the group residuals for the RPD values resulted in rejection of normality by the Shapiro-Wilk's test (p=0.04). Strong left-skewness for the SS rank values was indicated by a clear rejection of the Shapiro-Wilks test ($p = 5e^{-8}$). Consequently, confidence intervals on the difference in means between 2003 and 2005 for both variables were constructed using the non-parametric bootstrap-*t* method. Table 3-5 shows the summary statistics for the two years and results for the confidence intervals on the differences in means between the two years.

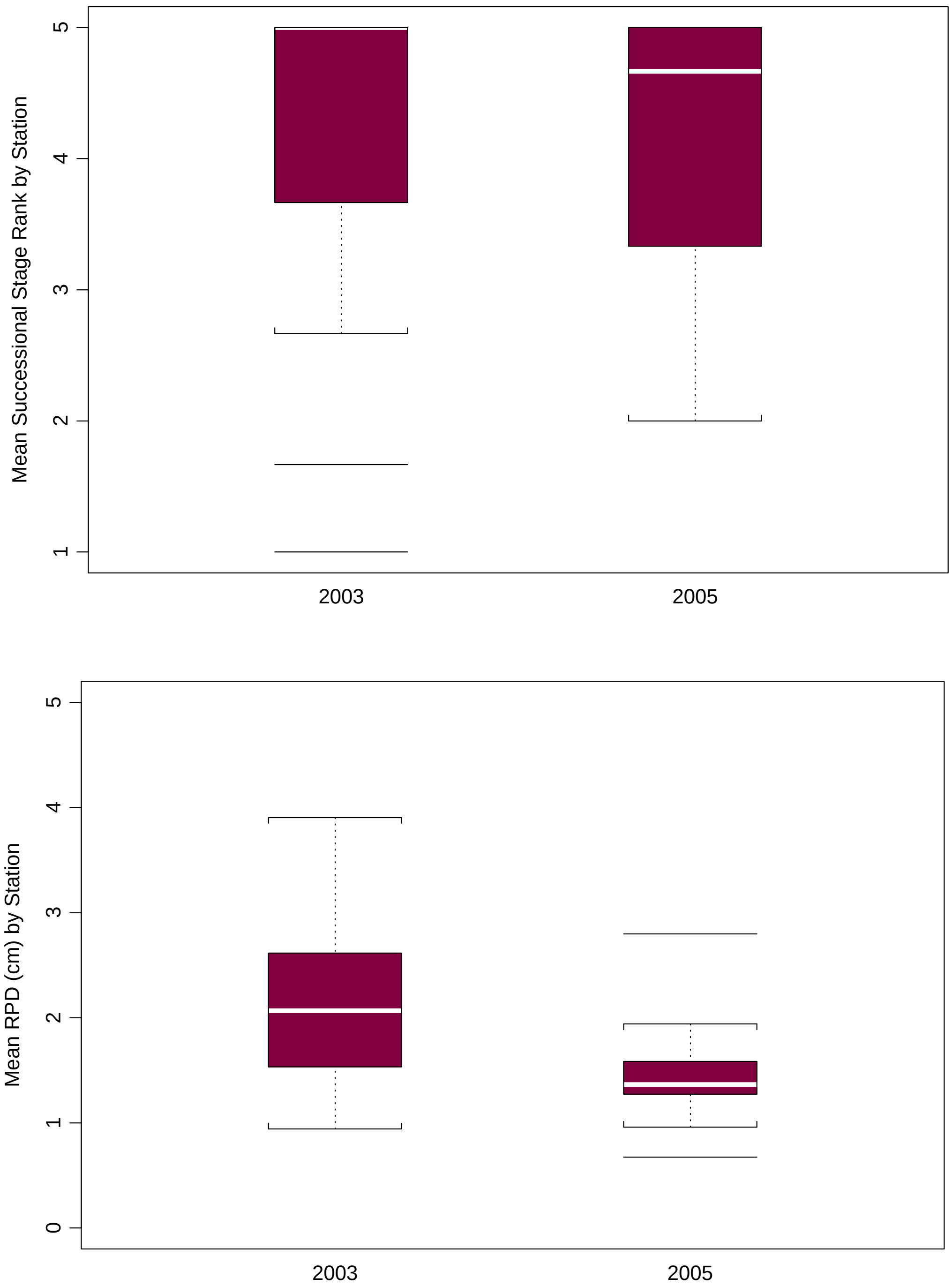

Figure 3-20. Boxplots showing distribution of station mean Successional Stage rank and RPD values at Tupper Ledge disposal area for 2003 and 2005

Table 3-5

Summary Statistics and Results of Bioequivalence Testing for Mean RPD and SS Rank Values Comparing 2003 and 2005 Mound Stations

	2003 data		2005 data					
Variable	**Mean**	**n**	**Mean**	**n**	**Observed Difference (2003-2005)**	**SE (*d*)**	**95% Lower Confidence Bound using bootstrap-t**	**95% Upper Confidence Bound using bootstrap-t**
Mean RPD	2.14	28	1.44	29	0.70	0.15	0.42	0.95
Mean SS Rank	4.24	29	4.2	28	1.04	0.28	-0.42	0.51

Both confidence bounds exclude 1, so we conclude that the two years are equivalent within 1 unit for both variables.

4.0 DISCUSSION

During the original survey of Tupper Ledge before the 2001 disposal events, the presence of high total organic carbon concentrations were identified in the sediments. It was proposed at that time that Tupper Ledge experienced relatively high rates of organic matter deposition due to its close proximity to rivers and its location with respect to estuarine circulation (SAIC, 2000). The estuarine circulation in the bay presumably acts to slow incoming water, facilitating the settling of suspended sediments and organic debris out of the water column, resulting in a depositional area (SAIC, 2000). Furthermore, the waters in the bay are stratified which can contribute to hypoxia. The sediment-profiling images taken before the 2001 disposal event showed reduced (black) patches noted at depth in some of the images. These were believed to be the result of anaerobic decomposition of wood particles present in sediments disposed at the site in the past (SAIC, 2000). The 2001 through 2003 disposal events at Tupper Ledge added additional old mill waste (sawdust, bark slabs and edging) that was mixed with the sands, silt, cobbles and boulders being dredged.

The present survey was completed to document the distribution of dredged material and disposal mound morphology as well as assess the benthic recolonization status and indicators of hypoxia on the seafloor. The bathymetry showed consolidation of the dredged material disposal mounds in the time since the last survey.

In the three years since disposal operations ceased at the Tupper Ledge Disposal Site, it was apparent that the whole embayment was still undergoing periodic hypoxia/anoxia based on the persistence of laminated sediments in the reference areas and the relatively shallow apparent RPD values (one would normally expect RPD values for subtidal, fine-grained “ambient” sediments in this region of New England to be between 3 to 4 cm). The relatively small distances below the sediment-water interface at which the sub-surface laminations were detected are further evidence of the occurrence of recent hypoxic/anoxic periods. Typical average bioturbational mixing depths is approximately 10 cm (Boudreau 1998) in estuarine sediments. If seasonal anoxia was not occurring in the bay, the resident infauna should have destroyed any laminae in the upper 10 cm of sediment (Figure 4-1) and also created a thicker oxidized surface layer. These laminated sediments were found in the three reference sites, the five stations located just outside the disposal site and at some the disposal site sampling locations indicating ongoing hypoxic conditions during the intervening period.

Even though the average RPD depths measured in the 2003 post-disposal survey at the stations with dredged material were essentially equivalent to those measured at those same stations in 2005, the overall sedimentary habitat characteristics have improved based on the paucity of *Beggiatoa* colonies in 2005. In 2003, these sulfur-reducing bacterial colonies were evident at about half the stations surveyed within the disposal site boundary as well as at five stations outside the disposal boundary (ENSR 2004); the presence of *Beggiatoa* was detected at only one station within the disposal site (I22) and was not evident in any of the images taken outside the site boundary. The benthic community on the dredged material was functionally equivalent to those assemblages found on the ambient seafloor, so we would consider the area within the disposal site boundary to be recovered from the combined stress of dredged material disposal and bay-wide anoxic episodes to the same degree as the ambient sediments.

Historically, Tupper Ledge was used for dredged material disposal from the Union River from the 1870s to 1910, a period of high saw mill activity on the river and a likely source for both dredged material and river-flow sources for mill waste and other organic materials deposited in the upper Bay. Before the present day disposal events at Tupper Ledge, it was proposed that the organic matter in the area provided a food source for the benthic community, but also limited the availability of oxygen below the surface layer (SAIC, 2000). The spring melting of snow and ice leading to increased land drainage and fresh water flow along with seasonal warming of the waters would be expected to increase bacterial activity and uptake of oxygen as the bacteria break down the organic matter. Therefore, as time increases after the disposal of dredged material, SPI monitoring data alone may not allow for separation of disposal related impacts from naturally occurring events within the general area.

It was clear that this relatively shallow embayment was still experiencing periodic hypoxia or anoxia because of the high sediment-oxygen demand, low current speed, and tendency for a stratified water column to occur during the late summer months. The low incidence of *Beggiatoa* colonies was an encouraging sign indicating a path to recovery. The periodic hypoxia/anoxia events are not new to the Tupper Ledge area, but recent surveys show that the benthic community is capable of rapid recovery from these periodic environmental stress events.

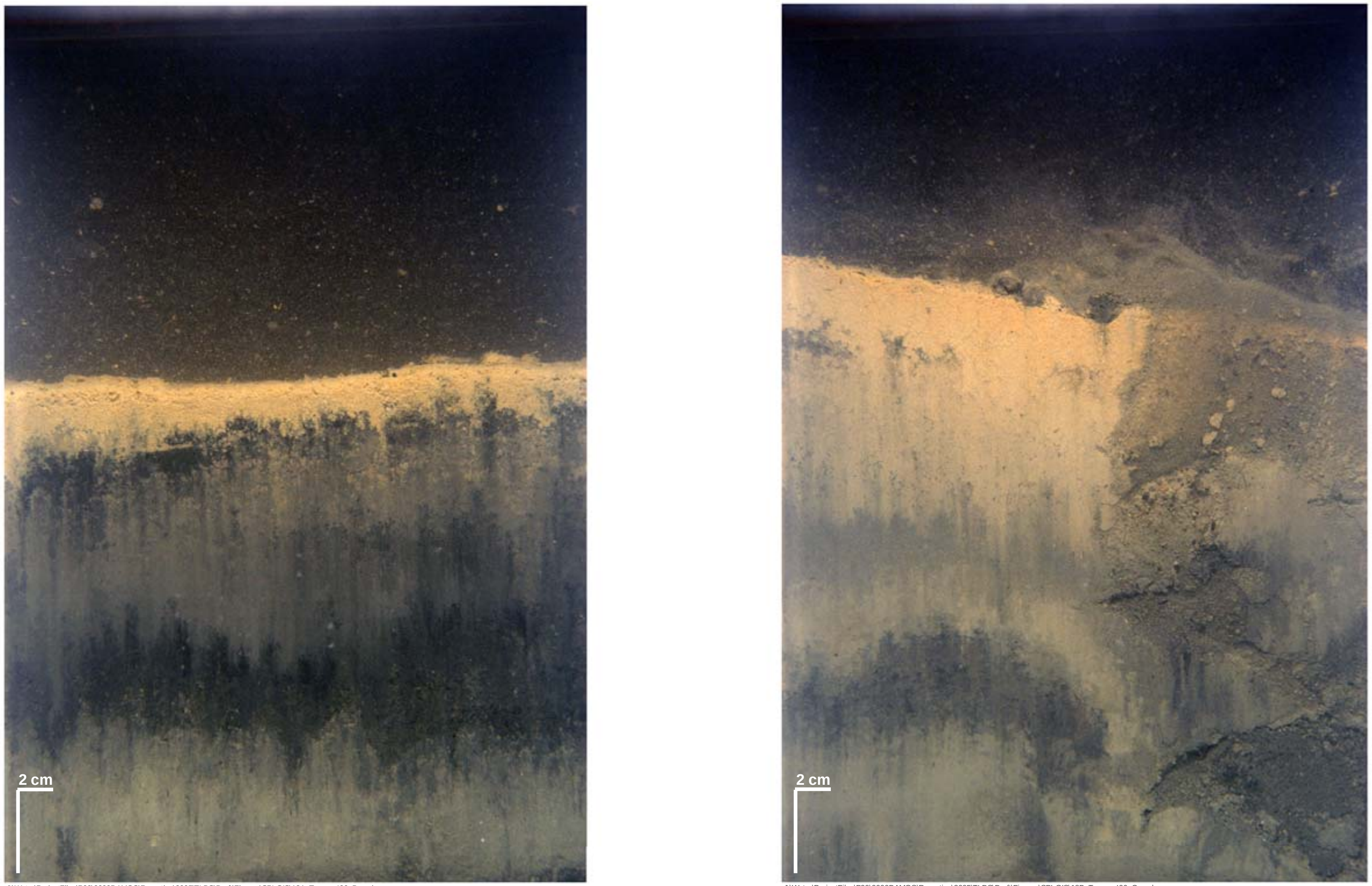

Figure 4-1. These two replicate images from Station I06 show preserved strata of anoxic events in the recent past (left) as well as the effects of bioturbational activities on disrupting this preserved signature

5.0 CONCLUSIONS

The July/September 2005 survey was performed to provide post-disposal bathymetric and SPI data at TLDS. During previous monitoring surveys, two disposal mounds were identified at TLDS from previous disposal events (2001 through 2003) and this survey documented the current distribution of the dredged material and disposal mound morphology. The September 2003 survey (ENSR, 2004) found the benthic recolonization of the sediment to be fairly advanced, but the presence of sulfur-reducing bacterial colonies and sediment banding indicated some organic enrichment and hypoxia. This survey was intended to further evaluate and monitor the recovery of the site by assessing the benthic recolonization status and indicators of hypoxia using sediment profile imaging.

- The bathymetric survey revealed that at both Mound A and Mound B the water depths were greater in the recent survey, indicating consolidation of the central portion of the mounds. Up to 0.5 meters (1.6 feet) of consolidation was measured over the mounds.

- The benthic community on the dredged material was found to be functionally equivalent to the assemblages found on the ambient seafloor.

- The relatively shallow Union River Bay was still showing signs of periodic hypoxia or anoxia because of the high sediment-oxygen demand, low current speed, and tendency for a stratified water column to occur during the late summer months. This was demonstrated by the persistence of laminated sediments in the reference areas and the relatively shallow apparent RPD values. Also the relatively small distance below the sediment-water interface of the sub-surface laminations were further evidence of the occurrence of recent hypoxic/anoxic periods.

- The paucity of sulfur reducing bacterial colonies of *Beggiatoa* in the 2005 survey in comparison to the 2003 survey support improvement in the overall sedimentary habitat characteristics even though the average RPD depths measured in 2005 and 2003 were essentially equivalent. In 2003, these sulfur-reducing bacterial colonies were evident at about half the stations surveyed within the disposal site boundary as well as at five stations outside the disposal boundary (ENSR, 2004); in 2005 the presence of *Beggiatoa* was detected at only one station within the disposal site (I22) and was not evident in any of the images taken outside the site boundary.

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APPENDIX A

SEDIMENT PROFILE IMAGING RESULTS

Table A-1

Grain Size Scale for Sediments

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

Table A-2
Sediment-Profile Imaging Results for TLDS September 2005

Station	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B - Biological, P - Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized, B-Both)	.	METHANE (N - None)	TOTAL DM AREA	TOTAL DM MEAN	TOTAL DM MIN	TOTAL DM MAX	Anoxia Laminations? (N - No, Y-Yes)	Low DO? (N - No, Y - Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	COMMENT
E Ref-01 A	9/8/2005	15:04:12	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	212.35	14.75	14.29	15.81	1.52	B	33.12	2.30	4	O		N	0	-	-	-	N	N	4	2.28	13.65	7.97	Stage 3	Tan to medium gray silt with reduced sediment at left SWI from B advection. Large multi-void gallery at right. Band of reduced sediment 9-10 cm down from SWI.
E Ref-01 B	9/8/2005	15:05:03	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	211.27	14.67	14.01	15.25	1.24	B	16.77	1.16	4	B		N	0	-	-	-	N	N	3	3.13	11.56	7.34	Stage 3	Tan to medium gray silt. Reduced sediment at SWI from bioturbation. Thin RPD but clear zone of intensive bioturbation in the upper 6-7 cm of sediment column. Large active voids in sediment column.
E Ref-01 C	9/8/2005	15:05:47	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	196.55	13.65	12.85	13.90	1.04	B	24.96	1.73	6	B		N	0	-	-	-	N	N	0	-	-	-	Stage 3	Tan to medium gray silt with fain banding 10-11 cm below SWI. No voids present but burrow in lower left-center. Three reps are generally similar.
E Ref-02 B	9/8/2005	14:56:10	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	228.42	15.86	15.42	16.29	0.87	B	33.28	2.31	>10	B		N	0	-	-	-	Y	N	2	3.98	12.88	8.43	Stage 3	Banded, tan to medium-dark gray silt/clay. Large burrow/void complex ar left and related void at right. Banding of sediment in lower portion of sediment column, most likely past anoxia given historical Beggiatoa presence
E Ref-02 C	9/8/2005	14:57:06	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	193.07	13.41	12.21	14.60	2.40	B	16.35	1.14	2	O		N	0	-	-	-	Y	N	2	3.35	8.74	6.05	Stage 3	Tan to medium dark gray silt/clay. Very large void/burrow at left and related void below it. Possible anoxic banding at lower sediment sediment column. Thin RPD and SWI appear disturbed. Penetration at angle.
E Ref-02 D	9/8/2005	17:00:10	11	0, doors added	14.40	>4	2	>4	>4 - 2	222.56	15.46	14.63	16.49	1.86	B	20.46	1.42	6	R		N	0	-	-	-	N	N	1	5.41	14.26	9.84	Stage 3	Tan to dark gray silt/cl;ay. Large burrow/void that extends over most of the subsurface sediment. Patch of organics that is being mined in lower right. Thin RPD. Three reps are very similar.
E Ref-03 A	9/8/2005	15:13:08	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	216.61	15.04	13.45	15.67	2.23	P	24.04	1.67	>10	B		N	0	-	-	-	N	N	1	13.45	??	-	Stage 3	Medium gray silt/clay with thin tan RPD. Layer of mudclasts at SWI. Mooderately organic in upper 8-10 cm. A few shallow burrows, tip of void exposed at bottom center of image
E Ref-03 B	9/8/2005	15:13:50	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	173.09	12.02	11.81	12.15	0.34	B	19.13	1.33	>20	R		N	0	-	-	-	N	N	0	-	-	-	Stage 1 -> 2	Light to medium gray silt/clay with thin tan RPD/ Mantling of gray sediment at SWI - possible l DO but mantle is over gold-hued RPD sediment and a few mudlast/tubes poke out of it. No anoxia banding. Several shallow burrows. Interesting.
E Ref-03 C	9/8/2005	15:14:30	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	140.49	9.76	9.22	10.49	1.27	B	17.68	1.23	5	B		N	0	-	-	-	N	N	0	-	-	-	Stage 2	Light to dark gray silt/clay. SWI has been recently disturbed and top-down recolonization occurring. Small burrow at left and several shallow burrows at SWI. Large mudclasts at right SWI. Very subtle RPD contrast. Three reps are generally similar.
E Ref-04 A	9/8/2005	15:09:12	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	238.24	16.54	16.01	17.11	1.10	B	18.27	1.27	>10	B		N	0	-	-	-	Y	N	2	5.86	7.39	6.62	Stage 1 on 3	Banded light to dark gray silt/clay. Small voids in upper sediment column. Disatinct banding consistent with anoxia features at depth within the sediment column. Although voids present, bitourbation insufficient to obscure banding. Mudclasts across SWI.
E Ref-04 B	9/8/2005	15:09:55	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	255.01	17.71	17.39	18.24	0.85	B	16.71	1.16	>10	B		N	0	-	-	-	N	N	1	10.26	12.35	11.30	Stage 1 on 3	Soft, light to medium-dark gray silt/clay with thin tan RPD. Mantling of reduced sediment across part of SWI. Burrow/void in lower left-center. SWI covered with mudclasts.
E Ref-04 C	9/8/2005	15:10:36	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	126.45	8.78	8.09	9.84	1.75	P	25.47	1.77	>10	B		N	0	-	-	-	N	N	0	-	-	-	Stage 1 on 3	Light to medium gray silt/clay. SWI has been disturbed and is coated with mudclasts that are mostly oxidized. Several shallow burrows and larger organism in upper center. Dissimilar from reps A and B, edge of burrow in lower right
E Ref-05 A	9/8/2005	14:59:56	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	161.81	11.24	10.94	11.64	0.70	B	23.67	1.64	>10	B		N	0	-	-	-	Y	N	0	-	-	-	Stage 2 -> 3	Faintly banded light to dark gray silt/clay with tan RPD. Several shallow to moderately deep (3-4 cm) burrows extending down from SWI. Numerous mudclasts at SWI. Historic anoxic banding at depth.
E Ref-05 B	9/8/2005	15:00:38	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	233.21	16.20	15.03	16.80	1.78	B	19.74	1.37	4	R		N	0	-	-	-	N	N	3	7.22	12.69	9.95	Stage 1 on 3	Soft light silt/clay over medium-dark gray silt/clay with tan RPD. Biogenic mound at right SWI and small tube. Deep burrow extending downward from SWI at left. Large voids in lowwer rght. Thin band of reduced sediment under RPD.
E Ref-05 C	9/8/2005	15:01:28	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	220.16	15.29	14.74	15.65	0.90	B	24.28	1.69	7	R		N	0	-	-	-	Y	N	1	5.08	5.69	5.39	Stage 1 on 3	Light to medium gray silt/clay with tan RPD and a large area of black reduced sediment in mid-right. Void above black organic sediment. Deep burrow in right center. SWI covered with mudclasts.
NW Ref-01 A	9/8/2005	16:25:32	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	187.63	13.03	12.46	13.70	1.24	B	19.16	1.33	3	O		N	0	-	-	-	Y	N	2	2.68	8.94	5.81	Stage 3	Banded medium and dark gray silt/clay with tan RPD at SWI. Void burrow in upper right and mid left-center. Oscillatory banding appears to be consistent with anaoxia laminations. No oxidized sediment in voids.
NW Ref-01 B	9/8/2005	16:26:16	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	217.97	15.14	14.91	15.59	0.68	B	18.97	1.32	3	B		N	0	-	-	-	Y	N	2	9.92	11.78	10.85	Stage 3	Banded medium and dark gray silt/clay with tan RPD at SWI. Voids, with some processed sediment at same strata within sediment column. Oscillatory banding appears to be consistent with anoxia laminations. Although large voids present, bioturbation is insufficient to obscure banding. Very similar to A.
NW Ref-01 C	9/8/2005	16:27:02	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	187.80	13.04	11.02	14.38	3.35	P	16.44	1.14	>10	R		N	0	-	-	-	Y	N	2	8.80	11.73	10.26	Stage 3	Banded medium and dark gray silt/clay with tan RPD at SWI. Oscillatory banding appears to be consistent with anoxia laminations. Although large voids present, bioturbation is insufficient to obscure banding. Voids show some mixing but contain no oxidized sediment. Mudclasts at S are artifactual. Three reps from this station very similar.
NW Ref-02 A	9/8/2005	16:20:14	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	218.46	15.17	14.69	15.70	1.01	B	15.78	1.10	3	O		N	0	-	-	-	Y	N	4	3.50	10.43	6.96	Stage 1 on 3	Banded light, medium and dark gray silt/clay with tan RPD at SWI. Oscillatory banding in uppr sediment column consistent with anoxia laminations. Large voids present and bioturbation is obscures banding in only the bottom of the frame. Biogenic mound at right.
NW Ref-02 B	9/8/2005	16:20:58	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	185.73	12.90	11.76	14.26	2.51	P	14.96	1.04	3	R		N	0	-	-	-	Y	N	1	6.94	8.15	7.54	Stage 1 on 3	Banded medium and dark gray silt/clay with tan RPD at SWI. Oscillatory banding in uppr sediment column appears to be consistent with anoxia laminations. Void in center and it does not contain any oxidized sediment. Similar to A.
NW Ref-02 C	9/8/2005	16:21:53	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	193.90	13.47	12.94	14.04	1.10	B	18.23	1.27	5	B		N	0	-	-	-	Y	N	2	3.69	6.99	5.34	Stage 1 on 3	Faintly banded light to medium and dark gray silt/clay. Banding partially obscured. Void in upper left and mid-right. Three reps are generally similar but A and B are very similar.
NW Ref-03 A	9/8/2005	16:16:20	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	191.60	13.31	12.60	13.90	1.30	P	17.30	1.20	6	R		N	0	-	-	-	Y	N	1	10.88	13.53	12.21	Stage 1 on 3	Banded medium and dark gray silt/clay with tan RPD at SWI. Oscillatory banding sediment column appears to be consistent with anoxia laminations. Void/burrow in lower right. A few tubes at left SWI. Bioturbation is not robust enough to obscure banding. Mudclasts are artifacts.

Table A-2
Sediment-Profile Imaging Results for TLDS September 2005

Station	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B - Biological, P - Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized, B-Both)	.	METHANE (N - None)	TOTAL DM AREA	TOTAL DM MEAN	TOTAL DM MIN	TOTAL DM MAX	Anoxia Laminations? (N - No, Y-Yes)	Low DO? (N - No, Y - Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	COMMENT
NW Ref-03 B	9/8/2005	16:17:00	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	161.01	11.18	10.71	11.81	1.10	B	15.77	1.10	1	R		N	0	-	-	-	Y	N	1	7.70	8.94	8.32	Stage 1 on 3	Banded light, medium and dark gray silt/clay. Void/burrow lower right. Appears to be faint amounts of reduced sediment in SWI background. Banding is irregular.
NW Ref-03 C	9/8/2005	16:17:38	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	221.65	15.39	13.62	16.49	2.88	P	Ind	0.97	>10	R		N	0	-	-	-	Ind	N	2	3.69	11.05	7.37	Stage 3	Faintly banded medium to dark gray silt/clay with tan RPD. Large mudclast artifacts at right SWI and they obscure RPD in this portion of frame. RPD mean estimated and is a linear measurement. Void in upper left and lower right. Similar to rep B.
NW Ref-04 A	9/8/2005	16:29:49	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	225.85	15.68	15.48	15.90	0.42	B	17.28	1.20	2	O		N	0	-	-	-	Y	N	5	1.92	12.52	7.22	Stage 1 on 3	Banded light, medium and dark gray silt/clay. Voids in upper left, upper right and lower left. Althouhg voids are large, banding is not obscured. RPD shows the difference between BMD a depth of oxygenation.
NW Ref-04 B	9/8/2005	16:30:29	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	165.15	11.47	11.22	11.90	0.68	B	20.49	1.42	9	O		N	0	-	-	-	Y	N	1	6.68	7.64	7.16	Stage 1 on 3	Banded light, medium and dark gray silt/clay. Void in center and no oxidized sediment in void. Oscillatory banding concsitent with periodic, historical anoxia. Several small mud tubes at SWI.
NW Ref-04 C	9/8/2005	16:31:03	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	283.62	19.70	18.49	20.72	2.23	P	14.13	0.98	0	-		N	0	-	-	-	Y	N	3	10.57	15.56	13.07	Stage 3	Very soft, tan to dark gray silt/clay. Faint anoxic banding in upper half of sediment column. SWI disturbed. Void/burrows in lower center. Bottom half of of sediment column appears more highly mixed than top half. Particulate organics in upper reduced band.
NW Ref-05 A	9/8/2005	16:11:48	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	176.56	12.26	10.60	12.77	2.17	P	16.00	1.11	>10	R		N	0	-	-	-	Y	N	0	-	-	-	Stage 2 -> 3	Banded, light to dark gray silt/clay with tan RPD. SWI covered with mudclasts. Banding clear in upper 2/3 of sediment column. Edge of transected burrow in lower right quadrant of image.
NW Ref-05 B	9/8/2005	16:12:34	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	172.01	11.95	11.28	12.46	1.18	P	10.86	0.75	>10	R		N	0	-	-	-	N	N	0	-	-	-	Stage 1 -> 2	Light gray silt/clay with patches of black sediment. Very thin RPD and SWI covered with mudclast artifacts. SWI appears recently disturbed. Different from A. Evidence of shallow burrows just below redox
NW Ref-05 C	9/8/2005	16:13:13	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	203.60	14.14	13.67	14.69	1.02	B	7.46	0.52	4	R		N	0	-	-	-	Y	N	1	6.96	8.29	7.63	Stage 1 on 3	Banded medium to dark gray silt/clay with tan RPD. Void in right center. Banding is distinct and well-preserved. Very thin RPD superimposed on upper biogenically mixed layer.
OW Ref-01 A	9/8/2005	14:47:04	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	253.66	17.62	15.98	20.30	4.31	B	40.84	2.84	>10	B		N	0	-	-	-	N	N	2	0.00	13.21	6.61	Stage 3	Soft tan to light gray silt clay with thin ban distcontinuous band band of black sediment. Large burrow/void running from upper left to lower right dominates subsurface sediment. SWI covered with mudclasts. Poor RPD contrast.
OW Ref-01 D	9/8/2005	16:52:49	11	0, doors added	14.40	>4	2	>4	>4 - 2	243.02	16.88	15.73	18.46	2.73	B	21.26	1.48	>10	B		N	0	-	-	-	Y	N	3	2.11	16.30	9.21	Stage 3	Soft, banded, light to dark gray silt clay. SWI covered with mudclasts. Biogenic depression, burrow and string of voids in right-center. Strata deflect downward at burrow. Nice pic.
OW Ref-01 E	9/8/2005	16:54:06	11	0, doors added	14.40	>4	2	>4	>4 - 2	188.17	13.07	12.69	13.53	0.85	B	21.75	1.51	3	O		N	0	-	-	-	Y	N	4	1.58	10.91	6.24	Stage 3	Banded, light gray to dark gray silt/clay with tan RPD. Voids in upper left, upper right, lower left and lower right.. Upper half of sediment column dramatically banded and bioturbation does not obscure banding. Reps D and E are similar.
OW Ref-07 A	9/8/2005	15:45:41	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	227.35	15.79	15.59	16.15	0.56	B	13.57	0.94	1	R		N	0	-	-	-	Y	N	2	9.02	11.90	10.46	Stage 1 on 3	Banded, light to dark gray silt/clay with tan RPD. Very regular, rhythmic banding throughout entire sediment column with banding intervals ranging from 1.5 - 3.1 cm. Void in mid-right and lower left. A few tubes at left-center SWI.
OW Ref-07 B	9/8/2005	15:46:28	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	179.59	12.47	12.32	12.88	0.56	B	18.22	1.26	1	R		N	0	-	-	-	Y	N	1	9.08	11.28	10.18	Stage 1 on 3	Faintly banded light to dark gray silt/clay with tan RPD. Void in lower left corner. Biogenic depression at left SWI and a few very small mud tubes. Banding is being obscured by bioturbation in the left half of the frame and the banding is not as pronounced as in rep A.
OW Ref-07 C	9/8/2005	15:47:13	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	180.09	12.51	12.29	13.00	0.70	P	9.65	0.67	1	O		N	0	-	-	-	Y	N	2	9.39	10.71	10.05	Stage 1 on 3	Banded, light to dark gray silt/clay with vry thin, tan RPD. Banding well-preserved in upper sediment column. Voids in lower center and lower left and are at same stratigraphic horizon. Podocerid tube at SWI. Three reps are slightly different in appearance but show similar process features.
OW Ref-08 A	9/8/2005	15:40:57	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	228.62	15.88	14.41	16.86	2.45	P	13.27	0.92	7	B		N	0	-	-	-	Y	N	1	7.78	8.26	8.02	Stage 1 on 3	Faintly banded, light to dark gray silt/clay with tan RPD. Large dragdown scar at right. Small void at mid left. Rythmic banding apparent in undisturbed half of sediment column and banding is present throughout entire depth of sediment column.
OW Ref-08 B	9/8/2005	15:41:38	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	273.41	18.99	17.39	20.66	3.27	B	21.24	1.48	0	-		N	0	-	-	-	Y	N	5	6.77	18.30	12.53	Stage 1 on 3	Banded. Light to dark gray silt/clay with tan, even RPD. Upper half of sediment column is very organic and shows 1.5-3 cm banding. Lower half of sediment is also banded but it is far less dark in appearance. Fine scale laminations preserved in upper sediment column. Large voids at right and lower left. Even though voids are large and appear active, the fine banding is still preserved.
OW Ref-08 C	9/8/2005	15:42:24	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	183.66	12.75	12.04	13.53	1.50	P	20.97	1.46	8	R		N	0	-	-	-	Y	N	0	-	-	-	Stage 2 -> 3	Banded. Light to dark gray silt/clay with tan, even RPD. Fine scale badning well-preserved in sediment column. Mudclasts at SWI are artifacts. Three reps show similar strata. Edge of 2 burrows transected at depth near center.
W Ref-01 A	9/8/2005	14:37:17	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	175.56	12.19	9.73	14.55	4.82	P	Ind	Indeterminate	>10	B		N	0	-	-	-	N	N	2	4.57	13.81	9.19	Stage 3	Light gray silt/clay with vestiges of a tan RPD. SWI is disturbed, presumably from sampling. Void in upper right and large burrow void in far left corner. Sediment column appears well-processed.
W Ref-01 B	9/8/2005	14:38:04	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	181.38	12.60	11.47	14.74	3.27	B	26.23	1.82	>10	O		N	0	-	-	-	N	N	4	0.40	9.50	4.95	Stage 1 on 3	Light gray silt/clay with a tan RPD. Large void/burrow in upper right and several void/burrows in upper to mid left. Faint thin band of organic sediment at left. A few tubes at SWI and biogenic mound at right. Sediment column appears moderately well processed.
W Ref-01 C	9/8/2005	14:38:50	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	244.87	17.01	15.90	17.98	2.09	P	Ind	Indeterminate	6	R		N	0	-	-	-	N	N	0	-	-	-	Indeterminate	Light gray silt/clay. SWI disturbed and large clot of black sediment smeared at SWI. Sediment column does appear to be processed of organics.
W Ref-02 A	9/8/2005	14:41:53	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	194.04	13.47	11.98	14.91	2.93	P	12.61	0.88	7	B		N	0	-	-	-	N	N	Ind	-	-	-	Stage 2	Light to medium gray silt/clay with tan RPD. Pull-away in upper sediment column/SWI and RPD is partially estimated. Possible void burrow complex at SWI but difficult to differentiate from disturbance. A recumbent tube at SWI.
W Ref-02 B	9/8/2005	14:42:38	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	166.15	11.54	9.81	11.95	2.14	B	30.99	2.15	0	-		N	0	-	-	-	N	N	3	4.91	11.53	8.22	Stage 1 on 3	Light to medium gray silt/clay with tan RPD. Void at far right and two at bottom right of frame. Numerous fine mude tubes at SWI. Sediment column appears relatively well-processed of organics. A couple of nice, pronounced, oxidized shallow burrows. Nice pic.

Table A-2
Sediment-Profile Imaging Results for TLDS September 2005

Station	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B - Biological, P - Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized, B-Both)	METHANE (N - None)	TOTAL DM AREA	TOTAL DM MEAN	TOTAL DM MIN	TOTAL DM MAX	Anoxia Laminations? (N - No, Y-Yes)	Low DO? (N - No, Y - Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	COMMENT
W Ref-02 C	9/8/2005	14:43:23	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	197.99	13.75	13.39	14.40	1.01	B	23.68	1.64	>10	B	N	0	-	-	-	Y	N	3	8.80	12.12	10.46	Stage 1 on 3	Banded, light to dark gray silt/clay with tan RPD. Voids in lower left-center and bottom center. Right SWI has been physically disturbed and diffusional RPD in spots. Nice burrow with oxidized halow in left SWI. Clear banding at left that is at an angle in comparison to SWI. Banding is obscured at right.
W Ref-03 A	9/8/2005	14:28:30	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	152.53	10.59	10.01	11.76	1.75	B	17.55	1.22	2	R	N	0	-	-	-	Y	N	1	9.27	10.04	9.65	Stage 1 on 3	Light gray silt/clay with tan RPD. Nice burrow with oxidzed walls in right center SWI; void at bottom center. Several small mud tubes at left SWI. Reduced sediment at SWI at right and appears to be related to recent bitorbation/disturbance. Faint banding at depth but has been mostly obscured. Sediment column relatively well-processed of organics.
W Ref-03 B	9/8/2005	14:29:23	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	240.86	16.73	15.87	17.59	1.72	B	27.72	1.93	0	-	N	0	-	-	-	Y	N	1	11.11	14.21	12.66	Stage 1 on 3	Light gray silt/clay with pelletized layer at right SWI. Large biogenic mound in center SWI and reduced organically depleted sediment at SWI right of mound and RPD hasn't reestablished ye Void in lower left. Faint, diffuse banding of unclear origin in lower sediment column.
W Ref-03 C	9/8/2005	14:30:10	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	181.22	12.58	10.57	13.90	3.33	P	18.52	1.29	>20	B	N	0	-	-	-	Y	N	0	-	-	-	Stage 1 -> 2	Banded, light to medium-dark gray silt/clay with tan RPD that is buried by layer of mudclasts at SWI. Banding is at high angle relative to SWI. Organism at right SWI. RPD estimated at left. Recent disturbance nearby.
W Ref-04 A	9/8/2005	14:33:07	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	216.56	15.04	14.69	15.42	0.73	B	18.33	1.27	1	O	N	0	-	-	-	Y	N	1	3.35	4.20	3.78	Stage 1 on 3	Banded, light to dark gray silt/clay with tan RPD. Void with oxidized sediment in upper center; several fine mud tubes at left SWI and in right SWI background.
W Ref-04 B	9/8/2005	14:33:52	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	155.34	10.79	10.40	11.25	0.85	P	20.16	1.40	>10	B	N	0	-	-	-	N	N	0	-	-	-	Stage 2	Light to medium gray silt/clay with tan RPD. Large mudclasts at SWI with some having an oxidized coating. Thin red polychaete in lower left. Sediment column appears processed of excess organics.
W Ref-04 C	9/8/2005	14:34:37	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	185.17	12.86	12.01	14.69	2.68	B	26.10	1.81	>10	B	N	0	-	-	-	N	N	1	10.77	11.02	10.90	Stage 1 on 3	Light gray silt/clay with tan RPD. SWI is littered with small mudclasts. Small void in lower left-center and evidence of relict void in upper center-left. Biogenic mound above void. Oxidized burrow trace in center, Very similar to rep B but with voids/infaunal features.
W Ref-05 G	9/8/2005	14:19:59	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	197.42	13.71	13.02	14.49	1.47	B	31.99	2.22	9	R	N	0	-	-	-	N	N	1	1.58	2.23	1.90	Stage 1 on 3	Light to medium-dark gray silt/clay with tan RPD. RPD contrast is very subtle. Active void in upper left and two relict voids in lower right corner. Burrow at right SWI. Several tubes in right SWI background. Sediment column appears processed of excess organics.
W Ref-05 H	9/8/2005	14:20:42	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	179.50	12.47	12.21	12.97	0.76	B	18.13	1.26	10	B	N	0	-	-	-	Ind	N	1	2.11	2.96	2.54	Stage 2 -> 3	Faintly banded, light to medium gray silt/clay with tan RPD. Void/tear in upper right. Several small mud tubes at SWI. Banding present in upper half of sediment column..
W Ref-05 I	9/8/2005	14:21:23	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	263.94	18.33	18.27	18.52	0.25	B	17.30	1.20	>10	B	N	0	-	-	-	Y	N	2	7.08	8.68	7.88	Stage 1 on 3	Banded light to dark gray silt/clay with tan RPD. Banding is rhythmic and likely anoxia related, perhaps superimposed on a seasonal deposition pattern. Small void/burrow in center of frame and small void at far left edge. A few tubes at SWI and infaunal fecal string in water column. Nice pic.
O-01 A	9/8/2005	15:52:42	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	185.79	12.90	12.43	13.31	0.87	B	19.01	1.32	2	O	N	185.79	> 12.90	> 12.43	> 13.31	N	N	0	-	-	-	Stage 1 -> 2	DM>P. Medium to dark gray silt/clay over homogeneous gray silt/clay. Thin RPD. Minor particulate organics in upper 2 cm.
O-01 B	9/8/2005	15:53:25	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	208.48	14.48	12.74	16.10	3.35	P	18.18	1.26	9	B	N	208.48	> 14.48	> 12.74	> 16.10	Y	N	0	-	-	-	Stage 1 -> 2	DM>P. Banded/layered medium to dark gray silt/clay. Black, reduced band in upper 1/3 of sediment column. Banding at bottom of frame is rhythmic. Thin RPD. Different from A.
O-01 C	9/8/2005	15:54:12	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	152.15	10.57	10.26	11.05	0.79	P	24.56	1.71	>10	B	N	152.15	> 10.57	> 10.26	> 11.05	Y	N	0	-	-	-	Stage 1 -> 2	DM>P. Banded/layered medium to very dark gray silt/clay. Banding appears to be both depositional and redox related. Banding well-preserved. Similar but slightly different from Rep B.
O-02 A	9/8/2005	16:00:09	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	85.46	5.93	4.93	6.57	1.64	B	9.64	0.67	>10	B	N	85.46	> 5.93	> 4.93	> 6.57	Y	N	0	-	-	-	Stage 1 -> 2	DM>P. Hard light gray silt/clay with bedform at SWI. Rounded mudclasts scattered at SWI. Tubes at SWI. Subsurface sediment is homogeneous. SWI is clearly physically disturbed with RPD removed in right half of frame. Interesting pic.
O-02 B	9/8/2005	16:00:56	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	152.27	10.57	10.26	10.80	0.54	B	25.37	1.76	4	R	N	152.27	> 10.57	> 10.26	> 10.80	Y	N	0	-	-	-	Stage 1 -> 2	DM>P. Firm, layered, lightto dark gray silt/clay. Biogenic depression in center SWI and worm below it. Several small mud tubes at SWI. Different from A and at time of picture not erosion/disturbed.
O-02 C	9/8/2005	16:01:45	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	97.47	6.77	5.78	7.55	1.78	P	21.02	1.46	3	R	N	97.47	> 6.77	> 5.78	> 7.55	N	N	0	-	-	-	Stage 1 -> 2	DM>P. Light gray silt clay with physical disturbance features at SWI. Nearly identical to rep A except this rep has complete RPD across frame and worm in lower left corner.
I-01 A	9/9/2005	8:05:41	11	0, doors added	14.40	>4	2	>4	>4 - 2	176.77	12.28	11.64	13.08	1.44	P	11.86	0.82	>10	B	N	117.35	8.15	5.86	11.78	Ind	N	0	-	-	-	Stage 1	DM/native. DM is dark gray to black silt/clay over light to nedium gray native sediment that is shows aome evidence of banding. Left SWI is disturbed.
I-01 B	9/9/2005	8:06:52	11	0, doors added	14.40	>4	2	>4	>4 - 2	214.94	14.93	14.86	15.19	0.34	B	19.79	1.37	4	O	N	0	0	-	-	Y	N	0	-	-	-	Stage 1 -> 2	Rhythmically banded light gray to black silt/clay with tan RPD. Banding consistent with oscillatory anoxia. Several tubes at SWI. Banding very well-preserved.
I-01 C	9/9/2005	8:07:39	11	0, doors added	14.40	>4	2	>4	>4 - 2	172.45	11.98	11.30	12.40	1.10	P	21.03	1.46	>10	R	N	92.50	6.42	5.05	7.70	Y	N	1	9.87	11.42	10.64	Stage 1 on 3	DM/Native DM is medium gray homogeneous silt/clay over light gray-medium gray native sediment. Void lower left. Ugly slide. Large mudclast at SWI that are artifacts. Relict RPD denotes start of native sediment.
I-02 A	9/9/2005	8:10:31	11	0, doors added	14.40	>4	2	>4	>4 - 2	161.15	11.19	10.85	11.70	0.85	B	16.94	1.18	8	B	N	102.77	7.14	5.50	9.30	Ind	N	3	4.88	8.63	6.75	Stage 1 on 3	DM/Native DM is medium gray homogeneous silt/clay over light gray-medium gray native sediment. Voids all at same horizon - bottom DM/top native. Incipient banding in DM. RPD is weird lens over and older RPD.
I-02 B	9/9/2005	8:11:25	11	0, doors added	14.40	>4	2	>4	>4 - 2	215.95	15.00	14.80	15.17	0.37	P	20.70	1.44	5	O	N	215.95	> 15.00	> 14.80	> 15.17	N	N	0	-	-	-	Stage 1	DM>P. Black to dark gray silt/clay with tan RPD. Possible relict RPD 5-7 cm below SWI. A few small mud tubes at SWI. High SOD.
I-02 C	9/9/2005	8:12:14	11	0, doors added	14.40	>4	2	>4	>4 - 2	161.47	11.21	10.43	12.18	1.75	P	18.70	1.30	>10	B	N	Ind	Indeterminate	Ind	Ind	Y	N	0	-	-	-	Stage 1	Rhythmically banded silt/clay with tan RPD. Possible DM but strata looks very similar to some of the reference stations. Mudclasts at SWI. Three reps at this station are very different.

Table A-2
Sediment-Profile Imaging Results for TLDS September 2005

Station	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B - Biological, P - Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized, B-Both)	METHANE (N - None)	TOTAL DM AREA	TOTAL DM MEAN	TOTAL DM MIN	TOTAL DM MAX	Anoxia Laminations? (N - No, Y-Yes)	Low DO? (N - No, Y - Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	COMMENT
I-03 A	9/9/2005	8:15:06	11	0, doors added	14.40	>4	2	>4	>4 - 2	191.26	13.28	12.63	13.81	1.18	B	16.53	1.15	3	R	N	121.86	8.46	6.62	10.71	Ind	N	0	-	-	-	Stage 1	DM/Native. Faint banding in upper DM. DM measured from bottom of subsurface dark gray/black layer. Relict mudclasts at SWI.
I-03 B	9/9/2005	8:16:02	11	0, doors added	14.40	>4	2	>4	>4 - 2	145.24	10.09	9.25	10.51	1.27	P	23.77	1.65	>10	B	N	145.24 >	10.09	> 9.25	> 10.51	N	N	1	5.19	8.54	6.87	Stage 1 on 3	DM>P. Mottled dark and medium gray silt/clay with tan RPD. Large mudclasts at SWI that may not be related to sampling. A few tubes at SWI. Biogenically mixed sediment at lower right.
I-03 C	9/9/2005	8:16:46	11	0, doors added	14.40	>4	2	>4	>4 - 2	199.69	13.87	12.83	14.97	2.14	B	14.73	1.02	6	R	N	141.84	9.85	8.71	12.52	Y	N	0	-	-	-	Stage 2	DM over native? Layered/banded medium to dark gray silt/clay with tan RPD. Layering may be due to DM deposition or anoxia - origin is unclear. DM measured to bottom of lower black laye Biogenic mound at left SWI. Three reps are slightly different.
I-04 A	9/9/2005	8:19:36	11	0, doors added	14.40	>4	2	>4	>4 - 2	123.46	8.57	8.43	9.02	0.59	P	19.34	1.34	>10	B	N	123.46 >	8.57	> 8.43	> 9.02	N	N	0	-	-	-	Stage 2	DM>P. Medium to dark gray, relatively homogeneous silt/clay with tan RPD. Well developed shallow burrows and infaunalization at center and left. Mudclasts at SWI are artifacts. Recumbent tube in right background.
I-04 B	9/9/2005	8:20:27	11	0, doors added	14.40	>4	2	>4	>4 - 2	187.63	13.03	12.63	13.39	0.76	B	15.42	1.07	2	R	N	147.79	10.26	9.27	11.73	Y	N	1	2.17	3.44	2.81	Stage 1 on 3	DM/native?. Layered/banded medium to dark gray silt/clay with tan RPD. Banding/layering may be related to either or both DM deposition and oscillatory anoxia. Bottom of DM deposit nominally defined as bottom of lower dark gray/black band. Difficult call. Void in upper center that has a sediment tear superimposed. Several mud tubes at SWI.
I-04 E	9/9/2005	8:43:04	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	194.32	13.49	13.00	13.84	0.85	B	24.92	1.73	0	-	N	118.16	8.21	7.05	9.61	Ind	N	2	6.00	8.65	7.33	Stage 1 on 3	DM/native?. Layered/banded medium to dark gray silt/clay with tan RPD. Banding/layering may be related to either or both DM deposition and oscillatory anoxia. Bottom of DM deposit nominally defined as bottom of lower dark gray/black band/contact with relict RPD. Difficult call. Void at far right and far left and are vertically, in the same horizon. Numerous tubes at SWI. Reps B and C are very similar.
I-05 A	9/9/2005	8:23:52	11	0, doors added	14.40	>4	2	>4	>4 - 2	131.11	9.10	7.75	9.56	1.80	B	20.24	1.41	7	R	N	131.11 >	9.10	> 7.75	> 9.56	Ind	N	1	8.51	9.11	8.81	Stage 1 on 3	DM>P. Banded medium to dark gray silt/clay with tan RPD. Burrow with oxidized sediment at bottom center of frame. Large burrow/biogenic depression at right SWI. Banding may be related to DM deposition; appears very similar to some native stations.
I-05 B	9/9/2005	8:24:45	11	0, doors added	14.40	>4	2	>4	>4 - 2	139.96	9.72	9.27	10.18	0.90	B	23.00	1.60	>10	B	N	139.96 >	9.72	> 9.27	> 10.18	N	N	2	7.02	9.67	8.34	Stage 1 on 3	DM>P. Banded medium to dark gray silt/clay with tan RPD. Burrow with oxidized sediment at bottom center of frame and void in lower right. Banding may be related to DM deposition; appears very similar to some native stations. Mudclasts coating the SWI. Particulate organics in sediment column. Similar to A.
I-05 C	9/9/2005	8:25:44	11	0, doors added	14.40	>4	2	>4	>4 - 2	169.97	11.80	11.50	12.07	0.56	B	17.53	1.22	6	B	N	169.97 >	11.80	> 11.50	> 12.07	N	N	3	3.69	10.83	7.26	Stage 1 on 3	DM>P. Banded medium to dark gray silt/clay with tan RPD. Multi-void gallery and burrow running from upper left to lower right. Banding may be related to DM deposition; appears very similar to some native stations. Mudclasts coating the SWI. Particulate organics in sediment column. Three reps from this station are very similar.
I-06 A	9/9/2005	9:10:12	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	177.93	12.36	11.13	13.48	2.34	B	19.23	1.34	7	B	N	177.93 >	12.36	> 11.13	> 13.48	N	N	0	-	-	-	Stage 1 -> 2	DM>P. Banded medium to dark gray silt/clay with tan RPD. Puckered ringpiece of a void in lower right-center. Banding may be related to DM deposition; or maybe not. Mudclasts coating the SWI. Particulate organics in sediment column. Possible native sediment in lower left corner.
I-06 B	9/9/2005	9:11:05	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	181.32	12.59	12.26	12.91	0.65	B	16.77	1.16	2	O	N	132.19	9.18	8.26	9.90	Y	N	0	-	-	-	Stage 1	DM/native? Layered/banded black and medium gray silt/clay over light-medium gray silt/clay. Tan RPD. Bottom of DM nominally denoted as the base of the lower black layer and dense accumulation of wood fibers/chips at this horizon. Banding may be related to either or both DM deposition and anoxia.
I-06 C	9/9/2005	9:11:54	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	209.30	14.53	13.47	15.45	1.97	B	15.38	1.07	3	R	N	167.81	11.65	10.68	13.51	Y	N	1	3.30	12.94	8.12	Stage 1 on 3	DM/native? Layered/banded black and medium gray silt/clay over light-medium gray silt/clay. Tan RPD. Bottom of DM nominally denoted as the base of the lower black layer. Banding may be related to either or both DM deposition and anoxia. Large scale burrowing at right with reduced sediment being jetted to SWI. Wood fibers in upper DM layer. DM extent defintion is ambiguous.
I-07 A	9/9/2005	9:05:25	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	197.81	13.74	13.50	13.98	0.48	B	19.51	1.36	>10	B	N	197.81 >	13.74	> 13.50	> 13.98	Ind	N	1	6.17	7.33	6.75	Stage 1 on 3	DM>P. Layered/banded light gray to blach silt clay with tan RPD and brown layer of wood chips/fibers at bottom of frame. Particulate organics in upper DM layer. Unclear whether there is an anoxia signal superimposed on DM layering. Large, classic, active void in upper left cent SWI is coated with mudclasts.
I-07 B	9/9/2005	9:06:20	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	164.35	11.41	9.78	12.46	2.68	B	16.12	1.12	5	B	N	164.35 >	11.41	> 9.78	> 12.46	Ind	N	1	10.09	11.56	10.83	Stage 1 on 3	DM>P. Layered/banded light gray to black silt clay with tan RPD. Particulate organics in upper DM layer. Unclear whether there is an anoxia signal superimposed on DM layering. Patch of biogenically mixed sediment at lower right. Numerous tubes of at least two types at SWI.
I-07 C	9/9/2005	9:07:17	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	133.12	9.24	8.82	9.53	0.70	B	20.44	1.42	>10	B	N	133.12 >	9.24	> 8.82	> 9.53	Ind	N	0	-	-	-	Stage 1 -> 2	DM>P. Faintly banded/layered gray to black silt clay with tan RPD. Particulate organics in upp DM layer. A few small tubes at SWI and numerous rounded mudclasts of many different sizes at SWI. Ugly.
I-08 A	9/9/2005	9:00:40	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	164.53	11.43	10.74	12.12	1.38	B	15.12	1.05	0	-	N	164.53 >	11.43	> 10.74	> 12.12	N	N	1	8.43	10.09	9.26	Stage 1 on 3	DM>P. Faintly banded/layered gray to black silt clay with tan RPD and dense accumulation of brownish wood fibers and chips at bottom of frame. Particulate organics in upper DM layer. A few small tubes at SWI. Void right above wood chip layer.
I-08 B	9/9/2005	9:01:32	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	141.54	9.83	9.58	10.15	0.56	B	11.50	0.80	4	R	N	141.54 >	9.83	> 9.58	> 10.15	Ind	N	1	6.91	9.67	8.29	Stage 1 on 3	DM>P. Banded/layered gray to black silt clay with tan RPD and brownish wood fibers and chips at bottom of frame. Particulate organics in upper DM layer. A few small tubes at SWI. Void at bottom right. Black organic patch in upper left and its SOD is modifying RPD - very cool. Thin red worm (capitellid?) at lower right.
I-08 C	9/9/2005	9:02:24	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	105.28	7.31	6.17	7.98	1.80	B	31.04	2.16	4	B	N	105.28 >	7.31	> 6.17	> 7.98	N	N	2	4.34	7.92	6.13	Stage 1 on 3	DM>P. Medium to dark gray silt/clay with tan RPD. Wood fragments and organic particles in sediment column. Burrow at right-center SWI with void below and another void in lower left corner. Several tubes at SWI. Reps A and B are similar.
I-09 A	9/9/2005	8:55:55	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	148.86	10.34	9.73	11.08	1.35	B	13.87	0.96	5	R	N	148.86 >	10.34	> 9.73	> 11.08	N	N	2	5.44	9.47	7.46	Stage 1 on 3	DM>P. Medium to dark gray silt/clay with tan RPD with layer of brownish wood chips/fibers/fragments at bottom of frame. Large void in mid left with wood ships left as lag and void in lower right corner. Several tubes at SWI.
I-09 B	9/9/2005	8:56:44	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	172.34	11.97	11.59	12.40	0.82	B	15.78	1.10	0	-	N	172.34 >	11.97	> 11.59	> 12.40	N	N	1	8.49	9.70	9.09	Stage 1 on 3	DM>P. Banded/layered gray to black silt clay with tan RPD and brownish wood fibers and chips at bottom right of frame. Particulate organics in upper DM layer. A few small tubes at SWI. Void at bottom right. Origin of banding is most likely dredged material layering .

Table A-2
Sediment-Profile Imaging Results for TLDS September 2005

Station	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B - Biological, P - Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized, B-Both)	.	METHANE (N - None)	TOTAL DM AREA	TOTAL DM MEAN	TOTAL DM MIN	TOTAL DM MAX	Anoxia Laminations? (N - No, Y-Yes)	Low DO? (N - No, Y - Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	COMMENT
I-09 C	9/9/2005	8:57:37	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	161.82	11.24	10.57	11.73	1.16	B	21.34	1.48	>10	B		N	161.82 >	11.24	> 10.57	> 11.73	N	N	2	6.20	7.39	6.79	Stage 1 on 3	DM>P. Gray to black silt clay with tan RPD and a layer of dense brownish wood fibers and chi at bottom of frame. Particulate organics in upper DM layer. A few small tubes at SWI and a biogenic/mound with a central depression. Voids above wood layer. Three reps are generally similar.
I-10 A	9/9/2005	8:50:03	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	107.18	7.44	4.88	9.39	4.51	P	11.54	0.80	>10	B		N	107.18 >	7.44	> 4.88	> 9.39	N	N	0	-	-	-	Stage 1	DM>P. DM homogeneous light to medium gray silt/clay. SWI appears recently disturbed with small rounded mudclasts and thinly developed RPD. A few shallow burrows extending down from SWI. Penetration at an angle.
I-10 B	9/9/2005	8:50:51	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	149.52	10.38	10.06	10.77	0.70	B	17.69	1.23	>10	B		N	149.52 >	10.38	> 10.06	> 10.77	N	N	3	1.38	7.22	4.30	Stage 1 on 3	DM>P. DM homogeneous light to medium gray silt/clay with minor particulate organics in upper portion of sediment column. SWI appears recently disturbed with small rounded mudclasts and a 1-2 cm RDSI over old, tan RPD. Only upper unit is measured as RPD. Void/burrow complex at right and void in upper left.
I-10 C	9/9/2005	8:51:45	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	220.02	15.28	14.21	16.41	2.20	B	15.90	1.10	3	B		N	220.02 >	15.28	> 14.21	> 16.41	N	N	3	4.79	11.47	8.13	Stage 1 on 3	DM>P. DM is faintly banded light to medium gray silt/clay with minor particulate organics in upp portion of sediment column. Void/burrow complex at lower right and void in upper left. The three reps show related but slightly different features. Appears to a gradient moving downmou from A.
I-11 A	9/9/2005	9:14:47	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	133.94	9.30	8.57	10.29	1.72	P	18.02	1.25	>10	B		N	133.94 >	9.30	> 8.57	> 10.29	N	N	1	3.64	4.43	4.03	Stage 2 -> 3	DM>P. DM is highly organic medium gray silt/clay with thick, dense accumulation of wood chips/fragments/fibers at bottom of frame. Small void in upper center of sediment column. SWI is covered with numerous rounded mudclats some with only reduced sediment and some with an oxidized coating.
I-11 B	9/9/2005	9:15:45	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	147.79	10.26	9.39	10.71	1.32	B	27.75	1.93	>10	R		N	147.79 >	10.26	> 9.39	> 10.71	N	N	4	3.24	7.55	5.40	Stage 1 on 3	DM>P. DM is highly organic medium gray silt/clay with thick, dense accumulation of wood chips/fragments/fibers at bottom of frame. Voids across frame at the upper portion of the wood fiber layer. Numerous tubes at SWI. Mudclasts across SWI. Very similar to Rep A.
I-11 C	9/9/2005	9:16:48	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	147.96	10.28	9.30	11.61	2.31	B	17.18	1.19	>10	B		N	147.96 >	10.28	> 9.30	> 11.61	N	N	2	4	7.75	6.05	Stage 1 on 3	DM>P. DM is highly organic medium gray silt/clay with an accumulation of wood chips/fragments/fibers at bottom of frame. Voids in lower center of frame. Reduced sediment being jetted to SWI at burrow in vry left of frame. High SOD. Mudclasts across SWI. Very similar to Reps A and B.
I-12 A	9/9/2005	9:28:12	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	146.80	10.19	9.42	11.02	1.61	B	19.10	1.33	0	-		N	146.80 >	10.19	> 9.42	> 11.02	N	N	3	3.64	6.00	4.82	Stage 1 on 3	DM>P. DM is highly organic medium gray silt/clay with an accumulation of wood chips/fragments/fibers at bottom of frame. Voids just above wood layer. Numerous very small tubes at SWI. Similar to I-11.
I-12 B	9/9/2005	9:29:03	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	130.99	9.10	8.49	10.26	1.78	B	17.06	1.18	0	-		N	130.99 >	9.10	> 8.49	> 10.26	N	N	2	3.75	6.93	5.34	Stage 1 on 3	DM>P. DM is highly organic medium gray silt/clay with an accumulation of wood chips/fragments/fibers at bottom of frame. Voids just above wood layer. Numerous very small tubes at SWI. Nearly identical to Rep A and I-11.
I-12 C	9/9/2005	9:30:06	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	133.98	9.30	8.96	9.58	0.62	B	18.10	1.26	>10	R		N	133.98 >	9.30	> 8.96	> 9.58	N	N	2	3.10	6.88	4.99	Stage 1 on 3	DM>P. DM is highly organic medium gray silt/clay with an accumulation of wood chips/fragments/fibers at bottom of frame. Voids just above wood layer. Nearly identical to Reps A and B but with higher SOD and mudclasts at SWI.
I-13 D	9/9/2005	10:09:13	13	0, doors added	14.40	>4	1	>4	>4 - 1	101.04	7.02	6.40	8.18	1.78	P	27.69	1.92	0	-		N	101.04 >	7.02	> 6.40	> 8.18	N	N	2	2.71	6.79	4.75	Stage 1 on 3	DM>P. Firm. DM is melange of light and dark gray silt with clots of very light gray/white cohesive clay. Particulate organics in upper sediment column. Burrow at bottom left with what appears to be resident crustacean. Burrow void in lower right by clay clot. Archetypal chaotic fabric.
I-13 H	9/9/2005	11:47:50	15	2, doors added	14.40	>4	1	>4	>4 - 1	203.22	14.11	12.49	15.90	3.41	P	59.39	4.12	>10	O		N	203.22 >	14.11	> 12.49	> 15.90	N	N	1	4.09	15.22	9.66	Stage 1 on 3	DM>P. DM is melange of light and dark gray silt with clots of very light gray/white cohesive cla Particulate organics in upper sediment column. Large multi-voided burrow/gallery complex that covers entire frame. Deep, high contrast RPD. Oxidized large mudclast at right that is now part of the sediment column. Similar sediment to rep A but with amped up bioturbation. Nice pic.
I-13 I	9/9/2005	11:48:43	15	2, doors added	14.40	>4	2	>4	>4 - 2	147.11	10.22	9.87	10.57	0.70	B	33.79	2.35	1	O		N	147.11 >	10.22	> 9.87	> 10.57	N	N	3	8.17	9.87	9.02	Stage 1 on 3	DM>P. Firm. DM is melange of light and dark gray silt with clots of very light gray/white cohesive clay. Particulate organics in upper sediment column. Archetypal chaotic fabric. Oxidized mudclasts have been amalgamated into sediment column at SWI. Very similar to Rep A and three reps are sedimentoloigcally identical.
I-14 A	9/9/2005	10:03:19	13	0, doors added	14.40	>4	2	>4	>4 - 2	222.47	15.45	14.32	16.15	1.83	B	23.28	1.62	>10	B		N	222.47 >	15.45	> 14.32	> 16.15	N	N	3	5.78	15.36	10.57	Stage 1 on 3	DM>P. DM is highly organic medium gray silt/clay with a thick accumulation of wood chips/fragments/fibers at bottom of frame. Void just above wood layer and two at bottom of frame. SWI is covered mudclasts. Biogenic mound with tubes at right. Similar to 11 and 12 but softer.
I-14 B	9/9/2005	10:04:13	13	0, doors added	14.40	>4	2	>4	>4 - 2	201.15	13.97	12.46	14.88	2.42	B	18.74	1.30	>10	B		N	201.15 >	13.97	> 12.46	> 14.88	N	N	3	5.27	7.95	6.61	Stage 1 on 3	DM>P. DM is highly organic medium gray silt/clay with a thick accumulation of wood chips/fragments/fibers at bottom of frame. Voids just above wood layer. SWI is covered mudclasts. Biogenic depression with tubes at left. Very similar to Rep A,
I-14 C	9/9/2005	10:05:01	13	0, doors added	14.40	>4	2	>4	>4 - 2	206.25	14.32	13.36	15.00	1.64	B	16.94	1.18	5	R		N	206.25 >	14.32	> 13.36	> 15.00	Y	N	1	3.21	4.54	3.88	Stage 1 on 3	DM>P. DM is banded, highly organic medium gray silt/clay with a thick accumulation of wood chips/fragments/fibers at bottom of frame. Upper portion of sediment column, above wood chips, shows oscillatory banding of anoxia. Very similar to Reps A and B.
I-15 A	9/9/2005	10:16:13	13	0, doors added	14.40	>4	2	>4	>4 - 2	261.50	18.16	17.70	18.55	0.85	B	22.03	1.53	1	O		N	261.50 >	18.16	> 17.70	> 18.55	N	N	3	6.06	16.55	11.30	Stage 1 on 3	DM>P. Dmis medium to darkgray silt/clay with a layer off wood chips/fragments halfway down frame. Large patch of black, high SOD sediment in center of frame. Reduced sediment at SWI from uppward conveyoring at left and conveyoring was ultra-vigorous based on "explosive texture" at left. Interesting photo.
I-15 B	9/9/2005	10:17:11	13	0, doors added	14.40	>4	2	>4	>4 - 2	278.49	19.34	18.75	20.24	1.49	P	15.70	1.09	>10	O		N	178.02	12.36	11.00	13.11	Y	N	3	15.45	18.97	17.21	Stage 1 on 3	Rythmically banded light to medium dark-gray silt/clay with 2.8 cm thick layer of wood chips/fragments/fibers 8 cm below the SWI. Likely DM but it does not appear to be DM with the exception of the Wood layer. Very very unusual in the context of the station. The banding in the upper portion of the sediment column is cositent with bith DM layering during deposition and oscillatory anoxia laminations. Very cool pic.
I-15 C	9/9/2005	10:18:14	13	0, doors added	14.40	>4	2	>4	>4 - 2	223.51	15.52	15.25	16.24	0.99	B	18.13	1.26	>10	B		N	223.51 >	15.52	> 15.25	> 16.24	Ind	N	0	-	-	-	Stage 2	DM>P. Faintly banded light to dark gray silt/clay over layer of brwon wood chips/fragments/fibers. Similar to B in terms of location of wood layer but unlike B, this rep looks like DM. A few tubes at SWI and burrow at right.
I-16 A	9/9/2005	10:47:36	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	137.59	9.55	9.25	9.81	0.56	B	23.58	1.64	8	B		N	137.59 >	9.55	> 9.25	> 9.81	N	N	1	6.03	7.05	6.54	Stage 2 -> 3	DM>P. Light to very dark gray silt/clay with scattered wood fragments at bottom of frame and tan RPD. Void in lower center and a few tubes at SWI. Several rounded mudclasts at SWI.

Table A-2
Sediment-Profile Imaging Results for TLDS September 2005

Station	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B - Biological, P - Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized, B-Both)	.	METHANE (N - None)	TOTAL DM AREA	TOTAL DM MEAN	TOTAL DM MIN	TOTAL DM MAX	Anoxia Laminations? (N - No, Y- Yes)	Low DO? (N - No, Y - Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	COMMENT
I-16 D	9/9/2005	11:41:00	15	2, doors added	14.40	>4	2	>4	>4 - 2	265.48	18.44	18.10	18.86	0.76	B	34.07	2.37	1	O		N	265.48 >	18.44	> 18.10	> 18.86	N	N	2	6.57	8.26	7.41	Stage 1 on 3	DM>P?. DM is light to dark gray organic silt/clay with thick well-sorted wood cip/gragment layer at base. DM measured to bottom of frame, the sediment below the wood layer is homogeneous which is a characteristic of DM here. Two void at top of wood layer and these voids may potentially be mechanically produced. Several small tubes at SWI.
I-16 E	9/9/2005	11:41:56	15	2, doors added	14.40	>4	2	>4	>4 - 2	248.60	17.26	16.15	18.46	2.31	P	22.67	1.57	0	-		N	248.60 >	17.26	> 16.15	> 18.46	N	N	3	3.98	5.84	4.91	Stage 1 on 3	DM>P?. DM is light to dark gray organic silt/clay with thick well-sorted wood chip/fragment layer at base. DM measured to bottom of frame, the sediment below the wood layer is homogeneous which is a characteristic of DM here. Three small real voids above wood chip layer. Several small tubes at SWI. Reps B and C are very similar.
I-17 A	9/9/2005	10:41:50	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	13.57	0.94	0.00	2.54	2.54	P	Ind	Indeterminate	0	-		N	13.57 >	0.94	> 0.00	> 2.54	N	N	Ind	-	-	-	Indeterminate	DM>P. Fine sediment draped over rock. No penetration. All reps identical - area of rock disposal
I-17 C	9/9/2005	10:43:28	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	9.72	0.67	0.28	0.99	0.71	P	9.72	0.67	0	-		N	9.72 >	0.67	> 0.28	> 0.99	N	N	Ind	-	-	-	Indeterminate	DM>P. Fine sediment draped over rock. No penetration. All reps identical - area of rock disposal
I-17 D	9/9/2005	11:35:56	15	2, doors added	14.40	>4	2	>4	>4 - 2	88.31	6.13	4.20	7.89	3.69	P	Ind	Indeterminate	>10	O		N	88.31 >	6.13	> 4.20	> 7.89	N	N	Ind	-	-	-	Indeterminate	DM>P. Melange of sediment clasts, tubes at SWI and fecal material. Hard to say what this truly represents. All other unanalyzed reps had zero or minimal penetration, rocks & fouling organisms seen in other reps
I-18 A	9/9/2005	10:37:03	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	174.60	12.12	11.33	12.74	1.41	B	19.78	1.37	9	B		N	174.60 >	12.12	> 11.33	> 12.74	N	N	2	4.03	6.20	5.12	Stage 2 -> 3	DM>P. Layered/banded medium to dark gray silt/clay with distinct thin wood chip/fragment/fiber layer and tan RPD. Voids above wood layer. A few small tubes at SWI. Rounded mudclasts at SWI. Similar to some other stations.
I-18 B	9/9/2005	10:37:49	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	127.64	8.86	8.03	9.39	1.35	B	28.26	1.96	>10	B		N	127.64 >	8.86	> 8.03	> 9.39	N	N	2	3.24	6.57	4.91	Stage 1 on 3	DM>P. DM is faintly banded light to medium gray organic silt/clay with a tan RPD. Particulate organics in upper sediment column. Large artifactual mudclast at SWI but numerous small rounded reduced mudclasts in background which are indicative of physical processes. VoiDs in upper left and right.
I-18 C	9/9/2005	10:38:37	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	163.33	11.34	11.13	11.56	0.42	B	20.41	1.42	>10	B		N	163.33 >	11.34	> 11.13	> 11.56	N	N	3	3.27	9.25	6.26	Stage 1 on 3	DM>P. DM is faintly banded light to medium gray organic silt/clay with a tan RPD. Particulate organics in upper sediment column and 2.5 cm thick layer of wood fragments 3.5 - 4 cm below the SWI. Numerous small rounded reduced mudclasts in background which are indicative of physical processes. Void in upper left, center and upper right. Numerous tubes at SWI. Intermediate between A and B..
I-19 A	9/9/2005	10:31:42	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	149.45	10.38	9.42	11.19	1.78	B	17.14	1.19	0	-		N	149.45 >	10.38	> 9.42	> 11.19	N	N	1	2.26	6.62	4.44	Stage 1 on 3	DM>P. DM is faintly banded light to medium gray organic silt/clay with a tan RPD. Large burrow at right which dominates sediment column. Abundant small mud tubes at left SWI.
I-19 B	9/9/2005	10:32:41	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	205.33	14.26	13.25	14.60	1.35	B	16.27	1.13	3	O		N	205.33 >	14.26	> 13.25	> 14.60	N	N	4	3.66	14.10	8.88	Stage 1 on 3	DM>P. DM is faintly banded light to medium gray organic silt/clay with a tan RPD. Particulate organics in upper sediment column. Voids in upper center, center, and bottom center of frame. RPD has been physically removed at far left SWI.
I-19 C	9/9/2005	10:33:38	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	194.65	13.52	13.02	14.26	1.24	B	22.83	1.59	>10	B		N	194.65 >	13.52	> 13.02	> 14.26	Ind	N	1	8.82	9.92	9.37	Stage 1 on 3	DM>P. DM is faintly banded light to medium gray organic silt/clay with a tan RPD. Particulate organics in upper sediment column and patches of brown, mixed, wood fragments/fibers/fragments at bottom of frame. Void at far right. A few tubes at SWI. Banding regular throughout sediment column. Three reps are generally similar but have some notable differences in strata.
I-20 A	9/9/2005	10:22:05	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	185.77	12.90	12.57	13.11	0.54	B	20.55	1.43	5	O		N	185.77 >	12.90	> 12.57	> 13.11	N	N	1	4.37	6.46	5.41	Stage 1 on 3	DM>P. DM is faintly banded light to medium gray organic silt/clay with a tan RPD. Particulate organics in upper sediment column and a band of brown, mixed, wood fragments/fibers/fragments at bottom of frame. Void at far left. Rounded, oxidized mudclasts at SWI.
I-20 B	9/9/2005	10:26:41	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	191.62	13.31	12.66	13.79	1.13	B	24.93	1.73	1	O		N	191.62 >	13.31	> 12.66	> 13.79	N	N	4	7.16	8.15	7.66	Stage 1 on 3	Light gray, bioturbated, silt/clay with tan RPD. Some particulate organics in upper sediment column. Station is nominally called DM but is very similar to native in terms of optical propertie Homogeneity of sediment column is a characteristic of DM. Dense tubes at left SWI.
I-20 C	9/9/2005	10:27:40	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	175.27	12.17	11.59	13.02	1.44	B	19.83	1.38	>10	B		N	175.27 >	12.17	> 11.59	> 13.02	N	N	1	6.71	7.27	6.99	Stage 1 on 3	Light gray, bioturbated, silt/clay with tan RPD. Some particulate organics in upper sediment column. Station is nominally called DM but is very similar to native in terms of optical propertie Homogeneity of sediment column is a characteristic of DM. Rounded mudclasts concentrated in biogenic depression at at SWI. Void in center of frame. Similar to Rep B.
I-21 A	9/9/2005	10:52:01	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	17.01	1.18	0.00	4.45	4.45	P	Ind	Indeterminate	4	B		N	17.01 >	1.18	> 0.00	> 4.45	N	N	Ind	-	-	-	Indeterminate	DM>P. High relief, little penetration. Assumed to be DM.
I-21 B	9/9/2005	10:52:54	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	74.51	5.17	2.40	7.75	5.36	P	28.65	1.99	>10	B		N	74.51 >	5.17	> 2.40	> 7.75	N	N	Ind	-	-	-	Indeterminate	DM>P. High relief, little penetration. Assumed to be DM. SWI is covered with rounded mudclasts that have clearly saltated. Medium to dark gray, organic silt/clat with abundant small wood chips/fragments in sediment column.
I-21 C	9/9/2005	10:53:45	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	219.04	15.21	14.72	15.50	0.79	B	21.98	1.53	1	O		N	219.04 >	15.21	> 14.72	> 15.50	Ind	N	0	-	-	-	Stage 2	DM>P, Layered/banded, light to dark gray, very organic, silt/clay. 3 cm thick band of diffuse mixed wood fragments 6 cm below the SWI. Three reps at this station are different and this one is the only one with decent penetration.
I-22 A	9/9/2005	10:57:25	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	152.23	10.57	10.04	11.11	1.07	B	24.71	1.72	1	R		N	152.23 >	10.57	> 10.04	> 11.11	N	N	1	8.94	10.07	9.50	Stage 1 on 3	DM>P. DM is medium to dark gray, highly organic silt/clay with layer of wood fragments at bottom of frame. Void in lower left. RPD modified by physical forces. Several tubes at SWI. Possible beggiatoa in center near mud clast.
I-22 B	9/9/2005	10:58:17	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	149.73	10.40	10.21	10.66	0.45	B	15.45	2.43	>10	R		N	149.73 >	10.40	> 10.21	> 10.66	N	N	2	6.54	7.70	7.12	Stage 1 on 3	DM>P. DM is medium to dark gray, highly organic silt/clay with layer of wood fragments at bottom of frame. Voids in lower center and left center just above wood fragments. SWI coated with mudclast artifacts. Very similar to A.
I-22 C	9/9/2005	10:59:11	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	134.62	9.35	9.16	9.89	0.73	B	21.07	1.46	>10	B		N	134.62 >	9.35	> 9.16	> 9.89	N	N	1	7.02	8.01	7.51	Stage 1 on 3	DM>P. DM is medium to dark gray, highly organic silt/clay with layer of wood fragments at bottom of frame. Void in lower right corner. Numerous rounded small mudclasts at SWI. Possible beggiatoa on sediment surface. All three reps from this station are very similar.
I-23 A	9/9/2005	11:02:23	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	123.54	8.58	6.91	9.87	2.96	B	34.06	2.37	8	B		N	123.54 >	8.58	> 6.91	> 9.87	Ind	N	0	-	-	-	Stage 1 on 3	DM>P. DM is is light to medium gray, faintly banded, organic, silt/clay. Particulate organics throughout upper sediment column. Large burrow with oxidized trace in left center. Rounded mudclasts at SWI. Similar to 19.

Table A-2
Sediment-Profile Imaging Results for TLDS September 2005

Station	DATE	TIME	Stop Collar Setting (in)	# of Lead Weights per Carriage	Calibration Constant	Grain Size Major Mode (phi)	Grain Size Maximum (phi)	Grain Size Minimum (phi)	GrnSize RANGE	Penetration Area (sq.cm)	Penetration Mean (cm)	Penetration Minimum (cm)	Penetration Maximum (cm)	Boundary Roughness (cm)	Boundary Roughness Type (B - Biological, P - Physical)	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized, B-Both)	.	METHANE (N - None)	TOTAL DM AREA	TOTAL DM MEAN	TOTAL DM MIN	TOTAL DM MAX	Anoxia Laminations? (N - No, Y- Yes)	Low DO? (N - No, Y - Yes)	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	COMMENT
I-23 B	9/9/2005	11:03:13	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	123.85	8.60	7.33	10.29	2.96	P	19.92	1.38	>10	B		N	123.85 >	8.60	> 7.33	> 10.29	Ind	N	1	2.09	2.71	2.40	Stage 2 -> 3	DM>P. DM is is light to dark gray, faintly banded, organic, silt/clay. Particulate organics throughout upper sediment column. Small void in upper left. SWI is coated with mudclast artifacts. Several tubes at SWI. Similar to A.
I-23 C	9/9/2005	11:04:03	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	158.18	10.98	9.42	11.56	2.14	B	13.49	0.94	0	-		N	158.18 >	10.98	> 9.42	> 11.56	Ind	N	1	8.82	9.33	9.08	Stage 1 on 3	DM>P. DM is is light to dark gray, faintly banded, organic, silt/clay over homogeneous light gray clay. Particulate organics throughout upper sediment column. Void in lower right and is small. Dragdown at upper left SWI and a few tubes at SWI. Biogenic mound above void. Three reps are generally similar althouhg C shows the most stratigraphy.
I-24 A	9/9/2005	11:07:16	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	201.38	13.98	13.31	14.66	1.35	B	30.70	2.13	2	R		N	132.37	9.19	8.21	10.43	Ind	N	3	8.60	14.35	11.48	Stage 1 on 3	DM/native? Dm interpeted to be layered/banded upper sediment column that consists of light to dark gray silt/clay over olive to light gray silt/clay. Native interpreted due to relict RPD in bottom part of frame. Entire sed column may in fact be DM. Voids in lower right and lower right center. Converges with native in appearance. Minor particulate organics in DM.
I-24 B	9/9/2005	11:08:05	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	193.44	13.43	12.97	13.62	0.65	B	22.54	1.57	1	R		N	193.44 >	13.43	> 12.97	> 13.62	Ind	N	1	5.38	12.21	8.80	Stage 1 on 3	DM>P. Layered light to dark gray silt/clay with tan RPD. Layereing persist to depth of penetration. Large void/burrow at left and numerous tubes at SWI. RPD partially physically influenced. Slightly different from A.
I-24 C	9/9/2005	11:09:01	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	181.22	12.58	11.92	13.39	1.47	B	19.82	1.38	>10	B		N	132.95	9.23	8.17	10.86	N	N	2	3.61	10.68	7.15	Stage 1 on 3	DM/native? Dm interpeted to be layered/banded upper sediment column that consists of light to dark gray silt/clay over olive to light gray silt/clay. Entire sed column may in fact be DM. Voids in upper right and biogenically mixed sediment in lower left. Converges with native in appearance. Minor particulate organics in DM. Very similar to A.
I-25 A	9/9/2005	11:12:56	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	229.97	15.97	15.56	16.27	0.71	B	25.32	1.76	>10	O		N	229.97 >	15.97	> 15.56	> 16.27	Y	N	1	2.59	3.52	3.06	Stage 1 on 3	Nominally called DM>P. Oscillatory banding or layering and similar to same native stations. Layering from both DM disposal and from periodic anoxia. Void in upper center. Sediment column does not appear organically enriched and layering well preserved.
I-25 B	9/9/2005	11:13:48	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	230.91	16.04	15.28	16.49	1.21	B	18.81	1.31	7	B		N	230.91 >	16.04	> 15.28	> 16.49	Y	N	1	12.04	12.55	12.29	Stage 1 on 3	Nominally called DM>P. Oscillatory banding or layering and similar to some native stations. Layering from both DM disposal and from periodic anoxia. Void in lowercenter. Sediment column does not appear organically enriched and layering well preserved. Numerous tubes at SWI. Nice pic.
I-25 C	9/9/2005	11:14:36	11.5	0, doors added	14.40	>4	2	>4	>4 - 2	164.73	11.44	11.11	11.73	0.62	B	26.70	1.85	1	R		N	164.73 >	11.44	> 11.11	> 11.73	N	N	2	7.16	10.35	8.75	Stage 1 on 3	DM>P. Very different from previous two reps. Light to medium gray, silt clay with a singl;e distinct band of medium gray sediment across middle of frame. Bottommost sediment homogeneous. Biogenic mound at lft and numerous small tubes at SWI. Void in center and lower left.

Appendix B

Non-parametric Bootstrapped Confidence Limits

1.0 Non-parametric Bootstrapped Confidence Limits

Bootstrapping is a statistical resampling procedure that uses the sample data to represent the entire population in order to construct confidence limits around population parameters. Bootstrapping assumes only that the sample data are representative of the underlying population, so random sampling is a pre-requisite for appropriate application of this method.

Bootstrapping procedures entail resampling, with replacement, from the observed sample of size n. Each time the sample is resampled, a summary statistic (e.g., mean or standard deviation) of the bootstrapped sample is computed and stored. After repeating this procedure many times, a summary of the bootstrapped statistics is used to construct the confidence limit. For the bootstrap-*t* method (e.g., Manly 1997, pp. 56-59; or Lunneborg 2000, pp. 129-131), the bootstrapped statistic (T) is a pivotal statistic, which means that the distribution of T is the same for all values of the true mean (θ). The bootstrap-*t* is essentially the "Studentized" version (i.e., subtract the mean and divide by the standard error, as is done to obtain the Student *t*-distribution for the sample mean) of the statistic of interest. This approach is quite versatile, and can be applied to construct a confidence interval around the difference between two means (Lunneborg 2000, p. 364).

For the purpose of constructing a confidence interval around the true difference between two means ($\Theta = \mu_y - \mu_x$) the pivotal statistic T for the true difference is defined as

$$T = \frac{d - \theta}{SE(d)} \quad \text{(Eq. 1)}$$

We assume that this is adequately approximated by the bootstrap sampling distribution of T, denoted T*:

$$T^* = \frac{d^* - \hat{\theta}}{SE(d^*)} \quad \text{(Eq. 2)}$$

This distribution is comprised of the studentized statistic (T^*_B) computed from a large number (B) of randomly chosen bootstrapped samples $x_1^*, x_2^*, \ldots x_B^*$ and $y_1^*, y_2^*, \ldots y_B^*$ from our two populations. Here, d^* is the difference in means for the bootstrapped sample; $\hat{\theta}$ is the observed difference in sample means from the original samples; $SE(d^*)$ is the estimated standard error of the difference of means.

The 5th and the 95th quantiles of the T^* distribution ($T^*_{0.05}$ and $T^*_{0.95}$, respectively) satisfy the equations:

$$\Pr\left[\frac{\theta - d}{SE(d)} > T^*_{0.05}\right] = 0.95 \quad \text{(Eq. 3a)}$$

$$\Pr\left[\frac{\theta - d}{SE(d)} < T^*_{0.95}\right] = 0.95 \quad \text{(Eq. 3b)}$$

Rearranging these equations yields 95% confidence in each of the following two inequalities:

$$\Pr[d + T^*_{0.05}\, SE(d) < \theta] = 0.95 \quad \text{(Eq. 4a)}$$

$$\Pr[d + T^*_{0.95}\, SE(d) > \theta] = 0.95 \quad \text{(Eq. 4b)}$$

Bootstrapping is used to estimate the values $T^*_{0.05}$, $T^*_{0.95}$ and *SE(d)*. The left side of equation 4a represents the 95% lower confidence limit on the difference equation ($\mu_y - \mu_x$); the left side of equation 4b is the 95% upper confidence limit on the difference equation. Based on the two one-sided testing (TOST) approach presented in McBride (1999), if the difference δ is not contained within the bounds computed by Equations 4a and 4b, then we conclude equivalence within δ units.

The specific steps used to compute the 95% upper and 95% lower confidence limits on the difference between two means using the bootstrap-*t* method are described below.

1. Bootstrap (sample with replacement from the original sample of size n) B = 10,000 samples of size n from each of the two populations separately.
2. Compute the T^*_B statistic for each bootstrapped pair of independent samples. T^*_i is the bootstrapped-*t* statistic computed from the i^{th} bootstrap sample, defined by the following equation

$$T^*_i = \frac{(\bar{y}^*_i - \bar{x}^*_i) - (\bar{y} - \bar{x})}{SE\left((\bar{y}^*_i - \bar{x}^*_i)\right)} = \frac{(\bar{y}^*_i - \bar{x}^*_i) - (\bar{y} - \bar{x})}{\sqrt{\frac{s^2_{y^*_i}}{n_y} + \frac{s^2_{x^*_i}}{n_x}}} \quad \text{(Eq. 5)}$$

   where $\bar{y}^*_i$, $\bar{x}^*_i$, $s^2_{y^*_i}$, and $s^2_{x^*_i}$ are the means and variances for the i^{th} bootstrapped sample from each of the two populations; and ($\bar{y} - \bar{x}$) is the observed difference in the original sample means. This yields 10,000 values of the bootstrapped-*t* statistic which comprise the "bootstrap-*t* distribution".

3. Compute the standard deviation of the 10,000 bootstrapped differences $(\bar{y}^*_i - \bar{x}^*_i)$ and save it as *SE(d)*. This is the bootstrap estimate of the true standard error.
4. Find $T^*_{0.05}$ and $T^*_{0.95}$, the 5^{th} and 95^{th} quantiles of the bootstrap-*t* distribution generated in Step 2. These values satisfy Equations 3a and 3b.
5. Applying Equations 4a and 4b using the values $T^*_{0.05}$ and $T^*_{0.95}$ found in Step 4 gives the bootstrap-*t* estimate of the 95% lower and upper confidence limits on the difference equation, i.e.,

$$\text{95\% LCL} = (\bar{y} - \bar{x}) + T^*_{0.05}\, SE(d) \quad \text{(Eq. 6a)}$$

$$\text{95\% UCL} = (\bar{y} - \bar{x}) + T^*_{0.95}\, SE(d) \quad \text{(Eq. 6b)}$$

   where ($\bar{y} - \bar{x}$) is the difference in means from the original samples, and *SE(d)* is the standard deviation of the bootstrapped differences computed in Step 3.