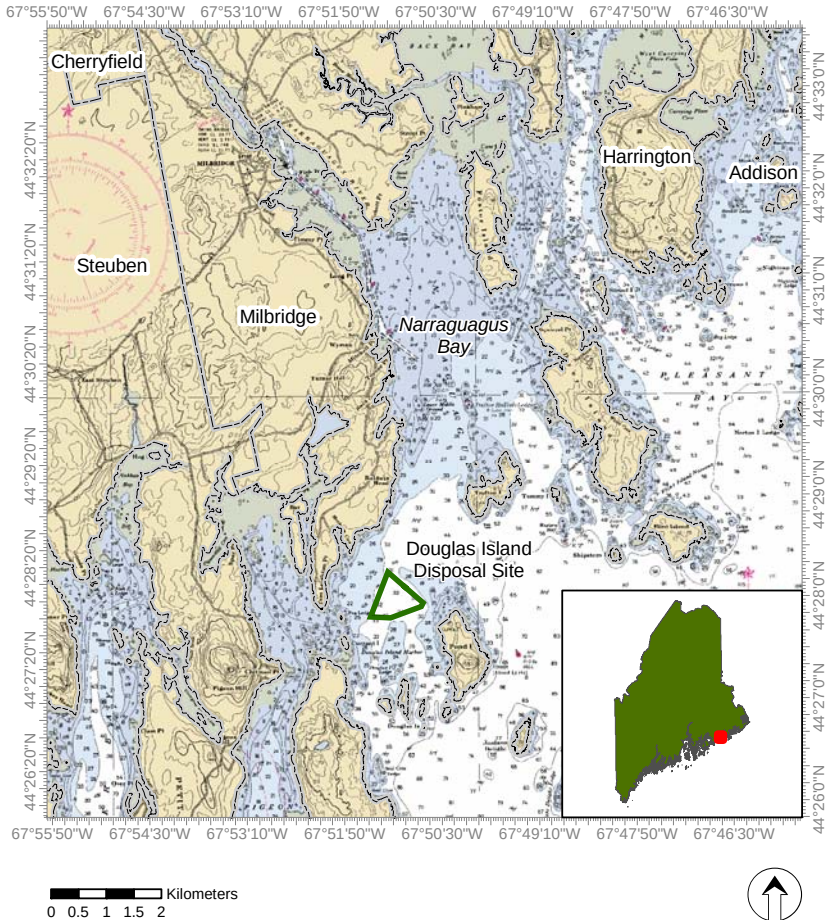
Monitoring Survey at the Douglas Island Disposal Site
Outer Narraguagus Bay, Maine
April 2003 / April 2004 / September 2005

Disposal Area Monitoring System DAMOS



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13. ABSTRACT

Monitoring surveys were conducted at the Douglas Island Disposal Site (DIDS) as part of the Disposal Area Monitoring System (DAMOS). DIDS is an infrequently used dredged material disposal site located in the waters of eastern Maine off the coast of Milbridge, ME, just northwest of Pond Island. DIDS was last used in 2004 for the disposal of approximately 77,000 m^3 (100,712 cubic yards) of material from the Narraguagus River Federal Navigation Project at Milbridge, Maine. The 2003 pre-disposal and the April 2004 post-disposal bathymetric surveys were conducted to monitor sea-floor morphology. The September 2005 field effort consisted of a sediment-profile imaging survey designed to evaluate the physical distribution of the dredged material and assess the status of the benthic community structure relative to ambient sediment conditions.

DIDS is situated in the center of Douglas Island Harbor, approximately 1.5 km (1 mile) north of Douglas Island. The harbor is located in the southwestern area of Narraguagus Bay in an area sheltered by the Milbridge and Pigeon Hill peninsulas to the west and a series of islands to the south and east. The pre and post-disposal bathymetric surveys were initiated in April 2003 and April 2004 respectively. Water depths at DIDS ranged from 11.25 meters (36.9 feet) to 7.5 meters (24.6 feet) at the disposal mound. Only one disposal mound was evident at DIDS. The deepest portion of the DIDS was located in the northeast area of the site and approximately 300 meters (984.3 feet) south of this area was the shallowest point.

Approximately one year after the disposal of dredged material from the first (2004) phase of Narraguagus River maintenance, the depths of the oxidized surface layers were essentially the same at both the disposal site and reference areas. The apparent RPD values for the Douglas Island reference sites were not as deep as those found at other reference sites for disposal areas because of periodic physical disturbance due to sediment transport and deposition in the areas.

The infaunal successional community within the disposal site has largely recovered; all but two stations sampled had Stage 3 infauna present. It is expected that the benthic community on the dredged material mound at the Douglas Island disposal site will be functionally equivalent to that on the ambient seafloor within a short time frame of about six to twelve months.

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EXECUTIVE SUMMARY

Monitoring surveys were conducted at the Douglas Island Disposal Site (DIDS) as part of the Disposal Area Monitoring System (DAMOS). DIDS is an infrequently used dredged material disposal site located in the waters of eastern Maine off the coast of Milbridge, ME, just northwest of Pond Island. DIDS was last used in 2004 for the disposal of approximately 77,000 m^3 (100,712 cy^3) of material from the Narraguagus River Federal Navigation Project at Milbridge, Maine. The 2003 pre-disposal and the April 2004 post-disposal bathymetric surveys were conducted to monitor sea-floor morphology. The September 2005 field effort consisted of a Sediment-Profile Imaging (SPI) survey designed to assess the status of the benthic community structure relative to ambient sediment conditions.

DIDS is situated in the center of Douglas Island Harbor, approximately 1.5 km (1 mile) north of Douglas Island. [The NAD83 coordinates for DIDS are: Center: -67.8511, 44.4659; NW: -67.8538, 44.4708; SW: -67.8574, 44.4633; SE: -67.8471, 44.4631; NE: -67.8458, 44.4660.] The harbor is located in the southwestern area of Narraguagus Bay in an area sheltered by the Milbridge and Pigeon Hill peninsulas to the west and a series of islands to the south and east. The pre and post-disposal bathymetric surveys were initiated in April 2003 and April 2004 respectively. Water depths at DIDS ranged from 11.25 meters (36.9 feet) to 7.5 meters (24.6 feet) at the disposal mound. Only one disposal mound was evident at DIDS. The deepest portion of the DIDS was located in the northeast area of the site and approximately 300 meters (984.3 feet) south of this area was the shallowest point.

Additional areas of the Narraguagus River Federal Navigation Project at Milbridge, Maine are scheduled for maintenance dredging during the winter of fiscal year 2007. The September 2005 field operations mark the first monitoring surveys conducted at DIDS under the DAMOS program. This survey provides a characterization of existing conditions at the disposal site that can serve as a point of reference against which future impacts can be assessed. Pre and post disposal bathymetric surveys were performed to map the seafloor and to record the creation of any disposal mounds.

The objective of the SPI survey was to assess the benthic community status within the site relative to reference conditions. The sediment-profile imaging survey was completed on 10 September 2005 aboard the *F/V Shanna Rose*. Surface sediments at most of the disposal site stations were composed of sandy silts (poorly-sorted muds with varying degrees of fine sand) and the grain-size major mode within the disposal site was $\geq 4\ \Phi$ at most stations. Four stations (4, 6, 7, and 17) had sediments that were mainly very fine sand. Average prism penetration at the site was 13.2 cm with the shallowest values found at stations with highest sand fractions. The average site small-scale surface boundary roughness was 1.5 cm and the majority of topographical roughness elements were due to biogenic feeding pits and mounds.

There was no evidence of low dissolved oxygen in the overlying water or subsurface methane generation at any of the sampled locations.

Bioequivalence or interval testing was used to compare both successional stage rank and mean RPD values from the reference areas with those from the disposal site. The test results showed that mean RPD values between these two areas were equivalent within our definition of "ecologically meaningful", while the successional stage rank values from the reference areas and disposal mounds were inequivalent.

Most stations in the disposal site and all reference areas showed evidence of mature infaunal successional communities with deposit-feeding Stage 3 taxa (head-down, deposit-feeding invertebrates) present. DIDS only had two stations that did not have a well-developed community of Stage 3 taxa. The site had an average mean apparent RPD value of 1.7 cm.

The apparent RPD values for the Douglas Island reference sites were not as deep as those found at other reference sites for disposal areas because of periodic physical disturbance due to sediment transport and deposition in the areas.

1.0 INTRODUCTION

Monitoring surveys were conducted at the Douglas Island Disposal Site over a three year period between April 2003 to September 2005 by the U.S. Army Corps of Engineers (USACE) New England District (NAE), ENSR International, and Germano and Associates. The U.S. Army Corps of Engineers (USACE) New England District (NAE) conducted the bathymetric surveys and ENSR International, in association with Germano and Associates, conducted the SPI survey. 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 Douglas Island Disposal Site is provided below.

1.1 Overview of the DAMOS Program

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

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

1.2 Introduction to the Douglas Island Disposal Site

The Douglas Island Disposal Site (DIDS) is an infrequently used dredged material disposal site located in the waters of eastern Maine off the coast of Milbridge, ME, just northwest of Pond Island (Figure 1-1). DIDS is situated in the center of Douglas Island Harbor, approximately 1.5 kilometer (1 mile) north of Douglas Island. Coordinates for DIDS (NAD83) are: Center: -67.8511, 44.4659; NW: -67.8538, 44.4708; SW: -67.8574, 44.4633; SE: -67.8471, 44.4631; NE: -67.8458, 44.4660. The disposal site is located in the southwestern area of Narraguagus Bay in an area sheltered by the Milbridge and Pigeon Hill peninsulas to the west and a series of islands to the south and east. The site lies in approximately 11 meters (36 feet) of water and covers approximately 0.42 km^2 (104 acres) of

the seafloor. It is shallower to the east and west of DIDS, with water depths of approximately 7.5 meters (24 feet) of water.

1.3 Recent DIDS Disposal Activity and Monitoring Events

DIDS was last used in 2004 for the disposal of approximately 77,000 m^3 (100,712 cy^3) of material from the Narraguagus River Federal Navigation Project. The recorded volume is based on loaded scow estimates prior to disposal. A volume of 48,932 m^3 (64,000 cy^3) was recorded in the Operations and Maintenance log and annual report FY04 (USACE 2005) for the Federal maintenance project, representing the amount of the total volume for which the contractor received compensation. The difference between these numbers is a result of the approximate nature of scow estimates and also, possibly, sediment volume that was dredged by the contractor deeper than the prism used to calculate payment. There has been no previous monitoring of DIDS under the DAMOS Program. The disposal site was first identified in 2003 as a replacement for the Traftons Ledge disposal site in upper Narraguagus Bay, which was abandoned due to fisheries resource concerns and the shallower depth at the site.

1.4 Survey Objectives

The objectives of the 2005 Douglas Island Disposal Site survey were to (1) document the distribution of dredged material and disposal mound morphology within DIDS using pre and post-disposal single-beam bathymetric surveys and (2) assess the benthic recolonization status of the DIDS seafloor using sediment-profile imaging.

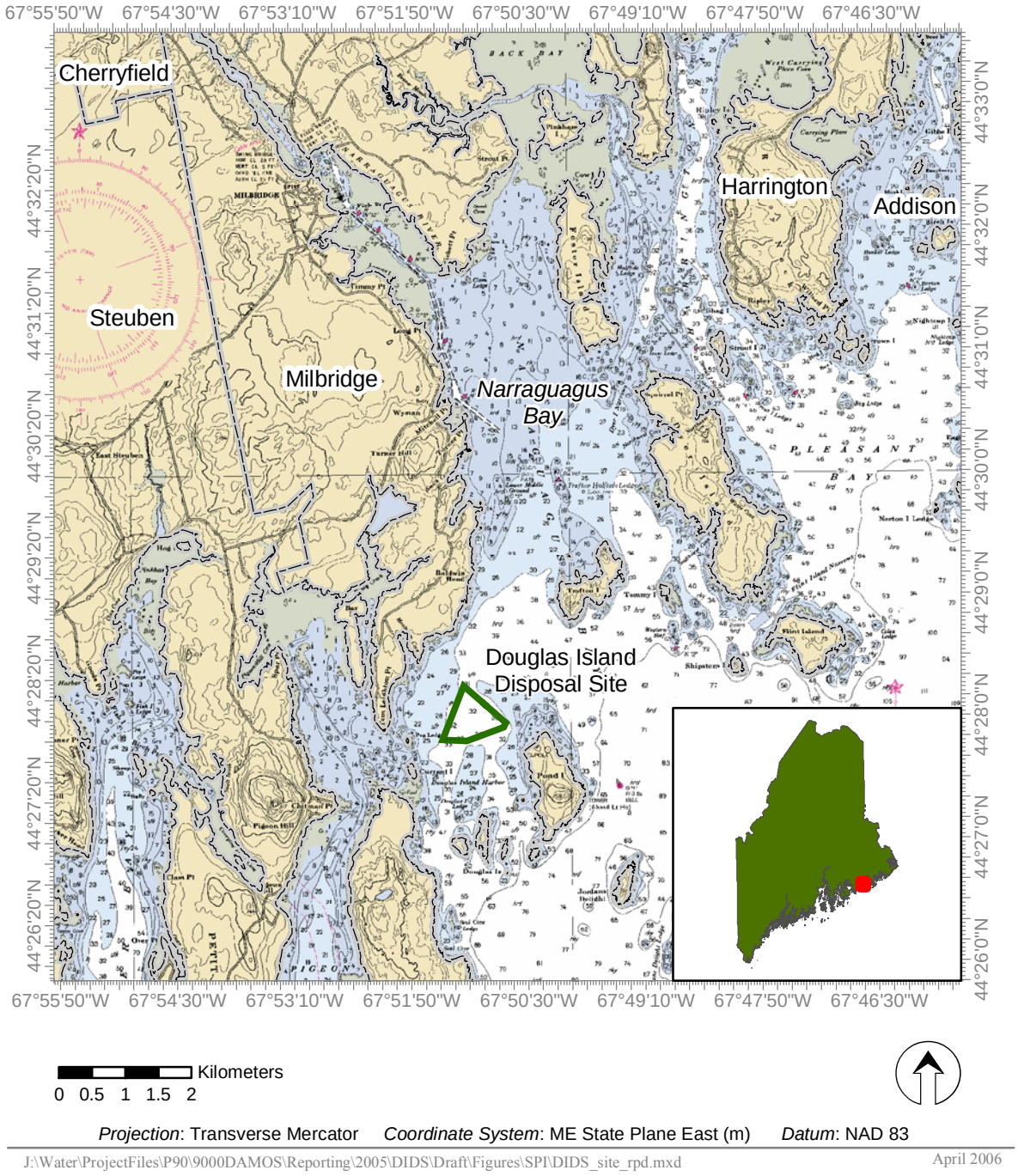

Figure 1-1. Location of Douglas Island Disposal Site

2.0 METHODS

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 station data.

2.2 Bathymetry

Two single-beam bathymetric surveys were conducted by the NAE Survey Section prior to and after the 2004 disposal at DIDS. The pre-disposal bathymetric survey was conducted in April 2003 over an approximate 975 x 840 meter (3199 x 2756 feet) irregularly shaped area, while the post-disposal survey was conducted in April 2004 over a slightly larger area, 1000 x 900 meters (3281 x 2953 feet) (Figure 2-1). Water depths were recorded in feet and referenced to a MLLW (mean lower low water) vertical datum. The data were transformed to meters after processing.

2.2.1 Bathymetric Data Acquisition and Processing

The bathymetric data were collected for both the pre-disposal and the post-disposal surveys using a 23-Foot Mon Ark Survey Boat with a single trace survey using an 8 degree beam; HYPACK Software; Mark 3 Odom Fathometer 9 (pre-disposal survey); Mark 2 Odom Fathometer 9 (post-disposal survey); Coast Guard Beacon System (GPS); and a Sound Velocity Meter (Odom). The survey consisted of 55 survey lines that ran every 50 feet.

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 DIDS April 2004 data were gridded to a cell size of 2.8 m^2 (9.2 ft^2) consistent with the bathymetric grid created for the previous (April 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 April 2003 and the April 2004 bathymetric data sets. This grid was calculated by subtracting interpolated depth estimates of April 2004 from the April 2003 depth estimates at each point throughout the grid. The resulting depth differences were contoured and displayed using ArcInfo 9.1®.

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 Muscongus Bay Disposal Site DAMOS survey report (ENSR et al. 2007).

2.3.1 SPI Data Acquisition

The SPI survey was conducted during September 2005, to assess the degree of benthic community recovery at the disposal site. The 2005 sediment-profile imaging survey design included 42 stations: 21 stations located within the disposal site, and 21 stations equally divided across three reference areas (Table 2-1, Figure 2-1). The 21 stations within DIDS were randomly distributed within a 200 meter (656 feet) radius circle, encompassing the area of recent disposal activity. As part of the 2005 survey, three reference areas were established, southeast of the disposal site (SEREF), southwest of the disposal site (SWREF), and north of the disposal site (NREF), to provide a basis of comparison between DIDS sediment conditions and the ambient sediment conditions in Narraguagus Bay. Seven stations were randomly selected within a 200-meter radius circle of each of the three reference areas.

The sediment-profile imaging survey was performed on 10 September 2005 aboard the F/V *Shanna Rose*. At each station, the vessel was positioned at the target coordinates, and the camera was deployed within a defined station tolerance of 10 meters (30 feet). Three replicate SPI images were collected at each of the 42 stations.

Table 2-1

DIDS Sediment-Profile Image Target Sampling Locations

Station	Latitude (N)	Longitude (W)	Station	Latitude (N)	Longitude (W)
DIDS-01	44° 27.942'	67° 51.126'	SWREF-01	44° 27.306'	67° 51.432'
DIDS-02	44° 27.918'	67° 51.024'	SWREF-02	44° 27.438'	67° 51.300'
DIDS-03	44° 27.918'	67° 51.132'	SWREF-03	44° 27.348'	67° 51.372'
DIDS-04	44° 28.008'	67° 50.994'	SWREF-04	44° 27.462'	67° 51.408'
DIDS-05	44° 27.942'	67° 51.066'	SWREF-05	44° 27.390'	67° 51.354'
DIDS-06	44° 28.062'	67° 51.132'	SWREF-06	44° 27.366'	67° 51.486'
DIDS-07	44° 27.978'	67° 50.970'	SWREF-07	44° 27.366'	67° 51.402'
DIDS-08	44° 27.990'	67° 51.090'	SEREF-01	44° 27.468'	67° 50.754'
DIDS-09	44° 28.020'	67° 51.084'	SEREF-02	44° 27.420'	67° 50.742'
DIDS-10	44° 27.924'	67° 51.174'	SEREF-03	44° 27.420'	67° 50.820'
DIDS-11	44° 27.894'	67° 51.114'	SEREF-04	44° 27.408'	67° 50.934'
DIDS-12	44° 27.996'	67° 51.036'	SEREF-05	44° 27.378'	67° 50.814'
DIDS-13	44° 27.894'	67° 51.000'	SEREF-06	44° 27.402'	67° 50.844'
DIDS-14	44° 27.978'	67° 51.024'	SEREF-07	44° 27.336'	67° 50.826'
DIDS-15	44° 27.894'	67° 51.054'	NREF-01	44° 28.380'	67° 51.126'
DIDS-16	44° 27.912'	67° 51.072'	NREF-02	44° 28.452'	67° 51.060'
DIDS-17	44° 27.954'	67° 50.982'	NREF-03	44° 28.458'	67° 51.138'
DIDS-18	44° 27.954'	67° 51.186'	NREF-04	44° 28.506'	67° 51.192'
DIDS-19	44° 28.008'	67° 51.054'	NREF-05	44° 28.566'	67° 51.084'
DIDS-20	44° 27.996'	67° 51.144'	NREF-06	44° 28.404'	67° 51.198'
DIDS-21	44° 28.038'	67° 51.054'	NREF-07	44° 28.446'	67° 51.108'

Notes: Coordinate system NAD83

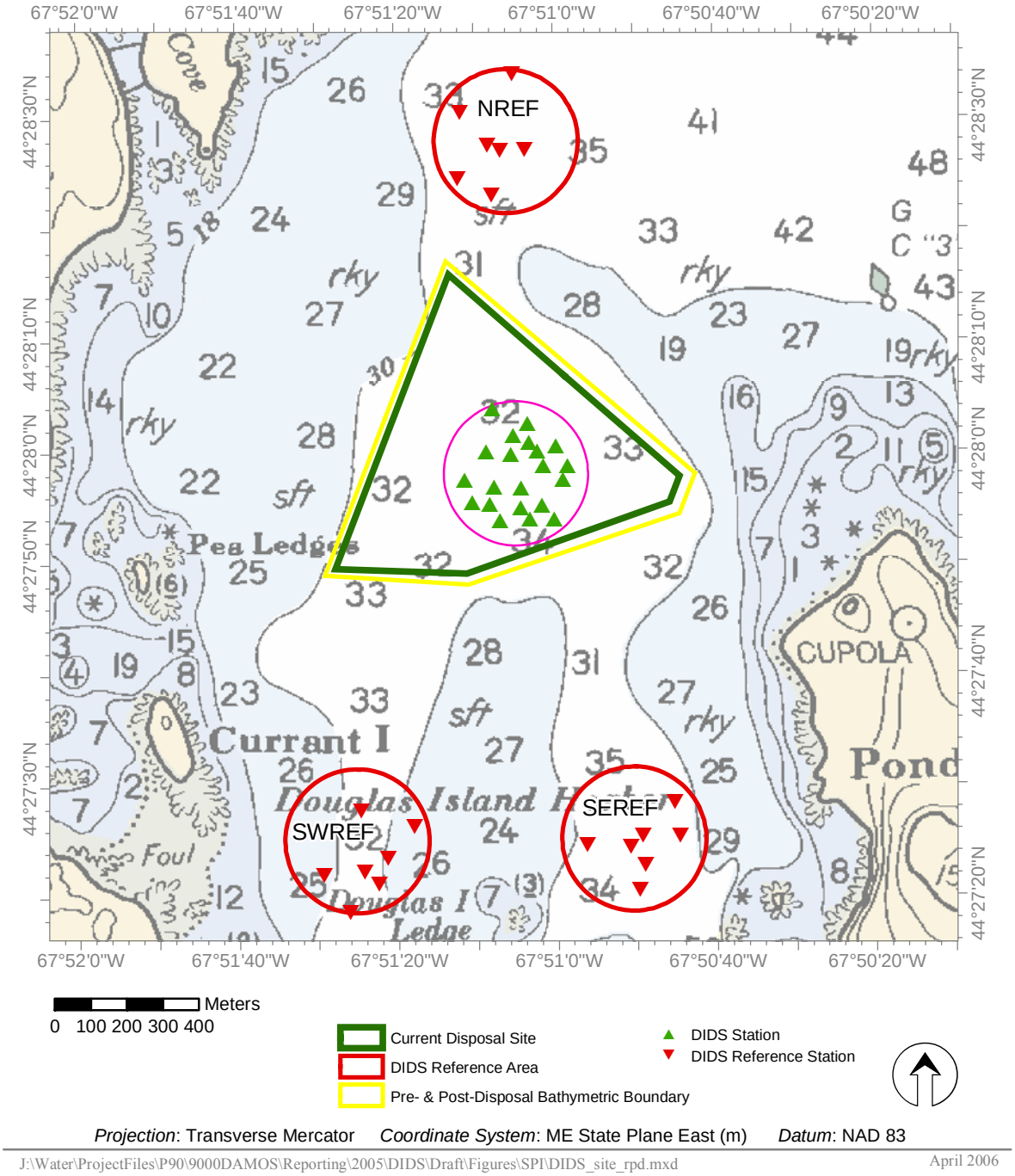

Figure 2-1. Location of bathymetric surveys at the Douglas Island Disposal Site in 2003 and 2004 and the locations of the SPI stations and associated reference areas surveyed in September, 2005

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 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 Douglas Island 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:

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

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. To determine the size of δ for RPD values, both the mean value and range of values from the reference areas for the expected difference between different areas on an undisturbed seafloor were examined. Based on the range of data found on the ambient seafloor outside the disposal site (Appendix A, Table 3-1), we used δ values of 1 for both RPD and SS rank.

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 will be transformed to approximate normality, if possible. Otherwise, a non-parametric bootstrapped interval will be used.

See Appendix B for a detailed discussion on bioequivalence testing of this data.

3.0 RESULTS

3.1 Bathymetry

Water depths at DIDS prior to disposal activity ranged from approximately 10 to 11 meters (33 to 36 feet) (Figure 3-1). Shallowest depths were located along the southern and western boundaries of the site. The deepest point was located midway along the northern boundary where depths reached 11.25 meters (36.9 feet). No disposal mounds were evident at DIDS prior to 2004.

The disposal of approximately 77,000 m^3 (100,712 cubic yards) of material from the Narraguagus River Project in 2004 resulted in the formation of a mound in the center of DIDS (Figure 3-2). Depths ranged from approximately 7.5 meters (24.6 feet) in the center of the site to approximately 11.25 meters (36 feet) along the northern boundary (Figure 3-2). The new mound was irregularly shaped and on average rose approximately 2 meters (6.6 feet) above the surrounding seafloor. The highest point of the new mound rose

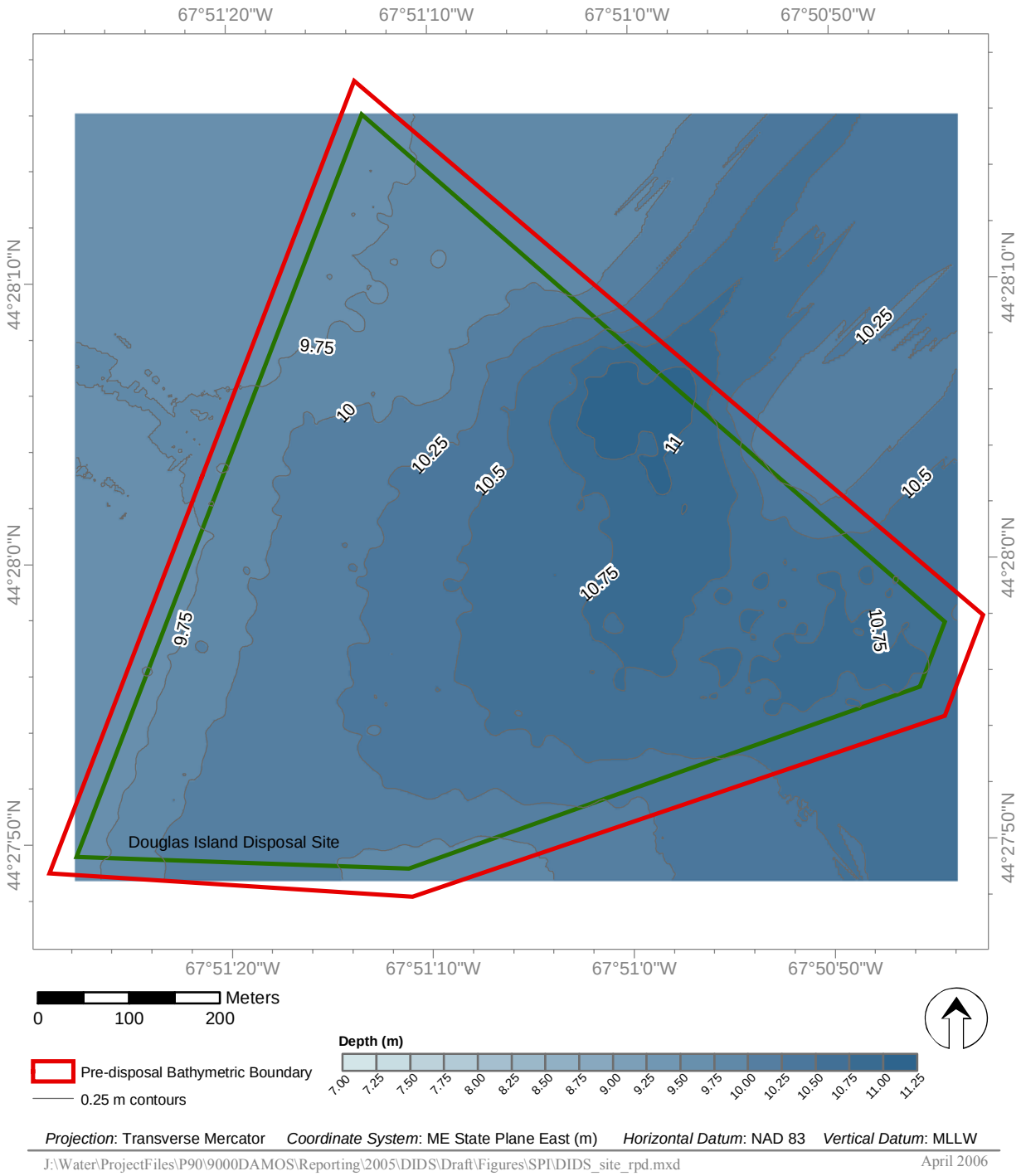

Figure 3-1. Bathymetric contour map of DIDS – April 2003 Pre-disposal Survey

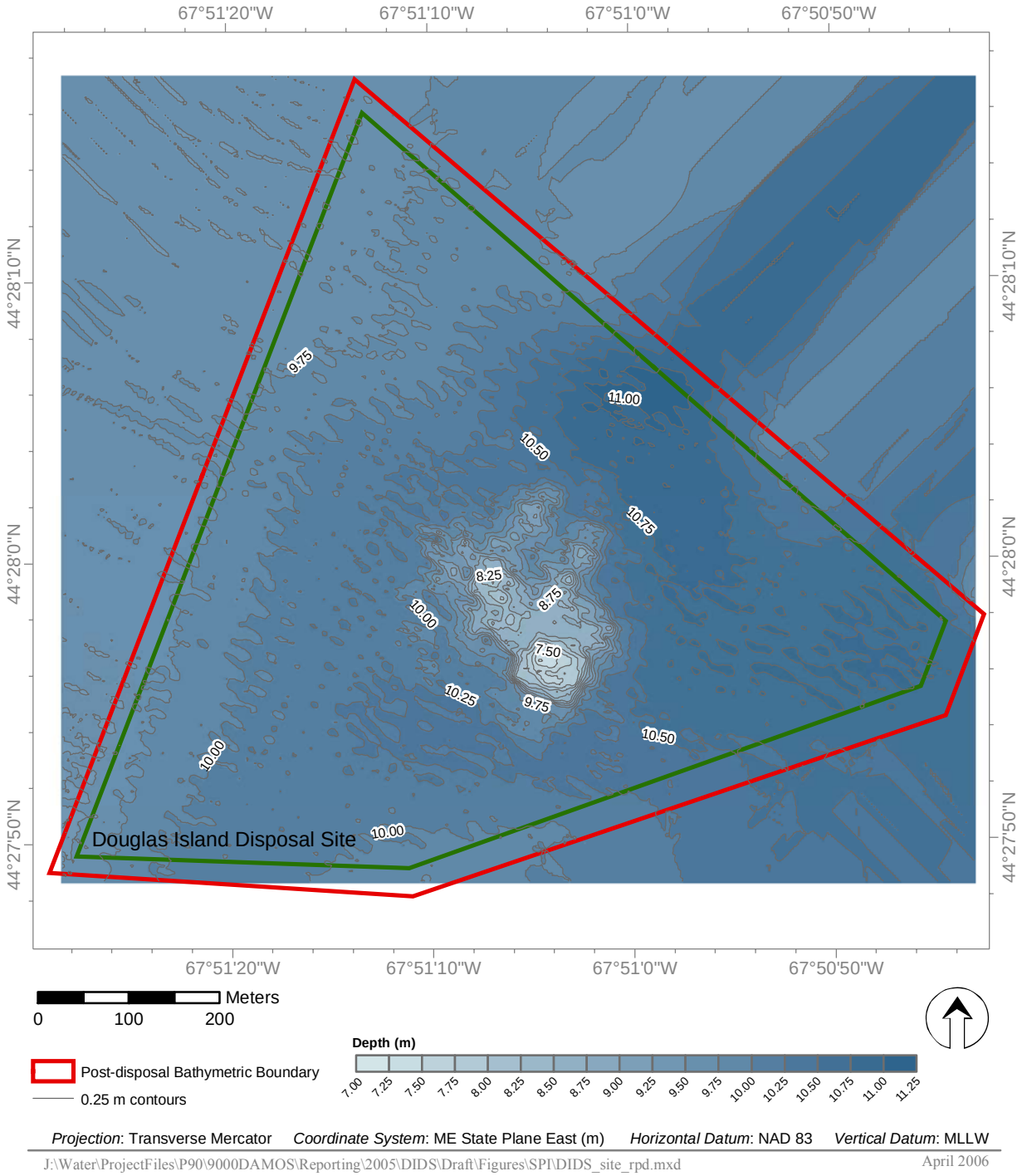

Figure 3-2. Bathymetric contour map of DIDS – April 2004 Post-disposal Survey

approximately 3 meters (9.8 feet) above the surrounding seafloor with a minimum depth of 7.5 meters (24.6 feet).

A depth-difference map was generated using the pre- and post-disposal bathymetric datasets (Figure 3-3). The depth-difference map confirmed the formation of a mound at the center of DIDS, approximately 200-250 meters (656-820 feet) in diameter and approximately 3 meters (9.8 feet) in height.

3.2 Sediment-Profile Imaging

The intent of the SPI survey was not to delineate the distribution of dredged material within the site; stations were placed within a defined target area on the disposal mound in order to assess the recolonization status and benthic habitat characteristics of representative areas on the dredged material deposit and at the reference areas. A station summary of some SPI parameters measured can be found in Tables 3-1 and 3-2, while a complete set of all SPI results can be found in Appendix A (Table A-2).

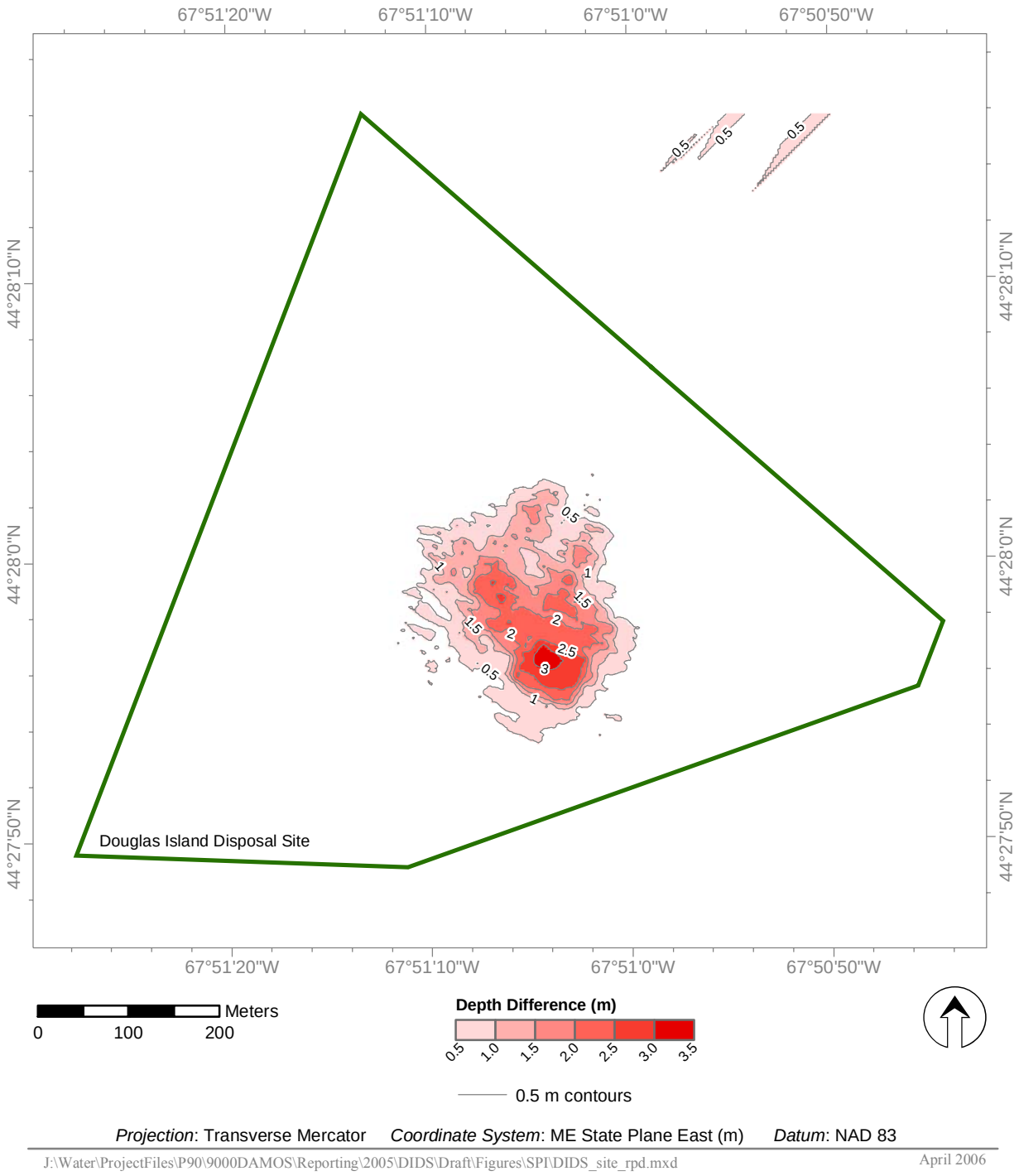

Figure 3-3. Depth-difference map of DIDS, April 2003 – April 2004

Table 3-1

Summary of Douglas Island Disposal Site (DIDS) Sediment-Profile Imaging Results, September 2005

	Grain Size Major Mode (phi)	Station Average Penetration (cm)	Station Average Boundary Roughness (cm)	Station Average RPD (cm)	Methane Present?		Station Average DM Thickness (cm)	Station Maximum Void Depth (cm)	Highest Successional Stage Present
DIDS-01	>4	12.96	1.23	1.61	NO	>	12.96	9.78	Stage 1 on 3
DIDS-02	>4	13.28	0.69	1.77	NO	>	13.28	12.04	Stage 1 on 3
DIDS-03	>4	15.69	1.33	1.33	NO	>	15.69	10.23	Stage 1 on 3
DIDS-04	4-3	12.61	1.01	1.75	NO	>	12.61	11.45	Stage 1 on 3
DIDS-05	>4	15.52	1.46	2.15	NO		16.16	10.54	Stage 1 on 3
DIDS-06	4-3	3.15	1.32	1.42	NO		0	0.00	Stage 2
DIDS-07	4-3	4.99	0.82	1.72	NO		0	4.65	Stage 1 on 3
DIDS-08	>4	17.77	1.46	2.10	NO	>	17.77	10.07	Stage 2
DIDS-09	>4	13.42	1.11	1.67	NO	>	13.42	12.63	Stage 1 on 3
DIDS-10	>4	13.92	1.83	1.38	NO		11.92	13.39	Stage 1 on 3
DIDS-11	>4	14.67	2.73	1.50	NO	>	14.67	13.00	Stage 1 on 3
DIDS-12	>4	14.85	3.91	1.51	NO	>	14.85	15.14	Stage 1 on 3
DIDS-13	>4	17.48	3.18	1.49	NO	>	17.48	16.41	Stage 1 on 3
DIDS-14	>4	17.25	0.74	1.75	NO	>	17.25	8.29	Stage 1 on 3
DIDS-15	>4	11.27	1.03	1.74	NO	>	11.27	5.41	Stage 1 on 3
DIDS-16	>4	16.12	0.96	1.60	NO	>	16.12	14.21	Stage 1 on 3
DIDS-17	4-3	5.66	1.61	2.00	NO	>	3.15	8.40	Stage 1 on 3
DIDS-18	>4	14.46	1.71	1.22	NO		10.87	11.73	Stage 1 on 3
DIDS-19	>4	15.14	0.99	2.02	NO	>	15.14	9.00	Stage 1 on 3
DIDS-20	>4	12.40	1.27	1.90	NO	>	12.40	12.38	Stage 1 on 3
DIDS-21	>4	14.29	1.07	1.56	NO		13.90	12.32	Stage 1 on 3
Average	NA	13.19	1.50	1.68	NA		12.42	10.53	NA
Minimum	NA	3.15	0.69	1.22	NA		0.00	0.00	NA
Maximum	NA	17.77	3.91	2.15	NA		17.77	16.41	NA

Table 3-2

Summary of Sediment-Profile Imaging Results for Douglas Island Disposal Site (DIDS) Reference Stations, September 2005

Station	Grain Size Major Mode (phi)	Station Average Penetration (cm)	Station Average Boundary Roughness (cm)	Station Average RPD (cm)	Methane Present?	Station Average DM thickness (cm)	Station Maximum Void Depth (cm)	Highest Successional Stage Present
NREF-01	4-3	9.78	1.72	1.49	NO	0	11.48	Stage 3
NREF-02	4-3	10.17	1.43	1.29	NO	0	11.53	Stage 3
NREF-03	4-3/>4	10.89	1.41	1.52	NO	0	12.10	Stage 1 on 3
NREF-04	4-3/>4	15.68	1.23	2.08	NO	0	15.85	Stage 3
NREF-05	4-3	8.37	0.77	1.39	NO	0	8.85	Stage 3
NREF-06	>4	10.38	0.65	1.72	NO	0	11.22	Stage 1 on 3
NREF-07	>4	10.81	0.75	1.67	NO	0	9.98	Stage 1 on 3
SEREF-01	>4	15.17	1.49	1.23	NO	0	14.89	Stage 1 on 3
SEREF-02	4-3/>4	15.84	0.74	2.42	NO	0	13.53	Stage 1 on 3
SEREF-03	>4	13.82	1.18	2.13	NO	0	13.91	Stage 3
SEREF-04	>4	16.99	2.70	2.42	NO	0	16.33	Stage 3
SEREF-05	>4	13.32	2.15	1.39	NO	0	9.14	Stage 3
SEREF-06	4-3/>4	14.77	1.26	1.51	NO	0	9.90	Stage 3
SEREF-07	4-3/>4	14.02	0.89	2.40	NO	0	11.56	Stage 1 on 3
SWREF-01	>4	16.10	1.52	1.93	NO	0	7.78	Stage 1 on 3
SWREF-02	>4	13.35	1.93	2.33	NO	0	12.15	Stage 1 on 3
SWREF-03	4-3/>4	16.75	0.71	2.14	NO	0	17.26	Stage 1 on 3
SWREF-04	4-3/>4	15.49	0.94	1.98	NO	0	12.72	Stage 1 on 3
SWREF-05	>4	17.53	0.90	1.28	NO	0	10.04	Stage 1 on 3
SWREF-06	4-3	14.27	1.96	2.11	NO	0	13.14	Stage 1 on 3
SWREF-07	>4	17.15	1.05	1.97	NO	0	15.65	Stage 3
Average	NA	13.84	1.30	1.83	NA	0.00	12.33	NA
Minimum	NA	8.37	0.65	1.23	NA	0.00	7.78	NA
Maximum	NA	17.53	2.70	2.42	NA	0.00	17.26	NA

3.2.1 Douglas Island Disposal Site: Physical Sediment Characteristics

The sediments at the stations sampled within the disposal site boundary were primarily sandy silts, i.e., poorly-sorted muds with varying degrees of fine sand. The sediment grain-size major mode was $\geq 4\ \Phi$ at all but 4 stations (Stations 4, 6, 7, and 17), where sediments were primarily very fine sand instead of silt-clay (Figure 3-4, Figure 3-5). Dredged material was present at all stations sampled except two (Stations 6 and 7) within the disposal site (Table 3-1, Figure 3-6); some of the stations showed evidence of wood chips/debris in the disposed sediments (Figure 3-7).

Average prism penetration ranged between 3.2 to 17.8 cm at stations within the disposal site, with an overall site average penetration of 13.2 cm (Table 3-1, Figure 3-8); not surprisingly, the shallowest penetration values were found at the stations with the highest sand fractions. Small scale surface boundary roughness values ranged from 0.7 to 3.9 cm, with an overall site average of 1.5 cm; the majority (70%) of the small-scale topographic roughness elements were due to biogenic feeding pits and mounds (Appendix A). No stations exhibited any evidence of low dissolved oxygen in the overlying water or signs of methane in the subsurface sediments.

3.2.2 Douglas Island Disposal Site: Biological Conditions and Benthic Recolonization

The mean apparent RPD values measured at this mound ranged from 1.2 to 2.2 cm, with an overall mound-averaged depth of 1.7 cm (Table 3-1; Figure 3-9). Evidence of mature, deposit-feeding benthic taxa was found at most stations within the disposal site (Figure 3-10, Figure 3-11); only two stations of the 21 sampled over the disposal mound did not have a well-developed community of Stage 3 taxa (head-down, deposit-feeding invertebrates) (Figure 3-10, Table 3-1).

3.2.3 Reference Areas: Physical Sediment Characteristics

The sediments at the three reference areas were much more variable in grain-size than those at the disposal site (Figure 3-12). Sediment grain-size major mode on the ambient seafloor outside the disposal site (as characterized by the surveyed reference stations) ranged from silt/clay to very fine sand, with transitional areas (layers of very fine sand over mud) interspersed. Evidence of past sediment transport events could be seen in the profile images with alternating layers of fine sand and mud (Figure 3-13). There was no evidence of dredged material at any of the reference stations.

Camera prism penetration ranged from 8.4 – 17.5 cm, with an overall reference area average penetration of 13.8 cm (Table 3-2, Figure 3-14). Small scale surface boundary

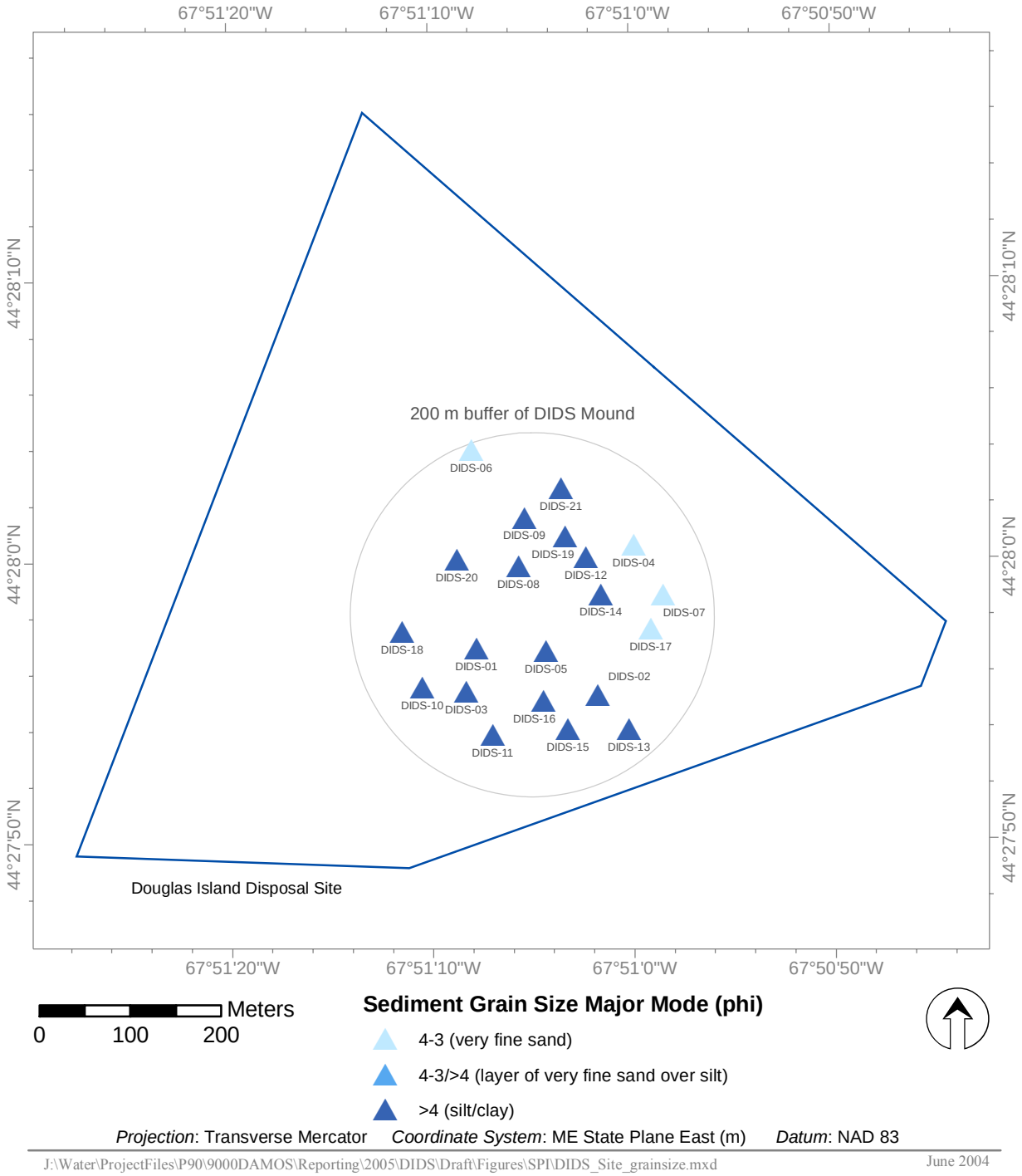

Figure 3-4. Distribution of sediment grain-size major mode (phi units) at the Douglas Island Disposal Site

Figure 3-5. While the majority of stations sampled within the Douglas Island disposal site boundary had a sediment grain-size major mode in the silt-clay range as shown in this image from Station 5 (left), a few stations, as shown in this image from Station 6 (right), had a sediment grain-size major mode in the very fine sand range

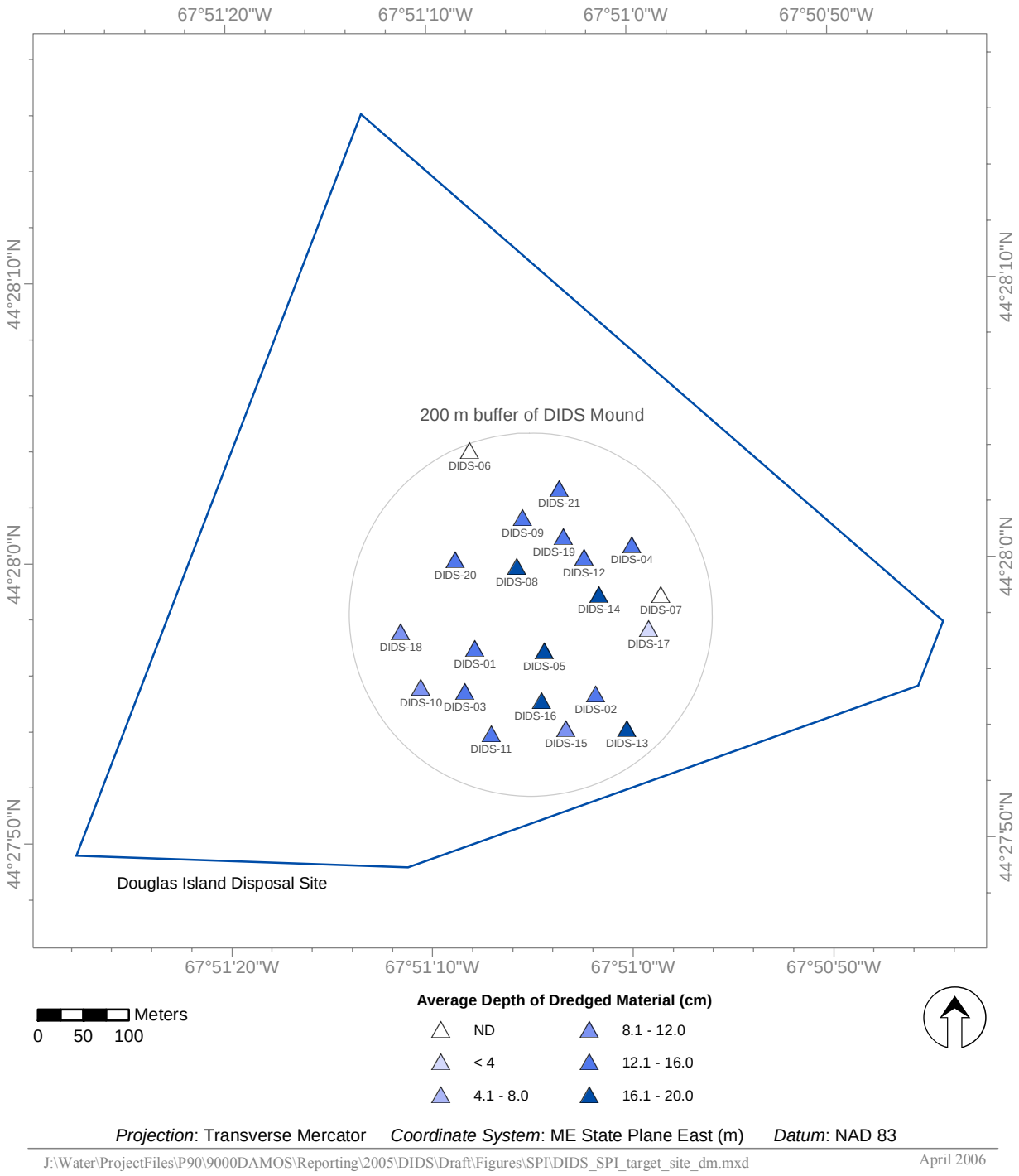

Figure 3-6. Distribution of dredged material thickness (cm) as detected by sediment-profile imaging at the Douglas Island Disposal Site; dredged material was thicker than camera prism penetration at most stations surveyed

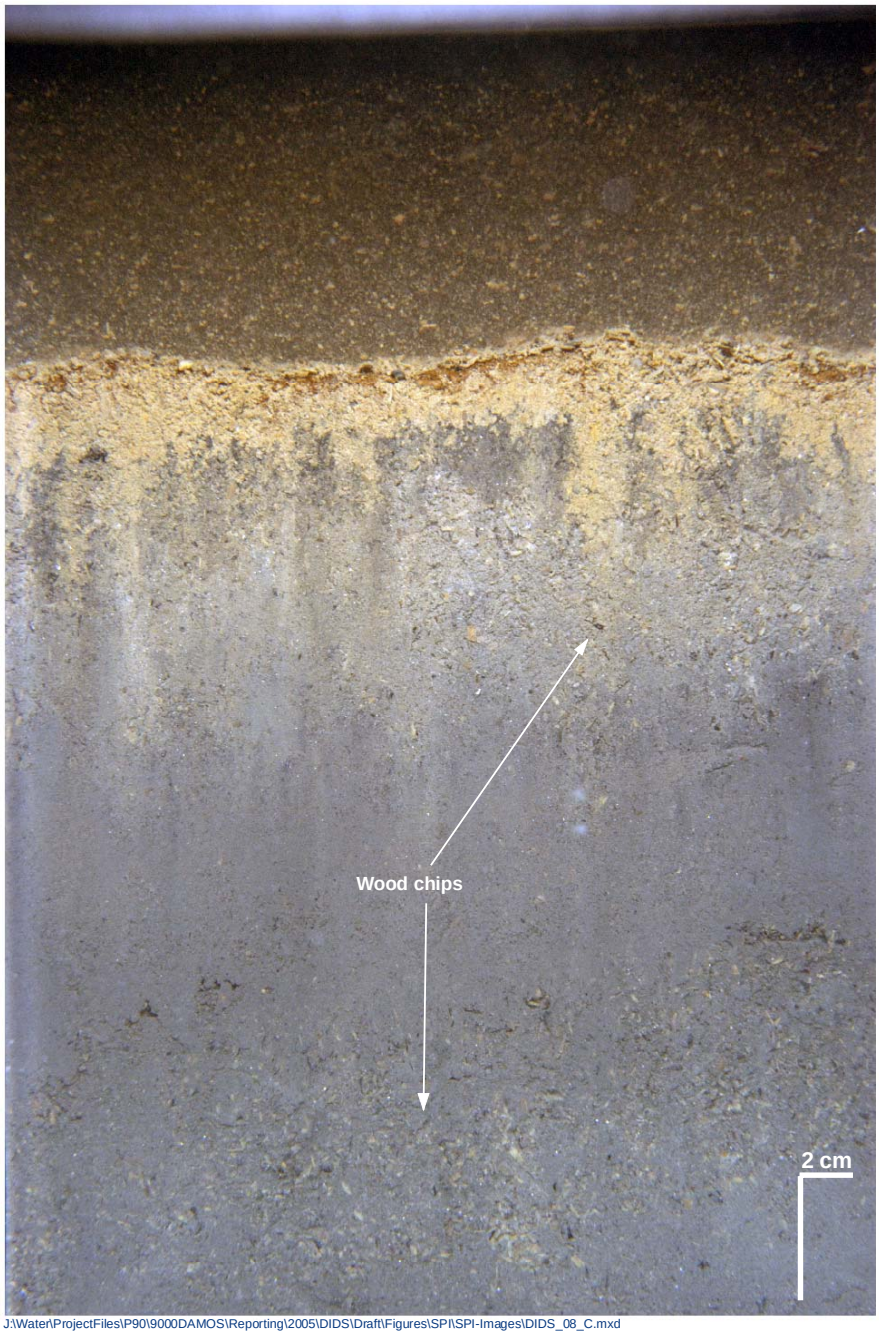

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Figure 3-7. Evidence of wood chips in sediments from the Narraguagus River can be seen just below the oxidized surface layer as well as at depth (arrows) in this sediment profile image from Station 8

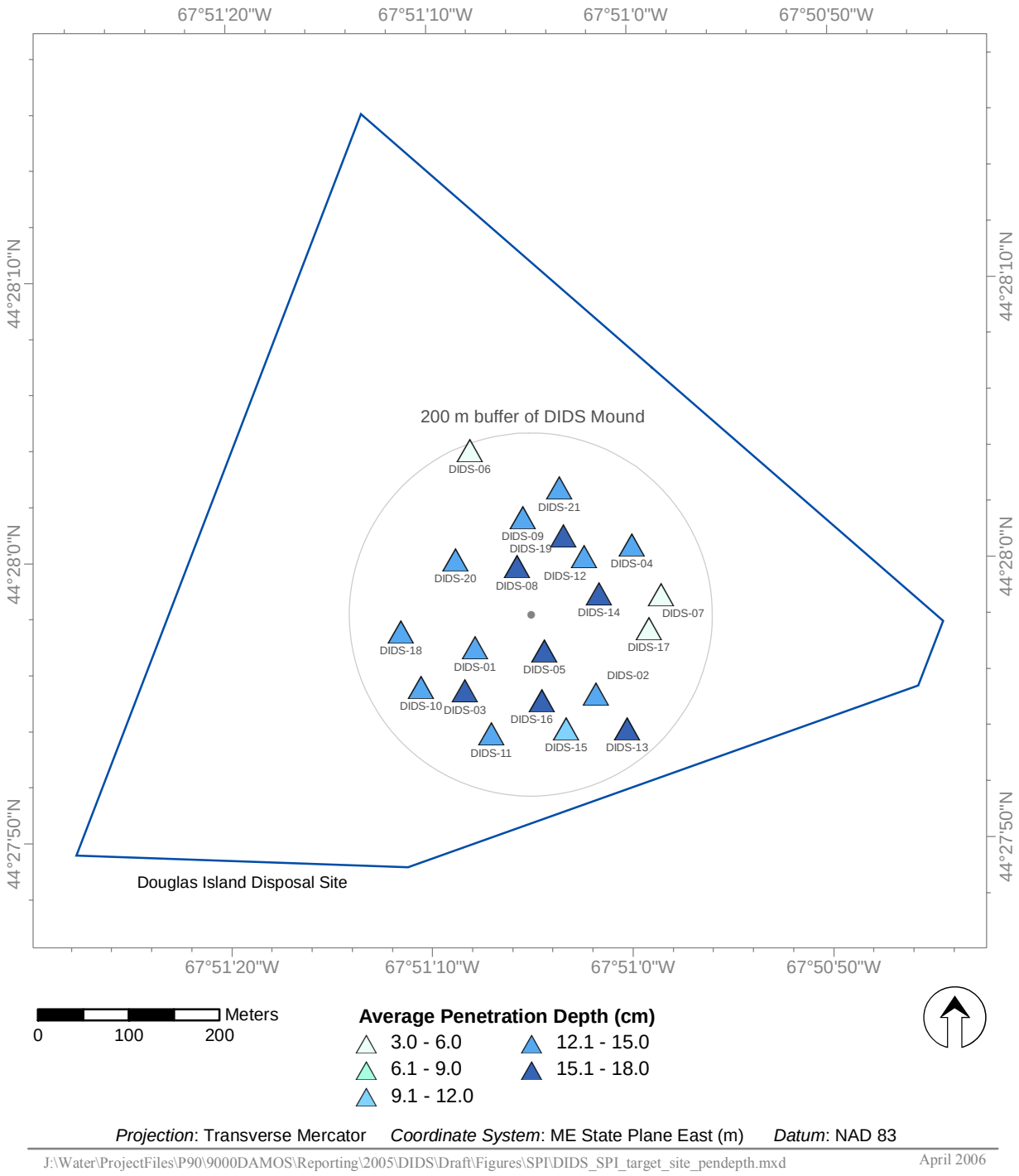


Figure 3-8. Distribution of mean camera prism penetration depths (cm) at the Douglas Island Disposal Site

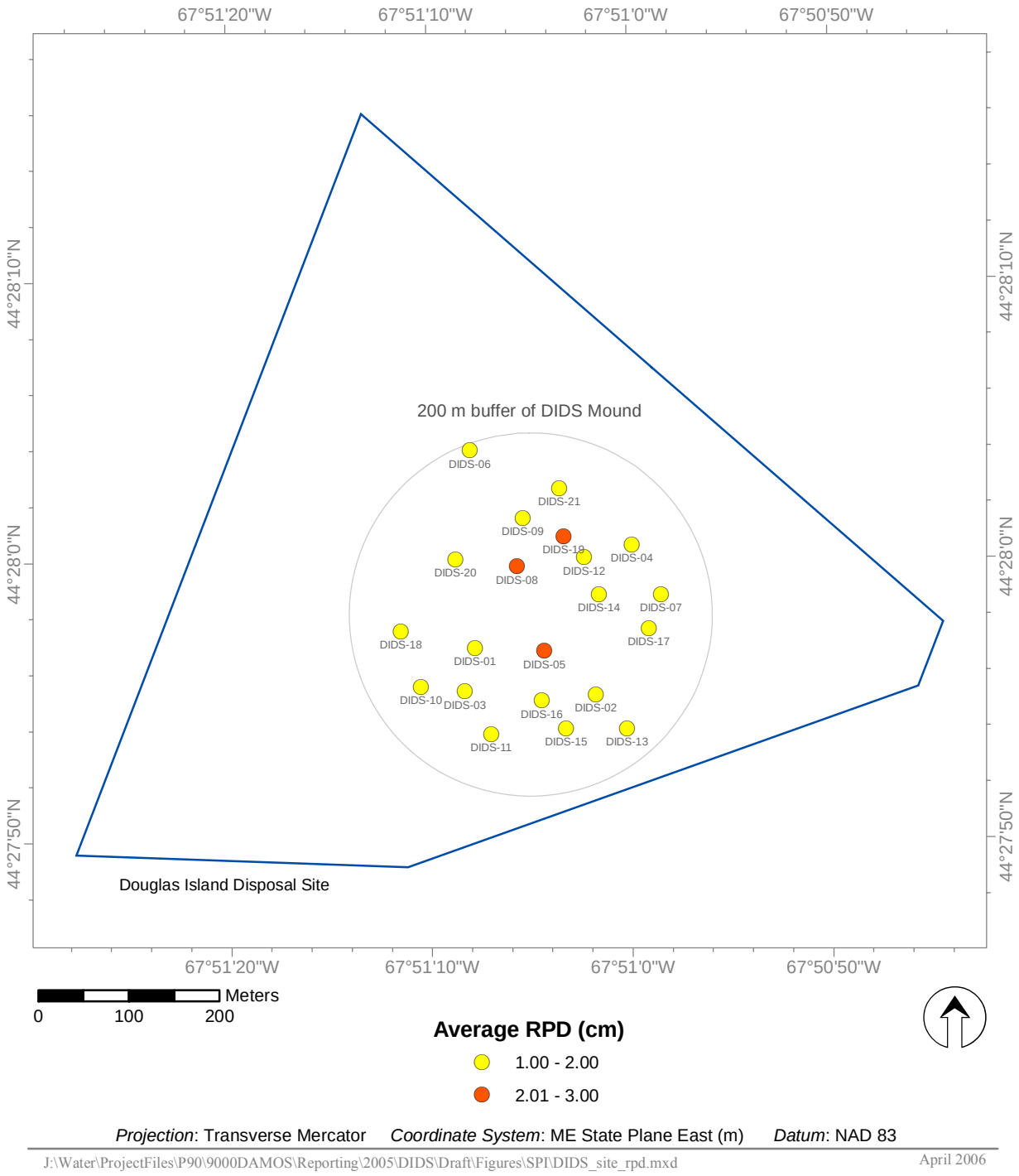


Figure 3-9. Distribution of mean apparent RPD values (cm) at the Douglas Island Disposal Site

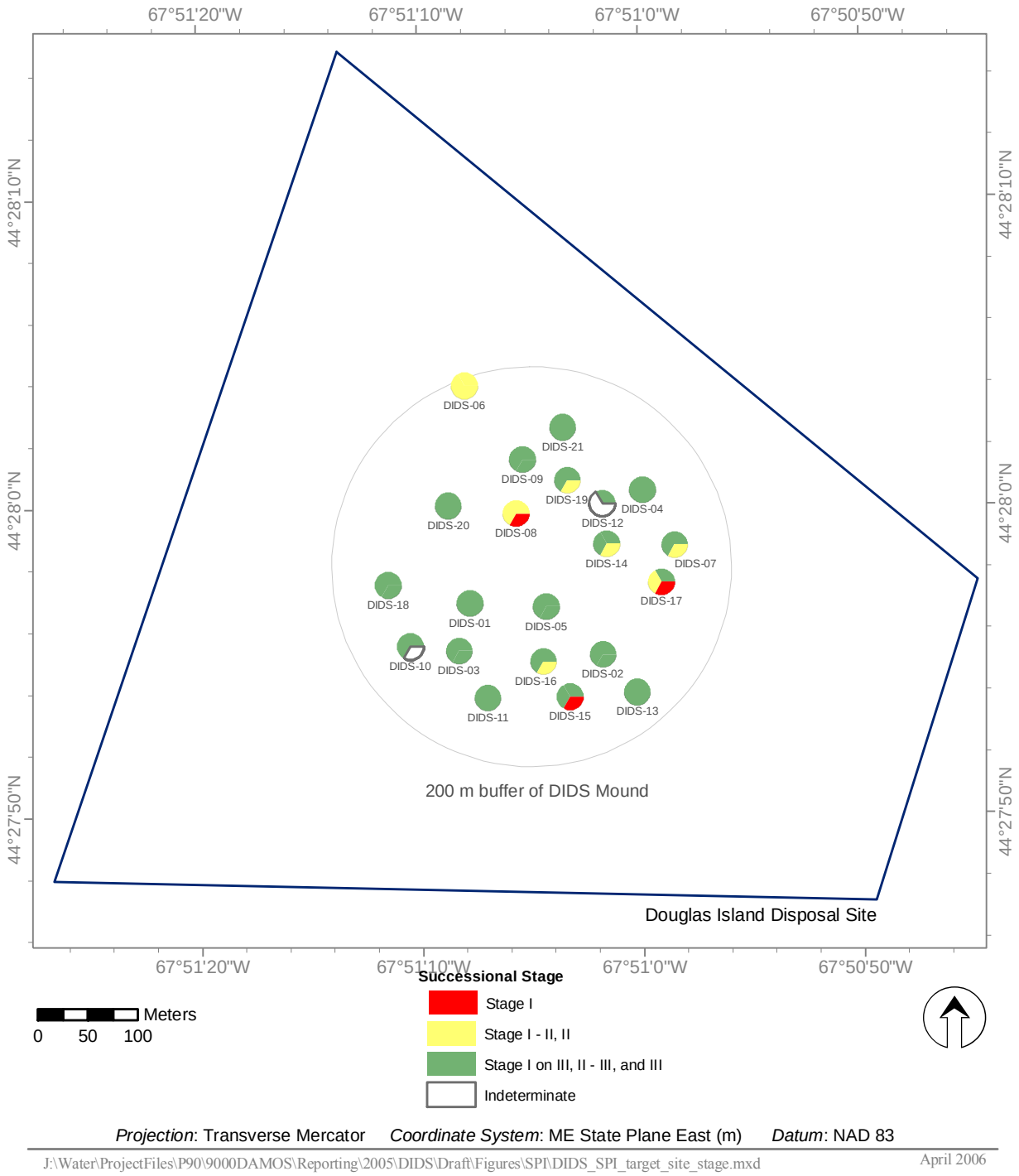
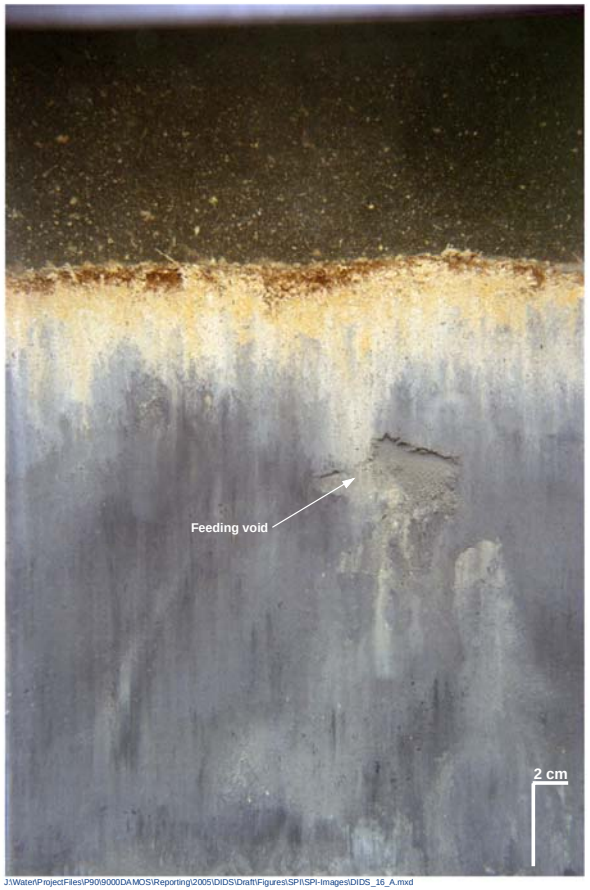


Figure 3-10. Distribution of infaunal successional stages at the Douglas Island Disposal Site



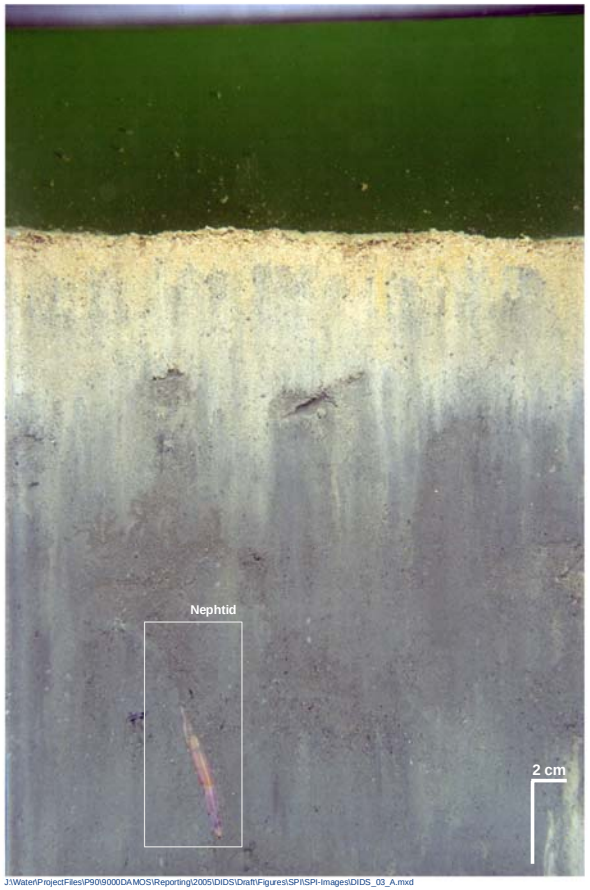


Figure 3-11. Evidence of Stage 3 taxa could be seen at the majority of stations on the dredged material mound, either in the form of sub-surface feeding voids as seen in this image from Station 16 (left), or an image of the actual organism, as seen in this image from Station 3 (right) showing a large nephtid against the camera faceplate

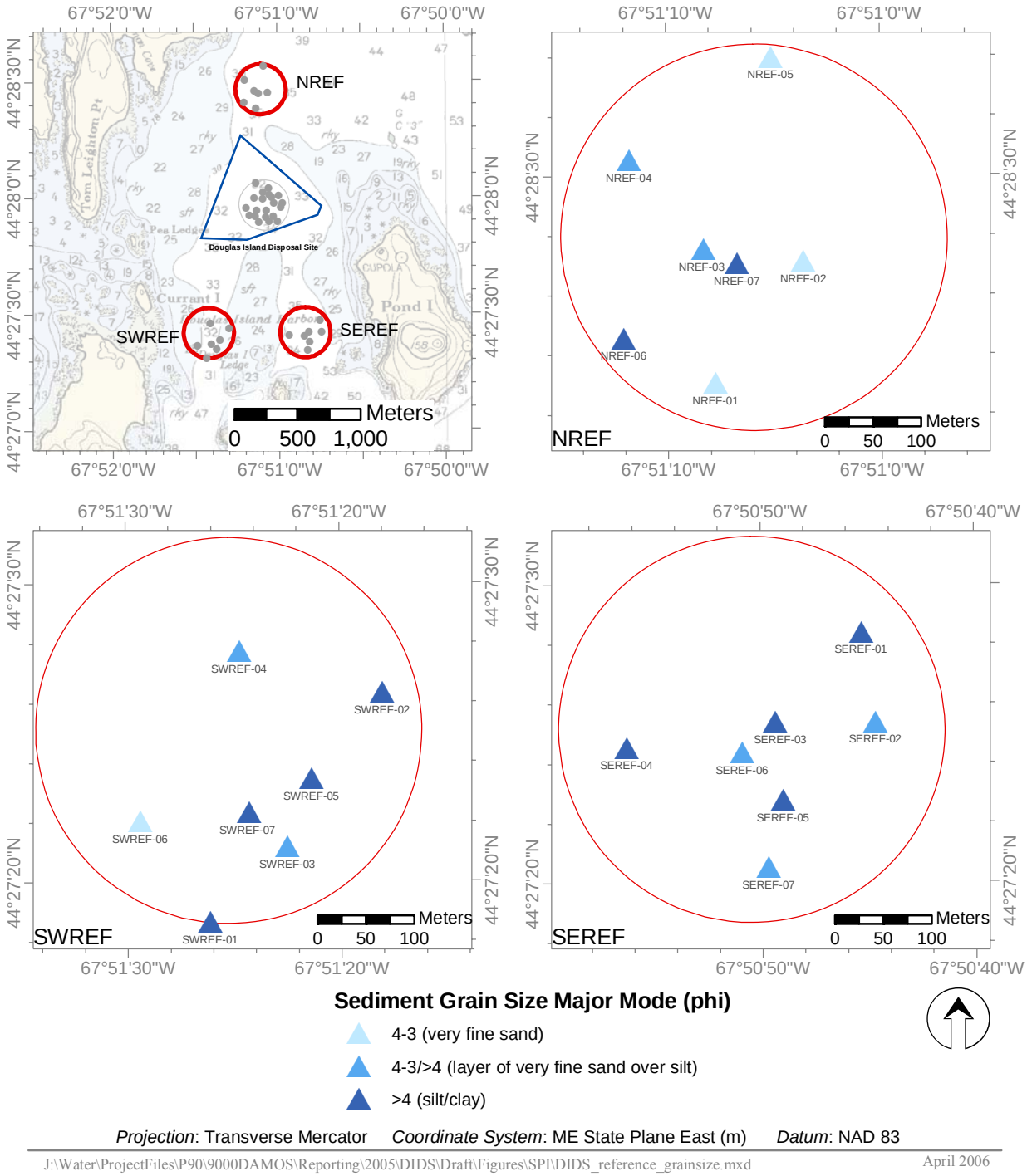


Figure 3-12. Distribution of sediment grain-size major mode (phi units) at the Douglas Island reference areas

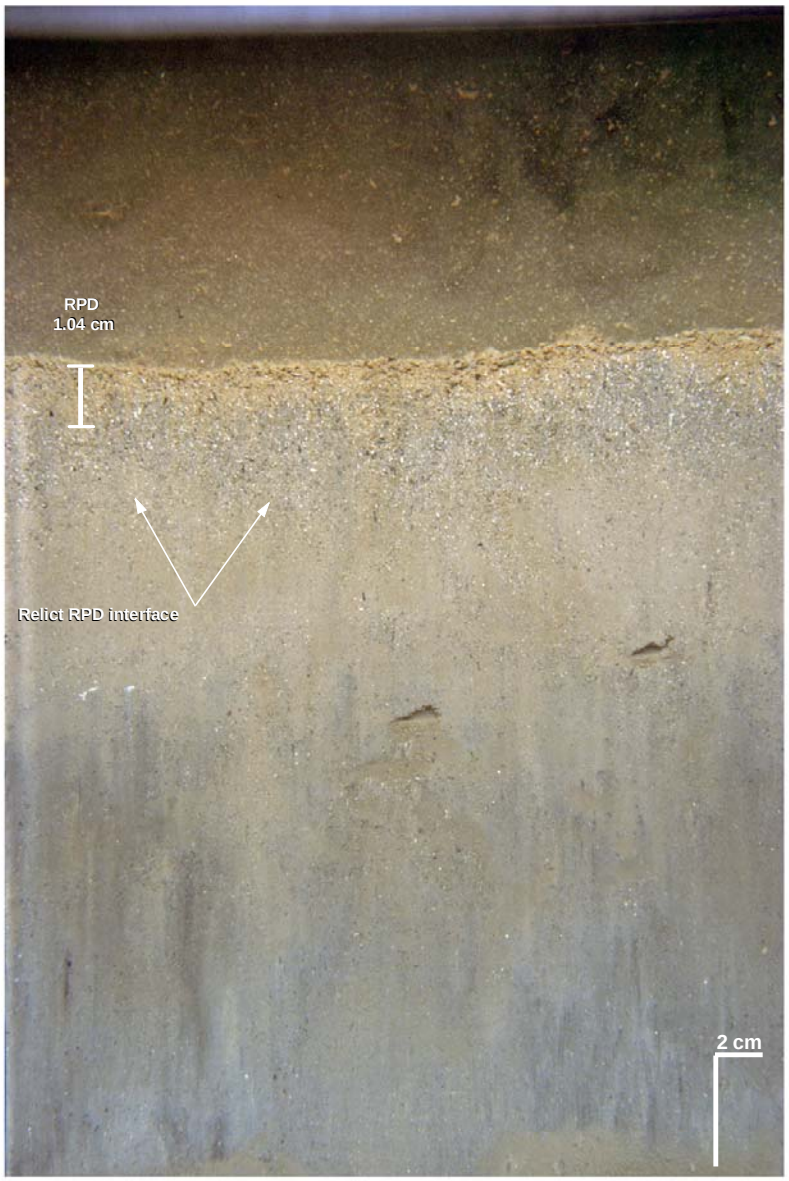


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Figure 3-13. This sediment profile image from SEREF 06 shows a surface layer of muddy, very fine sand with a newly-developed RPD layer (arrows) that has been deposited through natural physical transport processes on top of a silt-clay facies and relict RPD that represented the former sediment-water interface (arrows)

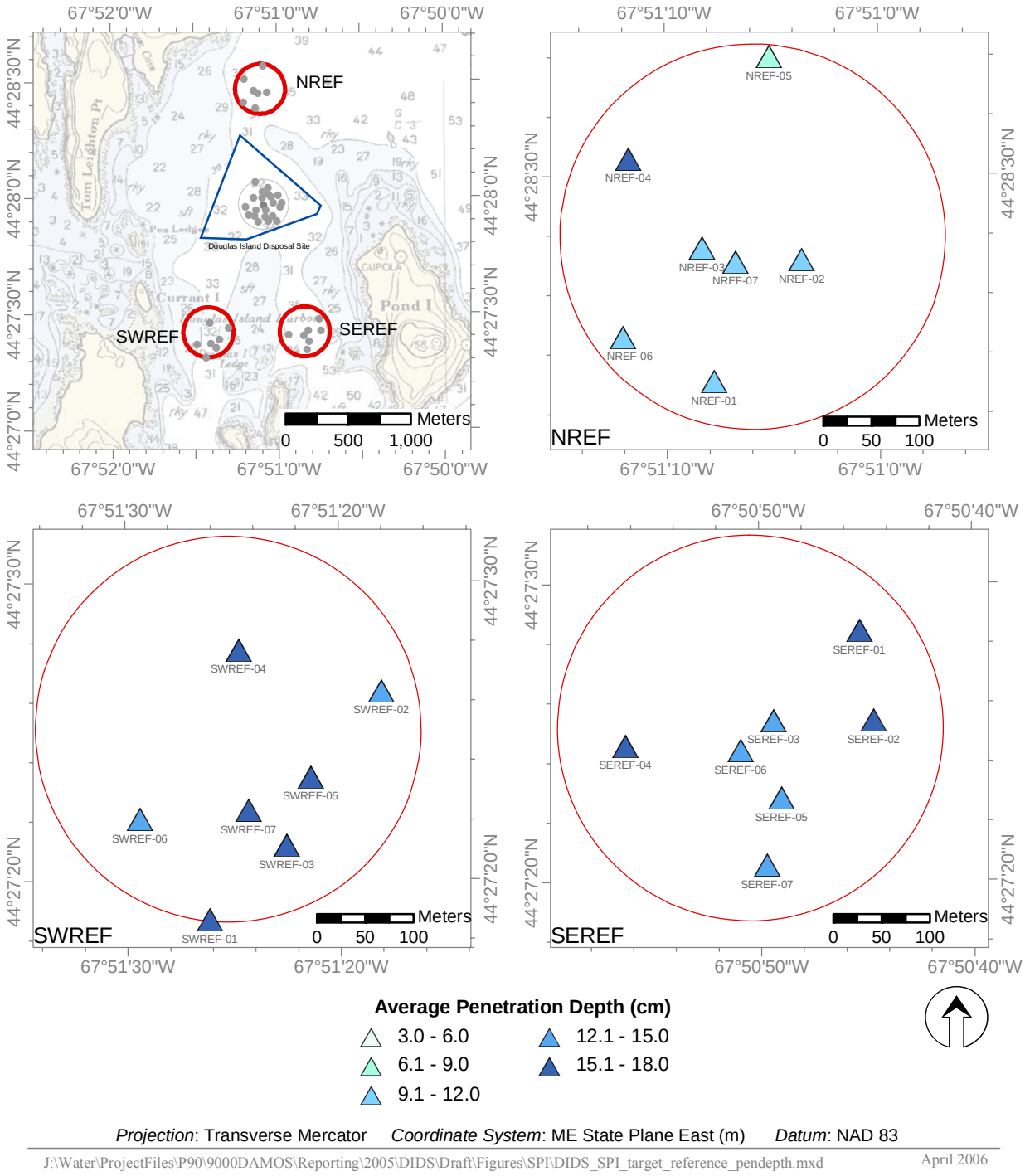

Figure 3-14. Distribution of mean camera prism penetration depths (cm) at the Douglas Island reference areas

roughness values ranged from 0.7 – 2.7 cm, with an overall site average of 1.3 cm; the majority (80%) of the small-scale topographic roughness elements were due to biogenic feeding pits and mounds (Appendix A). No stations exhibited any evidence of low dissolved oxygen in the overlying water or signs of methane in the subsurface sediments.

3.2.4 Biological Conditions

The mean apparent RPD values measured at the reference areas ranged from 1.2 – 2.4 cm, with an overall mound-averaged depth of 1.8 cm (Table 3-2; Figure 3-15). Evidence of mature, deposit-feeding fauna (Stage 3 communities) was found in every replicate image from all 21 stations surveyed in the reference areas (Figure 3-16). The maximum depth of subsurface infaunal structures (feeding voids/burrows) ranged from 7.8 – 17.2 cm (Table 3-2); these structures often were present at the limit of the camera prism penetration depth (Figure 3-17), indicating that the resident infauna were most likely reworking the sediment at many locations even deeper than recorded in the profile images.

3.2.5 Comparison Between Disposal Site and Reference Areas

Mean RPD Variable

The three reference areas showed some differences in mean values (Table 3-3, Figure 3-18) with N Ref having a lower mean than the other two. The maximum difference among reference locations was 0.37 (1.96 – 1.59), which is within the noise for these data as it is less than one standard deviation of the reference areas (0.39). The difference was minor, but the reference areas were included separately in the following analysis.

Table 3-3

Summary of Station Means by Sampling Location

		Mean RPD (cm)		SS rank	
Area	**N**	**Mean**	**Stdev**	**Mean**	**Stdev**
Reference Locations					
N Ref	7	1.59	0.26	5	0
SE Ref	7	1.93	0.53	5	0
SW Ref	7	1.96	0.33	5	0
Mean:		1.83		5	
Douglas Island Mound					
	21	1.68	0.25	4.3	0.91

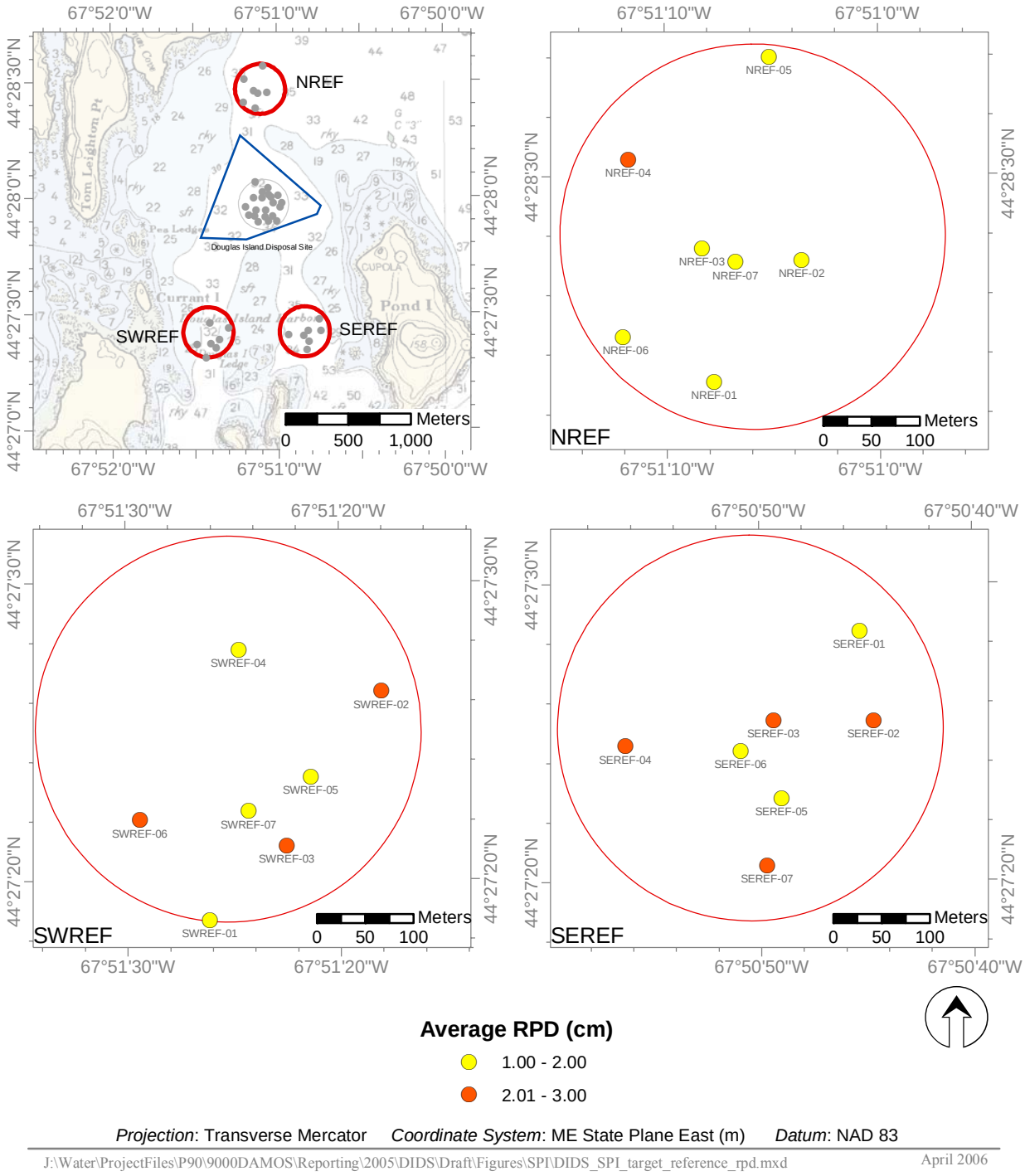

Figure 3-15. Distribution of mean apparent RPD values (cm) at the Douglas Island reference areas

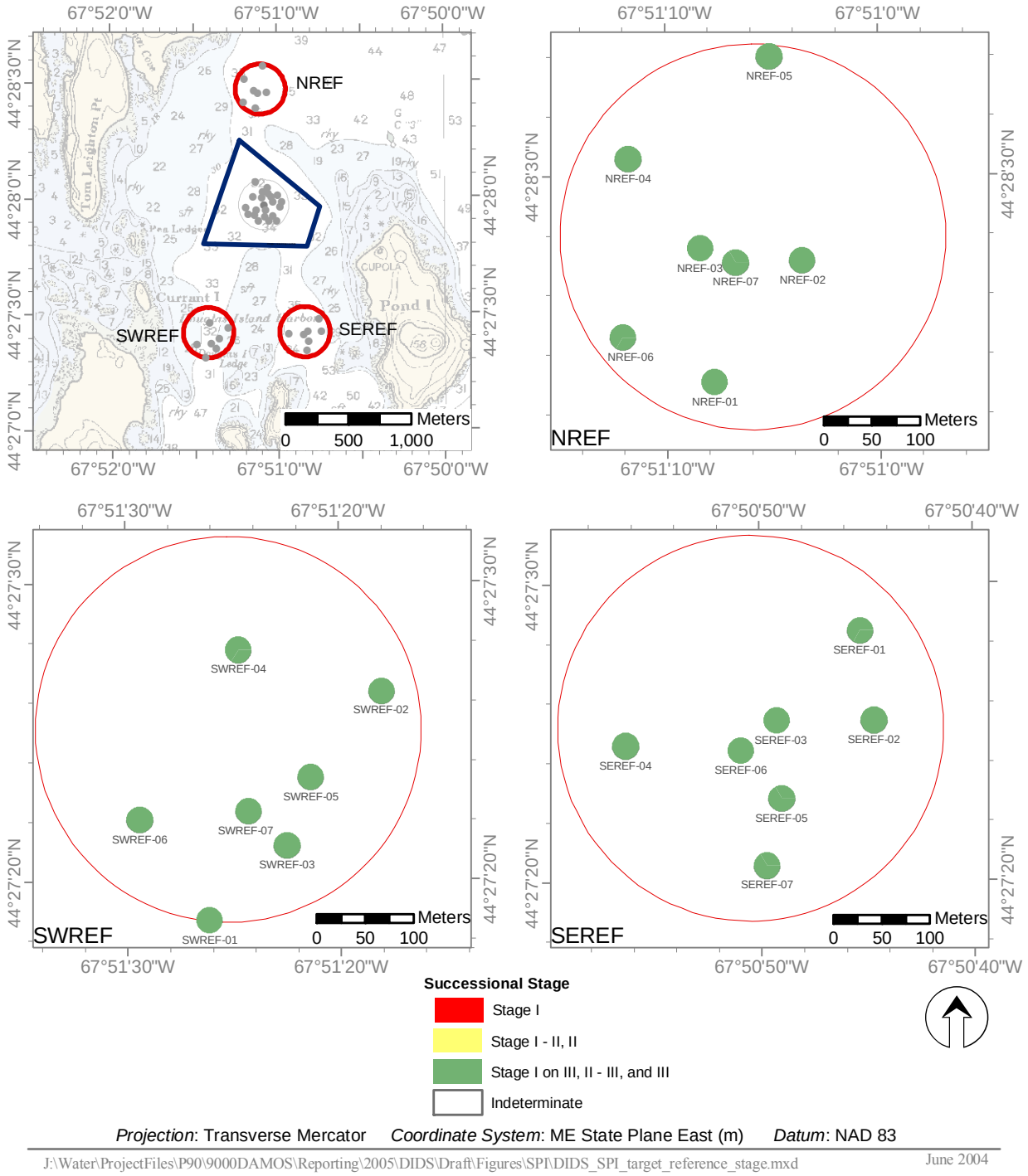

Figure 3-16. Distribution of infaunal successional stages at the Douglas Island reference areas

Figure 3-17. This sediment profile image from Station SWREF 03 shows evidence of deep infaunal re-working and bioturbation

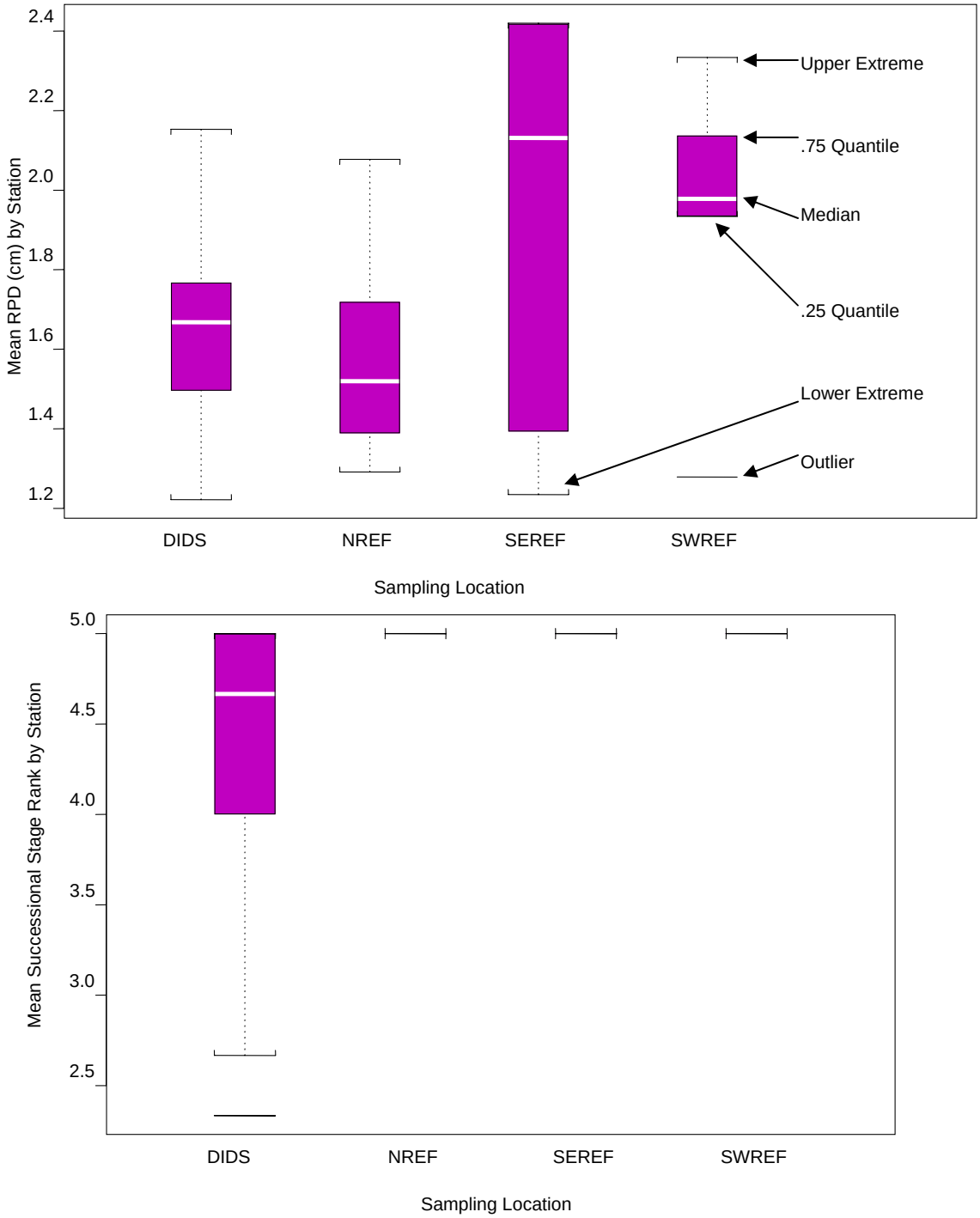

Figure 3-18. Boxplots showing distribution of station mean values for Douglas Island RPD values and successional stage rank

Results for the normality test indicate that normality of the area residuals (i.e., each observation minus the area mean) was not rejected by the Shapiro-Wilk's test (p = 0.28). The assumption of equal variances was rejected by Levene's test (p=0.02), due to the slightly larger variance observed at SE Ref relative to the other 3 areas. The effect of using a common pooled variance for all areas, rather than a separate variance for each of the four areas will slightly decrease the power for the test. Separate variances were used to compute the variance for the difference equation (Table 3-4).

Table 3-4

Summary Statistics and Results of Bioequivalence Testing for RPD Values

Difference Equation	**Observed Difference ($\hat{d}$)**	**SE($\hat{d}$)**	**df for SE($\hat{d}$)**	**95% Lower Confidence Bound**	**95% Upper Confidence Bound**
Ref – Mound	0.15	0.10	15	-0.02	0.33

The specified δ value of ±1 was outside of the 95% lower and upper confidence bounds for the observed difference. This indicates that the true difference between the mean RPD values from the reference areas and mean RPD values from the disposal mound 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 were identical with all stations displaying successional stage rank values of 5 (Table 3-3, Figure 3-18). With no variance among reference stations, the confidence interval for the bioequivalence test was determined exclusively by the variance among mound stations. The assumption of normality for the mound stations was rejected by the Shapiro-Wilk's test (p = 0.0003). A normalizing transformation could not be found for these left-skewed data. A non-parametric confidence interval was constructed on the difference between 5 (the reference mean, with no variance) and the mound mean using a bootstrap-t interval (Manly, 1997 pp. 56 – 59). (See bootstrap methods in Appendix B)

Table 3-5

Summary Statistics and Results of Bioequivalence Testing for SS Rank Values

Difference Equation	Observed Difference ($\hat{d}$)	SE($\hat{d}$)	95% Lower Confidence Bound using bootstrap-t	95% Upper Confidence Bound using bootstrap-t
Ref – Mound	0.71	0.20	0.43	1.2

The specified δ value of 1 is within the 95% lower and upper confidence bounds for the observed difference (Table 3-5). This indicates that the true difference between the successional stage rank values from the reference areas and disposal mounds was greater than 1 unit, and therefore the group means were inequivalent within our definition of "ecologically meaningful".

4.0 DISCUSSION

The objectives of the 2005 Douglas Island Disposal Site survey were to document the distribution of dredged material and disposal mound morphology within DIDS using pre and post-disposal single-beam bathymetric surveys and to assess the benthic recolonization status of the DIDS seafloor using sediment-profile imaging. Bathymetric surveys showed evidence of one disposal mound

The two most distinguishing characteristics from the sediment-profile images at the Douglas Island Disposal Site and reference areas were: 1) the consistent sediment grain-size (> 4 Φ) of the dredged material within the disposal site boundary as compared with the sandier sediments found on the ambient seafloor; and 2) the consistent evidence of natural physical sediment transport and deposition at the reference areas. Evidence of recently deposited sedimentary intervals could be seen at most of the locations sampled in the reference areas, with the uppermost sedimentary interval consisting of poorly-sorted muddy sands overlying what was formerly a silt-clay surface layer (Figure 4-1). Even though there is periodic sediment transport occurring on the ambient seafloor between naturally-occurring adjacent sand and mud facies, the particle advection by "conveyor belt feeders" (*sensu*

Rhoads, 1974) will keep mixing these deposited sedimentary intervals until they are texturally homogeneous and no longer recognizable as a discrete surface layer (Figure 4-2).

In the approximately one-year interval between the deposition of dredged material and the post-disposal SPI survey, the depth of the oxidized surface layer was essentially the same within the disposal site boundary as it was on the ambient seafloor. Although there was a healthy and diverse community of Stage 3 fauna on the ambient seafloor, the apparent RPD values were not as deep as those typically found in other disposal site reference areas because of periodic physical disturbance. Even though the newly-developing redox layer could be seen merging with the buried oxidized layer in many of the images from the reference areas, e.g., Figure 3-17, this intermittent burial of the sediment surface by recently deposited sedimentary intervals illustrates how natural seafloor processes affect these geochemical parameters in the same manner as deposition of dredged material.

The infaunal successional community within the disposal site has largely recovered, with Stage 3 infauna present at all but two stations surveyed within the disposal site; this recovery profile is well within the normal time-frame for soft-bottom benthic community succession following dredged material disposal (Rhoads et al. 1978; Germano et al. 1994; Bolam and Rees 2003). If there were no additional dredged material placed at the Douglas Island Disposal Site, we would expect that the benthic community on the dredged material mound would be functionally equivalent to that on the ambient seafloor within the next 6 to 12 months.

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Figure 4-1. A recently-deposited 3 cm-thick layer of muddy very fine sand can be seen on top of the former sediment-water interface in this profile image from Station SEREF 04

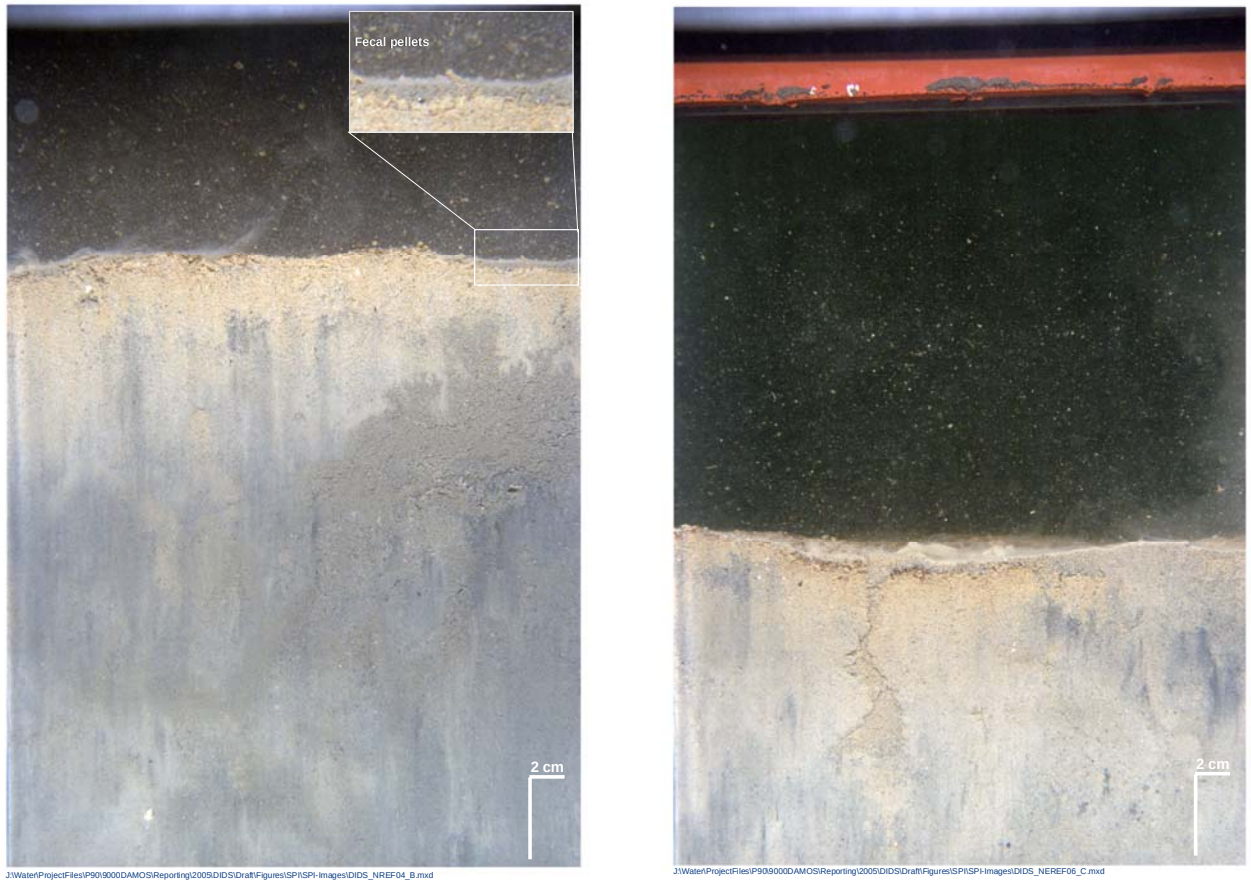

Figure 4-2. Evidence of subsurface particle advection by infaunal deposit feeders can be seen in the form of a layer of reduced fecal pellets and particles at the sediment surface in these profile images from Station NREF 04 (left) and NREF 06 (right).

5.0 CONCLUSIONS

The April 2003 and April 2004 surveys at Douglas Island Disposal Site were performed to provide pre and post-disposal bathymetric data. The September 2005 survey was intended to evaluate and monitor the recovery of the site by assessing the benthic recolonization status using sediment-profile imaging.

- The post-dredge bathymetric survey revealed one disposal mound from the disposal events and documented the current distribution of the dredged material and disposal mound morphology.

- The sediments within the disposal site were primarily sandy silts, poorly-sorted muds with varying degrees of fine sand while the reference areas consisted of sandier sediments.

- The reference areas showed signs of periodic physical disturbance caused by sediment transport and deposition. A review of local studies of seafloor transport or regional exposure to storm or current may provide some additional insight on the stability and any changes to the sediments in this area.

- The apparent RDP values were functionally equivalent at the disposal site and reference areas.

- Recovery of the benthic community at the disposal site is evident. Although the benthic community on the dredged material was not found to be functionally equivalent to the assemblages found on the ambient seafloor, it is expected to be within 6 to 12 months.

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APPENDIX A

SEDIMENT PROFILE IMAGING RESULTS OF DIDS SEPTEMBER 2005 SURVEY

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

Douglas Island Disposal Site Sediment-Profile Imaging Data form the September 2005 Survey

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	RPD Area (sq.cm)	Mean RPD (cm)	Mud Clast Number	Mud Clast State (R-Reduced, O-Oxidized, B-Both)	METHANE	TOTAL DM AREA	TOTAL DM MEAN	TOTAL DM MIN	TOTAL DM MAX	Low DO?	Feeding Void #	Void Minimum Depth (cm)	Void Maximum Depth (cm)	Void Average Depth (cm)	Successional Stage	COMMENT
N Ref-01 A	9/10/2005	15:49:19	13	4	14.41	4-3	2	>4	>4 - 2	168.03	11.66	11.36	11.87	0.51	Biological	25.09	1.74	>10	O	None	0.00	0	-	-	No	6	3.78	11.48	7.63	Stage 3	Tan to gray, poorly sorted very silty fine sand. Gallery of voids at left and void at right along with organism in lower right center, Several polychaetes in sediment column. Possible relict RPD 3-4 cm below SWI. SWI covered with small oxidized mudclasts which suggest a likely recent physical disturbance. Sediment column intensively bioturbated.
N Ref-01 B	9/10/2005	15:50:23	13	4	14.41	4-3	2	>4	>4 - 2	90.54	6.28	4.54	7.89	3.35	Physical	Ind	Ind	1	O	None	0.00	0	-	-	No	1	6.60	7.50	7.05	Stage 3	Tan to gray, poorly sorted very silty fine sand. Large mudclast with a few tubes and oxidized seston cover. SWI recently physically disturbed and does not appear to be sampling related based on oxidative state of mudclast, most likely due to trawling based on this & other reps at station. Oxidized thin void at lower right.
N Ref-01 C	9/10/2005	15:51:12	13	4	14.41	4-3	2	>4	>4 - 2	164.08	11.39	11.02	12.32	1.30	Physical	17.86	1.24	4	O	None	0.00	0	-	-	No	4	5.86	10.35	8.11	Stage 3	Tan to gray, poorly sorted very silty fine sand. Large oxidized mudclasts at SWI. Diffusional RPD at far right SWI. Possible relict RPD 3-4 cm below SWI. SWI physically disturbed unrelated to sampling. Voids run from center to lower left and several polychaetes in sediment column. Three reps are similar in showing disturbance at SWI and in particle size distribution.
N Ref-02 A	9/10/2005	16:09:20	13	4	14.41	4-3	2	>4	>4 - 2	154.32	10.71	9.59	11.17	1.58	Biological	22.82	1.58	2	R	None	0.00	0	-	-	No	4	2.17	9.84	6.01	Stage 3	Tan to gray, poorly sorted very silty fine sand. Large burrow at right SWI. Three voids in upper sediment column all concentrated on band of reduced sediment; another void in lower left. Polychaetes at right. Sediment column appears laminated by depositional processes. Some fine particulate organics in sediment column. Likely physically active SWI given thinly developed RPD.
N Ref-02 B	9/10/2005	16:10:11	13	4	14.41	4-3	2	>4	>4 - 2	174.68	12.12	11.39	12.66	1.27	Biological	14.28	0.99	0	-	None	0.00	0	-	-	No	4	3.83	11.53	7.68	Stage 3	Tan to gray, poorly sorted very silty fine sand. Oxidized sediment filled voids in upper center and upper left and distinct voids/burrows with oxidized floors at lower left. Numerous organisms including polychaetes in sediment column. Burrow at right SWI and incipient RPD in churned sediment. Upper 2 cm of sediment column appears distinctly sandier and is likely a result of period resuspension and physical disturbance at the SWI.
N Ref-02 C	9/10/2005	16:11:04	13	4	14.41	4-3	2	>4	>4 - 2	110.85	7.69	7.13	8.57	1.44	Biological	18.72	1.30	0	-	None	0.00	0	-	-	No	4	1.35	5.24	3.30	Stage 3	Firm, tan to gray, poorly sorted very silty fine sand. Large, shallow burrow/void in upper right and oxidized voids at left. SWI appears recently disturbed, shallow RPD. Three reps all show some level of SWI disturbance and a stable subsurface community.
N Ref-03 A	9/10/2005	15:59:51	13	4	14.41	>4	2	>4	>4 - 2	151.15	10.49	10.12	10.77	0.65	Biological	18.01	1.25	0	-	None	0.00	0	-	-	No	2	6.06	9.59	7.82	Stage 1 on 3	Tan to gray, poorly sorted, very fine sandy silt/clay. Void gallery in lower right, with small voids and patch of churned sediment. Thinly developed RPD. Numerous shallow burrows extending downward from SWI. Small patches of red algae at SWI at left. Numerous small red polychaetes in upper sediment column.
N Ref-03 B	9/10/2005	16:00:43	13	4	14.41	>4	2	>4	>4 - 2	139.99	9.71	8.26	11.14	2.88	Physical	26.05	1.81	0	-	None	0.00	0	-	-	No	1	5.30	7.02	6.16	Stage 1 on 3	Tan to gray, poorly sorted, very fine sandy silt/clay. Hummocked SWI. Void and bioturbated sediment in lower right. Band of dark gray to black reduced sediment 3-4 cm below the SWI and it follows the contour of the SWI. Minor incipient algae in SWI background. Organism in lower right center. Possible relict RPD just below current RPD and SWI appears sandier than underlying sediment.
N Ref-03 C	9/10/2005	16:01:33	13	4	14.41	4-3/>4	2	>4	>4 - 2	179.65	12.47	11.98	12.69	0.70	Biological	21.65	1.50	0	-	None	0.00	0	-	-	No	2	3.64	12.10	7.87	Stage 1 on 3	Tan very silty very fine sand over tan to gray poorly sorted very fine sandy silt. Numerous small rounded oxidized biogenic aggregates at SWI. Large megafaunal burrow at bottom center of frame with oxidized sediment present/ Relict RPD immediately below current RPD. Recent physical disturbance at SWI. All three reps exhibit the artifacts of similar physical processes.
N Ref-04 A	9/10/2005	16:17:57	13	4	14.41	4-3/>4	2	>4	>4 - 2	232.56	16.14	14.91	16.80	1.89	Biological	39.64	2.75	0	-	None	0.00	0	-	-	No	2	4.88	15.85	10.36	Stage 3	Tan to gray sorted very fine sand over tan to gray fine sandy silt/clay. SWI at right has been recently resuspended and has some detrital coating - resuspended fraction included in RPD. Relict RPD 4-6 cm below SWI. Void in upper left and very large void/burrow in lower right.
N Ref-04 B	9/10/2005	16:19:00	13	4	14.41	4-3/>4	2	>4	>4 - 2	221.87	15.40	14.80	15.73	0.93	Biological	28.04	1.95	0	-	None	0.00	0	-	-	No	2	3.78	10.18	6.98	Stage 3	Tan to gray sorted very fine sand over tan to gray fine sandy silt/clay. Small void with oxidized sediment in upper left-center and large void/burrow complex at upper right to mid right. Numerous streaks of oxidized sediment at depth within the sediment column. Small patches of red algae at SWI. Reduced sediment being brought to SWI at far right.
N Ref-04 C	9/10/2005	16:19:50	13	4	14.41	>4	2	>4	>4 - 2	223.60	15.52	15.14	16.01	0.87	Biological	22.12	1.54	0	-	None	0.00	0	-	-	No	1	4.71	5.50	5.10	Stage 3	Tan to gray, banded, very fine sandy silt/clay. Relict RPD multiples visible. Layering/banding appears to be largely depositional (I.e. vs. anoxia) as there is normal grading associated with the banding. Small, active oxidized void in upper right. Polychaete in upper left and organism at far right. SWI appears recently disturbed and a plethora of small biogenic aggregates at SWI.
N Ref-05 D	9/10/2005	16:24:26	13	4	14.41	4-3	2	>4	>4 - 2	119.48	8.29	7.84	8.80	0.96	Physical	18.63	1.29	0	-	None	0.00	0	-	-	No	1	3.16	4.09	3.62	Stage 3	Firm, tan to gray, poorly sorted, very silty very fine sand. Slight bedforms at SWI. Small void in upper right and several penetration related tears in sediment fabric. Numerous shallow burrows downward from SWI. Organism to left of void. SWI undergoes periodic physical disturbance.
N Ref-05 E	9/10/2005	16:25:11	13	4	14.41	4-3	2	>4	>4 - 2	132.17	9.17	8.77	9.59	0.82	Physical	21.08	1.46	0	-	None	0.00	0	-	-	No	4	4.51	8.85	6.68	Stage 3	Firm, tan to gray, poorly sorted, very silty very fine sand. Numerous voids, possibly of related gallery complex at bottom of frame. Numerous polychaetes of at least three species in sediment column. Shallow burrows extending downward from the SWI. SWI appear periodically disturbed. Interesting, bioturbated yet firm. Generally similar to A.
N Ref-05 F	9/10/2005	16:26:24	13	4	14.41	4-3	2	>4	>4 - 2	110.29	7.65	7.30	7.84	0.54	Physical	20.31	1.41	0	-	None	0.00	0	-	-	No	0	-	-	-	Stage 3	Firm, tan to gray, poorly sorted, very silty very fine sand. Shallow burrows extending downward from the SWI. SWI appear periodically disturbed. SWI covered with small biogenic aggregates. Organism and oxidized burrow trace in lower left. SWI physically disturbed. Similar to other two reps.
N Ref-06 A	9/10/2005	15:54:11	13	4	14.41	>4	2	>4	>4 - 2	160.06	11.11	10.85	11.36	0.51	Biological	25.99	1.80	0	-	None	0.00	0	-	-	No	5	2.34	11.22	6.78	Stage 1 on 3	Tan to gray very fine sandy silt/clay. Active voids in upper left, upper right, lower center and lower left. Several shallow burrows in RPD. A few small tubes at SWI and patches of algae at SWI. SWI biogenically aggregated. Band of sulphate reduction 3 cm below SWI. Possible faint rippling at SWI.
N Ref-06 B	9/10/2005	15:55:06	13	4	14.41	>4	2	>4	>4 - 2	172.77	11.99	11.79	12.24	0.45	Biological	25.91	1.80	0	-	None	0.00	0	-	-	No	3	8.88	11.19	10.04	Stage 1 on 3	Tan to gray very fine sandy silt/clay. Active voids across bottom of frame and a few mud tubes at SWI. Several patches of algae at SWI and some ambient light in water column. Faint banding of sediment column with relict RPDs 4 and 9-10 cm below the SWI. Based on grading, banding is related to natural depositional processes - which indicates periodic physical disturbance.
N Ref-06 C	9/10/2005	15:55:59	13	4	14.41	4-3	2	>4	>4 - 2	115.69	8.03	7.61	8.60	0.99	Biological	22.40	1.55	0	-	None	0.00	0	-	-	No	1	0.59	4.71	2.65	Stage 3	Tan to gray silty very fine sand. Void and burrow in left center and organism in burrow is actively pumping reduced sediment to the SWI. Another burrow at far right with reduced sediment being brought to the SWI. A few small polychaetes in lower left. Zone of more intense sulphate reduction immediately below the RPD. Three reps are similar.
N Ref-07 A	9/10/2005	16:04:30	13	4	14.41	>4	2	>4	>4 - 2	165.00	11.45	11.05	11.90	0.85	Biological	20.75	1.44	0	-	None	0.00	0	-	-	No	3	4.65	9.56	7.11	Stage 3	Tan to gray very fine sandy silt/clay. Layer of small oxidized, biogenically aggregated mudclasts at SWI. Void in center and left center and appear to be part of same gallery complex. Relict RPD 3 cm below SWI. Several red polychaetes in relict RPD at right. Similar to other N ref stations.
N Ref-07 B	9/10/2005	16:05:20	13	4	14.41	>4	2	>4	>4 - 2	159.17	11.05	10.74	11.25	0.51	Biological	26.55	1.84	0	-	None	0.00	0	-	-	No	2	5.81	8.86	7.33	Stage 3	Tan to gray very fine sandy silt/clay. Numerous small, oxidized mudclasts at SWI that are being biogenically aggregated and assimilated into sediment column (at present). Red algae at SWI. Large oxidized void in center, small sediment-filled (oxidized at left). Relict RPD 3-4 cm below SWI.

Table A-2

Douglas Island Disposal Site Sediment-Profile Imaging Data form the September 2005 Survey

N Ref-07 C	9/10/2005	16:06:07	13	4	14.41	>4	2	>4	>4 - 2	142.96	9.92	9.30	10.21	0.90	Biological	25.02	1.74	0	-	None	0.00	0	-	-	No	3	3.50	9.98	6.74	Stage 1 on 3	Tan to gray very fine sandy silt/clay. Numerous small, oxidized biogenic aggregates at SWI that are being assimilated into sediment column (at present). Red algae at SWI. Burrow/void at left and two large active void complexes at right. Several shallow burrows in RPD. Relict RPD 3 cm below SWI. Faint whitish material at left SWI. Three reps are very similar.
SE Ref-01 A	9/10/2005	15:23:34	13	4	14.41	>4	2	>4	>4 - 2	212.17	14.72	14.29	15.14	0.85	Biological	19.44	1.35	0	-	None	0.00	0	-	-	No	6	6.57	13.90	10.24	Stage 1 on 3	Soft, tan to light gray poorly sorted, very fine sandy silt/clay. Active voids throughout the subsurface. Burrow at left SWI and a few fine mud tubes at SWI. Several polychaetes in sediment column along with abundant particulate terrestrial organics. Relict RPD 2-3 cm below SWI. Sediment column appears well-bioturbated.
SE Ref-01 B	9/10/2005	15:24:30	13	4	14.41	>4	2	>4	>4 - 2	221.33	15.36	13.73	16.33	2.60	Biological	16.11	1.12	5	R	None	0.00	0	-	-	No	6	1.33	14.89	8.11	Stage 3	Soft, tan to light gray poorly sorted, very fine sandy silt/clay. Active voids throughout the subsurface. Large burrow at right. Mudclasts at SWI appear to be artifacts. Relict RPD 2-3 cm below SWI. Sediment column well bioturbated. Very similar to rep A.
SE Ref-01 C	9/10/2005	15:25:13	13	4	14.41	>4	2	>4	>4 - 2	222.28	15.43	14.72	15.73	1.02	Biological	17.82	1.24	1	R	None	0.00	0	-	-	No	2	7.70	13.42	10.56	Stage 1 on 3	Soft, tan to light gray poorly sorted, very fine sandy silt/clay. Tubes at left SWI background and oxidized sediment filled gallery in upper right center and small void with oxidized sediment floor at lower left. Relict RPD 2-3 cm below SWI. Sediment column well bioturbated. Very similar to reps A and B.
SE Ref-02 A	9/10/2005	15:07:00	13	4	14.41	4-3/>4	2	>4	>4 - 2	213.15	14.79	14.49	14.94	0.45	Biological	38.29	2.66	0	-	None	0.00	0	-	-	No	3	3.22	13.53	8.37	Stage 1 on 3	Soft, tan to light gray poorly sorted, very fine sandy silt/clay. Sediment column appears well-bioturbated with multi-void gallery complex spanning most of the subsurface sediment.
SE Ref-02 B	9/10/2005	15:07:48	13	4	14.41	4-3/>4	2	>4	>4 - 2	241.44	16.75	15.93	17.26	1.33	Biological	40.06	2.78	2	O	None	0.00	0	-	-	No	5	1.64	12.92	7.28	Stage 1 on 3	Soft, tan to light gray poorly sorted, very fine sandy silt/clay. Sediment column appears well-bioturbated with multi-void gallery complex spanning most of the subsurface sediment. Reduced sediment being advected to SWI at right. Nice pic. Similar to A.
SE Ref-02 C	9/10/2005	15:08:39	13	4	14.41	4-3/>4	2	>4	>4 - 2	230.20	15.98	15.76	16.21	0.45	Biological	26.25	1.82	0	-	None	0.00	0	-	-	No	0	-	-	-	Stage 1 on 3	Soft, very fine sand over tan to light gray poorly sorted, very fine sandy silt/clay. Sediment column appears well-bioturbated. No distinct void but sediment column riddled with oxidized sediment patches and void traces, distinct burrow structure right at bottom of image. Relict RPD 2-3 cm below current RPD and there is distinct separation between the two. A few tubes at SWI. Similar to reps A and B.
SE Ref-03 A	9/10/2005	15:01:24	13	4	14.41	>4	2	>4	>4 - 2	189.84	13.17	12.72	13.62	0.90	Biological	33.27	2.31	0	-	None	0.00	0	-	-	No	5	2.82	13.51	8.16	Stage 3	Soft, tan to gray poorly sorted, very fine sandy silt/clay. Sediment column appears well-bioturbated. Active, oxidized voids and void traces throughout sediment column and likely part of same gallery complex. Abundant, small, biogenic aggregates being assimilated into the sediment column at SWI.
SE Ref-03 B	9/10/2005	15:02:22	13	4	14.41	>4	2	>4	>4 - 2	202.23	14.03	13.84	14.35	0.51	Biological	28.15	1.95	0	-	None	0.00	0	-	-	No	4	2.54	13.91	8.22	Stage 3	Soft, tan to gray poorly sorted, very fine sandy silt/clay. Upper 2 -3 cm of sediment column appear enriched in sand relative to subsurface sediment. Sediment column appears well-bioturbated with a void in upper left and active, oxidized void traces throughout sediment column. Abundant, small, biogenic aggregates being assimilated into the sediment column at SWI. Numerous polychaetes in sediment column.
SE Ref-03 C	9/10/2005	15:03:19	13	4	14.41	>4	2	>4	>4 - 2	205.16	14.24	13.25	15.39	2.14	Physical	Ind	Indeterm	0	-	None	0.00	0	-	-	No	0	-	-	-	Stage 3	Tan to gray fine sandy silt. SWI has been disturbed by sampling. Subsurface sediment shows large areas of intense burrowing.
SE Ref-04 A	9/10/2005	14:49:16	13	4	14.41	>4	2	>4	>4 - 2	233.14	16.18	15.14	17.03	1.89	Biological	46.52	3.23	0	-	None	0.00	0	-	-	No	6	3.13	16.33	9.73	Stage 3	Very soft, tan to gray poorly sorted, very fine sandy silt/clay. Sediment column appears well-bioturbated with active voids and oxidized void traces throughout sediment column. Abundant, small, biogenic aggregates being assimilated into the sediment column at SWI. Numerous polychaetes in sediment column. Deep RPD and vestiges of a relict RPD below base of existing RPD.
SE Ref-04 B	9/10/2005	14:50:14	13	4	14.41	>4	2	>4	>4 - 2	244.59	16.97	14.72	18.27	3.55	Physical	28.83	2.00	0	-	None	0.00	0	-	-	No	0	-	-	-	Stage 3	Very soft, tan to gray poorly sorted, very fine sandy silt/clay. No voids but burrows and void traces are in subsurface sediment. Abundant, small, biogenic aggregates being assimilated into the sediment column at SWI. Interesting RPD. Relict RPD with separation at right and relict and present RPD converge at left.
SE Ref-04 C	9/10/2005	14:51:15	13	4	14.41	4-3/>4	1	>4	>4 - 1	256.77	17.82	16.44	19.09	2.65	Biological	29.18	2.03	0	-	None	0.00	0	-	-	No	2	7.39	14.01	10.70	Stage 3	Very soft, silty fine to medium sand over tan to gray very fine sandy silt/clay. Large prominent burrow/biogenic depression at left SWI. Active voids with oxidized sediment in upper and lower center of frame. Several small polychaetes in upper sediment column. Numerous small mudclasts at SWI. Again, RDSI and relict RPD 3 cm below the SWI and there is some physical influence of RPD .
SE Ref-05 A	9/10/2005	15:11:44	13	4	14.41	4-3/>4	1	>4	>4 - 1	207.41	14.39	14.13	14.72	0.59	Biological	21.96	1.52	0	-	None	0.00	0	-	-	No	6	4.14	6.99	5.57	Stage 1 on 3	Tan silty fine sand over tan to gray, poorly sorted very fine sandy silt/clay. Numerous active voids with oxidized sediment and patches of oxidized sediment throughout subsurface sediment column. A few small tubes at SWI. Possible faint banding. Two red polychaetes at center and left.
SE Ref-05 B	9/10/2005	15:12:42	13	4	14.41	>4	2	>4	>4 - 2	169.93	11.79	11.45	12.07	0.62	Physical	18.20	1.26	0	-	None	0.00	0	-	-	No	1	8.71	9.14	8.92	Stage 3	Tan to gray, poorly sorted very sandy silt/clay. Small oxidized void in lower center and numerous oxidized burrow/void traces in sediment column. SWI appears recently disturbed with incipient RPD. Conifer needles at SWI.
SE Ref-05 C	9/10/2005	15:13:33	13	4	14.41	>4	2	>4	>4 - 2	198.47	13.77	10.18	15.42	5.24	Physical	Ind	Ind	4	R	None	0.00	0	-	-	No	2	Ind	Ind	-	Stage 3	Tan to gray, poorly sorted very fine sandy silt/clay. SWI has been obliterated by sampling. Mudclasts are artifacts. Stage 3 clearly present based on voids and subsurface voids. Three reps are generally similar, but show a range of features.
SE Ref-06 A	9/10/2005	14:55:06	13	4	14.41	4-3/>4	1	>4	>4 - 1	221.57	15.38	14.52	15.70	1.18	Biological	29.47	2.05	0	-	None	0.00	0	-	-	No	2	2.31	7.89	5.10	Stage 3	Tan silty fine sand over tan to gray, poorly sorted very fine sandy silt/clay. Small void in upper right and small void in mid right. Oxidized burrow traces/relict voids throughout sediment column. Burrow at left SWI and few small mud tubes at SWI as well as shallow burrow traces extending downward from the SWI. Partial view of buried organism in lower left-center. Particulate terrestrial organics in sediment column.
SE Ref-06 B	9/10/2005	14:55:57	13	4	14.41	4-3/>4	1	>4	>4 - 1	220.83	15.32	15.06	15.70	0.65	Physical	15.04	1.04	0	-	None	0.00	0	-	-	No	2	5.55	7.73	6.64	Stage 3	Tan to medium gray, well-sorted fine to medium sand over tan to gray, poorly sorted, fine sandy silt/clay. The Rosetta Stone of the reference stations showing a recent well sorted sedimentary interval at the SWI that is coated with rounded biogenic aggregates. Demonstrative of the physical processes that are influence the upper sediment column dynamics across the reference areas. Two nice void in center and center-right. Obviously there is chronic physical disturbance at the SWI but the Stage 3 community remains stable. Great Pic.
SE Ref-06 C	9/10/2005	14:56:58	13	4	14.41	4-3/>4	1	>4	>4 - 1	196.16	13.61	12.18	14.13	1.95	Biological	20.94	1.45	0	-	None	0.00	0	-	-	No	4	4.29	9.90	7.09	Stage 3	Banded, tan to medium gray moderately sorted silty very fine sand over tan to dark gray very sandy silt/clay, Burrow at left SWI. Voids at far left, far right and in reduced patch at center. Relict RPDs 2-4 cm below SWI and 8.5-11 cm below the SWI. Similar to Rep B and shows periodic physical disturbance.
SE Ref-07 A	9/10/2005	15:16:13	13	4	14.41	4-3/>4	2	>4	>4 - 2	190.53	13.22	12.83	13.42	0.59	Biological	25.95	1.80	0	-	None	0.00	0	-	-	No	2	7.13	11.22	9.18	Stage 3	Tan to grey, shelly, very sandy silt/clay. Two prominent large, active voids with oxidized sediment in center and lower center of frame. Sediment column is riddles with voids and void traces - highly bioturbated and well process. SWI appear to have been physical disturbed and RPD thickening from top-down.
SE Ref-07 B	9/10/2005	15:17:09	13	4	14.41	>4	2	>4	>4 - 2	193.77	13.45	12.49	13.90	1.41	Biological	19.60	1.36	0	-	None	0.00	0	-	-	No	4	4.74	6.96	5.85	Stage 1 on 3	Tan to grey, shelly, very sandy silt/clay. Several voids across the frame about 1/3 way down from SWI. A few distinct, elongate tubes at SWI. Zone of more intense sulphate reduction immediately below the RPD. Possible RDSI. Beautiful oxidized hydric halos around burrows at left and left center, with one following a U-shaped burrow.
SE Ref-07 C	9/10/2005	15:18:30	13	4	14.41	4-3/>4	1	>4	>4 - 1	221.59	15.38	15.14	15.82	0.68	Biological	58.38	4.05	0	-	None	0.00	0	-	-	No	4	6.68	11.56	9.12	Stage 3	Tan, moderately sorted fine to medium sand over tan to gray very sandy silt/clay. RDSI at SWI and RDSI and relict RPD have coalesced - hence the thick RPD. Several classic, oxidized voids in center of frame. Distinctly segmented polychaete at left. Similar to A and B but each reps show a different progression after a disturbance.
SW Ref-01	9/10/2005	14:41:45	13	4	14.41	>4	2	>4	>4 - 2	213.29	14.80	14.07	15.54	1.47	Biological	18.30	1.27	0	-	None	0.00	0	-	-	No	0	-	-	-	Stage 1 on 3	Soft, tan to medium dark gray, very sandy silt/clay. Thinly developed RPD on RDSI and thick relict RPD beneath. Too much separation with reduced sediment to measure both combined. No voids visible but numerous patches of oxidized sediment and void traces in sediment column. Polychaete in center and right center.
SW Ref-01	9/10/2005	14:42:35	13	4	14.41	>4	2	>4	>4 - 2	240.72	16.70	16.16	17.20	1.04	Biological	46.89	3.25	0	-	None	0.00	0	-	-	No	2	1.86	3.19	2.52	Stage 1 on 3	Soft, tan to medium dark gray, very sandy silt/clay. Active voids in upper center left and upper left. Burrow and void traces throughout right side of sediment column. Abundant particulate terrestrial organics in upper sediment column. Tube at left SWI. Thick RPD. Deep Burrow at right.

Table A-2

Douglas Island Disposal Site Sediment-Profile Imaging Data form the September 2005 Survey

SW Ref-01	9/10/2005	14:43:26	13	4	14.41	>4	2	>4	>4 - 2	241.82	16.78	15.42	17.48	2.06	Biological	18.41	1.28	0	-	None	0.00	0	-	-	No	1	5.16	7.78	6.47	Stage 1 on 3	Soft, tan to medium dark gray, very sandy silt/clay. Oxidized sediment filled void/burrow at left and oxidized hydric halo around burrow continuation at lower left. SWI appear recently disturbed with thinly developed incipient RPD along with an increased proportion of fine sand in upper 2-3 cm of sediment column. A few small tubes at SWI. Three reps are sedimentologically similar but are at different stages of recovery after a physical disturbance. It is a patchy world out there.
SW Ref-02	9/10/2005	14:12:02	13	4	14.41	>4	2	>4	>4 - 2	244.10	16.94	16.61	17.42	0.82	Biological	43.15	2.99	0	-	None	0.00	0	-	-	No	3	9.53	12.15	10.84	Stage 1 on 3	Soft, tan to medium dark gray, very sandy silt/clay. Deep RPD and red algae at SWI. Numerous tubes at SWI and voids at far lower left, and at lower right. Organism in upper center. Particulate terrestrial organics in upper sediment column and sediment column appears well-bioturbated. Ambient light in water column (algae).
SW Ref-02	9/10/2005	14:12:53	13	4	14.41	4-3	1	>4	>4 - 1	109.96	7.63	6.99	8.29	1.30	Biological	25.04	1.74	0	-	None	0.00	0	-	-	No	2	2.23	6.60	4.42	Stage 1 on 3	Firm, tan to dark gray, shelly, poorly sorted, very silty fine sand. SWI appears to have been disturbed. Void in upper left and far right. A few tubes at SWI. Different from A. Zone of sulphate reduction immediately below RPD.
SW Ref-02	9/10/2005	14:13:40	13	4	14.41	>4	2	>4	>4 - 2	222.98	15.47	13.00	16.66	3.67	Biological	32.69	2.27	0	-	None	0.00	0	-	-	No	1	8.15	9.98	9.06	Stage 1 on 3	Soft, tan to medium gray, poorly sorted, very fine sandy silt/clay. High surface relief from burrow at left. Deep RPD at right and apparent relict RPD at left. Multi-chambered oxidized sediment-filled void in lower center and oxidized burrow trace (quite large) throughout the sediment column. Upper right is intensively bioturbated. Numerous tubes and small dissociated oxidized mudclasts at SWI. Similar to rep A.
SW Ref-03	9/10/2005	14:30:16	13	4	14.41	>4	2	>4	>4 - 2	221.88	15.40	14.86	15.87	1.02	Biological	45.98	3.19	0	-	None	0.00	0	-	-	No	4	4.93	13.56	9.25	Stage 1 on 3	Soft, tan to light gray very sandy silt/clay. Deep highly invaginated RPD with what appears to merging of RPD from RDSI an relict RPD - especially at the right side of the frame.. Four large classic voids with oxidized sediment. Reduced sediment being advected to SWI at right. Polychaete at left. Tubes and red algae at SWI and ambient light in water column.
SW Ref-03	9/10/2005	14:31:03	13	4	14.41	4-3/>4	2	>4	>4 - 2	255.89	17.76	17.40	18.02	0.62	Biological	25.01	1.74	0	-	None	0.00	0	-	-	No	6	4.23	17.26	10.74	Stage 1 on 3	Very soft, poorly sorted tan to dark gray very silty fine to medium sand over tan to gray poorly sorted sandy silt/clay RDSI at SWI with incipient RPD at SWI and relict RPD below base of RDSI. Active, classic voids at right. Biogenic mound at right SWI and burrow at left. Several small tubes at SWI. Nice pic redolent with unusual features.
SW Ref-03	9/10/2005	14:31:53	13	4	14.41	4-3/>4	2	>4	>4 - 2	246.45	17.10	16.63	17.14	0.51	Biological	21.40	1.49	2	B	None	0.00	0	-	-	No	4	2.68	9.19	5.94	Stage 1 on 3	Very soft, poorly sorted tan to dark gray very silty fine to medium sand over tan to gray poorly sorted sandy silt/clay RDSI at SWI and the new and relict RPDs are in the process of coalescing through bioturbation. Numerous shallow burrows with some having both FeO-OH and phaeopigment fixation. Burrow at left SWI. Active voids running from upper right to mid left. Particulate terrestrial organics in upper sediment column. Similar to rep B and three reps are generally similar.
SW Ref-04	9/10/2005	14:06:49	13	4	14.41	>4	2	>4	>4 - 2	238.70	16.56	16.10	16.92	0.82	Biological	30.65	2.13	>10	O	None	0.00	0	-	-	No	1	4.40	5.50	4.95	Stage 1 on 3	Poorly sorted, tan to gray, very sandy silt/clay with upper portion of the sediment column enriched in sand and particulate terrestrial organics relative to the subsurface. Burrow at left SWI which lead to sediment filled active void. Numerous patches of oxidized sediment and burrow traces in subsurface. SWI covered with small rounded, oxidized mudclasts - probably indicative of physical disturbance. Ambient light in water column.
SW Ref-04	9/10/2005	14:07:45	13	4	14.41	4-3	1	>4	>4 - 1	188.26	13.06	12.77	13.45	0.68	Biological	Ind	Indeterm	0	-	None	0.00	0	-	-	No	2	2.29	7.22	4.75	Stage 3	Poorly sorted very silty very fine sand. Void and burrow gallery at left and small void at far right. Most striking aspect of photo is distinct layer of reduced and oxidized sediment and aggregates at SWI. Red algae is buried. Another interesting pic.
SW Ref-04	9/10/2005	14:08:42	13	4	14.41	4-3/>4	2	>4	>4 - 2	242.47	16.83	16.13	17.45	1.33	Biological	26.36	1.83	0	-	None	0.00	0	-	-	No	4	5.19	12.72	8.95	Stage 1 on 3	Very soft, poorly sorted tan to dark gray very silty fine to medium sand over tan to gray poorly sorted sandy silt/clay RDSI at SWI and the new and relict RPDs are in the process of coalescing through bioturbation. A few tubes at SWI and some red algae at SWI. Large, well-formed, active voids in center and left. Nice pic. The three reps from this stations show a range of features but are generally similar.
SW Ref-05	9/10/2005	14:17:01	13	4	14.41	>4	2	>4	>4 - 2	250.16	17.36	16.97	17.62	0.65	Biological	19.70	1.37	2	O	None	0.00	0	-	-	No	2	2.99	9.33	6.16	Stage 1 on 3	Soft, poorly sorted very sandy silt/clay with RDSI at SWI. Relict RPD 2-3 cm below the SWI and Intense reduction under current RPD. Void in upper right and mid-left. Several oxidized rounded mudclasts at SWI. Polychaete at right and a couple of small tubes at SWI.
SW Ref-05	9/10/2005	14:17:52	13	4	14.41	4-3/>4	2	>4	>4 - 2	258.25	17.92	17.09	18.33	1.24	Physical	14.74	1.02	3	O	None	0.00	0	-	-	No	0	-	-	-	Stage 1 on 3	Soft, tan poor to moderately sorted silty fine sand over tan to gray poorly sorted sandy silt/clay. A few mudclasts at SWI and RDSI in upper 2-3 cm. Deep, thick relict RPD under RDSI. No voids visible but sediment column riddled with oxidized sediment patches, burrows and void traces. Polychaete upper center. Three reps are generally similar and show a range of features.
SW Ref-05	9/10/2005	14:18:40	13	4	14.41	>4	2	>4	>4 - 2	249.58	17.32	16.86	17.68	0.82	Biological	20.85	1.45	0	-	None	0.00	0	-	-	No	1	9.59	10.04	9.81	Stage 1 on 3	Soft, poorly sorted very sandy silt/clay with RDSI at SWI. Relict RPD 2-3 cm below the SWI and Intense reduction under current RPD. Sediment-filled void in center and numerous burrow and void traces throughout sediment column. Tubes at SWI. Three reps generally similar.
SW Ref-06	9/10/2005	14:36:18	13	4	14.41	4-3	1	>4	>4 - 1	187.52	13.01	11.45	13.62	2.17	Biological	17.82	1.24	0	-	None	0.00	0	-	-	No	5	1.18	10.18	5.68	Stage 1 on 3	Soft, poorly sorted, tan to medium dark gray very silty fine sand. Biogenic mound at left and large burrow at right SWI. Relict RPD 3-5 cm below SWI. Ophiuroid arm in center and numerous well-formed active voids throughout sediment column. Unclear whether relict RPD is due to physical disturbance or biogenic exhumation of reduced sediment and subsequent burial of SWI. Nice pic.
SW Ref-06	9/10/2005	14:37:03	13	4	14.41	4-3	1	>4	>4 - 1	186.15	12.92	10.85	14.01	3.16	Biological	Ind	3.78	0	-	None	0.00	0	-	-	No	2	7.78	13.14	10.46	Stage 1 on 3	Soft, poorly sorted, tan to medium dark gray very silty fine sand. Large dragdown feature in center of frame. RPD i estimate from linear measurements. Active void at left and lower right with each void having a large polychaete nearby. RPD well developed (no distinct RDSI).
SW Ref-06	9/10/2005	14:37:48	13	4	14.41	4-3	1	>4	>4 - 1	243.02	16.86	16.47	17.03	0.56	Biological	18.93	1.31	0	-	None	0.00	0	-	-	No	2	1.83	5.30	3.57	Stage 1 on 3	Soft, poorly sorted, tan to medium dark gray very silty fine sand. RDSI (1-2 cm thick) at SWI and relict RPD under RDSI. Active burrow/void in upper center and oxidized sediment-filled void in mid right. Layer of MC being incorporated into sediment column at SWI. Sedimentologically the three reps at this station are very similar.
SW Ref-07	9/10/2005	14:22:28	13	4	14.41	>4	2	>4	>4 - 2	244.27	16.95	16.72	17.06	0.34	Biological	22.86	1.59	0	-	None	0.00	0	-	-	No	5	2.96	12.04	7.50	Stage 3	Tan to medium gray, soft, poorly sorted very sandy silt/clay. 2-2.5 cm RDSI at SWI with incipient RPD and relict RPD at base. Numerous active voids throughout the sediment column. Nephtid at right. Rounded, very small mudclasts at SWI. Similar to other reference stations.
SW Ref-07	9/10/2005	14:23:19	13	4	14.41	>4	2	>4	>4 - 2	247.83	17.20	16.27	17.85	1.58	Physical	39.43	2.74	>20	B	None	0.00	0	-	-	No	3	5.72	14.47	10.09	Stage 3	Tan to medium gray, soft, poorly sorted very sandy silt/clay. Three distinct voids from upper right to lower left cente and a plethora of burrow and void traces throughout sediment column. Layer of oxidized and reduced, rounded, small mudclasts at SWI - good example of a reduced sediment clast that is behaving as a discrete particle. Reduced sediment being advected to SWI at right SWI. Sediment column well-bioturbated.
SW Ref-07	9/10/2005	14:24:09	13	4	14.41	>4	1	>4	>4 - 1	249.29	17.30	16.78	18.02	1.24	Biological	22.91	1.59	>20	B	None	0.00	0	-	-	No	3	3.22	15.65	9.43	Stage 3	Tan to medium gray, soft, poorly sorted very sandy silt/clay. 2-2.5 cm RDSI at SWI with incipient RPD and relict RPD at base. Void in upper right, lower right and mid-left. Several patches of oxidized sediment at depth and void/burrow traces. Thin layer of small rounded reduced and oxidized mudclasts at SWI. Similar to reps A and B. Biogenic mound at right SWI.
DIDS-01 A	9/10/2005	13:09:42	13	4	14.41	>4	2	>4	>4 - 2	172.78	11.99	11.67	12.55	0.87	Biological	23.95	1.66	0	-	None	172.78	> 11.99	> 11.67	> 12.55	No	0	-	-	-	Stage 1 on 3	DM>P. Tan RPD over dark gray organic silt over light gray cohesive silt/clay. No voids but large polychaete at far left and burrows at depth. Red Algae at SWI. Minor amounts of sand. A few tubes at SWI.
DIDS-01 B	9/10/2005	13:10:34	13	4	14.41	>4	2	>4	>4 - 2	174.61	12.12	10.71	12.77	2.06	Biological	22.53	1.56	1	R	None	174.61	> 12.12	> 10.71	> 12.77	No	2	6.09	8.54	7.32	Stage 1 on 3	DM>P. Tan RPD over dark gray silt with a few clots of light silt/clay. Voids in center and far right. SWI has coating of red colonial algae. Numerous reduced mudclasts litter SWI and background. Strong RPD contrast. Numerous thin red worms in upper sediment column.
DIDS-01 C	9/10/2005	13:11:27	13	4	14.41	>4	2	>4	>4 - 2	212.89	14.77	14.41	15.17	0.76	Biological	23.27	1.61	0	-	None	212.89	> 14.77	> 14.41	> 15.17	No	3	2.17	9.78	5.98	Stage 1 on 3	DM>P. Tan RPD over relatively homogenous dark bluish gray silt/clay. Upper portion of sediment column has abundant terrestrial organic matter. Small void in upper center, small void in lower right and void/burrow at far upper left. A few tubes at SWI. Strong RPD contrast. Reps B and C are similar.

Table A-2

Douglas Island Disposal Site Sediment-Profile Imaging Data form the September 2005 Survey

DIDS-02 A	9/10/2005	13:23:29	13	4	14.41	4-3	2	>4	>4 - 2	211.04	14.65	14.44	14.72	0.28	Biological	24.62	1.71	>20	B	None	211.04	>	14.65	>	14.44	>	14.72	No	0	-	-	-	Stage 2 -> 3	DM>P. RDSI over wood fiber rich very silty fine sand. RDSI appears to be composed of reworked DM based on organic fiber content. Numerous burrows extending 3-4 cm into the sediment column and a couple of tubes in SWI background. Abundant small oxidized and reduced mudclasts at SWI and overly red algal coating of the SWI. Interesting pic and shows similar physical process accounting for RDSI as did the reference stations.
DIDS-02 B	9/10/2005	13:24:14	13	4	14.41	>4	2	>4	>4 - 2	128.99	8.95	8.51	9.84	1.33	Physical	26.32	1.83	>20	B	None	128.99	>	8.95	>	8.51	>	9.84	No	3	3.50	8.18	5.84	Stage 1 on 3	DM>P. Tan RPD over medium blue-gray silt/clay. Voids at left and one at lower right. Bioturbation is not extensiv but localized in subsurface. Several shallow burrows and tube at right SWI. Colonial red algae over most of the frame width and a distinct layer of small rounded mudclasts at SWI. Very different from A in terms of sediment type.
DIDS-02 C	9/10/2005	13:25:01	13	4	14.41	>4	2	>4	>4 - 2	234.25	16.26	16.04	16.49	0.45	Biological	25.45	1.77	>10	O	None	234.25	>	16.26	>	16.04	>	16.49	No	6	3.98	12.04	8.01	Stage 1 on 3	DM>P. Highly organic, tan to medium gray slightly sandy silt. Red algae and some small rounded oxidized mudclasts at SWI. 3-4 cm RDSI at SWI that appears to be composed of same material as DM. Shows similar stratigraphic properties, in terms of process, as reference station. Voids throughout sediment column but there does not appear to have intensive bioturbation.
DIDS-03 A	9/10/2005	13:43:21	13	4	14.41	>4	2	>4	>4 - 2	230.90	16.02	15.85	16.18	0.34	Biological	18.55	1.29	0	-	None	230.90	>	16.02	>	15.85	>	16.18	No	3	3.33	9.05	6.19	Stage 1 on 3	DM>P. Tan, organic, fine sandy silt. RDSI at SWI that is 2-3 cm thick and highly organic and underlain by distinct relict RPD. RDSI is considered to be reworked DM. Voids in upper left and far right. Large nephtid in lower left. Ambient light in water column.
DIDS-03 B	9/10/2005	13:44:10	13	4	14.41	>4	2	>4	>4 - 2	224.08	15.55	14.10	16.41	2.31	Biological	18.31	1.27	1	O	None	224.08	>	15.55	>	14.10	>	16.41	No	2	4.96	10.23	7.60	Stage 1 on 3	DM>P. Tan, organic, fine sandy silt. RDSI at SWI that is 2-3 cm thick and highly organic and underlain by distinct relict RPD. RDSI is considered to be reworked DM and appears to biogenically deposited in this pic. Tubes at SWI, burrow in upper center and void at far right. Patch of wood fiber in mid right of sediment column. Biogenic mound at SWI.
DIDS-03 C	9/10/2005	13:44:58	13	4	14.41	>4	2	>4	>4 - 2	223.17	15.49	15.08	16.41	1.33	Biological	20.57	1.43	>10	B	None	223.17	>	15.49	>	15.08	>	16.41	No	0	-	-	-	Stage 2 -> 3	DM>P. Tan, organic, fine sandy silt. RDSI at SWI that is 2-3 cm thick and highly organic and underlain by distinct relict RPD. RDSI is considered to be reworked DM and appears to biogenically deposited in this pic. Patch of oxidized sediment that is related to infaunal reworking in center of frame. DM is rather featureless gray silt. Three reps are generally similar. Biogenic mound at right along with a coating of red/brown algae. SWI littered with small rounded mudclasts.
DIDS-04 A	9/10/2005	11:42:53	13	4	14.41	>4	2	>4	>4 - 2	175.98	12.21	11.93	12.52	0.59	Biological	29.02	2.01	3	R	None	175.98	>	12.21	>	11.93	>	12.52	No	4	1.78	11.45	6.61	Stage 1 on 3	DM>P. Layered, normally graded, uniform, dark gray sandy silt/clay with tan RPD. # graded layers present each 2 4 cm thick. Particulate organics in sediment column. Voids throughout sediment column - oxidized sand lag at bottom of frame. Several polychaetes in sediment column. Several fine tubes at SWI .
DIDS-04 B	9/10/2005	11:43:45	13	4	14.41	>4	2	>4	>4 - 2	192.23	13.34	12.55	13.67	1.13	Biological	25.06	1.74	2	R	None	192.23	>	13.34	>	12.55	>	13.67	No	6	1.21	8.01	4.61	Stage 1 on 3	DM>P. Layered, dark gray highly organic silt/sand. Normal grading in each layer. Numerous burrows and voids in upper sediment column. Patch of wood fibers in right center of sediment column. Reduced sediment being brought to SWI by burrow in background. Similar to rep A.
DIDS-04 C	9/10/2005	11:44:47	13	4	14.41	4-3	2	>4	>4 - 2	177.01	12.28	11.45	12.77	1.33	Biological	21.39	1.48	2	R	None	177.01	>	12.28	>	11.45	>	12.77	No	0	-	-	-	Stage 1 on 3	DM>P. Top layer is RDSI that appears to be reworked DM based on organics. Large band of sand and relict RPD 2.5-5 cm below the SWI. Patch of oxidized sediment related to infaunal burrowing in center of sediment column. RPD is redolent with biogenic aggregated particles, small rounded mudclasts. Three reps are similar in layering and features.
DIDS-05 A	9/10/2005	13:14:38	13	4	14.41	>4	2	>4	>4 - 2	272.94	18.94	17.99	19.85	1.86	Biological	37.67	2.61	0	-	None	272.94	>	18.94	>	17.99	>	19.85	No	6	2.90	10.54	6.72	Stage 1 on 3	DM>P. Appears to be older DM - gray, bioturbated, organic, silt/clay. Upper sediment column riddled with voids. Numerous fine tubes at SWI and dense coating of surface algae at SWI. High density of podocerids
DIDS-05 B	9/10/2005	13:15:21	13	4	14.41	>4	2	>4	>4 - 2	212.78	14.77	14.58	15.06	0.48	Biological	25.28	1.75	0	-	None	212.78	>	14.77	>	14.58	>	15.06	No	0	-	-	-	Stage 2 -> 3	DM>P. Relatively featureless, water-rich dark bluish gray silt. Strong RPD contrast. Oxidized burrow at lower right. Numerous fine tubes at SWI and SWI has extensive cover of red-brown algae. Numerous oxidized mudclasts, small and rounded, at SWI. Rather dull picture and sedimentologically similar to Rep A.
DIDS-05 C	9/10/2005	13:16:02	13	4	14.41	>4	2	>4	>4 - 2	185.24	12.86	11.45	13.48	2.03	Biological	30.12	2.09	>10	B	None	212.78		14.77		14.58		15.06	No	2	3.55	5.16	4.36	Stage 1 on 3	DM>P. Gray, organic slightly sandy silt with strong RPD contrast. SWI covered with fine tubes and small rounded reduced and oxidized mudclasts. Void in upper center and far right. Different from reps A and B but similar to other stations.
DIDS-06 A	9/10/2005	11:05:00	13	1	14.41	4-3	1	>4	>4 - 1	36.76	2.55	2.28	2.90	0.62	Physical	22.67	1.57	0	-	None	0.00		0		-		-	No	0	-	-	-	Stage 2	Tan to light gray, hard, silty fine sand with some shell fragments. SWI coated with red-brown algae. Numerous tubes poking through algae. Little penetration. Ripple at right. Unclear whether this is DM.
DIDS-06 B	9/10/2005	11:05:41	13	1	14.41	4-3	1	>4	>4 - 1	61.06	4.24	2.96	5.27	2.31	Physical	18.05	1.25	0	-	None	0.00		0		-		-	No	0	-	-	-	Stage 1 -> 2	Tan to dark gray, hard, silty fine sand with some shell fragments. Little penetration. Unclear whether this is DM. Coating of small reduced sediment and mudclasts at SWI. Red-brown algae at SWI. Shell dragdown at right-center. Similar to Rep A.
DIDS-06 D	9/10/2005	11:09:50	13	3	14.41	4-3	1	>4	>4 - 1	38.30	2.66	2.17	3.19	1.02	Physical	20.74	1.44	0	-	None	0.00		0		-		-	No	0	-	-	-	Stage 1 -> 2	Tan to light gray, hard, silty fine sand with some shell fragments. SWI coated with red-brown algae. Numerous tubes poking through algae. Little penetration. Ripple at right. Unclear whether this is DM. Nearly identical to Rep A. Three reps are very similar. Ambient light in all three reps - hydrodynamically active.
DIDS-07 A	9/10/2005	11:47:00	13	4	14.41	4-3	1	>4	>4 - 1	72.00	5.00	4.48	5.22	0.73	Biological	24.81	1.72	0	-	None	0.00		0		-		-	No	0	-	-	-	Stage 1 -> 2	Tan to light gray, hard, silty fine sand with some shell fragments. SWI coated with red-brown algae. Little penetration. Ripple at right. Unclear whether this is DM. SWI appear to be periodically physically disturbed.
DIDS-07 B	9/10/2005	11:47:50	13	4	14.41	4-3	1	>4	>4 - 1	67.59	4.69	4.51	4.88	0.37	Biological	27.12	1.88	0	-	None	0.00		0		-		-	No	2	2.96	4.65	3.81	Stage 1 on 3	Tan to light gray, hard, silty fine sand with some shell fragments. SWI coated with red-brown algae. Faint rippling of SWI. Burrow and void at left and reduced sediment being conveyored to SWI. Similar to Rep A.
DIDS-07 C	9/10/2005	11:48:34	13	4	14.41	4-3	1	>4	>4 - 1	76.04	5.28	4.65	6.01	1.35	Physical	22.52	1.56	0	-	None	0.00		0		-		-	No	0	-	-	-	Stage 1 on 3	Tan to light gray, hard, silty fine sand with some shell fragments. SWI coated with red-brown algae. Distinct rippling of SWI and RPD appears to be influenced highly by physical processes. Active burrow at bottom of frame center. Very similar to Reps A and B as well as to Station D-06.
DIDS-08 A	9/10/2005	12:03:41	13	4	14.41	>4	2	>4	>4 - 2	266.89	18.52	17.48	19.48	2.00	Physical	26.86	1.86	0	-	None	266.89	>	18.52	>	17.48	>	19.48	No	0	-	-	-	Stage 2	DM>P. Very soft, organic, tan to uniform medium gray, slightly fine sandy silt/clay. 2 cm RDSI at SWI which contains abundant wood and needle fibers. Layer of wood fibers 10.8-14.2 cm below the SWI. A few small polychaetes 7-9 cm below the SWI. Very little bioturbation. SWI has a red-brown algal coating across almost the entire frame. Sediment column contains a very high percentage of wood fibers.
DIDS-08 B	9/10/2005	12:04:32	13	4	14.41	>4	2	>4	>4 - 2	271.01	18.81	17.99	19.68	1.69	Physical	39.74	2.76	>20	B	None	271.01	>	18.81	>	17.99	>	19.68	No	2	3.83	10.07	6.95	Stage 2	DM>P. Very soft, organic, tan to uniform medium gray, slightly fine sandy silt/clay. Voids in upper left and mid right and although voids present, sediment column does not appear to be highly bioturbated. Irregular SWI morphology and deep RPD. Most of mudclasts at SWI are artifacts. Distinct layer of wood fibers 15-17 cm below the SWI. Similar Rep A although it appears that a RDSI layer has been bioturbated based on the thickness of the RPD. High proportion of mechanically broken wood fibers in sediment column.
DIDS-08 C	9/10/2005	12:05:25	13	4	14.41	>4	2	>4	>4 - 2	230.38	15.99	15.68	16.35	0.68	Biological	24.13	1.67	0	-	None	230.38	>	15.99	>	15.68	>	16.35	No	0	-	-	-	Stage 1	DM>P. Very soft, organic, tan to uniform medium gray, slightly fine sandy silt/clay. Void at mid-right and contain some oxidized sediment. Top 6 cm of sediment column loaded with mechanically chipped wood fibers and another layer of wood fibers 10-15 cm below the SWI. Relict RPD 3 cm below the SWI. Similar to reps AS and B and aesthetically unpleasant image.
DIDS-09 A	9/10/2005	11:28:42	13	4	14.41	>4	2	>4	>4 - 2	201.60	13.99	13.70	14.21	0.51	Biological	24.39	1.69	0	-	None	201.60	>	13.99	>	13.70	>	14.21	No	2	2.26	4.99	3.63	Stage 2 -> 3	DM>P. Soft, organic tan to black slightly sandy silt clay with clots of light clay and light gray silt throughout. Chaotic fabric. Voids in upper left. Wood fibers in upper portion sediment column. A few tubes at SWI and red-brown algal coating across entire width of image.
DIDS-09 B	9/10/2005	11:29:37	13	4	14.41	>4	2	>4	>4 - 2	205.88	14.29	13.59	15.06	1.47	Biological	26.43	1.83	>20	R	None	205.88	>	14.29	>	13.59	>	15.06	No	2	5.11	12.63	8.87	Stage 1 on 3	DM>P. Soft, tan to medium gray silt/clay. Void at mid left and burrow at right. Sediment very fluid around right burrow. Mudclasts at SWI are artifacts. Abundant wood fibers and chips in upper 3-4 cm of sediment column. Red algae at SWI. Similar to Rep A in SWI morphology.

Table A-2

Douglas Island Disposal Site Sediment-Profile Imaging Data form the September 2005 Survey

DIDS-09 C	9/10/2005	11:30:28	13	4	14.41	>4	2	>4	>4 - 2	172.62	11.98	11.28	12.63	1.35	Physical	21.28	1.48	>10	R	None	172.62	>	11.98	>	11.28	>	12.63	No	1	5.89	6.20	6.05	Stage 1 on 3	DM>P. Soft, tan to medium gray silt/clay with large clot of lighter colored clay at right. Chaotic fabric. Small active void in mid left and a couple of small lateral burrows in upper left. Wood fibers in upper 2-3 cm of sediment column. Similar to Rep A.
DIDS-10 A	9/10/2005	13:48:48	13	4	14.41	>4	2	>4	>4 - 2	190.89	13.25	12.97	13.51	0.54	Biological	Ind	Ind	Ind	Ind	None	190.89	>	13.25	>	12.97	>	13.51	No	Ind	Ind	Ind	-	Indeterminate	DM>P. Tan to medium gray, organic, slightly sandy silt/clay. Sediment column obscured by semi-fluid pellet layer.
DIDS-10 B	9/10/2005	13:49:37	13	4	14.41	>4	2	>4	>4 - 2	202.75	14.07	13.73	14.41	0.68	Biological	19.15	1.33	0	-	None	202.75	>	14.07	>	13.73	>	14.41	No	1	3.92	10.54	7.23	Stage 1 on 3	DM>P. Tan to medium dark gray, organic, slightly sandy silt/clay. 2-3 cm RDSI at SWI and relict RPD plainly visible under RDSI. Large burrow and void complex at right. Upper 5-6 cm of sediment column enriched in small wood fibers. Patches of red brown algae at SWI. A few very small worms in relict RPD at left.
DIDS-10 C	9/10/2005	13:50:35	13	4	14.41	>4	2	>4	>4 - 2	208.11	14.44	12.01	16.30	4.29	Physical	20.63	1.43	0	-	None	121.83		8.45		7.14		10.15	No	2	6.32	13.39	9.85	Stage 1 on 3	DM over native. DM is tan to medium gray, organic, uniform silt.clay over tan to olive gray, slightly sandy silt clay. Native sediment retains extensive relict bioturbation features. Distinct shift in optical properties. The upper portion of the DM is composed of moderately sorted very fine sand with interspersed wood fibers. Possible RDSI. Large active void at left and extensive burrow/void tracks at DM/native contact. Three reps at this station are different.
DIDS-11 A	9/10/2005	13:38:15	13	4	14.41	>4	2	>4	>4 - 2	169.95	11.79	9.81	13.70	3.89	Physical	17.94	1.24	0	-	None	169.95	>	11.79	>	9.81	>	13.70	No	1	9.81	11.05	10.43	Stage 1 on 3	DM>P. DM is tan to medium dark gray, organic, slightly sandy silt/clay. Debris at left SWI. Void at bottom left-center. Several polychaetes above void. Patch of distinct wood fibers at right.
DIDS-11 B	9/10/2005	13:39:01	13	4	14.41	>4	2	>4	>4 - 2	211.93	14.71	13.48	15.31	1.83	Physical	22.32	1.55	2	R	None	211.93	>	14.71	>	13.48	>	15.31	No	1	3.72	3.98	3.85	Stage 1 on 3	DM>P. DM is tan to medium dark gray, organic, slightly sandy silt/clay. Void in upper center. Podocerid tubes at SWI background. Possible relict RPD 2-3 cm below SWI. Abundant small wood fragments and fibers in sediment column. Similar to Rep A.
DIDS-11 C	9/10/2005	13:40:07	13	4	14.41	>4	2	>4	>4 - 2	252.33	17.51	16.30	18.78	2.48	Physical	24.41	1.69	0	-	None	252.33	>	17.51	>	16.30	>	18.78	No	3	4.82	13.00	8.91	Stage 1 on 3	DM>P. DM is tan to medium dark gray, organic, slightly sandy silt/clay. Voids at right with reduced sediment being brought to SWI at right - another void in relict RPD. 2-4 cm RDSI at SWI with distinct relict RPD. Abundant small wood fibers and wood chips in DM and in RDSI. White patch in left background - may be deteriorating shell or Beggiatoa patch - unclear. Three reps are similar.
DIDS-12 A	9/10/2005	11:38:02	13	4	14.41	>4	2	>4	>4 - 2	159.91	11.10	6.54	14.32	7.78	Physical	Ind	1.72	0	-	None	159.91	>	11.10	>	6.54	>	14.32	No	Ind	Ind	Ind	-	Indeterminate	DM>P. DM is tan to medium dark gray, highly organic, slightly sandy silt/clay. Large drag-down scar at left. RPD is estimated from linear measurements in undisturbed portion of frame. Thick relict RPD at right with high proportion of wood chips and wood fibers.
DIDS-12 B	9/10/2005	11:38:56	13	4	14.41	>4	2	>4	>4 - 2	233.32	16.19	16.01	16.44	0.42	Biological	18.87	1.31	0	-	None	233.32	>	16.19	>	16.01	>	16.44	No	3	2.82	9.36	6.09	Stage 1 on 3	DM>P. DM is tan to medium dark gray, organic, slightly sandy silt/clay. Voids in upper right and mid-left. Tube at center SWI. Upper 3 cm of sediment column has high proportion of mechanically fragmented, small wood chips. Wood chips and wood fibers in subsurface sediment column. Biogenic mound at far right and patch of red-brown surface algae.
DIDS-12 C	9/10/2005	11:39:47	13	4	14.41	>4	2	>4	>4 - 2	248.76	17.26	15.79	19.31	3.52	Physical	Ind	Indeterm	1	R	None	248.76	>	17.26	>	15.79	>	19.31	No	2	2.48	15.14	8.81	Indeterminate	DM>P. DM is layered, medium dark gray, organic, slightly sandy silt/clay. Void in upper right and lower left. SWI has been denuded of RPD and large reduced mudclast at right SWI is most likely an artifact. High angle to the bedding which is most likely related to the camera penetrating at an angle - very unlikely that tectonics caused the high angle bedding. Nice to see a typical DM signature. Three reps are all slightly different but B and C show some similar features.
DIDS-13 A	9/10/2005	13:28:10	13	4	14.41	>4	2	>4	>4 - 2	242.15	16.80	13.36	19.82	6.46	Ind	18.49	1.28	0	-	None	242.15	>	16.80	>	13.36	>	19.82	No	2	10.15	16.41	13.28	Stage 1 on 3	DM>P. DM is medium dark gray, organic, slightly sandy silt/clay. Void in mid right and bottom center. High surface topography and cannot determine origin conclusively. Several relict void and burrow traces in subsurface sediment. Abundant terrestrial organic particles and small wood fibers/fragments in sediment column.
DIDS-13 B	9/10/2005	13:29:09	13	4	14.41	>4	2	>4	>4 - 2	254.33	17.65	16.47	18.38	1.92	Biological	24.38	1.69	1	R	None	254.33	>	17.65	>	16.47	>	18.38	No	3	7.05	11.42	9.23	Stage 1 on 3	DM>P. DM is medium dark gray, organic, slightly sandy silt/clay. Void at far right, one at left and small burrow.void in center. Abundant wood fibers/fragments in sediment column. Reduced mudclast at left SWI is an artifact. Biogenic mound at right. Similar to A without the relief.
DIDS-13 C	9/10/2005	13:30:05	13	4	14.41	>4	2	>4	>4 - 2	259.29	17.99	17.34	18.50	1.16	Biological	21.65	1.50	0	-	None	259.29	>	17.99	>	17.34	>	18.50	No	1	4.99	7.61	6.30	Stage 1 on 3	DM>P. DM is medium dark gray, organic, slightly sandy silt/clay. Void/burrow in upper right. Several void/burrow traces in subsurface sediment although sediment column does not appear to be extensively bioturbated. Relict RPD at bottom of frame and it may reflect native surface - but insufficient information to that definitively. Some red-brown algae at SWI. Similar to Rep B.
DIDS-14 A	9/10/2005	11:57:14	13	4	14.41	>4	2	>4	>4 - 2	293.90	20.40	19.74	20.75	1.02	Biological	21.26	1.48	0	-	None	293.90	>	20.40	>	19.74	>	20.75	No	2	4.09	8.29	6.19	Stage 1 on 3	DM>P. DM is very soft, medium gray, organic, slightly sandy silt/clay. Voids in upper center and upper right. A few tubes at SWI and ambient light in water column. Minor wood fibers in sediment column. Center void has nice oxygenated wall. Deep oxidized burrow trace leading to void. Subsurface sediment rather featureless.
DIDS-14 B	9/10/2005	11:58:09	13	4	14.41	>4	2	>4	>4 - 2	210.21	14.59	14.46	14.72	0.25	Biological	24.22	1.68	5	B	None	210.21	>	14.59	>	14.46	>	14.72	No	3	1.97	8.13	5.05	Stage 2 -> 3	DM>P. DM is soft, medium gray, highly organic, slightly sandy silt/clay with abundant wood fiber and small, mechanically fragmented wood chips. Two voids in upper center of sediment column and small void in lower center, immediately above stringer of wood fragments. Wood fragments appear to be acting as inert particles.
DIDS-14 C	9/10/2005	11:59:10	13	4	14.41	>4	2	>4	>4 - 2	241.46	16.76	16.13	17.09	0.96	Biological	30.05	2.09	0	-	None	241.46	>	16.76	>	16.13	>	17.09	No	0	-	-	-	Stage 1 -> 2	DM>P. DM is soft, medium gray, organic, slightly sandy silt/clay with scattered wood fiber and small, mechanically fragmented wood chips. No void and little evidence of subsurface bioturbation. Several shallow to medium deep burrows and thin red worm at left. A couple of mud tubes at SWI and red-brown surface algae at left SWI. Three reps are slightly different but show some similar features.
DIDS-15 A	9/10/2005	13:33:52	13	4	14.41	>4	2	>4	>4 - 2	240.17	16.67	16.27	16.92	0.65	Biological	27.91	1.94	0	-	None	240.17	>	16.67	>	16.27	>	16.92	No	2	3.44	5.05	4.24	Stage 1 on 3	DM>P. Gray organic, slightly sand silt/clay with scattered wood fibers and fragments. Void in upper left and upper center. Appears to be a dragdown feature at mid to lower right attributable to a lens of small wood chips 6-7 cm below the SWI. Several tubes at the SWI and patches of red-brown algae across half the SWI.
DIDS-15 B	9/10/2005	13:34:40	13	4	14.41	>4	2	>4	>4 - 2	134.40	9.33	8.49	10.29	1.80	Physical	21.88	1.52	>20	B	None	134.40	>	9.33	>	8.49	>	10.29	No	0	-	-	-	Stage 1	DM>P. Layered, medium dark to light gray silt/clay. No voids visible. Several shallow burrows extending downward from the RPD. SWI is coated with small reduced and oxidized mudclasts. Red-brown algal coating across entire SWI. Thin red worm in upper right. Different from A.
DIDS-15 C	9/10/2005	13:35:29	13	4	14.41	>4	2	>4	>4 - 2	112.69	7.82	7.42	8.06	0.65	Physical	25.33	1.76	>20	B	None	112.69	>	7.82	>	7.42	>	8.06	No	2	3.75	5.41	4.58	Stage 2 -> 3	DM>P. Firm, organic medium gray silt/clay. Void at right and another at left-center. SWI covered with small reduced and oxidized mudclasts. Bedform. Algal coating over large percentage of SWI. Similar to Rep B.
DIDS-16 A	9/10/2005	13:18:18	13	4	14.41	>4	2	>4	>4 - 2	220.43	15.30	15.23	15.62	0.39	Biological	27.40	1.90	5-10	O	None	220.43	>	15.30	>	15.23	>	15.62	No	2	4.23	8.26	6.25	Stage 1 on 3	DM>P. DM is organic, medium to dark gray silt/clay. Subsurface sediment rather homogenous. Voids in upper right center. Several tubes at SWI and red-brown algae at the SWIacross the entire frame. DM doesn't appear overly fresh or too labile.
DIDS-16 B	9/10/2005	13:19:03	13	4	14.41	>4	2	>4	>4 - 2	219.08	15.20	14.94	15.85	0.90	Biological	14.89	1.03	>10	B	None	219.08	>	15.20	>	14.94	>	15.85	No	2	6.68	14.21	10.45	Stage 1 on 3	DM>P. DM is organic, medium to dark gray silt/clay. Distinct relict RPD 2-4 cm below SWI. Abundant fine organic particles, wood fibers and wood fibers in upper RDSI. Thin lens of wood fibers 8-9 cm below the SWI. Linear band of related voids and burrow at far right edge. Oxidized sediment filled void/burrow in right center. RDSI included in DM measure.
DIDS-16 C	9/10/2005	13:19:54	13	4	14.41	>4	2	>4	>4 - 2	257.29	17.85	16.92	18.50	1.58	Biological	26.99	1.87	0	-	None	257.29	>	17.85	>	16.92	>	18.50	No	0	-	-	-	Stage 2	DM>P. DM is organic, medium to dark gray silt/clay. No voids visible. Reduced burrow in upper right and several shallow burrows extending downward from the RPD. DM shows faint banding based on organic content. Abundant particulate organics in upper 4 cm of sediment column and appear to be very small wood fibers and fragments. Biogenic mound at right SWI. Intact tubes at left SWI. Coating of surface red-brown algae across SWI Reps are similar.
DIDS-17 A	9/10/2005	11:50:57	13	4	14.41	4-3	1	>4	>4 - 1	47.21	3.28	2.03	4.06	2.03	Physical	26.19	1.82	0	-	None	0.00		0		-		-	No	0	-	-	-	Stage 1	Hard, tan to medium gray, silty fine sand with some shell fragments. SWI coated with red-brown algae. Distinct rippling of SWI and RPD appears to be influenced highly by physical processes. It is possible that this is reworked DM but optical signature and penetration insufficient to make conclusive call.
DIDS-17 B	9/10/2005	11:51:47	13	4	14.41	4-3	1	>4	>4 - 1	61.07	4.24	3.47	5.30	1.83	Physical	35.33	2.45	1	R	None	0.00		0		-		-	No	0	-	-	-	Stage 1 -> 2	Hard, tan to medium gray, silty fine sand with some shell fragments. It is possible that this is reworked DM but optical signature and penetration insufficient to make conclusive call. Some red-brown algae on surface at right. Too intact and corner at perfect right angle - otherwise looks like kelp. Shell dragdown in center that mimics burrow and void. Artifact mudclast at left.

Table A-2

Douglas Island Disposal Site Sediment-Profile Imaging Data form the September 2005 Survey

DIDS-17 C	9/10/2005	11:52:44	13	4	14.41	4-3	1	>4	>4 - 1	136.20	9.45	9.22	10.18	0.96	Biological	24.84	1.72	0	-	None	136.20	>	9.45	>	9.22	>	10.18	No	3	2.74	8.40	5.57	Stage 1 on 3	DM>P. Layered, biologically and physically reworked DM. RDSI/sand lag/dark gray sandy silt/clay. Voids in upper center and lower center. Wood fibers and fragments in upper portion of sediment column. It appears the sandier layer in the middle of the sediment column is a lag and is temporarily covered by a RDSI. Reps A and B may also be DM but do not show the same signature. Interesting and key photo.
DIDS-18 A	9/10/2005	12:13:39	13	4	14.41	4/4-3/>	1	>4	>4 - 1	180.93	12.56	11.79	13.56	1.78	Biological	18.87	1.31	0	-	None	163.22		11.33		10.40		13.11	No	2	4.93	7.47	6.20	Stage 1 on 3	Tan to dark gray very silt very fine sand with some banding over olive light gray relict RPD at bottom of frame. Relict RPD at bottom postulated to native sediment/DM contact. RDSI 2-3 cm thick at SWI and very sandy relict RPD directly below. RDSI presumed to be reworked DM. Abundant small wood fragments and fibers in upper sediment column. Void in upper left center and void at far right. Interesting photo.
DIDS-18 B	9/10/2005	12:14:31	13	4	14.41	>4	1	>4	>4 - 1	164.20	11.39	10.83	12.04	1.21	Physical	Ind	Indeterm	>5	R	None	77.77		5.40		3.24		8.40	No	Ind	-	-	-	Stage 2 -> 3	Dark gray sandy silt/clay DM over very light olive gray very silty fine sand. Interpreted to native/DM contact based on the large difference in sediment properties. SWI is disturbed from sampling. Sense small polychaetes in relict RPD/native.
DIDS-18 C	9/10/2005	12:15:16	13	4	14.41	>4	1	>4	>4 - 1	280.16	19.44	18.10	20.24	2.14	Biological	16.34	1.13	3	R	None	228.84		15.88		13.14		17.73	No	2	9.36	11.73	10.55	Stage 1 on 3	Soft. Dark gray sandy silt/clay DM over very light olive gray very silty fine sand. Interpreted to native/DM contact based on the large difference in sediment properties. Layer of mechanically fragment wood chips at base of DM and dragged down by the prism. Interesting photo. Subsurface disturbed dragdown. Voids in center of frame. A few twigs and fibers at SWI. Generally similar to A and B but much more penetration into native.
DIDS-19 A	9/10/2005	11:33:28	13	4	14.41	>4	2	>4	>4 - 2	194.88	13.52	12.91	13.90	0.99	Biological	24.65	1.71	0	-	None	194.88	>	13.52	>	12.91	>	13.90	No	0	-	-	-	Stage 1 -> 2	DM>P. Medium to dark gray, very organic, slightly sandy silt/clay DM with highly abundant wood fibers and wood chips. Numerous tubes at the SWI and several shallow burrows extending down from the SWI but no voids visible. Small woodchip layer 4.6 to 7.3 cm below the SWI. Algal coating at SWI.
DIDS-19 B	9/10/2005	11:34:12	13	4	14.41	>4	2	>4	>4 - 2	207.29	14.38	13.65	15.06	1.41	Biological	28.92	2.43	>10	R	None	207.29	>	14.38	>	13.65	>	15.06	No	1	1.81	2.57	2.19	Stage 1 on 3	DM>P. Medium to dark gray, very organic, slightly sandy silt/clay DM with highly abundant wood fibers and wood chips. Numerous tubes at the SWI. Shallow void at upper right, immediately below biogenic depression at SWI. Burrow at left. Dense small wood fragments and fibers in the upper 5 cm of sediment column, relatively featureless below wood fragment layer. Red-brown surface algae at SWI and numerous reduced mudclast artifacts. Similar to rep A.
DIDS-19 C	9/10/2005	11:34:55	13	4	14.41	>4	2	>4	>4 - 2	252.24	17.50	17.17	17.73	0.56	Biological	27.45	1.90	5	R	None	252.24	>	17.50	>	17.17	>	17.73	No	2	2.76	9.00	5.88	Stage 1 on 3	DM>P. Medium to dark gray, very organic, slightly sandy silt/clay DM with highly abundant wood fibers and wood chips. Shallow void at upper right with reduced sediment being brought to the SWI, Sediment filled voids in right center. Dense small wood fragment and fiber layer 9.9 to 11.5 cm below SWI. Similar to reps A and B.
DIDS-20 A	9/10/2005	12:08:56	13	4	14.41	>4	2	>4	>4 - 2	187.17	12.99	12.07	13.56	1.49	Biological	29.63	2.06	6	B	None	187.17	>	12.99	>	12.07	>	13.56	No	3	5.61	12.38	9.00	Stage 1 on 3	DM>P. Medium to dark gray, organic, slightly sandy silt/clay DM. Upper portion of the sediment column appear to be slightly reworked and some of the labile organics processed. Void in center, right and bottom center. Tubes at SWI. Abundant wood fibers and fragments in top 2-3 cm of sediment column.
DIDS-20 B	9/10/2005	12:09:41	13	4	14.41	>4	2	>4	>4 - 2	174.71	12.12	11.53	12.97	1.44	Biological	28.33	1.97	>10	R	None	174.71	>	12.12	>	11.53	>	12.97	No	1	4.65	6.68	5.67	Stage 1 on 3	DM>P. Medium to dark gray, organic, slightly sandy silt/clay DM. SWI has surface red-brown algal coating and numerous reduced, mudclast artifacts. Void/burrow with reduced sediment in upper right immediately below biogenic mound at SWI. Patch of sandier sediment in middle of sediment column. Ugly texture. Vaguely similar to A.
DIDS-20 C	9/10/2005	12:10:26	13	4	14.41	>4	2	>4	>4 - 2	174.34	12.10	11.64	12.52	0.87	Biological	24.20	1.68	0	-	None	174.34	>	12.10	>	11.64	>	12.52	No	1	3.67	3.95	3.81	Stage 1 on 3	DM>P. Medium to dark gray, highly organic, slightly sandy silt/clay DM with dense wood fibers and wood fragments in upper half of the sediment column. SWI has surface red-brown algal coating. Void upper center of the sediment column and small red worm above void. Unclear whether whitish haze at SWI background in suspended sediment or possible Beggiatoa. Rep C has far more wood fibers and fragments than reps A and B.
DIDS-21 A	9/10/2005	11:14:38	13	4	14.41	>4	2	>4	>4 - 2	214.23	14.87	13.96	15.56	1.61	Biological	25.94	1.80	0	-	None	214.23	>	14.87	>	13.96	>	15.56	No	3	4.82	12.32	8.57	Stage 1 on 3	DM>P. Medium to dark gray, highly organic, slightly sandy silt/clay. Upper 3-4 cm appear to be physically reworked and high proportion of small wood fiber and wood fragments. Large multi-voided burrow/gallery at center to right. A few tubes at SWI and minor red-brown surface algae.
DIDS-21 B	9/10/2005	11:15:24	13	4	14.41	>4	2	>4	>4 - 2	199.31	13.83	13.53	14.80	1.27	Biological	20.25	1.41	3	R	None	199.31	>	13.83	>	13.53	>	14.80	No	2	1.41	8.01	4.71	Stage 1 on 3	DM>P. Medium to dark gray, highly organic, slightly sandy silt/clay. RDSI at SWI 2-3 cm thick. Sandy relict RPD under RDSI. Void in upper left and larger active void in lower mid-left. Several polychaetes in relict RPD, ophiuroid arm in center. Some red-brown algae at left SWI. Fuzzy at left SWI.
DIDS-21 C	9/10/2005	11:16:10	13	4	14.41	>4	2	>4	>4 - 2	204.40	14.18	14.04	14.38	0.34	Biological	21.23	1.47	0	-	None	187.38		13.00		11.56		13.42	No	1	4.76	8.85	6.81	Stage 1 on 3	Medium to dark gray, highly organic, slightly sandy silt/clay DM/olive relict RPD at bottom of frame that in nominally called native. Void/burrow in mid-right. Upper 3-4 cm has high proportion of wood fibers and fragments. Polychaete at left. Three reps are generally similar.

Appendix B

Statistical Analyses:

Bioequivalence Testing
and
Non-parametric Bootstrapped Confidence Limits

1.0 Bioequivalence (Interval) Testing

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

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

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

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

(a) If this confidence interval contains a specified δ then the true difference is greater than δ (H_0 above);
(b) if δ is not contained in this interval then the true difference is less than δ (H_A above) and you conclude equivalence within δ units.

In this sampling design, there are actually four distinct areas, three of which are categorized as reference locations, so the difference equation of interest is defined as the average of the three reference means minus the mound mean, 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 *j*th area (5, 5, 5, 30, for areas EREF, SREF, SWREF, SITE, respectively, or 15 and 30 for both areas if reference areas can be pooled).

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

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

Where:

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

$t_{\alpha,\upsilon}$ = 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 will be used.

2.0 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), the bootstrapped statistic (T) is a pivotal statistic, which means that the distribution of T is the same for all values of the mean. For the purpose of constructing a confidence interval around the difference (5 - μ), the pivotal statistic T is defined as

$$T = \frac{(5-\bar{x})-(5-\mu)}{SE\big((5-\bar{x})\big)} = \frac{\mu-\bar{x}}{SE(\bar{x})} \qquad \text{(Eq. 1)}$$

where μ is the true population mean and the values $\bar{x}$ and $SE(\bar{x})$ are sample estimates of the mean and the standard error of the mean, respectively. The 5th and the 95th quantiles of the T distribution ($T_{0.05}$ and $T_{0.95}$, respectively) satisfy the equations:

$$\Pr[\frac{\mu-\bar{x}}{SE(\bar{x})} > T_{0.05}] = 0.95 \qquad \text{(Eq. 2a)}$$

$$\Pr[\frac{\mu-\bar{x}}{SE(\bar{x})} < T_{0.95}] = 0.95 \qquad \text{(Eq. 2b)}$$

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

$$\Pr[(5-\mu) < (5-\bar{x}) - T_{0.05}SE(\bar{x})] = 0.95 \qquad \text{(Eq. 3a)}$$

$$\Pr[(5-\bar{x}) - T_{0.95}SE(\bar{x}) < (5-\mu)] = 0.95 \qquad \text{(Eq. 3b)}$$

Bootstrapping is used to estimate the $T_{0.05}$ and $T_{0.95}$ values while the other parameters are estimated from the original sample. The right side of equation 3a represents the 95% upper confidence limit on the difference equation (5 - μ); the left side of equation 3b is the 95% lower 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 3a and 3b, then we conclude equivalence within δ units.

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

1. Bootstrap (sample with replacement from the original sample of size n) 10,000 samples of size n (n=21) and compute the T statistic for each bootstrapped sample. $T_{B,i}$ is the bootstrapped-*t* value computed from the ith bootstrap sample, defined by the following equation

$$T_{B,i} = \frac{(5-\bar{x}_{B,i})-(5-\bar{x})}{SE\left((5-\bar{x}_{B,i})\right)} = \frac{\bar{x}-\bar{x}_{B,i}}{SE\left(\bar{x}_{B,i}\right)} \qquad \text{(Eq. 4)}$$

   where $\bar{x}_{B,i}$ and $SE\left(\bar{x}_{B,i}\right)$ are the mean and the standard error of the mean (the standard deviation divided by the square root of n) computed for the ith bootstrapped sample, and $\bar{x}$ is the original sample mean. This step yields 10,000 values of the bootstrapped-*t* statistic which comprise the "bootstrap-*t* distribution".

2. Find $T_{0.05}$ and $T_{0.95,}$ the 5th and 95th quantiles of the bootstrap-*t* distribution. These values satisfy Equations 2a and 2b.

3. Applying Equations 3a and 3b using the values $T_{0.05}$ and $T_{0.95}$ found in Step 2 gives the bootstrap-*t* estimate of the 95% upper and lower confidence limits on the difference equation (5-μ), i.e.,

$$95\%\ \text{UCL} = (5-\bar{x}) - T_{0.05}SE\left(\bar{x}\right) \qquad \text{(Eq. 5a)}$$

$$95\%\ \text{LCL} = (5-\bar{x}) - T_{0.95}SE\left(\bar{x}\right) \qquad \text{(Eq. 5b)}$$

   where $\bar{x}$ and $SE\left(\bar{x}\right)$ are the mean and the standard error of the mean (the standard deviation divided by the square root of n) computed from the original sample.