Monitoring Cruise at the Central Long Island Sound Disposal Site
June 2001

Disposal Area Monitoring System DAMOS

Contribution 142
January 2003

US Army Corps of Engineers
New England District

REPORT DOCUMENTATION PAGE

form approved
OMB No. 0704-0188

1. AGENCY USE ONLY (LEAVE BLANK)

2. REPORT DATE
January 2003

3. REPORT TYPE AND DATES COVERED
FINAL REPORT

4. TITLE AND SUBTITLE
Monitoring Cruise at the Central Long Island Sound Disposal Site, June 2001

5. FUNDING NUMBERS

6. AUTHOR(S)
Science Applications International Corporation

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Science Applications International Corporation
221 Third Street
Newport, RI 02840

8. PERFORMING ORGANIZATION REPORT NUMBER
SAIC No. 595

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

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
DAMOS Contribution No. 142

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

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

12b. DISTRIBUTION CODE

13. ABSTRACT

As part of the Disposal Area Monitoring System (DAMOS) Program, Science Applications International Corporation (SAIC) conducted an environmental monitoring survey over the Central Long Island Sound Disposal Site (CLDS) in June 2001. Field operations consisted of a single-beam bathymetric survey and sediment-profile imaging surveys over the most recently formed dredged material disposal mounds, as well as several historic bottom features. The bathymetric data were used to document changes in seafloor topography resulting from the placement of dredged sediments during the 2000–01 disposal season. The sediment-profile images were used to examine the benthic recolonization status and habitat conditions over individual disposal mounds relative to three CLDS reference areas and to the results of previous monitoring efforts.

Depth difference calculations indicated the CLIS 00 Mound was relatively small, with a height of 3m at the mound apex and a mound footprint 200 m in diameter. The sediment profile imaging results for the active area of CLDS indicated the CLIS 00 Mound was rapidly colonized by benthic infauna. The Organism-Sediment Index (OSI) value calculated for the CLIS 00 Mound (+6.7) was indicative of an undisturbed benthic habitat and suggesting habitat recovery was progressing more rapidly than anticipated. The findings for the CLIS 99 Mound were quite similar to the CLIS 00 results. An average OSI value of +6.9 indicates the CLIS 99 Mound and surrounding seafloor is recovering from the placement of dredged sediments as anticipated. The CLIS 1997/1998 Mound Complex and New Haven 1993 (NHAV 93) Mound both showed improved benthic habitat conditions relative to previous surveys. Both mounds displayed evidence of a stable benthic infaunal population and deeper RPD depths, yielding higher OSI values. These results indicate a continued improvement in habitat conditions as demonstrated by deeper RPDs and increased abundance of Stage III organisms. Despite the improved conditions detected over the majority of the NHAV 93 in June 2001, Station 200S continues to demonstrate benthic habitat quality lower than what would be expected for a seven-year-old dredged material deposit. Some spatial variability was identified in the three replicate photographs collected at Station 200S, but the overall trend suggests an alternative management approach (i.e., comprehensive testing, cap augmentation, etc.) is prudent.

14. SUBJECT TERMS Central Long Island Sound Disposal Site, Dredged Material

15. NUMBER OF TEXT PAGES: 65

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

MONITORING CRUISE AT THE CENTRAL LONG ISLAND SOUND DISPOSAL SITE JUNE 2001

CONTRIBUTION #142

January 2003

Report No.
SAIC-595

Submitted to:

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

Submitted by:
Science Applications International Corporation
Admiral's Gate
221 Third Street
Newport, RI 02840
(401) 847-4210

US Army Corps of Engineers®
New England District

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

Page

Page

LIST OF FIGURES (continued)

EXECUTIVE SUMMARY

As part of the Disposal Area Monitoring System (DAMOS) Program, Science Applications International Corporation (SAIC) conducted an environmental monitoring survey over the Central Long Island Sound Disposal Site (CLDS) in June 2001. Field operations consisted of a single-beam bathymetric survey and sediment-profile imaging surveys over the most recently formed dredged material disposal mounds, as well as several historic bottom features. The bathymetric data were used to document changes in seafloor topography resulting from the placement of dredged sediments during the 2000–01 disposal season. The sediment-profile images were used to examine the benthic recolonization status and habitat conditions over individual disposal mounds relative to three CLDS reference areas and to the results of previous monitoring efforts.

The June 2001 bathymetric survey was performed over a 1.0 km^2 area located near the center of CLDS and encompassed the new CLIS 99 and CLIS 00 disposal mounds. The CLIS 99 Mound was formed during the 1999–2000 disposal season by the placement of 86,000 m^3 of sediment. The morphology of the CLIS 99 Mound was originally documented during the September 2000 multibeam bathymetric survey over CLDS. The CLIS 00 Mound is the most recent disposal mound at CLDS and was the product of 71,000 m^3 of dredged material placed on the CLDS seafloor. Depth difference calculations based on comparisons with the September 2000 multibeam bathymetric survey indicated the presence of a small, conical-shaped disposal mound corresponding to the CDA 00 buoy position. The CLIS 00 Mound displayed a mound height of 3 m at the apex and an acoustically detectable footprint approximately 200 m in diameter. In addition, the depth difference comparison detected pockets of consolidation over the flank of the CLIS 99 Mound, located 200 m north of CLIS 00.

The sediment profile imaging results for the active area of CLDS indicated the CLIS 00 Mound was rapidly colonized by benthic infauna, with both Stage I surface dwellers and Stage III deposit feeders found in relative abundance. The depth of oxygenation within the sediment was deeper than expected for a new disposal mound, with an average redox potential discontinuity (RPD) depth of 2.3 cm. The Organism-Sediment Index (OSI) value calculated for the CLIS 00 Mound (+6.7) was lower than the composite value for the CLDS reference areas (+8.2), but still indicative of an undisturbed benthic habitat and suggesting habitat recovery was progressing more rapidly than anticipated.

The findings for the CLIS 99 Mound were quite similar to the CLIS 00 results as both Stage I pioneering polychaetes and evidence of Stage III activity were detected in the replicate images. The average RPD depth calculated for the CLIS 99 Mound was identical to the composite value for the CLDS reference areas (3 cm) during the June 2001 survey. The median OSI values derived from the CLIS 99 sediment profile images were fairly high, ranging from +4 to +11 with an overall average value of +6.9. These results indicate the CLIS 99 Mound and surrounding seafloor is recovering from the placement of dredged sediments as anticipated.

Two historic bottom features were also subjected to environmental monitoring operations during the June 2001 survey. The CLIS 1997/1998 Mound Complex and New Haven 1993 (NHAV 93) Mound both showed improved benthic habitat conditions relative to previous surveys. Both mounds displayed evidence of a stable benthic infaunal population and deeper RPD depths, yielding higher OSI values. The conditions over the CLIS 97/98 Mound Complex exceeded those detected at the CLDS reference areas, as an average OSI value of +9.6 was calculated for the 21 stations occupied in June 2001. The average OSI value for the NHAV 93 Mound in June 2001 (+7.2) was below the composite value calculated for the CLDS reference areas (+8.5). However, the benthic habitat conditions detected over the NHAV 93 Mound in June 2001 were essentially identical to those documented in September 1999. These results indicate a continued improvement in habitat conditions relative to the 1997 survey, as demonstrated by deeper RPDs and increased abundance of Stage III organisms.

Previous monitoring efforts have revealed that the sediments comprising the surface of the NHAV 93 Mound contain high levels of organic matter, which promotes an increased sediment oxygen demand as this material decomposes over time. Numerous sediment-profile imaging surveys performed over NHAV 93 have indicated this high sediment oxygen demand has a distinct impact on benthic habitat conditions during the summer months when bottom water dissolved oxygen concentrations typically decrease. Despite the improved conditions detected over the majority of the NHAV 93 in June 2001, Station 200S continues to demonstrate benthic habitat quality lower than what would be expected for a seven-year-old dredged material deposit. Some spatial variability was identified in the three replicate photographs collected at Station 200S, but the overall trend suggests an alternative management approach (i.e., comprehensive testing, cap augmentation, etc.) is prudent.

1.0 INTRODUCTION

1.1 Background

The New England District (NAE) of the US Army Corps of Engineers regulates coastal dredging and disposal activities from Eastport, Maine to Byram, Connecticut. In 1977, the Disposal Area Monitoring System (DAMOS) was developed in response to the recognized need for the managed disposal of sediment dredged from the ports and harbors of the northeastern United States. The DAMOS Program currently monitors ten open water disposal sites along coastal New England (Figure 1-1). These sites are utilized for the cost-effective and environmentally sound disposal of sediments dredged from the harbors within the New England District.

The Central Long Island Disposal Site (CLDS) is one of four regional dredged material disposal sites located in the waters of Long Island Sound. CLDS occupies a 6.86 km^2 (2 nmi^2) area centered at 41°08.905´ N, 72°53.073´ W (NAD 83). Located approximately 10.4 km (5.6 nmi) south of South End Point, East Haven, Connecticut, CLDS has historically been one of the most active disposal sites in the New England region (Figures 1-2 and 1-3). Sediments deposited at CLDS have originated from dredging projects in New Haven, Bridgeport, Stamford, and Norwalk Harbors, as well as numerous smaller harbors in the adjacent coastal areas.

Since 1977, the management strategy at CLDS entailed the controlled placement of small to moderate volumes of sediment to form individual disposal mounds on the seafloor. These discrete disposal mounds are monitored individually to assess mound stability, material thickness, and benthic recolonization status relative to the results of previous monitoring surveys and in comparison to ambient sediments within nearby reference areas. Beginning in 1984, this management strategy was modified to include the selection of dredged material placement locations in a manner that would promote the development of rings of disposal mounds on the CLDS seafloor. The networks of mounds would form containment cells on the seafloor that would facilitate subsequent large-scale confined aquatic disposal (CAD) operations. Containment cells are useful in limiting the lateral spread of unacceptably contaminated dredged material (UDM) to facilitate efficient coverage with capping dredged material (CDM; Fredette 1994). The New Haven 1993 (NHAV 93) Mound represents the first CAD mound developed at CLDS. Currently, two additional containment cells are nearing completion on the CLDS seafloor (Figure 1-4).

An environmental monitoring survey was conducted over CLDS in June 2001, as part of the DAMOS Program. The data acquired from this field effort were used to document changes in seafloor topography within the active areas of CLDS. In addition,

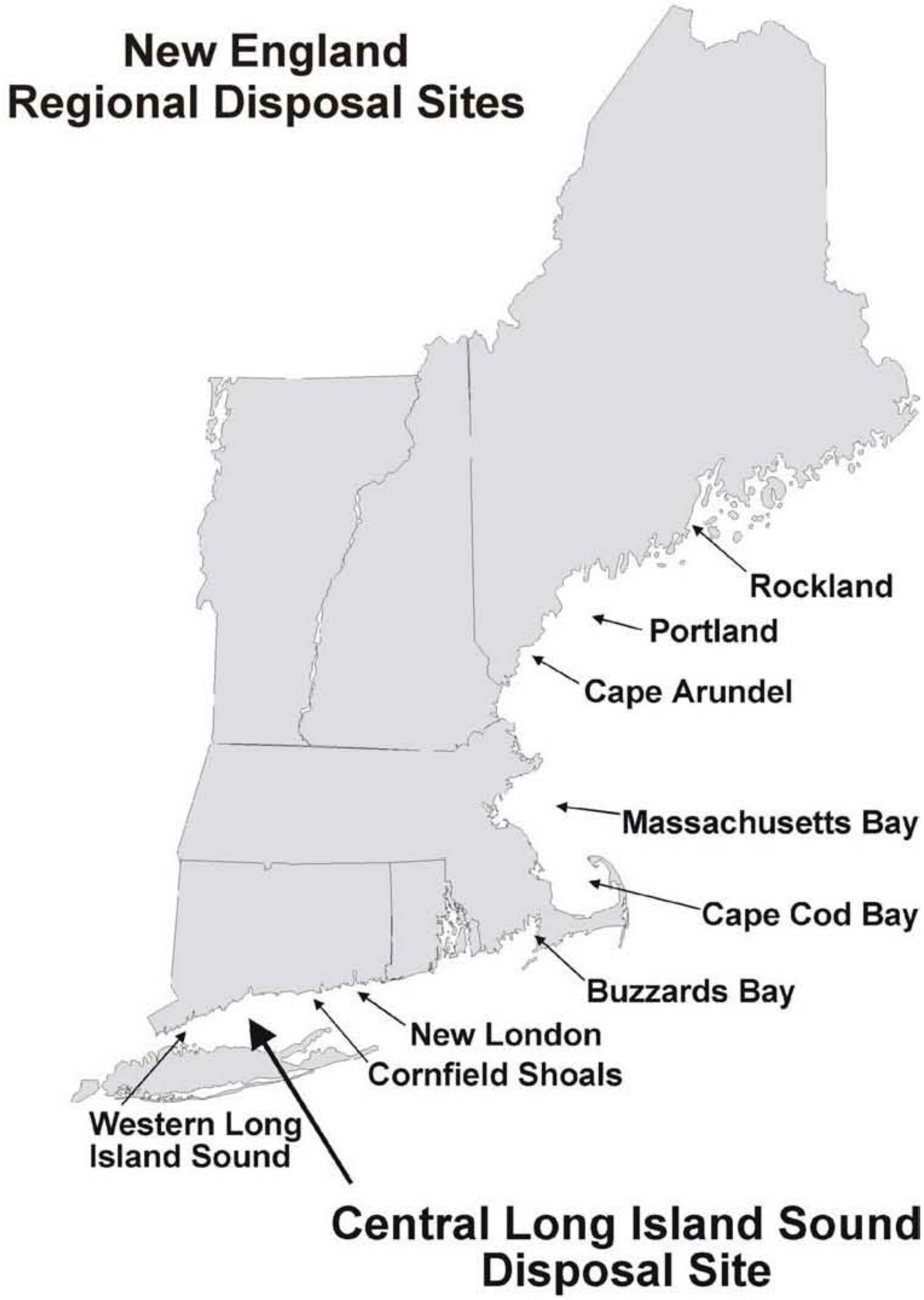


Figure 1-1. Location of the ten regional dredged material disposal sites along coastal New England regularly monitored by the DAMOS Program

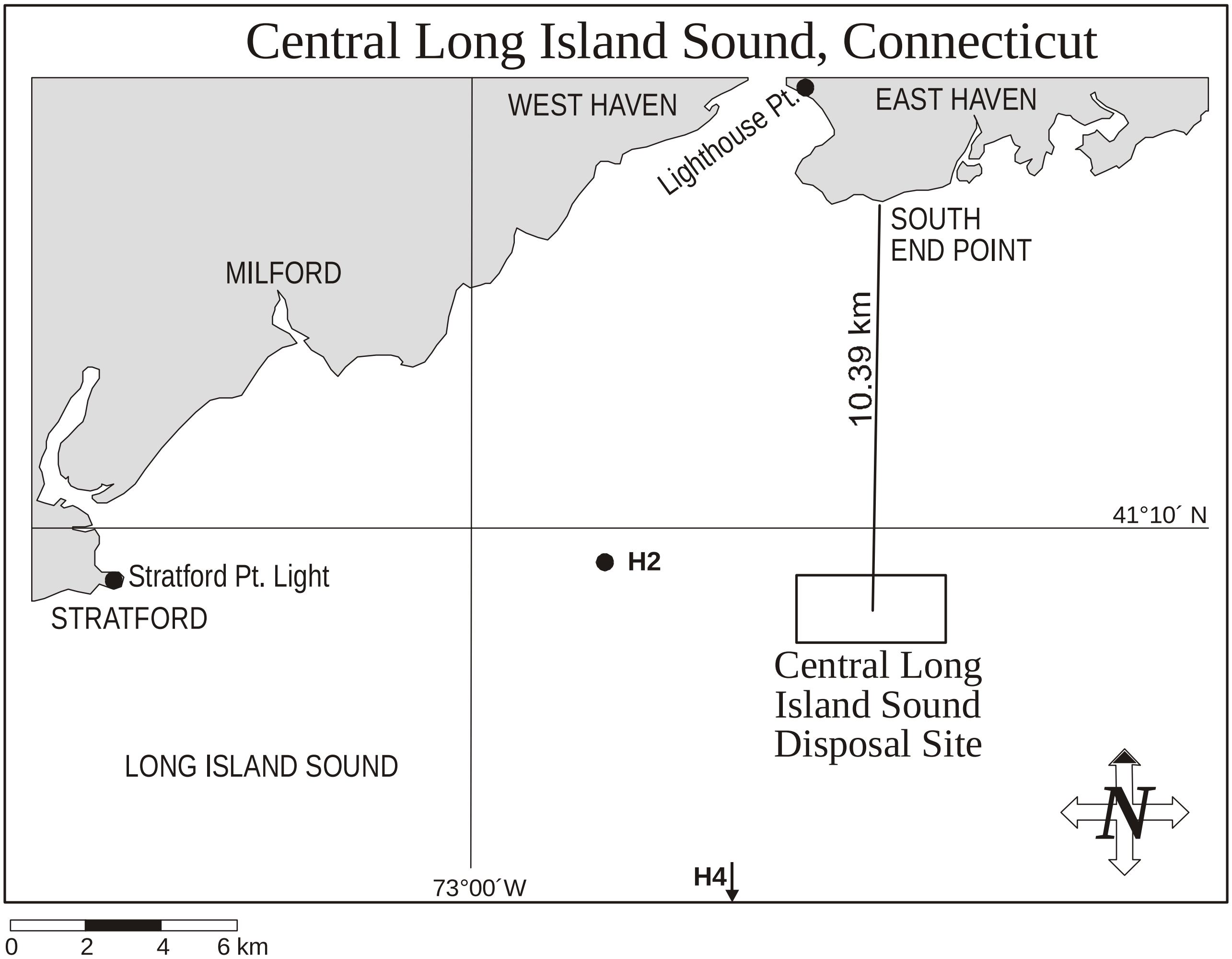


Figure 1-2. Location of the Central Long Island Sound Disposal Site relative to the Connecticut shoreline. The locations of water quality stations H2 and H4 sampled by the Connecticut Department of Environmental Protection also are shown.

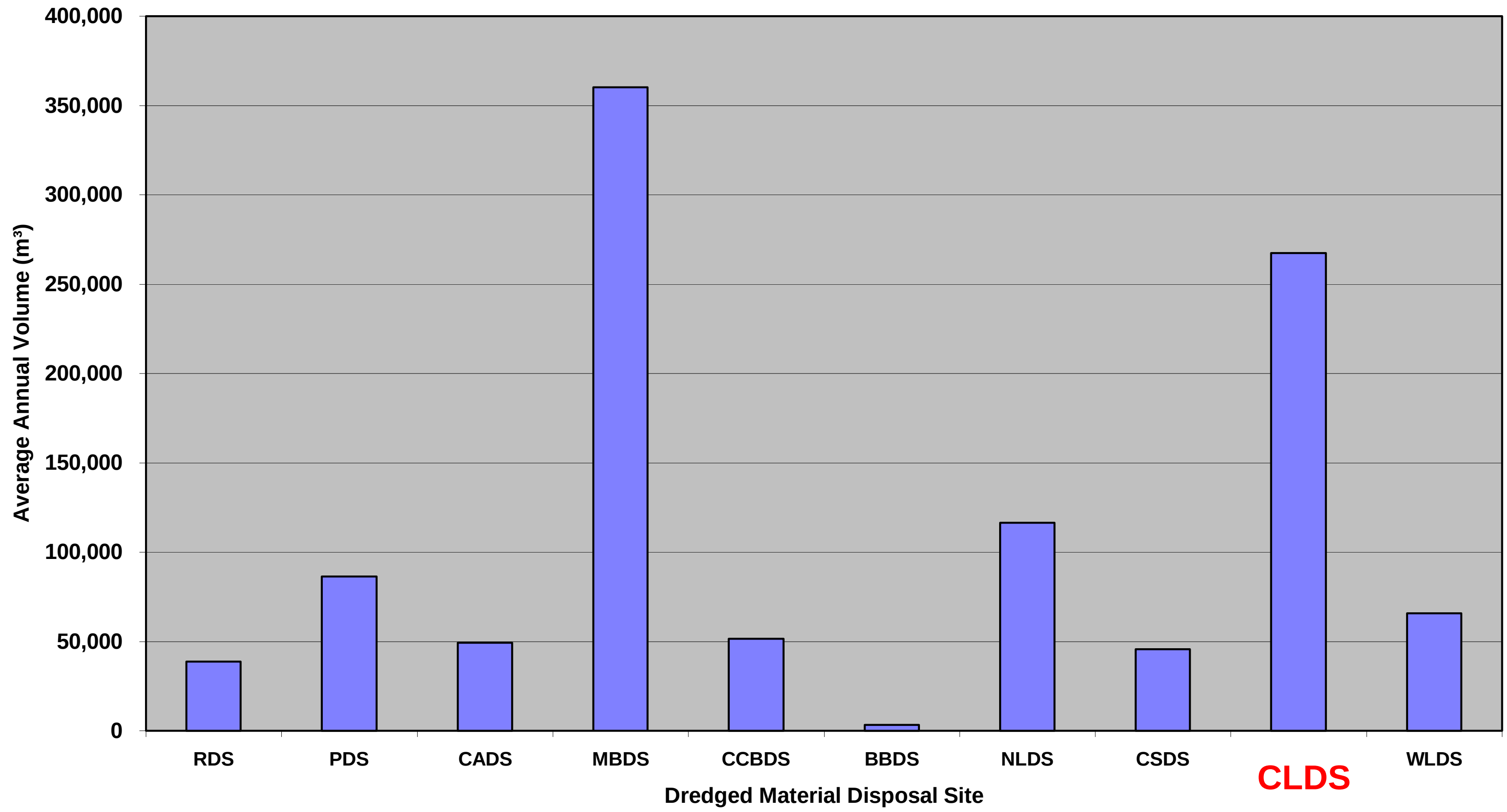


Figure 1-3. Histogram displaying the average annual dredged material disposal volumes for the ten New England disposal sites based on the period 1982 through 2001

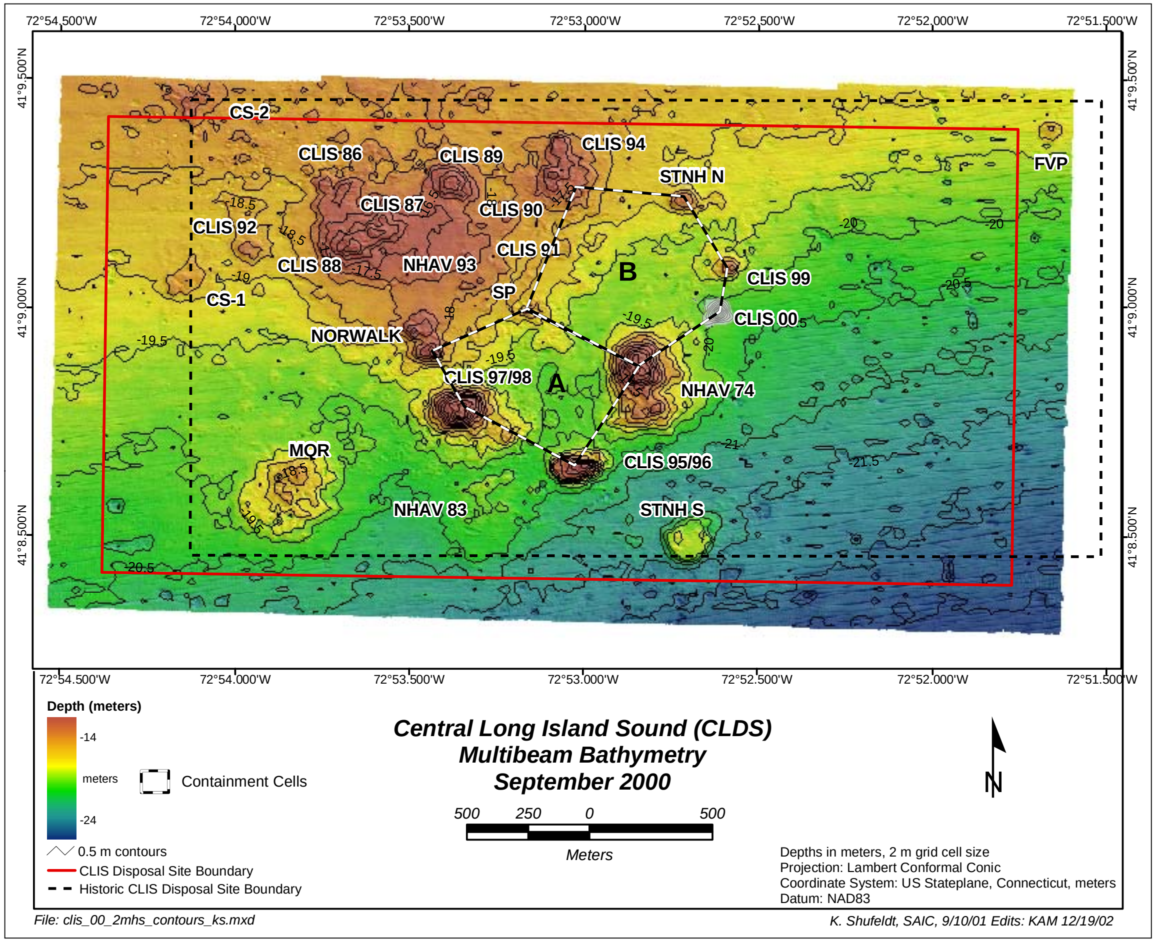


Figure 1-4. Bathymetric chart of CLDS based on the September 2000 multibeam survey, showing the current (red) and historic (dashed) disposal site boundaries and existing disposal mounds on the CLDS seafloor, 0.5 m contour interval. Two developing containment cells (A and B) are shown as black and white lines.

sediment-profile imaging was employed over several recent and historic disposal mounds to map the distribution of dredged material on the seafloor and examine trends in benthic recolonization relative to nearby reference areas. The following sections provide background details pertaining to the various disposal mounds surveyed in June 2001.

1.2 CLIS 99 and CLIS 00 Mounds

Dredged material placement activity at CLDS was reduced during the 1999–2000 and 2000–2001 disposal seasons in comparison to previous years. During the 1999–2000 disposal season, a number of small dredging projects in the region produced an estimated barge volume of 86,000 m^3 of dredged material. This material was transported to CLDS and deposited at the CDA 99 buoy, located at coordinates 41°09.090´ N, 72°52.635´ W (NAD 83), approximately halfway between the historic STNH-N and NHAV 74 disposal mounds (Figure 1-4). The resulting CLIS 99 Mound was apparent in the September 2000 multibeam survey; however, no benthic recolonization data had been acquired over this mound prior to the June 2001 monitoring survey.

During the 2000–2001 disposal season, an estimated barge volume of 71,070 m^3 of dredged material from numerous small projects was deposited at the CDA 00 buoy, which was deployed at coordinates 41°08.988´ N, 72°52.657´ W (NAD 83), approximately 175 m south of the CLIS 99 Mound (Appendix A). The development of the CLIS 99 and CLIS 00 Mounds in the central portion of CLDS has begun to form the eastern edge of another artificial containment cell (Cell B) on the seafloor (Figure 1-4). Dredged material disposal activity began in mid-October 2000 and continued sporadically until mid-May 2001. The final barge load of dredged material was placed at the CDA 00 buoy on 16 May 2001, allowing only six weeks between the last benthic disturbance and the June 2001 monitoring survey.

1.3 CLIS 97/98 Mound Complex

The CLIS 97/98 Mound Complex is an example of a moderate to large disposal mound formed over multiple disposal seasons. In September 1997, the CDA buoy was located at coordinates 41° 08.736' N, 72° 53.213' W (NAD 83), approximately 300 m northwest of the pre-existing CLIS 95/96 Mound Complex (Figure 1-5). An estimated barge volume of 57,000 m^3 of sediments from various small-scale dredging projects in the Branford, Housatonic, and West Rivers were disposed at the CDA 97 buoy to form a modest disposal mound (SAIC 2003). No bathymetric survey operations were performed at the conclusion of the 1997–98 disposal season.

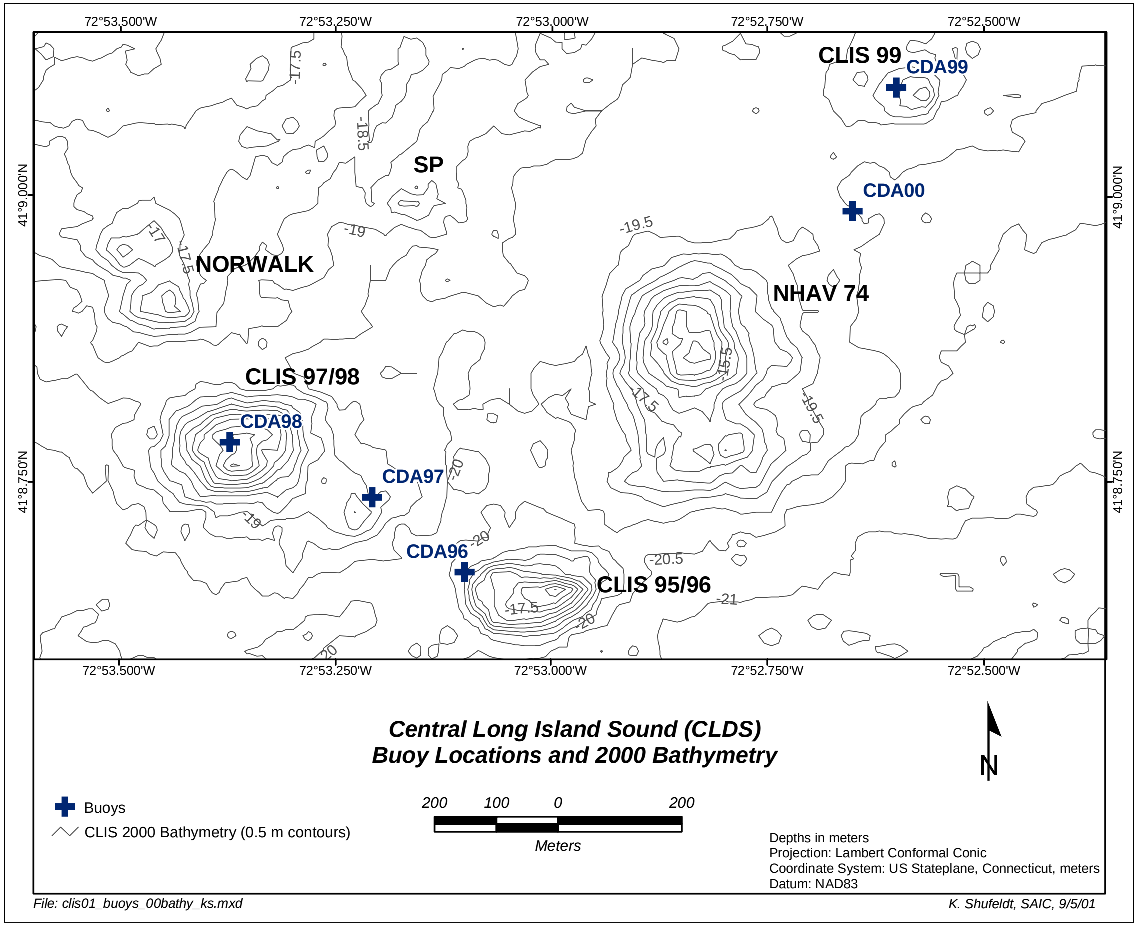


Figure 1-5. Bathymetric chart of the active area of disposal at CLDS with plotted DAMOS disposal buoy positions for the 1996–97, 1997–98, 1998–99, 1999–2000, and 2000–01 disposal seasons relative to the existing disposal mounds, September 2000 bathymetry, 0.5 m contour interval

In September 1998, the CDA buoy was deployed at coordinates 41°08.785' N, 72°53.378' W (NAD 83), 250 m northwest of the CDA 97 buoy position (Figure 1-5). Approximately 460,000 m^3 of material was removed from Mamaroneck Harbor in New York, as well as Bridgeport, New Haven, and Branford Harbors in Connecticut, transported to CLDS and deposited at the CDA 98 buoy (SAIC 2003). The relatively large volume of material deposited at the CDA 98 buoy formed a distinct disposal mound on the CLDS seafloor. The formation of the CLIS 97/98 Mound Complex completed an additional containment cell (Cell A) that can be used for a future large-scale CAD project (Figure 1-4).

1.4 NHAV 93 Mound

From 1984 to 1993, placement of small to moderate volumes of dredged material was controlled to create a ring of disposal mounds to form the first containment cell in the northwestern quadrant of CLIS. During the 1993–94 disposal season, approximately 590,000 m^3 of UDM dredged from the inner New Haven Harbor was deposited within the center of this containment cell. The UDM deposit was then capped to a thickness of 0.5 m to 1.0 m with 569,000 m^3 of CDM, yielding a CDM to UDM ratio of 0.96:1.0 (Morris and Tufts 1997). Based on subsequent monitoring surveys, the completed NHAV 93 Mound was found to be broad, stable, and adequately capped (Morris 1997, Morris 1998b).

Follow-on monitoring surveys performed near the center of the NHAV 93 Mound have shown a cyclical recovery and decline of benthic habitat conditions over the surface of the mound, roughly corresponding to the seasonal hypoxia patterns in the central Long Island sound region. In addition, these survey efforts have attributed the variations in conditions to elevated levels of labile organics, as well as the onset and severity of seasonal hypoxia. Sediment profile images collected over NHAV 93 in the past have displayed degraded benthic habitat conditions during the summer months due to the profound effects of seasonal hypoxia over the organically enriched dredged material. However, it is anticipated that the surface sediments will become less susceptible to the effects of seasonal hypoxia over time due to the gradual chemical oxidation and biological consumption of organic matter. The June 2001 survey provided another opportunity to examine the long-term recovery of NHAV 93.

1.5 CLDS Reference Areas

As part of the DAMOS monitoring protocols, reference area data are collected to provide a baseline against which the results from the dredged material mounds are compared. These areas are free of dredged material and are used to characterize the ambient conditions within the central Long Island Sound region during the period that monitoring operations are being conducted. In the past, natural (i.e., hypoxia) and/or anthropogenic (i.e., trawling activity) disturbances that have been found within the reference areas have been an important consideration in the interpretation of the monitoring data within CLDS.

1.6 Objectives and Predictions

The specific objectives of the June 2001 monitoring survey at CLDS were to

1) Map the distribution of dredged material deposited at the site during the 1999/2000 and 2000/2001 disposal seasons

2) Examine the benthic recolonization status over the recently formed CLIS 99 and CLIS 00 Mounds relative to the three CLDS reference areas

3) Continue to assess the benthic habitat recovery over specific areas of the NHAV 93 and the CLIS 97/98 Mounds relative to the three CLDS reference areas and results of previous monitoring efforts

The June 2001 field effort tested the following predictions:

- The dredged material deposited during the 2000–01 disposal season will result in the formation of a small, discrete mound on the CLDS seafloor.

- The most recently formed CLIS 00 Mound will be supporting a Stage I benthic community with limited advancement to Stage II or Stage III assemblages due to the timing of disposal operations.

- At one year post-completion, the surface of the CLIS 99 Mound is expected to support a stable Stage II or Stage III population.

- The sediments of the CLIS 97/98 Mound Complex should also be supporting a stable Stage II or Stage III community with advanced successional seres present in moderate abundance.

- Given the timing of survey operations relative to the seasonal reduction in bottom water dissolved oxygen concentrations, the NHAV 93 Mound should be supporting a mature benthic assemblage and display a relatively deep level of oxygen penetration (2 to 3 cm) into the surface sediments.

2.0 METHODS

Field operations involving precision bathymetry and sediment-profile imaging were conducted at CLDS aboard the M/V *Beavertail* from 26 to 28 June 2001. Both the sediment-profile imaging and single-beam bathymetric survey techniques used during the June 2001 survey are standard DAMOS methods and have been well documented in numerous previous reports (SAIC 2001a, SAIC 2001b, SAIC 2002a). The following will include any unique aspects of the 2001 survey operations and also list references to previous DAMOS reports that provide detailed descriptions of these techniques.

2.1 Navigation

Differentially-corrected Global Positioning System (DGPS) data in conjunction with Coastal Oceanographic's HYPACK® navigation and survey software were used to provide real-time navigation of the survey vessel to an accuracy of ±3 m. A DSMPro GPS receiver was used to obtain raw satellite data and provide vessel position information in the horizontal control of North American Datum of 1983 (NAD 83). The GPS receiver is integrated with a differential beacon receiver to improve overall accuracy of the satellite data to the necessary tolerances. The U.S. Coast Guard differential beacon broadcasting from Moriches, New York (293 kHz) was utilized for real-time satellite corrections due to its geographic position relative to CLDS.

The DGPS data were ported to HYPACK® data acquisition software for position logging and helm display. The target stations for sediment-profile imaging were determined before the start of survey operations and stored in a project database. Throughout the survey, individual stations were selected and displayed in order to position the survey vessel at the correct geographic location for sampling. The position of each replicate sample was logged with a time stamp in Universal Time Coordinated (UTC) and a text identifier to facilitate Quality Control (QC) and rapid input into a Geographic Information System (GIS) database.

2.2 Bathymetric Data Acquisition and Analysis

2.2.1 Bathymetric Data Acquisition

To fulfill the objectives of the 2001 CLDS monitoring survey, a bathymetric survey area was defined to examine both the CLIS 99 and CLIS 00 Mounds. A 1000 × 1000 m bathymetric survey centered at 41°08.988′ N, 72°52.657′ W (NAD 83) consisting of 41 lanes oriented in an east/west direction and spaced at 25 m intervals was completed (Figure 2-1). In addition, five survey lanes oriented in a north-south direction were completed to facilitate cross-check comparisons of the survey data and serve as an added quality control measure.

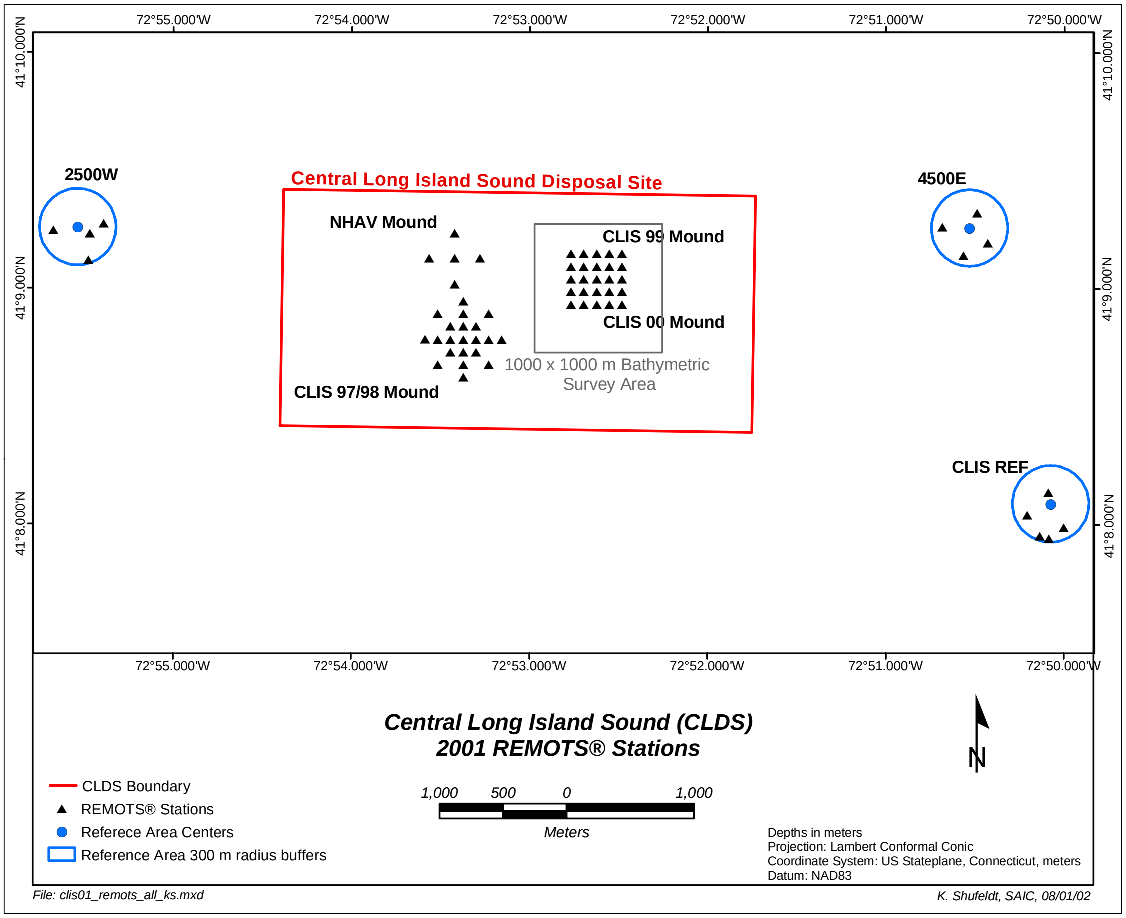


Figure 2-1. Chart of the 1.0 km² bathymetric survey area and REMOTS® sediment-profile imaging stations occupied over CLDS and the CLDS Reference Areas (2500W, 4500E, and CLISREF) during the June 2001 survey relative to the disposal site boundaries (red)

During the bathymetric survey, HYPACK® was interfaced with an Odom Hydrotrac® survey echosounder, as well as the Trimble DGPS. The Hydrotrac® uses a narrow-beam (3°), 208 kHz transducer to make discrete depth measurements and produce a continuous analog record of the seafloor. The Hydrotrac® transmits approximately 10 digital depth values per second (dependent upon water depth) to the data acquisition system. Within HYPACK®, the time-tagged position and depth data were merged to create continuous digital depth records along the actual survey track. These records could be viewed in near real-time to ensure adequate coverage of the survey area.

2.2.2 Bathymetric Data Processing

The bathymetric data were fully edited and processed using the HYPACK® data processing modules. Raw position and sounding data were edited as necessary to remove or correct questionable data. Sound velocity and transducer draft corrections were applied to the raw data before the records were reduced to the vertical datum of Mean Lower Low Water (MLLW) using observed tides obtained from the National Oceanic and Atmospheric Administration (NOAA).

During bathymetric survey data acquisition, an assumed and constant water column sound velocity was entered into the Odom echosounder. In order to account for the variable speed of sound through the water column, a Seabird Instruments, Inc. SEACAT SBE 19-01 conductivity, temperature, and depth (CTD) probe was used to obtain sound velocity profiles at the start and end of each field survey day. An average sound velocity was calculated for each day from the water column profile data, and then entered into a HYPACK® sound velocity correction table. Using the assumed sound velocity entered into the echosounder and the computed sound velocity from the CTD casts, HYPACK® then computed and applied the required sound velocity corrections to all of the sounding records.

Observed tide data were obtained through NOAA's National Water Level Observation Network. The NOAA six-minute tide data were downloaded in the MLLW datum and corrected for tidal offsets. SAIC used the water level data available from the operating NOAA tide station in Bridgeport, CT and applied the published time and height corrections for New Haven Harbor Entrance.

After the bathymetric data were fully edited and reduced to MLLW, cross-check comparisons on overlapping data were performed to verify the proper application of the correctors and to evaluate the consistency of the data set. After the full data set was verified, it was then run through the HYPACK® Mapper routine to systematically reduce its size. Because of the rapid rate at which a survey echosounder can generate data (approximately ten depths per second), the along-track data density for a single-beam survey tends to be very high (multiple soundings per meter). In most cases, these data sets contain many redundant data points that can be eliminated without any effect on overall data quality. The Mapper routine examines the data along each survey line and then extracts only the representative soundings based on a user-specified distance interval and selection criteria. The output from the Mapper routine is a merged ASCII-xyz (position and corrected depth) file that may contain anywhere from 2 to 10% of the original data set. These greatly reduced, but still representative, data sets are far more efficient to use in the subsequent modeling and analysis routines. For the 2001 CLDS survey, the data were mapped at intervals of 5 and 10 m for later analysis.

2.2.3 Bathymetric Data Analysis

The primary intent of this analysis was to evaluate the seafloor surface defined by the bathymetric data to identify topographic features and account for any observed differences with prior surveys. Because single-beam bathymetric survey data typically covers only a small percentage of the total seafloor area (approximately 5%), these analysis tools rely on a large degree of interpolation between the discrete survey data points to generate a three-dimensional seafloor surface model. This interpolation usually works well in flat or gently-sloping areas, but in steep and irregular areas the interpolation of the surface can be very dependent upon the orientation of the survey lines and the density of the data around the area.

The 2001 CLDS bathymetric survey data was converted into a surface model via the ArcInfo® Grid module, which generates a gridded data model for the entire survey area based on the full data set and a user-defined grid cell size. A 25 m × 25 m (625 m^2) grid cell size was employed to develop a surface model of the CLDS seafloor from the June 2001 single-beam bathymetry data. The surface model was then imported into ArcView® for additional analysis and review and to generate graphic products incorporating some of the other survey data sets. This model was also used for generating the depth difference comparisons with the prior multibeam survey data set.

2.3 REMOTS® Sediment-Profile Imaging Survey

Remote Ecological Monitoring of the Seafloor (REMOTS®) is a benthic sampling technique used to detect and map the distribution of thin (<20 cm) dredged material layers, map benthic disturbance gradients, and monitor the process of benthic recolonization at dredged material disposal mounds. This is a reconnaissance survey technique used for rapid collection, interpretation and mapping of data on physical and biological seafloor characteristics. The DAMOS Program has used this technique for routine disposal site monitoring for over 20 years. The REMOTS® hardware consists of a Benthos Model 3731 Sediment-Profile Camera designed to obtain undisturbed, vertical cross-section images (*in situ* profiles) of the upper 15 to 20 cm of the seafloor (Figure 2-2).

Computer-aided analysis of each REMOTS® image yields a suite of standard measured parameters, including sediment grain size major mode, camera prism penetration depth (an indirect measure of sediment bearing capacity/density), small-scale surface boundary roughness, depth of the apparent redox potential discontinuity (RPD, a measure of sediment aeration), infaunal successional stage, and Organism-Sediment Index (OSI, a summary parameter reflecting overall benthic habitat quality). OSI values are calculated based on the apparent RPD depth, successional status, and any indicators of sediment methane or low sediment oxygen. OSI values may range from –10 (azoic with low sediment dissolved oxygen and/or the presence of methane gas in the sediment) to +11 (healthy, aerobic environment with deep RPD depths and advanced successional stages). Standard REMOTS® image acquisition and analysis methods are described fully in Rhoads and Germano (1982; 1986) and in the recent DAMOS Contribution No. 128 (SAIC 2001b).

The 2001 REMOTS® survey at CLDS was used to characterize sediment composition, benthic recolonization status, and overall benthic habitat quality over several disposal mounds (CLIS 00, CLIS 99, CLIS 97/98, and NHAV 93). Three reference areas surrounding CLDS (CLISREF, 4500E, 2500W) were also sampled to provide adequate comparison of habitat quality over the disposal mounds relative to conditions within the ambient environment (Figure 2-1). Where feasible, the 2001 REMOTS® sampling stations were established to correspond with stations sampled during the 1999 survey. To meet the objectives of the 2001 survey, a total of 64 stations were sampled with REMOTS® imaging, with three replicate photographs collected over each station for analysis and comparison with previous data sets.

The REMOTS® survey at the CLIS 00 and CLIS 99 Mounds consisted of a 25-station rectangular grid centered at 41°09.041´ N, 72°52.630´ W (NAD 83). The sampling grid consisted of five north-south transects (A–E) with five stations (1–5) distributed at 100 m intervals along each transect (Figure 2-3; Table 2-1). The northernmost ten stations in the grid were used to characterize the CLIS 99 Mound, with Station D2 located approximately at the mound center. The remaining 15 stations characterized the recently developed CLIS 00 Mound, with Station C4 sampling the approximate center of this mound (Figure 2-3; Table 2-1).

The REMOTS® survey over the CLIS 97/98 Mound consisted of 21-station grid in a star-shaped pattern, centered on Station 61 (Figure 2-3; Table 2-1). Stations previously

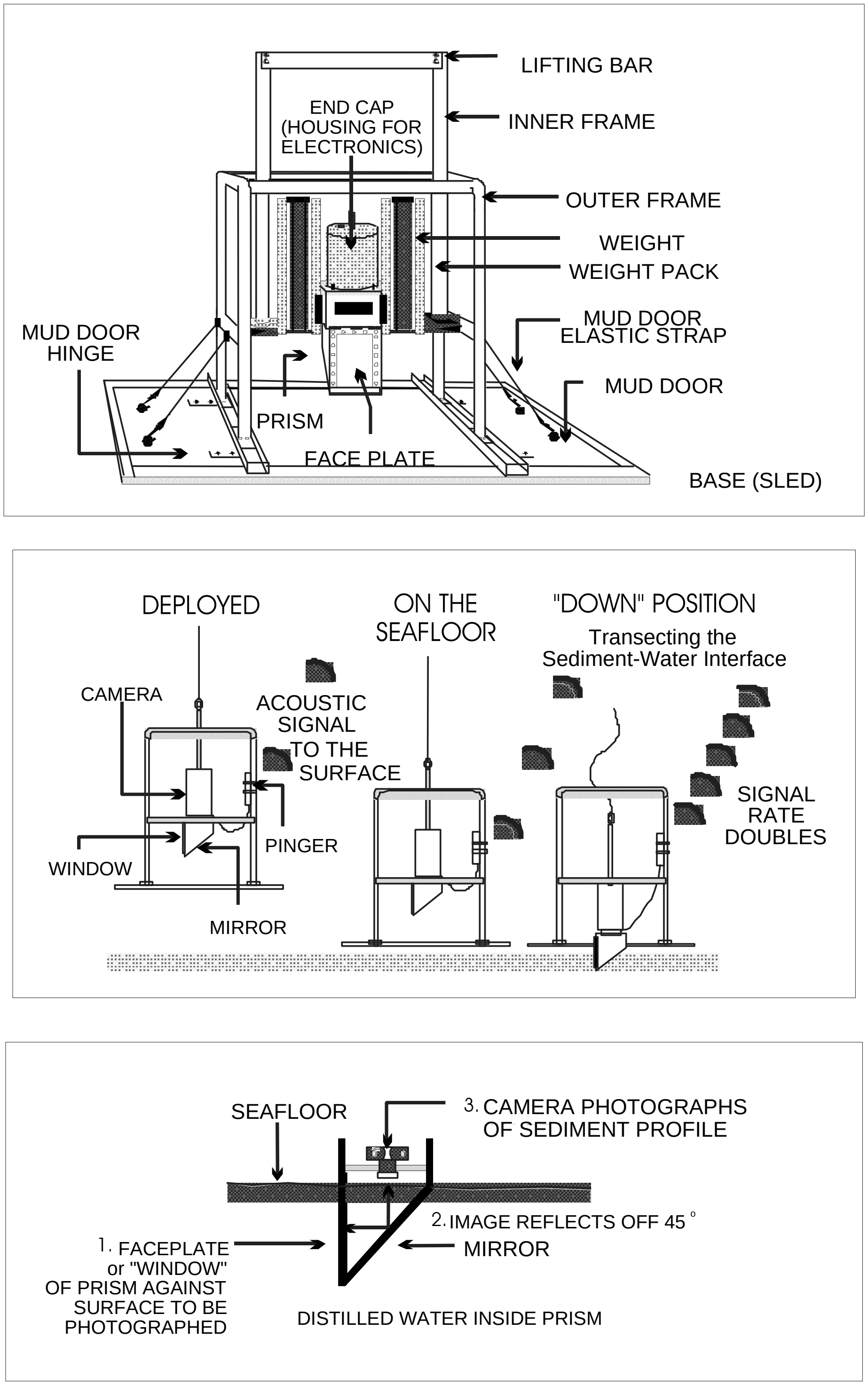


Figure 2-2. Schematic diagram of the Benthos Inc. Model 3731 REMOTS® sediment-profile camera and sequence of operation on deployment

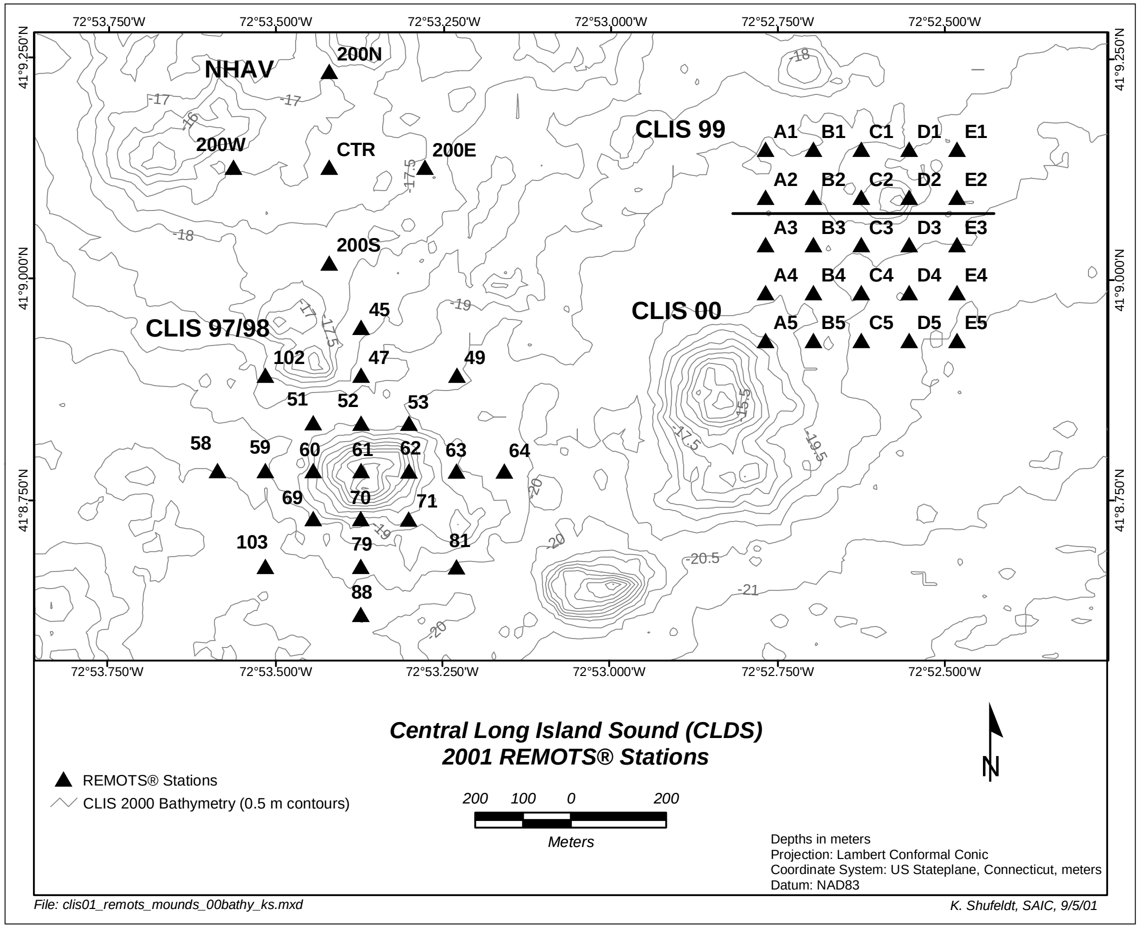


Figure 2-3. Distribution of the 2001 REMOTS® sediment-profile imaging stations over the CLIS 99, CLIS 00, and NHAV 93 Mounds, as well as the CLIS 97/98 Mound Complex

Table 2-1.

REMOTS® Station Locations over the CLDS Disposal Mounds

Area	Station Number	Latitude	Longitude
		NAD 83	
	A1	41° 09.149 N	72° 52.773´ W
	A2	41° 09.095 N	72° 52.773´ W
	B1	41° 09.149 N	72° 52.702´ W
CLIS 99	B2	41° 09.095 N	72° 52.702´ W
Mound	C1	41° 09.149 N	72° 52.630´ W
41° 09.096´ N	C2	41° 09.095 N	72° 52.630´ W
72° 52.591´ W	D1	41° 09.149 N	72° 52.559´ W
	D2	41° 09.095 N	72° 52.559´ W
	E1	41° 09.149 N	72° 52.487´ W
	E2	41° 09.095 N	72° 52.487´ W
	A3	41° 09.041 N	72° 52.773´ W
	A4	41° 08.987 N	72° 52.773´ W
	A5	41° 08.933 N	72° 52.773´ W
	B3	41° 09.041 N	72° 52.702´ W
	B4	41° 08.987 N	72° 52.702´ W
CLIS 00	B5	41° 08.933 N	72° 52.701´ W
Mound	C3	41° 09.041 N	72° 52.630´ W
41° 08.988´ N	C4	41° 08.987 N	72° 52.630´ W
72° 52.657´ W	C5	41° 08.933 N	72° 52.630´ W
	D3	41° 09.041 N	72° 52.559´ W
	D4	41° 08.987 N	72° 52.558´ W
	D5	41° 08.933 N	72° 52.558´ W
	E3	41° 09.041 N	72° 52.487´ W
	E4	41° 08.987 N	72° 52.487´ W
	E5	41° 08.933 N	72° 52.487´ W
	45	41° 08.947 N	72° 53.378´ W
	47	41° 08.893 N	72° 53.378´ W
	49	41° 08.893 N	72° 53.235´ W
	51	41° 08.839 N	72° 53.449´ W
	52	41° 08.839 N	72° 53.378´ W
	53	41° 08.839 N	72° 53.306´ W
CLIS 97/98	58	41° 08.785 N	72° 53.592´ W
Mound	59	41° 08.785 N	72° 53.520´ W
Complex	60	41° 08.785 N	72° 53.449´ W
41° 08.782´ N	61	41° 08.785 N	72° 53.378´ W
72° 53.362´ W	62	41° 08.785 N	72° 53.306´ W
	63	41° 08.785 N	72° 53.235´ W
	64	41° 08.785 N	72° 53.163´ W
	69	41° 08.731 N	72° 53.449´ W
	70	41° 08.731 N	72° 53.378´ W
	71	41° 08.731 N	72° 53.306´ W
	79	41° 08.677 N	72° 53.378´ W
	81	41° 08.677 N	72° 53.235´ W
	88	41° 08.623 N	72° 53.378´ W
	102	41° 08.893 N	72° 53.520´ W
	103	41° 08.677 N	72° 53.520´ W
NHAV 93	CTR	41° 09.128 N	72° 53.426´ W
Mound	200N	41° 09.236 N	72° 53.426´ W
41° 09.128´ N	200S	41° 09.020 N	72° 53.426´ W
72° 53.426´ W	200E	41° 09.128 N	72° 53.283´ W
	200W	41° 09.128 N	72° 53.569´ W

occupied during the September 1999 survey were sampled to facilitate comparisons between data sets. Three stations spaced at 100 m intervals extended from the center towards the north, south, east and west. Additional stations from the 1999 survey grid were selected as transects to the northwest, southeast, northeast and southwest, consisting of two stations each, at 140 m spacing. The outermost stations to the northwest (102) and southwest (103) were not part of the 1999 survey grid, but were added to complete the northwest and southwest transects (Figure 2-3).

The REMOTS® survey performed over the NHAV 93 Mound consisted of five stations with station spacing at 200 m over a cross-shaped grid (Figure 2-3; Table 2-1). This same sampling grid has been occupied to monitor benthic community recovery over the surface of the NHAV 93 Mound since July 1994.

A total of 13 stations were established within the CLDS reference areas to provide a basis of comparison between ambient Long Island Sound sediments and the disposal mounds within CLDS. Each station was randomly selected within a 300 m radius of the respective reference area centers. Four stations were distributed within 2500W (41°09.260´ N, 72°55.542´ W) and 4500E (41°09.260´ N, 72°50.538´ W), while five stations were established over the reference area CLISREF (41°08.091´ N, 72°50.082´ W; Figure 2-1 and Table 2-2).

Table 2-2.

REMOTS® Locations over the CLDS Reference Areas

Area	Station Number	Latitude	Longitude
		NAD 83	
2500W	2500W 1	41° 09.248´ N	72° 55.679´ W
41° 09.260´ N	2500W 2	41° 09.119´ N	72° 55.481´ W
72° 55.542´ W	2500W 3	41° 09.275´ N	72° 55.394´ W
	2500W 4	41° 09.233´ N	72° 55.474´ W
4500E	4500E 1	41° 09.322´ N	72° 50.494´ W
41° 09.260´ N	4500E 2	41° 09.262´ N	72° 50.690´ W
72° 50.538´ W	4500E 3	41° 09.143´ N	72° 50.570´ W
	4500E 4	41° 09.196´ N	72° 50.434´ W
	CLISREF 1	41° 08.138´ N	72° 50.095´ W
CLISREF	CLISREF 2	41° 08.043´ N	72° 50.213´ W
41° 08.091´ N	CLISREF 3	41° 07.943´ N	72° 50.093´ W
72° 50.082´ W	CLISREF 4	41° 07.991´ N	72° 50.007´ W
	CLISREF 5	41° 07.953´ N	72° 50.141´ W

3.0 RESULTS

3.1 Bathymetry

The June 2001 single-beam bathymetric survey covered a 1.0 km² area of the CLDS seafloor, which has been subjected to dredged material placement operations over the past two disposal seasons. The 1000 × 1000 m survey area encompassed the recent CLIS 99 and the CLIS 00 Mounds, as well as the historic NHAV 74 and STNH-N Mounds. Water depths for the June 2001 survey ranged from a minimum of 14.6 m over the NHAV 74 Mound to a maximum of 21.2 m in the southeast corner of the survey area (Figure 3-1). Two small bottom features corresponding to the CDA 99 and CDA 00 buoy positions were detected on the CLDS seafloor.

To facilitate depth difference calculations, a 1000 × 1000 m analysis area was identified in the September 2000 multibeam bathymetric data set that corresponded to the limits of the June 2001 survey (Figure 3-2). Depth difference comparisons based on the September 2000 bathymetric survey showed an accumulation of sediment 3 m high corresponding to the CDA 00 buoy position (Figure 3-3). The conical shaped CLIS 00 Mound displayed an acoustically detectable (0.25 m) dredged material footprint approximately 200 m in diameter. The depth difference figure also shows some small-scale and consistent difference values (blue) that are associated with minor consolidation over the flanks of the CLIS 99 Mound.

In addition, a variety of small-scale survey artifacts are also visible over the slopes of the NHAV 74 Mound, as well as along the northern and western margins of the 1.0 km² analysis area. These artifacts are the result of reprocessing of the September 2000 multibeam data set to facilitate comparison with the 2001 single-beam data. This process requires a significant amount of averaging to reduce the 1 m² coverage and produce a surface model identical to the configuration of the June 2001 single-beam model.

3.2 REMOTS® Sediment-Profile Imaging

3.2.1 CLIS 00 Mound

At the time of the June 2001 survey, the CLIS 00 Mound was the newest bottom feature on the CLDS seafloor. Fifteen of the 25 stations occupied within the rectangular survey grid were used to characterize the conditions over CLIS 00 (Figure 2-3). Although the survey grid was divided between CLIS 00 and CLIS 99, the aprons of the disposal mounds were likely overlapping and there was little overall difference in the REMOTS® results between the two mounds. Table 3-1 provides a summary of results for the data

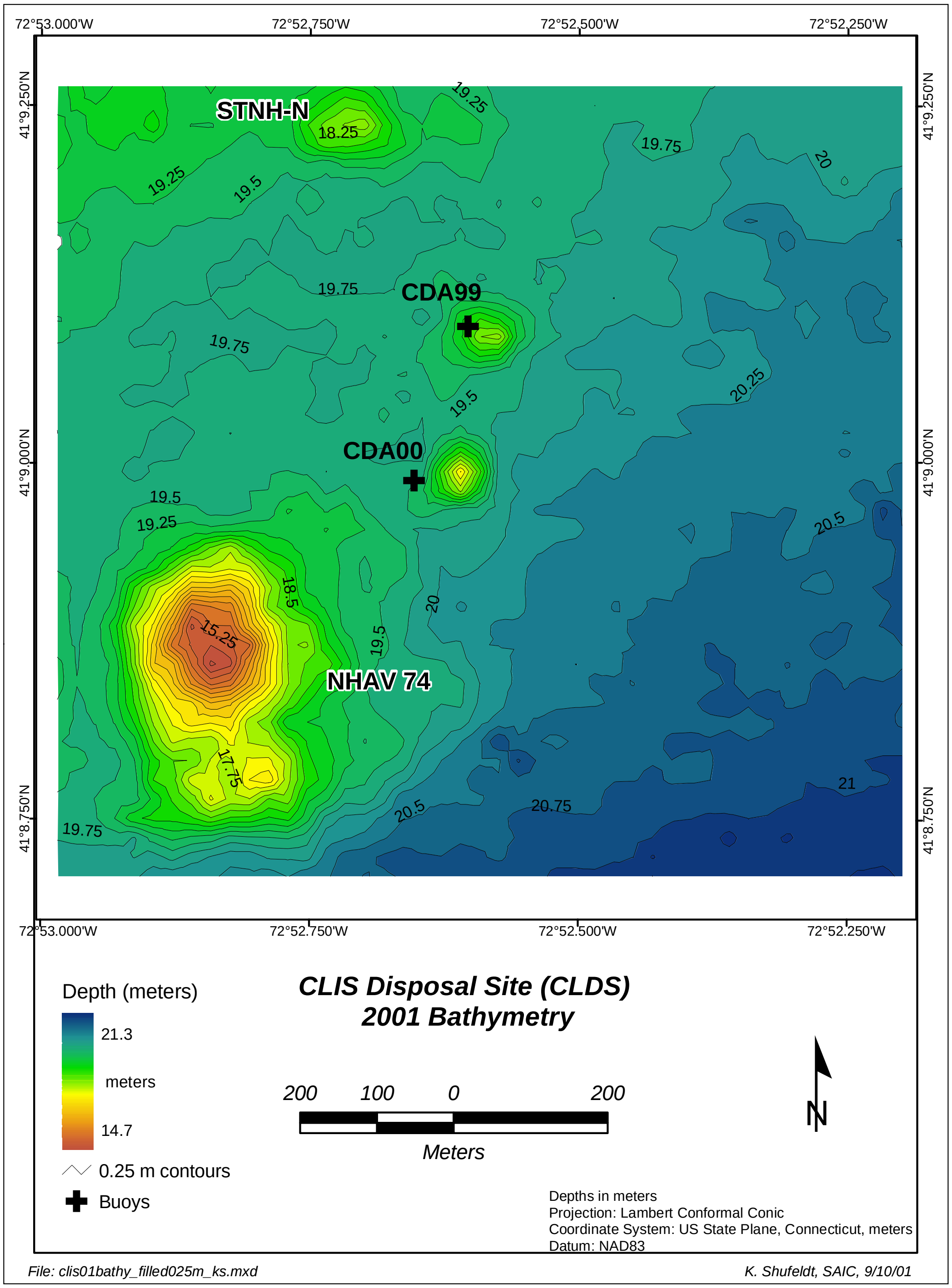


Figure 3-1. Bathymetric chart of the June 2001 survey over the active area of dredged material disposal at CLDS, 0.25 m contour interval

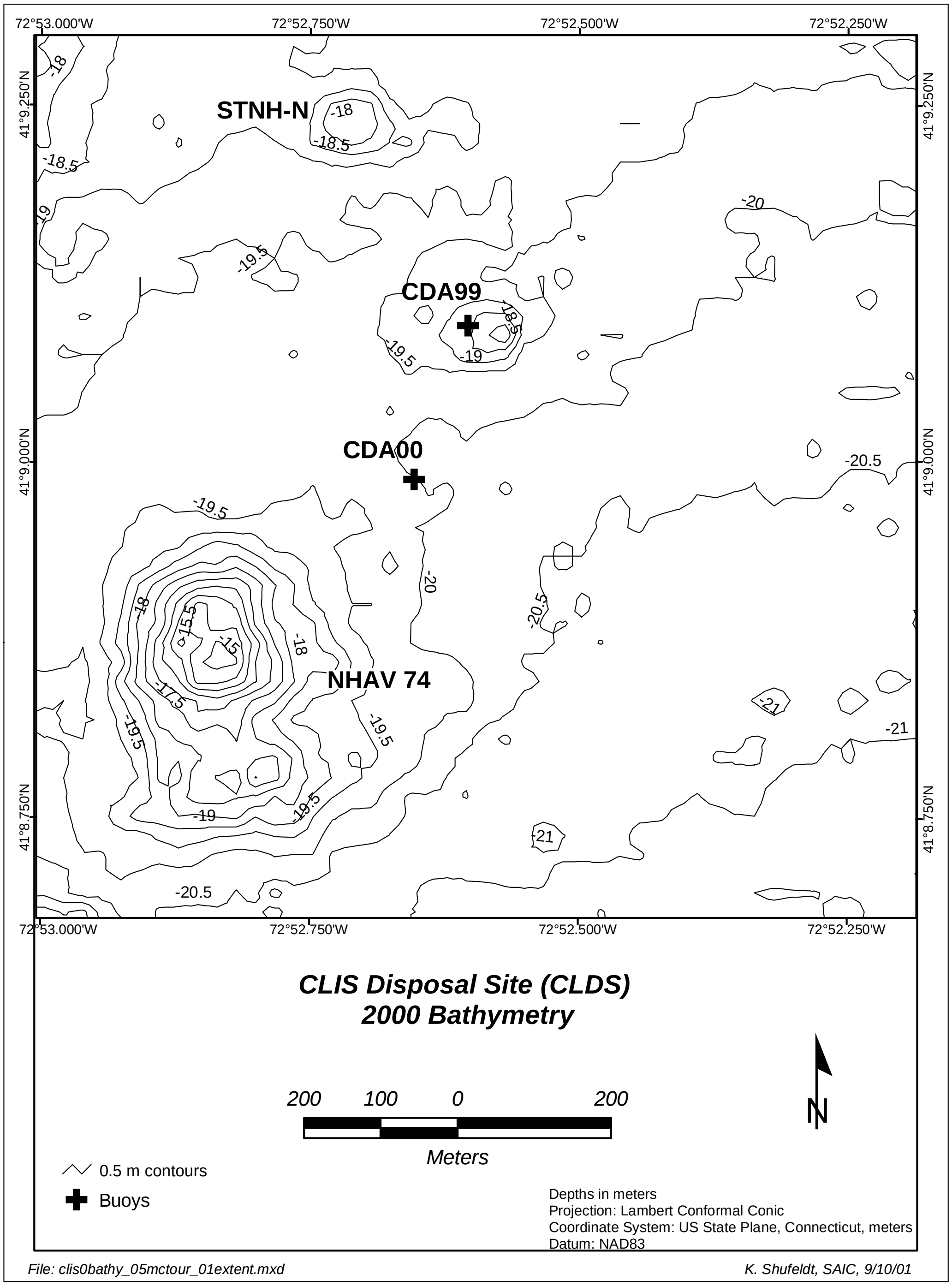


Figure 3-2. Bathymetric chart of the 1000 × 1000 m analysis area established for the September 2000 multibeam bathymetric survey performed over CLDS

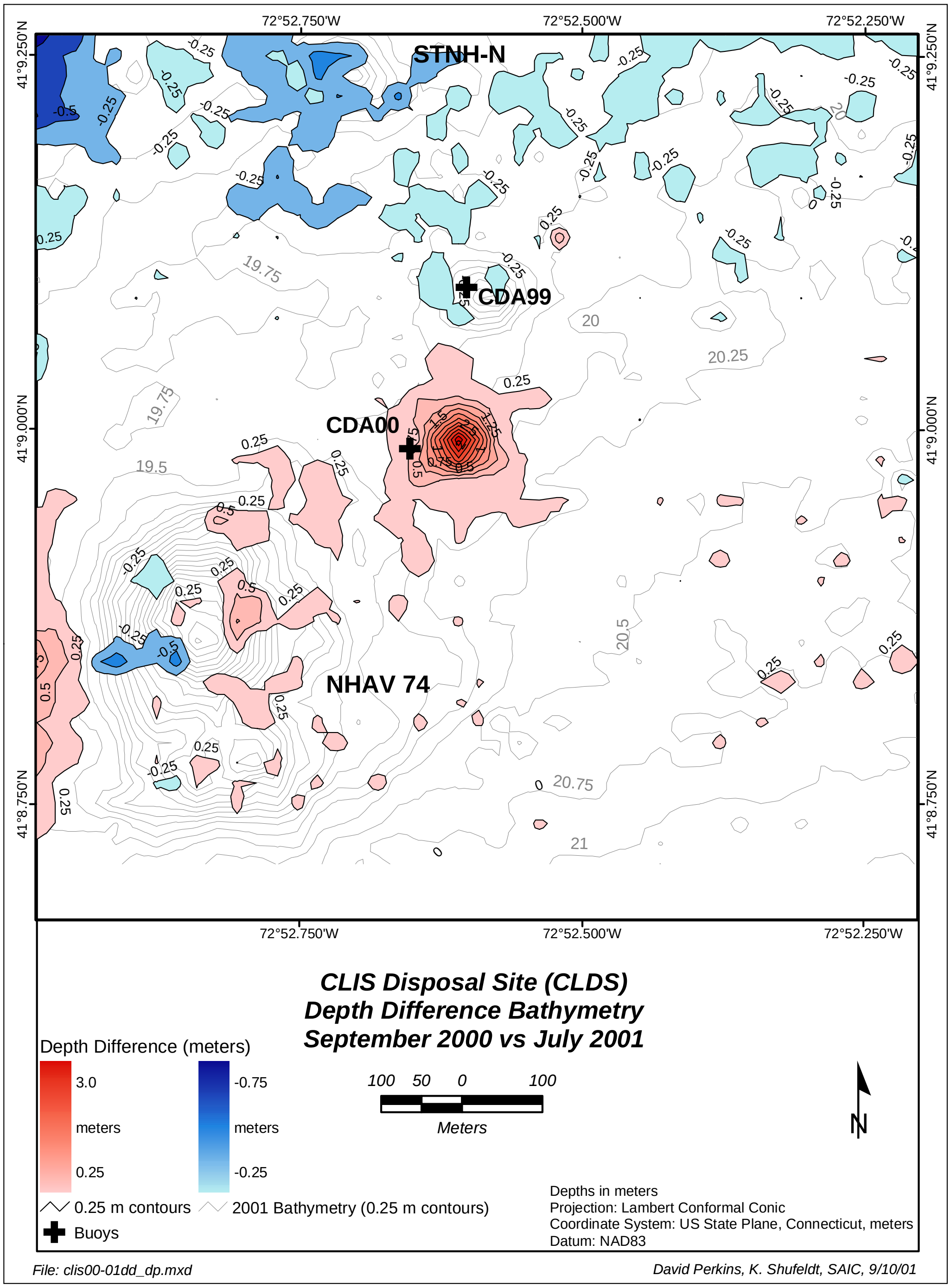


Figure 3-3. Depth difference plot showing apparent accumulation (red) and consolidation (blue) of sediment in the 1000 × 1000 m analysis area within CLDS

Table 3-1.

REMOTS® Sediment-Profile Imaging Results Summary for the CLIS 00 Mound, June 2001

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Surface DM Layer (cm)	Number of Reps with Dredged Material	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
A3	18.50	>18.50	6.61	3	1.83	I,III	ST_I_ON_III	>4	NO	7.67	8	0.23
A4	11.94	>11.94	0	3	3.36	I,III	ST_I_ON_III	>4	NO	7.00	7	1.45
A5	15.13	>15.13	6.41	3	2.05	I,III	ST_I_ON_III	>4	NO	8.33	8	0.96
B3	14.87	>14.87	9.8	3	2.76	I,III	ST_I_ON_III	>4	NO	7.67	9	1.02
B4	13.29	>13.29	3.8	3	2.83	I,III	ST_I_ON_III	>4	NO	9.33	9	1.12
B5	15.91	>15.91	6.78	3	2.54	I,III	ST_I_ON_III	>4	NO	7.33	8	0.74
C3	13.21	>13.21	2.02	3	2.09	I,III	ST_I_ON_III	>4	NO	6.00	5	0.97
C4	16.60	>16.60	6.83	3	2.90	I,III	ST_I_ON_III	>4	NO	8.00	8	0.73
C5	13.08	>13.08	7.58	3	3.27	I,III	ST_I_ON_III	>4	NO	8.67	10	0.89
D3	19.18	>19.18	0	3	2.59	I,III	ST_III	>4	NO	6.33	5	0.84
D4	13.69	>13.69	3.33	3	2.40	I,III	ST_I_ON_III	>4	NO	6.00	4	0.74
D5	13.84	>13.84	0	3	1.34	I,III	ST_I_ON_III	>4	NO	7.00	7	0.59
E3	17.12	>17.12	6.78	3	1.08	I,III	ST_I_ON_III	>4	NO	4.00	2	0.53
E4	17.15	>17.15	4.05	3	2.43	I,III	ST_I_ON_III	>4	NO	6.00	5	0.90
E5	15.19	>15.19	0	3	1.32	I,III	ST_I_ON_III	>4	NO	6.00	6	1.20
AVG	15.25	>15.25	4.27	3	2.32					7.02	6.73	0.86
MAX	19.18	>18.50	9.80	3	3.36					9.33	10	1.45
MIN	11.94	11.94	0.00	3	1.08					4.00	2	0.23

collected over the CLIS 00 Mound. A complete set of REMOTS® image analysis results is presented in Appendix B1.

3.2.1.1 Dredged Material Distribution and Physical Sediment Characteristics

The sediment-profile images acquired over the CLIS 00 portion of the survey grid indicated that the thickness of the dredged material layer was greater than the camera penetration (i.e., imaging) depth at every station (Figure 3-4). Replicate-averaged camera penetration depths over the CLIS 00 portion of the survey grid ranged from 11.9 cm at Station A4 to 19.2 cm at Station D3. Boundary roughness values were relatively low over the entire disposal mound, ranging from 0.2 to 1.5 cm and averaging 0.9 cm. Surface roughness was mostly attributed to physical disturbance associated with recent dredged material deposition.

Many stations showed distinct layering of fresh dredged material, characterized by fine-grained, low-reflectance sediment, over older dredged material layers (Figure 3-5). When distinct stratification between fresh dredged material and the underlying sediment was present, the layer of fresh dredged material was measured and recorded (Table 3-1, Figure 3-4). Similar to the CLDS reference areas, the REMOTS® images indicated the sediment composing the surface of the CLIS 00 Mound was predominantly fine-grained material, with a major modal grain size of >4 phi (silt/clay; Tables 3-1 and 3-2). Varying amounts of fine and very fine sand were noted in the replicate images collected over CLIS 00. Station C4, at the approximate mound center, showed variability in the composition of sediment placed at the CDA 00 buoy, likely due to the many small projects that deposited material during the 2000–2001 disposal season (Figure 3-6). This variability was also noted at Stations C3 and D4, and was the basis for the measurement of distinct dredged material layers over the central portion of the CLIS 00 Mound.

3.2.1.2 Biological Conditions and Benthic Recolonization

Three parameters were used to assess the benthic recolonization rate and overall habitat conditions of the CLIS 00 Mound, relative to the reference areas. The apparent RPD depth, OSI, and infaunal successional status were mapped on station location plots to outline the biological conditions at each station.

The RPD depth is measured on each image to estimate the apparent penetration of oxygen into the sediment. The RPD value is an indicator of near bottom dissolved oxygen conditions, as well as the incorporation of molecular oxygen (O_2) into the surface sediments. A well-developed RPD depth (defined as greater than 2 to 3 cm) generally indicates good or healthy sediment aeration as a result of active bioturbation by benthic organisms. Replicate-averaged RPD depths over the CLIS 00 Mound ranged from 1.1 cm at Station E3 to 3.4 cm at Station A4 (Figure 3-7; Table 3-1). The overall average RPD

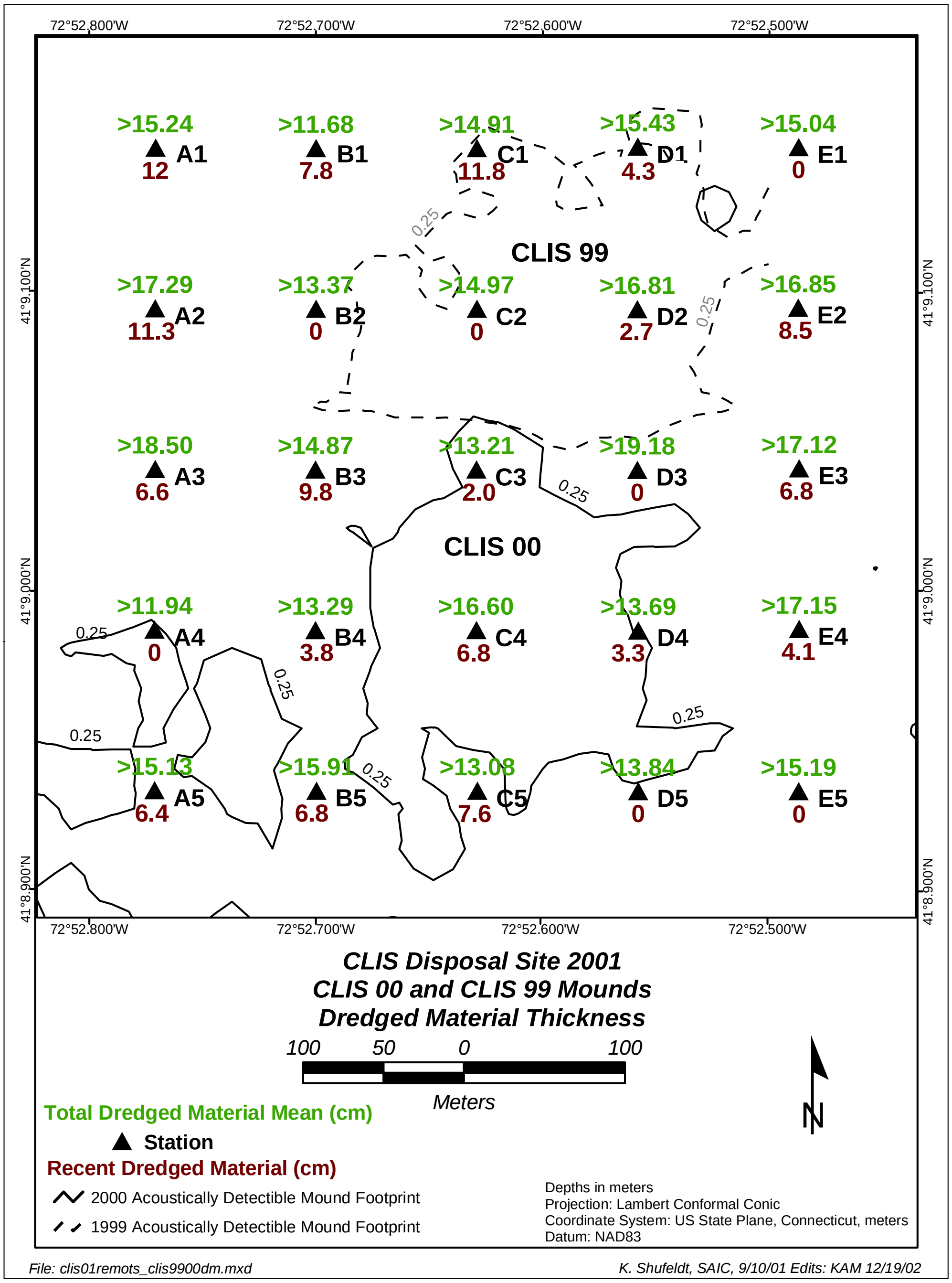


Figure 3-4. Map of replicate averaged total dredged material thickness (green) over the survey area relative to the acoustically detectable footprints of the CLIS 99 (dashed line) and CLIS 00 (solid line) Mounds. The apparent thickness of any recently deposited (<2 years) dredged material detected over historic layers is also provided (brown).

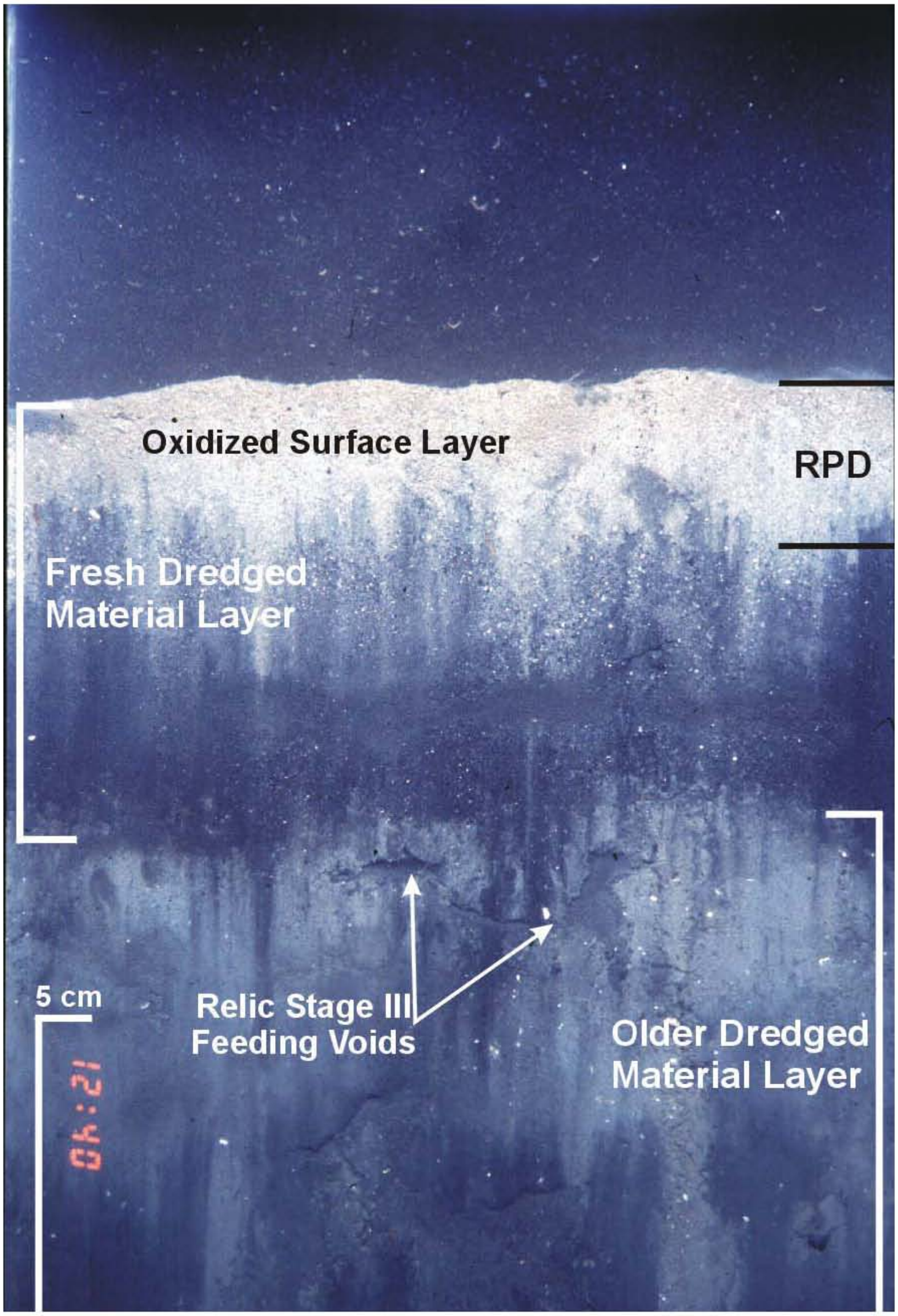


Figure 3-5. REMOTS® image collected from Station B5 over the CLIS 00 Mound displaying a layer of fresh dredged material over older dredged material

Table 3-2.

REMOTS® Sediment-Profile Imaging Results Summary from the CLDS Reference Areas, June 2001

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number of Reps with Dredged Material	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
2500W 1	17.85	0	0	3.74	I,III	ST_I_ON_III	>4	NO	10.33	10	1.09
2500W 2	18.29	0	0	3.19	I,III	ST_I_ON_III	>4	NO	8.33	10	0.83
2500W 3	18.21	0	0	3.91	I	ST_I_ON_III	>4	NO	8.67	9	1.50
2500W 4	18.35	0	0	2.94	I,III	ST_I_ON_III	>4	NO	7.67	8	1.41
4500E 1	14.74	0	0	3.09	I,III	ST_I_ON_III	>4	NO	8.33	8	0.42
4500E 2	14.88	0	0	3.14	I,III	ST_I_ON_III	>4	NO	8.33	9	0.24
4500E 3	14.05	0	0	2.44	I,III	ST_I_ON_III	>4	NO	8.67	9	0.89
4500E 4	13.72	0	0	2.33	I,III	ST_I_ON_III	>4	NO	7.33	9	0.38
CLISREF 1	12.54	0	0	2.35	I,III	ST_I_ON_III	>4	NO	5.67	4	1.25
CLISREF 2	10.46	0	0	3.64	I,III	ST_I_ON_III	>4	NO	9.00	10	0.75
CLISREF 3	10.65	0	0	2.57	I,III	ST_I_ON_III	>4	NO	7.33	8	0.93
CLISREF 4	13.38	0	0	3.27	I,III	ST_III	>4	NO	8.33	9	0.77
CLISREF 5	14.62	0	0	3.65	I,II,III	ST_I_ON_III	>4	NO	8.00	7	0.45
AVG	14.15	0	0	3.10					8.15	8.46	0.84
MAX	18.35	0	0	3.91					10.33	10	1.50
MIN	10.46	0	0	2.33					5.67	4	0.24

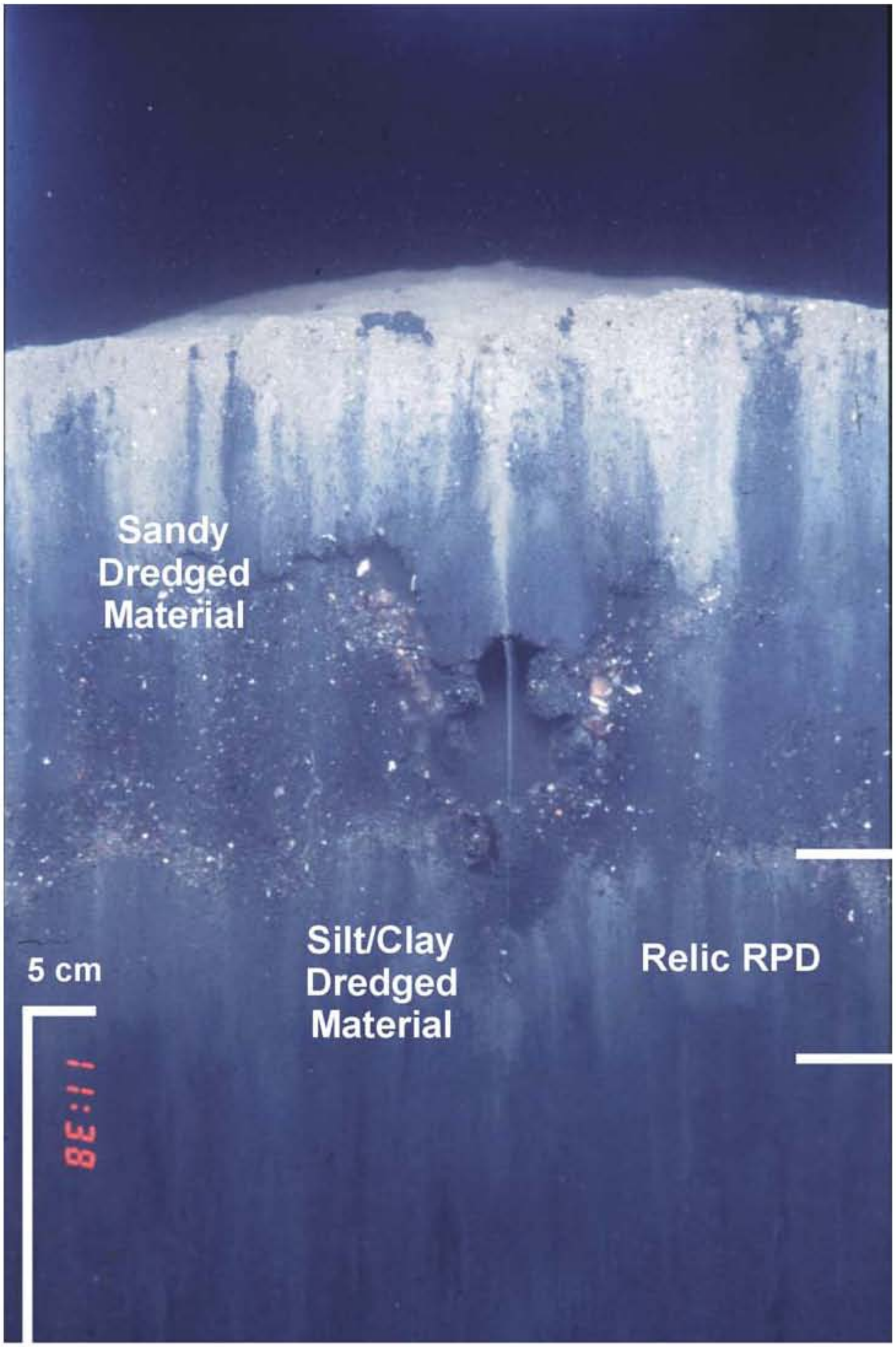


Figure 3-6. REMOTS® image collected from Station C4 over the CLIS 00 Mound illustrating the variable composition of dredged material deposited at the CDA 00 buoy position

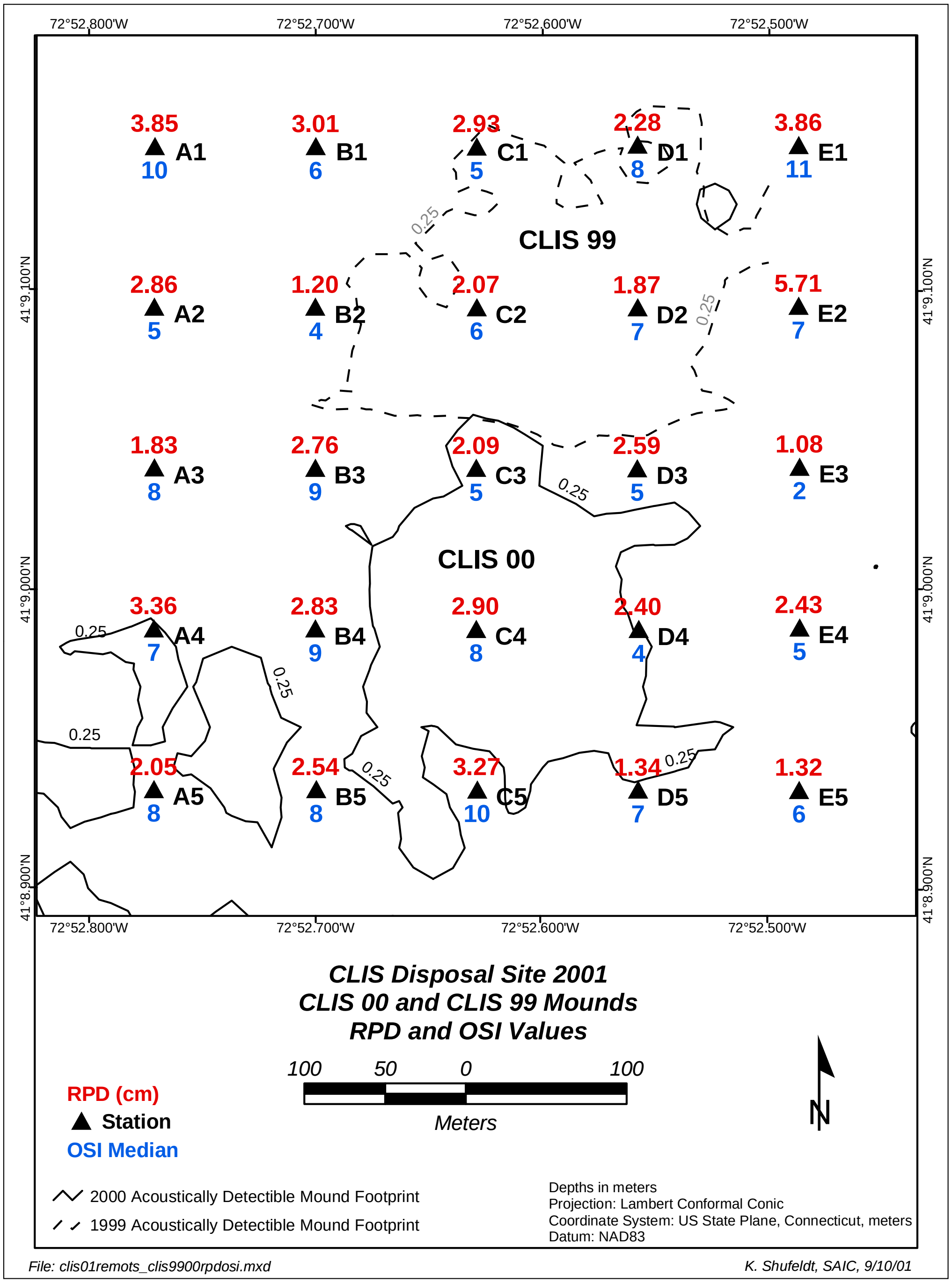


Figure 3-7. Map of replicate averaged RPD depths (red) and median OSI values (blue) detected within the active area of disposal relative to the acoustically detectable dredged material footprint of the CLIS 00 (solid line) and CLIS 99 (dashed line) Mounds

depth of 2.3 cm was shallower than the composite value calculated for the CLDS reference areas (3.1 cm), but still considered indicative of a well-oxygenated surficial sediment layer (Tables 3-1 and 3-2). The deepest RPD depths were detected south and west of the mound apex, on the flank of the NHAV-74 Mound (Figure 3-7). No low dissolved oxygen conditions, redox rebounds, or methane bubbles were observed in any of the replicate images from this region.

Although no redox rebound intervals were noted in the surficial sediment, relic RPDs (an indicator of sediment layering) were detected at several stations within the survey grid. Relic RPDs usually occur when a relatively thin layer of dredged material is placed over an older deposit or ambient sediments, and represent the depth of oxygenation in the underlying material prior to being covered by the fresh deposit. A new RPD will be formed at the sediment surface as oxygen is incorporated into the surficial sediments via the bioturbational activity of benthic infauna. In addition, layering of dredged material is often detected due to different textures or composition of the sediment comprising the layers (e.g., Figure 3-6).

The successional stage status at the majority of stations over the CLIS 00 Mound was classified as Stage I on III, as opportunistic, surface-dwelling polychaetes (Stage I) were seen in abundance with Stage III deposit feeders at depth (Table 3-1 and Figure 3-8). Stage I organisms tend to quickly colonize a fresh sediment deposit (2 to 6 weeks), taking advantage of the competition-free space. In the absence of further benthic disturbance, Stage III organisms, representing an advanced successional sere, colonize the sediment later in the recovery period to exploit the concentrated food source (organic matter entrained within the sediment). All stations displayed evidence of Stage III activity, including those over the center region of the mound and on the apron, indicating that the benthic habitat was recovering more rapidly than anticipated given that dredged material placement operations concluded only six weeks prior to the June 2001 survey (Figure 3-8).

Due to the moderate to deep RPD depths and the widespread presence of Stage III organisms in the surficial sediments, OSI values at the CLIS 00 Mound in June 2001 were quite high for a recent sediment deposit. Median OSI values ranged from +2 at Station E3 to +10 at Station C5 (Figure 3-7; Table 3-1). The overall average of +6.7 for the CLIS 00 Mound indicates undisturbed or healthy benthic habitat conditions existed over the mound and surrounding area at the time of the survey. However, benthic conditions were still slightly below those displayed at the CLDS reference areas, as a composite OSI value of +8.5 was calculated for the ambient central Long Island Sound sediments (Table 3-2). The lowest median OSI (+2) at Station E3 on the eastern edge of the survey grid was due to low abundance of Stage III organisms in combination with shallow RPD depths.

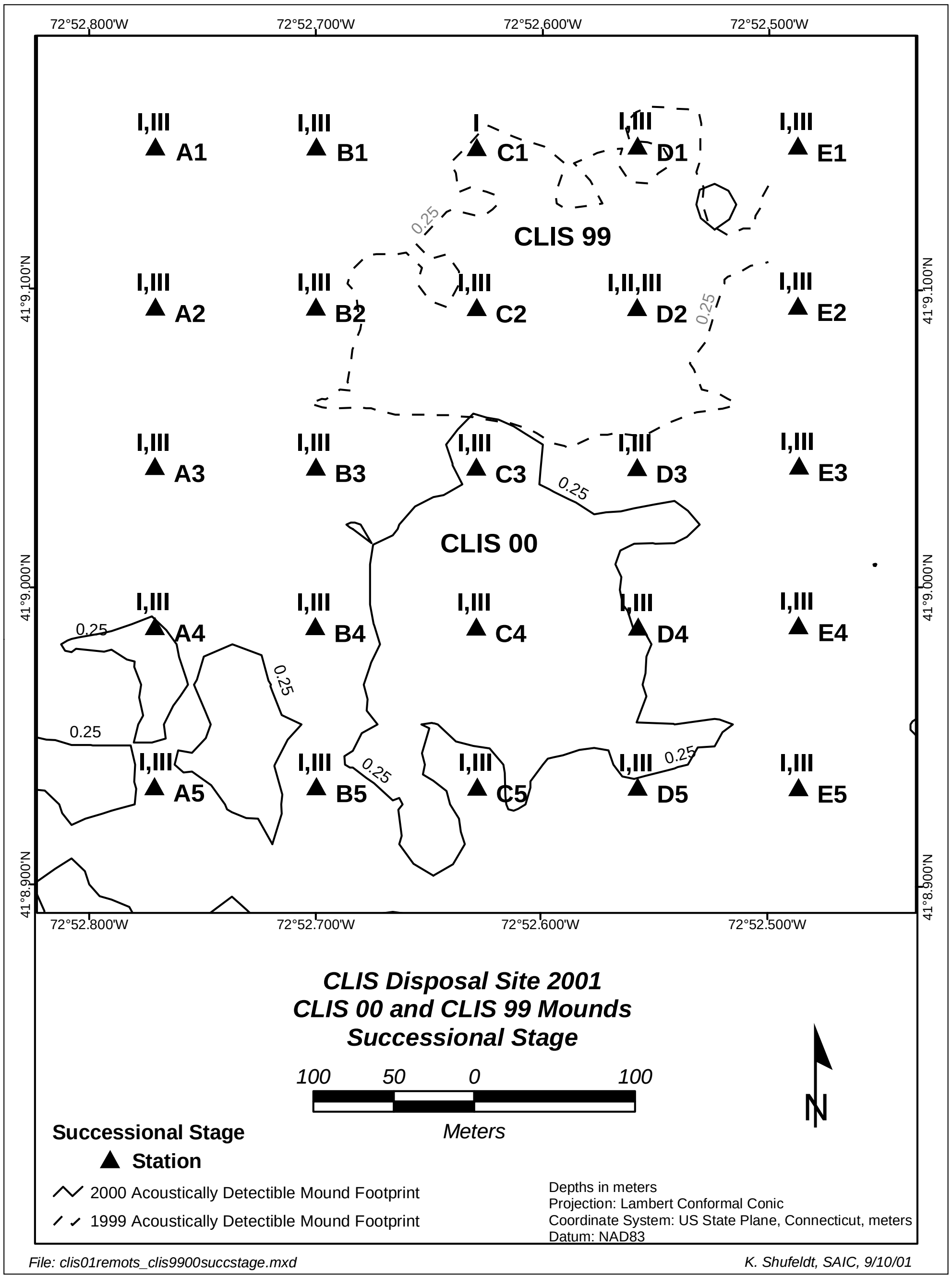


Figure 3-8. Map of infaunal successional stages found to be present at each REMOTS® station established within the active area of disposal, relative to the acoustically detectable dredged material footprints of the CLIS 00 (solid line) and CLIS 99 (dashed line) Mounds

3.2.2 CLIS 99 Mound

The remaining ten stations of the 25-station rectangular grid were assigned to the CLIS 99 Mound, as they would best represent the one-year-old sediment deposit. Although this small disposal mound was formed during the 1999–2000 disposal season, the June 2001 survey represents the first benthic recolonization survey performed over this sediment deposit. Table 3-3 presents a summary of results for the data collected over the CLIS 99 Mound, while a complete set of REMOTS® image analysis results is provided in Appendix B2.

3.2.2.1 Dredged Material Distribution and Physical Sediment Characteristics

Dredged material thickness was classified as greater than the penetration depth of the sediment-profile camera at all stations occupied over the CLIS 99 Mound (Table 3-3). Replicate-averaged camera penetration depths ranged from 11.7 to 17.3 cm over the surface of the CLIS 99 Mound. Boundary roughness values were similar to both CLIS 00 and the CLDS reference areas with a range of 0.4 to 1.5 cm and an overall average of 0.8 cm. Surface roughness was again predominantly the result of physical disturbance.

Similar to the CLIS 00 Mound, layering of fresh or recent dredged material was noted at the majority of the stations sampled (Figure 3-9). Stations A1 and B1 in the northwest corner of the survey grid displayed conditions characteristic of relic dredged material over ambient sediment. Overall, sediment composition was similar to the CLIS 00 Mound, consisting of dark, fine-grained sediments with a major modal grain size of >4 phi (Table 3-3).

3.2.2.2 Biological Conditions and Benthic Recolonization

The replicate-averaged RPD depths were slightly deeper at the CLIS 99 Mound in comparison to the CLIS 00 Mound, and equivalent to the depths of oxygenation at the CLDS reference areas. RPD depths ranged from 1.2 cm at Station B2 to 5.7 cm at Station E2, with an overall average of 3.0 cm (Figure 3-7; Table 3-3). The deepest RPD depths were concentrated to the north of the CLIS 99 Mound apex, away from the effects of deposition at the CDA 00 buoy (Figure 3-7). No low dissolved oxygen conditions, redox rebounds, or methane bubbles were observed in any of the replicates collected over the CLIS 99 Mound.

The successional status over the CLIS 99 Mound was comparable to the benthic community inhabiting the CLIS 00 Mound, with the majority of the stations classified as Stage I over III (Figure 3-8; Table 3-3). Stage III activity was detected in all but one

Table 3-3.

REMOTS® Sediment-Profile Imaging Results Summary for the CLIS 99 Mound, June 2001

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Surface DM Layer (cm)	Number of Reps with Dredged Material	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
A1	15.24	>15.24	12	3	3.85	I,III	ST_I_ON_III	>4	NO	9.00	10	0.38
A2	17.29	>17.29	11.33	3	2.86	I,III	ST_I_ON_III	>4	NO	6.67	5	0.52
B1	11.68	>11.68	7.8	3	3.01	I,III	ST_I_ON_III	>4	NO	7.00	6	0.69
B2	13.37	>13.37	0	3	1.20	I,III	ST_III	>4	NO	4.00	4	0.97
C1	14.91	>14.91	11.83	3	2.93	I	ST_I	>4	NO	8.67	5	1.24
C2	14.97	>14.97	0	3	2.07	I,III	ST_I_ON_III	>4	NO	5.67	6	0.71
D1	15.43	>15.43	4.33	3	2.28	I,III	ST_I_ON_III	>4	NO	8.00	8	1.54
D2	16.81	>16.81	2.67	3	1.87	I,II,III	ST_I_ON_III	>4	NO	7.00	7	0.55
E1	15.04	>15.04	0	3	3.86	I,III	ST_I_ON_III	>4	NO	9.33	11	0.48
E2	16.85	>16.85	8.46	3	5.71	I,III	ST_I_ON_III	>4	NO	8.33	7	1.13
AVG	15.16	>15.16	5.84	3	2.96					7.37	6.90	0.82
MAX	17.29	>17.29	12.00	3	5.71					9.33	11	1.54
MIN	11.68	11.68	0.00	3	1.20					4.00	4	0.38

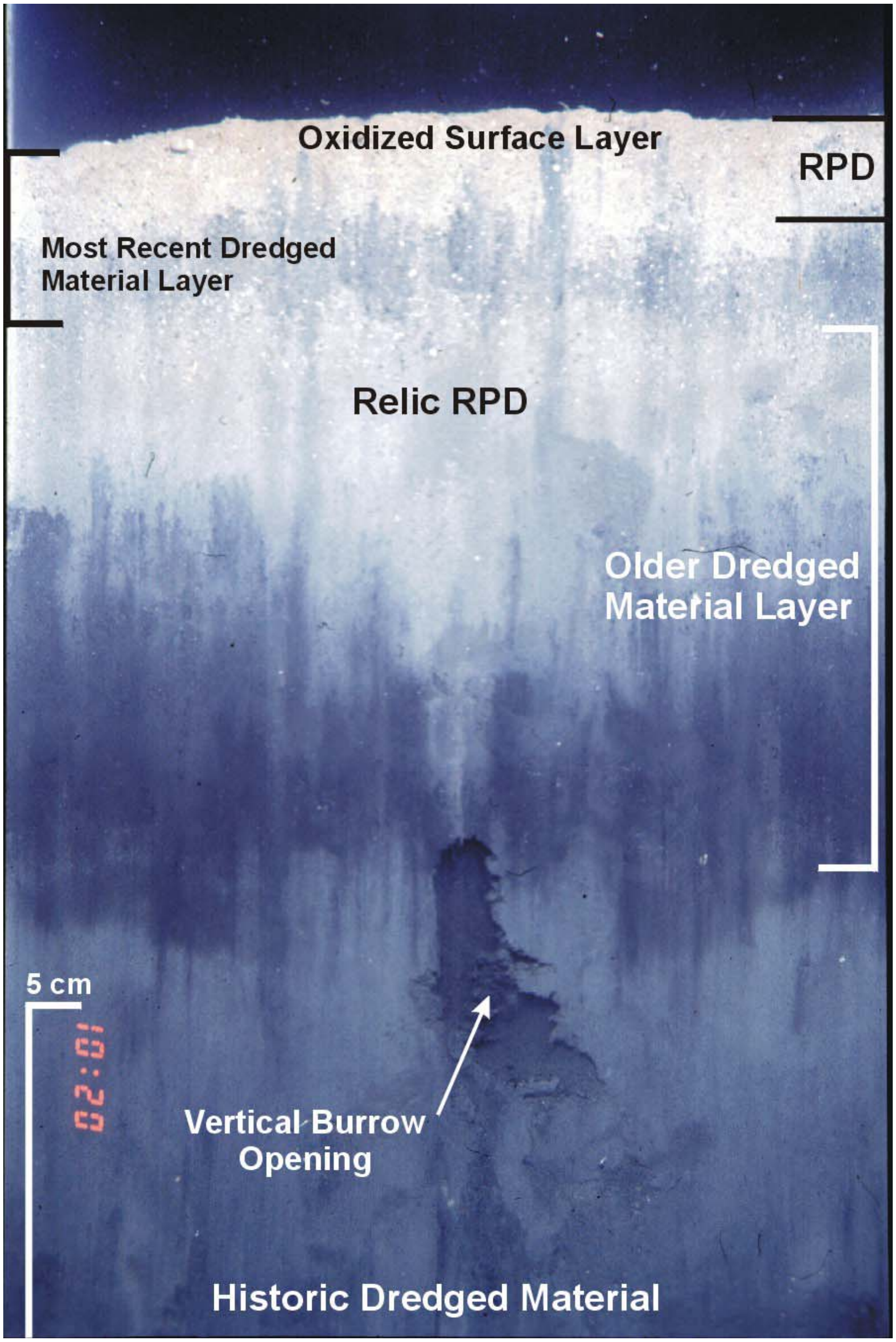


Figure 3-9. REMOTS® image collected from Station A2 over the CLIS 99 Mound displaying multiple layers of dredged material composing the apron of the disposal mound

station (Station C1) over the CLIS 99 Mound, indicating a well-established and stable benthic community (Figure 3-8; Table 3-3). Median OSI values were fairly high, ranging from +4 to +11 and reflecting the advanced successional stage and deep RPD depths (Figures 3-7 and 3-10). The overall average OSI value for the CLIS 99 Mound was +6.9, below the composite value for the CLDS reference area (+8.5), but still indicative of an undisturbed benthic habitat (Figure 3-7; Tables 3-2 and 3-3).

3.2.3 CLIS 97/98 Mound

A 21-station REMOTS® sampling grid was occupied over the CLIS 97/98 Mound Complex as part of the June 2001 survey. A total of 19 stations within the grid had been sampled during the September 1999 survey, providing a strong basis for comparison of benthic habitat conditions between surveys, while two new stations (102 and 103) were added to complete the northwest and southwest transects. Table 3-4 presents a summary of results for the data collected over the CLIS 97/98 Mound Complex. A complete set of REMOTS® image analysis results is provided in Appendix B3.

3.2.3.1 Dredged Material Distribution and Physical Sediment Characteristics

Older dredged material was detected at all stations in layers exceeding the penetration depth of the sediment-profile camera (Table 3-4). The surface of the CLIS 97/98 Mound Complex was primarily composed of fine-grained sediment (>4 phi; silt/clay). Consistent with the findings of the September 1999 survey, stations in close proximity to the CDA 98 deposit (62, 70, and 71) had slightly coarser sediment, consisting primarily of fine sands and silts (Table 3-4). Camera penetration varied from 8.8 cm at Station 62, which had fine sand (3 to 2 phi), to 17.1 cm at Station 59, with an overall mound average of 13.7 cm. Boundary roughness varied from 0.4 cm to 2.2 cm (Table 3-4). Surface roughness was attributed to a combination of physical and biological factors.

3.2.3.2 Biological Conditions and Benthic Recolonization

Replicate-averaged RPD depths over the CLIS 97/98 Mound Complex ranged from 1.2 cm at Station 62 to 4.8 cm at Station 88 during the June 2001 survey (Figure 3-11). The average RPD value for this historic disposal mound was 3.7 cm, deeper than the composite value of 3.1 cm for the CLDS reference areas (Tables 3-2 and 3-4). As the average value indicates, the majority of the CLIS 97/98 REMOTS® stations displayed RPD depths greater than 3 cm, with little significant spatial variation. No low dissolved oxygen conditions, redox rebounds, or methane bubbles were observed in any of the replicate images from this mound.

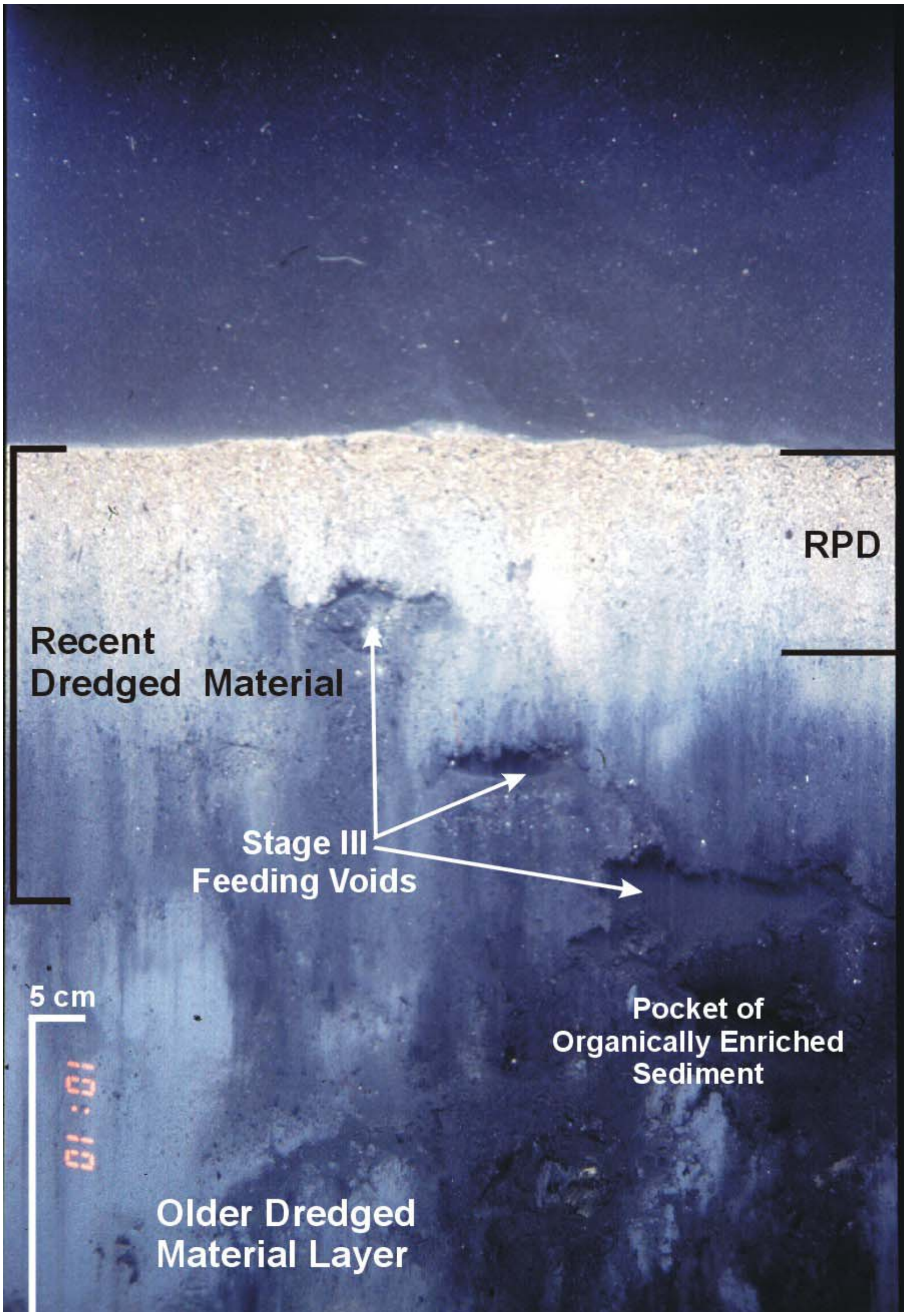


Figure 3-10. REMOTS® image collected from Station E1 over the CLIS 99 Mound displaying a deep RPD and large Stage III feeding voids at depth, yielding an OSI value of +11

Table 3-4.

REMOTS® Sediment-Profile Imaging Results Summary for the CLIS 97/98 Mound Complex, June 2001

Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number of Reps with Dredged Material	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
11.34	>11.34	3	4.46	I,III	ST_I_ON_III	>4	NO	10.67	11	0.96
16.41	>16.41	3	2.51	I,III	ST_I_ON_III	>4	NO	6.00	5	0.77
16.74	>16.74	3	2.43	I,III	ST_I_ON_III	>4	NO	7.33	8	0.82
16.04	>16.04	3	4.68	I,III	ST_I_ON_III	>4	NO	7.67	7	0.62
11.50	>11.50	3	4.27	I,III	ST_I_ON_III	>4	NO	11.00	11	0.45
16.06	>16.06	3	4.63	I,II,III	ST_I_ON_III	>4	NO	10.67	11	0.80
12.73	>12.73	3	3.98	I,III	ST_I_ON_III	>4	NO	9.00	9	0.54
17.11	>17.11	3	3.87	I,II,III	ST_I_ON_III	>4	NO	9.33	11	0.94
10.84	>10.84	3	2.98	I,III	ST_I_ON_III	>4	NO	8.33	9	0.69
13.77	>13.77	3	3.05	I,II,III	ST_II_ON_III	>4	NO	9.67	9	2.15
8.81	>8.81	3	1.17	I,III	ST_III	3 to 2	NO	10.00	10	2.03
15.20	>15.20	3	3.52	I,III	ST_I_ON_III	>4	NO	9.67	10	1.26
16.39	>16.39	3	3.48	I,III	ST_I_ON_III	>4	NO	8.67	9	0.62
10.60	>10.60	3	4.04	I,II,III	ST_II_TO_III	>4	NO	8.67	10	0.36
11.48	>11.48	3	4.55	I,III	ST_I_ON_III	4 to 3	NO	10.67	11	1.10
10.20	>10.20	3	4.15	III	ST_III	4 to 3	NO	10.67	11	1.25
15.92	>15.92	3	4.39	I,III	ST_I_ON_III	>4	NO	10.67	11	1.18
15.46	>15.46	3	3.57	I,III	ST_I_ON_III	>4	NO	8.67	9	0.38
12.17	>12.17	3	4.81	I,III	ST_III	>4	NO	9.33	11	0.56
14.13	>14.13	3	3.40	III	ST_III	>4	NO	9.67	9	0.50
14.81	>14.81	3	4.66	I,III	ST_I_ON_III	>4	NO	8.67	10	0.76

13.70	>13.69	3	3.74					9.29	9.62	0.89
17.11	>17.11	3	4.81					11.00	11	2.15
8.81	8.81	3	1.17					6.00	5	0.36

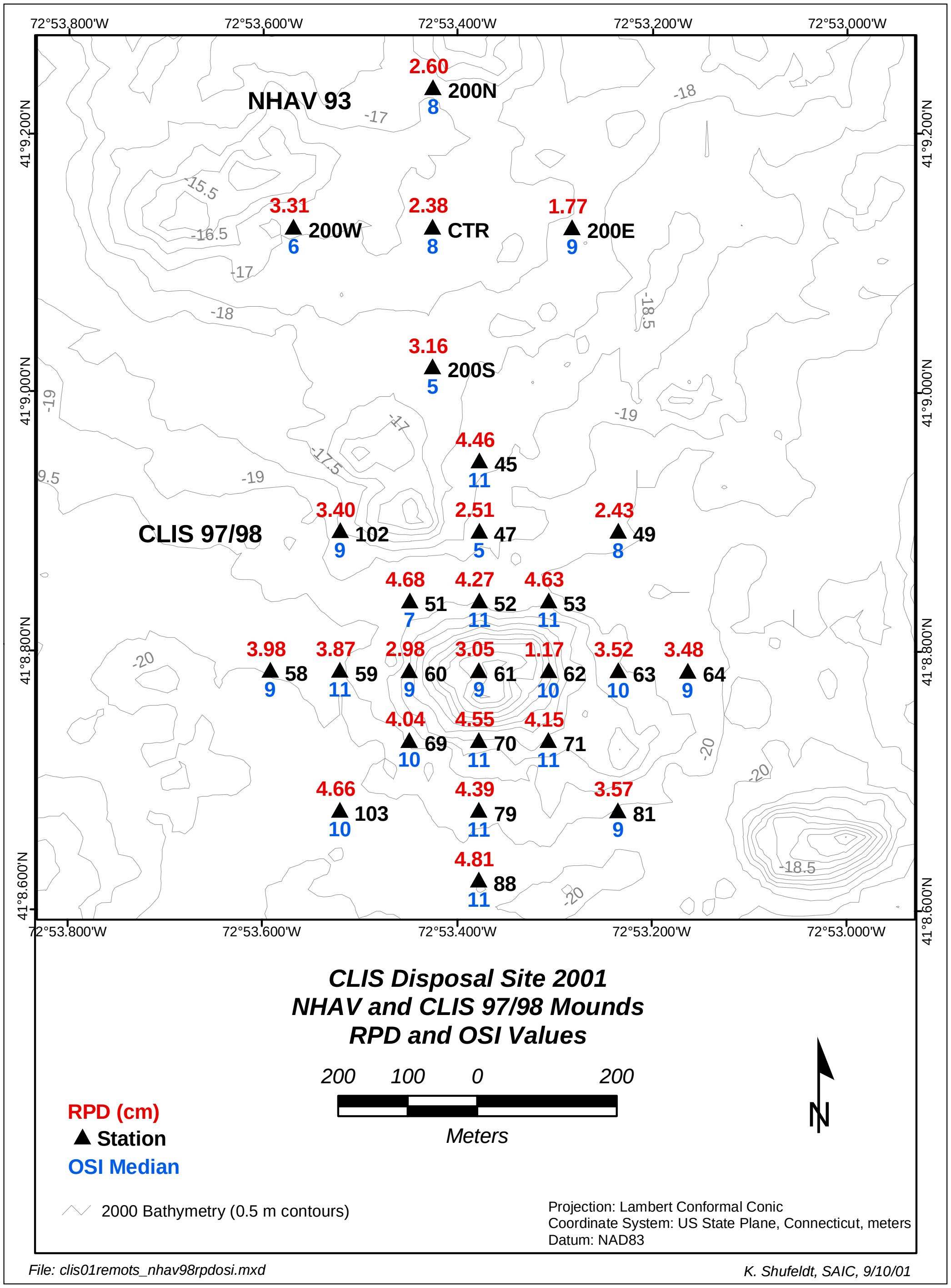


Figure 3-11. Map of replicate averaged RPD depths (red) and median OSI values (blue) detected over the CLIS 97/98 Mound Complex and the NHAV 93 Mound

The successional stage over the CLIS 97/98 Mound was predominately Stage I on III, with all stations having Stage III organisms present (Figure 3-12; Table 3-4). This represents a more advanced successional stage over the last survey of the mound complex in September 1999. As a result, it appears the recovery of the benthic community over the CLIS 97/98 Mound Complex is well within expectations for a three-year-old sediment deposit. Based on the abundance of Stage III organisms and the presence of deep RPD depths, the OSI values for the CLIS 97/98 Mound Complex were quite high (Figures 3-11 and 3-13). The station median OSI values varied from +5 to +11, with an overall average of +9.6 (Figure 3-11). The overall average OSI value in June 2001 (+9.6) was greater than the reference area average of +8.5 and exceeded the average of +6.1 calculated for the previous survey of September 1999 (Tables 3-2 and 3-4).

3.2.4 NHAV 93 Mound

Since its completion in the spring of 1994, the NHAV 93 Mound has displayed a cyclical pattern of benthic recovery and decline, suggesting an increased susceptibility to regional disturbance (i.e., seasonal hypoxia) relative to the CLDS reference areas and surrounding disposal mounds (Morris 1998a). Due to the origin of the CDM and lack of toxicity in a well-oxygenated environment, the instability in the benthic habitat is likely related to labile organics within the deposited sediment and sediment oxygen demand (Morris and Tufts 1997). The June 2001 survey represents the seventh sediment-profile imaging survey performed over this disposal mound, focusing on areas of concern located near the center of the capped mound. Table 3-5 presents a summary of results for the data collected over the NHAV 93 Mound in June 2001. A complete set of REMOTS® image analysis results is provided in Appendix B4.

3.2.4.1 Dredged Material Distribution and Physical Sediment Characteristics

Historic dredged material was detected in layers greater than the REMOTS® camera penetration depth in all the images collected over the NHAV 93 Mound (Table 3-5). As in previous surveys, the surficial sediments were composed of predominantly fine-grained material (>4 phi, silt/clay), indicating no detectable coarsening (winnowing) relative to previous surveys. A relatively thick layer of tan (oxidized) silt was observed over low-reflectance, organically enriched dredged material at depth.

Replicate averaged camera penetration values ranged from 13.3 cm at Station 200S to 15.1 cm at Station 200E. Boundary roughness values were fairly low, ranging from 0.3 to 1.1 cm. Surface roughness over the NHAV 93 Mound was attributed to a combination of physical and biological factors.

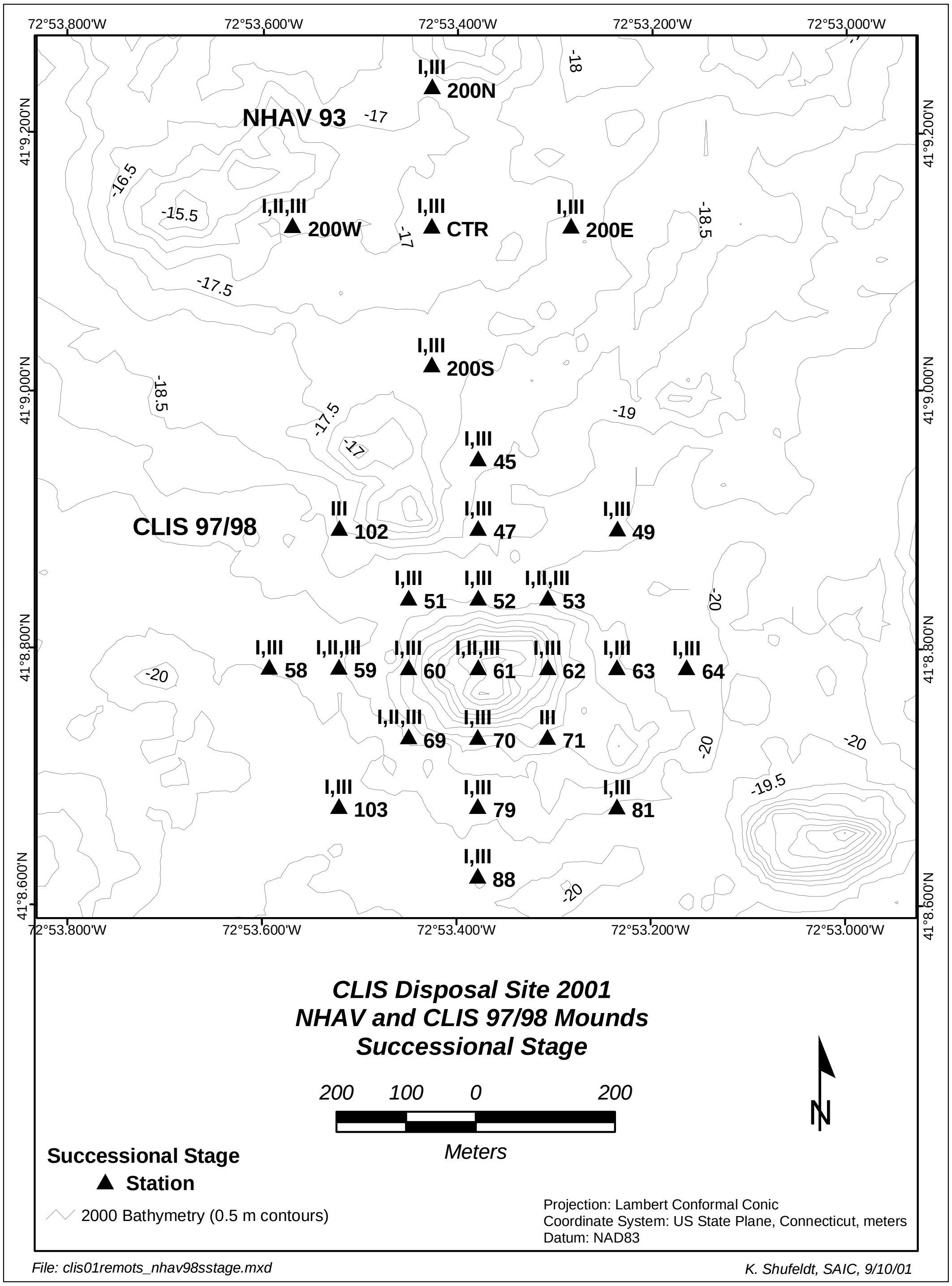


Figure 3-12. Map of successional stage status for the REMOTS® stations established over the CLIS 97/98 Mound Complex and the NHAV 93 Mound

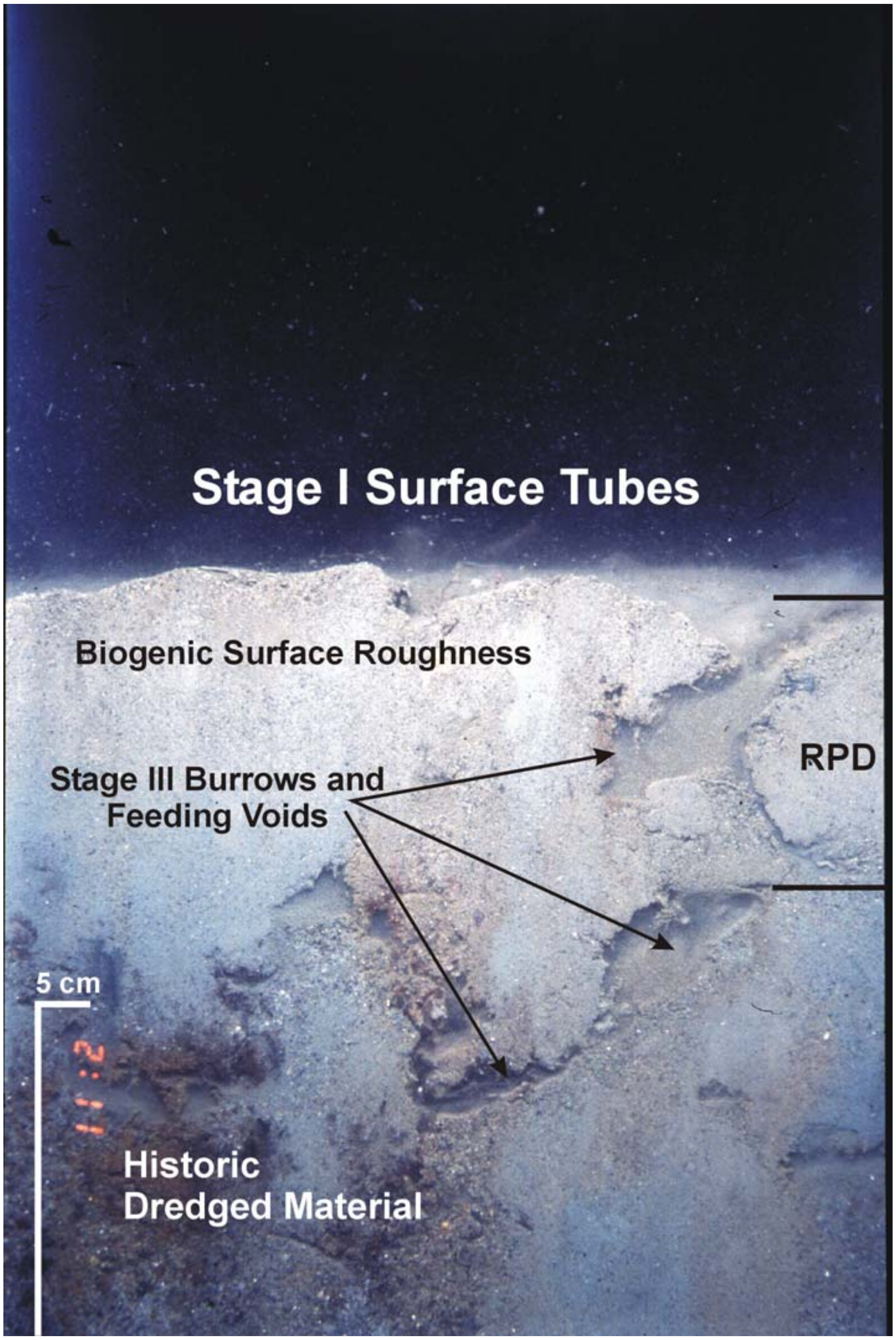


Figure 3-13. REMOTS® image collected from Station 69 over the CLIS 97/98 Mound Complex displaying a deep RPD; biogenic surface roughness due to burrowing activity of the resident biota; Stage I surface; and large Stage III feeding voids at depth, yielding an OSI value of +11

Table 3-5.

REMOTS® Sediment-Profile Imaging Results Summary for the NHAV 93 Mound, June 2001

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number of Reps with Dredged Material	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
CTR	13.96	>13.96	3	2.38	I,III	ST_I_ON_III	>4	NO	7.33	8	1.02
200N	13.94	>13.94	3	2.60	I,III	ST_I_ON_III	>4	NO	7.67	8	1.07
200S	13.31	>13.31	3	3.16	I,III	ST_I_ON_III	>4	YES	5.00	5	0.33
200E	15.13	>15.13	3	1.77	I,III	ST_I_ON_III	>4	NO	9.00	9	0.90
200W	14.14	>14.14	3	3.31	I,II,III	ST_I_ON_III	>4	NO	7.00	6	0.82
AVG	14.10	>14.10	3	2.64					7.20	7.20	0.83
MAX	15.13	>15.13	3	3.31					9.00	9	1.07
MIN	13.31	13.31	3	1.77					5.00	5	0.33

3.2.4.2 Biological Conditions and Benthic Recolonization

The depth of sediment oxygenation as indicated by replicate-averaged RPD values varied from nearly 1.8 cm at Station 200E to 3.3 cm at Station 200W (Figure 3-11; Table 3-5). The overall average RPD value for the disposal mound was 2.6 cm, slightly shallower than the composite CLDS reference area value of 3.1 cm. Although no redox rebound or low dissolved oxygen conditions were identified in any replicate image, one replicate from Station 200S did show the presence of methane bubbles in the sediments (Figure 3-14). This station has consistently displayed evidence of organic loading and increased susceptibility to fluctuations in bottom water dissolved oxygen concentrations during prior monitoring surveys.

The successional stage status was advanced over NHAV 93, with evidence of Stage III activity at all five stations (Figure 3-12; Table 3-5). In addition, all of the images also displayed Stage I polychaete tubes at the sediment-water interface. Based on evidence of Stage III activity and relatively deep RPD depths, the station median OSI values varied from +5 at Station 200S to +9 at Station 200E during the June 2001 survey (Figure 3-11; Table 3-5). The overall average OSI value of +7.2 indicates significant improvement in benthic habitat conditions relative to previous years (1994 through 1997) and was equivalent to the value calculated in September 1999. Benthic habitat conditions remain slightly degraded in comparison to the CLDS reference areas (Table 3-2).

3.2.5 CLDS Reference Areas

Thirteen stations were distributed between three reference areas (2500W, 4500E, and CLISREF) and sampled with the REMOTS® sediment-profile camera. Three replicate images were collected at each reference station to provide a statistically valid basis of comparison between ambient sediments and conditions over the surface of the disposal mounds. Table 3-2 presents a summary of results for the data collected over the CLDS reference areas. A complete set of REMOTS® image analysis results is provided in Appendix B5.

3.2.5.1 Physical Sediment Characteristics

All of the replicates were characterized as ambient sediment, with no indications of dredged material placement or anthropogenic activity (i.e., trawling, anchor scars, etc). Each of the reference area replicates was comprised of fine-grained silt/clay with a consistent major mode grain size of >4 phi (Figure 3-15; Table 3-2). Replicate-averaged camera penetration depths ranged from 10.5 to 18.4 cm, providing a composite average of 14.2 cm. Boundary roughness values were low, ranging from 0.2 to 1.5 cm (average 0.8 cm). Surface roughness was attributed to physical factors in most of the replicate

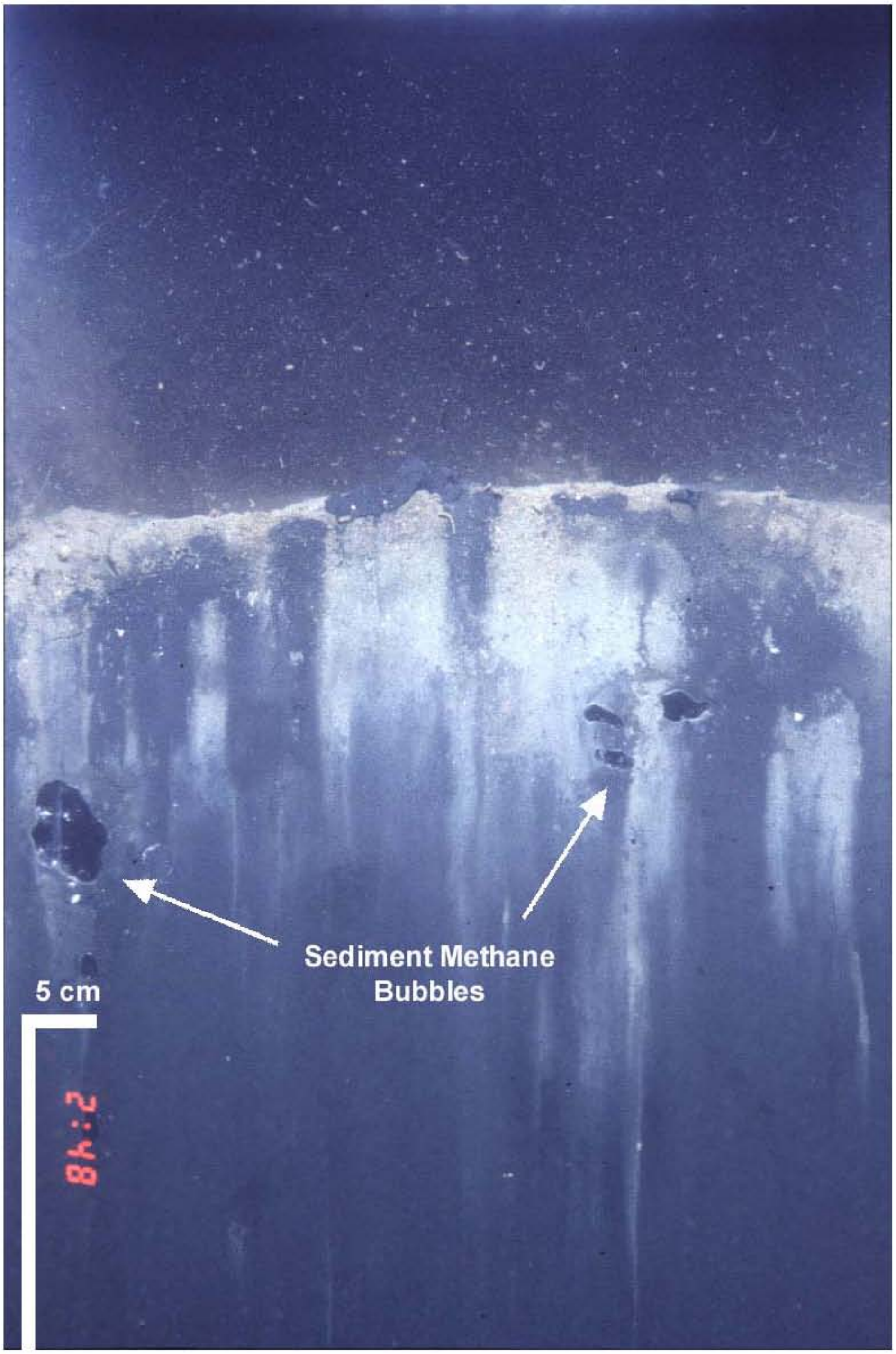


Figure 3-14. REMOTS® image collected at Station 200S over the NHAV 93 Mound displaying several large methane bubbles entrained within the sediment and a moderate RPD depth of 2.6 cm

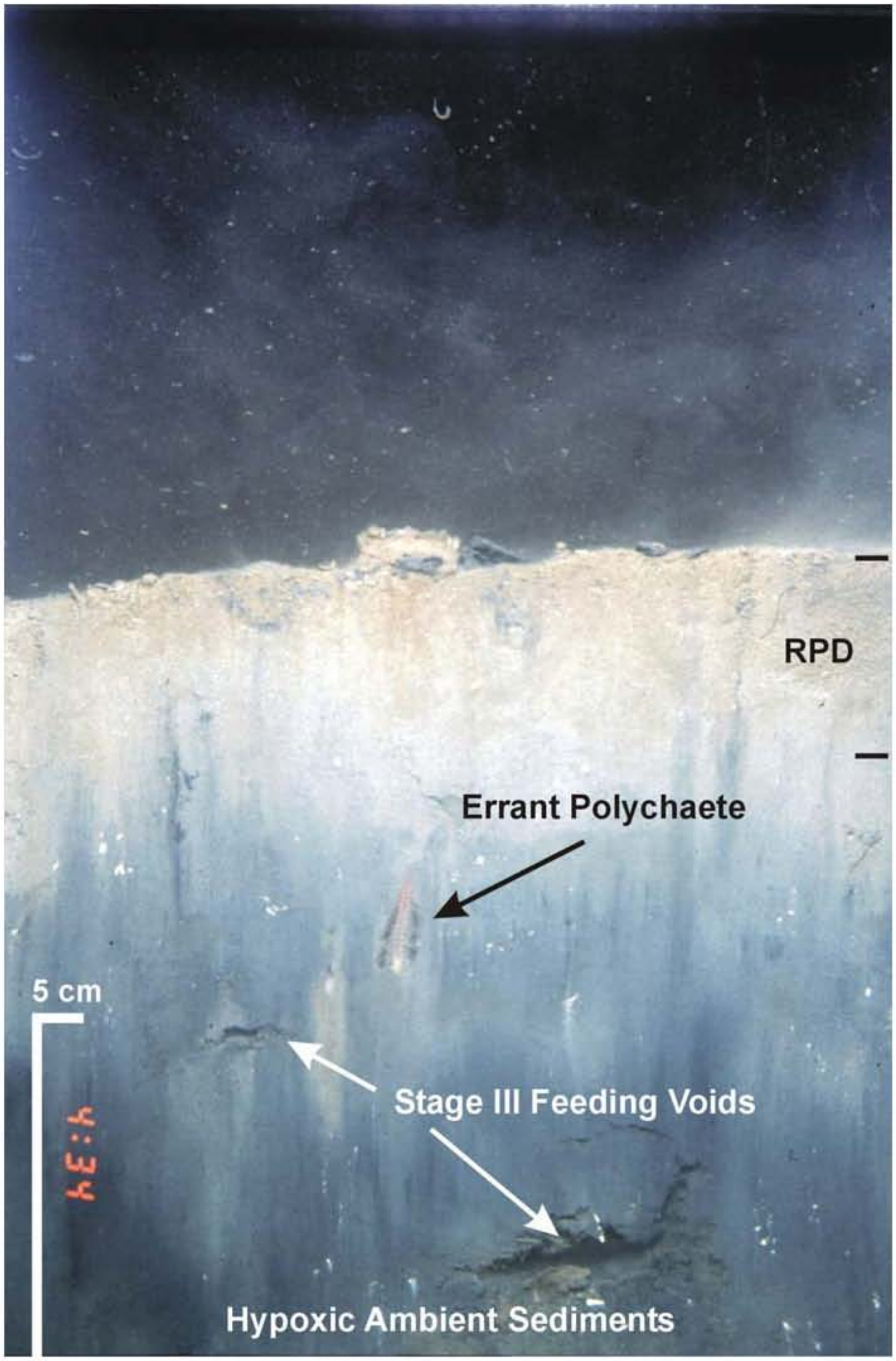


Figure 3-15. REMOTS® image collected at CLISREF 3 displaying >4 phi silt and clay at the sediment-water interface, as well as a well-established RPD, several large Stage III feeding voids, and an errant polychaete (likely Nephtys sp.) burrowing in the subsurface sediment

images analyzed. At Station 4500E1, surface roughness was classified as biogenic in all replicate images due to the presence of large tubes at the sediment-water interface.

3.2.5.2 Biological Conditions

Replicate-averaged RPD depths at all three reference areas ranged from 2.3 to 3.9 cm, with an overall average of 3.1 cm, indicating a well-oxygenated surficial sediment layer (Table 3-2). No redox rebound intervals nor any indications of low dissolved oxygen or methane were identified in the images acquired from the reference area stations.

As anticipated, the successional stage status at the reference areas indicated an abundance of Stage III activity, with active feeding voids, burrows, or deposit feeding worms observed in 26 of the 39 replicate images (Figure 3-15). Stage I tubes were also seen at the sediment-water interface in many of the images, prompting the classification of Stage I on III at the majority of the stations sampled (Table 3-2). Burrowing anemones were seen in one image from CLISREF and one image from 2500W, with a few macrofaunal burrows observed at the reference areas, as well. The station median OSI values for the CLDS reference areas varied from +4 to +10, with a composite value of nearly +8.5. There were no obvious signs of recent or historic benthic disturbance (natural or anthropogenic) in any of the replicate images.

4.0 DISCUSSION

4.1 Seafloor Topography

Dredged material placement operations at CLDS entail directing disposal barges to a taut-wire buoy over the course of each disposal season (October through May) to form a discrete dredged material mound on the seafloor. This management strategy is employed to efficiently utilize the capacity of the disposal site while preserving the capability to monitor discrete disposal mounds individually. The results of the September 2001 single-beam bathymetric survey confirmed predictions, indicating that dredged material placement activities at CLDS during the 1999–2000 and 2000–2001 disposal seasons were concentrated within the central portion of the disposal site and resulted in the formation of two discrete disposal mounds.

Since 1983, disposal buoys at CLDS have been positioned in a manner that promoted the formation of small to moderated-sized disposal mounds in a circular pattern on the seafloor. These rings of mounds eventually serve as artificial containment basins for volumes of unconsolidated sediments that require confined aquatic disposal (Morris et al. 1996). The basin features limit the lateral spread of the initial UDM deposit, preventing the formation of a wide, thin apron of dredged material and facilitating efficient coverage with layers of cap. During the 2000–2001 disposal season, approximately 71,000 m^3 of sediment was dredged from harbors in the region and placed at the CDA 00 buoy, forming the CLIS 00 Mound. Prior to the development of the CLIS 00 Mound, an estimated barge volume of 86,000 m^3 of dredged material was deposited at the CDA 99 buoy between October 1999 and May 2000 to form the CLIS 99 Mound. Both mounds are of similar morphology and begin to form the western boundary of the third artificial containment cell at CLDS (Figure 1-4).

During the 1993–94 disposal season, the first artificial containment cell constructed on the CLDS seafloor was filled with approximately 1,160,000 m^3 of dredged material, forming the NHAV 93 Mound (Figure 1-4; Morris and Tufts 1997). An additional artificial containment cell (A) incorporating the CLIS 97/98 and 95/96 Mound Complexes, as well as the NHAV 74, SP, and NORWALK Mounds, is nearing completion to the southeast of NHAV 93 (Figure 1-4). Although small gaps exist between the CLIS 97/98, CLIS 95/96, and NHAV 74 Mounds, the ring of disposal mounds appears to be properly configured to function as a containment basin. With the recent development of the CLIS 00 and CLIS 99 Mounds to the east of the NHAV 93 Mound, yet another containment cell (B) is also nearly complete. This cell utilizes the flanks of the SP, CLIS 91, CLIS 94, STNH-N, CLIS 99, CLIS 00, and NHAV 74 Mounds (Figure 1-4).

4.2 Benthic Habitat Assessment

4.2.1 Seasonal Hypoxia in Long Island Sound

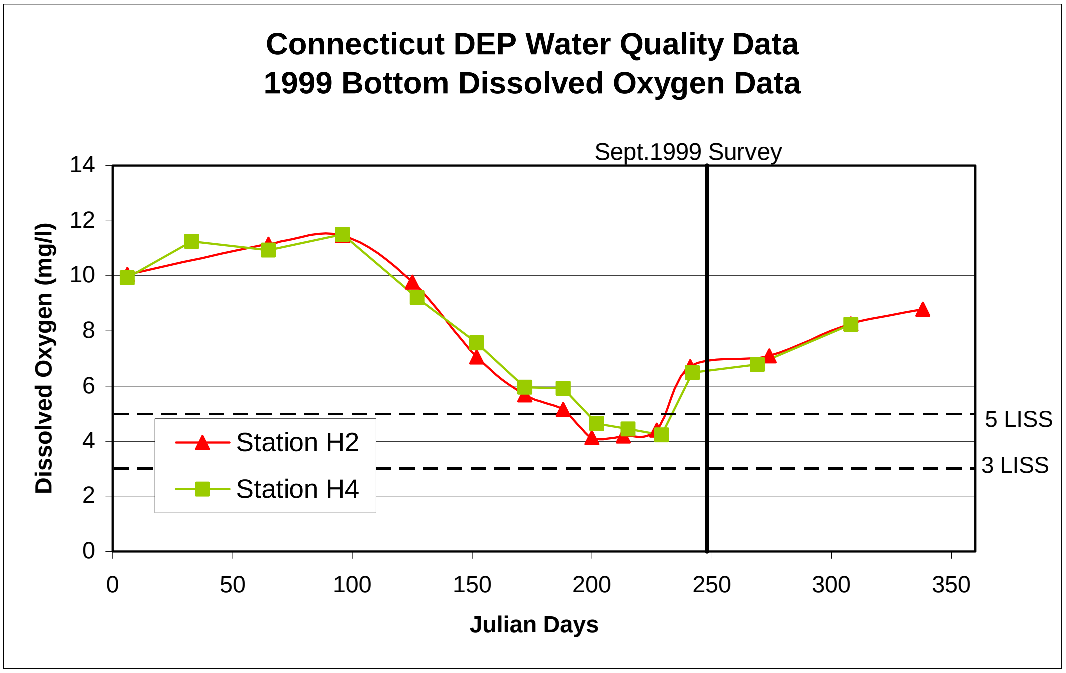
The depth and intensity of bioturbation by benthic infauna is one of the major factors that dictate the overall depth of oxygen penetration within the sediments and, in turn, the OSI value calculated for each replicate image. Bioturbational activity is affected by a number of variables, including dissolved oxygen concentrations, bottom water temperatures, and organic load within the sediments. The metabolism and activity level of the poikilothermic organisms are lower in cooler water temperatures, then tend to increase as the bottom water warms through the spring and summer months. When bottom water temperatures rise in Long Island Sound and the benthos becomes more active, dissolved oxygen levels tend to decrease as molecular oxygen is consumed by increased biological respiration, as well as chemical oxidation of organic matter introduced into the sediments as part of the spring plankton bloom. Hypoxia occurs when bottom water dissolved concentrations within the region fall below critical levels, causing an increase in environmental stress within the benthic community. Oxygen concentrations of ≥ 5 mg·l^{-1} are thought to be protective of most Long Island Sound marine life, while hypoxia is considered to occur at concentrations of ≤ 3 mg·l^{-1} (LISS 1990). Numerous DAMOS contributions pertaining to the regional dredged material disposal sites in central and western Long Island Sound have identified and discussed the relationship between benthic habitat conditions and bottom water dissolved oxygen concentrations within the region (Morris 1997, Morris 1998a, SAIC 2002b, Morris 1998b, and Murray and Saffert 1999).

Since 1995, bottom water dissolved oxygen concentrations in the central Long Island Sound region have been used to qualify sediment-profile imaging results for CLDS, and remain an important factor in the interpretation of REMOTS® photographs. Monitoring surveys performed over CLDS and the Western Long Island Sound Disposal Site (WLDS) in August and September have often shown the impacts of the seasonal reduction in dissolved oxygen concentrations in dredged material deposits, as well as the ambient sediments of the reference areas. These impacts are detected as significant reductions in RPD depths and at times decreased levels of Stage III organism activity in the subsurface sediments, which equate to low OSI values and indications of disturbed benthic habitat. As a result, the 2001 monitoring survey was intentionally scheduled during the month of June (late spring or early summer) for the assessment of benthic habitat conditions over CLDS when dissolved oxygen concentrations are typically higher within the region. This strategy permits a clearer evaluation of organism/sediment relations over the disposal mounds without the biases introduced by hypoxia.

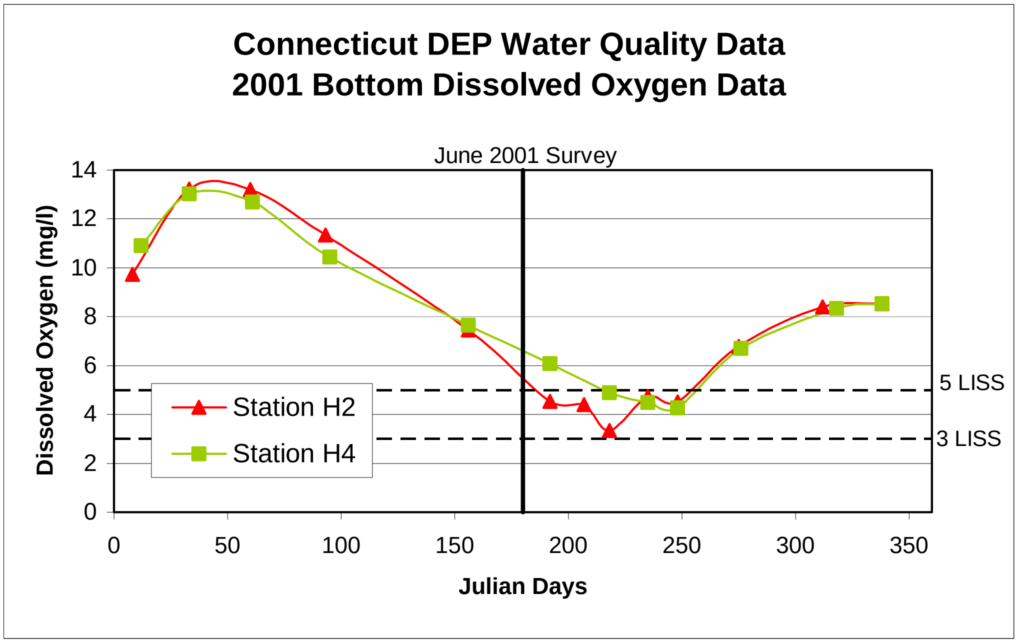
Water quality data obtained from the Connecticut Department of Environmental Protection (CTDEP) for Stations H2 and H4 (Figure 1-2) are used to examine bottom water dissolved concentrations in the Central Long Island Sound region relative to the timing of survey operations. In 1999, the benthic habitat assessment survey was performed in September, after the seasonal reduction in bottom water dissolved oxygen had occurred (Julian Day 250; Figure 4-1A). Following the pattern typical for the waters of central Long Island Sound, a relatively high concentration of dissolved oxygen was documented in the bottom waters during the winter months with a gradual reduction through the summer months as the waters became warmer and oxygen consumption increased. Dissolved oxygen concentrations fell below 5 $mg \cdot l^{-1}$ in early July (Julian Day 190) and remained at levels slightly above 4 $mg \cdot l^{-1}$ for approximately seven weeks before rebounding one to two weeks prior to the September 1999 survey. Although bottom water dissolved oxygen concentrations in the region never reached truly hypoxic levels, the decrease in available oxygen would tend to elevate environmental stress within the benthic community, possibly causing a reduction in Stage III activity and triggering a decrease in RPD depths (Diaz and Rosenberg 1995; Ritter and Montagna 1999). These impacts are often more obvious in the newer dredged material disposal mounds, which usually contain a higher inventory of organic matter and are more susceptible to fluctuations in dissolved oxygen concentrations.

In contrast, the June 2001 survey was performed six weeks after the completion of the 2000–2001 disposal season and prior to the seasonal decline in dissolved oxygen levels in the bottom waters of the Sound. Water quality data collected by the CTDEP in 2001 confirmed that the June REMOTS® survey was completed while bottom water dissolved oxygen concentrations were relatively high (between 6.5 and 5.5 $mg \cdot l^{-1}$) and prior to the onset of hypoxic conditions (Figure 4-1B). The continuous records for Stations H2 and H4 indicate dissolved oxygen concentrations were quite high throughout the winter and early spring, and tended to decrease during the period from April to July (Julian Days 90–190) as the waters of Long Island Sound began to warm and oxygen demand increased. Molecular oxygen (O_2) concentrations remained at approximately 4 $mg \cdot l^{-1}$ from mid-July through early September (Julian Days 192–248), but were above hypoxic levels (3 $mg \cdot l^{-1}$). The lowest level of dissolved oxygen observed was 3.4 $mg \cdot l^{-1}$ at Station H2 in early August, well after the completion of the survey.

The results from the benthic habitat assessments performed over the disposal mounds in June 2001 generally indicated the presence of undisturbed benthic habitat conditions at all mounds surveyed. The depth of oxygenation within the sediments was often in excess of 2 cm, and advanced benthic communities were identified at most stations sampled. Based on comparisons to data sets acquired in previous years, the resulting OSI values from the June 2001 data signify a substantial improvement in overall benthic habitat conditions. Given the timing of the most recent survey, these improvements are likely a product of reduced stress within the benthic community due to the higher dissolved oxygen concentrations in the bottom waters, relative to previous surveys.



A



B

Figure 4-1. Observed changes in bottom water dissolved oxygen concentrations at the Department of Environmental Protection dissolved oxygen sampling stations H2 (red) and H4 (green) for 1999 (A) and 2001 (B)

4.2.2 CLIS 00 Mound

No baseline data from 1999 were available to serve as a basis of comparison for habitat conditions over the CLIS 00 Mound. However, the June 2001 REMOTS® images collected over CLIS 00 indicate that benthic recolonization has surpassed expectations for a new sediment deposit and exhibits conditions similar to those observed at the CLDS reference areas. Benthic habitat conditions detected over the CLIS 00 Mound were indicative of an undisturbed environment at six weeks post-disposal. The surface of the CLIS 00 Mound was supporting a Stage III community and displayed RPD depths in excess of 2 cm at the majority of the stations sampled. As a result, the OSI values calculated for the CLIS 00 Mound were generally higher than what would be anticipated. This finding is particularly noteworthy since a newly formed disposal mound typically supports a Stage I community with limited progression to Stage II or Stage III assemblages on the fringes of the sediment deposit six weeks after the final dredged material placement event. The images collected over the CLIS 00 Mound show an advanced benthic infaunal community, as evidence of Stage III activity was present at every station after this short recovery period.

Based on the fact that the June 2001 survey was conducted so soon after the disposal activities, it can be assumed that the widespread recruitment of Stage III organisms over the CLIS 00 Mound can be attributed to processes other than reproduction within the surrounding infaunal population. Based on the 0.25 m acoustically detectable footprint of the CLIS 00 Mound, the REMOTS® grid placed 10 of the 15 sampling stations on the outer apron of the sediment deposit while the remaining five stations were located over a relatively thick layer of dredged material in the central portion of the mound (Figure 3-8). The advanced successional stage organisms detected within the interior portions of the mound inhabit the surface of a thick (>10 cm) dredged material deposit and are likely the product of relocation from the sediment source areas. The Stage III organisms that exist on the mound apron may be the result of relocation as well, but could also represent the incorporation of individuals from the underlying sediments. Since dredged material placed during the 2000–2001 disposal season covered the pre-existing sediment-water interface, these deposit feeders may have migrated up through the thin layers (<10 cm) of fresh material.

Although there is no direct comparison to previous data sets, the June 2001 survey would be expected to yield favorable benthic habitat conditions, because the survey occurred before bottom water dissolved oxygen concentrations approached hypoxic levels. Although the results of the survey indicated conditions were below those of the ambient sediment at the CLDS reference areas, habitat conditions over the mound and surrounding seafloor have surpassed expectations for a six-week-old dredged material deposit. As the resident benthic infauna continue to exploit the newly deposited sediment as a source of organic material, the bioturbational activity will incorporate oxygenated bottom waters deeper into the sediment. Depending upon the timing of follow-on survey efforts, future surveys should detect similar or deeper RPD depths than the results obtained in June 2001. Barring a significant disturbance in the future (e.g., placement of additional dredged material or a severe seasonal hypoxia event), a stable Stage III assemblage will likely continue to exist over the surface of the CLIS 00 Mound.

4.2.3 CLIS 99 Mound

Although the June 2001 bathymetric survey indicated that the CLIS 99 and CLIS 00 Mounds remain separate features on the seafloor, the benthic habitat conditions over the newest disposal mounds were quite similar. The mean RPD value over the CLIS 99 Mound (approximately 3 cm) exceeded the average depth of oxygenation for the CLIS 00 Mound (2.3 cm), and was similar to the composite value calculated for the CLDS reference areas. Nine of the ten stations occupied over the CLIS 99 Mound displayed evidence of Stage III activity. The advanced successional stage coupled with the deep RPD depths yielded high OSI values for a relatively new disposal mound. The overall average OSI value of +6.9 was slightly above CLIS 00, but below the +8.5 composite value for the reference areas. The June 2001 survey represented the first benthic recolonization assessment performed over CLIS 99. Since the average OSI value for this mound was nearly +7, it can be assumed that the seafloor surrounding the CLIS 99 Mound is recovering from the benthic disturbance associated with the 1998–1999 disposal season as anticipated. However, continued monitoring of this disposal mound is recommended over the next several years to verify that habitat conditions continue to improve as the benthic infauna exploit the deposited sediments as a habitat and food source.

4.2.4 CLIS 97/98 Mound Complex

In general, the benthic habitat over the CLIS 97/98 Mound Complex has displayed a significant improvement over time. In fact, the RPD depths, successional stage status, and OSI values calculated for the images collected over CLIS 97/98 in June 2001 exceeded those documented over the CLDS reference areas (Tables 4-1 and 4-2). In September 1999, a 32-station REMOTS® grid was used to assess conditions over the dredged material deposits formed during the 1997–1998 and 1998–1999 disposal seasons (SAIC 2003). The surface of the mound complex followed the typical recovery pattern with a stable Stage I community and progression to a Stage III assemblage at the majority of the stations sampled. OSI values ranged from +3 to +11 and were strongly correlated to RPD depth, which ranged from 1 to 4.4 cm. In June 2001, 19 of those 32 original stations were reoccupied to facilitate strong comparison to 1999 conditions (Table 4-1).

Table 4-1.

Summary of REMOTS® Sediment-Profile Imaging Results over the CLIS 97/98 Mound Complex in June 2001 and September 1999

Station	2001 RPD Mean (cm)	1999 RPD Mean (cm)	2001 Successional Stages Present	1999 Successional Stages Present	2001 OSI Mean	1999 OSI Mean	2001 OSI Median	1999 OSI Median
45	4.46	0.98	I,III	I,III	10.67	5.67	11	7
47	2.51	1.52	I,III	I,III	6.00	5.00	5	4
49	2.43	1.51	I,III	I	7.33	3.67	8	4
51	4.68	1.88	I,III	I	7.67	4.00	7	4
52	4.27	1.95	I,III	I	11.00	4.33	11	4
53	4.63	2.19	I,II,III	I,III	10.67	5.67	11	5
58	3.98	2.06	I,III	I,III	9.00	5.67	9	5
59	3.87	1.26	I,II,III	I,III	9.33	8.00	11	8
60	2.98	2.40	I,III	I,III	8.33	7.50	9	7.5
61	3.05	1.29	I,II,III	I,III	9.67	6.00	9	7
62	1.17	2.40	I,III	I,III	10.00	6.33	10	5
63	3.52	2.04	I,III	I,III	9.67	8.33	10	8
64	3.48	1.75	I,III	I,III	8.67	7.00	9	7
69	4.04	1.98	I,II,III	I	8.67	4.33	10	4
70	4.55	1.92	I,III	I,III	10.67	6.67	11	8
71	4.15	4.37	III	I	10.67	6.67	11	7
79	4.39	2.55	I,III	I,III	10.67	6.33	11	5
81	3.57	3.14	I,III	I,III	8.67	7.33	9	6
88	4.81	3.97	I,III	I,III	9.33	9.00	11	9
AVG	3.71	2.17			9.30	6.18	9.63	6.03
MAX	4.81	4.37			11.00	9.00	11	9
MIN	1.17	0.98			6.00	3.67	5	4

Table 4-2.

Summary of REMOTS® Sediment-Profile Imaging Results over the CLDS Reference Areas in June 2001 and September 1999

Station	2001 RPD Mean (cm)	1999 RPD Mean (cm)	2001 Successional Stages Present	1999 Successional Stages Present	2001 OSI Mean	1999 OSI Mean	2001 OSI Median	1999 OSI Median
2500W 1	3.74	2.80	I,III	I,III	10.33	8.00	10	8
2500W 2	3.19	2.29	I,III	I,III	8.33	8.67	10	8
2500W 3	3.91	1.47	I	I,III	8.67	7.67	9	8
2500W 4	2.94	2.90	I,III	I,III	7.67	9.33	8	8
AVG	3.44	2.37			8.75	8.42	9.25	8.00
4500E 1	3.09	2.80	I,III	I,III	8.33	7.67	8	9
4500E 2	3.14	3.58	I,III	I,III	8.33	8.33	9	9
4500E 3	2.44	2.34	I,III	I,III	8.67	8.67	9	9
4500E 4	2.33	2.84	I,III	I,III	7.33	7.00	9	6
AVG	2.75	2.89			8.17	7.92	8.75	8.25
CLISREF 1	2.35	3.98	I,III	I,III	5.67	10.33	4	11
CLISREF 2	3.64	4.40	I,III	I,III	9.00	10.33	10	11
CLISREF 3	2.57	3.99	I,III	I,III	7.33	10.00	8	11
CLISREF 4	3.27	4.51	I,III	I,III	8.33	9.33	9	11
CLISREF 5	3.65	4.66	I,II,III	I,III	8.00	8.00	7	7
AVG	3.10	4.31			7.67	9.60	7.60	10.20

Composite Values

AVG	3.10	3.19			8.15	8.72	8.46	8.92
MAX	3.91	4.66			10.33	10.33	4	11
MIN	2.33	1.47			5.67	7.00	10	6

Direct comparisons of the 1999 and 2001 benthic community assessment data for the stations occupied over the CLIS 97/98 Mound Complex show improving benthic habitat conditions. All stations occupied during the 2001 survey displayed evidence of Stage III activity and a significant increase in average RPD values (1.5 cm on average). As a result, the median OSI values calculated for each station were consistently higher in 2001 relative to the September 1999 data, with all but one station displaying undisturbed benthic habitat conditions (Table 4-1). Station 47, located 200 m north of the CLIS 98 sediment deposit center, had an OSI value below +6 and was the only station considered moderately disturbed. The lower OSI value was due to the low abundance of Stage III organisms at this location, despite RPD depths greater than 2 cm.

The DAMOS Monitoring Program has indicated that dredged material mounds will tend to support higher population densities of benthic infauna by providing a concentrated food source relative to the more depleted ambient sediments (Germano et al. 1994). The findings of the June 2001 survey over the CLIS 97/98 Mound Complex reinforce this concept and suggest the significant improvement in benthic habitat conditions is part of the normal disposal mound recovery process. However, with 84% of the stations displaying average RPD depths of ≥ 3 cm and median OSI values of ≥+9, higher dissolved oxygen concentrations at the time of the habitat assessment survey have likely contributed to this marked improvement. Continued monitoring of this disposal mound complex is recommended on a periodic basis over the next five to ten years to verify that the seafloor surrounding CLIS 97/98 continues to display undisturbed benthic habitat conditions despite seasonal fluctuations in dissolved oxygen concentrations.

4.2.5 NHAV 93 Mound

Over the years, benthic recolonization near the center of the NHAV 93 Mound has shown a cyclical recovery and decline, generally corresponding to the seasonal hypoxia patterns in the Central Long Island Sound region (Morris 1998a). Previous survey efforts have indicated that the CDM on the surface of the NHAV 93 Mound contained an elevated level of labile organics (Morris and Tufts 1997). In addition, methane gas bubbles, a product of the microbial consumption of organic material in an anaerobic environment, have been detected in follow-on monitoring surveys completed over the NHAV 93 Mound since 1997 (SAIC 2002b). The higher organic load within the sediments creates increased sediment oxygen demand over the NHAV 93 Mound relative to other disposal mounds and CLDS reference areas. As a result, the surface of this mound tends to be more susceptible to the effects of regional hypoxia.

As with the other CLDS disposal mounds surveyed in June 2001, the timing of sampling relative to bottom water dissolved oxygen concentrations has contributed to the documentation of satisfactory benthic conditions over most of the NHAV 93 Mound.

However, the OSI values calculated for the June 2001 images remain below those of the ambient sediments within the CLDS reference areas. Despite slightly deeper RPD depths in the most recent images and Stage III communities present at all stations, median OSI values for the NHAV 93 Mound stations were essentially identical to those calculated for the September 1999 data set (+7.2; Table 4-3). Methane gas was present at 200S, a station with a history of poor benthic conditions, contributing to the median value of +5 and serving to diminish the overall average OSI value for the mound.

Although the majority of the NHAV 93 Mound appears to be recovering as anticipated, Station 200S continues to be an area of concern with a lower than expected OSI value for a seven-year-old dredged material deposit. The replicate-averaged RPD depths appeared to be within the measured range for the mound, but evidence of Stage III activity continues to be scarce compared to other stations on the mound. In both 1999 and 2001, Station 200S displayed the lowest median OSI value (+4 in 1999 and +5 in 2001) for the five station REMOTS® grid. However, data obtained from within the 25 m sampling radius of Station 200S displayed a significant amount of spatial variability (Figure 4-2). In addition, Station 45 of the CLIS 97/98 Mound Complex grid, located approximately 150 meters southeast of Station 200S, had a median OSI value of +11 and average RPD of 4.46 cm, indicating excellent benthic conditions (Figure 3-11). These findings suggest that a highly localized pocket of overly enriched dredged material continues to exist at Station 200S and is likely the cause for the delayed recovery.

Based on periodic benthic habitat assessment efforts since July 1994, the data acquired from Station 200S has not indicated significant improvement in benthic habitat conditions. Although a March 1998 sampling event did show a median OSI value approaching +6, likely due to higher bottom water dissolved oxygen concentrations in the colder bottom waters, median OSI values calculated for summer survey efforts have remained below expectations (SAIC 2002b). This overall trend suggests an alternative management approach (i.e., comprehensive testing, cap augmentation, etc.) may be required in the near future to promote full recovery of the benthic environment at Station 200S. Placement of supplemental CDM may improve benthic habitat conditions near the sediment-water interface by isolating the enriched sediments. Further monitoring of the NHAV 93 Mound with REMOTS® sediment-profile imaging is recommended for at least another year. The results for Station 200S should be closely evaluated to determine if comprehensive testing (bulk sediment chemistry, pore water chemistry, sediment toxicity) or cap augmentation is warranted. Based upon the findings for the remainder of the NHAV 93 stations, benthic habitat conditions over most of the mound should continue to support a stable infaunal community despite the continued chemical oxidation of organics within the sediments.

Table 4-3.

Summary of REMOTS® Sediment-Profile Imaging Results over the NHAV 93 Mound in June 2001 and September 1999

Station	2001 RPD Mean (cm)	1999 RPD Mean (cm)	2001 Successional Stages Present	1999 Successional Stages Present	2001 OSI Mean	1999 OSI Mean	2001 OSI Median	1999 OSI Median
CTR	2.38	2.46	I,III	I,III	7.33	7.67	8	8
200N	2.60	2.39	I,III	I,III	7.67	8.33	8	8
200S	3.16	2.02	I,III	I,III	5.00	5.67	5	4
200E	1.77	2.41	I,III	I,III	9.00	7.33	9	9
200W	3.31	1.77	I,II,III	I,III	7.00	6.67	6	7
AVG	2.64	2.21			7.20	7.13	7.20	7.20
MAX	3.31	2.46			9.00	5.67	9	9
MIN	1.77	1.77			5.00	8.33	5	4

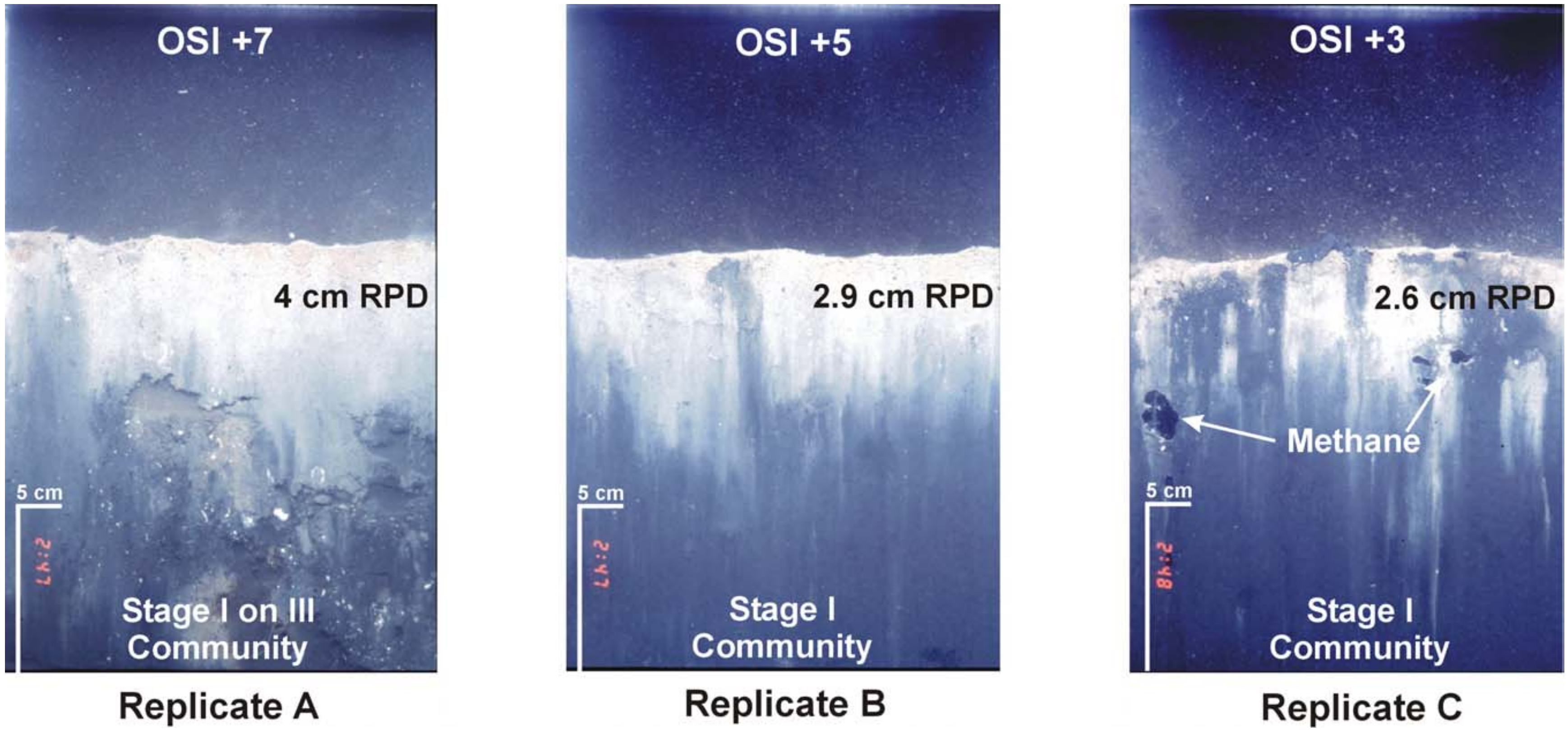


Figure 4-2. Three replicate images collected over Station 200S on the NHAV 93 Mound showing the variability in conditions within the 25 m sampling radius. OSI values of +7, +5, and +3 yield a median value of +5 that was used to characterize the benthic habitat

4.2.6 CLDS Reference Areas

The three CLDS reference areas (2500W, 4500E, and CLISREF) serve as a basis of comparison between benthic conditions detected over the disposal mounds and those of the ambient sediments in the central Long Island Sound region. These areas are generally free from anthropogenic impacts and are located within the same depositional environment as the disposal site. As a result, the reference areas are believed to be subjected to the same physical, chemical, and biological processes as CLDS, with the exception of dredged material input. The sediments within 2500W, 4500E, and CLISREF are characterized as >4 phi silt and clay material with a thick layer of tan (oxidized) silt over a gray to black (hypoxic) silty clay (Figure 3-15). Due to its origin (natural deposition), this sediment tends to contain less organic matter than the sediments dredged from coastal harbors and deposited at CLDS. However, ambient sediments within the reference areas, as well as the entire central Long Island Sound region, are subject to annual inputs of organic matter during the final phases of the spring plankton bloom.

Although the comparison of the sediment-profile imaging data acquired over the CLDS disposal mounds indicated improved benthic habitat conditions in June 2001 relative to September 1999, similar comparisons performed with the composite OSI values acquired over the CLDS reference areas suggest minimal to no difference in benthic habitat conditions. When evaluating the overall OSI values calculated for the reference areas in 1999 versus 2001, the comparisons actually indicate a slight decline in benthic habitat conditions (+8.9 in 1999 versus +8.5 in 2001; Table 4-2). Upon closer examination of the data acquired over the individual reference areas, median OSI values calculated for the stations occupied within 2500W and 4500E indicate small-scale improvement in benthic habitat in June 2001 due to slightly deeper RPD depths and higher abundance of Stage III organisms (Table 4-2). These findings are generally consistent with the trends documented over the disposal mounds. However, the results obtained over CLISREF show a noticeable reduction in OSI values (+10.2 in 1999 versus +7.6 in 2001), primarily due to shallower RPD depths relative to September 1999. Although this apparent decline in benthic habitat conditions is not a significant concern since the average OSI value is well above +6 and the apparent depth of oxygen penetration is still in excess of 2 cm, the overall trends from this dataset are noteworthy. This information may offer some insight to the existing, natural variability in the Long Island Sound system that could be helpful in comparisons of the dredged material disposal mounds to the reference areas.

The benthic habitat conditions documented over CLISREF in September 1999 were quite favorable, with four of the five stations displaying median OSI values of +11 and an average of +10.2 calculated for this reference area (Table 4-2). Although the OSI values calculated from the June 2001 data set were generally indicative of an undisturbed benthic environment (+7.6), they were below the values obtained from the previous survey (+10.2). Reference area stations are randomly selected within a 300 m radius of the reference area center for each monitoring survey. As a result, the lower OSI values do not imply a degradation of conditions has occurred at individual stations that were re-occupied, but do represent a trend over the entire area. CLISREF is situated approximately 2 km southeast of the center of CLDS in 25 m of water. The other reference areas and disposal mounds surveyed as part of the 2001 field effort were located in water depths of 20 m or less. Given the timing of the benthic habitat assessment survey, the basis for the lower OSI values at CLISREF could be related to slower response in the benthos due to cooler bottom waters or differences in the cyclical input of organic detritus and its subsequent consumption or decomposition. The net result would be less molecular oxygen incorporated within the sediments relative to the stations located at 4500E, 2500W, and over the CLDS disposal mounds, yielding shallower RPD depths.

5.0 CONCLUSIONS

- The June 2001 single-beam bathymetry survey covered a relatively small but active 1.0 km^2 area of CLDS. The survey was able to detect the formation of a small disposal mound (CLIS 00 Mound) resulting from the placement of approximately 71,000 m^3 dredged material from multiple projects during the 2000–01 disposal season.

- The REMOTS® sediment-profile imaging data collected over the active area of CLDS showed both fresh and historic dredged material present at all stations over the CLIS 00 and CLIS 99 Mounds. Benthic recolonization over these recent sediment deposits was advanced, with both Stage I and Stage III organisms found to be in abundance over the surface of both mounds. In fact, the recolonization of the CLIS 00 Mound exceeded expectations for a recent sediment deposit with widespread evidence of Stage III activity, six weeks after the final disposal event.

- Benthic habitat quality over the historic disposal mounds CLIS 97/98 and NHAV 93 showed continued recovery and general improvement relative to the September 1999 survey. The most profound improvement in benthic conditions was documented over the CLIS 97/98 Mound Complex with deep RPD depths and Stage III organisms in abundance. This resulted in 84% of the stations displaying median OSI values of +9 or above, which exceeded the benthic habitat conditions detected at the CLDS reference areas.

- Although the overall habitat conditions over the majority of the NHAV 93 Mound appeared to be improving, Station 200S continues to be an area of concern with lower OSI values than the remainder of this capped mound and the presence of methane gas entrained within the sediments. Evidence of Stage III activity continued to be scarce at this station during the June 2001 survey, indicating these sediments have not fully recovered and are not yet capable of supporting a stable benthic community. Although this appears to be a highly localized issue, an alternate management technique (i.e., cap augmentation) may be required to promote full recovery.

- The results from the benthic habitat assessments performed over the disposal mounds in June 2001 indicated an improvement in overall benthic habitat conditions. Given the timing of the most recent survey, these improvements are likely a product of reduced stress within the benthic community due to the higher dissolved oxygen concentrations in the bottom waters, relative to previous surveys. However, comparison of reference area data from the 2001 and 1999 surveys actually displayed a slight decline in overall benthic habitat conditions in the June 2001 images. This reduction in composite OSI values was the product of a minor degradation of benthic habitat conditions within CLISREF, which may be attributable to differences in the natural processes governing organic matter input and consumption within the sediments of this reference area.

6.0 REFERENCES

Diaz, R.J. and R. Rosenberg. 1995. Marine benthic hypoxia: A review of its ecological effects and behavioral responses of benthic macrofauna. Oceanography and Marine Biology Annual Review 33:245-303.

Fredette, T.J. 1994. Disposal site capping management: New Haven Harbor. Reprinted from Dredging '94, Proceedings of the Second International Conference, November 3–16, 1994. U.S. Army Corps of Engineers, New England Division, Waltham, MA.

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

Long Island Sound Study (LISS). 1990. Status report and interim actions for hypoxia management. US Environmental Protection Agency, Region I, Boston, MA and Region II, New York, NY.

Morris, J.T. 1997. Monitoring cruise at the Central Long Island Sound Disposal Site, September 1995. DAMOS Contribution No. 118 (SAIC Report No. 373). US Army Corps of Engineers, New England District, Concord, MA.

Morris, J.T. 1998a. Monitoring cruise at the Central Long Island Sound Disposal Site, July 1996. DAMOS Contribution No. 120 (SAIC Report No. 385). U.S. Army Corps of Engineers, New England District, Concord, MA.

Morris, J.T. 1998b. Monitoring cruise at the Western Long Island Sound Disposal Site, July 1996. DAMOS Contribution No. 119 (SAIC Report No. 383). U.S. Army Corps of Engineers, New England District, Concord, MA.

Morris, J.T.; Charles, J.; Inglin, D. 1996. Monitoring surveys of the New Haven capping project, 1993-1994. DAMOS Contribution No. 111 (SAIC Report No. 19). U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Morris, J.T; Tufts, G. J. 1997. Monitoring cruise at the Central Long Island Sound Disposal Site, July 1994. DAMOS Contribution No. 117 (SAIC Report No. 327). U.S. Army Corps of Engineers, New England Division, Waltham, MA.

Murray, P.M.; Saffert, H.L. 1999. Monitoring Cruises at the Western Long Island Sound Disposal Site, September 1997 and March 1998. DAMOS Contribution 125 (SAIC Report 441). U.S. Army Corps of Engineers, New England District, Concord, MA.

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

Rhoads, D. C., Germano, J. D. 1986. Interpreting long-term changes in benthic community structure: a new protocol. Hydrobiologia 142:291-308

Ritter, C. and P.A. Montagna. 1999. Seasonal hypoxia and models of benthic response in a Texas Bay. Estuaries 22:7-20.

SAIC 2001a. Monitoring at the New London Disposal Site, August 2000. DAMOS Contribution 133 (SAIC Report No. 512). US Army Corps of Engineers, New England District, Concord, MA.

SAIC. 2001b. Monitoring at the New London Disposal Site, 1992-1998, Volume I. DAMOS Contribution No. 128 (SAIC Report No. 515). U.S. Army Corps of Engineers, New England District, Concord, MA.

SAIC 2002a. Monitoring cruise at the Massachusetts Bay Disposal Site, Fall 2000. DAMOS Contribution 134 (SAIC Report No. 545). US Army Corps of Engineers, New England District, Concord, MA.

SAIC. 2002b. Monitoring cruise at the Central Long Island Sound Disposal Site, September 1997 and March 1998. DAMOS Contribution 135 (SAIC Report No. 464). U.S. Army Corps of Engineers, New England District, Concord, MA.

SAIC 2003. Central Long Island Sound Disposal Site Synthesis Report, 1999-2000. DAMOS Contribution 139 (SAIC Report No. 547). US Army Corps of Engineers, New England District, Concord, MA.

Appendix A
2000–2001 Disposal Logs

Appendix B
2001 REMOTS® Survey Results

Appendix B1

REMOTS® Results for the June 2001 Survey over the CLIS 00 Mound

Station	Replicate	Date	Time	Grain Size			Camera Penetration (cm)				Surface Roughness	Apparent RPD Thickness (cm)			Successional Stage	Low DO	OSI	Mud Clasts	
				Min	Max	Maj Mode	Min	Max	Range	Mean		Min	Max	Mean				Count	Diameter
A3	A	6/27/2001	10:58	>4	2	>4	19.08	19.47	0.39	19.28	PHYSICAL	1.45	2.51	2.25	ST_I_ON_III	NO	8	0	0
A3	B	6/27/2001	10:59	>4	2	>4	18.45	18.55	0.1	18.5	PHYSICAL	0.19	4.64	2.25	ST_I_ON_III	NO	8	8	0.38
A3	C	6/27/2001	11:00	>4	2	>4	17.63	17.83	0.19	17.73	PHYSICAL	0.05	2.37	0.99	ST_I_ON_III	NO	7	10	0.49
A4	B	6/27/2001	11:26	>4	2	>4	16.58	16.99	0.41	16.79	PHYSICAL	0.67	4.3	2.79	ST_I_ON_III	NO	9	0	0
A4	D	6/28/2001	12:27	>4	1	>4	9.02	10.98	1.97	10	PHYSICAL	1.4	4.15	2.82	ST_I	NO	5	0	0
A4	E	6/28/2001	12:28	>4	1	>4	8.03	10	1.97	9.02	BIOGENIC	1.4	6.74	4.48	ST_I	NO	7	0	0
A5	D	6/27/2001	12:19	>4	2	>4	14.69	16.57	1.88	15.63	BIOGENIC	0.24	3.67	1.7	ST_I_ON_III	NO	8	0	0
A5	E	6/27/2001	12:20	>4	2	>4	14.66	15.34	0.67	15	PHYSICAL	0.77	4.35	2.6	ST_I_ON_III	NO	9	0	0
A5	F	6/27/2001	12:21	>4	2	>4	14.59	14.93	0.34	14.76	PHYSICAL	0.05	2.95	1.85	ST_I_ON_III	NO	8	0	0
B3	B	6/27/2001	11:04	>4	3	>4	16.04	17	0.97	16.52	PHYSICAL	1.16	4.15	2.94	ST_I_ON_III	NO	9	2	0.92
B3	E	6/28/2001	12:34	>4	3	>4	13.96	14.83	0.87	14.4	PHYSICAL	0.1	4.59	2.8	ST_I	NO	5	0	0
B3	F	6/28/2001	12:35	>4	3	>4	13.09	14.3	1.21	13.7	BIOGENIC	0.41	3.42	2.53	ST_I_ON_III	NO	9	0	0
B4	A	6/27/2001	11:31	>4	2	>4	12.02	13.99	1.97	13.01	PHYSICAL	0.16	4.72	2.4	ST_I_ON_III	NO	9	4	0.7
B4	B	6/27/2001	11:32	>4	1	>4	12.95	13.52	0.57	13.24	BIOGENIC	0.1	5.23	2.01	ST_I_ON_III	NO	8	0	0
B4	C	6/27/2001	11:32	>4	1	>4	13.21	14.04	0.83	13.63	PHYSICAL	2.23	5.54	4.07	ST_I_ON_III	NO	11	0	0
B5	A	6/27/2001	12:40	>4	2	>4	14.73	15.27	0.53	15	PHYSICAL	1.21	4.25	2.49	ST_I_ON_III	NO	9	0	0
B5	B	6/27/2001	12:41	>4	2	>4	15.02	16.38	1.35	15.7	PHYSICAL	0.72	3.77	2.24	ST_I_ON_III	NO	8	0	0
B5	C	6/27/2001	12:42	>4	2	>4	16.86	17.2	0.34	17.03	PHYSICAL	1.4	3.91	2.9	ST_I	NO	5	0	0
C3	A	6/27/2001	11:07	>4	3	>4	13.06	13.58	0.52	13.32	PHYSICAL	1.35	3.11	2.45	ST_I_ON_III	NO	9	0	0
C3	B	6/27/2001	11:08	>4	3	>4	11.71	12.28	0.57	11.99	PHYSICAL	0.36	3.42	1.57	ST_I	NO	4	0	0
C3	C	6/27/2001	11:09	>4	3	>4	13.42	15.24	1.82	14.33	PHYSICAL	1.24	3.03	2.26	ST_I	NO	5	0	0
C4	A	6/27/2001	11:37	>4	1	>4	15.75	16.68	0.93	16.22	INDETERMINATE	1.5	3.73	2.73	ST_I_ON_III	NO	9	0	0
C4	B	6/27/2001	11:38	>4	1	>4	15.96	16.53	0.57	16.24	BIOGENIC	0.26	4.35	2.16	ST_I_ON_III	NO	8	0	0
C4	C	6/27/2001	11:38	>4	1	>4	17	17.68	0.68	17.34	PHYSICAL	0.92	5.31	3.81	ST_I	NO	7	0	0
C5	A	6/27/2001	12:45	>4	2	>4	8.36	9.81	1.45	9.08	PHYSICAL	1.69	5.51	3.35	ST_I	NO	6	0	0
C5	B	6/27/2001	12:46	>4	3	>4	15.7	16.23	0.53	15.97	PHYSICAL	1.71	3.99	3.05	ST_I_ON_III	NO	10	0	0
C5	C	6/27/2001	12:47	>4	2	>4	13.86	14.54	0.68	14.2	PHYSICAL	0.63	6.47	3.42	ST_I_ON_III	NO	10	3	0.69
D3	A	6/27/2001	11:12	>4	3	>4	19.33	19.43	0.1	19.38	PHYSICAL	2.18	3.16	2.59	ST_III	NO	9	0	0
D3	B	6/27/2001	11:13	>4	3	>4	18.6	20.05	1.45	19.33	PHYSICAL	1.81	4.09	2.88	ST_I	NO	5	3	0.49
D3	C	6/27/2001	11:14	>4	3	>4	18.34	19.33	0.98	18.83	PHYSICAL	0.41	3.63	2.3	ST_I	NO	5	2	0.26
D4	A	6/27/2001	11:41	>4	3	>4	13.96	14.69	0.72	14.32	PHYSICAL	1.5	5.85	3.43	ST_I_ON_III	NO	10	0	0
D4	B	6/27/2001	11:42	>4	3	>4	10.97	11.26	0.29	11.11	PHYSICAL	0.48	3.57	2.06	ST_I	NO	4	4	0.24
D4	C	6/27/2001	11:43	>4	3	>4	15.02	16.23	1.21	15.63	PHYSICAL	0.29	2.71	1.71	ST_I	NO	4	0	0
D5	D	6/28/2001	12:46	>4	2	>4	13.96	14.54	0.58	14.25	PHYSICAL	0.58	2.95	1.45	ST_I_ON_III	NO	7	0	0
D5	E	6/28/2001	12:46	>4	3	>4	12.27	13.04	0.77	12.66	PHYSICAL	0.53	1.93	1.37	ST_I_ON_III	NO	7	0	0
D5	F	6/28/2001	12:47	>4	2	>4	14.4	14.83	0.43	14.61	PHYSICAL	0.24	2.51	1.21	ST_I_ON_III	NO	7	0	0
E3	A	6/27/2001	11:17	>4	3	>4	16.99	17.41	0.41	17.2	PHYSICAL	0.05	2.5	2..83	ST_I_ON_III	NO	8	0	0
E3	B	6/27/2001	11:17	>4	2	>4	16.53	17.36	0.83	16.94	PHYSICAL	0.05	2.18	0.5	ST_I	NO	2	1	0.47
E3	C	6/27/2001	11:18	>4	3	>4	17.05	17.41	0.36	17.23	PHYSICAL	0.1	1.81	0.75	ST_I	NO	2	0	0
E4	A	6/27/2001	11:46	>4	3	>4	18.79	19.08	0.29	18.94	PHYSICAL	1.11	3.57	2.54	ST_I_ON_III	NO	9	0	0
E4	B	6/27/2001	11:47	>4	2	>4	17.41	18.2	0.79	17.8	PHYSICAL	1.96	2.7	2.5	ST_I	NO	5	0	0
E4	E	6/28/2001	12:41	>4	3	>4	13.9	15.51	1.61	14.71	PHYSICAL	0.59	3.56	2.24	ST_I	NO	4	0	0
E5	C	6/27/2001	11:54	>4	3	>4	18.54	19.76	1.22	19.15	PHYSICAL	NA	NA	NA	ST_I	NO	99	1	0.59
E5	F	6/28/2001	12:54	>4	3	>4	13.71	14.59	0.88	14.15	PHYSICAL	1.46	3.8	2.17	ST_I	NO	4	6	0.36
E5	G	6/28/2001	12:55	>4	3	>4	11.51	13.02	1.51	12.27	PHYSICAL	0.88	2.5	1.79	ST_I_ON_III	NO	8	6	0.36

Appendix B1 (continued)
REMOTS® Results for the June 2001 Survey over the CLIS 00 Mound

Station	Replicate	Date	Time	Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Methane				DM Surface	Comments
				Min	Max	Mean	Min	Max	Mean	Diameter	Min	Max	Mean	Layer	
A3	A	6/27/2001	10:58	19.08	19.47	>19.28	0	0	0	0	0	0	0	6.33	DM>P,FRESH DM&RPD/HISTORICAL DM&RPD,TUBES@SURF,FILLED VOID NEAR TIME STAMP?
A3	B	6/27/2001	10:59	18.45	18.55	>18.5	0	0	0	0	0	0	0	6.61	DM>P,FRESH DM&RPD/HISTORICAL DM&RPD,ORGANISM CHANNEL,REDUCED SEDS@SURF
A3	C	6/27/2001	11:00	17.63	17.83	>17.73	0	0	0	0	0	0	0	6.9	DM>P,DM LAYERING,RELIC RPD,REDUCED SED@SURF,CLASTS,VOID LEFT OF TIME?PHYSICAL
A4	B	6/27/2001	11:26	16.58	16.99	>16.79	0	0	0	0	0	0	0	0	DM>P,BURROW/VOID,SM TUBES@SURF UPPER RT
A4	D	6/28/2001	12:27	9.02	10.98	>10	0	0	0	0	0	0	0	0	DM>P,SHELL HASH&CLASTS&ROCK@SURF
A4	E	6/28/2001	12:28	8.03	10	>9.02	0	0	0	0	0	0	0	0	DM>P.DISTURBED SEDS,PATCHES OF REDUCED SED
A5	D	6/27/2001	12:19	14.69	16.57	>15.63	0	0	0	0	0	0	0	5.8	DM>P,DM LAYERING,BIO BURROWS@SURF&DEPTH,TUBES@SURF,VOIDS
A5	E	6/27/2001	12:20	14.66	15.34	>15	0	0	0	0	0	0	0	7.39	DM>P? OR DM OVER AMBIENT?,DM LAYERING,WIPER CLAST@SURF?
A5	F	6/27/2001	12:21	14.59	14.93	>14.76	0	0	0	0	0	0	0	6.03	DM>P OR DM OVER AMBIENT,VOIDS,WIPER CLASTS@SURF?
B3	B	6/27/2001	11:04	16.04	17	>16.52	0	0	0	0	0	0	0	8.61	DM>P,DM LAYERING,RELIC RPD,VOID LOWER RIGHT
B3	E	6/28/2001	12:34	13.96	14.83	>14.4	0	0	0	0	0	0	0	8.79	DM>P,DM LAYERING,RELIC RPD,REDUCED SED NEAR SURF
B3	F	6/28/2001	12:35	13.09	14.3	>13.7	0	0	0	0	0	0	0	12	DM>P,DM LAYERING,RELIC RPD,BURROW,VOID?,REDUCED SED@SURF
B4	A	6/27/2001	11:31	12.02	13.99	>13.01	0	0	0	0	0	0	0	11.39	DM>P,DM LAYERING,VOID
B4	B	6/27/2001	11:32	12.95	13.52	>13.24	0	0	0	0	0	0	0	0	DM>P,LG HORIZONTAL BURROW,REDUCED SED@SURF,VOID BENEATH BURROW
B4	C	6/27/2001	11:32	13.21	14.04	>13.63	0	0	0	0	0	0	0	0	DM>P,LG HORIZONTAL BURROW,SM TUBES@SURF,VOID NEAR LEFT OF BURROW?
B5	A	6/27/2001	12:40	14.73	15.27	>15	0	0	0	0	0	0	0	6.91	DM>P OR DM OVER AMBIENT,DM LAYERING,RELIC RPD,BURROWS,VOIDS,TUBES@SURF
B5	B	6/27/2001	12:41	15.02	16.38	>15.7	0	0	0	0	0	0	0	6.68	DM>P OR DM/AMBIENT,RELIC RPD,LG BURROW,VOIDS,TUBES@SURF,WIPER CLASTS@SURF
B5	C	6/27/2001	12:42	16.86	17.2	>17.03	0	0	0	0	0	0	0	6.76	DM>P OR DM/AMBIENT,VERY LG BURROW,TUBES@SURF
C3	A	6/27/2001	11:07	13.06	13.58	>13.32	0	0	0	0	0	0	0	6.06	DM>P,DM LAYERING,LIGHT CLAY LOWER RT
C3	B	6/27/2001	11:08	11.71	12.28	>11.99	0	0	0	0	0	0	0	0	DM>P,SM WORM UNDER RPD,WIPER CLAST@SURF
C3	C	6/27/2001	11:09	13.42	15.24	>14.33	0	0	0	0	0	0	0	0	DM>P,REDUCED SED@SURF,MOTTLED DM
C4	A	6/27/2001	11:37	15.75	16.68	>16.22	0	0	0	0	0	0	0	12.5	DM>P,EXTENSIVE BURROWING,SHELL&SM TUBES@SURF,DM LAYERING
C4	B	6/27/2001	11:38	15.96	16.53	>16.24	0	0	0	0	0	0	0	8	DM>P,EXTENSIVE BURROW,REDUCED SED@SURF,DM LAYERING
C4	C	6/27/2001	11:38	17	17.68	>17.34	0	0	0	0	0	0	0	0	DM>P,RPD W/MEDIUM SAND,TUBES@SURF,S/M
C5	A	6/27/2001	12:45	8.36	9.81	>9.08	0	0	0	0	0	0	0	9.08	FRESH DM>P?, NO VOIDS?
C5	B	6/27/2001	12:46	0	0	0	0	0	0	0	0	0	0	6.8	FRESH DM LAYER/HISTORIC DM?,DM /AMBIENT?,REDUCED CLAST IN FF
C5	C	6/27/2001	12:47	13.86	14.54	>14.2	0	0	0	0	0	0	0	6.86	DM>P OR DM LAYER/AMBIENT?,VOIDS
D3	A	6/27/2001	11:12	19.33	19.43	>19.38	0	0	0	0	0	0	0	0	DM>P,DM LAYERING,VOID,MOTTLED SEDS IN RPD
D3	B	6/27/2001	11:13	18.6	20.05	>19.33	0	0	0	0	0	0	0	0	DM>P,DM LAYERING,SM TUBE@SURF,REDUCED SEDS@SURF,WIPER CLASTS
D3	C	6/27/2001	11:14	18.34	19.33	>18.83	0	0	0	0	0	0	0	0	DM>P, DM LAYERING
D4	A	6/27/2001	11:41	13.96	14.69	>14.32	0	0	0	0	0	0	0	0	DM>P,VOIDS,WORMS,TUBES@SURF
D4	B	6/27/2001	11:42	10.97	11.26	>11.11	0	0	0	0	0	0	0	0	DM>P,FINE SAND BELOW RPD,SM CLASTS,GRADED BEDDING
D4	C	6/27/2001	11:43	15.02	16.23	>15.63	0	0	0	0	0	0	0	10	DM>P,DM LAYERING
D5	D	6/28/2001	12:46	0	0	0	0	0	0	0	0	0	0	0	POSSIBLY AMBIENT >P OR RELIC DM,TUBES@SURF
D5	E	6/28/2001	12:46	0	0	0	0	0	0	0	0	0	0	0	AMBIENT>P OR RELIC DM,BURROW,SM VOIDS,WIPER CLASTS@SURF
D5	F	6/28/2001	12:47	0	0	0	0	0	0	0	0	0	0	0	AMBIENT>P OR RELIC DM,SM VOID, SM WIPER CLAST@SURF
E3	A	6/27/2001	11:17	16.99	17.41	>17.2	0	0	0	0	0	0	0	6.33	DM>P,DM LAYERING,SM VOID,TUBES@SURF
E3	B	6/27/2001	11:17	16.53	17.36	>16.94	0	0	0	0	0	0	0	0	DM>P,DM LAYERING,WORMS,TUBES@SURF,BURROWING ANEMONE
E3	C	6/27/2001	11:18	17.05	17.41	>17.23	0	0	0	0	0	0	0	14	DM>P,DM LAYERING,REDUCED SED&TUBES@SURF
E4	A	6/27/2001	11:46	18.79	19.08	>18.94	0	0	0	0	0	0	0	6.14	DM>P,FRESHER DM/BANDS OF HISTORICAL DM OR AMBIENT SED,SM VOIDS@TUBES
E4	B	6/27/2001	11:47	17.41	18.2	>17.8	0	0	0	0	0	0	0	0	DM>P,DM LAYERING, TUBES, RELIC RPD
E4	E	6/28/2001	12:41	13.9	15.51	>14.71	0	0	0	0	0	0	0	6	DM>P,DM LAYERING,SM WORM
E5	C	6/27/2001	11:54	18.54	19.76	>19.15	0	0	0	0	0	0	0	0	DM>P OR AMBIENT?,TUBES@SURF,WIPER CLAST
E5	F	6/28/2001	12:54	13.71	14.59	>14.15	0	0	0	0	0	0	0	0	DM>P OR AMBIENT?
E5	G	6/28/2001	12:55	11.51	13.02	>12.27	0	0	0	0	0	0	0	0	DM>P OR AMBIENT SILT/CLAY?

Appendix B2
REMOTS® Results for the June 2001 Survey over the CLIS 99 Mound

Station	Replicate	Date	Time	Grain Size			Camera Penetration (cm)				Surface Roughness	Apparent RPD Thickness (cm)			Successional Stage	Low DO	OSI	Mud Clasts	
				Min	Max	Maj Mode	Min	Max	Range	Mean		Min	Max	Mean				Count	Diameter
A1	A	6/27/2001	9:42	>4	2	>4	15.57	15.89	0.31	15.73	PHYSICAL	2.08	4.43	3.49	ST_I_ON_III	NO	10	0	0
A1	B	6/27/2001	9:43	>4	3	>4	15.1	15.47	0.36	15.29	PHYSICAL	0.78	4.37	3.07	ST_I_ON_III	NO	10	0	0
A1	C	6/27/2001	9:44	>4	3	>4	14.48	14.95	0.47	14.71	PHYSICAL	0.68	7.03	5	ST_I	NO	7	0	0
A2	A	6/27/2001	10:19	>4	3	>4	15.65	16.43	0.78	16.04	PHYSICAL	2.38	5.54	4.27	ST_I_ON_III	NO	11	0	0
A2	B	6/27/2001	10:20	>4	3	>4	18.19	18.81	0.62	18.5	PHYSICAL	1.24	2.8	2.02	ST_I	NO	4	0	0
A2	C	6/27/2001	10:23	>4	3	>4	17.25	17.41	0.16	17.33	PHYSICAL	0.88	2.85	2.29	ST_I	NO	5	0	0
B1	B	6/27/2001	9:48	>4	3	>4	14.17	15.16	0.99	14.66	PHYSICAL	3.18	7.24	3.58	ST_I_ON_III	NO	11	0	0
B1	C	6/27/2001	9:48	>4	3	>4	14.56	15.13	0.57	14.84	PHYSICAL	1.4	4.87	3.4	ST_I	NO	6	0	0
B1	E	6/27/2001	9:57	>4	3	>4	5.28	5.8	0.52	5.54	PHYSICAL	0.05	2.95	2.05	ST_I	NO	4	0	0
B2	A	6/27/2001	10:26	>4	3	>4	14.09	15.91	1.81	15	PHYSICAL	NA	NA	NA	ST_I	NO	99	0	0
B2	B	6/27/2001	10:27	>4	3	>4	15.49	16.22	0.73	15.85	PHYSICAL	0.73	3.58	2.49	ST_III	NO	5	0	0
B2	C	6/27/2001	10:28	>4	3	>4	9.07	9.43	0.36	9.25	PHYSICAL	0.26	2.59	1.12	ST_I	NO	3	2	0.86
C1	A	6/27/2001	10:01	>4	3	>4	14.04	16.58	2.54	15.31	PHYSICAL	0.52	5.8	4.03	ST_I	NO	17	2	0.7
C1	B	6/27/2001	10:02	>4	3	>4	13.89	14.77	0.88	14.33	PHYSICAL	0.31	4.56	2.75	ST_I	NO	5	2	0.31
C1	C	6/27/2001	10:03	>4	3	>4	14.92	15.23	0.31	15.08	PHYSICAL	1.3	5.23	2.02	ST_I	NO	4	4	0.22
C2	A	6/27/2001	10:33	>4	3	>4	16.06	16.37	0.31	16.22	PHYSICAL	0.31	2.07	1.3	ST_I	NO	3	0	0
C2	B	6/27/2001	10:32	>4	3	>4	14.4	15.22	0.82	14.81	PHYSICAL	1.3	4.98	3.07	ST_I	NO	6	2	0.6
C2	C	6/27/2001	10:33	>4	3	>4	13.38	14.4	1.01	13.89	PHYSICAL	0.77	3.43	1.84	ST_I_ON_III	NO	8	1	0.46
D1	A	6/27/2001	10:06	>4	3	>4	17.88	18.19	0.31	18.03	PHYSICAL	2.69	6.99	3	ST_I	NO	5	0	0
D1	B	6/27/2001	10:06	>4	3	>4	11.5	15.8	4.3	13.65	BIOGENIC	NA	NA	NA	ST_I	NO	99	0	0
D1	C	6/27/2001	10:07	>4	3	>4	14.61	14.61	0	14.61	PHYSICAL	2.38	5.03	3.83	ST_I_ON_III	NO	11	0	0
D2	A	6/27/2001	10:36	>4	2	>4	14.35	15.02	0.68	14.69	PHYSICAL	0.72	2.95	2.42	ST_I_TO_II	NO	6	0	0
D2	B	6/27/2001	10:37	>4	2	>4	19.52	19.81	0.29	19.66	PHYSICAL	0.26	1.5	1.01	ST_I_ON_III	NO	7	4	0.2
D2	C	6/27/2001	10:39	>4	2	>4	15.75	16.43	0.68	16.09	PHYSICAL	0.43	3.19	2.17	ST_I_ON_III	NO	8	1	0.4
E1	A	6/27/2001	10:10	>4	3	>4	14.04	14.4	0.36	14.22	PHYSICAL	2.07	4.72	3.81	ST_III	NO	11	0	0
E1	B	6/27/2001	10:11	>4	3	>4	15.34	16.22	0.88	15.78	PHYSICAL	1.5	5.65	4.22	ST_I_ON_III	NO	11	0	0
E1	C	6/27/2001	10:11	>4	3	>4	15.03	15.23	0.21	15.13	PHYSICAL	0.16	5.54	3.54	ST_I	NO	6	0	0
E2	A	6/27/2001	10:42	>4	2	>4	18.12	19.04	0.92	18.58	PHYSICAL	3.86	9.32	8.12	ST_I	NO	7	1	0.4
E2	B	6/27/2001	10:43	>4	2	>4	14.11	16.23	2.13	15.17	BIOGENIC	0.5	1.56	1.08	ST_I_ON_III	NO	7	4	0.88
E2	C	6/27/2001	10:44	>4	2	>4	16.62	16.96	0.34	16.79	PHYSICAL	2.75	9.47	7.94	ST_I_ON_III	NO	11	3	0.24

Appendix B2 (continued)
REMOTS® Results for the June 2001 Survey over the CLIS 99 Mound

Station	Replicate	Date	Time	Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Methane				DM Surface	Comments
				Min	Max	Mean	Min	Max	Mean	Diameter	Min	Max	Mean	Layer	
A1	A	6/27/2001	9:42	0	0	0	0	0	0	0	0	0	0	12	RELIC DM OVER AMBIENT, SANDY M, SM TUBES, HYDROID?, VOID, BURROW, RELIC RPD
A1	B	6/27/2001	9:43	0	0	0	0	0	0	0	0	0	0	12	RELIC DM/AMBIENT, SANDY M, RELIC RPD, SM VOID LOWER LEFT, SM TUBES
A1	C	6/27/2001	9:44	0	0	0	0	0	0	0	0	0	0	12	RELIC DM/AMBIENT, SANDY M, SM WORMS @Z,SHELL BITS,RELIC RPD
A2	A	6/27/2001	10:19	15.65	16.43	>16.04	0	0	0	0	0	0	0	10	DM>P,VOIDS,TUBES@SURF,LAYERED DM,RELIC RPD
A2	B	6/27/2001	10:20	18.19	18.81	>18.5	0	0	0	0	0	0	0	12	DM>P,LAYERED DM, RELIC RPD,BURROW,TUBES@SURF
A2	C	6/27/2001	10:23	17.25	17.41	>17.33	0	0	0	0	0	0	0	12	DM>P,LAYERED DM,RELIC RPD
B1	B	6/27/2001	9:48	14.17	15.16	>14.66	0	0	0	0	0	0	0	12	RELIC DM>P,HISTORIC RPD DEEP,DM LAYERING
B1	C	6/27/2001	9:48	14.56	15.13	>14.84	0	0	0	0	0	0	0	11.39	RELIC DM>P,SM TUBES@SURF
B1	E	6/27/2001	9:57	5.28	5.8	>5.54	0	0	0	0	0	0	0	0	DM>P,RPD>P
B2	A	6/27/2001	10:26	14.09	15.91	>15	0	0	0	0	0	0	0	0	DM>P,DEBRIS@SURF SHELL OR MAN MADE
B2	B	6/27/2001	10:27	15.49	16.22	>15.85	0	0	0	0	0	0	0	0	DM>P,BANDED&MIXED RPD/HISTORICAL DM&RPD,VOIDS
B2	C	6/27/2001	10:28	9.07	9.43	>9.25	0	0	0	0	0	0	0	0	DM>P,MOTTLED RPD,CLASTS IN FF
C1	A	6/27/2001	10:01	14.04	16.58	>15.31	0	0	0	0	0	0	0	11.5	DM>P,DM LAYERING, RELIC RPD
C1	B	6/27/2001	10:02	13.89	14.77	>14.33	0	0	0	0	0	0	0	12	DM>P,SMALL WORM@CENTER,LAYERED DM,RELIC RPD
C1	C	6/27/2001	10:03	14.92	15.23	>15.08	0	0	0	0	0	0	0	12	DM>P,LAYERED DM,RELIC RPD
C2	A	6/27/2001	10:33	16.06	16.37	>16.22	0	0	0	0	0	0	0	0	DM>P,TUBES@SURF,MOTTLED RPD,REDUCED SEDS@SURF
C2	B	6/27/2001	10:32	14.4	15.22	>14.81	0	0	0	0	0	0	0	0	DM>P,FRESH DM/HISTORIC?,TUBES@SURF
C2	C	6/27/2001	10:33	13.38	14.4	>13.89	0	0	0	0	0	0	0	0	DM>P,VOIDS
D1	A	6/27/2001	10:06	17.88	18.19	>18.03	0	0	0	0	0	0	0	13	DM>P,LAYERED DM,RELIC RPD
D1	B	6/27/2001	10:06	11.5	15.8	>13.65	0	0	0	0	0	0	0	0	DM&RPD>P,DISECTED BURROW@SURF
D1	C	6/27/2001	10:07	14.61	14.61	>14.61	0	0	0	0	0	0	0	0	DM>P,LAYERED DM,BURROW W/FECAL?,WIPER CLAST@SURF
D2	A	6/27/2001	10:36	14.35	15.02	>14.69	0	0	0	0	0	0	0	0	DM>P,AMP.TUBE, SANDY DM
D2	B	6/27/2001	10:37	19.52	19.81	>19.66	0	0	0	0	0	0	0	0	DM>P,REDUCED SEDS@SURF, VOID
D2	C	6/27/2001	10:39	15.75	16.43	>16.09	0	0	0	0	0	0	0	8	DM>P,LAYERED DM, RELIC RPD,VOID,TUBES@SURF,REDUCED SED@SURF
E1	A	6/27/2001	10:10	14.04	14.4	>14.22	0	0	0	0	0	0	0	0	DM>P,MANY BURROWS/VOIDS
E1	B	6/27/2001	10:11	15.34	16.22	>15.78	0	0	0	0	0	0	0	0	DM>P,MANY BURROWS/VOIDS
E1	C	6/27/2001	10:11	15.03	15.23	>15.13	0	0	0	0	0	0	0	0	DM>P,TUBES@SURF,SM WORM IN RPD
E2	A	6/27/2001	10:42	18.12	19.04	>18.58	0	0	0	0	0	0	0	14	DM>P,LAYERED DM,RELIC RPD,TUBES@SURF
E2	B	6/27/2001	10:43	14.11	16.23	>15.17	0	0	0	0	0	0	0	0	DM>P,HISTORICAL DM OR AMBIENT SEDS AT DEPTH,BURROW&REDUCED SED@SURF
E2	C	6/27/2001	10:44	16.62	16.96	>16.79	0	0	0	0	0	0	0	11.39	DM>P?,FRESH DM/HISTORICAL DM OR AMBIENT SEDS?,VOID LOWER LEFT,SM TUBES@SURF

Appendix B3
REMOTS® Results for the June 2001 Survey over the CLIS 97/98 Mound Complex

Station	Replicate	Date	Time	Grain Size			Camera Penetration (cm)				Surface Roughness	Apparent RPD Thickness (cm)			Successional Stage	Low DO	OSI	Mud Clasts	
				Min	Max	Maj Mode	Min	Max	Range	Mean		Min	Max	Mean				Count	Diameter
45	A	6/27/2001	13:00	>4	4	>4	6.74	8.2	1.47	7.47	PHYSICAL	2.06	4.35	3.61	ST_I_ON_III	NO	10	1	0.98
45	C	6/27/2001	13:02	>4	2	>4	14.55	15.34	0.79	14.95	BIOGENIC	3.26	5.56	4.64	ST_III	NO	11	0	0
45	F	6/28/2001	12:00	>4	2	>4	11.29	11.91	0.62	11.6	BIOGENIC	3.48	6.35	5.14	ST_I_ON_III	NO	11	0	0
47	A	6/27/2001	13:13	>4	2	>4	15.28	16.74	1.46	16.01	PHYSICAL	1	3	2	ST_I_ON_III	NO	8	0	0
47	B	6/27/2001	13:14	>4	2	>4	16.29	16.85	0.56	16.57	BIOGENIC	2.03	4.01	2.75	ST_I	NO	5	0	0
47	C	6/27/2001	13:15	>4	2	>4	16.52	16.8	0.28	16.66	BIOGENIC	2	5	2.77	ST_I	NO	5	0	0
49	A	6/27/2001	13:19	>4	2	>4	16.4	17.53	1.12	16.97	INDETERMINATE	0.5	2.5	2	ST_I_ON_III	NO	8	0	0
49	B	6/27/2001	13:20	>4	2	>4	16.85	17.19	0.34	17.02	PHYSICAL	0.2	4	2.28	ST_I	NO	5	0	0
49	C	6/27/2001	13:20	>4	2	>4	15.73	16.74	1.01	16.24	PHYSICAL	1.57	5.34	3	ST_I_ON_III	NO	9	1	0.71
51	A	6/27/2001	13:27	>4	2	>4	17.13	17.42	0.28	17.28	PHYSICAL	2.5	5	3	ST_I	NO	5	0	0
51	B	6/27/2001	13:28	>4	2	>4	15.11	16.03	0.92	15.57	PHYSICAL	3.86	7.01	5.81	ST_I	NO	7	0	0
51	C	6/27/2001	13:29	>4	4	>4	14.95	15.6	0.65	15.27	PHYSICAL	2.93	6.74	5.22	ST_I_ON_III	NO	11	0	0
52	A	6/27/2001	13:32	>4	2	>4	11.09	11.47	0.38	11.28	BIOGENIC	2.93	5.76	4.74	ST_I_ON_III	NO	11	0	0
52	B	6/27/2001	13:36	>4	2	>4	11.25	11.47	0.22	11.36	PHYSICAL	1.52	4.73	4.07	ST_III	NO	11	0	0
52	C	6/27/2001	13:39	>4	2	>4	11.47	12.23	0.76	11.85	PHYSICAL	3	5	4	ST_III	NO	11	0	0
53	A	6/27/2001	13:44	>4	2	>4	14.51	15.54	1.03	15.03	PHYSICAL	4	6	5	ST_I_ON_III	NO	11	0	0
53	B	6/27/2001	13:44	>4	2	>4	16.78	17.43	0.66	17.1	BIOGENIC	2.68	5.74	4.55	ST_II	NO	10	0	0
53	C	6/27/2001	13:45	>4	2	>4	15.68	16.39	0.71	16.04	BIOGENIC	0.87	4.97	4.35	ST_I_ON_III	NO	11	0	0
58	A	6/27/2001	8:57	>4	2	>4	16.27	16.49	0.22	16.38	PHYSICAL	3.28	7.22	4.55	ST_I	NO	7	0	0
58	B	6/27/2001	8:57	>4	2	>4	6.55	7.11	0.56	6.83	INDETERMINATE	0.22	6.05	4.4	ST_I_ON_III	NO	11	0	0
58	C	6/27/2001	8:58	>4	2	>4	14.55	15.38	0.83	14.97	BIOGENIC	0.44	4.28	3	ST_I_ON_III	NO	9	0	0
59	A	6/27/2001	9:00	>4	2	>4	19.05	19.38	0.33	19.21	BIOGENIC	1.17	5.94	5.26	ST_I_ON_III	NO	11	0	0
59	B	6/27/2001	9:01	>4	2	>4	15.16	16.88	1.72	16.02	PHYSICAL	2	5	2.5	ST_I_TO_II	NO	6	1	0.7
59	C	6/27/2001	9:02	>4	2	>4	15.72	16.49	0.78	16.1	PHYSICAL	1.06	4.44	3.86	ST_I_ON_III	NO	11	2	1.13
60	A	6/27/2001	9:04	>4	2	>4	9.16	10.27	1.11	9.72	INDETERMINATE	1	3	2.5	ST_III	NO	9	0	0
60	B	6/27/2001	9:05	>4	1	>4	8.33	8.89	0.56	8.61	PHYSICAL	2.5	4.83	3.99	ST_I	NO	7	0	0
60	C	6/27/2001	9:06	>4	1	>4	13.99	14.38	0.39	14.19	BIOGENIC	1	4	2.45	ST_I_ON_III	NO	9	0	0
61	A	6/27/2001	9:08	>4	2	>4	12.32	16.41	4.09	14.36	PHYSICAL	1.55	5.58	4.35	ST_I_ON_III	NO	11	0	0
61	B	6/27/2001	9:09	>4	2	>4	10.94	12.65	1.71	11.8	PHYSICAL	0.99	3	2.36	ST_I_ON_III	NO	9	0	0
61	C	6/27/2001	9:09	>4	2	>4	14.81	15.47	0.66	15.14	BIOGENIC	3.15	4.2	2.45	ST_II_ON_III	NO	9	0	0
62	C	6/27/2001	9:19	>4	1	>4	4.92	9.06	4.14	6.99	PHYSICAL	2.76	5.03	3.51	ST_III	NO	10	0	0
62	E	6/28/2001	12:07	>4	1	3 to 2	12.76	13.2	0.44	12.98	INDETERMINATE	NA	NA	NA	ST_I	NO	99	0	0
62	F	6/28/2001	12:08	>4	1	2 to 1	5.71	7.23	1.52	6.47	PHYSICAL	NA	NA	NA	ST_I	NO	99	0	0
63	A	6/28/2001	9:15	>4	2	>4	15.7	16.25	0.54	15.98	INDETERMINATE	3.48	6.36	4.75	ST_I_ON_III	NO	11	0	0
63	B	6/27/2001	9:16	>4	2	>4	17.25	17.83	0.58	17.54	PHYSICAL	2.8	4.39	3.55	ST_I_ON_III	NO	10	5	0.55
63	C	6/27/2001	9:16	>4	2	>4	10.76	13.42	2.66	12.09	PHYSICAL	1.85	4.89	2.25	ST_I_ON_III	NO	8	0	0
64	A	6/27/2001	9:19	>4	2	>4	15.59	16.41	0.82	16	PHYSICAL	0.43	5	3.67	ST_I_ON_III	NO	10	1	0.64
64	B	6/27/2001	9:20	>4	2	>4	15.38	16.08	0.71	15.73	PHYSICAL	0.22	3	2.5	ST_I_ON_III	NO	9	0	0
64	C	6/27/2001	9:20	>4	2	>4	17.28	17.61	0.33	17.44	BIOGENIC	0.98	5.81	4.28	ST_I	NO	7	0	0
69	A	6/27/2001	14:11	>4	2	>4	11.58	11.86	0.27	11.72	BIOGENIC	3	6	4.5	ST_I_ON_III	NO	11	0	0
69	B	6/27/2001	14:12	>4	2	3 to 2	14.12	14.67	0.55	14.4	BIOGENIC	3.19	5.93	4.9	ST_II_TO_III	NO	10	0	0
69	C	6/27/2001	14:12	>4	2	>4	5.55	5.82	0.27	5.68	INDETERMINATE	0.27	4.18	2.72	ST_I	NO	5	0	0
70	A	6/27/2001	14:06	>4	2	4 to 3	6.56	8.74	2.19	7.65	PHYSICAL	2.02	4.59	3.52	ST_III	NO	10	0	0
70	B	6/27/2001	14:07	>4	3	4 to 3	11.64	12.3	0.66	11.97	BIOGENIC	3.11	7.49	5.64	ST_III	NO	11	0	0
70	C	6/27/2001	14:08	>4	2	>4	14.59	15.03	0.44	14.81	BIOGENIC	2.24	5.41	4.48	ST_I_ON_III	NO	11	0	0
71	C	6/28/2001	14:02	>4	2	4 to 3	13.61	14.54	0.93	14.07	PHYSICAL	1.24	4.28	3.66	ST_III	NO	10	0	0
71	D	6/28/2001	12:12	>4	1	4 to 3	4.81	6.67	1.86	5.74	PHYSICAL	2.19	4.7	3.84	ST_III	NO	11	0	0
71	E	6/28/2001	12:12	>4	2	4 to 3	10.32	11.27	0.95	10.79	PHYSICAL	2.06	5.71	4.95	ST_III	NO	11	0	0
79	A	6/27/2001	14:24	>4	2	>4	17.61	18.7	1.09	18.15	BIOGENIC	3	6	5.04	ST_I_ON_III	NO	11	0	0
79	B	6/27/2001	14:25	>4	2	>4	14.4	15.54	1.14	14.97	PHYSICAL	0.16	6.47	4.6	ST_III	NO	11	0	0
79	C	6/27/2001	14:26	>4	2	>4	13.97	15.29	1.32	14.63	BIOGENIC	0.5	4.06	3.54	ST_I_ON_III	NO	10	0	0
81	A	6/27/2001	14:18	>4	4	>4	14.51	15	0.49	14.76	BIOGENIC	1.47	5.22	3.73	ST_I_ON_III	NO	10	0	0
81	B	6/27/2001	14:18	>4	2	>4	16.03	16.58	0.54	16.3	PHYSICAL	1.74	5.6	4.14	ST_I	NO	7	1	0.22
81	C	6/27/2001	14:19	>4	2	>4	15.27	15.38	0.11	15.33	BIOGENIC	0.65	3.64	2.85	ST_I_ON_III	NO	9	0	0
88	A	6/27/2001	14:38	>4	2	>4	6.52	7.45	0.92	6.98	PHYSICAL	1.63	4.84	3.12	ST_I	NO	6	0	0
88	B	6/27/2001	14:38	>4	2	>4	13.91	14.62	0.71	14.27	BIOGENIC	3.32	6.68	5.18	ST_III	NO	11	0	0
88	C	6/27/2001	14:39	>4	2	>4	15.22	15.27	0.05	15.25	BIOGENIC	3.26	8.37	6.12	ST_III	NO	11	0	0
102	A	6/27/2001	13:06	>4	2	>4	12.42	12.81	0.39	12.61	PHYSICAL	1.29	4.33	2.36	ST_III	NO	9	0	0
102	B	6/27/2001	13:08	>4	2	>4	15.28	15.73	0.45	15.51	PHYSICAL	2.53	6.07	2.67	ST_III	NO	9	0	0
102	C	6/27/2001	13:08	>4	2	>4	13.93	14.61	0.67	14.27	BIOGENIC	2.19	6.07	5.16	ST_III	NO	11	0	0
103	A	6/27/2001	14:31	>4	2	>4	14.89	15.11	0.22	15	BIOGENIC	2.34	9.95	7.75	ST_I_ON_III	NO	11	0	0
103	B	6/27/2001	14:32	>4	2	>4	14.41	15.83	1.42	15.12	BIOGENIC	2	6.5	3.5	ST_I_ON_III	NO	10	0	0
103	C	6/27/2001	14:33	>4	2	>4	13.97	14.62	0.65	14.3	PHYSICAL	2	5.17	2.74	ST_I	NO	5	0	0

Appendix B3 (continued)
REMOTS® Results for the June 2001 Survey over the CLIS 97/98 Mound Complex

Station	Replicate	Date	Time	Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Methane				DM Surface	Comments
				Min	Max	Mean	Min	Max	Mean	Diameter	Min	Max	Mean	Layer	
45	A	6/27/2001	13:00	6.74	8.2	>7.47	0	0	0	0	0	0	0	0	historic dm>pen, clay at depth, Mercenaria shell, large clast background
45	C	6/27/2001	13:02	14.55	15.34	>14.95	0	0	0	0	0	0	0	0	historic dm>pen, reduced material w shell hashf deep, active voids
45	F	6/28/2001	12:00	11.29	11.91	>11.6	0	0	0	0	0	0	0	0	historic dm>pen,shear or collapsed voids, shell frags
47	A	6/27/2001	13:13	15.28	16.74	>16.01	0	0	0	0	0	0	0	8	historic dm>pen, layered dm w relic rpd,void, shell on surface
47	B	6/27/2001	13:14	16.29	16.85	>16.57	0	0	0	0	0	0	0	0	historic dm>pen,possible collaspsed void left, tubes surface
47	C	6/27/2001	13:15	16.52	16.8	>16.66	0	0	0	0	0	0	0	0	historic dm>pen,layered dm mud w relic rpd, tubes surface
49	A	6/27/2001	13:19	16.4	17.53	>16.97	0	0	0	0	0	0	0	11	historic dm>pen,layered dm w relic rpd, active void
49	B	6/27/2001	13:20	16.85	17.19	>17.02	0	0	0	0	0	0	0	11	historic dm>pen, reduced, worm at depth,layered dm, faint relic rpd
49	C	6/27/2001	13:20	15.73	16.74	>16.24	0	0	0	0	0	0	0	11	historic dm>pen,layered dmw relic rpd
51	A	6/27/2001	13:27	17.13	17.42	>17.28	0	0	0	0	0	0	0	11	historic dm>pen,layered dm,relic rpd or clay smear??
51	B	6/27/2001	13:28	15.11	16.03	>15.57	0	0	0	0	0	0	0	10	historic dm>pen,clay fraction,silty surface, some shell hash
51	C	6/27/2001	13:29	14.95	15.6	>15.27	0	0	0	0	0	0	0	10	historic dm>pen, plant matter?/red material layer,voids?
52	A	6/27/2001	13:32	11.09	11.47	>11.28	0	0	0	0	0	0	0	0	historic dm>pen,voids,some reduced material, particles of plant matter?
52	B	6/27/2001	13:36	11.25	11.47	>11.36	0	0	0	0	0	0	0	0	historic dm>pen,sandy mud at depth,clay smears, void
52	C	6/27/2001	13:39	11.47	12.23	>11.85	0	0	0	0	0	0	0	0	historic dm>pen,mud w sand&shell hash,void, snail@surface
53	A	6/27/2001	13:44	14.51	15.54	>15.03	0	0	0	0	0	0	0	0	historic dm>pen,sandy mud reduced at depth, feeding voids
53	B	6/27/2001	13:44	16.78	17.43	>17.1	0	0	0	0	0	0	0	0	historic dm>pen,void/burrow?,reduced at depth,tubes surface
53	C	6/27/2001	13:45	15.68	16.39	>16.04	0	0	0	0	0	0	0	0	historic dm>pen,feeding voids,reduced at depth, silty surface
58	A	6/27/2001	8:57	16.27	16.49	>16.38	0	0	0	0	0	0	0	0	historic dm>pen, layered dm , burrow/shear at depth,shell frags
58	B	6/27/2001	8:57	6.55	7.11	>6.83	0	0	0	0	0	0	0	0	historic dm>pen, light mud/clay, shallow pen, void
58	C	6/27/2001	8:58	14.55	15.38	>14.97	0	0	0	0	0	0	0	0	historic dm>pen, collapsed void,feeding halo,tubes surface,reduced at depth
59	A	6/27/2001	9:00	19.05	19.38	>19.21	0	0	0	0	0	0	0	0	historic dm>pen, voids, shell hash at depth,tubes surface
59	B	6/27/2001	9:01	15.16	16.88	>16.02	0	0	0	0	0	0	0	0	historic dm>pen, coarser material at depth?,amp. tube?,shell frags
59	C	6/27/2001	9:02	15.72	16.49	>16.1	0	0	0	0	0	0	0	0	historic dm>pen,layered mud,active void,shell frags
60	A	6/27/2001	9:04	9.16	10.27	>9.72	0	0	0	0	0	0	0	0	historic dm>pen,active void,reddish clay/silt? patch organic matter?
60	B	6/27/2001	9:05	8.33	8.89	>8.61	0	0	0	0	0	0	0	0	sandy historic dm>pen, mud with coarser fraction, shell
60	C	6/27/2001	9:06	13.99	14.38	>14.19	0	0	0	0	0	0	0	0	historic dm>pen,collapsed void, Nephtyes, shell and shell hash
61	A	6/27/2001	9:08	12.32	16.41	>14.36	0	0	0	0	0	0	0	0	historic dm>pen,mud/clay voids or shear?,shells surface
61	B	6/27/2001	9:09	10.94	12.65	>11.8	0	0	0	0	0	0	0	0	historic dm>pen,active voids,tubes surface,crusteacean parts?
61	C	6/27/2001	9:09	14.81	15.47	>15.14	0	0	0	0	0	0	0	0	historic dm>pen, active voids, Chaetopterus tubes,shell frags, amp. tubes
62	C	6/27/2001	9:19	4.92	9.06	>6.99	0	0	0	0	0	0	0	0	sandy,historic dm>pen, Chaetopterus tube,, clay/shell clumps at surface
62	E	6/28/2001	12:07	12.76	13.2	>12.98	0	0	0	0	0	0	0	0	sandy historic dm>pen,mud w shell hash and clay at depth, shell at surface
62	F	6/28/2001	12:08	5.71	7.23	>6.47	0	0	0	0	0	0	0	0	historic dm>pen,mud/shell/f.sand,Chaetopterus tube
63	A	6/28/2001	9:15	15.7	16.25	>15.98	0	0	0	0	0	0	0	0	historic dm>pen,voids,reduced at depth,tubes surface
63	B	6/27/2001	9:16	17.25	17.83	>17.54	0	0	0	0	0	0	0	0	HISTORIC DM>P, SANDY M, TUBES, VOIDS, OX&RED CLSTS, RELIC RPD?, WORMS @Z
63	C	6/27/2001	9:16	10.76	13.42	>12.09	0	0	0	0	0	0	0	0	historic dm>pen. homogen. mud, burrows and voids, tubes surface
64	A	6/27/2001	9:19	15.59	16.41	>16	0	0	0	0	0	0	0	0	historic dm>pen, layered dm mud,voids
64	B	6/27/2001	9:20	15.38	16.08	>15.73	0	0	0	0	0	0	0	0	historic dm>pen,layered dm mud, feeding void, halo
64	C	6/27/2001	9:20	17.28	17.61	>17.44	0	0	0	0	0	0	0	10	historic dm>pen, layer dm ,shell frags, tubes surface
69	A	6/27/2001	14:11	11.58	11.86	>11.72	0	0	0	0	0	0	0	0	historic dm>pen,sandy mud w plant matter?red material large burrow/void
69	B	6/27/2001	14:12	14.12	14.67	>14.4	0	0	0	0	0	0	0	0	historic dm>pen,sandy dm mud,silty surface, tubes
69	C	6/27/2001	14:12	5.55	5.82	>5.68	0	0	0	0	0	0	0	0	historic dm>pen,mud/clay with plant matter?red material, tube ?
70	A	6/27/2001	14:06	6.56	8.74	>7.65	0	0	0	0	0	0	0	0	historic dm>pen,sandy mud, Chaetopterus tubes, burrow
70	B	6/27/2001	14:07	11.64	12.3	>11.97	0	0	0	0	0	0	0	0	historic dm>pen,sandy mud,burrow/void bisected, shell frags
70	C	6/27/2001	14:08	14.59	15.03	>14.81	0	0	0	0	0	0	0	0	historic dm>pen,sandy mud w sand layer, large burrow/void,organic matter@z
71	C	6/28/2001	14:02	13.61	14.54	>14.07	0	0	0	0	0	0	0	0	historic dm>pen,light sandy mud,Chaetoperus, voids
71	D	6/28/2001	12:12	4.81	6.67	>5.74	0	0	0	0	0	0	0	0	histOric dm>pen, light sandy mud,Chaetopterus, burrow edge
71	E	6/28/2001	12:12	10.32	11.27	>10.79	0	0	0	0	0	0	0	0	HISTORIC DM>P, SANDY M, VOIDS, SHELL FRAGS, OCCUPIED BURROWS-OPNING, DEEP RPD
79	A	6/27/2001	14:24	17.61	18.7	>18.15	0	0	0	0	0	0	0	0	historic dm>pen, dm mud w deep burrow,sandy
79	B	6/27/2001	14:25	14.4	15.54	>14.97	0	0	0	0	0	0	0	10	historic dm>pen,layered dm mud w relic rpd, void, shell
79	C	6/27/2001	14:26	13.97	15.29	>14.63	0	0	0	0	0	0	0	0	historic dm>pen,layered dm mud, feeding void
81	A	6/27/2001	14:18	14.51	15	>14.76	0	0	0	0	0	0	0	10	histroic dm>pen,dm mud layers,relic rpd, voids
81	B	6/27/2001	14:18	16.03	16.58	>16.3	0	0	0	0	0	0	0	10	historic dm>pen,layered dm mud w relic rpd, wiper clast surface
81	C	6/27/2001	14:19	15.27	15.38	>15.33	0	0	0	0	0	0	0	7	historic dm>pen,layered dm mud,feeding void,silty surface, faint relic rpd
88	A	6/27/2001	14:38	6.52	7.45	>6.98	0	0	0	0	0	0	0	0	historic dm>pen,light dm mud, reduced and red material
88	B	6/27/2001	14:38	13.91	14.62	>14.27	0	0	0	0	0	0	0	0	historic dm>pen,dm mud w sand, voids,clay w sand
88	C	6/27/2001	14:39	15.22	15.27	>15.25	0	0	0	0	0	0	0	0	historic dm>pen,plant matter?reddish material, reduced at depth,void?
102	A	6/27/2001	13:06	12.42	12.81	>12.61	0	0	0	0	0	0	0	7.5	historic dm>pen,layered dm mud,voids/shear at depth
102	B	6/27/2001	13:08	15.28	15.73	>15.51	0	0	0	0	0	0	0	0	historic dm>pen, dm mud reduced at depth,some shell frags,2 small voids
102	C	6/27/2001	13:08	13.93	14.61	>14.27	0	0	0	0	0	0	0	0	historic dm>pen,active feeding void, deep rpds,vertical burrow
103	A	6/27/2001	14:31	14.89	15.11	>15	0	0	0	0	0	0	0	0	historic dm>pen,mud/clay w large burrow/shear, shell frags at depth
103	B	6/27/2001	14:32	14.41	15.83	>15.12	0	0	0	0	0	0	0	0	historic dm>pen,dmmud, large void,silty surface
103	C	6/27/2001	14:33	13.97	14.62	>14.3	0	0	0	0	0	0	0	0	historic dm>pen, layered dm mud,silty surface

Appendix B4
REMOTS® Results for the June 2001 Survey over the NHAV 93 Mound

Station	Replicate	Date	Time	Grain Size			Camera Penetration (cm)				Surface Roughness	Apparent RPD Thickness (cm)			Successional Stage	Low DO	OSI	Mud Clasts	
				Min	Max	Maj Mode	Min	Max	Range	Mean		Min	Max	Mean				Count	Diameter
CTR	A	6/27/2001	15:01	>4	2	>4	12.84	13.79	0.95	13.32	BIOGENIC	0.11	3.74	2.89	ST_I	NO	5	0	0
CTR	B	6/27/2001	15:02	>4	2	>4	13.32	13.47	0.16	13.39	PHYSICAL	0.74	4.74	2.66	ST_I_ON_III	NO	9	2	0.25
CTR	C	6/27/2001	15:03	>4	3	>4	14.21	16.16	1.95	15.18	PHYSICAL	0.16	3.26	1.58	ST_I_ON_III	NO	8	5	0.27
200N	A	6/27/2001	15:17	>4	2	>4	13.89	14.68	0.79	14.29	PHYSICAL	2.21	5.68	3.71	ST_I_ON_III	NO	10	0	0
200N	B	6/27/2001	15:18	>4	2	>4	13.63	14.53	0.89	14.08	PHYSICAL	0.21	3.84	2.33	ST_I	NO	5	0	0
200N	C	6/27/2001	15:19	>4	2	>4	12.68	14.21	1.53	13.45	PHYSICAL	0.53	2.58	1.75	ST_I_ON_III	NO	8	2	0.37
200S	A	6/27/2001	14:47	>4	3	>4	13.55	13.72	0.16	13.63	PHYSICAL	1.09	5.19	3.95	ST_I_ON_III	NO	7	0	0
200S	B	6/27/2001	14:47	>4	3	>4	13.01	13.11	0.11	13.06	PHYSICAL	0.22	4.15	2.93	ST_I	NO	5	0	0
200S	C	6/27/2001	14:48	>4	3	>4	12.9	13.61	0.71	13.25	PHYSICAL	0.05	4.32	2.6	ST_I	NO	3	3	0.6
200E	A	6/27/2001	15:10	>4	3	>4	15.32	16.16	0.84	15.74	PHYSICAL	1.74	4.37	2.87	ST_I_ON_III	NO	9	0	0
200E	B	6/27/2001	15:11	>4	2	>4	14	15.32	1.32	14.66	PHYSICAL	0.74	3.89	2.43	ST_I_ON_III	NO	9	8	0.17
200E	C	6/27/2001	15:11	>4	2	>4	14.74	15.26	0.53	15	PHYSICAL	NA	NA	NA	ST_I_ON_III	NO	99	0	0
200W	A	6/27/2001	14:53	>4	3	>4	13.66	14.43	0.77	14.04	PHYSICAL	1.97	6.07	3.69	ST_I_ON_III	NO	10	0	0
200W	B	6/27/2001	14:55	>4	3	>4	13.42	14.16	0.74	13.79	BIOGENIC	0.11	5	2.87	ST_I_TO_II	NO	5	0	0
200W	C	6/27/2001	14:56	>4	2	>4	14.11	15.05	0.95	14.58	PHYSICAL	0.47	4.47	3.37	ST_I	NO	6	0	0

Appendix B4 (continued)
REMOTS® Results for the June 2001 Survey over the NHAV 93 Mound

Station	Replicate	Date	Time	Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Methane				DM Surface	Comments
				Min	Max	Mean	Min	Max	Mean	Diameter	Min	Max	Mean	Layer	
CTR	A	6/27/2001	15:01	12.84	13.79	>13.32	0	0	0	0	0	0	0	0	DM>P, BRN SANDY M/BLK M, FILLED VERT BURROW, TUBES, SHELL FRAGS
CTR	B	6/27/2001	15:02	13.32	13.47	>13.39	0	0	0	0	0	0	0	0	DM>P, BRN SANDY M/SULFIDIC M, TUBES, VOID, OX&RED CLSTS, SHELL BITS, WORM@Z
CTR	C	6/27/2001	15:03	14.21	16.16	>15.18	0	0	0	0	0	0	0	0	DM>P, SANDY M/V.BLK SULFIDIC M, VOIDS, TUBES, OX&RED CLSTS, RED SED@SURF
200N	A	6/27/2001	15:17	13.89	14.68	>14.29	0	0	0	0	0	0	0	0	DM>P, SANDY M/BLK M, TUBES,SMALL VOIDS, SHELL FRAGS, VERT BURROW
200N	B	6/27/2001	15:18	13.63	14.53	>14.08	0	0	0	0	0	0	0	0	DM>P, SANDY M/BLK M, TUBES, HYRDOID, SHELL FRAGS, RED SED
200N	C	6/27/2001	15:19	12.68	14.21	>13.45	0	0	0	0	0	0	0	0	DM>P, SANDY M/BLK M, SM TUBES, VOIDS, WIPER CLSTS, RED CLSTS, RED SED
200S	A	6/27/2001	14:47	13.55	13.72	>13.63	0	0	0	0	0	0	0	8.7	DM>P,MANY BURROWS,SHELL FRAGS,TUBES@SURF,VOIDS
200S	B	6/27/2001	14:47	13.01	13.11	>13.06	0	0	0	0	0	0	0	0	DM>P,TUBES@SURF,REDUCED SED NEAR SURF
200S	C	6/27/2001	14:48	12.9	13.61	>13.25	0	0	0	0.55	1.57	1.06	1.315	0	DM>P,REDUCED SED@SURF,METHANE,TUBES@SURF,WIPER CLASTS@SURF
200E	A	6/27/2001	15:10	15.32	16.16	>15.74	0	0	0	0	0	0	0	0	DM>P, SANDY M/SULFIDIC M, TUBES, VOIDS, SM WORMS @Z
200E	B	6/27/2001	15:11	14	15.32	>14.66	0	0	0	0	0	0	0	0	DM>P, SANDY M/BLK SULFIDIC M, TUBES, VOIDS, BURROW, OX&RED CLSTS, RED SED
200E	C	6/27/2001	15:11	14.74	15.26	>15	0	0	0	0	0	0	0	0	DM>P, SANDY M/BLK SULFIDIC M, SM VOID?, WIPER SMEARS, RED SED
200W	A	6/27/2001	14:53	13.66	14.43	>14.04	0	0	0	0	0	0	0	0	DM>P,TUBES@SURF,SM VOIDS
200W	B	6/27/2001	14:55	13.42	14.16	>13.79	0	0	0	0	0	0	0	0	DM>P, SANDY M/BLK SULFIDIC M, TUBES, BURROW OPENINGS,MULINIA? SHELL FRAGS, RED SED
200W	C	6/27/2001	14:56	14.11	15.05	>14.58	0	0	0	0	0	0	0	0	DM>P, SANDY M/BLK SULFIDIC M, HYDROIDS, SHELL BITS, RED SED

Appendix B5
REMOTS® Results for the June 2001 Survey over the CLIS Reference Areas

Station	Replicate	Date	Time	Grain Size			Camera Penetration (cm)				Surface Roughness	Apparent RPD Thickness (cm)			Successional Stage	Low DO	OSI	Mud Clasts	
				Min	Max	Maj Mode	Min	Max	Range	Mean		Min	Max	Mean				Count	Diameter
2500W 1	A	6/27/2001	7:59	>4	2	>4	16.02	17.18	1.16	16.6	PHYSICAL	0.94	7.79	3.69	ST_I_ON_III	NO	10	2	0.47
2500W 1	B	6/27/2001	7:59	>4	2	>4	17.95	19	1.05	18.48	PHYSICAL	5.08	6.24	3.72	ST_I_ON_III	NO	10	0	0
2500W 1	C	6/27/2001	8:00	>4	2	>4	17.95	19	1.05	18.48	BIOGENIC	4.31	6.13	3.8	ST_I_ON_III	NO	11	0	0
2500W 2	A	6/27/2001	8:35	>4	2	>4	18.31	19.02	0.71	18.67	PHYSICAL	3.64	7.44	3.43	ST_I_ON_III	NO	10	0	0
2500W 2	B	6/27/2001	8:36	>4	2	>4	16.9	18.15	1.25	17.52	INDETERMINATE	1.79	6.19	3.58	ST_I_ON_III	NO	10	0	0
2500W 2	C	6/27/2001	8:37	>4	2	>4	18.42	18.96	0.54	18.69	BIOGENIC	3.31	8.75	2.57	ST_I	NO	5	0	0
2500W 3	A	6/27/2001	8:28	>4	2	>4	16.74	18.96	2.23	17.85	PHYSICAL	2.45	6.9	2.74	ST_III	NO	9	0	0
2500W 3	B	6/27/2001	8:28	>4	2	>4	17.61	18.53	0.92	18.07	PHYSICAL	3.53	6.68	5.79	ST_I	NO	7	1	0.83
2500W 3	C	6/27/2001	8:29	>4	2	>4	18.04	19.4	1.36	18.72	PHYSICAL	2.55	5.11	3.2	ST_I_ON_III	NO	10	0	0
2500W 4	A	6/27/2001	8:07	>4	2	>4	17.79	20.22	2.43	19	PHYSICAL	1.38	7.62	2.21	ST_I_on_III	NO	8	0	0
2500W 4	B	6/27/2001	8:09	>4	2	>4	19.45	20.22	0.77	19.84	INDETERMINATE	2.54	8.4	3.6	ST_III	NO	10	0	0
2500W 4	C	6/27/2001	8:10	>4	2	>4	15.71	16.74	1.03	16.22	PHYSICAL	2.66	6.25	3	ST_I	NO	5	3	0.46
4500E 1	A	6/27/2001	3:47	>4	2	>4	14.35	14.84	0.49	14.59	BIOGENIC	0.87	5.6	3.45	ST_III	NO	10	0	0
4500E 1	B	6/27/2001	3:49	>4	2	>4	14.45	14.84	0.38	14.65	BIOGENIC	0.71	5.43	4.26	ST_I	NO	7	0	0
4500E 1	C	6/27/2001	3:50	>4	2	>4	14.78	15.16	0.38	14.97	BIOGENIC	0.5	2	1.55	ST_I_ON_III	NO	8	1	0.05
4500E 2	A	6/27/2001	15:41	>4	2	>4	13.69	14.02	0.33	13.86	BIOGENIC	2.12	3.75	2.93	ST_I_ON_III	NO	9	0	0
4500E 2	B	6/27/2001	15:41	>4	2	>4	15.76	16.08	0.33	15.92	PHYSICAL	1.74	5.32	3.9	ST_III	NO	11	0	0
4500E 2	C	6/27/2001	15:42	>4	2	>4	14.83	14.89	0.05	14.86	PHYSICAL	0.22	3.06	2.59	ST_I	NO	5	0	0
4500E 3	A	6/27/2001	16:04	>4	2	>4	11.79	12.71	0.92	12.25	BIOGENIC	0.54	5.27	3.69	ST_I_on_III	NO	10	0	0
4500E 3	B	6/27/2001	16:05	>4	2	>4	14.07	15.11	1.03	14.59	PHYSICAL	0.51	2.59	1.1	ST_I_ON_III	NO	7	2	0.72
4500E 3	C	6/27/2001	16:06	>4	2	>4	14.94	15.65	0.71	15.3	PHYSICAL	0.82	3	2.54	ST_I_ON_III	NO	9	1	1.27
4500E 4	A	6/27/2001	15:56	>4	2	>4	13.26	13.69	0.43	13.48	PHYSICAL	1.02	3.12	2.5	ST_I_ON_III	NO	9	0	0
4500E 4	B	6/27/2001	15:57	>4	2	>4	14.29	14.67	0.38	14.48	PHYSICAL	1	3	2	ST_I	NO	4	1	0.46
4500E 4	C	6/27/2001	15:57	>4	2	>4	13.04	13.37	0.33	13.21	PHYSICAL	1.74	4	2.5	ST_III	NO	9	3	0.65
CLIS REF 1	A	6/27/2001	16:16	>4	2	>4	13.26	14.08	0.81	13.67	PHYSICAL	2	4	3	ST_I_ON_III	NO	9	0	0
CLIS REF 1	B	6/27/2001	16:17	>4	2	>4	11.57	14.18	2.61	12.88	PHYSICAL	0.11	2.57	2.02	ST_I	NO	4	2	0.46
CLIS REF 1	C	6/27/2001	16:17	4	2	>4	10.92	11.25	0.33	11.08	PHYSICAL	0.82	2.51	2.02	ST_I	NO	4	2	0.51
CLIS REF 2	A	6/27/2001	16:22	>4	2	>4	8.59	9.56	0.98	9.07	PHYSICAL	1.2	4.18	3.2	ST_III	NO	10	0	0
CLIS REF 2	B	6/27/2001	16:23	>4	3	>4	8.86	9.62	0.76	9.24	PHYSICAL	0.71	4.35	3.44	ST_I	NO	6	1	0.27
CLIS REF 2	C	6/27/2001	16:24	>4	2	>4	12.81	13.31	0.51	13.06	PHYSICAL	3.26	5.28	4.28	ST_I_ON_III	NO	11	0	0
CLIS REF 3	A	6/27/2001	16:34	>4	2	>4	12.08	12.81	0.73	12.44	PHYSICAL	2	5	3	ST_I_ON_III	NO	9	0	0
CLIS REF 3	B	6/27/2001	16:35	>4	2	>4	6.59	7.71	1.12	7.15	PHYSICAL	1.51	6.14	2.07	ST_III	NO	8	12	0.86
CLIS REF 3	C	6/27/2001	16:38	>4	2	>4	11.9	12.85	0.95	12.37	BIOGENIC	0.22	3.97	2.65	ST_I	NO	5	0	0
CLIS REF 4	A	6/27/2001	16:29	>4	2	>4	12.08	13.32	1.24	12.7	PHYSICAL	1.74	4.04	2.73	ST_III	NO	9	0	0
CLIS REF 4	B	6/27/2001	16:29	>4	2	>4	13.09	13.48	0.39	13.29	INDETERMINATE	0.22	4	2.7	ST_I	NO	5	1	0.66
CLIS REF 4	C	6/27/2001	16:30	>4	3	>4	13.82	14.49	0.67	14.16	BIOGENIC	3.76	5.11	4.38	ST_III	NO	11	0	0
CLIS REF 5	A	6/27/2001	16:42	>4	2	>4	13.57	13.74	0.17	13.66	BIOGENIC	2.12	4.86	3.85	ST_I	NO	7	0	0
CLIS REF 5	B	6/27/2001	16:43	>4	2	>4	14.47	14.97	0.5	14.72	INDETERMINATE	2.79	4.47	3.84	ST_I_TO_II	NO	7	0	0
CLIS REF 5	C	6/27/2001	16:44	>4	2	>4	15.14	15.81	0.67	15.47	PHYSICAL	2.5	4	3.25	ST_I_ON_III	NO	10	1	0.31

Appendix B5 (continued)
REMOTS® Results for the June 2001 Survey over the CLIS Reference Areas

Station	Replicate	Date	Time	Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)			Methane				Comments
				Min	Max	Mean	Min	Max	Mean	Diameter	Min	Max	Mean	
2500W 1	A	6/27/2001	7:59	0	0	0	0	0	0	0	0	0	0	ambient,oxy. mud,feeding halo?macro burrow torn by camera
2500W 1	B	6/27/2001	7:59	0	0	0	0	0	0	0	0	0	0	ambient, oxygen. mud,shell hash,voids
2500W 1	C	6/27/2001	8:00	0	0	0	0	0	0	0	0	0	0	ambient, oxygen. mud, anemone & burrow at depth,
2500W 2	A	6/27/2001	8:35	0	0	0	0	0	0	0	0	0	0	ambient, oxgen mud, large burrow/shear at depth, shell frags, shallow voids
2500W 2	B	6/27/2001	8:36	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay active void,clay shear at depth
2500W 2	C	6/27/2001	8:37	0	0	0	0	0	0	0	0	0	0	ambient, oxygen. mud,vertical burrow,shell frags
2500W 3	A	6/27/2001	8:28	0	0	0	0	0	0	0	0	0	0	ambient, oxygen mud, void at depth, shell hash, shallow voids
2500W 3	B	6/27/2001	8:28	0	0	0	0	0	0	0	0	0	0	ambient, oxygen. mud, shell frags, feeding halo
2500W 3	C	6/27/2001	8:29	0	0	0	0	0	0	0	0	0	0	ambient, oxygen. mud,collasped feeding void?shell frags
2500W 4	A	6/27/2001	8:07	0	0	0	0	0	0	0	0	0	0	ambient, oxygen mud/clay, void/shear at depth, St. I tubes surface
2500W 4	B	6/27/2001	8:09	0	0	0	0	0	0	0	0	0	0	ambient,oxygen. mud, shell hash, void at depth
2500W 4	C	6/27/2001	8:10	0	0	0	0	0	0	0	0	0	0	ambient, oxygen. mud/clay, shell hash,clasts surface
4500E 1	A	6/27/2001	3:47	0	0	0	0	0	0	0	0	0	0	ambient,mud/clay,feeding voids,shell frags at depth, vertical burrow
4500E 1	B	6/27/2001	3:49	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay, shell frags at depth
4500E 1	C	6/27/2001	3:50	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay, feeding voids,patchy rpd
4500E 2	A	6/27/2001	15:41	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay, voids, shell frags
4500E 2	B	6/27/2001	15:41	0	0	0	0	0	0	0	0	0	0	ambient, mud, collapsed void,semi cirle depression surface
4500E 2	C	6/27/2001	15:42	0	0	0	0	0	0	0	0	0	0	ambient, homgen. mud/clay, small shell frags
4500E 3	A	6/27/2001	16:04	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay,shell frags, tubes surface,voids
4500E 3	B	6/27/2001	16:05	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay,burrow shearedat depth, feeding halo
4500E 3	C	6/27/2001	16:06	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay,void/camera shear at depth, tubes surface
4500E 4	A	6/27/2001	15:56	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay, void, shell frags, Stg. I tubes surface
4500E 4	B	6/27/2001	15:57	0	0	0	0	0	0	0	0	0	0	ambient,oxygen. mud/clay, shell frags
4500E 4	C	6/27/2001	15:57	0	0	0	0	0	0	0	0	0	0	ambient, oxygen. mud/clay, sheared burrow, voids at depth
CLIS REF 1	A	6/27/2001	16:16	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay, feeding voids, shell frags
CLIS REF 1	B	6/27/2001	16:17	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay,burrowing anemone, sloping topo,shell frags
CLIS REF 1	C	6/27/2001	16:17	0	0	0	0	0	0	0	0	0	0	ambient,mud/clay, clast surface, some shell frags
CLIS REF 2	A	6/27/2001	16:22	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay, voids at depth, shell frags
CLIS REF 2	B	6/27/2001	16:23	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay, large clast, shell frags
CLIS REF 2	C	6/27/2001	16:24	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay,large burrow, voids,tubes surface
CLIS REF 3	A	6/27/2001	16:34	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay, active voids, feeding halo, Nephytes,shell frags
CLIS REF 3	B	6/27/2001	16:35	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay,wiper clast surface, voids, shell frags
CLIS REF 3	C	6/27/2001	16:38	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay,tubes surface,shell frags
CLIS REF 4	A	6/27/2001	16:29	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay, slight pullaway, voids, shellfrags
CLIS REF 4	B	6/27/2001	16:29	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay, clast surface,shellfrags
CLIS REF 4	C	6/27/2001	16:30	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay,active void,feeding halos, shell hash at depth
CLIS REF 5	A	6/27/2001	16:42	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay tube surface?shell frags
CLIS REF 5	B	6/27/2001	16:43	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay, wiperclasts surface?,shell frags,reduced patch at depth
CLIS REF 5	C	6/27/2001	16:44	0	0	0	0	0	0	0	0	0	0	ambient, mud/clay,voids, wiper clast surface

INDEX