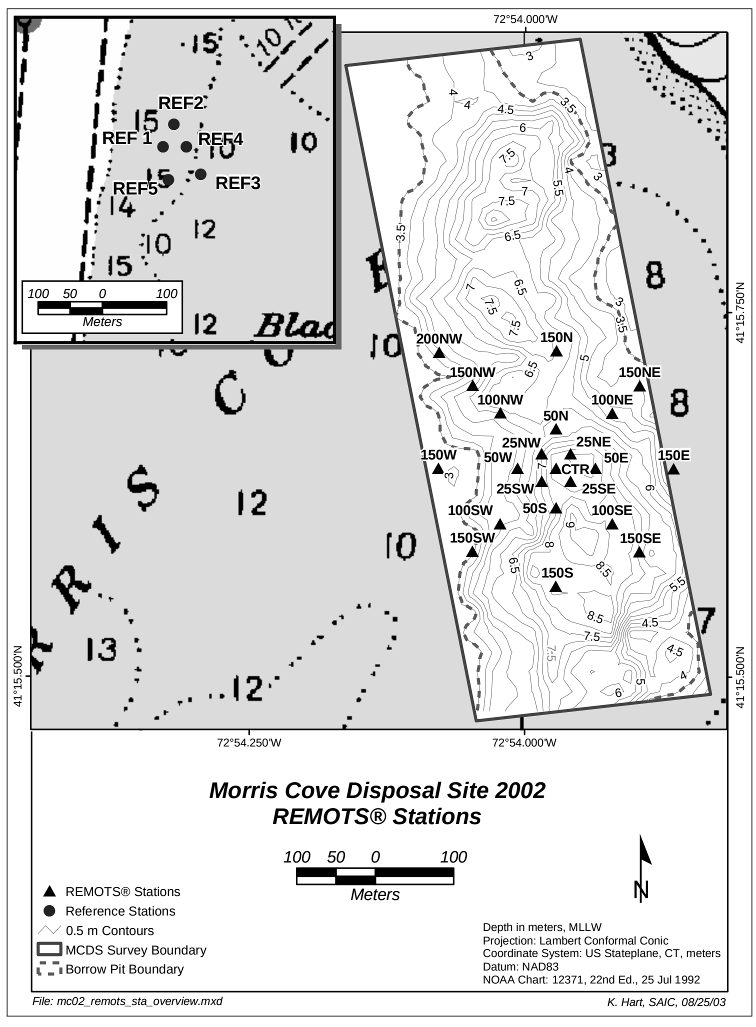
Monitoring Cruise at the Morris Cove Borrow Pit
May 2002

Disposal Area Monitoring System DAMOS



D A M O S

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13. ABSTRACT
During January and May 2000, an estimated total of 14,200 m^3 of sediment dredged from the U.S. Coast Guard Base in East Haven, Connecticut, was placed in a small, man-made depression (borrow pit) in Morris Cove, located in outer New Haven Harbor. The initial environmental monitoring survey to examine the impacts associated with the dredged material placement and subsequent recovery of the seafloor was completed in late September 2000. A follow-up monitoring survey was conducted over the Morris Cove borrow pit in late May 2002, to document the continued recovery of the benthic habitat within the borrow pit, to examine the distribution of sediments at the disposal area, and to calculate the remaining dredged material capacity within the pit for future dredged material placement.

The bathymetric and side-scan sonar data showed a clearly defined borrow pit boundary and good differentiation between softer sediments within the borrow pit and the coarser, more compact sediments that comprise its outer margin. Water depths within the survey area ranged from 3 m over the ambient Morris Cove seafloor to 9 m within the deepest portion of the borrow pit. It is estimated that the managed placement of approximately 468,000 m^3 of additional dredged material within the borrow pit would fill the man-made depression and return the bottom of Morris Cove to its original uniform topography. Benthic recolonization of the dredged material deposit was progressing as expected two years post-disposal. An advanced Stage II and/or Stage III community was observed at the majority of stations (73%), many in combination with Stage I pioneering polychaetes at the sediment water interface. A Stage I benthic community was seen at four of the remaining borrow pit stations, while two stations were classified as indeterminate due to low camera prism penetration. Redox potential discontinuity (RPD) depths greater than 2 cm observed at the majority of the stations sampled. A wide range of Organism-Sediment Index (OSI) values (-3 to +11) were calculated over the survey area. However, 16 of the 22 stations displayed OSI values of +6 or greater, suggesting an undisturbed or non-degraded benthic habitat exists over most of the survey area. Results from sediment grab samples showed that species richness across the sampling stations totaled 38 discrete taxa. Sixteen of these taxa were annelids, eight were mollusks, and eleven were arthropods. These taxa coincided with the sediment-profile image results that also showed primarily advanced Stage II and/or Stage III communities present over most of the sediment deposit.

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EXECUTIVE SUMMARY

During January and May 2000, an estimated total of 14,200 m^3 of sediment dredged from the U.S. Coast Guard Base in East Haven, Connecticut, was placed in a small, man-made depression (borrow pit) in Morris Cove, located in outer New Haven Harbor. The initial environmental monitoring survey to examine the impacts associated with the dredged material placement and subsequent recovery of the seafloor was completed in late September 2000. A follow-up monitoring survey was conducted over the Morris Cove borrow pit in late May 2002, to document the continued recovery of the benthic habitat within the borrow pit, to examine the distribution of sediments at the disposal area, and to calculate the remaining dredged material capacity within the pit for future dredged material placement.

The environmental monitoring activity involved the use of single-beam bathymetry, side-scan sonar, sediment-profile imaging, and benthic grab sampling to evaluate conditions within and adjacent to the Morris Cove borrow pit. Sediment-profile images and benthic samples were also obtained at a reference area located at the mouth of Morris Cove to provide a comparison between the findings within the borrow pit with conditions over the ambient New Haven Harbor seafloor.

The bathymetric and side-scan sonar data showed a clearly defined borrow pit boundary and good differentiation between softer sediments within the borrow pit and the coarser, more compact sediments that comprise its outer margin. Water depths within the survey area ranged from 3 m over the ambient Morris Cove seafloor to 9 m within the deepest portion of the borrow pit. Several bottom features with increased vertical relief and surface roughness were detected within a 50 m radius of the central disposal point employed during the 2000 disposal activity and attributed to dredged material deposition. Using the 3.5 m contour to represent the margins of the borrow pit, it is estimated that the managed placement of approximately 468,000 m^3 of additional dredged material would fill the man-made depression and return the bottom of Morris Cove to its original uniform topography. The placement of 577,000 m^3 of sediment would yield a depth of 3 m (MLLW) within the survey area and result in positive relief, or mounding over ambient bottom.

The sediment-profile images confirmed the presence of dredged material in close proximity to the disposal buoy position and extending out 100 to 150 m from this central disposal point. The measured thickness of the dredged material layer typically exceeded the penetration depth of the sediment-profile camera (i.e., greater than approximately 10 to 15 cm). The dredged material was predominantly fine-grained and consisted of soft, sandy silt. No evidence of erosion or sediment transport (i.e., winnowing) was identified in the replicate images.

Benthic recolonization of the dredged material deposit was progressing as expected two years post-disposal, with a well established benthic community detected within the Morris Cove borrow pit. An advanced Stage II and/or Stage III community was observed at the majority of stations (73%), many in combination with Stage I pioneering polychaetes at the sediment water interface. A Stage I benthic community was seen at four of the remaining borrow pit stations, while two stations were classified as indeterminate due to low camera prism penetration. Oxygen penetration into the surficial sediments was found to be relatively deep, with redox potential discontinuity (RPD) depths greater than 2 cm observed at the majority of the stations sampled. A wide range of Organism-Sediment Index (OSI) values (-3 to +11) were calculated over the survey area. However, 16 of the 22 stations displayed OSI values of +6 or greater, suggesting an undisturbed or non-degraded benthic habitat exists over most of the survey area.

Comparisons to the September 2000 survey indicate improved benthic habitat conditions over the majority of the sediment deposit. However, degraded benthic habitat conditions were observed at two stations on the eastern side of the dredged material deposit (50E and 100SE). The median OSI values calculated for both stations declined significantly over a two year period due to shallow RPD depths, lack of an advanced successional stage and the presence of methane gas within the sediments. Continued monitoring of this portion of the borrow pit is recommended.

Results from the sediment grab samples showed that species richness across the sampling stations totaled 38 discrete taxa. Sixteen of these taxa were annelids, eight were mollusks, and eleven were arthropods. These taxa coincided with the sediment-profile image results that also showed primarily advanced Stage II and/or Stage III communities present over most of the sediment deposit.

1.0 INTRODUCTION

1.1 Background

During the 1999/2000 disposal season, a small dredging project was completed at the U.S. Coast Guard base in New Haven Harbor, East Haven, Connecticut. A total barge volume of 14,200 m^3 of sediment deemed suitable for unconfined open water disposal was removed from the berthing areas to improve the efficiency of operations within the boat basin. Normally these sediments would be transported to the Central Long Island Sound Disposal Site (CLDS) and incorporated within an active disposal mound on the seafloor. However, recent interest in alternative uses for dredged material and innovative disposal methods prompted a change in management strategy for these sediments.

A small, man-made bottom depression, or borrow pit, located in Morris Cove was selected as an alternative disposal site for the sediments removed from the Coast Guard boat basin. The borrow pit was created several decades ago when sand and gravel were mined for use as fill for the construction of Interstate Highway 95 through New Haven. The sediments were excavated along a north-northwest to south-southeast axis, resulting in a submerged pit approximately 200 m wide and 750 m in length (Figure 1-1). Currently, water depths in the vicinity range from approximately 3 m on the harbor substrate to 9 m within the borrow pit. A large area of the pit has depths that are approximately 3.5 to 6 m deeper than the surrounding harbor bottom, suggesting that the pit could contain a substantial amount of additional dredged material.

In early January 2000, a small disposal buoy (MCDA) was placed at 41°15.644´ N, 72°53.972´ W (NAD 83) in the southern region of the borrow pit (Figure 1-1). An estimated 10,400 m^3 of the USCG dredged material was deposited at the buoy during January and early February 2000, before the dredging operation was interrupted by heavy ice in the harbor. Dredging and disposal operations resumed in May, with an additional 3,800 m^3 of material deposited at the MCDA buoy (Table 1-1).

In September 2000 the first monitoring survey was conducted over the Morris Cove borrow pit (approximately five months post-disposal) to document the distribution of the dredged material, verify the stability of the deposit, and examine the benthic recolonization of the sediments (SAIC 2001a). This report presents the findings of the second monitoring survey conducted in late May 2002 (approximately two years post-disposal).

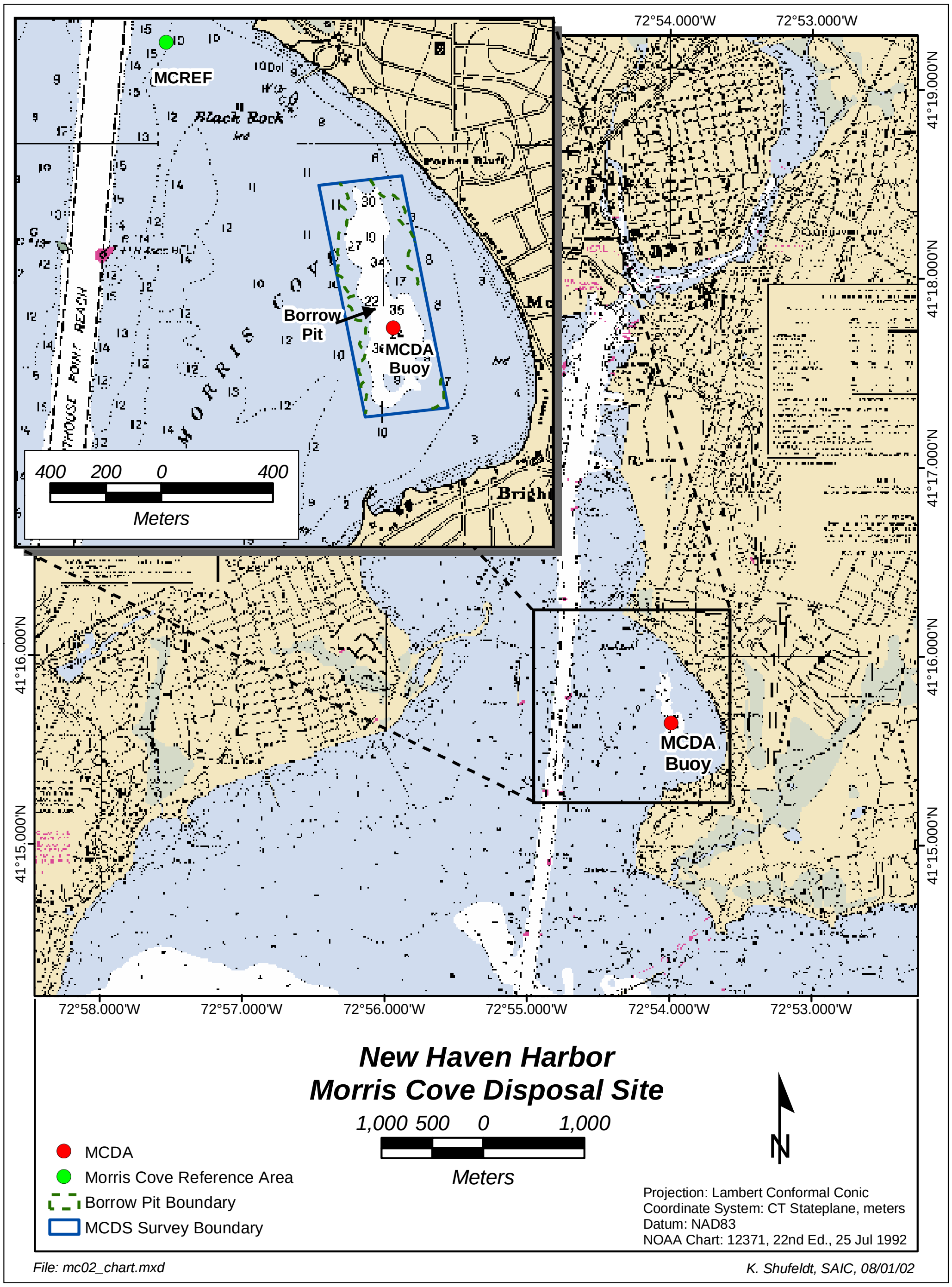


Figure 1-1. Location of Morris Cove borrow pit, MCDA buoy (central disposal point), and Morris Cove Reference Area (MCREF), relative to East Haven shoreline. The dashed green line represents the borrow pit boundary based on the 3.5 m bathymetric contour.

Table 1-1.
Disposal Log Summary Table

Disposal Site		MORRIS COVE							
Project		Channel & Dock Area							
Permit Number		199901985							
Permittee		U.S. Coast Guard							
	Log ID	Departure Date	Disposal Date	Return Date	Latitude	Longitude	Distance from Buoy	Direction from Buoy	Volume (CY)
1st Phase	18383	01/10/00	01/10/00	01/10/00	41.259833	-72.900833	20'	SSW	300
	18384	01/11/00	01/11/00	01/11/00	41.260333	-72.901667	30'	NNW	600
	18385	01/12/00	01/12/00	01/12/00	41.236667	-72.913333	40'	NNE	600
	18386	01/13/00	01/13/00	01/13/00	41.260717	-72.901200	10'	NE	700
	18387	01/13/00	01/13/00	01/13/00	41.266000	-72.900383	5'	S	400
	18388	01/13/00	01/13/00	01/13/00	41.260617	-72.900650	10'	SSW	600
	18389	01/15/00	01/15/00	01/15/00	41.261450	-72.900583	30'	NW	700
	18390	01/15/00	01/15/00	01/15/00	41.260450	-72.900517	20'	W	800
	18391	01/15/00	01/15/00	01/15/00	41.261233	-72.899700	20'	SSW	400
	18392	01/16/00	01/16/00	01/16/00	41.261533	-72.900183	30'	NE	650
	18393	01/19/00	01/19/00	01/19/00	41.260833	-72.900583	15'	S	500
	18394	01/20/00	01/20/00	01/20/00	41.261233	-72.900650	10'	WNW	800
	18395	01/20/00	01/20/00	01/20/00	41.261233	-72.900650	10'		800
	18396	01/27/00	01/27/00	01/27/00	41.260833	-72.900583	15'		800
	18397	01/27/00	01/27/00	01/27/00	41.260833	-72.900583	15'		900
	18398	01/28/00	01/28/00	01/28/00	41.260800	-72.900783	10'		500
	18399	01/30/00	01/30/00	01/30/00	41.261283	-72.900450	15'		400
	18400	02/01/00	02/01/00	02/01/00	41.260967	-72.899983	15'		450
	18401	02/02/00	02/02/00	02/02/00	41.260717	-72.900250	10'	SE	400
	18402	02/03/00	02/03/00	02/03/00	41.260183	-72.900800	20'	SW	400
	18403	02/04/00	02/04/00	02/04/00	41.260533	-72.900117	30'	SSE	450
	18404	02/05/00	02/05/00	02/05/00	41.260233	-72.900583	40'	SSW	400
	18405	02/06/00	02/06/00	02/06/00	41.260717	-72.900250	50'	E	350
	18406	02/07/00	02/07/00	02/07/00	41.260533	-72.900117	20'	NW	400
	18407	02/07/00	02/07/00	02/08/00	41.260317	-72.900183	50'	SE	300
									Total Cubic Yards = 13600
									Total Cubic Meters = 10398
2nd Phase	18694	05/08/00	05/08/00	05/08/00	41.260670	-72.899670	15	SW	400
	18695	05/09/00	05/09/00	05/09/00	41.260667	-72.899670	10 FT	SW	500
	18696	05/10/00	05/10/00	05/10/00	41.260830	-72.899330	30 FT	NE	500
	18697	05/11/00	05/11/00	05/11/00	41.260670	-72.899670	20 FT	SW	450
	18698	05/12/00	05/12/00	05/12/00	41.260830	-72.899500	20	NNE	400
	18699	05/13/00	05/13/00	05/13/00	41.260830	-72.899170	30 FT	E	300
	18700	05/15/00	05/15/00	05/15/00	41.260670	-72.899670	10 FT	SW	100
	18701	05/02/00	05/02/00	05/02/00	41.261000	-72.899830	20 FT	NW	300
	18702	05/04/00	05/04/00	05/04/00	41.260670	-72.899830	25 FT	SW	550
	18703	05/05/00	05/05/00	05/05/00	41.260580	-72.899670	20 FT	SW	600
	18704	05/06/00	05/06/00	05/06/00	41.260670	-72.899670	15 FT	SW	400
	18705	05/07/00	05/07/00	05/07/00	41.260670	-72.899670	25 FT	SW	500
									Total Cubic Yards = 5000
									Total Cubic Meters = 3823

1.2 Objectives and Predictions

The objectives of the May 2002 environmental monitoring survey were to:

1) Conduct a geophysical survey to document the distribution of the dredged material deposit on the seafloor and better define the margins of the Morris Cove borrow pit.

2) Determine the remaining capacity of the Morris Cove borrow pit to aid in the management of any future dredged material placement at this site.

3) Document the continued benthic recolonization within the surface sediment deposit, relative to ambient New Haven Harbor sediments.

The May 2002 field effort tested the following predictions:

- The dredged sediments placed within the Morris Cove borrow pit have remained within the confines of this bottom feature.

- The Morris Cove borrow pit offers significant capacity for the future placement of dredged material.

- At two years post-disposal, the benthic community within the Morris Cove borrow pit will primarily consist of advanced successional stage assemblages (Stage II and Stage III organisms), while pioneering polychaetes (Stage I) will continue to be found in relative abundance at the sediment-water interface.

2.0 METHODS

Field operations over the Morris Cove borrow pit were conducted in two parts due to the configuration of the survey area and the limitations of the survey vessels employed. The M/V *Menemsha* was used to support the single-beam bathymetry, side-scan sonar, and sediment profile imaging elements of the monitoring survey. These operations were performed on 24 and 25 May 2002. Benthic grab sampling activities were completed aboard the M/V *Beavertail* on 4 June 2002.

The bathymetric and side-scan sonar data were used to evaluate the geophysical attributes over the pit area and to calculate the remaining borrow pit capacity for future dredged material disposal. The sediment profile imaging and grab samples were used to evaluate the distribution of dredged material and the status of the benthic community within and adjacent to the borrow pit area. Sediment-profile images and grab samples were also obtained at a reference area located northwest of the borrow pit to provide a comparison between the ambient benthic conditions within New Haven Harbor and those existing within the borrow pit.

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 New Haven Harbor.

The DGPS data were ported to HYPACK® data acquisition software for position logging and helm display. Throughout the survey, individual stations and survey lanes were selected and displayed in order to position the survey vessel at the correct geographic location. All point sampling (sediment-profile imaging and benthic grab sample) positions were logged with a time stamp in Universal Time Coordinate (UTC) and a text identifier to facilitate Quality Control (QC) and rapid input into a Geographic Information System (GIS) database. Position information was logged continuously during the acquisition of side-scan sonar and bathymetric survey data.

2.2 Bathymetric Data Acquisition and Analysis

2.2.1 Bathymetric Data Acquisition

A bathymetric survey area was defined to examine the Morris Cove borrow pit in its entirety and the surrounding harbor substrate. A 300 × 800 m bathymetric survey centered at 41°15.703´ N, 72°54.000´ W (NAD 83) consisting of 13 lanes oriented in a northwest/southeast direction and spaced at 25 m intervals was completed (Figure 2-1). The survey area was designed to document the distribution of the dredged material deposit and to permit calculation of the remaining capacity of the pit for future dredged material disposal.

During the survey the HYPACK® navigation system was interfaced with an Odom Hydrotrac fathometer for the collection of depth profiles prior to the side-scan sonar survey. The fathometer was equipped with a narrow beam (3°), 208 kHz transducer to obtain depth soundings to a resolution of 1 cm. Approximately 10 measured depth values were collected, adjusted for transducer depth (draft), and transmitted to HYPACK® at a frequency of 1 Hz. The fathometer data recorded by HYPACK® were averaged, merged with time and position information, and written to a series of navigation log files at a frequency of 2 Hz. Within HYPACK®, the time-tagged position and depth data were merged to create continuous digital depth records along the actual survey track. At the conclusion of the survey, raw depth soundings were plotted over the survey lines to re-create vessel track, verify data quality, and 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. 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

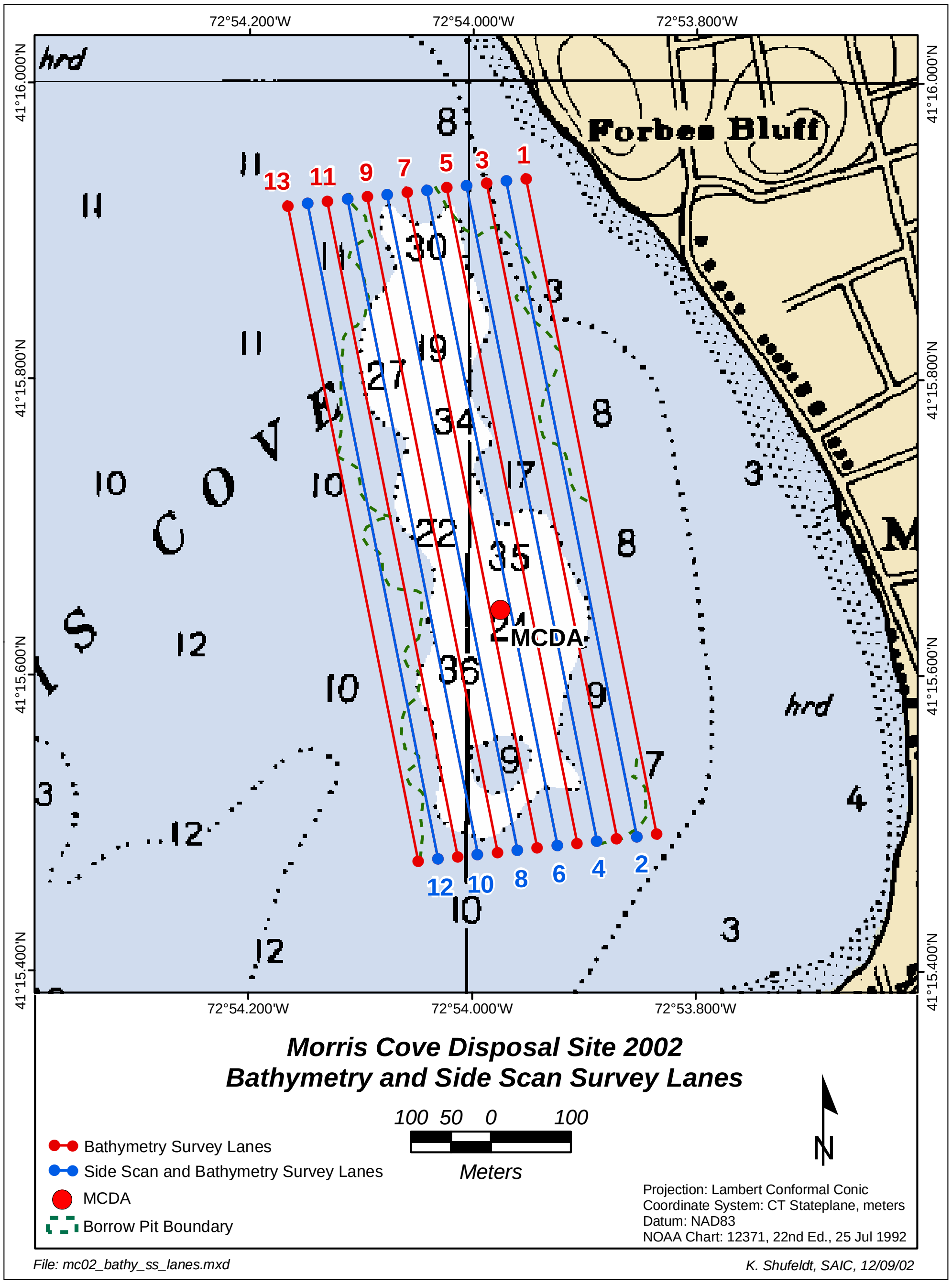


Figure 2-1. Single-beam bathymetric (red/blue) and side-scan sonar lanes (blue) completed over the Morris Cove borrow pit as part of the May 2002 environmental monitoring survey. The dashed green line represents the borrow pit boundary based on the 3.5 m bathymetric contour.

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 New Haven Harbor, CT (station number 8465705). 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.

2.2.3 Bathymetric Data Analysis

The primary intent of the bathymetric data analysis was to evaluate the bottom topography and provide a basis for dredged material capacity calculations. Because single-beam bathymetric survey data typically cover 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 2002 bathymetric survey data for Morris Cove were converted into a surface model via the ArcInfo® Geographic Information System (GIS) 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 × 25 m (625 m^2) grid cell size was employed to develop the surface model. This surface model was then imported into an ArcView® GIS for additional analysis and review and to generate graphic products incorporating some of the other survey data sets.

2.3 Side-Scan Sonar

A six-lane side-scan sonar survey was conducted over the borrow pit to delineate the edges of the man-made depression, as well as provide information pertaining to the distribution of dredged material (Figure 2-1). Side-scan sonar data were collected using a Marine Sonic Technology PC side-scan system operating at a frequency of 300 kHz. Six longitudinal survey lines were completed over the borrow pit, with lane spacing and sonar range controlled to maximize resolution and aerial coverage. After collection, the side-scan data were used to develop a mosaic of the survey area. The data were processed using SonarWeb Pro® processing software developed by Chesapeake Technology, Inc.

2.4 REMOTS® Sediment-Profile Imaging

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 (expressed in phi units), 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 conditions). 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).

A total of 22 sediment-profile stations were occupied over the Morris Cove borrow pit to evaluate the distribution and thickness of dredged material layers and to assess benthic recolonization (Table 2-1; Figure 2-3). The stations were arranged in a radial pattern centered at the MCDA disposal buoy position (Station CTR) and spaced at 25, 50, 100, 150, and 200 m intervals from the buoy. In addition, a five-station REMOTS® grid was established over a nearby reference area located northwest of the borrow pit in New Haven Harbor (Table 2-1; Figure 2-3). The location of the reference area stations for the May 2002 survey differed from the locations of the September 2000 survey due to fishing activity over an active oyster bed. Concerns from local fishermen resulted in the reference area stations being relocated further north of the previous reference area. At both the

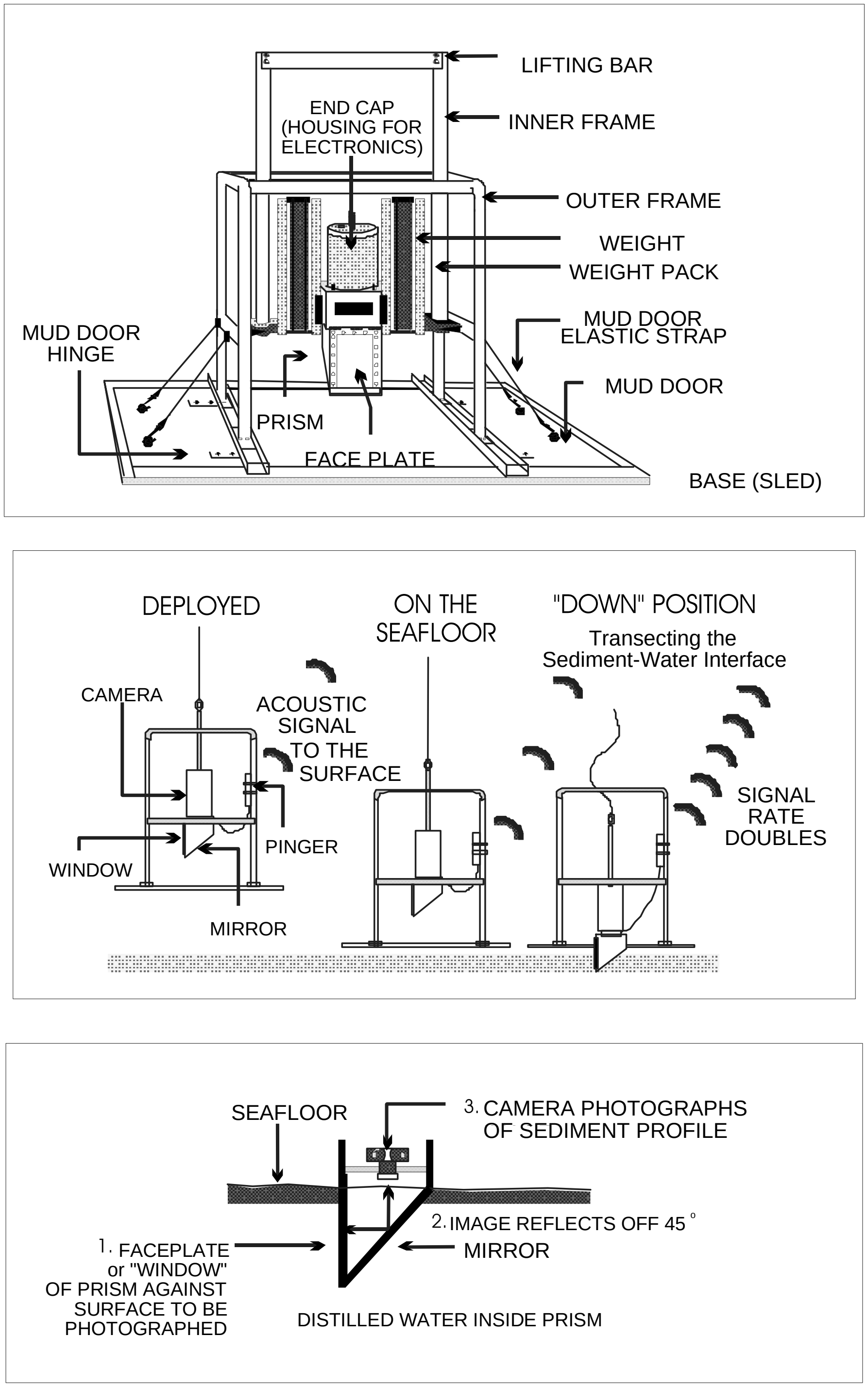


Figure 2-2. Schematic diagram of a Benthos Inc. sediment-profile camera and sequence of operation on deployment

Table 2-1.

Morris Cove Borrow Pit and Reference Area
REMOTS® Sediment-Profile Imaging and Benthic Grab Sampling Stations

Area	Station	Latitude	Longitude
MORRIS COVE **41° 15.644´ N** **72° 53.975´ W** **NAD 83**	CTR	41° 15.644´ N	72° 53.975´ W
	25NE	41° 15.654´ N	72° 53.962´ W
	25SE	41° 15.635´ N	72° 53.962´ W
	25SW	41° 15.635´ N	72° 53.988´ W
	25NW	41° 15.654´ N	72° 53.988´ W
	50N	41° 15.671´ N	72° 53.975´ W
	50E	41° 15.644´ N	72° 53.939´ W
	50S	41° 15.617´ N	72° 53.975´ W
	50W	41° 15.644´ N	72° 54.010´ W
	100NE	41° 15.682´ N	72° 53.924´ W
	100SE	41° 15.606´ N	72° 53.924´ W
	100SW	41° 15.606´ N	72° 54.026´ W
	100NW	41° 15.682´ N	72° 54.026´ W
	150N	41° 15.725´ N	72° 53.975´ W
	150E	41° 15.644´ N	72° 53.868´ W
	150S	41° 15.563´ N	72° 53.975´ W
	150W	41° 15.644´ N	72° 54.082´ W
	150NW	41° 15.701´ N	72° 54.051´ W
	150NE	41° 15.701´ N	72° 53.899´ W
	150SW	41° 15.587´ N	72° 54.051´ W
	150SE	41° 15.587´ N	72° 53.899´ W
**designated as 200NW for September 2000 survey	200NW**	41° 15.723´ N	72° 54.081´ W
Reference Area			
MC REF	REF 1	41° 16.201´ N	72° 54.595´ W
	REF 2	41° 16.220´ N	72° 54.583´ W
	REF 3	41° 16.178´ N	72° 54.553´ W
	REF 4	41° 16.201´ N	72° 54.569´ W
	REF 5	41° 16.173´ N	72° 54.589´ W

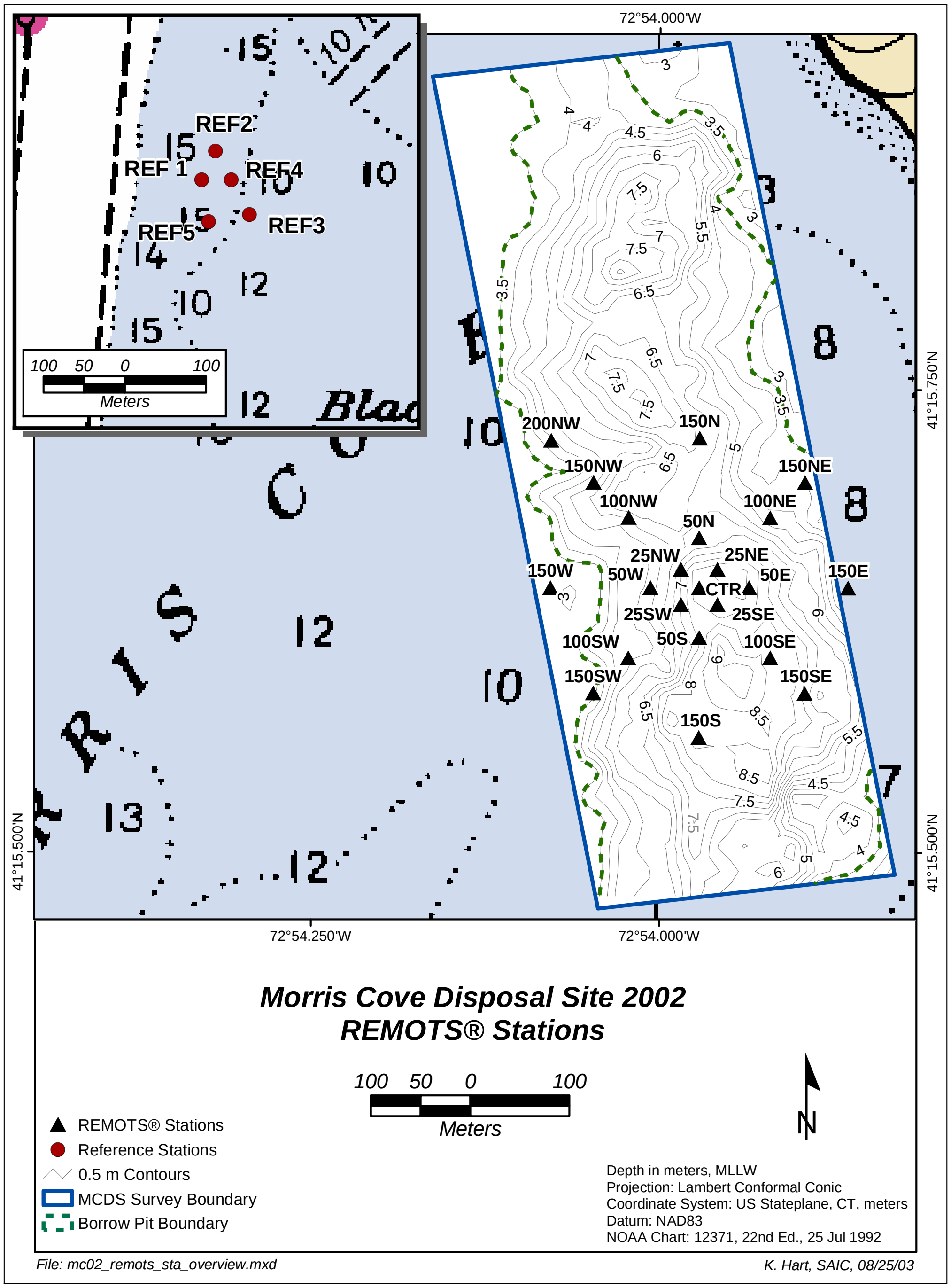


Figure 2-3. Location of REMOTS® sediment-profile imaging stations occupied over the Morris Cove borrow pit and nearby reference area as part of the May 2002 environmental monitoring survey. The dashed green line represents the borrow pit boundary based on the 3.5 m bathymetric contour.

borrow pit and reference area REMOTS® stations, the sediment-profile camera was lowered to the seafloor multiple times in an attempt to obtain three replicate images suitable for subsequent analysis.

2.5 Benthic Grab Sampling

A 0.04 m^2 Young-modified van Veen grab sampler was used to obtain a single sediment grab sample at four stations located within the borrow pit (Stations 100NE, 50N, 25SE, and CTR) and at one reference area station (Station RB4; Table 2-1; Figure 2-4). The sediment samples were then sieved through a 0.5 mm screen. All material remaining on the screen (biota, shell, wood fragments, etc.) was transferred to individual one-liter plastic containers and fixed with a 10% buffered formalin/seawater/Rose Bengal solution. The samples were delivered to Normandeau Associates, Inc. (NAI) of Bedford, New Hampshire for species identification and enumeration.

Upon arrival at the laboratory the samples were inventoried against the Chain of Custody (COC) form. Each sample was washed through a 0.5 mm mesh screen and elutriated to separate heavy and light fractions of the sample for more efficient sorting. To facilitate sorting, samples that had heterogeneously sized residue and/or organisms were washed through a series of graduated sieves, with the finest sieve being 0.5 mm mesh.

Sorting of the entire sample was conducted using a dissecting microscope. Organisms removed from each sample were placed in vials by major taxonomic group and preserved with 70% Ethanol. Each vial included an internal label with sample identification information. Information pertinent to further processing, and the initials of the processor, were recorded in the Sample Log Book. After completion, each sorted sample was checked to determine if the sample had been pre-selected for quality control re-sorting. Samples pre-selected for re-sorting were re-examined by the Quality Control Supervisor, with results recorded on Quality Control Record Sheets. All completed samples were re-preserved with formalin and stored until project requirements were satisfied.

Normandeau taxonomists who specialize in various benthic infaunal groups had samples distributed to them for identification and enumeration. Organisms were identified to lowest practical taxon. Samples to be re-identified for quality control were randomly selected from the Sample Quality Control Log and distributed to a different taxonomist. Results were logged on Quality Control Record Sheets. Data were recorded on laboratory data sheets and submitted for analysis following quality control.

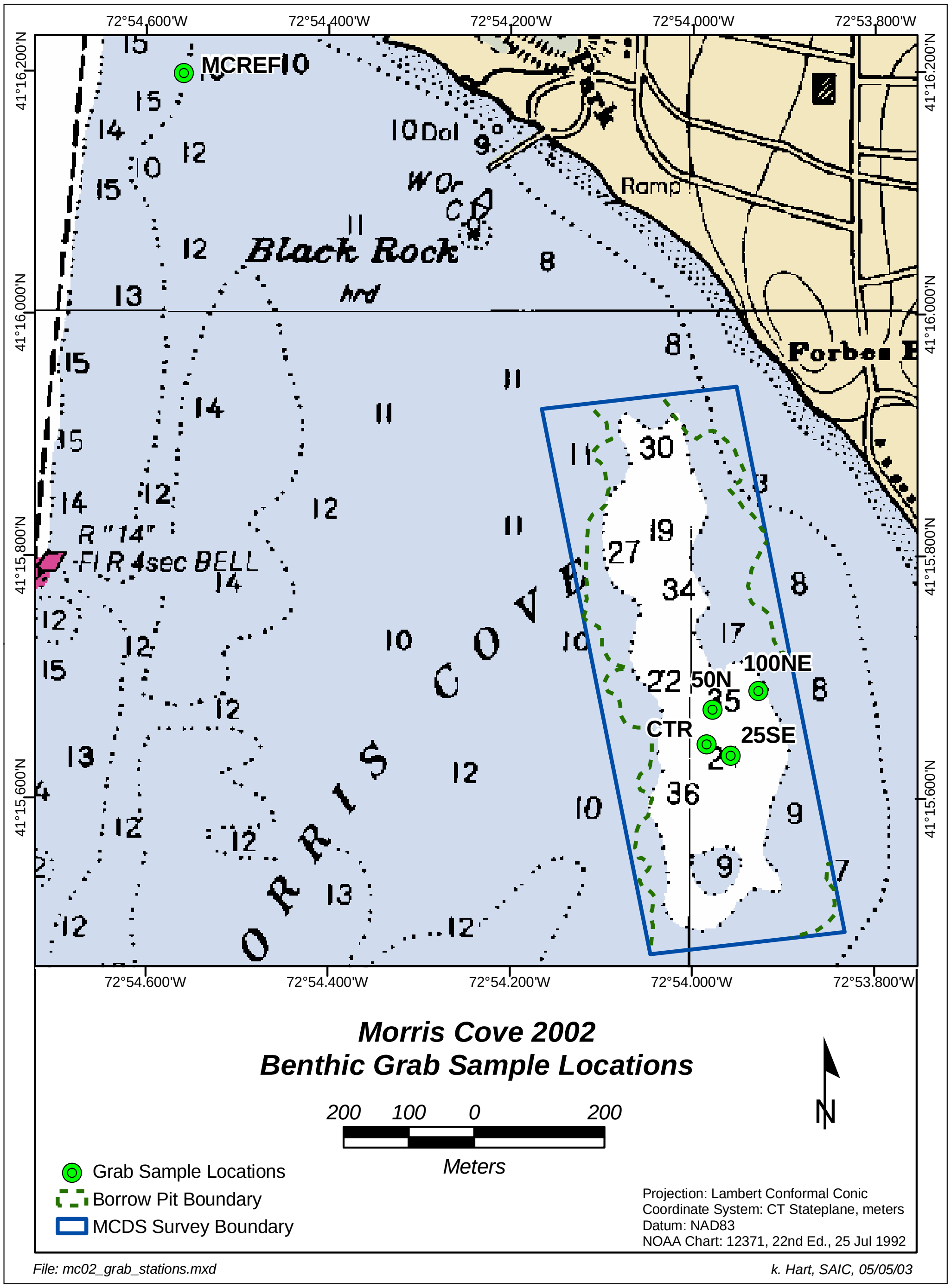


Figure 2-4. Location of benthic grab sample stations occupied over the Morris Cove borrow pit and nearby reference area as part of the May 2002 environmental monitoring survey. The dashed green line represents the borrow pit boundary based on the 3.5 m bathymetric contour.

Quality control (QC) assessment of sorting and identification entailed the reprocessing of 10% of each technician's samples, with a target of at least 95% of the organisms removed or identified. Quality control of a sorter or taxonomist was performed on a batch basis of 10 samples. Samples RB4 and 25SE were selected from the batch of five samples for sorting QC. For station 25SE, a total of 167 organisms were sorted and none were found during re-sorting, reflecting a 0% error rate. For station RB4, a total of 1,012 organisms were sorted and two were found during re-sorting, reflecting a 0.2% error rate. Re-identification of sample 25SE resulted in a 1.6% error rate for arthropoda, a 0% error rate for mollusca, and a 1.6% error rate for polychaeta. Results of all QCs were recorded on Quality Control Record Sheets and stored with the project file.

3.0 RESULTS

3.1 Bathymetry

Water depths within the 0.24 km² survey area established over the Morris Cove borrow pit ranged from 3 m over the ambient Morris Cove seafloor adjacent to the borrow pit to a maximum depth of 9 m in the southern portion of the pit (Figure 3-1). The dredged material deposit was not readily discernible as a mound formation with the bathymetric data, likely due to the small volume (14,200 m^3) of the material deposited and the variable topography of the seafloor.

In general, the bathymetric data showed the borrow pit to be comprised primarily of three distinct depressions that differ in depth from the surrounding ambient seafloor by approximately 3.5 to 6 m (Figure 3-1). Water depths over the ambient seafloor surrounding the pit were approximately 3 to 4 m, with a uniform bottom that displayed little topographic relief. The deepest and largest of the depressions in the borrow pit was found in the southern portion of the pit near the location of the MCDA buoy, with a maximum depth of 9 m. The other two depressions were located primarily in the northern half of the pit, with maximum depths of 8.5 m (northern-most depression) and 7.5 m.

3.2 Side-Scan Sonar

The side-scan sonar data were used to create an acoustic map of the seafloor surrounding the borrow pit and to differentiate between ambient sediment and dredged material placed within the pit. The full mosaic of the swath data displays strong acoustic returns corresponding to the margins of the Morris Cove borrow pit (Figure 3-2). Within the borrow pit, apparent dredged material deposits can be seen as slightly darker sonar returns near the location of the January 2000 MCDA disposal buoy (Figure 3-2). Slight differences in surface texture detected in close proximity to the MCDA buoy position, relative to the remainder of the sediments in the pit, provide subtle distinctions between the deposited dredged material and the ambient sediments. Multiple bottom features with vertical relief and increased surface roughness were detected within a 50 m radius of the central disposal point. The larger bottom features, approximately 30 m in diameter, were concentrated to the west of the MCDA disposal buoy. Based on their position relative to the disposal buoy and size, these features are likely attributable to dredged material placement.

Differences in sediment types and bottom features can also be seen throughout the pit, including softer, fine-grained sediments (light colored areas caused by weaker sonar returns) mottled with occasional, more reflective sediments and/or differences in depths

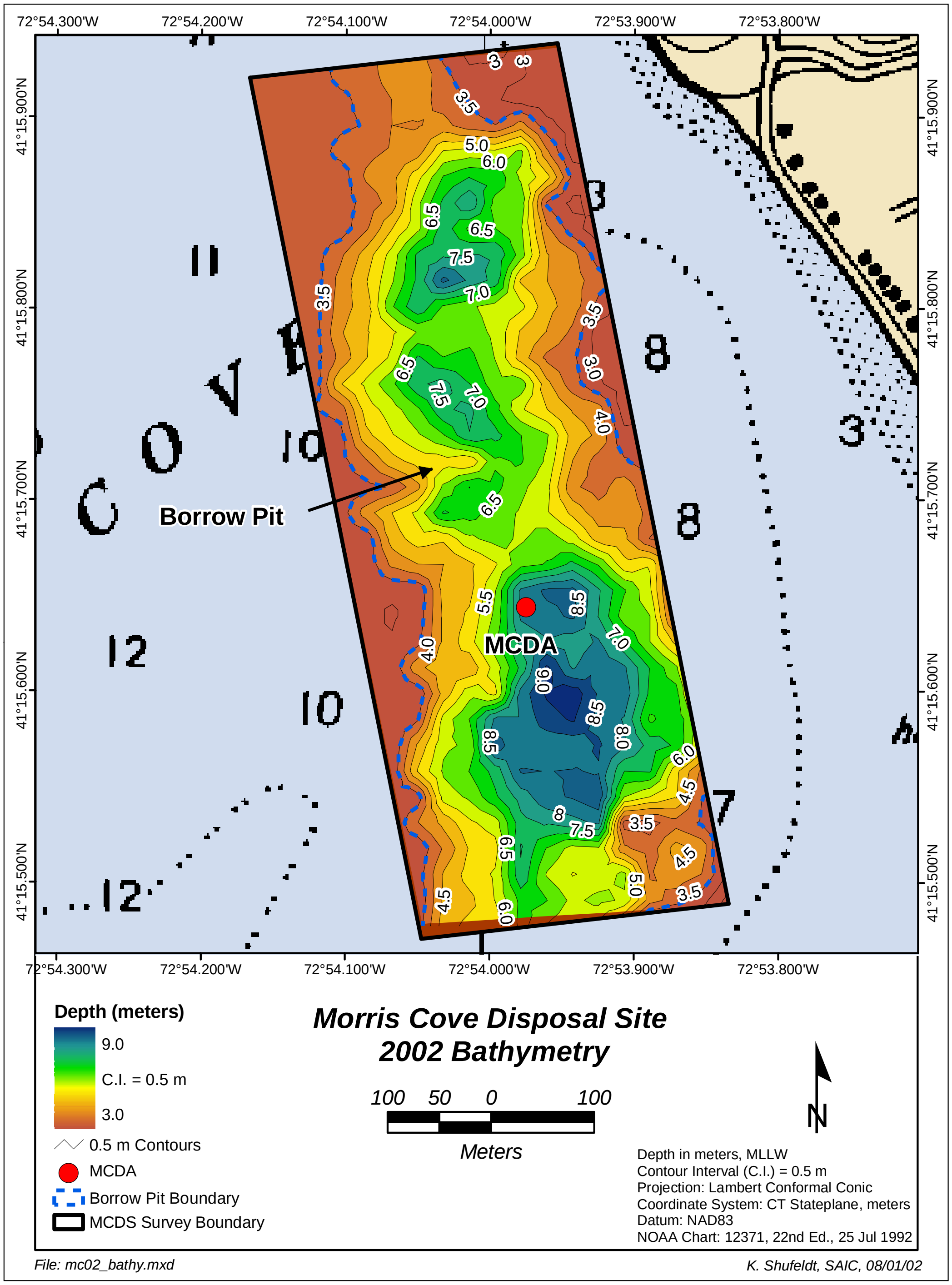


Figure 3-1. Bathymetric chart of the seafloor within the 0.24 km² survey area established over Morris Cove, 0.5 m contour interval. The blue dotted line designates the borrow pit boundary based on the 3.5 m bathymetric contour.

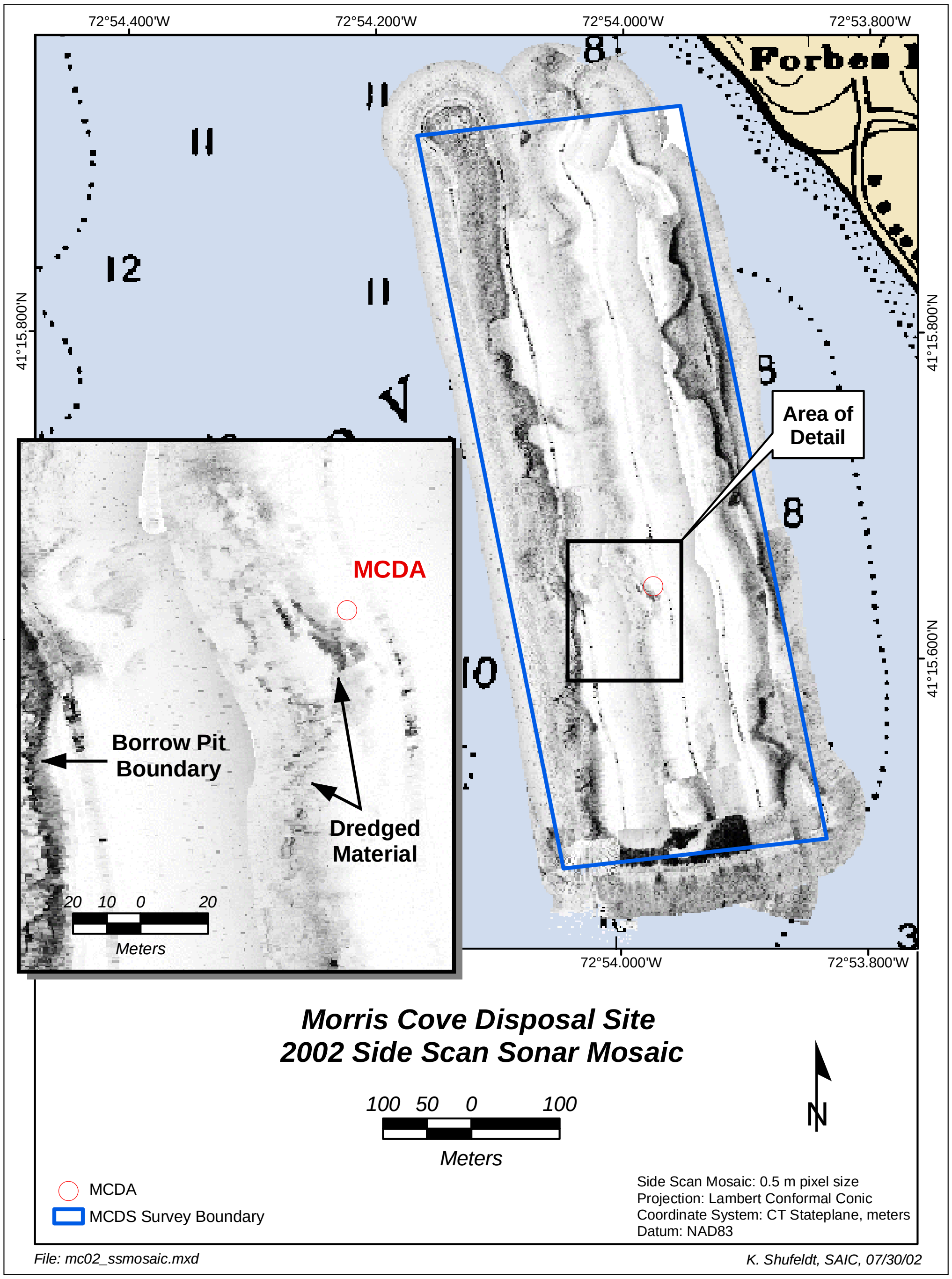


Figure 3-2. Mosaic of the side-scan sonar data collected over the Morris Cove borrow pit during the May 2002 survey. The acoustic returns show the margins of the bottom feature, dredged material deposit, and areas of soft sediment accumulation relative to the location of the MCDA buoy.

that produce darker features (Figure 3-2). Given the relatively small volume (14,200 m^3) of dredged material that was disposed from the USCG project, and the position of the disposal point (southern portion), most of the fine-grained material detected within the confines of the pit is likely the result of natural deposition. This fine-grained material could be emanating from the Mill and Quinnipiac Rivers, advected from other areas of New Haven Harbor, or could be the product of multiple sources. The side-scan mosaic shows a gradual strengthening of signal in close proximity to the margins of the pit, suggesting a coarsening of the sediments relative to the center. This change in texture is probably related to an increase in the sand or shell content of the sediments located near the walls of the borrow pit.

3.3 Sediment-Profile Imaging

The REMOTS® results for the May 2002 survey were used primarily to assess the benthic recolonization status of the sediments comprising the surface of the dredged material deposit within the Morris Cove borrow pit. A complete set of REMOTS® image analysis results for the disposal site and reference area stations are provided in Appendix A. These results are summarized in Tables 3-1 and 3-2.

3.3.1 Morris Cove Borrow Pit

3.3.1.1 Dredged Material Distribution and Physical Sediment Characteristics

Dredged material was detected in the REMOTS® images collected from 16 of the 22 borrow pit stations, and exceeded the penetration depth of the camera prism at each of these stations (i.e., dredged material greater than penetration; Table 3-1; Figure 3-3). Surface sediments considered to be ambient bottom (i.e., unaffected by dredged material disposal) were located at six stations on the outer margins of the survey grid (150E, 150NE, 150SW, 150W, 200NW, and 100NW).

The dredged material within the borrow pit was composed of fine-grained sediments with tan, oxidized silt over sulfidic black silt, occasionally exhibiting a mottled appearance (Figure 3-4A). A grain size major mode of >4 phi was commonly detected within the borrow pit, while the ambient material outside the confines of the pit displayed larger grain size sediments (3 and/or 2 phi) due to a higher sand component (Table 3-1; Figure 3-4B).

The penetration depth of the sediment-profile camera prism serves as a measure of sediment density or compaction. The potential range of penetration values is 0 cm (no penetration, hard bottom) to 20 cm (very soft mud). Replicate-averaged camera prism penetration depths for the borrow pit ranged from 1.3 cm at Station 150NE to 18.9 cm at

Table 3-1.

Summary of REMOTS® Results from the May 2002 Survey over the Morris Cove Borrow Pit

Station	Grain Size Major Mode (phi), # of Replicates	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number of Replicates with Dredged Material	Boundary Roughness Mean (cm)	Successional Stages Present	Highest Successional Stage Present
100NE	> 4 phi (3)	17.82	>17.82	3.00	0.95	I	ST I
100NW	< -1 phi (1), 3-2 phi (1), 4-3 phi (1)	1.79	0.00	0.00	1.77	INDET	INDET
100SE	> 4 phi (3)	16.90	>16.90	3.00	0.97	Azoic,I	ST I
100SW	> 4 phi (3)	14.99	>11.36	2.00	0.79	I,II,III	ST I on III
150E	3-2 phi (2), 4-3 phi (1)	11.23	0.00	0.00	0.85	I,III	ST I on III
150N	> 4 phi (3)	18.88	> 18.88	3.00	1.04	I,III	ST I on III
150NE	< -1 phi (1), 3-2 phi (1)	1.26	0.00	0.00	1.61	INDET	INDET
150NW	> 4 phi (3)	16.63	>16.63	3.00	1.69	I,III	ST III
150S	> 4 phi (3)	16.16	>16.16	3.00	0.57	I,III	ST I on III
150SE	> 4 phi (3)	15.59	>15.59	3.00	2.57	Azoic,II	ST II
150SW	> 4 phi (1), 4-3 phi (2)	12.27	0.00	0.00	1.19	I,II,III	ST II on III
150W	> 4 phi (3)	13.95	0.00	0.00	1.56	II,III	ST II on III
200NW	> 4 phi (1), 4-3 phi (1)	14.43	0.00	0.00	1.23	II,III	ST II on III
25NE	> 4 phi (3)	17.47	> 17.47	3.00	0.36	I,III	ST I on III
25NW	> 4 phi (3)	15.99	>15.99	3.00	1.64	II,III	ST II to III
25SE	> 4 phi (3)	16.14	>16.14	3.00	1.52	I,III	ST I on III
25SW	> 4 phi (3)	18.21	>18.21	3.00	1.44	I	ST I
50E	> 4 phi (3)	15.44	>15.44	3.00	1.19	I	ST I
50N	> 4 phi (3)	18.90	> 18.9	3.00	1.35	Azoic,I,III	ST III
50S	> 4 phi (3)	18.22	>18.22	3.00	0.70	I,II,III	ST I on III
50W	> 4 phi (3)	18.37	> 18.37	3.00	0.88	I,II,III	ST II on III
CTR	> 4 phi (3)	10.97	> 10.97	3.00	1.33	I,II,III	ST II to III
AVG		14.62	>11.96	2.14	1.24		
MAX		18.90	>18.88	3.00	2.57		
MIN		1.26	0.00	0.00	0.36		

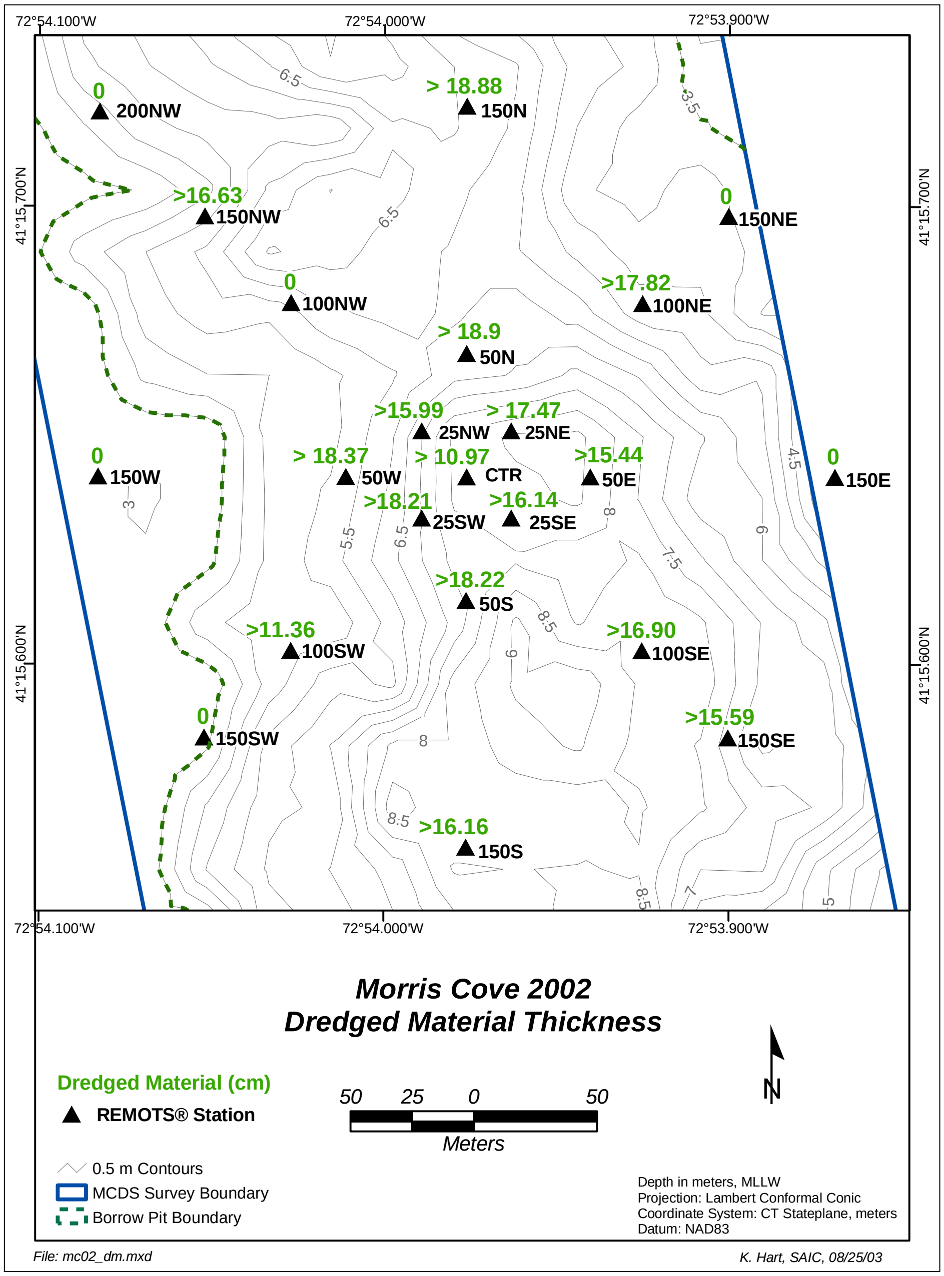


Figure 3-3. Dredged material distribution and replicate-averaged thickness for the stations occupied over the Morris Cove borrow pit as part of the May 2002 environmental monitoring survey. A "greater than" sign indicates that the dredged material extended below the imaging depth of the sediment-profile camera. The dashed green line represents the borrow pit boundary based on the 3.5 m bathymetric contour.

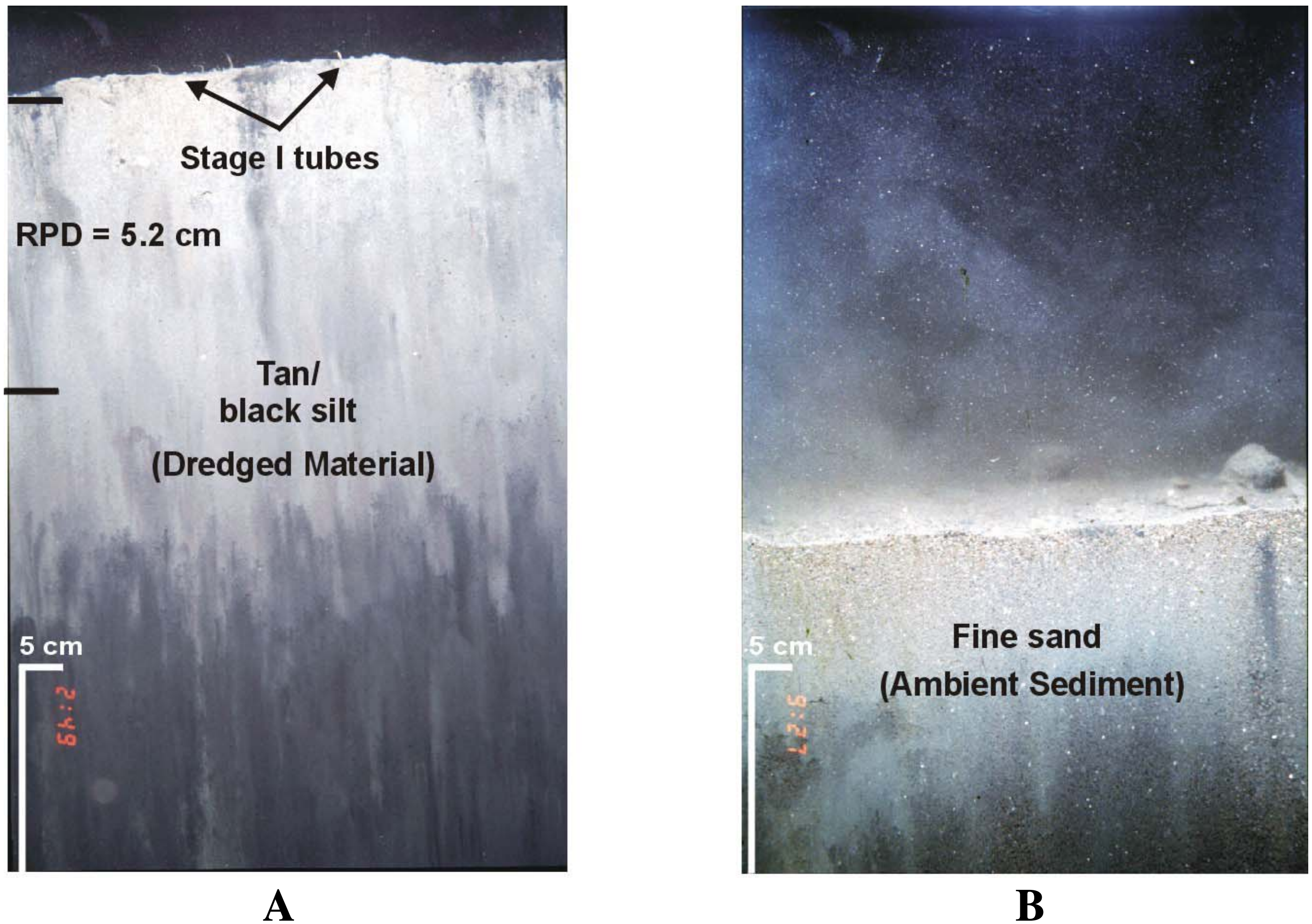


Figure 3-4. REMOTS® sediment-profile images obtained from Stations 150NW (A) and 150E (B) showing the various sediment types encountered within the survey grid established over the Morris Cove borrow pit

Station 50N, with an overall average of 14.6 cm indicating relatively soft sediments (Table 3-1). Over- or under-penetration of the REMOTS® camera in hard or very soft bottoms prevented the analysis of key parameters (e.g., RPD, successional status, surface roughness, and OSI) in seven replicate images. Hard bottom consisting of sand, shell, and cobble prevented sufficient penetration of the sediment-profile camera at Stations 100NW and 150NE, precluding the detailed analysis of all replicate images at these stations.

Replicate-averaged boundary roughness values for the borrow pit stations ranged from 0.4 cm at Station 25NE to 2.6 cm at Station 150SE, with an overall value of 1.2 cm (Table 3-1). There was no obvious pattern to these relatively low boundary roughness values. Surface roughness was attributed primarily to physical factors at the sediment-water interface at most stations. A number of stations also exhibited biogenic surface roughness as a result of dense mats of tubicolous amphipods (*Ampelisca* sp.), dense polychaete tubes, fecal mounds/layers, and biological surface reworking by burrowing infauna at the sediment-water interface (Figure 3-5). A number of gastropods were also observed at the sediment-water interface at some stations. Shells, shell fragments, and apparent flocculent layers were observed at the sediment surface at several stations.

3.3.1.2 Biological Conditions and Benthic Recolonization

Three parameters were used to assess the benthic recolonization status and overall benthic habitat conditions within the borrow pit relative to the selected reference area. The apparent Redox Potential Discontinuity (RPD) depth, Organism-Sediment Index (OSI) and infaunal successional status were mapped on station location plots to describe the biological conditions at each station (Figures 3-6 and 3-7).

The RPD provides a measure of the apparent depth of oxygen penetration into the surface sediments and is representative of the degree of biogenic and sediment mixing, as well as total sediment oxygen demand. The replicate-averaged RPD measurements for the borrow pit stations ranged between relatively high values of 5.9 and 5.1 cm at Stations 200NW and 50W, respectively, to a low value of 0.8 cm at Station 50E (Table 3-1; Figures 3-6 and 3-8). The overall average RPD value of 3.4 cm is considered indicative of well-aerated surface sediments within the borrow pit and is comparable to the composite value calculated for the reference area (4.4 cm). Although RPDs were relatively deep, black, sulfidic sediment was visible at or near the sediment-water interface in several replicate images within the borrow pit. Low apparent sediment dissolved oxygen conditions were detected within nine individual replicate images collected from eight different sampling stations within the survey grid (Table 3-1). Methane gas bubbles were observed within the sediment in the images obtained at Stations 100SE, 150S, 25NE, 50E, and 50N (Table 3-1; Figure 3-8B and 3-9). The presence of methane suggests that the dredged material at these

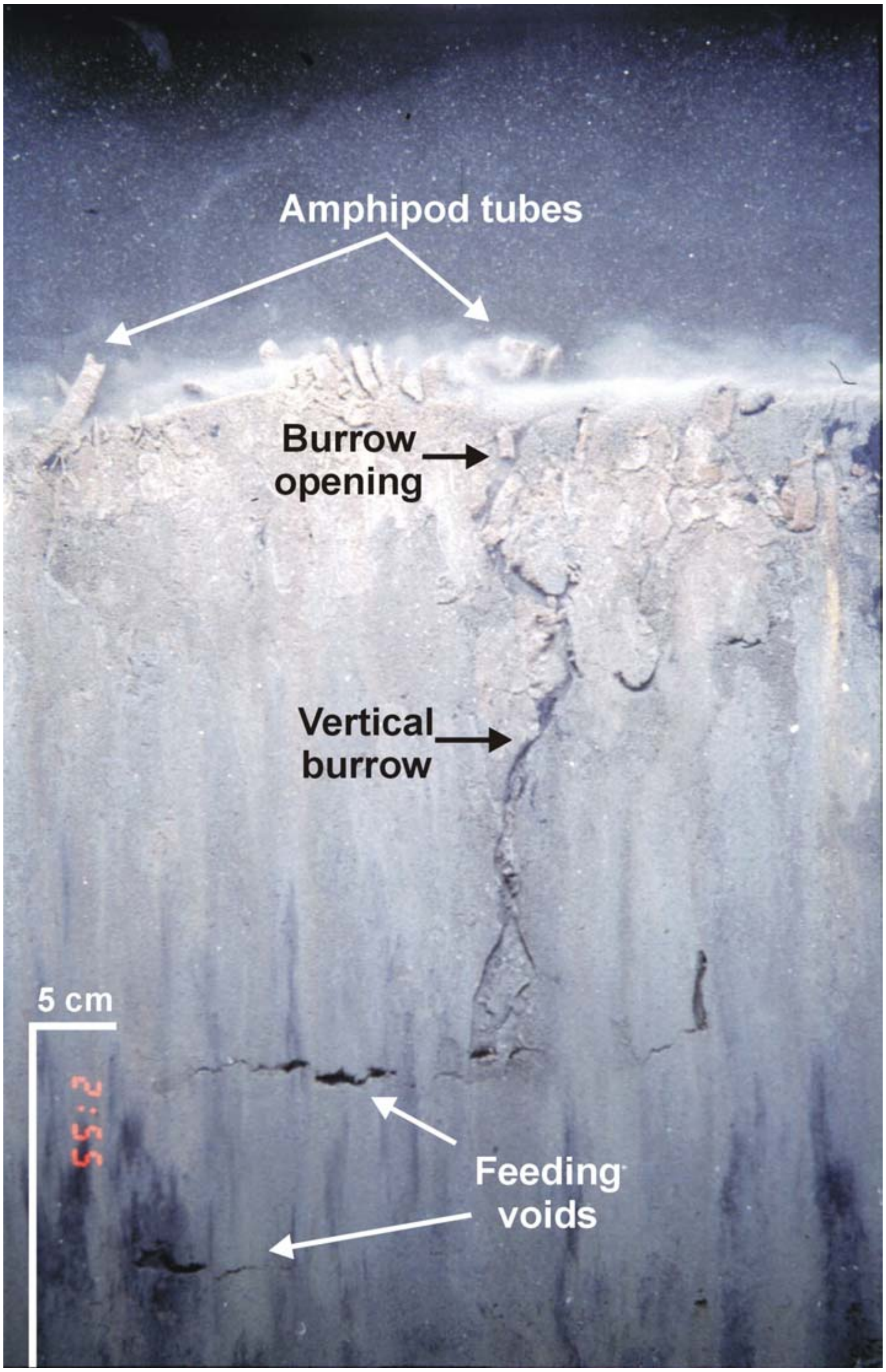


Figure 3-5. REMOTS® image obtained from Station 200NW displaying biological surface roughness at the sediment-water interface due to the presence of burrow openings and mature amphipod tubes

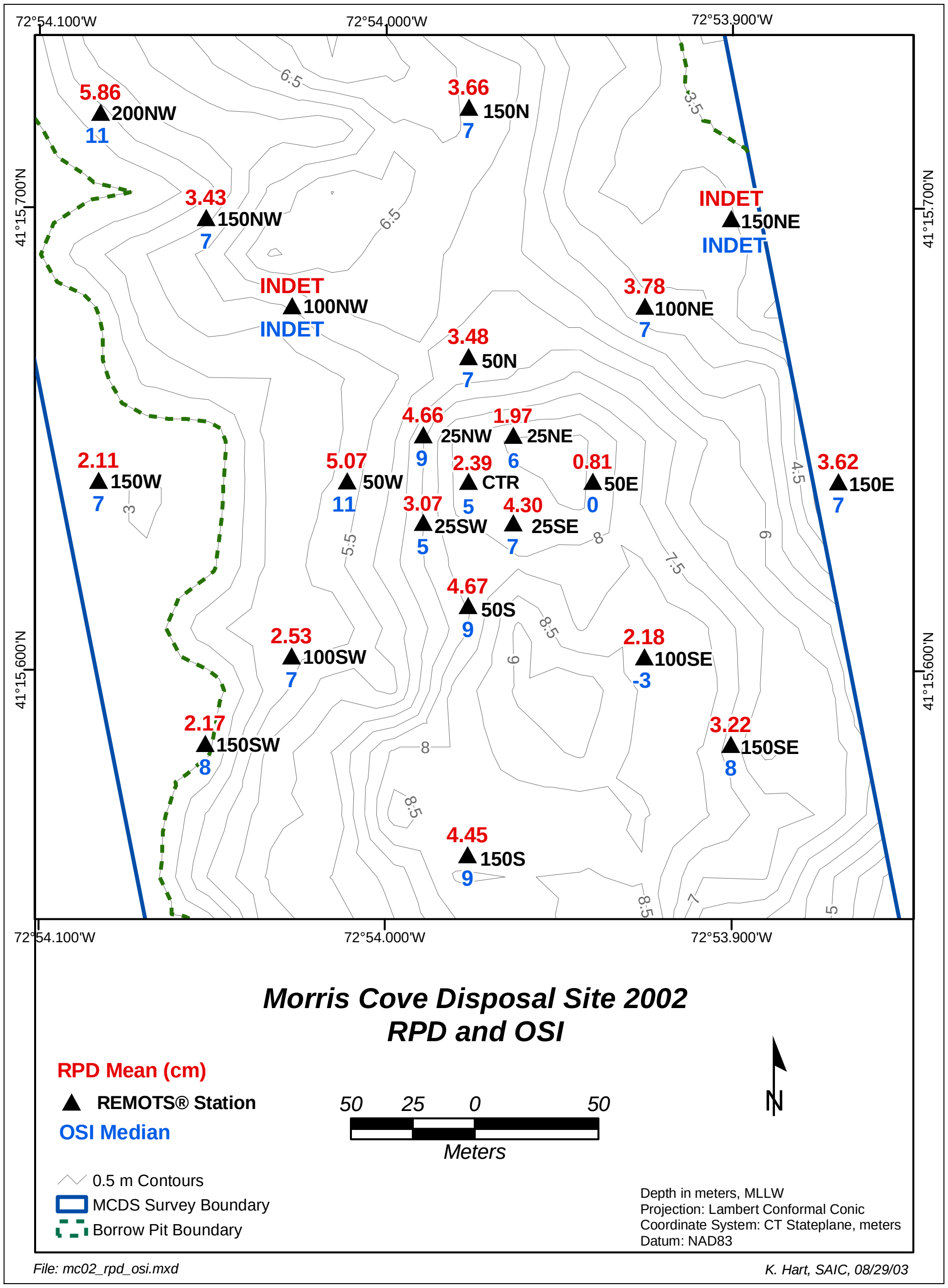


Figure 3-6. Replicate-averaged redox potential discontinuity (RPD) depths in red and median Organism-Sediment Index (OSI) values in blue calculated from the sediment-profile images obtained over the Morris Cove borrow pit as part of the May 2002 environmental monitoring survey. The dashed green line represents the borrow pit boundary based on the 3.5 m bathymetric contour.

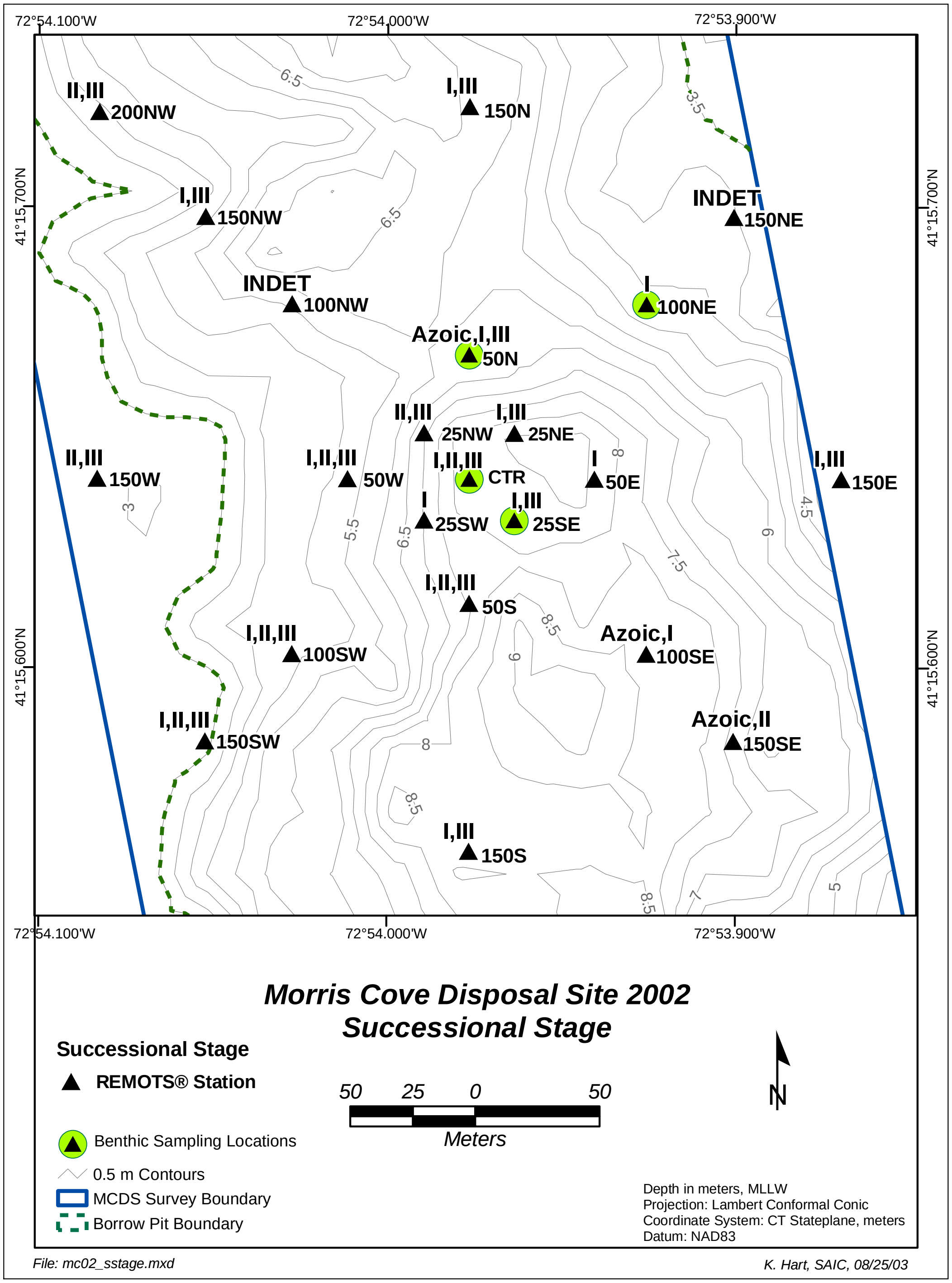


Figure 3-7. Map showing successional stages present at the sediment-profile imaging stations occupied over the Morris Cove borrow pit as part of the May 2002 environmental monitoring survey. The dashed green line represents the borrow pit boundary based on the 3.5 m bathymetric contour.

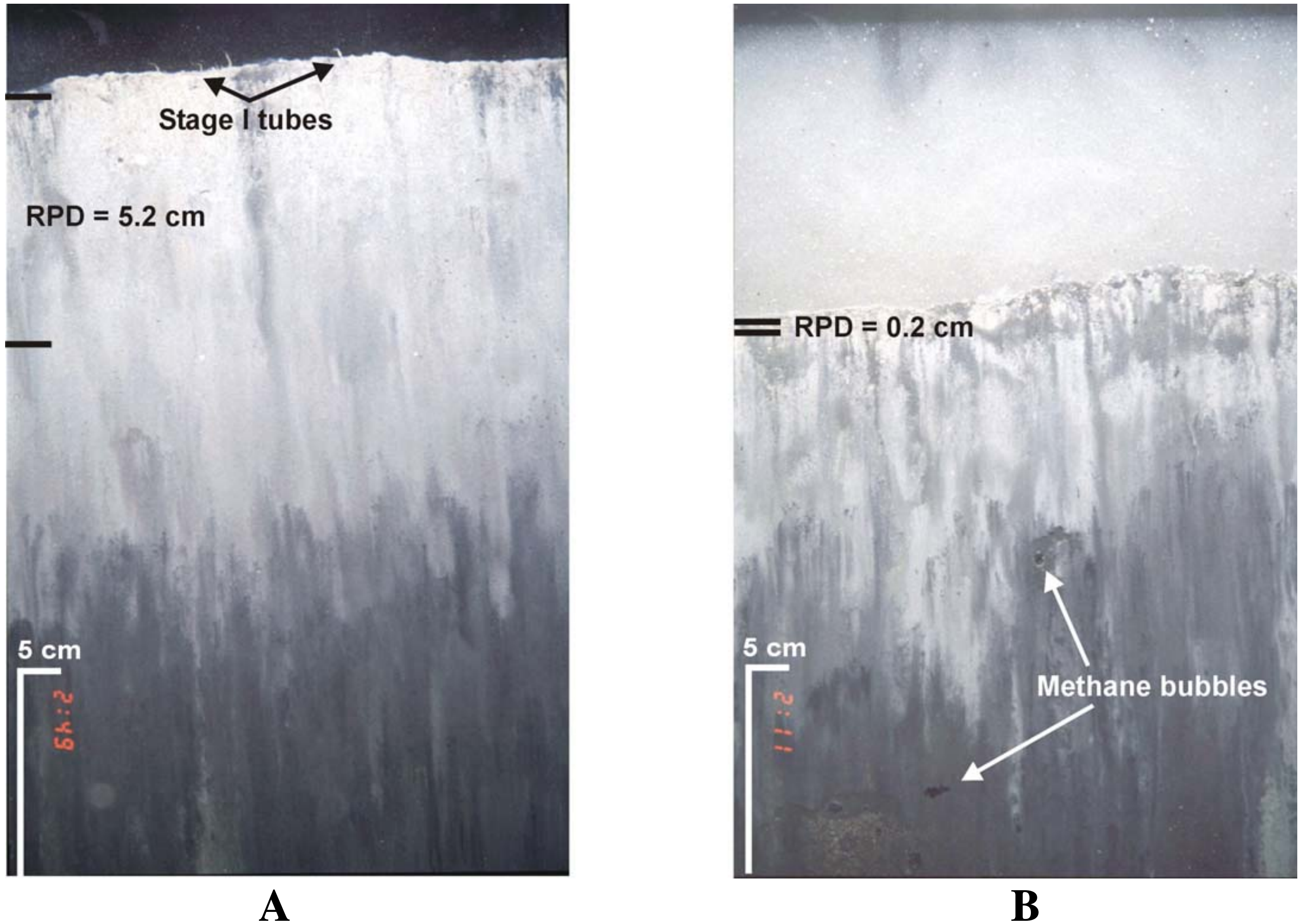


Figure 3-8. REMOTS® images obtained from Stations 200NW (A) and 50E (B) showing differences in the depth of oxygen penetration within the surficial sediments

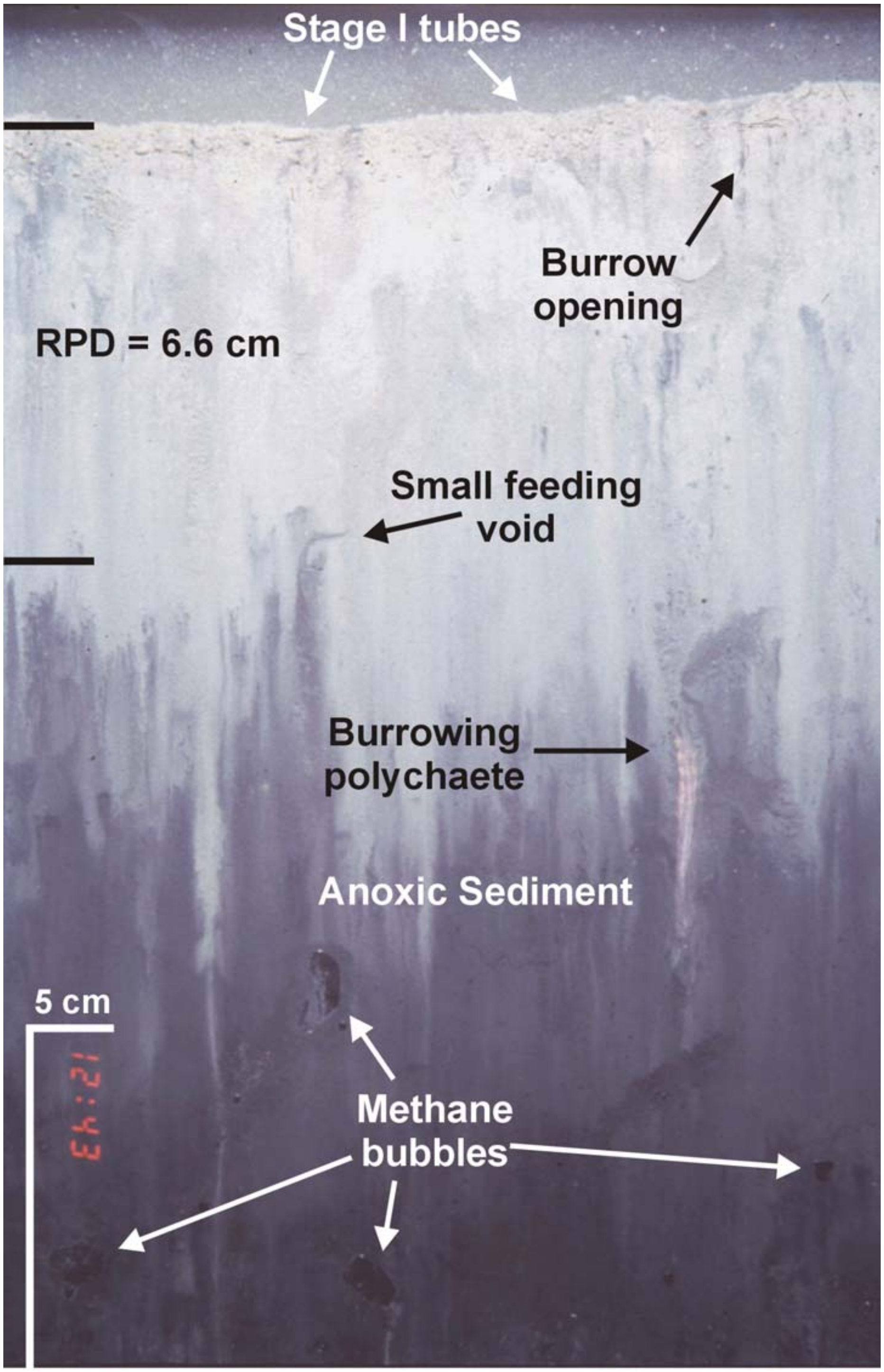


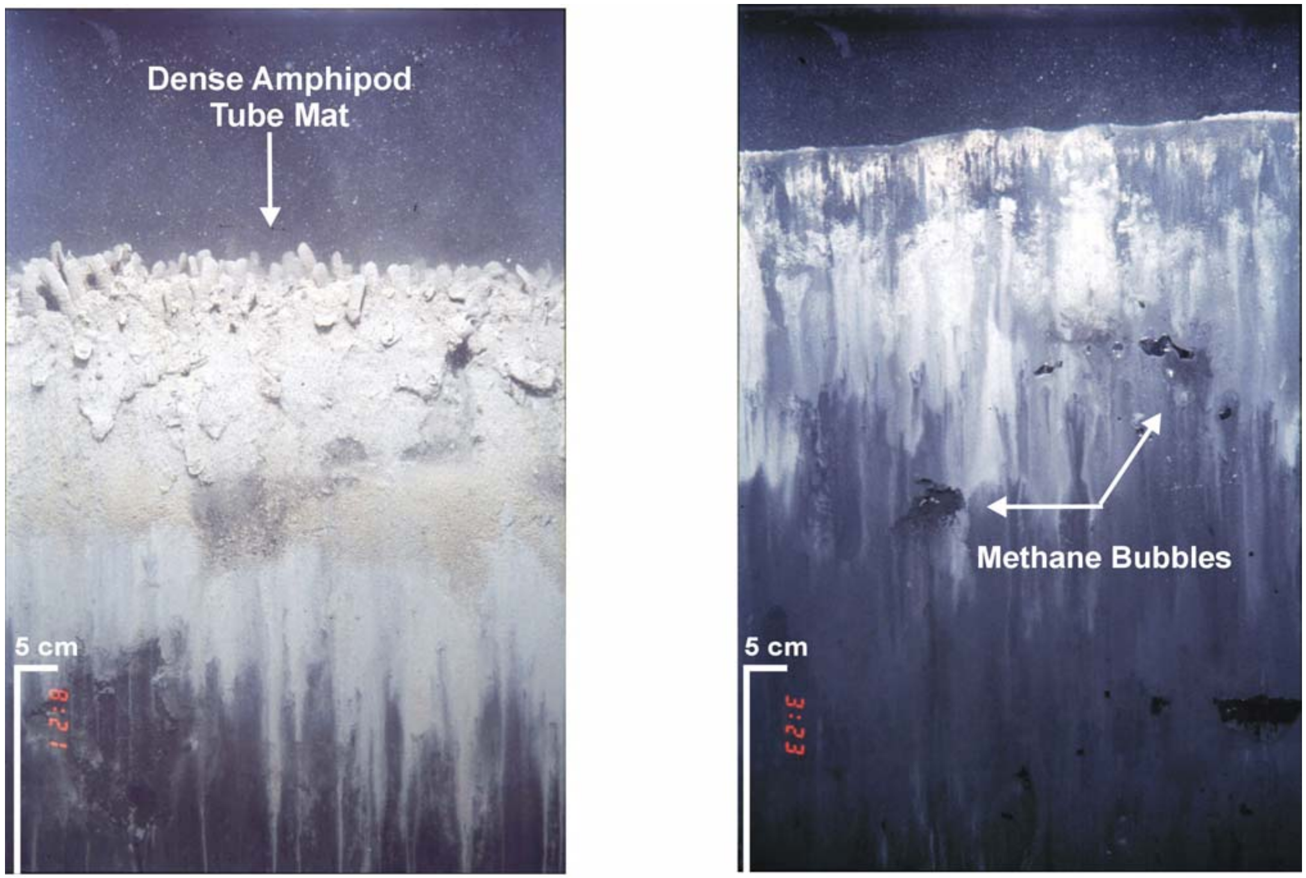
Figure 3-9. REMOTS® image obtained from Station 150S showing several methane gas bubbles within a black, anoxic sediment matrix at depth despite a deep RPD and evidence of Stage III activity.

stations contains a relatively high inventory of organic matter and that the material is decomposing under anaerobic conditions at depth. Despite the presence of methane, the surface sediments at many of these and other stations within the borrow pit appeared well oxygenated.

At approximately two years post-disposal, the successional stage recolonization status of the Morris Cove borrow pit was relatively advanced and included Stage I pioneering polychaetes, Stage II infaunal tubicolous amphipods (*Ampelisca* sp.), and Stage III head-down, deposit-feeding infauna (Table 3-1; Figure 3-7). Overall, evidence of Stage III activity was detected at 15 of the 22 (68%) stations occupied over the borrow pit. When present, Stage III activity was marked by active feeding voids or burrows in the subsurface sediments, and commonly accompanied by either Stage I or Stage II organisms at the sediment-water interface (Figure 3-7). Tube-dwelling amphipods (*Ampelisca* sp.) were observed in 41% of the images collected and were the sole representative of the Stage II successional sere in the sediment profile images (Figures 3-5 and 3-10A). High densities of both intact and decaying amphipod tubes were visible at the sediment-water interface at many stations, but the overall distribution of amphipod tubes was variable and showed no distinct spatial pattern (Figure 3-7).

Low-order seres (azoic or only Stage I taxa) were present in replicate images from various stations located within the borrow pit (Figure 3-7). Stations 25SW, 50E, 100NE, and 100SE appear to be recovering slowly from dredged material placement, as a Stage I benthic community was detected at each of these stations (Figure 3-7). Azoic conditions were observed in one image acquired from the three replicate images collected at Stations 100SE, 150SE and 50N (Figure 3-10B), indicating that a portion of the sediment deposit was still in the early stage of recovery or subjected to recent benthic disturbance.

The median OSI values for the stations within the borrow pit ranged from –3 at Station 100SE to +11 at Stations 50W and 200NW (Table 3-1; Figure 3-6). The average OSI value of +6.7 calculated for the borrow pit is generally indicative of undisturbed or non-degraded benthic habitat conditions, but it is lower than the composite value for the ambient sediments within the reference area (+9.4). The OSI values at the lower end of the scale (-3 to +6) reflect an absence of advanced Stage II and III infauna and/or the presence of methane or low sediment dissolved oxygen conditions. Conversely, the higher median OSI values reflect higher mean RPD depths, the presence of Stage III organisms, and a reduction in the presence of methane or low sediment dissolved oxygen conditions. Extremely shallow RPD depths, low sediment oxygen conditions, and/or the presence of methane at certain station replicates are attributed to small-scale variability in levels of organic carbon within the dredged material (Figure 3-8).



A **B**

Figure 3-10. REMOTS® images obtained from Stations 50S (A) and 100SE (B) showing difference in biological conditions over the Morris Cove sediment deposit. The image from Station 50S displays a stable Stage II benthic community represented by a dense amphipod tube mat at the sediment water interface. The replicate image from Station 100SE displays degraded habitat conditions with black, anoxic sediment and methane gas bubbles at depth with no indications of biological activity (classified as azoic).

The wide range of OSI values over the survey grid suggests significant variability in benthic habitat conditions exists across the area, ranging from the classification of disturbed or highly degraded (OSI values less than +3) to undisturbed or non-degraded (OSI values greater than +6). Many stations in the borrow pit survey area with and without dredged material have OSI values comparable to the range of values measured at the reference area (+8 to +11; see Section 3.3.2.2 below). The two borrow pit stations exhibiting very low OSI values were located on the eastern side of the sediment deposit (Stations 50E and 100SE), but were surrounded by stations exhibiting undisturbed habitat conditions. These findings suggest that this isolated area of seafloor within the borrow pit has been recently subjected to a benthic disturbance or may be slow to recover due to a high inventory of organic material contained within the sediments.

3.3.2 Reference Area

3.3.2.1 Physical Sediment Characteristics

Sediments at the reference area stations were similar to those within the borrow pit and were characterized as fine-grained tan over black silt (major modal grain size of >4 phi; Table 3-2). Mean camera prism penetration measurements ranged from 15.7 cm at Station REFB4 to 18.0 cm at Station REFB1, with an overall average of 16.9 cm (Table 3-2). This relatively deep camera prism penetration was comparable to that observed at the borrow pit stations and is typical for soft, fine-grained ambient sediments.

The average boundary roughness value for the reference area (1.3 cm) was similar to that observed at the stations within the borrow pit (1.2 cm), suggesting only minor small-scale surface relief. Contrary to the borrow pit stations, the majority of reference area stations displayed biogenic surface roughness, with only four replicate images exhibiting physical surface roughness. Biogenic activity was the result of dense polychaetes and/or tubicolous amphipod tubes, fecal layers or mounds, and biological surface reworking by burrowing infauna (burrow openings) at the sediment-water interface (Figure 3-11).

3.3.2.2 Biological Conditions

Replicate-average RPD measurements at the reference areas were relatively high, ranging from 2.6 cm at Station REFB2 to 6 cm at Station REFB3 (Table 3-2). Several replicate images had RPD measurements greater than 5 cm in depth (Figure 3-11). The overall average RPD value of 4.4 cm was higher, but still comparable to that observed at the borrow pit stations (3.4 cm) and is similarly indicative of well-oxygenated surface

Table 3-2.

Summary of REMOTS® Results from the May 2002 Survey over the Morris Cove Reference Area

Station	Grain Size Major Mode (phi), # of Replicates	Camera Penetration Mean (cm)	Boundary Roughness Mean (cm)	Successional Stages Present	Highest Successional Stage Present	RPD Mean (cm)	Methane Present	Low DO	OSI Mean	OSI Median
REFB1	> 4 phi (3)	18.00	0.87	II,III	ST II on III	5.25	No	No	9.67	9
REFB2	> 4 phi (3)	16.10	1.35	I,II,III	ST II on III	2.63	No	No	7.00	8
REFB3	> 4 phi (3)	17.36	1.47	II,III	ST II on III	6.00	No	No	10.33	11
REFB4	> 4 phi (3)	15.73	0.78	I,III	ST I on III	3.02	No	No	9.33	9
REFB5	> 4 phi (3)	17.33	1.88	II,III	ST II to III	4.99	No	No	9.67	10
AVG		16.91	1.27			4.38			9.20	9.4
MAX		18.00	1.88			6.00			10.33	11
MIN		15.73	0.78			2.63			7.00	8

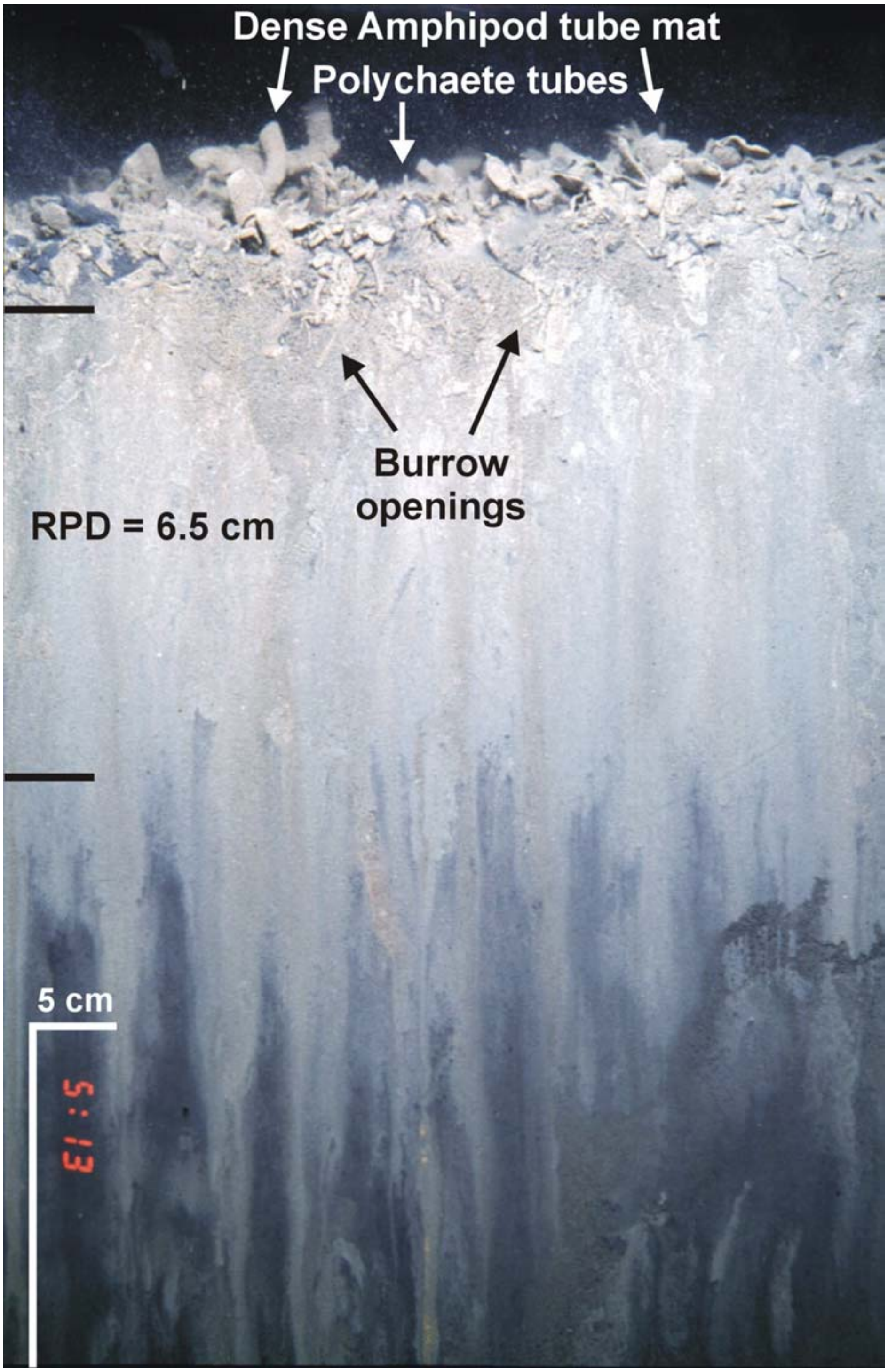


Figure 3-11. REMOTS® image acquired from Station REFB5 showing a deep (6.5 cm) RPD and a surface mat composed of both Stage II amphipod tubes and Stage I polychaete tubes

sediments. There was no indication of low sediment dissolved oxygen conditions, methane gas bubbles, or visible redox rebounds at the reference area stations.

Similar to the borrow pit stations, a combination of successional stages was observed at the reference area stations. Overall, the successional status within the reference area was advanced, with Stage III activity evident at all stations (Table 3-2). The Stage III activity was consistently associated with either Stage I pioneering polychaetes or Stage II amphipods at the sediment-water interface. One station (REFB5) exhibited a Stage II to III successional status, which indicates the presence of both Stage II infaunal amphipods at the sediment surface together with evidence of active bioturbation by deeper burrowing infauna at sediment depth. The notable scarcity of only low-order seres (Stage I) in each replicate image suggests that the reference areas displayed an advanced benthic community at the time of the survey.

Replicate-averaged OSI values for the reference area stations ranged from +8 at Station REFB2 to +11 at Station REFB3, with an overall median OSI value of +9.4 (Table 3-2). Deep RPD depths (overall 4.4 cm) and the dominance of Stage III organisms yielded OSI values reflective of non-degraded or undisturbed benthic habitat conditions. While many borrow pit survey area stations yielded OSI values within this range (+8 to +11), the composite value for the reference area (+9.4) was higher than the value calculated for the borrow pit stations (+6.7).

3.4 Benthic Grab Sampling

The benthic grab samples contained a small percentage of fine shell hash and sediments along with varying amounts of soft detritus material. Representatives of the phyla Nematoda, Annelida, Mollusca and Arthropoda were present at all five stations sampled; Nemertea were present at two of the five stations and Bryozoa at one station (Table 3-3). None of the stations had representatives from all six phyla.

Species richness across the five stations totaled 38 discrete taxa. In some cases damaged or small individuals could not be identified to species. These incompletely identified taxa were excluded from species richness when related individuals that could be identified more precisely were present. Of the discrete taxa found, 16 were annelids, 8 were molluscs, and 11 were arthropods. Other phyla, including Nemertea, Bryozoa and Nematoda were each represented by one species. Station 100NE had the greatest taxa richness with 20 discrete taxa, followed by Station RB4 with 18, and Station CTR with 14 (Table 3-3). Stations 25SE and 50N were represented with the lowest number of individual taxa at 13.

Table 3-3.

Abundance (Number of Organisms Per 0.04 m^2) of Benthic Macrofauna New Haven, Connecticut, June 4, 2002

Taxon	100NE-A	25SE-A	CTR-A	RB4-A	50N
Nemertea					
Amphiporus bioculatus			1	1	
Nematoda	1	2	11	6	1
Annelida					
Polychaeta					
Harmothoe extenuata	1				
Harmothoe imbricata	1				
Eteone heteropoda					1
Paranaitis speciosa	1				
Podarke obscura		1			
Nephtys incisa	5	13	10	9	8
Glycera americana				1	
Glycinde solitaria	1		2		
Leitoscoloplos sp.	7	1			
Streblospio benedicti		17	41	1	8
Tharyx acutus		1			
Cossura delta	1	3	48	32	2
Mediomastus ambiseta	2	24	143	745	2
Pectinaria gouldii				2	
Asabellides oculata					1
Oligochaeta	2	3	4	66	1
Mollusca					
Gastropoda	2		15		
Turbonilla interrupta				4	
Turbonilla elegantula				1	
Rictaxis punctostriatus			1		
Acteocina canaliculata	10	3		11	
Bivalvia					
Nucula annulata				2	
Yoldia limatula			1	3	
Macoma tenta	2	1	5	5	
Tellina agilis					3
Arthropoda					
Ostracoda	1				
Cumacea					
Leucon americanus	3	3			2
Diastylis sculpta	1				
Amphipoda					
Ampelisca abdita	400	97	113	121	40
Unciola irrorata	1		2	1	
Gammarus daiberi					1
Jassa marmorata				1	
Stenothoe brevicornis var. canadensis	1				
Decapoda					
Crangon septemspinosa					1
Dyspanopeus sayi	1				
Insecta					
Chironomidae			1		
Bryozoa					
Electra crustulenta	P				
Total abundance	**445**	**169**	**398**	**1012**	**71**
Number of Discrete Taxa	**20**	**13**	**14**	**18**	**13**
Shannon-Weiner Diversity (H')	**0.58**	**1.48**	**1.74**	**1.02**	**1.61**
Shannon-Weiner Evenness (J')	**0.19**	**0.58**	**0.64**	**0.35**	**0.63**

P = Colonials are noted as present and not enumerated.

Averaging over all stations, mean abundance (individuals/0.04m^2) was highest for the Stage I polychaete *Mediomastus ambiseta* (183.2). The next most abundant was the Stage II amphipod *Ampelisca abdita* (154.2). Ranking third was the Stage III polychaete *Cossura delta* (17.2). The next seven, ranked in descending order, were Oligochaeta (15.2); the polychaetes *Streblospio benedicti* (Stage I; 13.4), *Nephtys incisa* (Stage III; 9); the gastropod *Acteocina canaliculata* (4.8); Nematoda (4.2); various minor Gastropods (3.4); and the Stage II bivalve *Macoma tenta* (2.6).

Total abundance among the five stations was highest at the reference station RB4 (1,012), followed by 100NE (445), CTR (398), 25SE (169), and 50N (71) over the dredged material deposit (Table 3-4). The most abundant species are listed in Table 3-4 using a 1% total count as the lowest possible percentage. The amphipod *A. abdita* was the most abundant species at three stations and the polychaete *M. ambiseta* was the most abundant at the remaining two stations. *A. abdita* was most abundant at Stations 100NE (89.9%) 50N (56.3%) and 25SE (57.4%); *M. ambiseta* was most abundant at Stations CTR (35.9%) and RB4 (73.6%). Dominants also included polychaete worms *N. incisa* and *C. delta,* the gastropod *A. canaliculata* and various Oligochaetes, as well as *S. benedicti* and Nematoda.

Diversity (H') ranged from a low of 0.58 at Station 100NE (evenness 0.19) to a high of 1.74 at Station CTR (evenness 0.64) (Table 3-3). Stations CTR and RB4 were the most similar because of the high abundance of both *M. ambiseta* and *A. abdita*. Overall, diversity was relatively low at the five stations, reflecting the numerical dominance of one or two species (*A. abdita* and *M. ambiseta*) in each station. For number of taxa, diversity, and evenness metrics, the reference area station (RB4) values were comparable to the range of values calculated for the borrow pit stations. However, total abundance at the reference area station was more than twice the maximum abundance value from the borrow pit stations (Table 3-3).

Table 3-4.

Dominant Taxa Representing Greater than 1.0% of the Total for Each Station (Includes Non-Unique Taxa)

Taxon	% Total Count	Count
100NE-A		
Ampelisca abdita	89.9%	400
Acteocina canaliculata	2.3%	10
Leitoscoloplos sp.	1.6%	7
Nephtys incisa	1.1%	5
Total Abundance:		**445**
25SE-A		
Ampelisca abdita	57.4%	97
Mediomastus ambiseta	14.2%	24
Streblospio benedicti	10.1%	17
Nephtys incisa	7.7%	13
Oligochaeta	1.8%	3
Acteocina canaliculata	1.8%	3
Leucon americanus	1.8%	3
Cossura delta	1.8%	3
Nematoda	1.2%	2
Total Abundance:		**169**
CTR-A		
Mediomastus ambiseta	35.9%	143
Ampelisca abdita	28.4%	113
Cossura delta	12.1%	48
Streblospio benedicti	10.3%	41
Gastropoda	3.8%	15
Nematoda	2.8%	11
Nephtys incisa	2.5%	10
Macoma tenta	1.3%	5
Oligochaeta	1.1%	4
Total Abundance:		**398**
Taxon	**% Total Count**	**Count**
RB4-A		
Mediomastus ambiseta	73.6%	745
Ampelisca abdita	12.0%	121
Oligochaeta	6.5%	66
Cossura delta	3.2%	32
Acteocina canaliculata	1.1%	11
Total Abundance:		**1012**
50-N		
Ampelisca abdita	56.3%	40
Nephtys incisa	11.3%	8
Streblospio benedicti	11.3%	8
Tellina agilis	4.2%	3
Cossura delta	2.8%	2
Mediomastus ambiseta	2.8%	2
Leucon americanus	2.8%	2
Asabellides oculata	1.4%	1
Crangon septemspinosa	1.4%	1
Oligochaeta	1.4%	1
Nematoda	1.4%	1
Gammarus daiberi	1.4%	1
Eteone heteropoda	1.4%	1
Total Abundance:		**71**

4.0 DISCUSSION

4.1 Disposal Site Management Strategy

The rationale for the placement of dredged sediments within the Morris Cove borrow pit was to begin the process of re-establishing flat, uniform bottom topography and promoting improved water quality within Morris Cove. The Morris Cove borrow pit, formed by sand mining operations over fifty years ago, has reportedly become a sink for organic detritus in New Haven Harbor. While the predominance of sandy substrate in the vicinity of the borrow pit is indicative of the influence of wave and tidal current energy acting on the bottom sediments, the borrow pit constitutes a distinct depression that may enhance deposition of fine-grained material. The pit's distinct margins tend to limit the flow within the pit and the volume of water exchanged.

The National Marine Fisheries Service (NMFS) has identified Morris Cove as an important spawning and nursery area for a variety of commercially important fish species, including winter flounder (Pereira et al. 1992, 1994, 2002). NMFS has expressed concern regarding the presence of the borrow pit within Morris Cove and the potential for reduced water exchange (flushing) to trap organic material within the bottom feature. As organic material within the borrow pit undergoes the process of decay, the quality of the bottom waters (dissolved oxygen, nutrient content, pH, etc.) could degrade sufficiently to result in poor habitat conditions for marine organisms. These conditions would be especially prevalent and have the most profound impacts during the summer months when dissolved oxygen concentrations tend to be lower due to the warmer water temperatures within New Haven Harbor and Long Island Sound (in excess of 20° C), as well as reduced surface mixing (i.e., gas exchange via short-period waves) relative to the remainder of the year.

In the summer and fall of 2002, the National Marine Fisheries Service (NMFS) in Milford, CT, deployed water quality monitoring instruments within Morris Cove to examine dissolved oxygen concentrations and determine if conditions within the borrow pit could be detrimental to the development of juveniles of several species. The instruments were placed at locations that would allow the comparison of conditions within the basin feature to those in the shallow waters over ambient bottom (Figure 4-1). In general, the data collected as part of this study indicate distinct differences in water quality existed between the two areas during both the summer (early-August) and fall (mid-October) months. These differences in water quality are likely the result of stratified water flow and poor flushing within the man-made bottom feature.

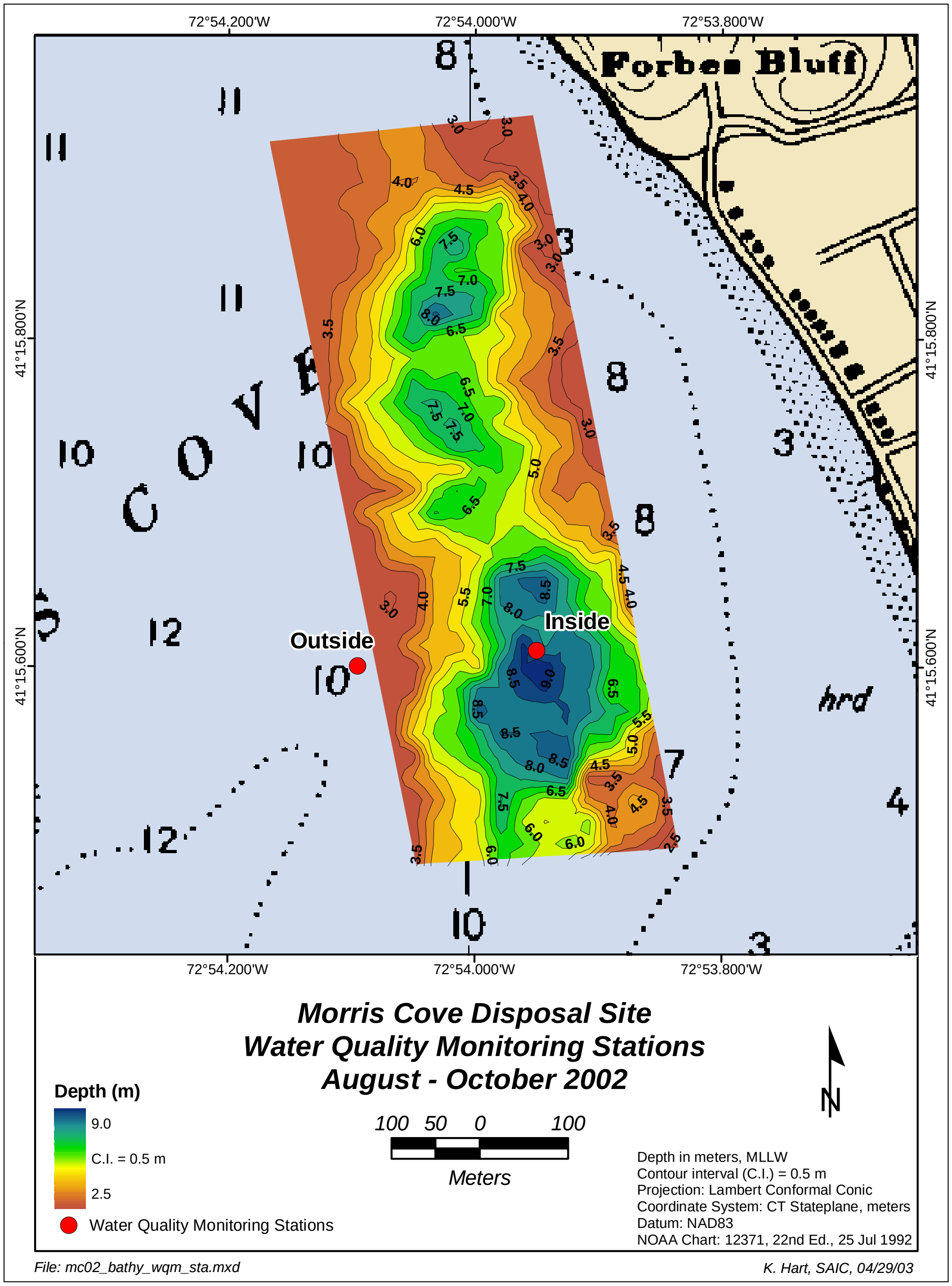
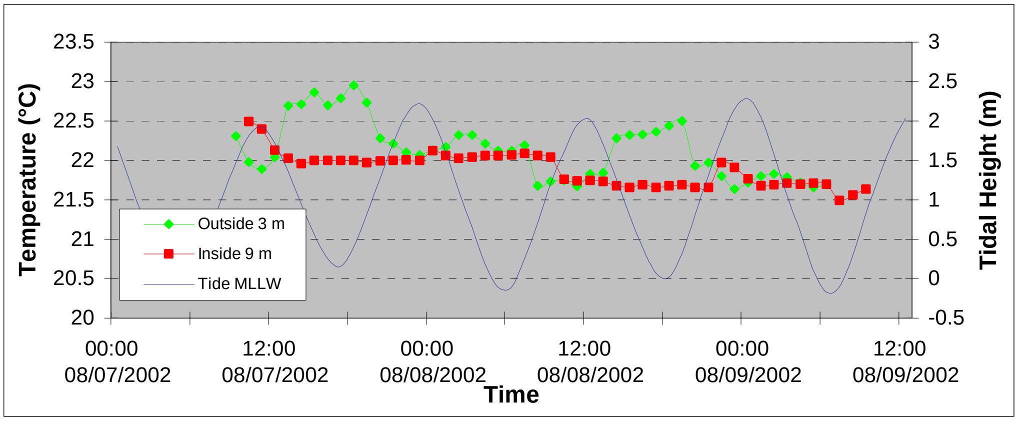


Figure 4-1. Graphic showing the location of water quality instrumentation placed within Morris Cove during the summer and fall of 2002 to compare conditions within the borrow pit to those over ambient bottom

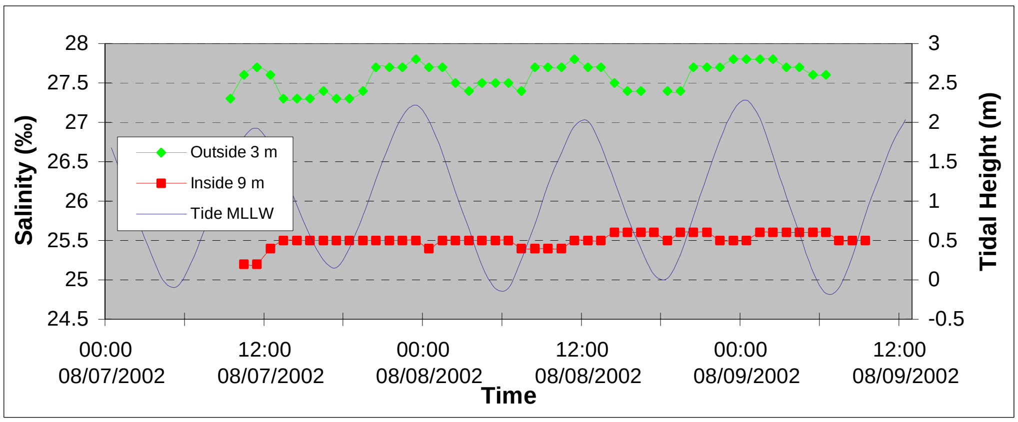
During the 48-hour August deployment period, water temperatures within the borrow pit remained relatively constant at 22° C, and in contrast to the shallow water location, appeared to be uninfluenced by the tidal cycle within New Haven Harbor (Figure 4-2A). The overall similarity in water temperatures measured inside and outside the confines of the borrow pit suggest the deeper water within the basin feature offers little value as a refuge to marine organisms seeking cooler waters during the summer months. Salinity inside the pit failed to show the variation typically observed in a tidally dominated, estuarine environment, while the record from the instrument located over ambient bottom displayed the effects of fresh and salt water infusion during the ebb and flood tides (Figure 4-2B). In addition, the salinity record obtained from within the pit detected a lower salt content despite the deeper water, which may be attributable to ground water infiltration and the subsequent dilution of bottom waters or simple sensor bias.

The most significant difference between the two deployment locations was observed in dissolved oxygen records. Bottom water oxygen concentrations within the borrow pit were noticeably lower than those collected over ambient seafloor in Morris Cove (Figure 4-2C). Furthermore, dissolved oxygen concentrations steadily declined over the 48-hour period, remaining at levels classified as hypoxic by the Long Island Sound Study ($\leq$3 $mg \cdot l^{-1}$) for the majority of the deployment (LISS 1990). During the early morning hours of 9 August 2002, oxygen depletion within the borrow pit continued to near anoxic levels (0 $mg \cdot l^{-1}$) before rebounding to approximately 2 $mg \cdot l^{-1}$ by mid-morning. Both periodic and prolonged episodes of anoxia have an impact on the character of the benthic community in the borrow pit and reduce the value of the affected area of seafloor to both sessile and motile marine organisms.

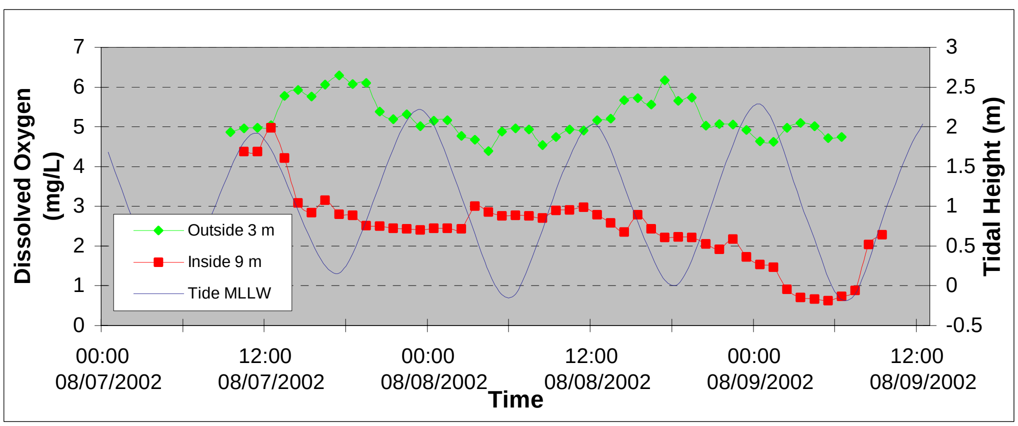
The results from the six day instrument deployment in October 2002 displayed improved water quality conditions within the borrow pit relative to those detected in August. In general, bottom water temperatures within the borrow pit tracked 0.5° C cooler than the shallow water site (Figure 4-3A). Salinity data collected within the borrow pit and over ambient bottom showed strong agreement during the first three days of the record until a large run-off event triggered a significant reduction in salinity at the shallow water site on 19 August (Figure 4-3B). A large volume of fresh water likely moved out of New Haven Harbor and into Long Island Sound in several days after the passage of a significant regional storm event on 16 and 17 October (SAIC 2003). The run-off from this storm was sufficient to reduce salinity by 12‰ within a three hour period at the shallow water site, as well as impact salinity within Long Island Sound for several days. Salinity values within the borrow pit displayed a subtle reduction (0.5‰) in response to the run-off event, but returned to normal levels within 24 hours.



A

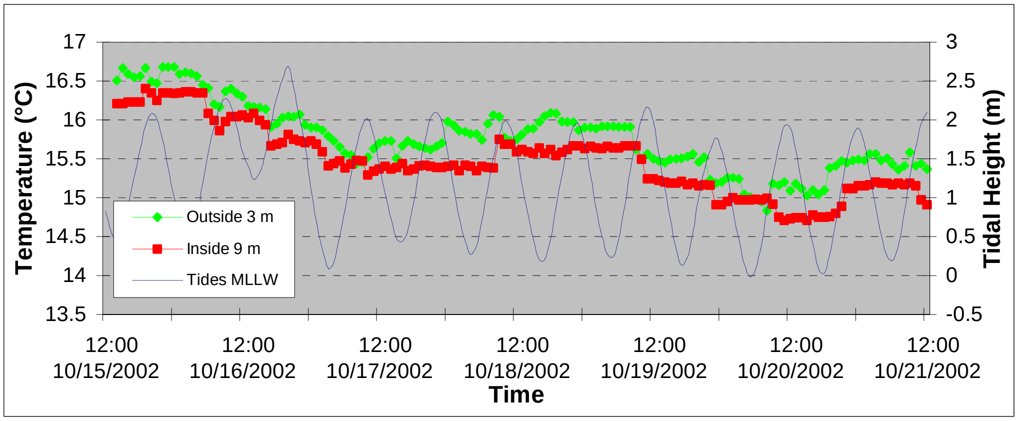


B

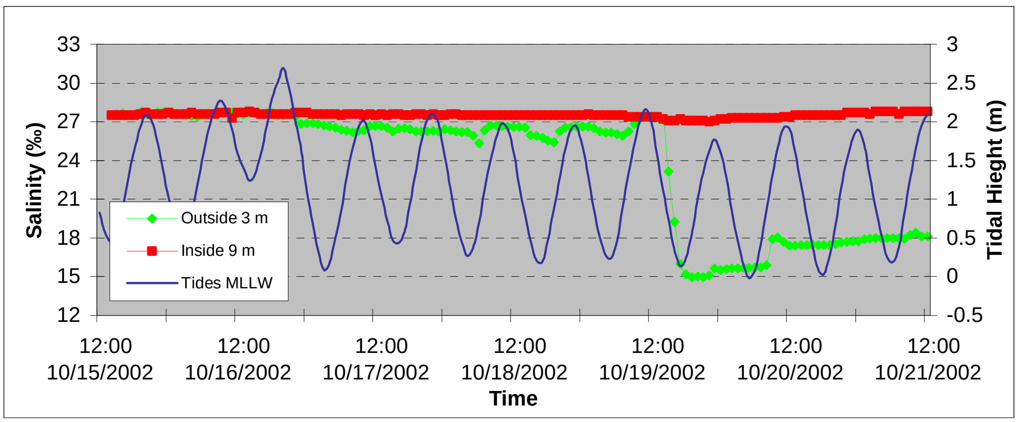


C

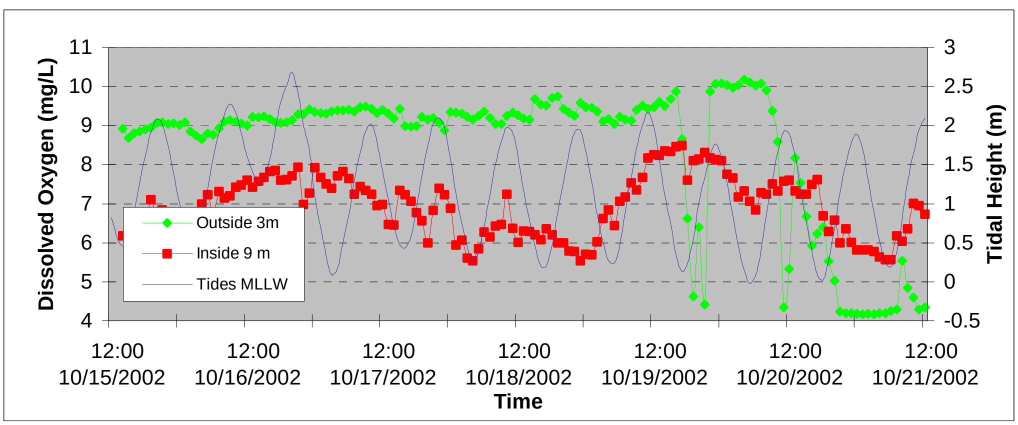
Figure 4-2. Charts comparing water quality conditions (Temperature [A], Salinity [B], and Dissolved Oxygen concentrations [C]) within the Morris Cove borrow pit to those outside the bottom feature relative to tides within New Haven Harbor in August 2002. Data provided by the National Marine Fisheries Service office in Milford, CT.



A



B



C

Figure 4-3. Charts comparing water quality conditions (Temperature [A], Salinity [B], and Dissolved Oxygen concentrations [C]) within the Morris Cove borrow pit to those outside the bottom feature relative to tides within New Haven Harbor in October 2002. Data provided by the National Marine Fisheries Service office in Milford, CT.

Dissolved oxygen concentrations within the borrow pit were 1 to 3 $mg \cdot l^{-1}$ lower than those measured over ambient bottom, but remained above levels found to be protective of marine life (5 $mg \cdot l^{-1}$; Figure 4-3C; LISS 1990). The dissolved oxygen record for the shallow water site showed concentrations approaching 10 $mg \cdot l^{-1}$ before displaying strong deflections in the record on 19 October in association with the run-off event. Oxygen content was variable at the deeper site in the Morris Cove borrow pit as well, but appeared unaffected by the influx of fresh water into the system.

Although the data records for the August and October deployment are brief, the results confirm a lack of seawater mixing within the borrow pit, poor tidal flushing, and the lack of any temperature refuge that would be exploited by various marine organisms dwelling in New Haven Harbor. Dissolved oxygen concentrations are generally lower within the bottom feature relative to ambient seafloor, and can potentially become anoxic for periods of time during the summer months when water quality conditions deteriorate throughout the region. From a water quality perspective, the borrow pit appears to offer little benefit to the benthic and pelagic species inhabiting Morris Cove. Therefore it is recommended that the borrow pit continue to be used for the placement of small to moderate volumes of sediment deemed suitable for unconfined open water disposal.

4.2 Dredged Material Distribution

The distribution of dredged material placed during the 1999/2000 disposal season, as detected by REMOTS® sediment profile imaging and side-scan sonar, indicates the sediment deposit remains contained within the southern portion of the borrow pit and extends approximately 100 to 150 m southeast from the MCDA buoy position. The average thickness of the dredged material based on the sediment profile images exceeded 11 cm. The distribution and thickness of the dredged material was similar to the results from the September 2000 monitoring survey, suggesting no appreciable changes in the morphology of the deposit, and no indications of erosion or sediment transport (i.e., winnowing of fines).

One of the objectives of the May 2002 survey was to estimate the remaining capacity of the borrow pit for potential dredged material disposal in the future. The bathymetric data collected as part of the 2002 monitoring efforts were used as the basis for those calculations. When overlaid on the side-scan sonar mosaic, the margins of the Morris Cove borrow pit detected by side-scan correlated with the 3.5 m and 4 m depth contours (Figure 4-4). As a result, the 3.5 m depth contour shown by the bathymetry was determined to be the approximate margin of the borrow pit (Figure 3-1). To achieve greatest horizontal and vertical precision while estimating borrow pit capacity, the 3.5 m depth contour was presented as the borrow pit boundary in all figures instead of the

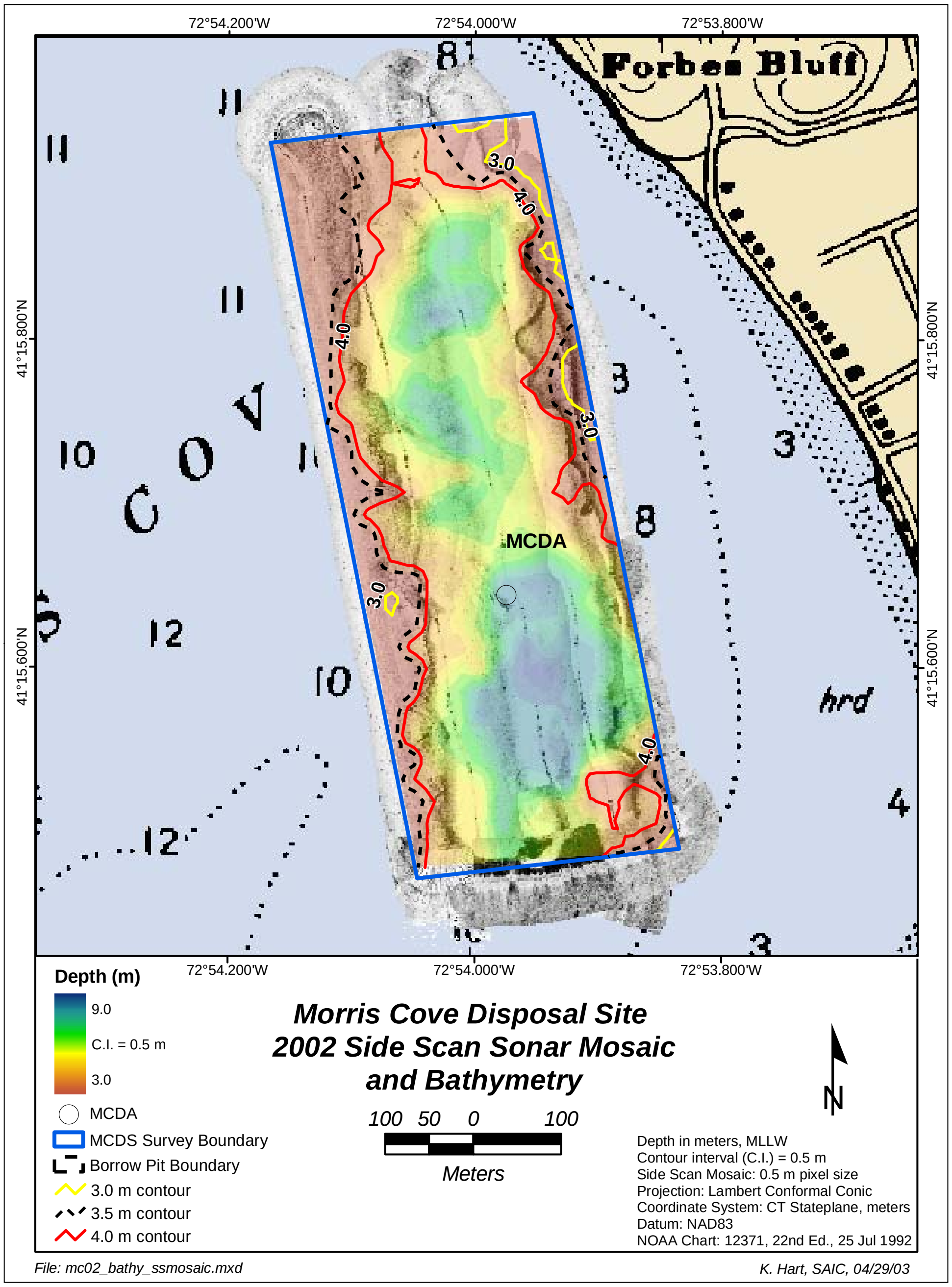


Figure 4-4. Composite graphic displaying the side-scan sonar mosaic overlain by the May 2002 bathymetry data to examine the relationship between the margins of the Morris Cove borrow pit, water depth (MLLW), and potential dredged material capacity. The dashed black line represents the borrow pit boundary based on the 3.5 m bathymetric contour, while the red line represents the 4 m depth contour.

indistinct boundary detected in the side-scan sonar mosaic. Using a GIS program, the volume of the borrow pit was calculated based on filling the bottom feature with dredged sediments up to the 3.5 m depth contour line (borrow pit boundary), as well as to the 3 m depth contour. (Figures 4-4 and 4-5).

The 3.5 m contour represents approximately the shallowest depth of the pit to which material could be placed without breaching the existing margins (Figure 4-5). Based on these calculations it is estimated that the pit could contain approximately 468,000 m^3 of additional dredged material. If the pit was filled to a depth of 3 m (MLLW), it is estimated that it could contain approximately 577,000 m^3 of sediment; however, positive relief (mounding) over ambient would be expected to occur.

4.3 Benthic Recolonization and Habitat Conditions

Under the DAMOS tiered monitoring protocol (Germano et al. 1994), surveys are conducted at regular intervals to verify that populations of benthic organisms recolonize dredged material deposits in a manner consistent with expectations. Therefore, a major objective of the May 2002 survey over the Morris Cove borrow pit was to evaluate the benthic recolonization status at approximately two years post-disposal. This objective was addressed through the use of two different, but complimentary, sampling techniques: REMOTS® sediment-profile imaging, and benthic grab sampling with subsequent taxonomic analysis. The June 2002 REMOTS® survey re-occupied 22 stations within the borrow pit that were sampled previously in September 2000. Grab samples for benthic taxonomy were collected and processed at three borrow pit stations and one reference area station in June 2002. Benthic grab samples were not obtained as part of the 2000 monitoring effort.

The results from sediment profile images indicated that a diverse benthic community consisting of both surface-dwelling and deeper-dwelling infauna has successfully colonized the majority of the dredged material deposit. This benthic infaunal community appeared to be similar to that observed in the ambient sediments of the nearby reference area. The overall median OSI value of +6.7 for the REMOTS® stations occupied over the borrow pit is indicative of a relatively stable, non-degraded benthic habitat at the time of the May 2002 survey. This value is a product of both moderately deep oxygenation of the surface sediments and the presence of Stage II and III organisms at the majority of stations sampled. The composite OSI for the reference area stations was higher (+9.4), due to the consistent presence of a mature benthic infaunal community, deep RPD depths, and lack of methane or low dissolved oxygen conditions in the surficial sediments. The composite OSI value observed for the borrow pit station does not necessarily reflect poor benthic habitat

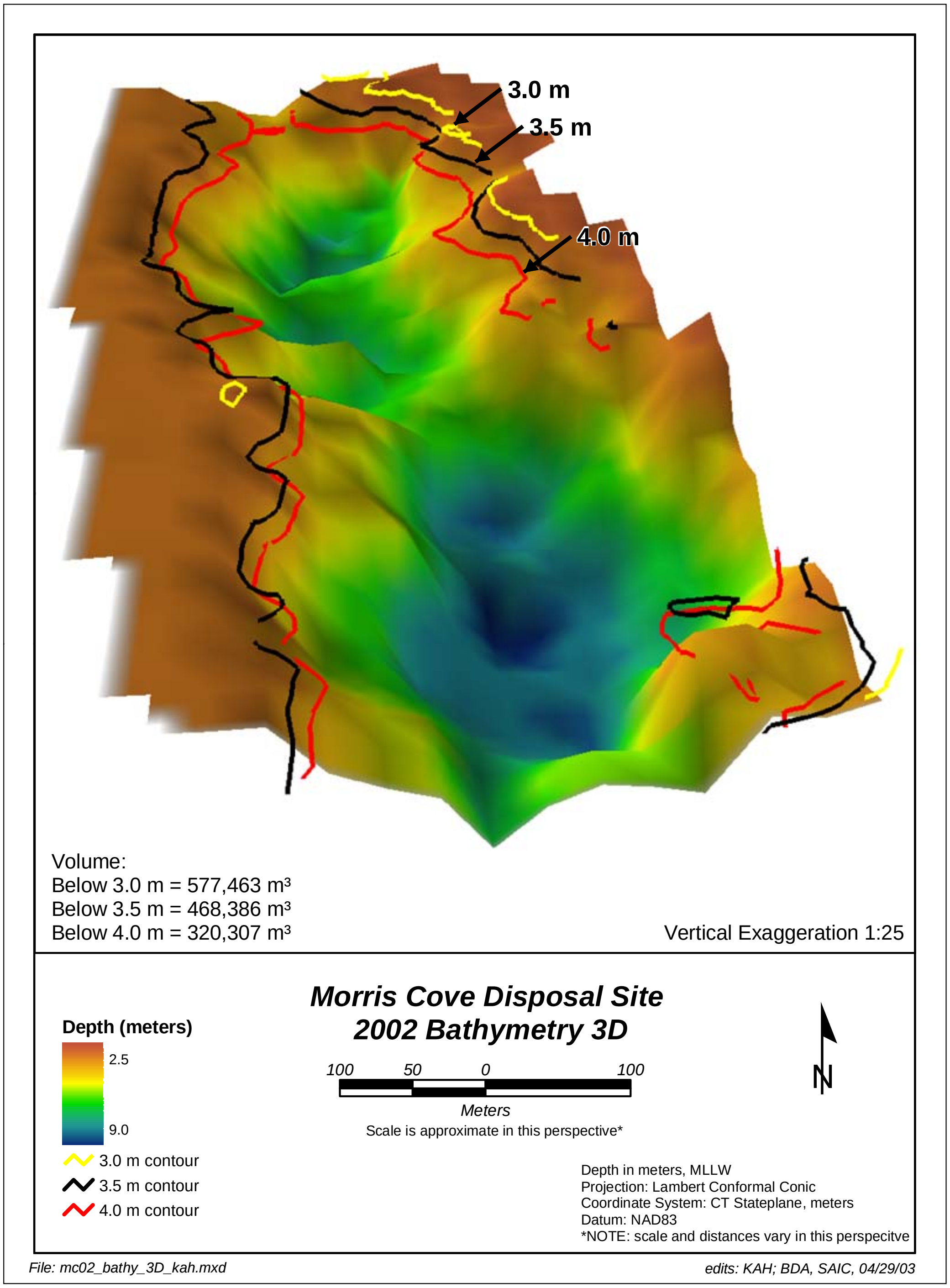


Figure 4-5. Three-dimensional representation of the Morris Cove borrow pit based on single-beam bathymetry, used to calculate the remaining capacity of the bottom feature for potential dredged material placement in the future

conditions since OSI values greater than +6 represent a well established benthic community in the seafloor sediments. The difference between the OSI values of the Morris Cove borrow pit stations and the reference areas indicates that the seafloor in the borrow pit is still recovering from the initial placement of dredged material in winter and spring of 2000.

In comparison to the September 2000 dataset, the May 2002 results over the borrow pit indicate a general improvement in benthic habitat conditions at the majority of stations occupied. As expected, the mean RPD depth has deepened over the past two years (mean RPD depth of 3.4 cm in 2002 compared to 3 cm in 2000), reflecting increased levels of bioturbation by recolonizing infauna and associated consumption of organic matter within the surface sediments. Likewise, median OSI values have increased from +5.6 in 2000 to +6.7 in 2002, reflecting both deeper RPD depths and an increase in the abundance of advanced successional stages.

Although improvement in benthic habitat conditions was documented over most of the sediment deposit, the results obtained from Stations 50E and 100SE in May 2002 display a substantial decline in benthic habitat conditions relative to September 2000 as median OSI values fell 7.5 and 6 points, respectively. Shallower RPD depths, lack of an advanced successional stage, and methane gas within the sediments were the basis for the reduction in OSI values. The presence of methane bubbles below the sediment-water interface is a product of microbial decomposition of organic matter within an anaerobic environment in the subsurface sediment layers. As a result, the production of methane generally serves as an indicator of organic loading within the sediments, which may be attributable to the properties of the dredged material placed in Morris Cove or related to subsequent deposition of organics or anthropogenic disturbance.

Moderate inputs of organic matter experienced at sufficient distance from an organic loading point source can actually have a stimulatory effect on benthic production by providing forage for deposit feeding invertebrates, as noted over most of the survey grid (Pearson and Rosenberg 1978; Grizzle and Penniman 1991; Simboura et al. 1995; Maurer et al. 1993). The sediments located at Stations 50E and 100SE likely have elevated levels of organic matter contained within this material, which tends to cause a localized increase in total sediment oxygen demand that can delay the recovery process. However, as the inventory of organic matter undergoes microbial decomposition and direct consumption by benthic organisms, it is anticipated that benthic conditions at Stations 50E and 100SE will show gradual improvement. Although the poor benthic habitat conditions detected at these two stations appear to be isolated to the eastern flank of the sediment deposit, continued monitoring of the entire sediment deposit formed within the Morris Cove borrow pit is recommended in the coming years. Particular emphasis should be on Stations 50E and 100SE to verify that habitat conditions improve and the benthic infauna exploit the deposited sediments as a habitat and food source.

4.4 Benthic Community Analysis

The benthic taxonomy data served to supplement the sediment profile imaging successional stage designations, showing the community consisted of high relative numbers of surface-dwelling Stage I and II taxa, and fewer subsurface-dwelling, advanced Stage III taxa. Some surface-dwelling, tubiculous Stage I polychaetes were encountered, but were not particularly prevalent in either the sediment-profile images or the benthic taxonomy grab samples. The Stage II, tube building amphipod (*Ampelisca abdita*) and the Stage I, surface deposit feeding polychaete worm (*Mediomastus ambiseta*) dominated the benthic community over the dredged material deposit, as well as the nearby reference area. Stage III polychaetes *Nephtys incisa* and *Cossura delta* were also among the numerically dominant taxa over the dredged material deposit and reference area (Table 3-4).

The benthic taxonomy results from the individual sediment grab samples were generally in agreement with the findings of the REMOTS® sediment profile images, with the exception of the data collected at Station 100NE. Grab samples confirmed that the benthic community at Station 100NE was dominated by Stage II amphipods (90% of total count), with a minor presence of Stage III polychaete worms (1.1%). Sediment profile imaging data indicated only the presence of Stage I community in all three replicate images at the time of the REMOTS® survey. The difference in benthic community determination could be the result of spatial variability within the sampling radius surrounding Station 100NE, the establishment of a significant amphipod population in this area of the borrow pit within the 12 days between the REMOTS® and grab sampling surveys, and difficulties in determining the presence of small populations of Stage III polychaetes in REMOTS® images.

Each of the five benthic grab sampling stations occupied during the 2002 monitoring survey showed the dominance of primarily *A. abdita* and *M. ambiseta*. Dominance by one or two species generally indicates a stressed or recovering benthic environment. *A. abdita* constructs tubes at the sediment-water interface where it feeds by filtering the bottom water. It is considered to be a pioneering-to-intermediate stage species, indicative of a moderately stable environment and absence of pollution. Thick mats of amphipod tubes are capable of stabilizing the underlying sediments and promoting settlement by other species. However, this species can be an ephemeral component of the benthic community as naturally occurring, annual population cycles can result in changes in density within a given year. In addition, wave activity that reaches the seafloor, such as may occur during storm events, can displace the tube mats and resident populations.

The Stage I polychaete *M. ambiseta* is considered a surface deposit feeder that generally lives near the sediment-water interface (Fauchald and Jumars 1970). Weisberg et al. (1997) considered this species to be pollution-sensitive and representative of a healthy benthic community. The presence and high relative abundance of *M. ambiseta* over the two year-old sediment deposit therefore serves to indicate increased sediment stability and reduced levels of environmental stress.

Benthic organisms considered components of a Stage III benthic community (*Cossura delta* and *Nephtys incisa)* were detected in varying numbers at all four stations sampled over the dredged material deposit and nearby reference area. *C. delta* is a head-down deposit-feeding invertebrate that actively forages below the sediment-water interface ingesting sediment particles to obtain nutrients from organic detritus within the sediment. *N. incisa* is a motile polychaete that has demonstrated both sub-surface deposit feeder and carnivorous tendencies (Fauchald and Jumars 1970). Both species are relatively large-bodied organisms and are capable of extensive bioturbation, resulting in the formation of deep RPDs.

All stations exhibit mixed characteristics relative to environmental stress levels. In particular, the dominance by one or two species suggests that the benthic communities would have limited resilience to various types of stress (e.g., storm events, hypoxia, burial). On the other hand, the species richness is moderate, considering the small sample size and absence of replication. A number of the polychaete species encountered are burrowers, confirming that the underlying sediments are oxygenated and capable of supporting benthic infauna. The dominant species are characteristic of a moderately stable community.

Benthic community metrics for the reference area were comparable to the range of values determined for the borrow pit stations with the exception of total abundance. The reference area station exhibited more than twice the abundance of the maximum borrow pit abundance value. However, all abundance values (1,775/m^2 to 25,300/m^2) would be considered typical of a fine-grained estuarine site. Comparison data are available for the general vicinity from the EPA Environmental Monitoring and Assessment Program (EMAP) which sampled the benthic community using grab samples at a station in New Haven Harbor in 1993 (USEPA 1993). That study yielded a mean count of 12,243 individuals/m^2 from three grab samples collected at a relatively sandy site (3.3% silt and clay) in the harbor entrance approximately 3,000 m southwest from the borrow pit. Additional comparison information is available from a Yale University characterization of the West River, which sampled the benthic community at 17 stations, yielding a range of abundances from 72 to 4,768 individuals/m^2 and a mean abundance of 108 individuals/m^2 (Cuomo and Zinn 1997). As a result, the mean abundances that were seen over the Morris Cove borrow pit and reference stations during the spring 2002 monitoring survey appear to be within the range of normal variability within the benthic infaunal community within New Haven Harbor.

5.0 CONCLUSIONS

All of the objectives for the 2002 Morris Cove borrow pit survey were successfully accomplished. The findings of this survey include:

- Sediment-profile images and side-scan sonar data indicated the continued presence of dredged material in close proximity to the MCDA buoy position and extending out 100 to 150 m from the central disposal point. Results confirmed that the dredged material has remained contained in the southern portion of the pit. There were no indications of erosion of the dredged material deposit or coarsening of surface sediments due to sediment transport.

- The capacity of the Morris Cove borrow pit for the potential deposition of dredged material in the future remains quite large. Approximately 468,000 m^3 of dredged material may be strategically placed within the pit to fill it to a depth of 3.5 m MLLW, roughly even with the surrounding ambient bottom.

- At approximately two years post-disposal, benthic recolonization over the majority of the dredged material deposit appears to be progressing as expected and is similar to the biological assemblage present at a nearby reference area. The benthic taxonomy results from the individual sediment grab samples generally in supported with the findings of the REMOTS® sediment profile images, with the exception of Station 100NE. The differences noted at Station 100NE may be the result of spatial variability within the sampling radius or the development of an amphipod population over this area of seafloor within the 12 day period between sediment profile imaging and sediment sampling surveys.

- In comparison to the September 2000 data set, benthic habitat conditions within the Morris Cove borrow pit showed general improvement at all but two stations. The majority of the stations within the borrow pit displayed moderate to deep RPD depths and advanced successional status (Stage II and/or III organisms). As a result, median OSI values were relatively high for the majority of the stations occupied over this two-year old dredged material deposit.

- A significant decrease in median OSI values was noted at Stations 50E and 100SE, relative to the September 2000 survey. An abundance of methane gas was present at these two stations, suggesting a high inventory of organic matter is entrained within the underlying sediments, which may be the basis for the decline. The degraded benthic habitat appears to be isolated to the eastern side of the sediment deposit and is expected to gradually improve as the organic matter is consumed through biological consumption, chemical oxidation, and microbial action. Subsequent monitoring efforts over the Morris Cove borrow pit should examine Stations 50E and 100SE in detail to verify the improvement in benthic habitat conditions over time.

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Appendix A

Appendix A1

Morris Cove Borrow Pit Sediment-Profile Imaging Data from the May 2002 Survey

Station	Replicate	Date	Time	Successional Stage	Grain Size (phi) Min	Grain Size (phi) Max	Grain Size (phi) Maj Mode	Mud Clasts Count	Mud Clasts Avg. Diam	Camera Penetration (cm) Min	Camera Penetration (cm) Max	Camera Penetration (cm) Range	Camera Penetration (cm) Mean	Dredged Material Thickness (cm) Min	Dredged Material Thickness (cm) Max	Dredged Material Thickness (cm) Mean	Redox Rebound Thickness (cm) Min	Redox Rebound Thickness (cm) Max	Redox Rebound Thickness (cm) Mean
CTR	A	5/24/2002	12:28	ST II to III	> 4 phi	4-3 phi	> 4 phi	2	0.14	7.91	9.48	1.57	8.69	> 7.91	> 9.48	> 8.69	0	0	0
CTR	B	5/24/2002	12:29	ST II	> 4 phi	4-3 phi	> 4 phi	2	0.53	14.21	15.25	1.04	14.73	> 14.21	> 15.25	> 14.73	0	0	0
CTR	C	5/24/2002	12:29	ST I	> 4 phi	4-3 phi	> 4 phi	1	0.43	8.79	10.18	1.39	9.49	> 8.79	> 10.18	> 9.49	0	0	0
25NE	H	5/24/2002	16:02	INDET	> 4 phi	4-3 phi	> 4 phi	0	0	20.34	20.45	0.11	20.4	> 20.34	> 20.45	> 20.4	0	0	0
25NE	K	5/25/2002	08:33	ST I	> 4 phi	4-3 phi	> 4 phi	1	0.45	17.09	17.73	0.64	17.41	> 17.09	> 17.73	> 17.41	0	0	0
25NE	L	5/25/2002	08:33	ST I on III	> 4 phi	4-3 phi	> 4 phi	2	0.6	14.43	14.77	0.34	14.6	> 14.43	> 14.77	> 14.6	0	0	0
25SE	A	5/24/2002	15:09	ST I on III	> 4 phi	4-3 phi	> 4 phi	0	0	18.2	20.82	2.62	19.51	> 18.2	> 20.82	> 19.51	0	0	0
25SE	C	5/24/2002	15:13	ST I	> 4 phi	4-3 phi	> 4 phi	0	0	18.34	19.8	1.46	19.07	> 18.34	> 19.8	> 19.07	0	0	0
25SE	F	5/25/2002	08:41	ST I	> 4 phi	4-3 phi	> 4 phi	6	0.25	9.62	10.09	0.47	9.85	> 9.62	> 10.09	> 9.85	0	0	0
25SW	A	5/24/2002	13:25	ST I	> 4 phi	4-3 phi	> 4 phi	1	0.25	19.16	19.95	0.79	19.56	> 19.16	> 19.95	> 19.56	0	0	0
25SW	D	5/24/2002	13:27	ST I	> 4 phi	4-3 phi	> 4 phi	3	1	18.79	20.04	1.25	19.42	> 18.79	> 20.04	> 19.42	0	0	0
25SW	I	5/25/2002	09:03	ST I	> 4 phi	4-3 phi	> 4 phi	0	0	14.52	16.8	2.28	15.66	> 14.52	> 16.8	> 15.66	0	0	0
25NW	C	5/24/2002	15:45	ST II to III	> 4 phi	4-3 phi	> 4 phi	0	0	18.88	21	2.12	19.94	> 18.88	> 21	> 19.94	0	0	0
25NW	F	5/25/2002	08:27	ST II	> 4 phi	4-3 phi	> 4 phi	0	0	14.64	15.96	1.32	15.3	> 14.64	> 15.96	> 15.3	0	0	0
25NW	H	5/25/2002	08:28	ST II	> 4 phi	4-3 phi	> 4 phi	5	0.32	11.98	13.45	1.47	12.72	> 11.98	> 13.45	> 12.72	0	0	0
50N	B	5/24/2002	12:21	ST III	> 4 phi	4-3 phi	> 4 phi	4	0.31	19.66	20.66	1	20.16	> 19.66	> 20.66	> 20.16	0	0	0
50N	D	5/24/2002	12:23	Azoic	> 4 phi	4-3 phi	> 4 phi	0	0	16.91	19.11	2.2	18.01	> 16.91	> 19.11	> 18.01	0	0	0
50N	F	5/25/2002	08:25	ST I	> 4 phi	4-3 phi	> 4 phi	4	0.26	18.11	18.95	0.84	18.53	> 18.11	> 18.95	> 18.53	0	0	0
50E	D	5/24/2002	14:10	ST I	> 4 phi	4-3 phi	> 4 phi	4	0.36	18.18	19.23	1.05	18.7	> 18.18	> 19.23	> 18.7	0	0	0
50E	E	5/24/2002	14:11	ST I	> 4 phi	4-3 phi	> 4 phi	2	0.22	13.48	14.84	1.36	14.16	> 13.48	> 14.84	> 14.16	0	0	0
50E	F	5/25/2002	08:39	ST I	> 4 phi	4-3 phi	> 4 phi	0	0	12.89	14.04	1.15	13.47	> 12.89	> 14.04	> 13.47	0	0	0
50S	A	5/24/2002	12:35	ST I on III	> 4 phi	4-3 phi	> 4 phi	0	0	20.11	20.5	0.39	20.31	> 20.11	> 20.5	> 20.31	0	0	0
50S	B	5/24/2002	12:36	ST I on III	> 4 phi	4-3 phi	> 4 phi	0	0	19.96	20.68	0.72	20.32	> 19.96	> 20.68	> 20.32	0	0	0
50S	F	5/25/2002	08:21	ST II	> 4 phi	4-3 phi	> 4 phi	0	0	13.54	14.54	1	14.04	> 13.54	> 14.54	> 14.04	0	0	0
50W	A	5/24/2002	14:15	ST II on III	> 4 phi	4-3 phi	> 4 phi	0	0	19.5	20.55	1.05	20.02	> 19.5	> 20.55	> 20.02	0	0	0
50W	B	5/24/2002	14:16	ST I on III	> 4 phi	4-3 phi	> 4 phi	4	0.23	19.77	20.45	0.68	20.11	> 19.77	> 20.45	> 20.11	0	0	0
50W	F	5/25/2002	09:05	ST II	> 4 phi	4-3 phi	> 4 phi	0	0	14.52	15.43	0.91	14.98	> 14.52	> 15.43	> 14.98	0	0	0
100NE	C	5/24/2002	13:49	ST I	> 4 phi	4-3 phi	> 4 phi	0	0	18.8	19.79	0.99	19.3	> 18.8	> 19.79	> 19.3	0	0	0
100NE	D	5/24/2002	13:50	ST I	> 4 phi	4-3 phi	> 4 phi	3	0.3	18.29	19.5	1.21	18.9	> 18.29	> 19.5	> 18.9	0	0	0
100NE	F	5/25/2002	08:36	ST I	> 4 phi	4-3 phi	> 4 phi	0	0	14.95	15.59	0.64	15.27	> 14.95	> 15.59	> 15.27	0	0	0
100SE	D	5/24/2002	15:22	ST I	> 4 phi	4-3 phi	> 4 phi	4	0.26	17.96	19.34	1.38	18.65	> 17.96	> 19.34	> 18.65	0	0	0
100SE	E	5/24/2002	15:23	Azoic	> 4 phi	4-3 phi	> 4 phi	0	0	17.43	18.41	0.98	17.92	> 17.43	> 18.41	> 17.92	0	0	0
100SE	F	5/25/2002	08:45	ST I	> 4 phi	4-3 phi	> 4 phi	0	0	13.86	14.41	0.55	14.14	> 13.86	> 14.41	> 14.14	0	0	0
100SW	A	5/24/2002	13:16	ST I to II	> 4 phi	4-3 phi	> 4 phi	0	0	16.41	17.05	0.64	16.73	> 16.41	> 17.05	> 16.73	0	0	0
100SW	D	5/24/2002	13:19	ST I on III	> 4 phi	4-3 phi	> 4 phi	0	0	16.75	17.98	1.23	17.36	> 16.75	> 17.98	> 17.36	0	0	0
100SW	I	5/25/2002	08:59	ST I	> 4 phi	4-3 phi	> 4 phi	0	0	10.62	11.12	0.5	10.87	0	0	0	0	0	0
100NW	B	5/24/2002	15:52	INDET	1-0 phi	< -1 phi	< -1 phi	0	0	0.3	3.54	3.24	1.92	0	0	0	0	0	0
100NW	G	5/25/2002	09:17	INDET	4-3 phi	< -1 phi	3-2 phi	0	0	0.91	2.07	1.16	1.49	0	0	0	0	0	0
100NW	H	5/25/2002	09:18	INDET	4-3 phi	3-2 phi	4-3 phi	0	0	1.5	2.41	0.91	1.96	0	0	0	0	0	0
150N	B	5/24/2002	12:11	ST I	> 4 phi	4-3 phi	> 4 phi	0	0	14.82	17.04	2.22	15.93	> 14.82	> 17.04	> 15.93	0	0	0
150N	C	5/24/2002	12:12	ST I	> 4 phi	4-3 phi	> 4 phi	0	0	20.45	20.73	0.28	20.59	> 20.45	> 20.73	> 20.59	0	0	0
150N	E	5/24/2002	12:14	ST I on III	> 4 phi	4-3 phi	> 4 phi	0	0	19.82	20.43	0.61	20.12	> 19.82	> 20.43	> 20.12	0	0	0
150NE	C	5/24/2002	13:55	INDET	2-1 phi	< -1 phi	0 - -1 phi	0	0	0.29	0.89	0.6	0.59	0	0	0	0	0	0
150NE	E	5/24/2002	13:57	INDET	0 - -1 phi	< -1 phi	< -1 phi	0	0	0.25	3.09	2.84	1.67	0	0	0	0	0	0
150NE	F	5/25/2002	09:21	INDET	4-3 phi	< -1 phi	3-2 phi	0	0	0.84	2.23	1.39	1.53	0	0	0	0	0	0
150E	F	5/25/2002	09:27	ST I	> 4 phi	3-2 phi	4-3 phi	0	0	13.64	13.98	0.34	13.81	0	0	0	0	0	0
150E	G	5/25/2002	09:27	ST I	>4 phi	3-2 phi	3-2 phi	0	0	8.21	8.98	0.77	8.59	0	0	0	0	0	0
150E	H	5/25/2002	09:28	ST I on III	>4 phi	3-2 phi	3-2 phi	0	0	10.57	12	1.43	11.28	0	0	0	0	0	0
150SE	D	5/24/2002	15:29	Azoic	> 4 phi	4-3 phi	> 4 phi	0	0	12.98	17.39	4.41	15.18	> 12.98	> 17.39	> 15.18	0	0	0
150SE	F	5/25/2002	08:50	ST II	> 4 phi	4-3 phi	> 4 phi	0	0	14.21	16.77	2.56	15.49	> 14.21	> 16.77	> 15.49	0	0	0
150SE	G	5/25/2002	08:50	ST II	> 4 phi	4-3 phi	> 4 phi	0	0	15.73	16.46	0.73	16.09	> 15.73	> 16.46	> 16.09	0	0	0
150S	A	5/24/2002	12:43	ST I on III	> 4 phi	4-3 phi	> 4 phi	1	0.11	19.25	19.89	0.64	19.57	> 19.25	> 19.89	> 19.57	0	0	0
150S	F	5/25/2002	08:54	ST I on III	> 4 phi	4-3 phi	> 4 phi	0	0	12.29	12.71	0.42	12.5	> 12.29	> 12.71	> 12.5	0	0	0
150S	G	5/25/2002	08:55	ST I	> 4 phi	4-3 phi	> 4 phi	3	0.41	16.07	16.73	0.66	16.4	> 16.07	> 16.73	> 16.4	0	0	0
150SW	A	5/24/2002	12:53	ST II on III	> 4 phi	3-2 phi	4-3 phi	0	0	12.36	13.86	1.5	13.11	0	0	0	0	0	0
150SW	B	5/24/2002	12:53	ST II on III	> 4 phi	3-2 phi	> 4 phi	0	0	10.77	11.29	0.52	11.03	0	0	0	0	0	0
150SW	C	5/24/2002	12:54	ST I on III	> 4 phi	3-2 phi	4-3 phi	3	0.33	11.88	13.43	1.55	12.66	0	0	0	0	0	0
150W	A	5/24/2002	14:36	ST II to III	> 4 phi	4-3 phi	> 4 phi	0	0	10.62	12.25	1.63	11.43	0	0	0	0	0	0
150W	B	5/24/2002	14:37	ST II	> 4 phi	4-3 phi	> 4 phi	2	0.32	13.62	14.29	0.67	13.95	0	0	0	0	0	0
150W	C	5/24/2002	14:38	ST II on III	> 4 phi	4-3 phi	> 4 phi	0	0	15.27	17.66	2.39	16.47	0	0	0	0	0	0
150NW	B	5/24/2002	14:49	ST I	> 4 phi	4-3 phi	> 4 phi	0	0	18.84	19.8	0.96	19.32	> 18.84	> 19.8	> 19.32	0	0	0
150NW	C	5/24/2002	14:50	ST III	> 4 phi	4-3 phi	> 4 phi	0	0	9.89	12.57	2.68	11.23	> 9.89	> 12.57	> 11.23	0	0	0
150NW	D	5/24/2002	14:50	ST I	> 4 phi	4-3 phi	> 4 phi	6	0.25	18.62	20.04	1.42	19.33	> 18.62	> 20.04	> 19.33	0	0	0
150WN	A	5/24/2002	14:55	ST II on III	> 4 phi	4-3 phi	> 4 phi	1	0.5	14.25	15.48	1.23	14.86	0	0	0	0	0	0
150WN	B	5/24/2002	14:55	ST II on III	> 4 phi	4-3 phi	>4 phi	0	0	16.89	17.8	0.91	17.34	0	0	0	0	0	0
150WN	E	5/24/2002	15:01	ST II to III	> 4 phi	4-3 phi	4-3 phi	3	2.17	10.3	11.86	1.56	11.08	0	0	0	0	0	0

Appendix A1 (continued)

Morris Cove Borrow Pit Sediment-Profile Imaging Data from the May 2002 Survey

Station	Replicate	Date	Time	Apparent RPD Thickness (cm)				Methane		OSI	Surface	Low	Comments
				Min	Max	Mean	Count	Mean Depth	Diameter		Roughness	DO	
CTR	A	5/24/2002	12:28	0.07	1.29	0.25	0	0	0	5	Physical	FALSE	DM>P, GRY&BLK SILT&CLAY, THIN RPD, LOW DO??, ANOXIC SED @SURF=artifact?, RED M CLASTS, SM VOIDS, AMP & POLY TUBES, RED SED PATCHES @Z, BURROWS
CTR	B	5/24/2002	12:29	3.81	9.84	6.79	0	0	0	9	Biogenic	FALSE	DM>P, TAN/BLK SULFIDIC M, DENSE AMP TUBE MAT, RED CLASTS, BURROWING WORM @Z, POLY TUBES, RED SED PATCHES @Z
CTR	C	5/24/2002	12:29	0.07	0.93	0.12	0	0	0	-2	Physical	TRUE	DM>P, BLK&GRY M, ANOXIC SED>P, LOW DO, THIN RPD, RED CLAST, SM TUBES
25NE	H	5/24/2002	16:02	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	FALSE	DM>P, TAN/BLK SULFIDIC SOFT M, OVERPEN, METHANE BUBBLES, ANOXIC SED @Z
25NE	K	5/25/2002	08:33	0.07	6.86	1.98	0	0	0	4	Physical	FALSE	DM>P, TAN&BLK MOTTLED M, ANOXIC SED @SURF & @ Z, RED CLAST, WORMS @Z, PATCHY RPD
25NE	L	5/25/2002	08:33	0.14	7.37	1.96	0	0	0	8	Physical	FALSE	DM>P, TAN&BLK MOTTLED M, RED CLASTS, ANOXIC SED @ SURF = camera artifact; red sec@ Z, VOID, PATCHY RPD, SM TUBES
25SE	A	5/24/2002	15:09	4.19	8.95	5.22	0	0	0	11	Biogenic	FALSE	DM>P, TAN/BLK SULFIDIC M, VOIDS, BURROWING WORM @Z, BURROW OPENING?, BIOGENIC MOUND
25SE	C	5/24/2002	15:13	0.65	10.37	6.89	0	0	0	7	Physical	FALSE	DM>P, TAN/BLK SULFIDIC M, SM BURROWS
25SE	F	5/25/2002	08:41	0.07	3.97	0.79	0	0	0	3	Physical	FALSE	DM>P, TAN&BLK MOTTLED consolidated clay, Anoxic SED @SURF,THIN&PATCHY RPD, OX&RED CLASTS, RED SED PATCHES @Z
25SW	A	5/24/2002	13:25	2.24	8.01	3.83	0	0	0	7	Physical	FALSE	DM>P, TAN/BLK SULFIDIC M, OX CLAST, RED SED @ SURF, SM TUBES
25SW	D	5/24/2002	13:27	0.36	9.39	2.61	0	0	0	5	Physical	FALSE	DM>P, TAN/BLK MOTTLED mud-clay, PATCHY RPD, surface FLOCK OR sand LYR?, WORMS @Z, M CLUMPS-FAR
25SW	I	5/25/2002	09:03	0.07	8.80	2.78	0	0	0	1	Physical	TRUE	DM>P, BLK&TAN M, PATCHY RPD, LOW DO, ANOXIC SED @ SURF & @ Z, BURROW-OPENING, IRREG TOPO, WIPER CLASTS
25NW	C	5/24/2002	15:45	0.07	8.75	2.81	0	0	0	8	Physical	FALSE	DM>P, TAN&BLK MOTTLED M, PATCHY RPD, ANOXIC SED @SURF & @ Z, AMP TUBES?, POLY TUBES, VOID, WORMS @Z
25NW	F	5/25/2002	08:27	4.02	8.84	5.60	0	0	0	9	Biogenic	FALSE	DM>P, TAN/BLK SULFIDIC M, AMP & POLY TUBES, SURF REWORKING, RED SED @SURF, BURROW OPENINGS
25NW	H	5/25/2002	08:28	2.67	8.80	5.58	0	0	0	9	Physical	FALSE	DM>P, TAN/BLK SULFIDIC M, RED M CLASTS, AMP TUBES
50N	B	5/24/2002	12:21	0.72	8.54	3.54	0	0	0	10	Physical	FALSE	DM>P, TAN/BLK M, ANOXIC SED @ SURF & @ Z, OX & RED CLASTS, very small and deep VOIDS, GREEN ALGAL DETRITUS= dragged down, PATCHY RPD
50N	D	5/24/2002	12:23	0.07	7.86	0.87	65	12.08	1.33	-8	Physical	TRUE	DM>P, TAN & BLK SULFIDIC M, ANOXIC SED>P, LOW DO, METHANE, THIN & PATCHY RPD, FLOCK LYR, DIST SURF
50N	F	5/25/2002	08:25	3.38	10.80	6.04	0	0	0	7	Physical	FALSE	DM>P, TAN/BLK M, RED CLASTS, SM TUBES, RED SED @ SURF & @ Z, apparent void=scanning artifact = not on original slide
50E	D	5/24/2002	14:10	0.07	6.27	2.03	0	0	0	4	Physical	FALSE	DM>P, BLK& TAN mottled mud-clay, SHELL BITS, RELIC RPD?, ANOXIC SED @ SURF = camera smear artifact, PATCHY RPD, RED CLASTS, RED SED @ Z
50E	E	5/24/2002	14:11	0.07	0.50	0.18	5	10.33	0.39	0	Physical	FALSE	DM>P, TAN&BLK MOTTLED M, PATCHY RPD, RED SED @ SURF & @ Z, METHANE, RED CLASTS
50E	F	5/25/2002	08:39	0.07	0.43	0.21	1	13	0.3	0	Physical	FALSE	DM>P, BLK & TAN M, ANOXIC SED @ SURF, thin RPD, RED SED @ Z, SM TUBES?, PATCHY RPD (not a void, but methane)
50S	A	5/24/2002	12:35	2.37	8.83	4.79	0	0	0	11	Physical	FALSE	DM>P, TAN SANDY M/BLK SULFIDIC M, SM TUBES, very small and deep VOID, BURROW
50S	B	5/24/2002	12:36	0.43	8.26	2.62	0	0	0	9	Physical	FALSE	DM>P, TAN/BLK SULFIDIC M, sea lettuce dragdown, VOID, SM TUBES, RED SED @ Z, BURROW-OPENING?, PATCHY RPD
50S	F	5/25/2002	08:21	5.77	9.81	6.59	0	0	0	9	Biogenic	FALSE	DM>P, TAN/BLK M, PULL AWAY, DENSE AMP TUBE MAT, RED SED @ Z, BURROW OPENING, VOID?
50W	A	5/24/2002	14:15	3.81	8.41	5.18	0	0	0	11	Physical	FALSE	DM>P, TAN/BLK M, AMP&POLY TUBES, VOID, ANOXIC SED @ SURF & @ Z, FLOCK LYR?, BURROWS
50W	B	5/24/2002	14:16	0.79	9.60	5.10	0	0	0	11	Physical	FALSE	DM>P, TAN/BLK SULFIDIC M, SM TUBES, VOID, RED CLASTS, RED SED @SURF, FECAL MOUND?, SM BURROW OPENING
50W	F	5/25/2002	09:05	0.94	7.88	4.92	0	0	0	9	Biogenic	FALSE	DM>P, TAN/BLK SULFIDIC M, AMP TUBE MAT, POLY TUBES
100NE	C	5/24/2002	13:49	0.50	9.87	4.57	0	0	0	7	Physical	FALSE	DM>P, TAN/BLK SANDY M, ANOXIC SED @SURF= possible smear artifact, GASTROPODS @SURF, RED SED @Z
100NE	D	5/24/2002	13:50	0.58	7.64	3.86	0	0	0	7	Physical	FALSE	DM>P, TAN/BLK SANDY M, RED SED @SURF & @ Z, SM TUBES, WIPER CLASTS, BURROW OPENING?
100NE	F	5/25/2002	08:36	0.22	7.06	2.90	0	0	0	5	Biogenic	FALSE	DM>P, Grey/black consolidated clay, RED SED @Z, surf TUBES, WIPER CLASTS, PATCHY RPD
100SE	D	5/24/2002	15:22	0.07	6.71	1.31	4	14.71	2.05	-3	Physical	TRUE	DM>P, TAN/BLK SULFIDIC consolidated clay, ANOXIC SED @SURF, LOW DO, METHANE BUBBLES, RED CLASTS, PATCHY RPD, TUBE OR OBJECT @SURF?
100SE	E	5/24/2002	15:23	0.07	6.28	1.84	16	9.54	1.18	-7	Physical	TRUE	DM>P, TAN&BLK/BLK SULFIDIC M, ANOXIC SED @SURF, LOW DO, PATCHY RPD, METHANE BUBBLES, RELIC RPD
100SE	F	5/25/2002	08:45	0.50	6.85	3.38	0	0	0	6	Physical	FALSE	DM>P, TAN/BLK SULFIDIC SOFT M, RED SED @ SURF, TUBES
100SW	A	5/24/2002	13:16	2.60	6.56	3.33	0	0	0	7	Biogenic	FALSE	DM>P, TAN/GRY/BLK SULFIDIC M, REDOX REBOUND, SM TUBES and subsurface burrow, SM WORM @Z
100SW	D	5/24/2002	13:19	0.07	2.96	0.31	0	0	0	2	Physical	TRUE	DM>P, TAN&BLK MOTTLED M, ANOXIC SED @ SURF & @ Z, LOW DO, THIN&PATCHY RPD, RELIC RPD?, SM VOIDS
100SW	I	5/25/2002	08:59	3.90	5.93	3.94	0	0	0	7	Physical	FALSE	DM?, TAN/BLK SANDY M, PULL AWAY, WORM @Z
100NW	B	5/24/2002	15:52	-99.00	-99.00	-99.00	0	0	0	99	Indeterminate	FALSE	HARD BOTTOM, UNDERPEN, ROCKS, SHELLS, PEBBLES
100NW	G	5/25/2002	09:17	-99.00	-99.00	-99.00	0	0	0	99	Physical	FALSE	UNDERPEN, TAN SAND>P, SHELL HASH, ROCK
100NW	H	5/25/2002	09:18	-99.00	-99.00	-99.00	0	0	0	99	Physical	FALSE	UNDERPEN, AMBIENT BRN SAND, SHELLS, HERMIT CRAB @ SURF, ORG-FARFIELD?
150N	B	5/24/2002	12:11	0.14	7.90	2.23	0	0	0	0	Physical	TRUE	DM>P, TAN&BLK MOTTLED M, ANOXIC SED @SURF & @ Z, LOW DO??, PATCHY RPD, TUBES, CHAOTIC FABRIC, FLOCK LYR?
150N	C	5/24/2002	12:12	4.39	9.73	5.35	0	0	0	7	Physical	FALSE	DM>P, TAN/BLK SULFIDIC M, RED SED @SURF, SM WORM @Z, SM BURROW, PATCHY RPD
150N	E	5/24/2002	12:14	0.43	7.39	3.40	0	0	0	10	Biogenic	FALSE	DM>P, TAN/BLK SULFIDIC M, VOIDS, SM TUBES, BURROWS
150NE	C	5/24/2002	13:55	-99.00	-99.00	-99.00	0	0	0	99	Physical	FALSE	ambient HARD BOTTOM, UNDERPEN, ROCKS, SHELLS, MACRO ALGAE
150NE	E	5/24/2002	13:57	-99.00	-99.00	-99.00	0	0	0	99	Physical	FALSE	HARD BOTTOM, UNDERPEN, SHELL BED, ROCKS, MACRO ALGAE= Ulva latuca = sea lettuce
150NE	F	5/25/2002	09:21	-99.00	-99.00	-99.00	0	0	0	99	Physical	FALSE	HARD BOTTOM, UNDERPEN, SHELL BED/SAND, ENCRUSTED ROCK, TUBES?, FLOCK LYR
150E	F	5/25/2002	09:27	2.89	6.28	4.16	0	0	0	7	Physical	FALSE	AMBIENT TAN FINE SAND/BLK SANDY M, red sed@z, SM TUBES, GASTROPOD, WORM @Z, BURROW, SHELL BITS
150E	G	5/25/2002	09:27	0.36	4.06	2.46	0	0	0	5	Physical	FALSE	AMBIENT TAN/BLK FINE SAND, SHELL BITS, ROCKS-FAR
150E	H	5/25/2002	09:28	1.66	6.80	4.23	0	0	0	11	Physical	FALSE	AMBIENT TAN/BLK FINE SAND over mud, TUBES, VOID, BURROW, SHELL FRAG @Z?, GASTROPODS-FAR, SM WORMS @Z
150SE	D	5/24/2002	15:29	0.00	0.00	0.00	0	0	0	-8	Indeterminate	TRUE	DM>P, BLK M, DIST SURF, LOW DO, ANOXIC SED >P, surface sulfur bacteria (beggiota) mat?
150SE	F	5/25/2002	08:50	4.99	9.25	6.03	0	0	0	9	Biogenic	FALSE	DM>P, TAN/BLK SANDY M, DENSE AMP TUBE MAT, RED SED @ SURF & @ Z, SURF REWORKING, FECAL LYR
150SE	G	5/25/2002	08:50	0.51	7.45	3.64	0	0	0	8	Biogenic	FALSE	DM>P, TAN/BLK M, AMP & POLY TUBES, RED SED @ SURF & @ Z, FECAL LYR, SURF REWORKING
150S	A	5/24/2002	12:43	4.61	10.37	6.59	12	15.87	0.94	9	Physical	FALSE	DM>P, TAN/BLK SULFIDIC M, SM TUBES, SM VOID, METHANE, ANOXIC SED @Z, LG BURROWING WORM @Z, BURROW OPENING, OX CLAST, FLUID CLAST LYR?
150S	F	5/25/2002	08:54	1.30	7.30	4.28	0	0	0	11	Physical	FALSE	DM>P, TAN/BLK M, SM TUBES, VOIDS, RED SED @ SURF & @ Z
150S	G	5/25/2002	08:55	0.07	7.66	2.47	0	0	0	5	Physical	FALSE	DM>P, TAN&BLK MOTTLED Mud or clay, PATCHY RPD, ANOXIC SED @ SURF & @ Z, TUBES, AMP TUBES WITHIN SURF SED?
150SW	A	5/24/2002	12:53	0.36	4.90	2.04	0	0	0	8	Biogenic	FALSE	AMBIENT TAN FINE SAND/BLK SILT, AMP & POLY TUBES, VOIDS, BURROW (OCCUPIED)- OPENING, DEBRIS-FAR?, WORMS @Z, RED SED @Z, FECAL MOUND
150SW	B	5/24/2002	12:53	0.50	4.32	1.82	0	0	0	8	Biogenic	FALSE	AMBIENT TAN/GRY&BLK SANDY M, AMP TUBES, VOIDS, RED SED @Z, SM BURROWS-OPENING, FECAL MOUND
150SW	C	5/24/2002	12:54	0.07	5.72	2.66	0	0	0	9	Physical	FALSE	AMBIENT TAN FINE SAND/BLK SILT, VOIDS, SHELL BITS, BURROWS-OPENINGS, OX&RED CLASTS, PATCHY RPD, RED SED @SURF & @ Z
150W	A	5/24/2002	14:36	0.58	4.83	1.60	0	0	0	7	Physical	FALSE	AMBIENT? TAN/BLK SANDY M, VOIDS, SHELL BITS, AMP&POLY TUBES, ROCK/M CLUMP-FAR, SM BURROW
150W	B	5/24/2002	14:37	0.07	4.63	1.65	0	0	0	6	Biogenic	FALSE	AMBIENT, TAN SANDY M/BLK M, AMP & POLY TUBES, OX&RED CLASTS, BURROW OPENING, SHELL BITS, WORMS @Z, RED SED @ SURF & @ Z, PATCHY RPD
150W	C	5/24/2002	14:38	0.22	6.50	3.07	0	0	0	10	Biogenic	FALSE	AMBIENT TAN/BLK SULFIDIC SANDY M, DENSE LIVE & DECAYING AMP TUBES, VOIDS, SURF REWORKING, SM BURROW-OPENING, WORMS @Z
150NW	B	5/24/2002	14:49	0.22	9.33	5.17	0	0	0	7	Physical	FALSE	DM>P, TAN/BLK SULFIDIC M, TUBES, RED SED @SURF = wiper artifacts, WORMS @Z
150NW	C	5/24/2002	14:50	0.00	0.00	0.00	0	0	0	1	Physical	TRUE	DM>P, BLK & TAN mottled consolidated clay, ANOXIC SED>P, LOW DO, FLOCK LYR, VOIDS, THIN&PATCHY RPD, BURROW OPENING, WORM @Z
150NW	D	5/24/2002	14:50	0.79	8.22	5.11	0	0	0	7	Physical	FALSE	DM>P, TAN/BLK M, SM TUBES, RED CLASTS, BURROWING WORM @Z, RED SED @ SURF & @ Z, BURROW OPENINGS
150WN	A	5/24/2002	14:55	0.07	10.19	7.02	0	0	0	11	Biogenic	FALSE	AMBIENT TAN/BLK SANDY M, DENSE AMP TUBES, VOIDS, EXTENSIVE BURROW SYSTEM-OPENINGS, SURF REWORK, WORM
150WN	B	5/24/2002	14:55	5.49	10.84	7.26	0	0	0	11	Biogenic	FALSE	AMBIENT TAN/GRY&BLK SANDY M, AMP & POLY TUBES, VOIDS, SHELL BITS, WORMS @Z, FECAL LYR, BURROW OPENING, SURF REWORKING, RED SED @Z
150WN	E	5/24/2002	15:01	1.08	6.07	3.29	0	0	0	9	Biogenic	FALSE	AMBIENT TAN/GRY&BLK SANDY M, RED M CLASTS, DENSE AMP TUBES, BURROW-OPENING, VOID?, FECAL OR FLOCK LYR?, RED SED @Z, WORMS @Z

Appendix A2

Reference Area Sediment-Profile Imaging Data from the May 2002 Survey

Station	Replicate	Date	Time	Successional Stage	Grain Size (phi)			Mud Clasts		Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness (cm)		
					Min	Max	Maj Mode	Count	Avg. Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean
REFB1	A	5/24/2002	17:06	ST II	> 4 phi	4-3 phi	> 4 phi	4	0.97	16.68	18	1.32	17.34	0	0	0	0	0	0
REFB1	B	5/24/2002	17:07	ST II on III	> 4 phi	4-3 phi	> 4 phi	4	1.12	18.25	18.8	0.55	18.52	0	0	0	0	0	0
REFB1	E	5/24/2002	17:10	ST II	> 4 phi	4-3 phi	> 4 phi	6	1.66	17.77	18.5	0.73	18.14	0	0	0	0	0	0
REFB2	B	5/24/2002	17:01	ST II	> 4 phi	4-3 phi	> 4 phi	0	0	15.46	16.7	1.24	16.08	0	0	0	0	0	0
REFB2	C	5/24/2002	17:01	ST II on III	> 4 phi	4-3 phi	> 4 phi	3	1.35	16.02	16.73	0.71	16.38	0	0	0	0	0	0
REFB2	D	5/24/2002	17:02	ST I	> 4 phi	4-3 phi	> 4 phi	0	0	14.8	16.91	2.11	15.85	0	0	0	0	0	0
REFB3	A	5/24/2002	17:19	ST II	> 4 phi	4-3 phi	> 4 phi	3	0.59	14.43	15.62	1.19	15.02	0	0	0	0	0	0
REFB3	B	5/24/2002	17:19	ST II on III	> 4 phi	4-3 phi	> 4 phi	6	0.56	16.8	18.7	1.9	17.75	0	0	0	0	0	0
REFB3	E	5/24/2002	17:21	ST II on III	> 4 phi	4-3 phi	> 4 phi	2	1.18	18.64	19.95	1.31	19.3	0	0	0	0	0	0
REFB4	A	5/24/2002	16:53	ST I on III	> 4 phi	4-3 phi	> 4 phi	0	0	14.55	15.25	0.7	14.9	0	0	0	0	0	0
REFB4	E	5/24/2002	16:57	ST I on III	> 4 phi	3-2 phi	> 4 phi	0	0	16.05	16.8	0.75	16.42	0	0	0	0	0	0
REFB4	F	5/24/2002	16:58	ST I on III	> 4 phi	4-3 phi	> 4 phi	3	0.25	15.43	16.32	0.89	15.88	0	0	0	0	0	0
REFB5	A	5/24/2002	17:13	ST II to III	> 4 phi	4-3 phi	> 4 phi	0	0	17.05	17.88	0.83	17.47	0	0	0	0	0	0
REFB5	C	5/24/2002	17:14	ST II to III	> 4 phi	4-3 phi	> 4 phi	0	0	17.21	18.73	1.52	17.97	0	0	0	0	0	0
REFB5	D	5/24/2002	17:15	ST II	> 4 phi	4-3 phi	> 4 phi	0	0	14.91	18.2	3.29	16.56	0	0	0	0	0	0

Appendix A2 (continued)

Reference Area Sediment-Profile Imaging Data from the May 2002 Survey

Station	Replicate	Date	Time	Apparent RPD Thickness (cm) Min	Max	Mean	Methane Min	Max	Mean	OSI	Surface Roughness	Low DO	Comments
REFB1	A	5/24/2002	17:06	0.22	7.87	3.88	0	0	0	9	Biogenic	FALSE	AMBIENT TAN/BLK SANDY M, DENSE AMP TUBE MAT, RED CLASTS, RED SED @SURF, POLY TUBES
REFB1	B	5/24/2002	17:07	0.43	10.22	5.90	0	0	0	11	Biogenic	FALSE	AMBIENT TAN/GRY&BLK SANDY M, DENSE AMP TUBE MAT, SURF REWORKING, RED CLASTS, VOID, BURROW, POLY TUBES, RED SED @Z
REFB1	E	5/24/2002	17:10	0.43	9.45	5.97	0	0	0	9	Biogenic	FALSE	AMBIENT TAN/BLK SANDY M, DENSE AMP TUBES, RED CLASTS, POLY TUBES, RED SED @SURF & @ Z, BURROW OPENINGS, SURF REWORKING, FECAL LYRS
REFB2	B	5/24/2002	17:01	0.14	7.94	3.03	0	0	0	8	Biogenic	FALSE	AMBIENT TAN/BLK SANDY M, RED SED @SURF & @ Z, AMP & POLY TUBES, RED CLASTS, GASTROPOD @ SURF
REFB2	C	5/24/2002	17:01	0.29	4.84	2.03	0	0	0	8	Biogenic	FALSE	AMBIENT TAN/BLK SANDY M, VOIDS, TUBES, AMP TUBES?, BURROW-OPENING, FECAL MOUND, RED CLASTS, RED SED @ SURF & @ Z
REFB2	D	5/24/2002	17:02	0.07	6.05	2.84	0	0	0	5	Physical	FALSE	AMBIENT TAN/BLK SANDY M, SM TUBES, AMP TUBE?, WORMS @Z, FECAL MOUND?
REFB3	A	5/24/2002	17:19	0.87	7.35	4.27	0	0	0	9	Biogenic	FALSE	AMBIENT TAN/GRY&BLK SANDY M, DENSE AMP TUBE MAT, POLY TUBES, RED CLASTS, WORMS @Z, RED SED @SURF, BURROW OPENING
REFB3	B	5/24/2002	17:19	1.08	9.33	4.93	0	0	0	11	Biogenic	FALSE	AMBIENT TAN/BLK SANDY M, DENSE LIVE & DECAYING AMP TUBES, POLY TUBES, RED CLASTS, VOIDS, FECAL LYR, SURF REWORKING, RED SED @ SURF & @ Z, SM WORMS @Z
REFB3	E	5/24/2002	17:21	6.81	13.18	8.80	0	0	0	11	Biogenic	FALSE	AMBIENT TAN/BLK SANDY M, RED SED @ SURF & @ Z, DECAYING AMP TUBE MAT, VOID, BURROW OPENINGS, WIPER CLASTS, RED CLASTS, WORM OR ORG @ Z
REFB4	A	5/24/2002	16:53	1.25	6.38	3.71	0	0	0	10	Physical	FALSE	AMBIENT TAN/BLK SULFIDIC SANDY M, VOIDS, TUBES, WORMS @Z, GASTROPOD @ SURF?
REFB4	E	5/24/2002	16:57	0.07	6.22	2.61	0	0	0	9	Physical	FALSE	AMBIENT TAN/BLK SULFIDIC SANDY M, TUBES, LG oxidized VOID, RED SED @SURF, SM WORMS @Z?
REFB4	F	5/24/2002	16:58	0.22	5.76	2.75	0	0	0	9	Physical	FALSE	AMBIENT TAN/BLK SULFIDIC SANDY M, SM TUBES, RED CLASTS, WORMS @Z, RED SED @SURF, VOID
REFB5	A	5/24/2002	17:13	3.89	9.52	6.52	0	0	0	10	Biogenic	FALSE	AMBIENT TAN/BLK SULFIDIC SANDY M, DENSE LIVE & DECAYING AMP TUBE MAT, BURROWS-OPENING, BURROWING WORMS, SM VOIDS?, POLY TUBES
REFB5	C	5/24/2002	17:14	1.81	8.10	4.15	0	0	0	10	Biogenic	FALSE	AMBIENT TAN/BLK SULFIDIC SANDY M, DENSE LIVE & DECAYING AMP TUBE MAT, WIPER CLASTS, SM VOID, WORMS @Z, BURROWS, RED SED @SURF, SURF REWORKING
REFB5	D	5/24/2002	17:15	0.79	7.79	4.29	0	0	0	9	Biogenic	FALSE	AMBIENT TAN/BLK SULFIDIC SANDY M, LIVE & DECAYING AMP TUBES, BURROW-OPENINGS, WORMS @Z, GASTROPOD @ SURF, POLY TUBES, BIOGENIC MOUND?

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