Monitoring Cruise at the Morris Cove Borrow Pit

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 New Haven, CT was placed in a small, man-made depression (borrow pit) in Morris Cove, located in outer New Haven Harbor. A monitoring survey was conducted over the Morris Cove borrow pit in late September 2000 to document the distribution of the dredged material on the seafloor, verify the stability of the sediment deposit, and evaluate recolonization of the deposit by benthic organisms. The monitoring involved the use of REMOTS® sediment-profile imaging, side-scan sonar, single-beam bathymetry, and towed video to evaluate benthic conditions within and adjacent to the borrow pit. Sediment-profile images also were obtained at a reference area located approximately 800 m west of the borrow pit to provide a comparison with ambient seafloor conditions.

The side-scan sonar data showed a clear differentiation between softer sediments within the borrow pit and coarser, more compact sediments comprising the outer walls of the pit. Multiple bottom features with increased vertical relief and surface roughness detected within a 50 m radius of the central disposal point and to the east of this point were attributed to dredged material deposition. Both the side-scan sonar and towed video data suggested that the impacts associated with the deposition of dredged material were contained largely within the southern portion of the Morris Cove borrow pit. The controlled placement of small barge loads of dredged material had facilitated the creation of a small-scale sediment deposit within the confines of the pit. The REMOTS® sediment-profile images served to confirm the presence of dredged material at stations located within the borrow pit. The dredged material was observed at stations 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 about 10 or 15 cm). The dredged material was predominantly fine-grained, consisting of soft, sandy silt.

The presence of methane gas bubbles in the sediment at three stations within the borrow pit suggested that some of the dredged material continues to contain a high inventory of organic matter. Fine-grained sediments having relatively high surface boundary roughness, shell lag deposits, and shallow depth of aeration characterized the reference area. It was hypothesized that the shallow reference area may experience periodic physical disturbance from fishing activities or the scouring action of waves and currents during high wind events.

At the time of the survey (5 months post disposal), it appeared that benthic recolonization of the dredged material deposit was progressing as expected. The sediment-profile images showed that the benthic infauna included primarily Stage I opportunistic polychaetes (i.e., pioneering taxa) at the sediment surface. Relatively well-developed redox depths were noted at most stations, and advanced successional stages (Stages II and/or III) were observed at 8 of the 22 stations occupied. Due to the protected nature of the borrow pit and the recent input of organically enriched sediment, overall benthic habitat quality within the borrow pit was considered to be better than that at the nearby, shallow reference area.

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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 New Haven, CT was placed in a small, man-made depression (borrow pit) in Morris Cove, located in outer New Haven Harbor. A monitoring survey was conducted over the Morris Cove borrow pit in late September 2000 to document the distribution of the dredged material on the seafloor, verify the stability of the sediment deposit, and evaluate recolonization of the deposit by benthic organisms.

The monitoring involved the use of REMOTS® sediment-profile imaging, side-scan sonar, single-beam bathymetry, and towed video to evaluate benthic conditions within and adjacent to the borrow pit. Sediment-profile images also were obtained at a reference area located approximately 800 m west of the borrow pit to provide a comparison with ambient seafloor conditions.

The side-scan sonar data showed a clear differentiation between softer sediments within the borrow pit and coarser, more compact sediments comprising the outer walls of the pit. Multiple bottom features with increased vertical relief and surface roughness detected within a 50 m radius of the central disposal point and to the east of this point were attributed to dredged material deposition. Both the side-scan sonar and towed video data suggested that the impacts associated with the deposition of dredged material were contained largely within the southern portion of the Morris Cove borrow pit. The controlled placement of small barge loads of dredged material had facilitated the creation of a small-scale sediment deposit within the confines of the pit.

The REMOTS® sediment-profile images served to confirm the presence of dredged material at stations located within the borrow pit. The dredged material was observed at stations 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 about 10 or 15 cm). The dredged material was predominantly fine-grained, consisting of soft, sandy silt.

The presence of methane gas bubbles in the sediment at three stations within the borrow pit suggested that some of the dredged material continues to contain a high inventory of organic matter. Fine-grained sediments having relatively high surface boundary roughness, shell lag deposits, and shallow depth of aeration characterized the reference area. It was hypothesized that the shallow reference area may experience periodic physical disturbance from fishing activities or the scouring action of waves and currents during high wind events.

At the time of the survey (5 months post disposal), it appeared that benthic recolonization of the dredged material deposit was progressing as expected. The sediment-profile images showed that the benthic infauna included primarily Stage I opportunistic

polychaetes (i.e., pioneering taxa) at the sediment surface. Relatively well-developed redox depths were noted at most stations, and advanced successional stages (Stages II and/or III) were observed at 8 of the 22 stations occupied. Due to the protected nature of the borrow pit and the recent input of organically enriched sediment, overall benthic habitat quality within the borrow pit was considered to be better than that at the nearby, shallow reference area.

1.0 OBJECTIVE OF THE MONITORING SURVEY

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 (CLIS) 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 alternate disposal site for the USCG sediments. 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 ambient 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 at the borrow pit range from 3 m to 12 m. The deepest areas of the pit are upwards of 8 m deeper than the surrounding ambient seafloor, suggesting a substantial capacity that could be utilized for the deposition of dredged sediments.

In early January 2000, a small disposal buoy (MCDA) was placed at 41° 15.644′ N, 72° 53.972′ W in the southern region of the borrow pit (Figure 1-1). An estimated 10,400 m^3 of dredged material was deposited at the buoy during January 2000, before the dredging operation was interrupted by heavy ice in the harbor. Dredging and disposal operations were reinstated on 2 May and continued through 15 May, with an additional 3,800 m^3 of material deposited at the MCDA buoy (Table 1-1; Appendix A).

A monitoring survey was conducted over the Morris Cove borrow pit in late September 2000 (5 months post-disposal) to:

- document the distribution of the dredged material on the seafloor;
- verify the stability of the sediment deposit; and
- examine benthic recolonization over the new sediment deposit, relative to ambient New Haven Harbor sediments.

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

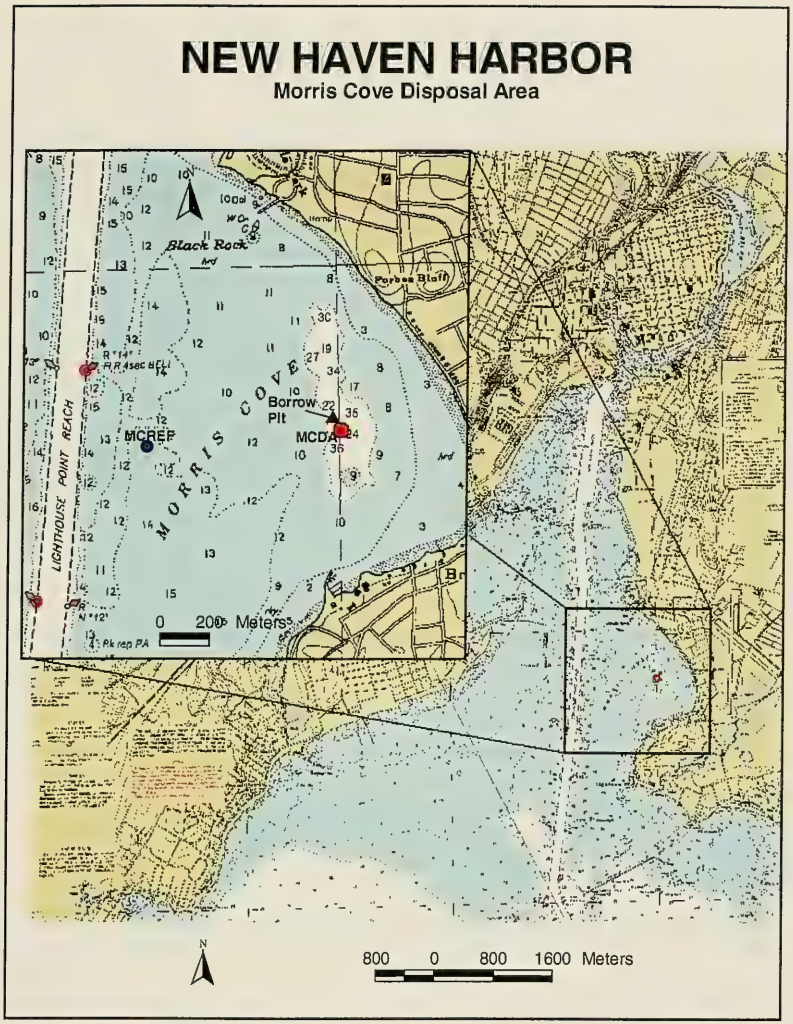


Figure 1-1. Location of the Morris Cove borrow pit, central disposal point (MCDA buoy), and Morris Cove Reference Area, relative to the East Haven shoreline

2.0 METHODS

Field operations were conducted over the Morris Cove borrow pit area aboard the M/V *Beavertail* on September 28, 2000 and October 2, 2000. Remote Ecological Monitoring of the Seafloor (REMOTS®) sediment-profile photography was used in conjunction with side-scan sonar, single beam bathymetry, and towed video to evaluate benthic conditions within and adjacent to the borrow pit. Sediment profile images also were obtained at a reference area located approximately 800 m to the west of the disposal buoy to provide a comparison between ambient conditions and those existing within the borrow pit (Figure 1-1).

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 to an accuracy of ±3 m. A Trimble 4000 RSi 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 was interfaced with a Trimble NavBeacon XL differential receiver to improve overall accuracy of the satellite data to the necessary tolerances. The U.S. Coast Guard differential beacon broadcasting from Moriches, NY (293 kHz) was utilized for real-time satellite corrections.

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 (REMOTS®) 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 survey lane data (side-scan sonar, bathymetry profiles, and towed video footage).

Side-scan Sonar

A three-lane side-scan sonar survey was conducted over the Morris Cove borrow pit to aid in defining the edges of the bottom feature, as well as provide additional information pertaining to the distribution of dredged material. Side-scan sonar data was collected using a Marine Sonic Technology PC Side-scan System operating at a frequency of 300 kHz. Three longitudinal transects were completed over the burrow pit, with lane spacing and sonar range controlled to maximize resolution and aerial coverage (Figure 2-1). After collection, the side-scan data were used to develop a mosaic of the survey area.

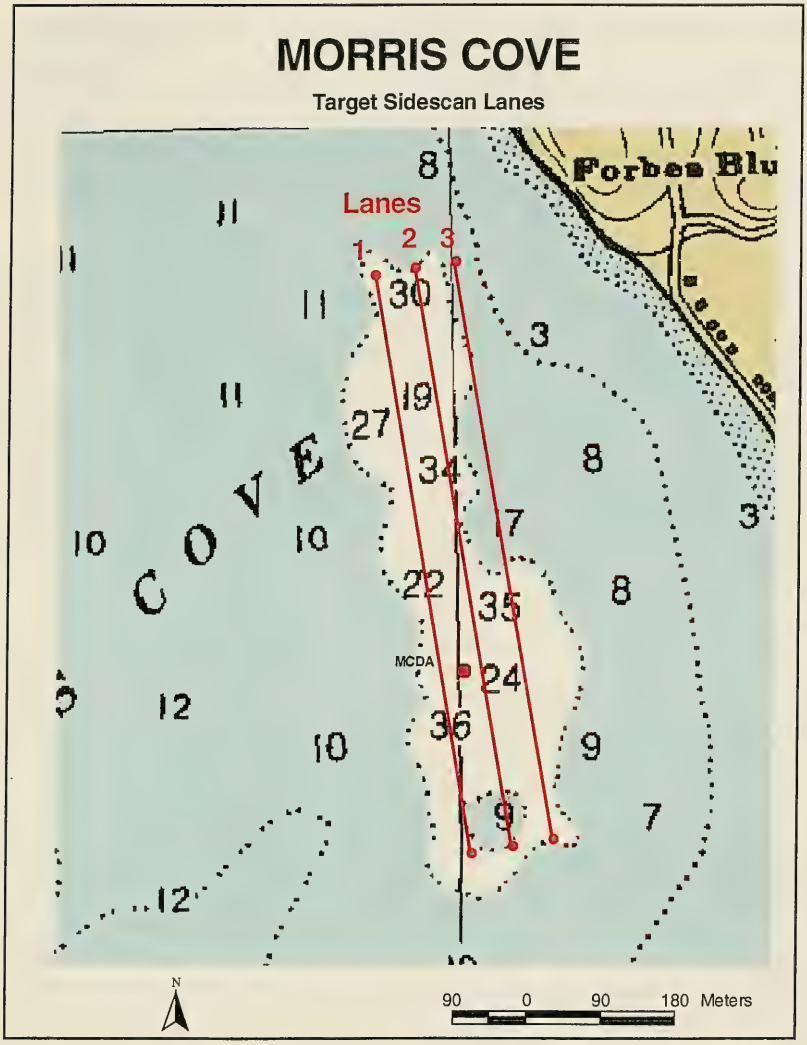


Figure 2-1. Longitudinal survey lines occupied over the Morris Cove borrow pit for collection of side-scan sonar data

REMOTS® Sediment-Profile Imaging

REMOTS® sediment profile imaging is a benthic sampling technique in which a specialized camera is used to obtain undisturbed, vertical cross-section photographs (*in situ* profiles) of the upper 15 to 20 cm of the seafloor. This is a reconnaissance survey technique used for rapid collection, interpretation and mapping of data on physical and biological seafloor characteristics; measurements obtained from sediment-profile images can be used to characterize sediment types, evaluate benthic habitat quality, map disturbance gradients and follow ecosystem recovery after disturbance abatement.

The REMOTS® hardware consists of a wedge-shaped optical prism having a standard 35-mm camera mounted horizontally above in a watertight housing. The prism resembles an inverted periscope, with a clear Plexiglas window measuring 15 cm wide and 20 cm high and an internal mirror mounted at a 45° angle to reflect the image in the window up to the camera (Figure 2-2). To equalize pressure, the prism is filled with water, and light is provided by an internal strobe. The prism sits inside a stainless steel external frame, and the entire assembly is lowered to the seafloor using a standard winch mounted aboard the survey vessel. Upon contact with the bottom, the prism descends slowly into the seafloor, cutting a vertical cross-section profile of the upper 15 to 20 cm of sediment, and a photograph is taken of the sediment in contact with the window. The resulting 35-mm slides (images) showing relatively undisturbed sediment profiles are then analyzed for a standard suite of measured parameters (Rhoads and Germano 1982; 1986).

Computer-aided analysis of each REMOTS® sediment profile image yielded a suite of measurements. The standard measured parameters are sediment grain size major mode (expressed in phi units), benthic habitat classification, camera prism penetration depth (an indirect measure of sediment bearing capacity/density), depth of the apparent redox potential discontinuity (RPD), infaunal successional stage, and Organism-Sediment Index (a summary parameter reflecting the overall benthic habitat quality).

A total of 22 REMOTS® sediment profile photography stations were established over the Morris Cove borrow pit to evaluate the distribution and thickness of dredged material layers and to assess benthic recolonization. The stations were arranged in a radial pattern centered at the MCDA disposal buoy position and spaced at 25, 50, 100 and 150 meter intervals from the buoy (Figure 2-3; Table 2-1). In addition, a five-station REMOTS® grid was established over the nearby reference area located in New Haven Harbor approximately 800 m to the west of the borrow pit (MC REF; 41° 15.615´N, 72° 54.553´W; see Figure 1-1). One station was established over the center reference point, while four additional stations were randomly distributed within a 75-meter radius. At both the borrow pit and reference area REMOTS® stations, the sediment profile camera was lowered at least three times in an attempt to obtain three replicate images suitable for subsequent analysis.

Table 2-1
Morris Cove Borrow Pit REMOTS® Sediment-Profile Photography 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
	150WN	41° 15.723´ N	72° 54.081´ W
Reference Area			
MC REF 41° 15.629´ N 72° 54.575´ W	REF 1	41° 15.616´ N	72° 54.554´ W
	REF 2	41° 15.648´ N	72° 54.544´ W
	REF 3	41° 15.629´ N	72° 54.575´ W
	REF 4	41° 15.584´ N	72° 54.549´ W
	REF 5	41° 15.613´ N	72° 54.520´ W

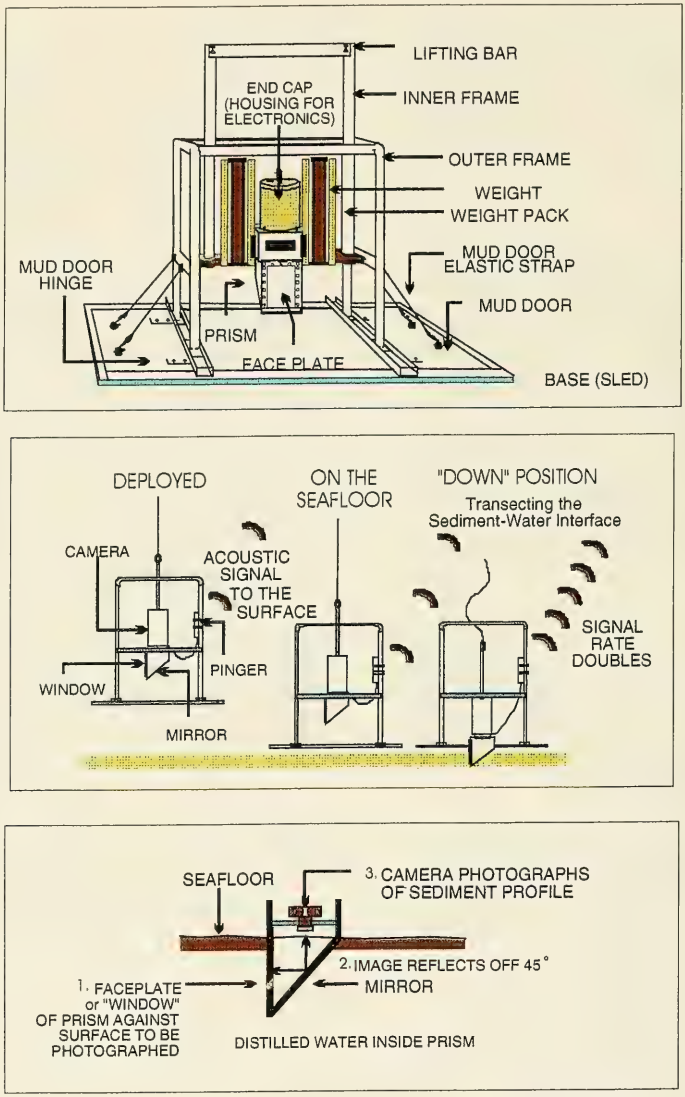


Figure 2-2. Schematic diagram of a Benthos Inc. Model 3731 REMOTS® sediment-profile camera and sequence of operation on deployment

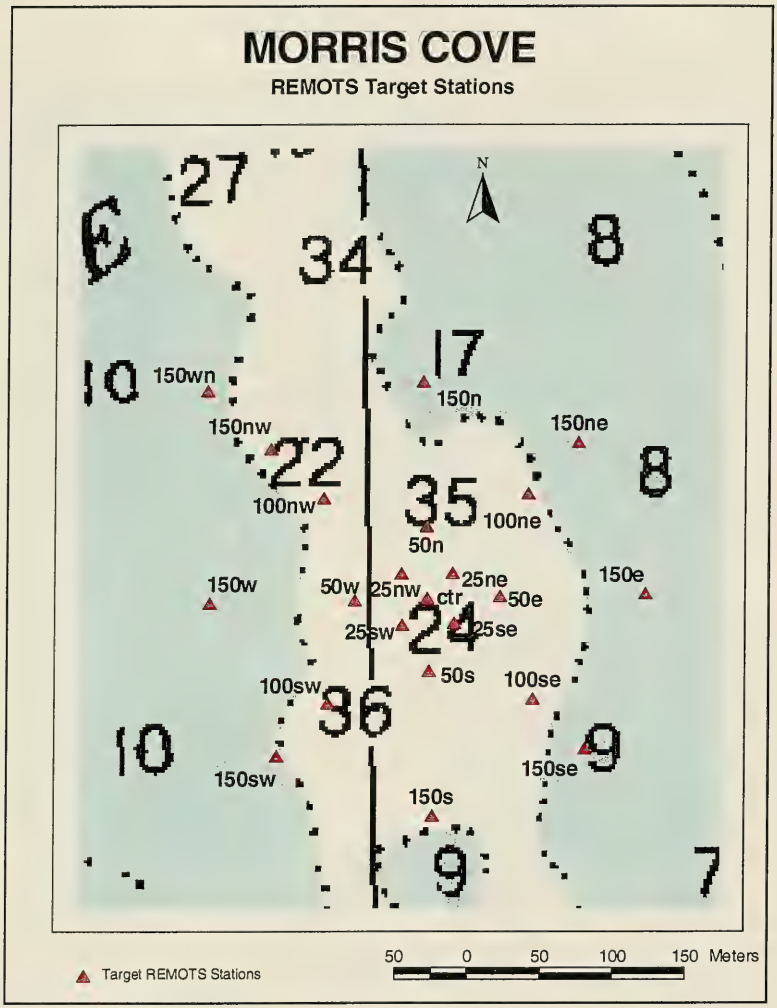


Figure 2-3. REMOTS® Sediment-Profile Photography Stations established over the Morris Cove borrow pit

However, under- or over-penetration of the camera prism into the sediment prevented analysis of all three replicates at a subset of the stations.

Towed Video Sled

A towed video sled operated by CR Environmental, Inc. was used to conduct a benthic video survey over the Morris Cove borrow pit. A high-resolution 8 mm video camera, contained within a specialized pressure housing, was mounted on an aluminum tow sled. The sled was lowered to the seafloor by a mechanical cable and pulled along a series of predetermined transect lines by the survey vessel. Video was recorded on tape by the video camera and simultaneously transferred to the survey vessel via coaxial cable. A topside Super VHS video recording system recorded the images captured by the video camera and provided a time stamp for correlation with navigation data.

Three longitudinal and four transverse transects were occupied in an effort to assess the distribution of dredged material in the Morris Cove borrow pit. Furthermore, the video was used to characterize the composition of ambient sediment and macrofauna in the pit and surrounding area (Figure 2-4). The position of the tow sled, based on cable layback, was logged continuously by the HYPACK® navigation system during the survey operation.

Bathymetric Data Collection and Processing

In addition to displaying vessel position, HYPACK® was interfaced with an Odom Hydrotrac Fathometer for the collection of depth profiles during both the side-scan sonar and towed video surveys. 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. At the conclusion of survey, raw depth soundings were plotted over the survey lines to re-create vessel track and verify data quality.

The bathymetric data were later processed and analyzed using the HYPACK® single-beam hydrographic data processing module. Raw bathymetric data files were standardized to the vertical datum of Mean Lower Low Water (MLLW) using National Oceanographic and Atmospheric Administration (NOAA) observed tides. Observed tidal data were obtained through NOAA's Ocean and Lake Levels Division's (OLLD) National Water Level Observation Network. The NOAA 6-minute tide data for 28 September 2000 were downloaded from http://co-ops.nos.noaa.gov from station (8465705) in New Haven Harbor and used to formulate tidal height correctors.

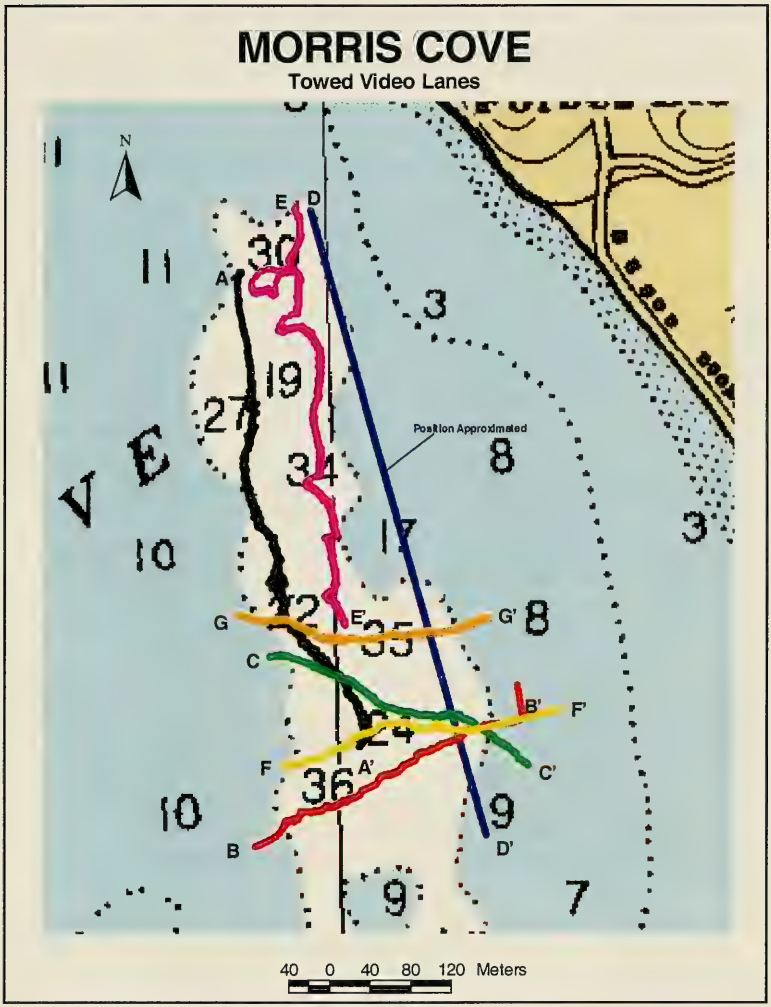


Figure 2-4. Track lines for longitudinal transects and transverse transects occupied with the video towfish.

The bathymetric data were used to examine bottom topography and correlate sediment composition information to relative depth within the cell. Precision sound velocity measurements were not collected during the Morris Cove borrow pit survey. However, an appropriate value of 1500 $m \cdot s^{-1}$ was set in the fathometer for the shallow water survey to provide acceptable depth data. As a result, a small offset (~20 cm) may exist between the depth reported in the profile data and the actual water level over the survey area.

3.0 RESULTS

3.1 Side-scan Sonar

The side-scan sonar data were used to create an acoustic map of the seafloor surrounding the borrow pit and potentially differentiate between ambient sediment and dredged material placed within the pit. Three lanes of swath data were overlaid to create a mosaic of the survey area (Figure 3-1). Data collection was curtailed somewhat by shallow water to the east and an active mooring field in the southern portion of the borrow pit.

The western and northeastern margins of the borrow pit provided a strong sonar return to the transducer (represented by a thick, dark line) and were readily apparent in the mosaic (Figure 3-1). Soft sediment (weaker return) appears to have accumulated within both the northern and southern portions of the borrow pit. Approximately 14,200 m^3 of sediment dredged from the USCG basin were deposited in the southern portion of the pit. Given the relatively small volume of dredged material disposed and 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 the product of multiple sources. The side-scan image 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.

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 recently deposited dredged material and the ambient sediments (Figure 3-2). 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 east of the MCDA disposal buoy. Based on their position relative to the disposal buoy and size, these features are attributed to dredged material deposition.

3.2 REMOTS® Sediment-Profile Imaging

The complete set of REMOTS® image analysis results for both the borrow pit and reference area stations is presented in Appendix B; these results are summarized in Tables 3-1 and 3-2.

Table 3-1
REMOTS® Summary Table for the Morris Cove Borrow Pit Stations

Station	Camera Penetration Mean (cm)	Dredged Material Thickness Mean (cm)	Number of Reps w/ Dredged Material	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	Methane Present	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
100NE	19.77	>19.77	3	4.07	I,III	ST_I_ON_III	>4	YES	11*	11*	1.46
100NW	6.18	0	0	0.90	I	ST_I	>4	NO	3	3	2.79
100SE	19.14	>19.14	3	2.70	I	ST_I	>4	YES	3	3	2.43
100SW	10.02	>10.02	3	3.54	I,II,III	ST_I_ON_III	>4	NO	10	10	2.88
150E	3.21	0	0	1.63	I	ST_I	4 to 3	NO	4	4	1.59
150N	14.24	>14.24	3	3.70	I	ST_I	>4	NO	6.33	7	1.53
150NE	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET
150NW	13.60	>13.60	3	2.62	I,II,III	ST_II_ON_III	>4	NO	7	7	3.58
150S	19.35	>19.35	3	6.33	I,II,III	ST_II_ON_III	>4	NO	8.5	8.5	1.05
150SE	20.77	INDET	INDET	2.77	I	ST_I	>4	NO	5	5	1.65
150SW	8.04	0	0	1.27	I	ST_I	>4	NO	3.33	3	3.46
150W	14.09	0	0	3.01	I	ST_I	>4	NO	5.67	5	1.51
150WN	6.58	0	0	1.65	I,II	ST_II	4 to 3	NO	4.5	4.5	1.63
25NE	14.91	>14.91	3	3.50	I,II	ST_II	>4	NO	6.67	7	2.34
25NW	14.87	>14.87	3	4.55	I	ST_I	>4	YES	6	6	1.82
25SE	13.66	>13.66	3	2.61	I	ST_I	>4	NO	5	5	2.43
25SW	10.30	>10.30	3	2.74	I	ST_I	>4	NO	5	5	2.41
50E	18.62	>18.62	3	2.84	I,II,III	ST_II_ON_III	>4	NO	7.5	7.5	2.62
50N	16.02	>16.02	3	3.75	I	ST_I	>4	NO	5.67	5	3.26
50S	9.93	>9.93	3	3.93	I	ST_I	>4	NO	5.33	5	3.71
50W	11.38	>11.38	3	2.92	I,II	ST_I_TO_II	>4	NO	6.33	6	2.58
CTR	12.12	>12.12	3	2.90	I	ST_I	>4	NO	5	5	2.28
AVG	13.18	>13.18	2.52	3.04					5.64	5.58	2.33
MAX	20.77	>20.77	3	6.33					11	11	3.71
MIN	3.21	>3.21	0	0.9					3	3	1.05

Table 3-2
REMOTS® Summary Table for the New Haven Harbor Reference Areas Stations

Station	Camera Penetration Mean (cm)	RPD Mean (cm)	Successional Stages Present	Highest Stage Present	Grain Size Major Mode (phi)	OSI Mean	OSI Median	Boundary Roughness Mean (cm)
REF1	14.06	1.03	I	ST_I	>4	3	3	2.59
REF2	13.88	3.50	I,III	ST_III	>4	7	7	2.98
REF3	13.98	2.78	I	ST_I	>4	5	5	4.56
REF4	10.76	0.56	I	ST_I	>4	2	2	4.37
REF5	12.29	0.46	I	ST_I	>4	2	2	3.02
AVG	12.99	1.66				3.8	3.8	3.50
MAX	14.06	3.5				7	7	4.56
MIN	10.76	0.46				2	2	2.59

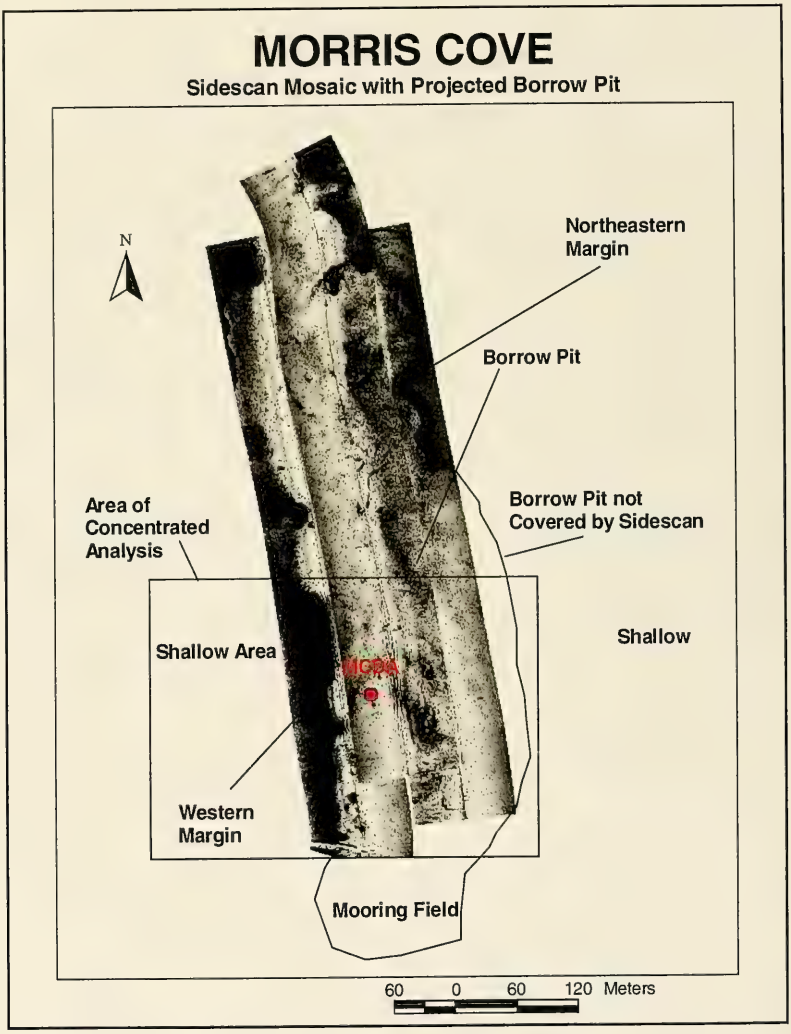


Figure 3-1. Side-scan sonar mosaic of the three lanes occupied over the Morris Cove borrow pit

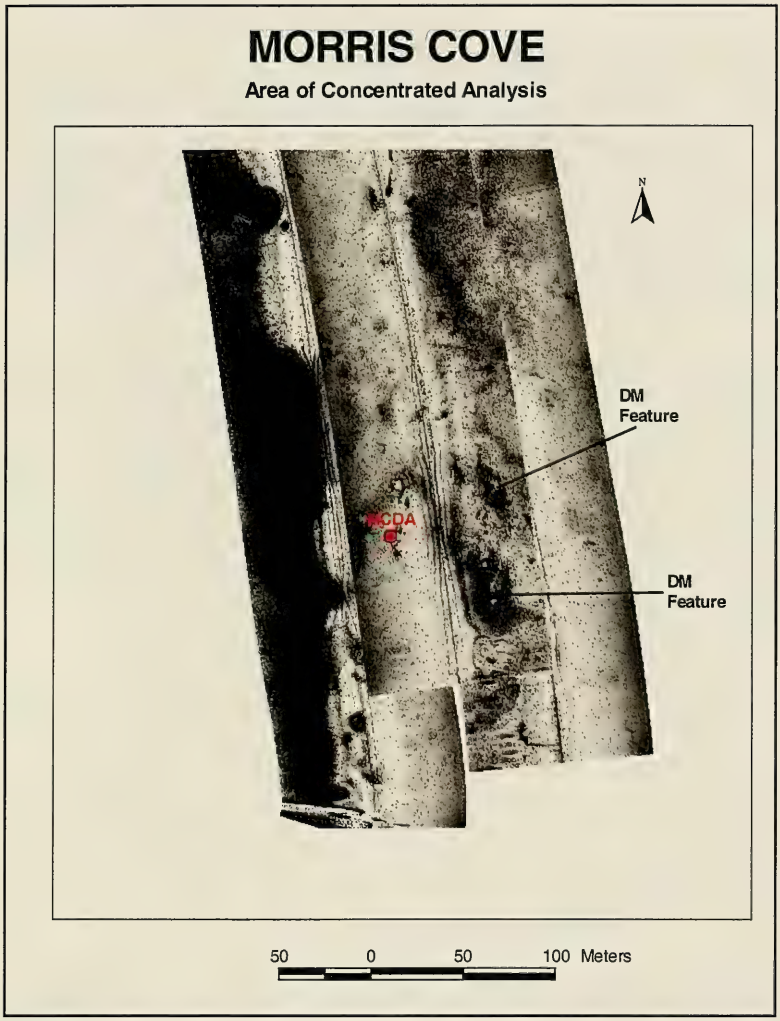


Figure 3-2. Side-scan sonar image displaying several acoustically detectable bottom features within the Morris Cove borrow pit in close proximity to the MCDA buoy position

3.2.1 Dredged Material Distribution and Physical Sediment Characteristics

Dredged material was detected in the REMOTS® images at 15 of 22 borrow pit stations (Table 3-1; Figure 3-3). The dredged material layer extended from the sediment surface to below the imaging depth of the REMOTS® camera at all of these stations (i.e., dredged material greater than penetration, denoted by a "greater than" sign in Table 3-1 and Figure 3-3). Surface sediments considered to be ambient bottom (i.e., unaffected by dredged material disposal) were observed in the replicate images at Stations 100NW, 150E, 150SW, 150W, and 150WN located outside or on the presumed edges of the pit (Table 3-1; Figure 3-3). At Stations 150NE and 150SE, it could not be clearly determined from the images whether the material present was dredged material or ambient sediment (INDET = indeterminate in Table 3-1 and Figure 3-3).

The dredged material comprising the surface sediment within the borrow pit was fine-grained, composed mainly of sandy silt having a grain size major mode of >4 phi (Table 3-1; Figure 3-4). At Station 150NE, a hard bottom prevented sufficient penetration of the sediment profile camera. Replicate-averaged camera penetration depths for the borrow pit stations ranged from 3.2 cm at Station 150E to 20.8 cm at Station 150SE, with an overall average of 13.2 cm (Table 3-1). The majority of the penetration depth values were greater than 10 cm, suggesting the dredged material within the pit was relatively soft. As previously indicated, the soft nature of the sediment caused the replicate images at some stations to be overpenetrated, obscuring the sediment-water interface and preventing the measurement of key parameters (e.g., RPD, successional status, OSI, and boundary roughness).

The average boundary roughness value for the borrow pit stations was 2.33 cm, indicating a moderate amount of small-scale surface relief (Table 3-1). The irregular and/or sloping small-scale topography observed at many stations was deemed to be physical in nature, due to the presence of cohesive clay clumps resulting from the dredging and subsequent disposal operations (Figure 3-4). There was no obvious spatial pattern in the boundary roughness values across the surveyed area. A single occurrence of biogenic surface roughness was due to the presence of a dense mat of tubicolous amphipods (*Ampelisca* sp; see Figure 3-4) at station 25NE. Shells and shell hash were observed at the sediment surface at several stations.

Sediments at the reference area stations were similar to those within the borrow pit in being predominantly fine-grained (major modal grain size of >4; Table 3-2 and Figure 3-5). Dredged material was not observed in any of the images at the reference area stations. Mean camera penetration depths ranged from 10.76 cm at Station REF4 to 14.06 cm at Station REF1, with an overall average of 13 cm (Table 3-2). This is moderately deep penetration, comparable to that at the borrow pit stations, which is considered typical for the soft, fine-grained ambient sediment present at the reference areas.

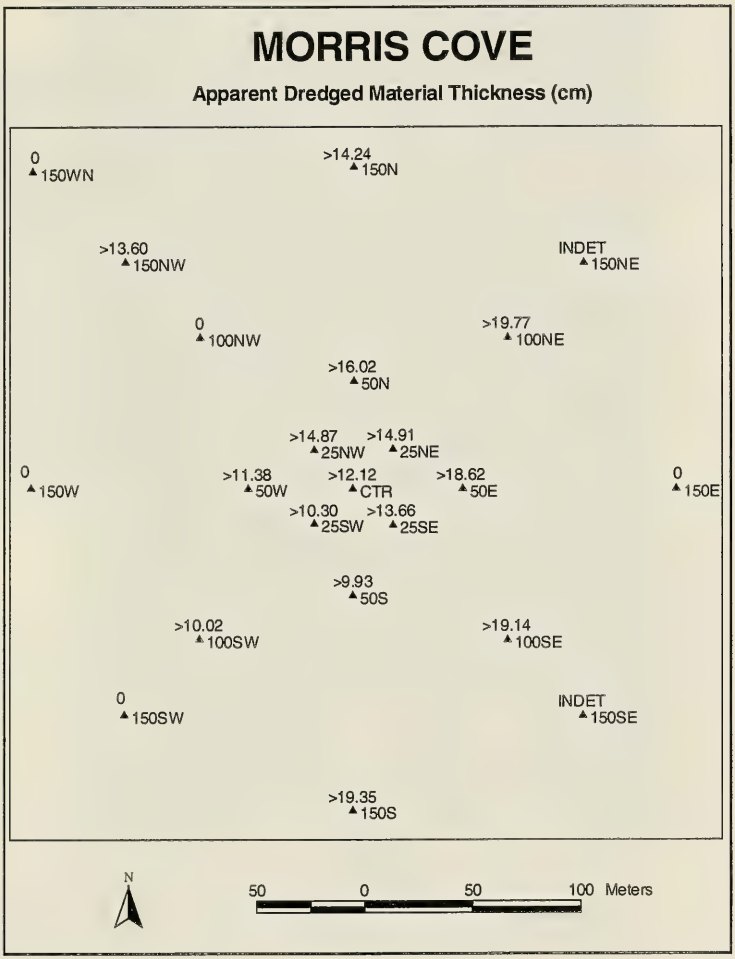


Figure 3-3. Map showing the average thickness of the dredged material layer observed in replicate sediment profile images at each station. A "greater than" sign indicates that the dredged material layer extended below the imaging depth of the sediment profile camera.

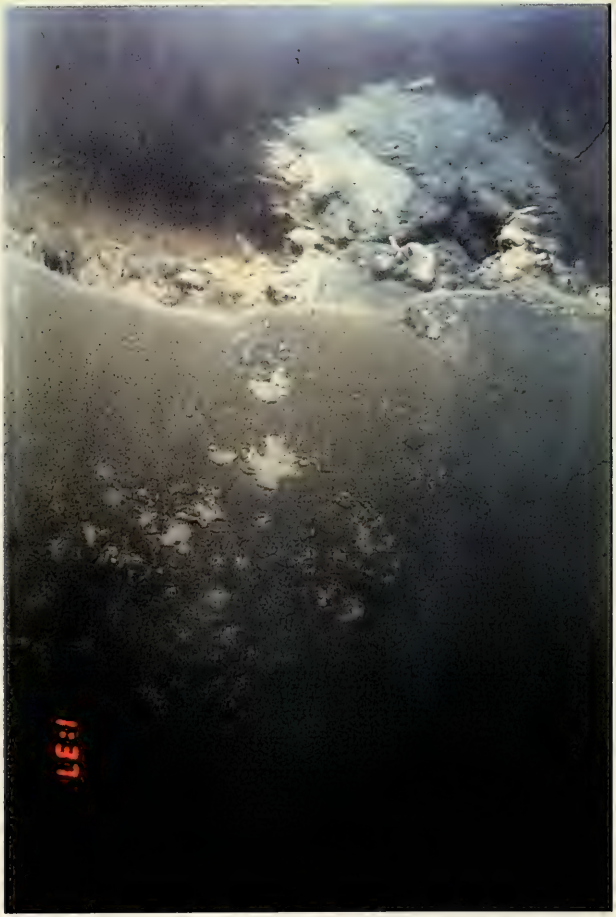


Figure 3-4. REMOTS® image from station 100SW within the Morris Cove borrow pit, showing a layer of fine-grained dredged material extending from the sediment-water interface to below the imaging depth of the camera (i.e., dredged material greater than penetration). A clump of cohesive clay measuring 7 cm in diameter is visible on the sediment surface, resulting in increased small-scale boundary roughness. Numerous Stage I polychaete tubes protrude from the clay clump, and a dense Ampeliscid amphipod tube mat (Stage II) is visible on the left side of image.

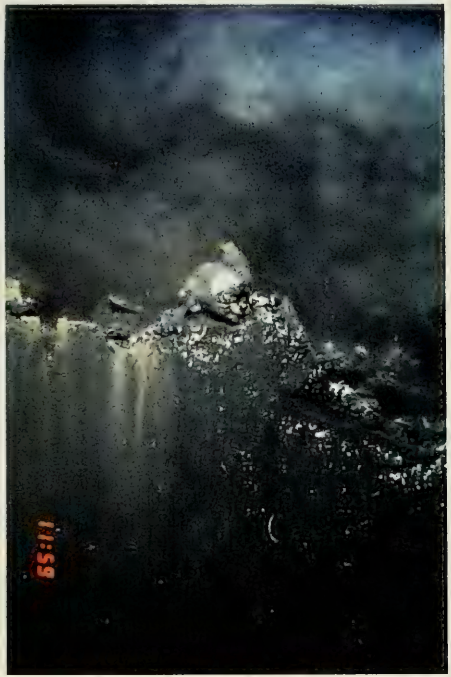


Figure 3-5. REMOTS® images from stations REF4 (left) and REF5 (right) illustrating the relatively soft, fine-grained sediment (grain size major mode of >4 phi) which characterized the reference area stations. Both images show a surface shell lag deposit, irregular topography, and an exceptionally thin RPD layer, possibly due to periodic scouring of the sediment surface by currents/waves.

The average small-scale surface boundary roughness for the reference area stations (3.5 cm) was higher than that observed at the stations within the borrow pit (2.33 cm). The reference stations are located in relatively shallow water, where the bottom may be affected by the scouring action of waves and currents during high-wind events or by fishing (oyster dredging) activity. The increased boundary roughness, presence of a surface shell lag deposit, and shallow RPD depths observed at several of the reference stations may reflect such periodic physical disturbance (Figure 3-5). However, it is notable that similar evidence of physical disturbance was not observed at the borrow pit stations.

3.2.2 Biological Conditions and Benthic Recolonization

Three parameters can be used to assess the benthic recolonization rate and overall health of the benthic environment within the borrow pit relative to the reference area: apparent Redox Potential Discontinuity (RPD) depth, infaunal successional status, and the Organism Sediment Index (OSI).

The redox potential discontinuity (RPD) measured in each image provides an estimate of the apparent depth of oxygen penetration into the surface sediment. The replicate-averaged apparent RPD measurements for the borrow area stations ranged between relatively high values of 6.33 cm and 4.55 cm at Stations 150S and 25NW, respectively, to a low value of 0.90 cm at Station 100NW (Table 3-1; Figure 3-6). The overall average RPD value of 3.04 cm is considered indicative of relatively well-aerated surface sediments within the borrow pit. None of the replicate images obtained within the borrow pit showed any evidence of low dissolved oxygen conditions or visible redox rebounds. However, methane gas bubbles were observed within the sediment column in the images obtained at Stations 100NE, 25NW, and 100SE (Table 3-1). The presence of methane suggests that the dredged material at these stations contains a relatively high inventory of organic matter that is being decomposed under anaerobic conditions at depth. It is notable, however, that the dredged material at the sediment surface at these and other stations within the borrow pit appeared well oxygenated.

The overall average RPD value for the reference area stations (1.66 cm) was considerably lower than the borrow pit station average of 3.04 cm (Table 3-2). Replicate images at Stations REF5 and REF4 had extremely shallow RPD depths of 0.42 cm and 0.52 cm, respectively, possibly related to physical disturbance of the sediment surface (Figure 3-5). There was no indication of low dissolved oxygen conditions, methane, or visible redox rebounds at the reference area stations.

As expected for a recent dredged material deposit, the successional stage recolonization status of the Morris Cove borrow pit included principally Stage I pioneering

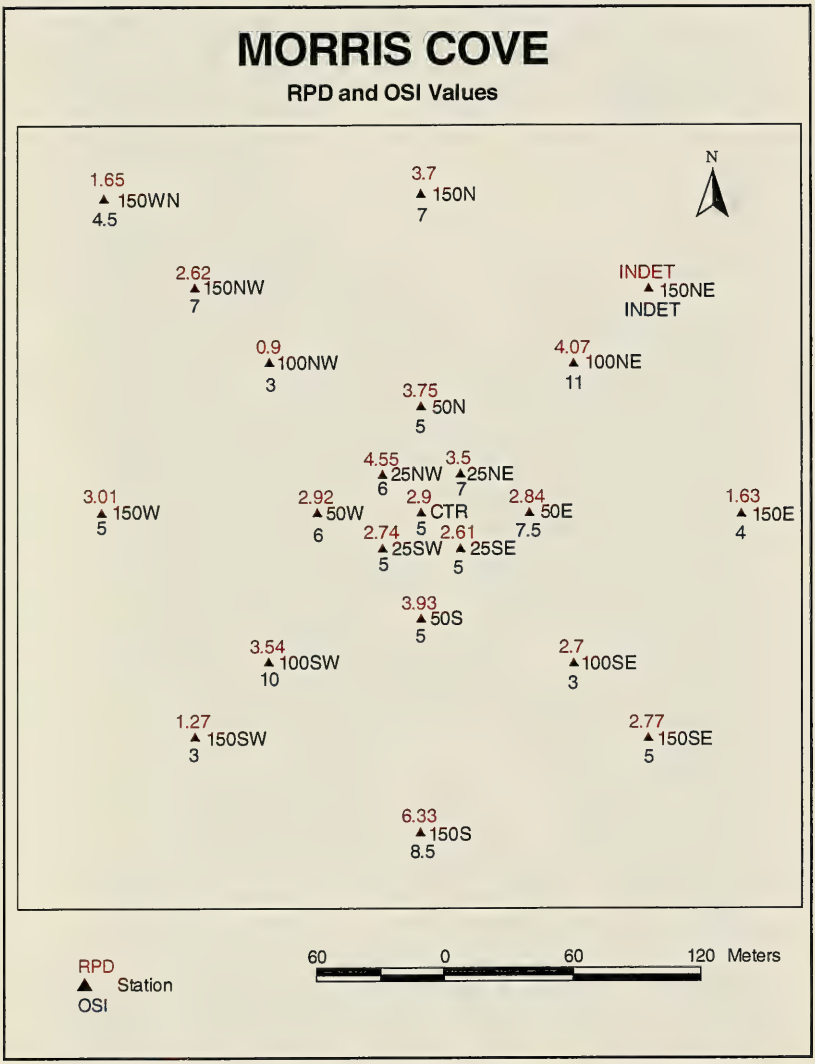


Figure 3-6. Map showing average RPD and OSI values at each borrow pit station.

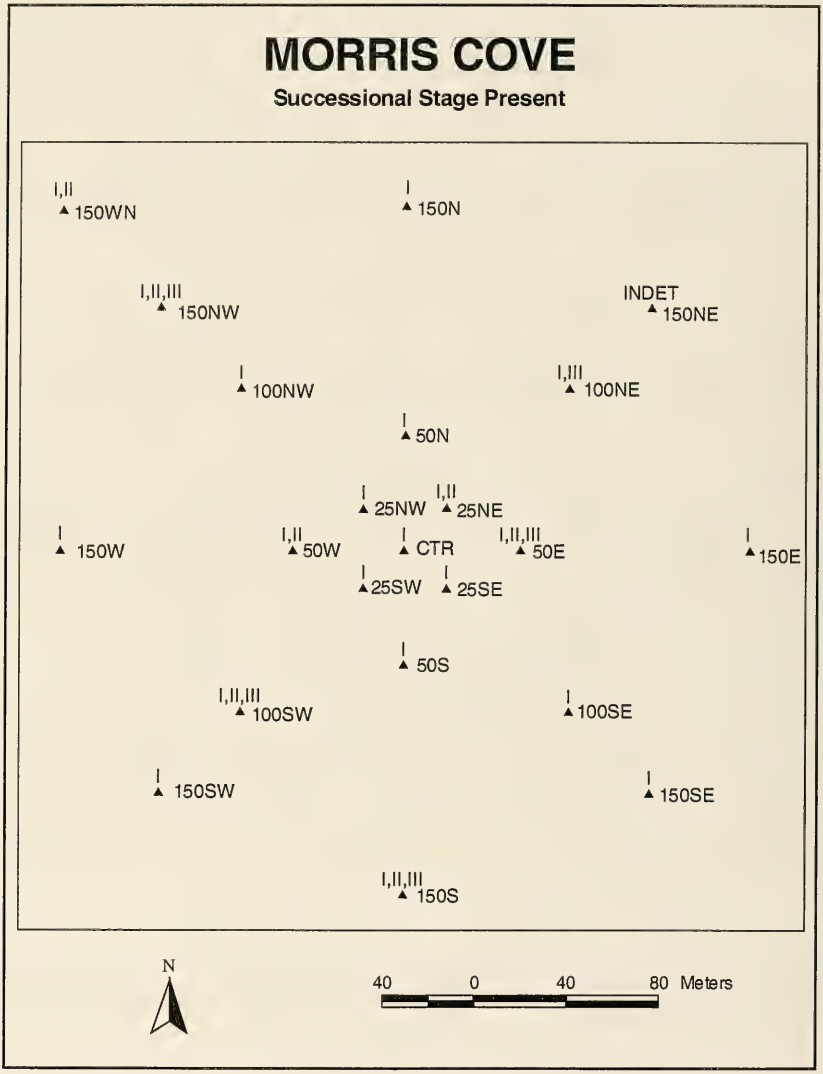


Figure 3-7. Map showing infaunal successional stages present at each borrow pit station.

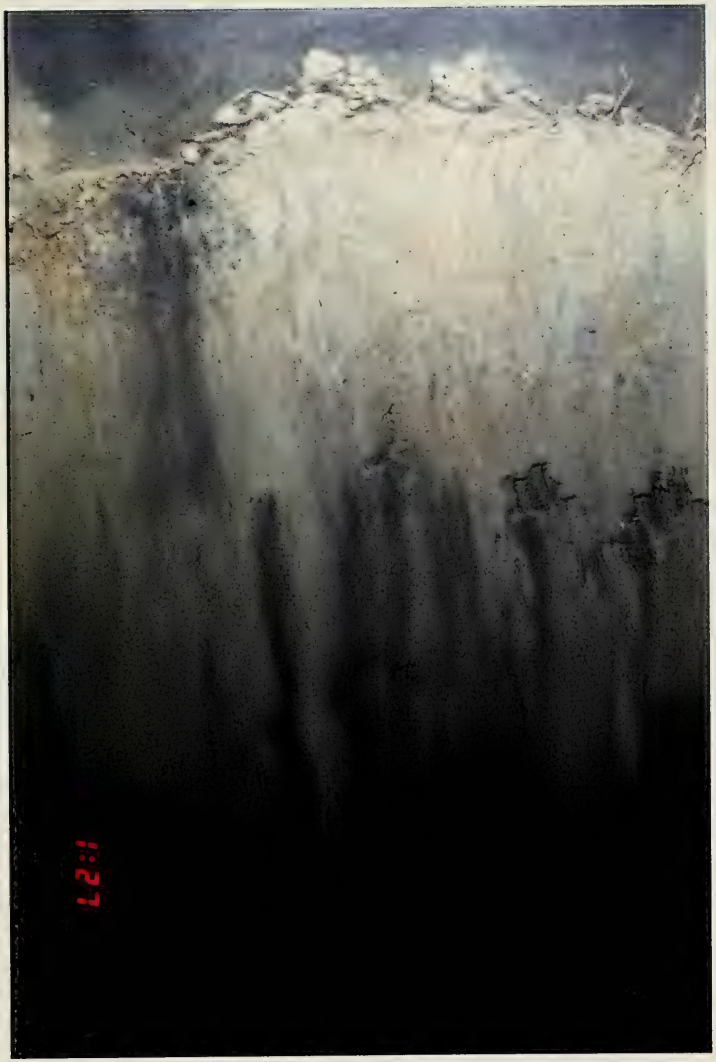


Figure 3-8. REMOTS® image showing small, tubicolous, opportunistic polychaetes (Stage I) present at the surface of fine-grained dredged material at station 100SW within the borrow pit.

polychaetes present at the sediment surface (Figures 3-7 and 3-8; Table 3-1). Tube-dwelling amphipods (*Ampelisca* sp), representative of Stage II, were observed at 7 of the 22 stations (Figures 3-7 and 3-9). Stage III activity, evidenced by active feeding voids produced by head-down, deposit-feeding infauna, was predominately noted in the subsurface at Stations 100NE, 100SW, 150NW, 150S, and 50E (Figures 3-7 and 3-9). Overall, the presence of a diverse mixture of Stages I, II and III organisms at the stations within the borrow pit indicate that benthic recolonization of this area was occurring as expected at the time of the September 2000 survey.

Stage I successional status dominated the reference areas, with only a single occurrence of Stage III activity marked by active feeding voids in one replicate image at Station REF2 (Table 3-2). Dense tube-building Stage I polychaetes, as well as a fecal mound, were noted in one of the replicate images at station REF2. The dominance of Stage I organisms and the notable scarcity of Stage III at the reference area stations may again be due to periodic physical disturbance experienced in this shallow area.

Median OSI values for the borrow pit stations ranged from +3 at Stations 100NW, 150SW, and 100SE to +11 at Station 100NE (Table 3-1 and Figure 3-6). This range of values suggests variable benthic habitat quality across the area, ranging from moderately disturbed (OSI values of +3 to +6) to healthy or undisturbed (OSI values >+6).

Values at the lower end of the scale (+3 to +6) reflect somewhat shallow RPD depths, an absence of Stage II and III infauna, and/or the presence of methane in the sediment. Values greater than +6 generally reflect well-developed RPD depths and the presence of both Stage II and III recolonizing organisms. Such spatial variability in conditions is typical for an area, like the borrow pit, which had experienced significant physical disturbance related to dredged material placement as recently as 5 months prior to the September 2000 survey. Benthic organisms appeared to have recolonized some areas of the dredged material deposit to a more advanced degree (i.e., Stages II and III) than others (dominated by Stage I only). This variability in the distribution of recolonizing benthos is normal so soon after the initial disturbance, and it is anticipated that organisms representing more advanced successional stages will become more widely distributed over time. In the absence of additional dredged material disposal, increases in the density of Stage II and III organisms should be reflected in higher OSI values at the borrow pit stations in the future.

Shallow mean RPD depths together with only Stage I activity at the Morris Cove reference areas served to diminish the median OSI values to a range of +2 to +7 (Table 3-2). The exceptionally low OSI values for Stations REF4 and REF5 reflect very shallow mean RPD depths and the lack of Stage II or III individuals (Figure 3-5). The northernmost reference areas (REF2 and REF3) appeared to display somewhat healthier benthic conditions than the surrounding stations with deeper mean RPD depths, Stage III

Figure 3-9. REMOTS® images from station 50E (left) and 150S (right) showing Stage I and II tubes visible at the sediment surface, and feeding voids (evidence of Stage III activity) at depth within the sediment.

individuals, and elevated OSI values. Overall, the lower average OSI value for the reference area stations (+3.8) compared to the borrow pit (+5.6) suggests that the ambient bottom in Morris Cove was more highly disturbed at the time of the survey.

3.3 Towed Video Survey

The towed video survey was conducted to document the apparent composition of the surface sediments within the borrow pit. A series of seven transects (three longitudinal and four transverse) were occupied in and around the Morris Cove borrow pit. Individual transects are displayed in Figures 3-10 through 3-14 with both an aerial perspective and a profile view presented. The corrected bathymetric profiles were used to compare depth and slope to apparent surface sediment composition. A summary graphic displaying the composite results of all seven transects is presented in Figure 3-15.

3.3.1 Sediment Composition

In general, fine sand, silt, and shell fragments were detected in patches throughout the entire borrow pit. As expected, a correlation between bottom slope and sediment composition was observed, with silt accumulating in the deeper, low relief areas of seafloor and fine, silty sand/shell fragments detected along the walls of the borrow pit. Distinctions between ambient sediment and recently deposited dredged material were difficult to detect on the surface due to the age of the deposit, similar lithology (fine sand and silt), and the high optical reflectance of the well-oxygenated surface layer.

Transect A was a longitudinal pass within the boundaries of the borrow pit, concentrating on the western margin of the bottom feature (Figure 3-10). The starting point for this line was placed approximately 450 m north of the MCDA buoy position. Soft material was observed for the majority of this transect with silty sand and shell fragments observed as the video sled encountered the sloping walls of the pit. Silt was predominant in areas of low relief and tended to be found at water depths below 5 m. A few patches of pebble and cobble sized rock were also observed on the bottom, as the video sled was towed south and east through the pit. The seafloor within a 30 m radius of the MCDA buoy position was characterized as a silty sand, but showed no obvious differences from the surface sediments in the northern portion of the borrow pit.

Transect B represents the first transverse route occupied over the Morris Cove borrow pit. The video sled passed approximately 60 m southeast of the disposal buoy position (Figure 3-11). Fine, silty sand was observed in the shallow areas on either end of the transect, and patches of silt were found at depth. Once again, a correlation with bottom slope was detected as the margins of the pit were composed of fine sand or fine sand with shell.

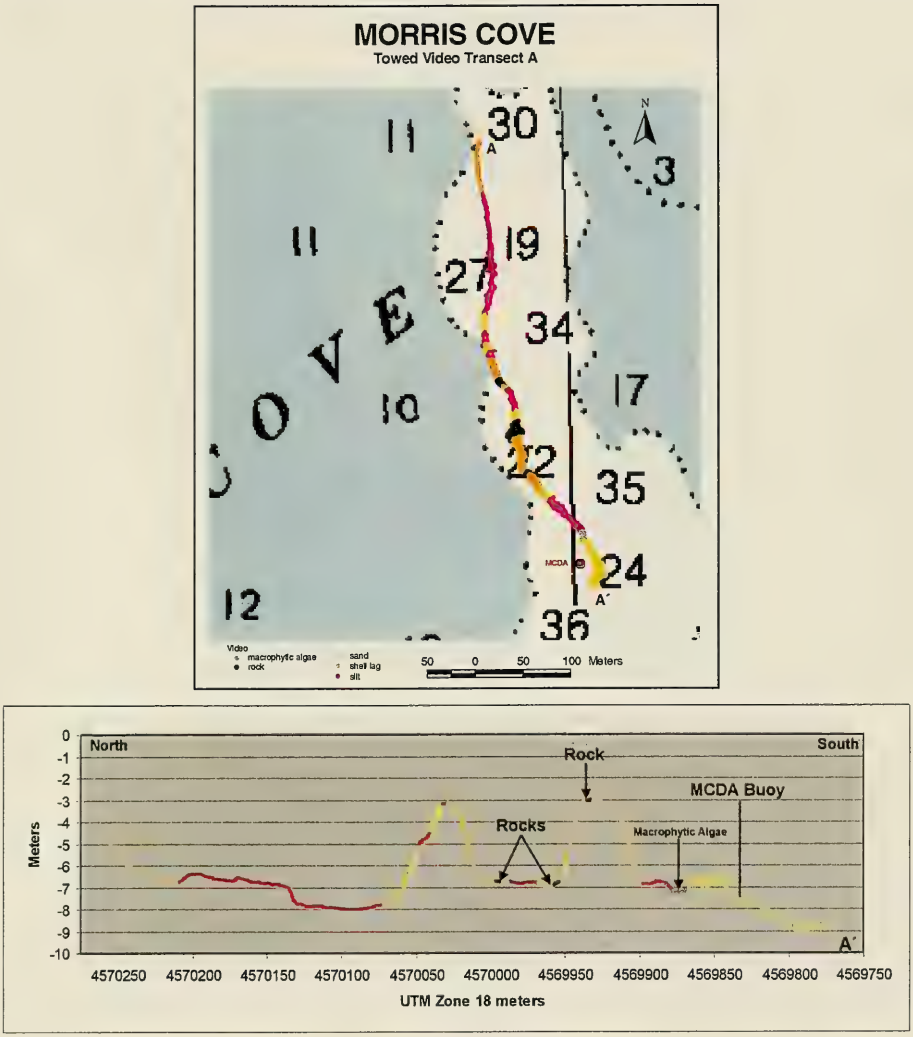


Figure 3-10. Aerial perspective and profile view of surface sediment characterization data obtained for Transect A displaying distribution of fine sand (yellow), silt (magenta), shell lag (tan), rock (black) and macrophytic algae (gray).

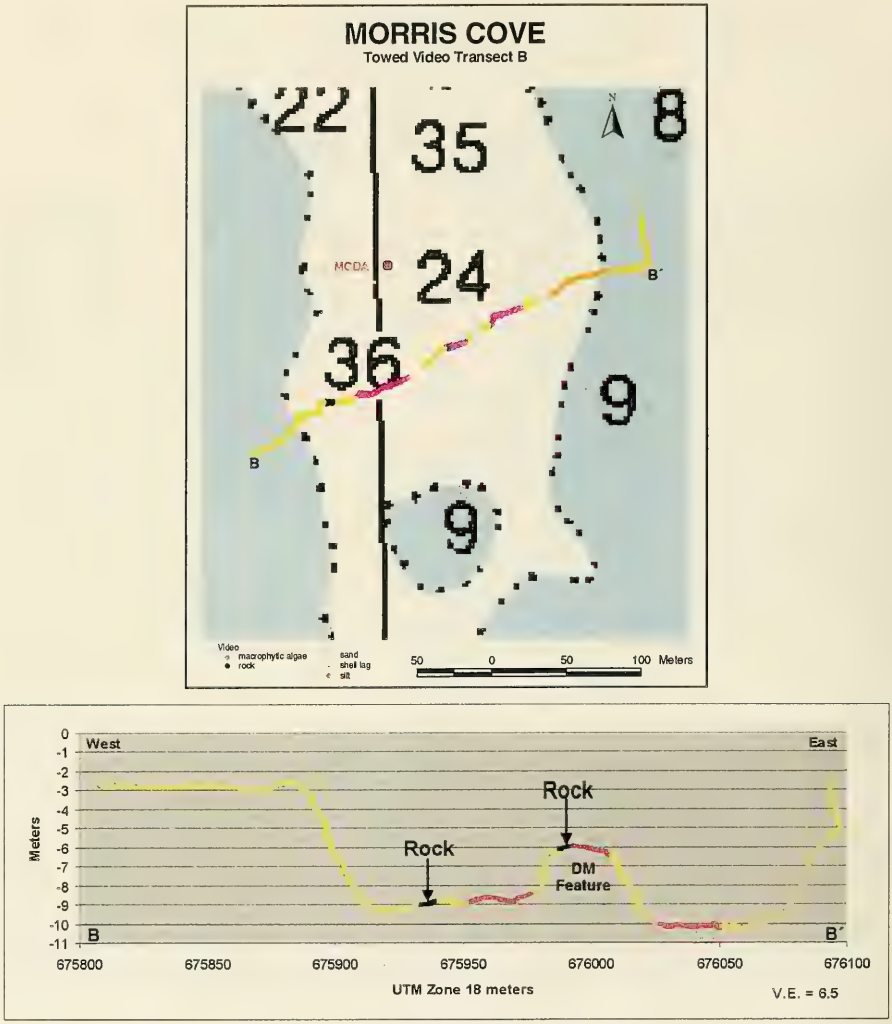
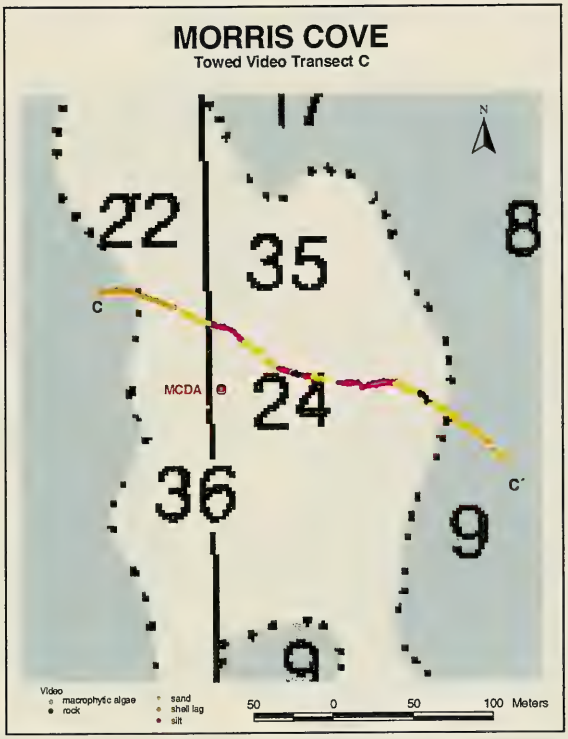


Figure 3-11. Aerial perspective and profile view of surface sediment characterization data obtained for Transect B displaying distribution of fine sand (yellow), silt (magenta), shell lag (tan), rock (black) and macrophytic algae (gray).



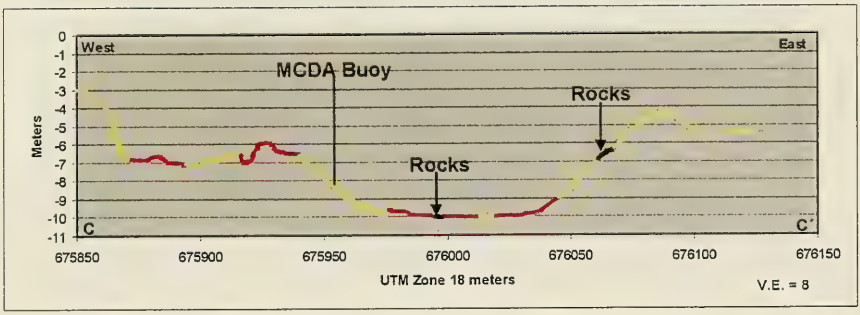


Figure 3-12. Aerial perspective and profile view of surface sediment characterization data obtained for Transect C displaying distribution of fine sand (yellow), silt (magenta), shell lag (tan), rock (black) and macrophytic algae (gray).

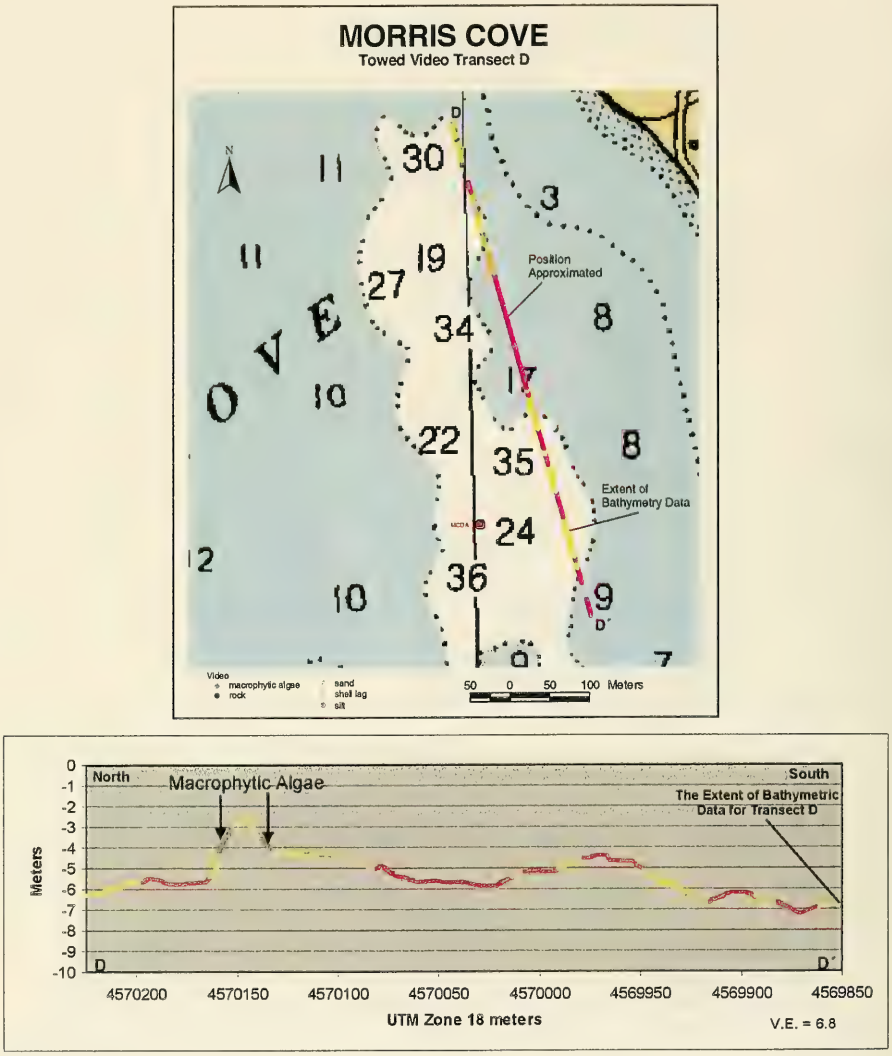
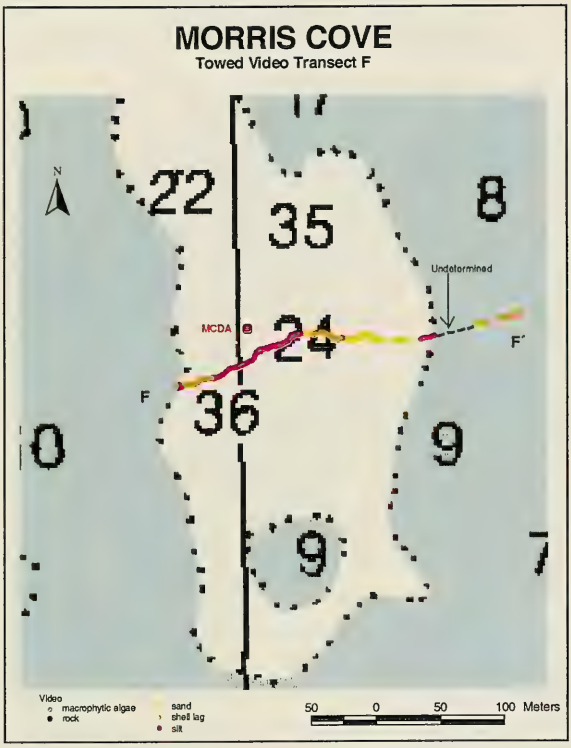


Figure 3-13. Aerial perspective and profile view of surface sediment characterization data obtained for Transect D displaying distribution of fine sand (yellow), silt (magenta), shell lag (tan), rock (black) and macrophytic algae (gray).



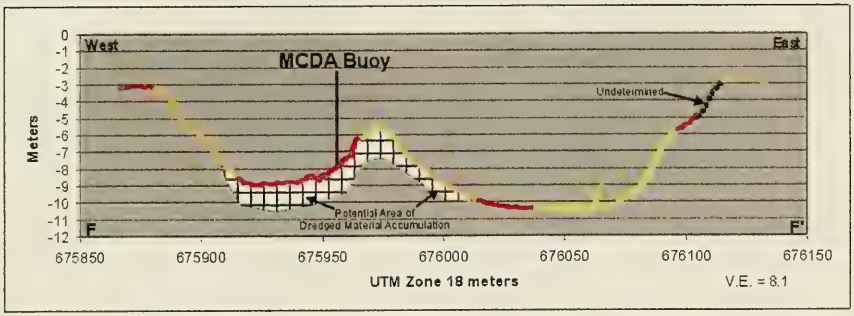


Figure 3-14. Aerial perspective and profile view of surface sediment characterization data obtained for Transect F displaying distribution of fine sand (yellow), silt (magenta), shell lag (tan), and macrophytic algae (gray).

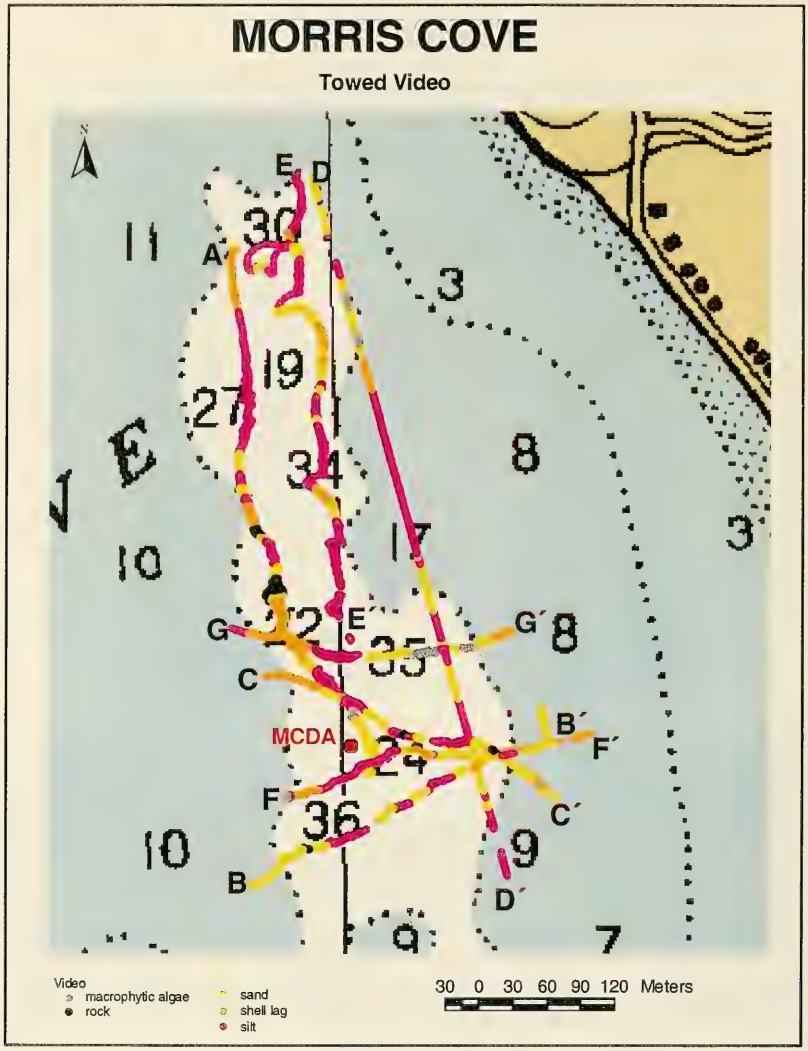


Figure 3-15. Aerial perspective of towed video Transects A through G showing agreement in sediment classification between overlapping and closely spaced tracklines.

Silt tended to accumulate in the deeper (>5 m), low relief areas in the pit. A few small patches of rock were noted along this line, one of which was found on a bathymetric feature near the mid-point of the transect.

The depth profile for Transect B displayed a bottom feature with vertical relief of 2.5 m and a diameter of 50 m near the center of the pit (Figure 3-11). The margins of this feature were composed of fine sand and the sediments over the relatively flat top of the mound were classified as silt. Based on its location relative to the disposal buoy (southeast), this feature is likely the product of recent dredged material disposal activity.

Transect C also represents a transverse pass over the borrow pit. Once again, small patches of silt, fine silty sand, fine sand with shell, and a limited amount of pebble and cobble sized rocks were observed within the video record (Figure 3-12). The video sled passed 20 m northeast of the disposal buoy position as it was towed east-southeast across the borrow pit. Similar to the interpretations of Transect A, the surface sediments in close proximity to the MCDA buoy position were characterized as fine, silty sand. No obvious visual distinctions were observed between ambient sediment and the surface of the recent dredged material deposit. The depth profile for Transect C showed limited vertical relief to the west of the buoy position before the bottom gradually sloped to the deepest portion of the pit (water depth of 10 m). Silt was the major constituent of the sediments within the deepest portion of the pit.

Transect D was the second longitudinal pass made over the Morris Cove borrow pit, and designed to document the composition of sediment along the eastern margin of the pit. Due to unreliable navigation data from the DGPS unit during the occupation of Transect D, the position of the video sled was approximated for the majority of this line. The bathymetric data were used in conjunction with the NOAA chart pictured in Figure 3-13 to place the line along the eastern margin of the borrow pit. Overall, a similar lithology and distribution of sediments were observed, relative to other transects. Fine sand with varying shell content was noted in areas near the walls of the pit and silt was found over the flat areas within the pit. The video data collected in the southern portion of the borrow pit suggested that seafloor composition east of the buoy position is quite patchy.

Transect F was a third transverse pass made over the borrow pit and sampled an area approximately 25 m southeast of the MCDA buoy position. In general, Transect F displayed similar combinations in bottom composition relative to Transects C and B with silt, shell lag, and sand represented in the video images (Figure 3-14). A strong bathymetric feature east of the MDCA buoy with a minimum depth of 5.5 m was detected in the depth profile. However, due to the lack of baseline bathymetric data, it is difficult to discern whether this feature is the direct result of dredged material deposition or simply enhanced by the placement of 14,000 m^3 of sediment.

The depth soundings collected during this video transect indicated the western side of the borrow pit sloped down into a small basin composed primarily of silt. This flat region displayed a depth of 9 m before depths gradually decreased in association with the presence of the dredged material feature. The depth values within the borrow pit as indicated on the NOAA chart for New Haven Harbor suggest the water column along Transect F was deeper at one time (Figure 3-14). Extrapolating from the NOAA soundings, a potential area of recent dredged material accumulation was identified in the basin and over the apex of a shallow area (originally 24 ft). Based on the reported disposal volume, narrow configuration of the borrow pit, and relatively shallow water depths, a dredged material deposit ranging in thickness from 0.5 to 1.5 m is possible.

Two additional transects (one longitudinal and one transverse) were occupied and results overlaid on the data from Transects A, B, C, D, and F (Figure 3-15). In general, strong agreement was observed in the classification of sediment along the margins and within the northern portion of the borrow pit. The surface sediment distribution within the southern portion of the borrow pit appeared more heterogeneous as differences in sediment classification were noted on several overlapping, or closely spaced tracklines (i.e. Transects A and F). This disagreement is likely the result of the chaotic nature of the dredged material and the many small patches of fine sand, silt, and shell on the surface of the deposit.

3.3.2 Benthic Macrofauna

The macrofauna encountered during the towed video survey included horseshoe crabs (*Limulus polyphemus*), sea stars (*Asterias sp.*), Common Oysters (*Crassostrea virginica*), as well as active mussel beds, and various finfish. The bivalves and sea stars were found inhabiting the walls of the pit, as well as concentrated in the areas outside the pit. The horseshoe crabs and finfish were found foraging in the silt deposits within the borrow pit. Macrophytic algae (mainly *Ulva*) were detected in small clumps along several survey lines (Figure 3-15). However, there was no discernable pattern in spatial distribution.

4.0 CONCLUSIONS

The findings of this survey indicate that the use of the Morris Cove borrow pit as an alternate dredged material disposal site during the 1999-2000 disposal season was successful.

- Controlled disposal of small barge loads of dredged material facilitated the development of a small-scale sediment deposit within the confines of the pit.

- REMOTS® photographs indicated the presence of sediments displaying characteristics of dredged material in close proximity to the MCDA buoy position and extending out 100 m to 150 m from the central disposal point.

- Side-scan sonar and towed video data suggest the impacts associated with the deposition of new material (small-scale bottom features and heterogeneous surface sediment composition) were contained within the southern portion of the borrow pit.

- At five months post-disposal, benthic recolonization of the new sediment deposit appears to be progressing as expected.

- Many of the REMOTS® stations within the borrow pit displayed moderate to deep RPD depths and advanced successional status (Stage II and/or III organisms present at 8 of the 22 stations occupied).

- Due to the protected nature of the borrow pit and the recent input of organically enriched sediment, benthic habitat conditions exceeded those observed at the New Haven Harbor reference area.

5.0 REFERENCES

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Appendix A
Morris Cove Borrow Pit Disposal Logs

Appendix A, Disposal Logs

2000 MORRIS COVE

Project: Channel & Dock Area

Permit Number: 199901985 **Permittee:** U.S. Coast Guard

Buoy	Departure	Disposal	Return	Latitude	Longitude	Buoy's Vector	Volume (CY)
MCDS	1/10/00	1/10/00	1/10/00	41.25983333	-72.9008333	20' SSW	300
MCDS	1/11/00	1/11/00	1/11/00	41.26033333	-72.9016667	30' NNW	600
MCDS	1/12/00	1/12/00	1/12/00	41.23666667	-72.9133333	40' NNE	600
MCDS	1/13/00	1/13/00	1/13/00	41.26071667	-72.9012	10' NE	700
MCDS	1/13/00	1/13/00	1/13/00	41.266	-72.9003833	5' S	400
MCDS	1/13/00	1/13/00	1/13/00	41.26061667	-72.90065	10' SSW	600
MCDS	1/15/00	1/15/00	1/15/00	41.26145	-72.9005833	30' NW	700
MCDS	1/15/00	1/15/00	1/15/00	41.26045	-72.9005167	20' W	800
MCDS	1/15/00	1/15/00	1/15/00	41.26123333	-72.8997	20' SSW	400
MCDS	1/16/00	1/16/00	1/16/00	41.26153333	-72.9001833	30' NE	650
MCDS	1/19/00	1/19/00	1/19/00	41.26083333	-72.9005833	15' S	500
MCDS	1/20/00	1/20/00	1/20/00	41.26123333	-72.90065	10' WN	800
MCDS	1/20/00	1/20/00	1/20/00	41.26123333	-72.90065	10'	800
MCDS	1/27/00	1/27/00	1/27/00	41.26083333	-72.9005833	15'	800
MCDS	1/27/00	1/27/00	1/27/00	41.26083333	-72.9005833	15'	900
MCDS	1/28/00	1/28/00	1/28/00	41.2608	-72.9007833	10'	500
MCDS	1/30/00	1/30/00	1/30/00	41.26128333	-72.90045	15'	400
MCDS	2/1/00	2/1/00	2/1/00	41.26096667	-72.8999833	15'	450
MCDS	2/2/00	2/2/00	2/2/00	41.26071667	-72.90025	10' SE	400
MCDS	2/3/00	2/3/00	2/3/00	41.26018333	-72.9008	20' SW	400
MCDS	2/4/00	2/4/00	2/4/00	41.26053333	-72.9001167	30' SSE	450
MCDS	2/5/00	2/5/00	2/5/00	41.26023333	-72.9005833	40' SSW	400
MCDS	2/6/00	2/6/00	2/6/00	41.26071667	-72.90025	50' E	350
MCDS	2/7/00	2/7/00	2/7/00	41.26053333	-72.9001167	20' NW	400
MCDS	2/7/00	2/7/00	2/8/00	41.26031667	-72.9001833	50' SE	300
MCDS	5/2/00	5/2/00	5/2/00	41.261	-72.89983	20 FT NW	300
MCDS	5/4/00	5/4/00	5/4/00	41.26067	-72.89983	25 FT SW	550
MCDS	5/5/00	5/5/00	5/5/00	41.26058	-72.89967	20 FT SW	600
MCDS	5/6/00	5/6/00	5/6/00	41.26067	-72.89967	15 FT SW	400
MCDS	5/7/00	5/7/00	5/7/00	41.26067	-72.89967	25 FT SW	500
MCDS	5/8/00	5/8/00	5/8/00	41.26067	-72.89967	15 SW	400
MCDS	5/9/00	5/9/00	5/9/00	41.2606666	-72.89967	10 FT SW	500
MCDS	5/10/00	5/10/00	5/10/00	41.26083	-72.89933	30 FT NE	500
MCDS	5/11/00	5/11/00	5/11/00	41.26067	-72.89967	20 FT SW	450
MCDS	5/12/00	5/12/00	5/12/00	41.26083	-72.8995	20 NNE	400
MCDS	5/13/00	5/13/00	5/13/00	41.26083	-72.89917	30 FT E	300
MCDS	5/15/00	5/15/00	5/15/00	41.26067	-72.89967	10 FT SW	100
				Project Total Volume:		**14,222 CM**	**18,600 CY**
				Yearly Total Volume:		**14,222 CM**	**18,600 CY**

Appendix B
Morris Cove Borrow Pit September 2000 REMOTS® Results

Appendix B

Morris Cove REMOTS® Sediment-Profile Photography Data from the 2000 Survey

Station	Replicate	Date	Successional Stage	Grain Size (phi)			Mud Class		Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness			Apparent RPD Thickness (cm)			Methane				OSI	Surface Roughness	Low DO	Comments
				Min	Max	Mdl Mode	Count	Avg. Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Count	Min	Max	Mean				
100NE	A	9/28/00	ST_I, ON_III	4	>4	>4	0	0	16.87	19.09	2.22	17.98	16.87	19.09	>17.98	0	0	0	1.35	4.82	4.07	0	0	0	0	11	PHYSICAL	NO	DMb-pen; mud reduced @ 2; void; mulines surface?
100NE	E	10/2/00	INDET	>4	>4	>4	0	0	20.89	20.89	0	20.89	20.89	20.89	>20.89	0	0	0	NA	NA	NA	4	9.63	12.17	10.9	99	INDET	NO	DMb-pen; mud reduced at depth;overpen; 4 methane bubbles
100NE	F	10/2/00	INDET	>4	>4	>4	0	0	20.1	20.79	0.69	20.44	20.1	20.79	>20.44	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	DMb-pen; overpen; mud reduced at depth
100NW	D	10/2/00	ST_I	3	>4	>4	0	0	4.79	7.58	2.79	6.18	0	0	0	0	0	0	0.36	1.3	0.9	0	0	0	0	3	PHYSICAL	NO	Ambient bottom; mud/sand; old shell at surface
100SE	A	9/28/00	INDET	>4	>4	>4	0	0	21.1	21.1	0	21.1	21.1	21.1	>21.1	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	DMb-pen; overpen; mud reduced at depth; shell pieces?
100SE	B	9/28/00	ST_I	4	>4	>4	2	0.79	18.78	19.41	0.63	19.09	18.78	19.41	>19.09	0	0	0	1.22	2.8	2.14	1	12.06	12.54	12.3	2	INDET	NO	DMb-pen; mud reduced; methane at depth
100SE	C	9/28/00	ST_I	>4	>4	>4	0	0	15.13	19.36	4.23	17.24	15.13	19.36	>17.24	0	0	0	1.92	5.18	3.26	2	15.6	16.11	15.85	4	PHYSICAL	NO	DMb-pen; mud reduced @ 2; methane-2bubbles; shell/foams
100SW	B	9/28/00	INDET	>4	>4	>4	0	0	0.05	0.05	0	0.05	0.05	0.05	>0.05	0	0	0	NA	NA	NA	0	0	0	0	99	PHYSICAL	NO	DMb-pen; mud;disturbed or pulleywy; surface ind.;possible tubes center?
100SW	D	10/2/00	ST_I, ON_III	3	>4	5	0.85	17	17.17	18.95	1.78	18.06	17.17	18.95	>18.06	0	0	0	0.52	5.03	3.54	0	0	0	0	10	PHYSICAL	NO	DMb-pen; mud reduced at depth; tubes; surface clasts
100SW	G	10/2/00	ST_II	3	>4	>4	0	0	9.95	13.93	3.98	11.94	9.95	13.93	>11.94	0	0	0	NA	NA	NA	0	0	0	0	99	PHYSICAL	NO	DMb-pen; disturbed surf; dense Amp tube mat;sg clasts w/tubes
150E	C	10/2/00	ST_I	2	>4	4 to 3	0	0	2.41	4	1.59	3.21	0	0	0	0	0	0	0.94	3.08	1.63	0	0	0	0	4	PHYSICAL	NO	Ambient bottom; mud/ sand w shells and shell hash;reduced;low pen
150N	E	10/2/00	ST_I	3	>4	>4	0	0	15.79	18.21	2.42	17	15.79	18.21	>17	0	0	0	0.16	5.23	2.54	0	0	0	0	5	PHYSICAL	NO	DMb-pen;mud reduced at depth; sloping topography
150N	F	10/2/00	ST_I	3	>4	>4	0	0	12.68	13.42	0.74	13.05	12.68	13.42	>13.05	0	0	0	1.86	5.26	3.81	0	0	0	0	7	INDET	NO	DMb-pen; mud reduced at depth; stgl tubes
150N	G	10/2/00	ST_I	3	>4	>4	0	0	11.95	13.37	1.42	12.66	11.95	13.37	>12.66	0	0	0	2.26	5.53	4.74	0	0	0	0	7	PHYSICAL	NO	DMb-pen; mud; reduced at depth; STGI tubes
150NE		10/2/00	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	INDET	Hard bottom prevented sufficient penetration - no data
150NW	A	9/28/00	ST_I	4	4	>4	0	0	13.44	18.87	5.44	16.15	13.44	18.87	>16.15	0	0	0	0.65	6.81	3.5	0	0	0	0	6	PHYSICAL	NO	DMb-pen; mud; tubes; reduced at depth
150NW	C	9/28/00	ST_II, ON_III	4	>4	>4	2	1.03	14.31	17.74	3.44	16.03	14.31	17.74	>16.03	0	0	0	0.77	2.72	1.74	0	0	0	0	6	PHYSICAL	NO	DMb-pen; mud; disturbed surface; void; tubes(Ampelisca)
150NW	D	9/28/00	ST_I	4	>4	>4	2	0.71	7.69	9.54	1.85	8.62	7.69	9.54	>8.62	0	0	0	NA	NA	NA	0	0	0	0	99	PHYSICAL	NO	DMb-pen; reduced mud; partial pulleywy;STG I tubes
150S	F	10/2/00	INDET	4	>4	>4	0	0	20.74	20.79	0.05	20.76	20.74	20.79	>20.76	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	DMb-pen;mud reduced at depth; overpen
150S	G	10/2/00	ST_I	3	>4	>4	0	0	17.53	18.74	1.21	18.13	17.53	18.74	>18.13	0	0	0	1.53	5.53	3.28	0	0	0	0	6	PHYSICAL	NO	DMb-pen;mud reduced at depth;slight disturbed surface; camera tilt
150S	H	10/2/00	ST_II, ON_III	3	>4	>4	0	0	18.21	20.1	1.9	19.16	18.21	20.1	>19.16	0	0	0	8.26	10.21	9.38	0	0	0	0	11	PHYSICAL	NO	DMb-P; deep RPD; Ampelisca; voids
150SE	A	10/2/00	INDET	4	>4	>4	0	0	21.06	21.06	0	21.06	INDET	INDET	INDET	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	DM7; overpen; reduced; some shell hash
150SE	B	10/2/00	INDET	4	>4	>4	0	0	21.06	21.06	0	21.06	INDET	INDET	INDET	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	DM7; reduced mud; overpen
150SE	C	10/2/00	ST_I	>4	>4	>4	0	0	19.35	21	1.65	20.18	INDET	INDET	INDET	0	0	0	0.41	3.82	2.77	0	0	0	0	5	PHYSICAL	NO	DM7; mud reduced at depth; collapsed burrow; tubes
150SW	D	9/28/00	ST_I	3	>4	>4	0	0	5.64	7.02	1.38	6.33	0	0	0	0	0	0	0.65	1.78	1.27	0	0	0	0	3	PHYSICAL	NO	Ambient bottom;mud/fine sand;cold shell & hash, tube
150SW	B	9/28/00	ST_I	2	>4	>4	0	0	7.28	9.48	2.2	8.38	0	0	0	0	0	0	0.26	2.15	1.62	0	0	0	0	4	PHYSICAL	NO	Ambient; fluidized layer; shell; reduced
150SW	C	9/28/00	ST_I	3	>4	>4	0	0	8.01	12.82	4.81	9.41	0	0	0	0	0	0	0.53	1.76	0.92	0	0	0	0	3	PHYSICAL	NO	Ambient; sandy mud; shallow RPD;old oraspidula shell;tubes
150W	A	10/2/00	ST_I	4	>4	>4	0	0	15.12	16.12	1	15.62	0	0	0	0	0	0	1.41	2.82	2.32	0	0	0	0	5	PHYSICAL	NO	Ambient;mud reduced at depth; stgl tubes; shell frags
150W	B	10/2/00	ST_I	3	>4	>4	0	0	12.50	14.71	2.12	13.65	0	0	0	0	0	0	3.12	5.18	4.03	0	0	0	0	7	PHYSICAL	NO	Ambient; collapsed void; worm left? stgl tubes
150W	C	10/2/00	ST_I	4	>4	>4	3	0.98	12.29	13.71	1.41	13	0	0	0	0	0	0	1.41	5.24	2.69	0	0	0	0	5	PHYSICAL	NO	Ambient; mud; surface clasts; stg I tubes surface
150WN	D	10/2/00	ST_I	3	>4	4 to 3	0	0	3.79	5	1.21	4.4	0	0	0	0	0	0	1.32	2.63	2.04	0	0	0	0	4	PHYSICAL	NO	Ambient bottom; fine sand/mud; shell surface hermit crab
150WN	E	10/2/00	ST_II	3	>4	4 to 3	0	0	7.74	9.79	2.05	8.76	0	0	0	0	0	0	0.31	3.06	1.28	0	0	0	0	5	PHYSICAL	NO	Ambient bottom; mud/fine sand; shell surf;Ampelisca; tubes
25NE	A	9/28/00	ST_I	>4	>4	>4	3	0.62	14.44	17.4	2.96	15.92	14.44	17.4	>15.92	0	0	0	3.52	6.83	4.66	0	0	0	0	7	PHYSICAL	NO	DMb-pen; mud reduced at depth; surface clasts; deep oxy layer
25NE	F	9/28/00	ST_I	>4	>4	>4	0	0	17.98	20.15	2.17	19.07	17.98	20.15	>19.07	0	0	0	2.12	2.86	2.52	0	0	0	0	5	PHYSICAL	NO	DMb-pen; mud; deep oxy layer
25NE	H	10/2/00	ST_III	3	>4	4 to 3	0	0	8.79	10.68	1.89	9.74	8.79	10.68	>9.74	0	0	0	0.26	4.21	3.31	0	0	0	0	8	BIOGENIC	NO	DMb-pen, sandy DM, dense Ampelisca
25NW	G	10/2/00	ST_I	3	>4	>4	0	0	13.82	16.06	2.23	14.94	13.82	16.06	>14.94	0	0	0	2.06	5.06	4.47	0	0	0	0	7	PHYSICAL	NO	DMb-pen;oxy. mud reduced at depth; tubes
25NW	H	10/2/00	ST_I	2	>4	>4	0	0	14.53	15.53	1	15.03	14.53	15.53	>15.03	0	0	0	1.29	5.24	3.67	0	0	0	0	6	PHYSICAL	NO	DMb-pen;oxy. mud reduced at depth; dredgdown of reduced wiper clast
25NW	I	10/2/00	ST_I	3	>4	>4	4	0.63	13.53	15.78	2.24	14.65	13.53	15.78	>14.65	0	0	0	1.04	7.88	5.52	1	2.29	7	4.65	5	PHYSICAL	NO	DMb-pen;mud reduced at depth;bescied large methane bubble;released smaller
25SE	A	9/28/00	ST_I	2	>4	>4	0	0	11.27	16.71	5.45	13.99	11.27	16.71	>13.99	0	0	0	1.53	4.65	2.81	0	0	0	0	5	PHYSICAL	NO	DMb-pen; sandy mud; irregular topography
25SE	D	10/2/00	ST_I	2	>4	>4	20	0.76	14.6	15.71	1.11	15.15	14.6	15.71	>15.15	0	0	0	0.26	2.49	1.96	0	0	0	0	4	PHYSICAL	NO	DMb-pen; sandy mud; surface layer of clasts; medium sand @surf
25SE	F	10/2/00	ST_I	2	>4	>4	0	0	11.47	12.2	0.73	11.83	11.47	12.2	>11.83	0	0	0	2.86	3.94	3.16	0	0	0	0	6	PHYSICAL	NO	DMb-pen; sandy mud; reduced at depth
25SW	A	9/28/00	INDET	4	>4	>4	20	1.41	1.69	3.49	1.8	2.59	1.69	3.49	>2.59	0	0	0	NA	NA	NA	0	0	0	0	99	PHYSICAL	NO	DMb-pen; lg clay clasts;disturbed mud/clay; fluidized layer
25SW	B	9/28/00	ST_I	4	>4	>4	10	0.42	12.67	16.21	3.54	14.44	12.67	16.21	>14.44	0	0	0	1.09	4.09	2.74	0	0	0	0	5	PHYSICAL	NO	DMb-pen;mud/clay reduced at depth; slightpulleywy;smear irregular surface
25SW	C	9/28/00	INDET	4	>4	>4	15	0.81	12.92	14.82	1.9	13.87	12.92	14.82	>13.87	0	0	0	NA	NA	NA	0	0	0	0	99	PHYSICAL	NO	DMb-pen; partial pulleywy
50E	A	9/28/00	ST_II, ON_III	3	>4	>4	0	0	15.14	20.06	4.92	17.6	15.14	20.06	>17.6	0	0	0	0.98	5.85	3.81	0	0	0	0	11	PHYSICAL	NO	DMb-pen; oxy. mud; void; collapsed void; Amp tubes
50E	B	9/28/00	INDET	>4	>4	>4	0	0	19	20.73	1.73	19.87	19	20.73	>19.87	0	0	0	NA	NA	NA	0	0	0	0	99	INDET	NO	DMb-pen;oxy. mud overpen;partial pulleywy; fluidized surface
50E	C	9/28/00	ST_I	>4	>4	>4	0	0	17.8	19	1.2	18.4	17.8	19	>18.4	0	0	0	0.47	2.46	1.87	0	0	0	0	4	PHYSICAL	NO	DMb-pen; surface mud clast layer; reduced at depth
50N	A	9/28/00	ST_I	>4	>4	>4	0	0	14.28	17.72	3.44	16	14.28	17.72	>16	0	0	0	3.06	7.62	5.66	0	0	0	0	7	PHYSICAL	NO	DMb-pen;mud reduced at depth;irregular topography
50N	D	10/2/00	ST_I	>4	>4	>4	2	0.72	12.06	16.4	4.34	14.23	12.06	16.4	>14.23	0	0	0	0.42	5.08	2.7	0	0	0	0	5	PHYSICAL	NO	DMb-pen; mud reduced at depth; irregular topography
50N	E	9/28/00	ST_I	>4	>4	>4	5	0.74	16.82	18.83	2.01	17.82	16.82	18.83	>17.82	0	0	0	0.16	6.37	2.69	0	0	0	0	5	PHYSICAL	NO	DMb-pen; mud reduced at depth;surface clasts; smearing
50S	A	9/28/00	ST_I	4	>4	>4	8	0.41	10.53	15.92	5.4	13.22	10.53	15.92	>13.22	0	0	0	5.34	10.73	8.8	0	0	0	0	7	PHYSICAL	NO	DMb-pen;mud/clay;reduced at depth; surf mud clast lyr; sloping surf
50S	D	10/2/00	ST_I	4	>4	>4	0	0	5.71	10.17	4.45	7.94	5.71	10.17	>7.94	0	0	0	1.27	3.12	2.17	0	0	0	0	4	PHYSICAL	NO	DMb-pen; mud/clay; mounded topography;sg clay clasts; stg I tubes
50S	E	10/2/00	ST_I	2	>4	>4	0	0	7.99	9.26	1.27	8.62	7.99	9.26	>8.62	0	0	0	1.53	3.7	2.81	0	0	0	0	5	PHYSICAL	NO	DMb-pen; sandy mud; possible worm st depth
50W	A	9/28/00	ST_I_TO_II	3	>4	>4	0	0	14.4	15.98	1.47	15.13	14.4	15.98	>15.13	0	0	0	1.35	4.2	3.32	0	0	0	0	7	PHYSICAL	NO	DMb-pen; mud; reduced at depth; Ampelisca tubes
50W	B	9/28/00	ST_I_TO_II	3	>4	>4	4	0.22	9.21	13.98	4.78	11.6	9.21	13.98	>11.6	0	0	0	0.94	3.98	2.67	0	0	0	0	6	PHYSICAL	NO	DMb-p; worm & Ampelisca tubes; mud clasts
50W	C	9/28/00	ST_I_TO_II	3	>4	>4	10	0.32	6.65	8.17	1.52	7.41	6.65	8.17	>7.41	0	0	0	0.83	4.2	2.77	0	0	0	0	6	PHYSICAL	NO	DMb-pen; mud; STG I & Ampelisca tubes; reduced clasts surface
CTR	E	10/2/00	ST_I	2	>4	>4	0	0	8.41	9.53	1.12	8.97	8.41	9.53	>8.97	0	0	0	0.65	2.41	2.15	0	0	0	0	4	PHYSICAL	NO	DMb-pen;mud/f. sand at depth;stgl tube
CTR	F	10/2/00	ST_I	2	>4	>4	1	1.53	12	14.50	2.59	13.3	12	14.50	>13.3	0	0	0	1.12	4.41	3.58	0	0	0	0	6	PHYSICAL	NO	DMb-pen;mud w f.sand;tube; hermit crab
CTR	G	10/2/00	ST_I	3	>4	>4	6	0.74	12.53	15.66	3.13	14.1	12.53	15.66	>14.1	0	0	0	0.98	5.24	2.97	0	0	0	0	5	PHYSICAL	NO	DMb-pen;mud w/ fine sand; sand at depth; tube

Appendix B

Morris Cove Reference Area REMOTS® Sediment-Profile Photography Data from the 2000 Survey

Station	Replicate	Date	Successional Stage	Grain Size (phi)			Mud Clasts		Camera Penetration (cm)				Dredged Material Thickness (cm)			Redox Rebound Thickness			Apparent RPD Thickness (cm)			Methane	OSI	Surface Roughness	Low DO	Comments
				Min	Max	Maj Mode	Count	Avg. Diam	Min	Max	Range	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean					
REF1	D	10/2/00	ST_I	3	>4	>4	4	0.96	8.72	9.41	0.69	9.07	0	0	0	0	0	0	0.21	0.67	0.42	0	2	PHYSICAL	NO	Ambient mud; mud clast surf lyr; fine shell hash; shallow RPD
REF1	E	10/2/00	ST_I	2	>4	>4	0	0	17.71	20.05	2.34	18.88	0	0	0	0	0	0	0.73	1.76	1.13	0	3	PHYSICAL	NO	Ambient mud; shell hash in surf lyr; reduced @depth; depositional layer?
REF1	F	10/2/00	ST_I	2	>4	>4	0	0	11.86	16.6	4.73	14.23	0	0	0	0	0	0	0.88	2.85	1.53	0	4	PHYSICAL	NO	Ambient mud; shell hash surface layer
REF2	A	10/2/00	ST_I	2	>4	>4	0	0	12.18	12.55	0.37	12.37	0	0	0	0	0	0	3.99	5.43	4.65	0	7	PHYSICAL	NO	Ambient mud; shell hash surface; dense tubes; fecal mound
REF2	B	10/2/00	ST_III	2	>4	>4	0	0	12.87	15.9	3.03	14.39	0	0	0	0	0	0	1.76	4.73	3.75	0	10	PHYSICAL	NO	Ambient mud; shell hash surface; irregular topo ;voids
REF2	C	10/2/00	ST_I	2	>4	>4	1	1.32	12.13	17.66	5.53	14.89	0	0	0	0	0	0	0.57	4.09	2.09	0	4	PHYSICAL	NO	Ambient mud; shell hash surface; irregular topo
REF3	A	10/2/00	ST_I	2	>4	>4	0	0	10.69	14.41	3.72	12.55	0	0	0	0	0	0	1.87	4.2	2.85	0	5	PHYSICAL	NO	Ambient mud; tubes surf; sloping topography; shell hash
REF3	C	10/2/00	ST_I	3	>4	>4	0	0	9.41	18.09	8.67	13.75	0	0	0	0	0	0	2.02	8.56	4.42	0	7	PHYSICAL	NO	Ambient mud; shell hash surface layer
REF3	D	10/2/00	ST_I	2	>4	>4	0	0	15	16.28	1.28	15.64	0	0	0	0	0	0	0.67	2.12	1.06	0	3	PHYSICAL	NO	Ambient mud; shell hash; STGI tubes; shallow RPD
REF4	A	10/2/00	ST_I	2	>4	>4	0	0	7.58	10.84	3.26	9.21	0	0	0	0	0	0	0.05	1.24	0.52	0	2	PHYSICAL	NO	Ambient mud; shell hash; shell surface; shallow RPD
REF4	B	10/2/00	ST_I	2	>4	>4	0	0	11.53	16.05	4.53	13.79	0	0	0	0	0	0	0.36	1.09	0.64	0	2	PHYSICAL	NO	Ambient mud; shell hash surface; irregular topography
REF4	C	10/2/00	ST_I	2	>4	>4	0	0	6.63	11.95	5.32	9.29	0	0	0	0	0	0	0.21	0.93	0.52	0	2	PHYSICAL	NO	Ambient mud;shell hash; fluidized surface; disturbed; shallow RPD
REF5	A	10/2/00	ST_I	2	>4	>4	0	0	15.85	17.82	1.97	16.84	0	0	0	0	0	0	NA	NA	NA	0	99	PHYSICAL	NO	Ambient mud; reduced; shell hash surface; ppa
REF5	B	10/2/00	ST_I	2	>4	>4	2	1.15	9.95	12.58	2.63	11.26	0	0	0	0	0	0	0.16	0.88	0.49	0	2	PHYSICAL	NO	Ambient mud; reduced clasts surf; shell hash; shallow RPD
REF5	C	10/2/00	ST_I	2	>4	>4	3	0.37	6.53	11	4.47	8.76	0	0	0	0	0	0	0	0	0.42	0	2	PHYSICAL	NO	Ambient mud; reduced; shell hash; shallow RPD; dist. surf