SCIENCE APPLICATIONS, INC.

RESULTS OF MONITORING STUDIES AT CAP SITES #1, #2 AND THE FVP SITE IN CENTRAL LONG ISLAND SOUND AND A CLASSIFICATION SCHEME FOR THE MANAGEMENT OF CAPPING PROCEDURES

CONTRIBUTION #38

August 17, 1984

SAI-84/7506&C38

Contract #DACW33-83-D-0004

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

TABLE OF CONTENTS (CONT.)

LIST OF TABLES

LIST OF TABLES (CONT.)

LIST OF FIGURES

LIST OF FIGURES (CONT.)

LIST OF FIGURES (CONT.)

LIST OF FIGURES (CONT.)

LIST OF FIGURES (CONT.)

LIST OF FIGURES (CONT.)

1.0 INTRODUCTION

During the spring of 1983, a series of concurrent dredging operations were conducted in harbors on the north shore of Long Island Sound. Because the sediments dredged from these harbors varied dramatically in contaminant levels and physical parameters and since all disposal was assigned to the Central Long Island Sound Disposal Site (CLIS), these operations provided a unique opportunity to address some of the important questions regarding environmental impacts of dredged material disposal and procedures for managing and monitoring such disposal operations. A summary of dredging and disposal operations at the CLIS disposal site which took place during this period is presented as Appendix I.

In particular, since the dredged material properties ranged from clean sand to relatively contaminated organic silts, sufficient sediment was available to conduct an in-situ measurement program to assess the geophysical aspects of dredged material capping operations. Because capping procedures are often used as a management technique to reduce the potential environmental impact of contaminated sediment disposal in open water, it is important to understand the physical properties and processes which affect the efficiency and effectiveness of this technique. Furthermore, as these parameters are more fully understood, operational guidelines must be developed to increase the overall effectiveness of the procedure.

This report presents the results of the first year in a three year research program to study the geophysical parameters of capping and to develop a basis for future operational specifications for capping procedures to insure maximum effectiveness and isolation of contaminants. A summary of the monitoring operations conducted to evaluate disposal at the FVP and Cap sites in CLIS is presented in Appendix II. During the first year of the program, three major study areas were addressed:

1) The disposal and capping of sediments from Black Rock and New Haven Harbor at the Central Long Island Sound Disposal Site was closely monitored to determine the current state of the art in capping procedures and monitoring techniques.

2) Geotechnical properties of sediments at the dredging site, in the disposal scows and in the capped mound were measured to determine changes caused by dredging and to assess their influence on the resulting deposit.

3) A preliminary "Classification Scheme" was developed to assist permit personnel in designation of potential capping sites in evaluation of the suitability of specific sediments for capping, and in specification of operational procedures required for a successful result.

All of these subjects require further development and research during future years of the program. Consequently, this report provides a summary of progress to date and a basis for modification of the program to insure that the objectives of the Corps of Engineers are met.

1.1 Background

Several major capping operations have been conducted by the Corps of Engineers in the New England region, including the Stamford/New Haven project at the Central Long Island Sound Disposal Site and extensive covering of sediments at the Mud Dump Site in New York Bight. In the Stamford/New Haven project, Stamford sediments that were high in heavy metal contamination were deposited in two mounds, one of which was capped with silt from New Haven and the other with sand from the outer breakwater area of New Haven Harbor. The disposal operations were very successful, in that the Stamford material was concentrated in small mounds that were well covered by New Haven material (Morton, 1979a,b). Post-disposal monitoring of these sites has indicated some loss of material from the silt cap during Hurricane David (Sept, 1979), but that there were essentially stable conditions for both sand and silt caps since that event (Morton, 1983). Both caps have recolonized, however, the population on the sand cap is markedly different from the natural fauna of the area due to the difference in substrate (Brooks, 1983).

At the Mud Dump Site, larger volumes of sediment containing heavy metal and organic contaminants were capped primarily with sand from Ambrose Channel. Extensive monitoring programs similar to those conducted at the Central Long Island Sound Site were also undertaken in this area. The results obtained were similar in that both the "contaminated" and "capping" sediments were deposited successfully, and have remained stable over a period of time (O'Connor & O'Connor, 1982).

Both of these programs have demonstrated the feasibility of capping operations over the short term. Of major concern are the long term stability of the capping material, relative to the hydrodynamic properties of the environment and the ability of existing monitoring procedures to detect movement of that material. Assuming that the cap remains in place, the efficiency of capping material in covering and isolating the contaminated sediment from the overlying water column and biota is also of primary importance.

In 1983, Black Rock and New Haven Harbors (Fig. 1-1) were dredged concurrently, and the disposal location for both sites was designated as the Central Long Island Sound Disposal Site. These operations provided an excellent opportunity to duplicate the experiment conducted with the Stamford/New Haven projects in 1979, and to evaluate in more detail the procedures

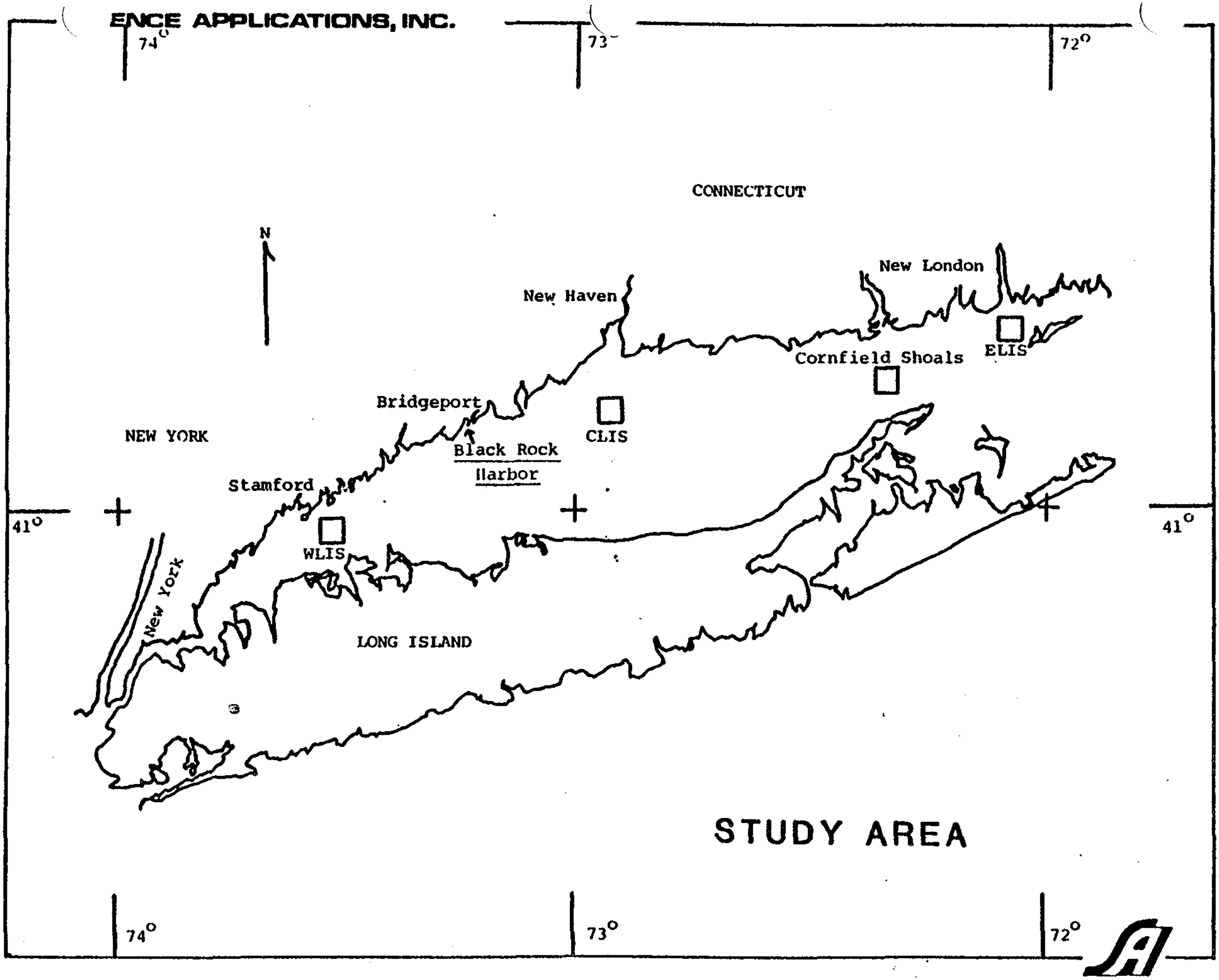

ENCE APPLICATIONS, INC.
74°
73°
72°
CONNECTICUT
N
New London
New Haven
Cornfield Shoals
ELIS
Bridgeport
CLIS
NEW YORK
Black Rock Harbor
Stamford
41°
41°
WLIS
New York
LONG ISLAND
STUDY AREA
74°
73°
72°

FIGURE 1-1

and results of current capping operations and subsequent monitoring techniques.

Based on samples taken by the New England Division (NED) of the Corps of Engineers (NED, 1980, 1982), Black Rock Harbor sediment was classified as a highly contaminated sediment consisting primarily of organic silts and clays with relatively high concentrations of oil, grease and heavy metals, combined with significant, but not excessively high, concentrations of PCB's. Conversely, New Haven Harbor sediments were classified as having moderate to low contaminant levels (NED, 1980) consisting of fine silts toward the head of the harbor and medium to coarse sands near the mouth.

Using these data, a project plan was developed where contaminated sediments from Black Rock Harbor were to be placed at two specified locations within the Central Long Island Sound Disposal Site using point dumping procedures under Loran-C navigation control. The resulting deposits were capped with material from New Haven Harbor; one with silt and the other with sand. The dredging and disposal of Black Rock Harbor material was closely coordinated with the Field Verification Program (FVP), a joint research effort sponsored by the Corps of Engineers and the EPA. In order to provide comparison between the capped and the uncapped sediment used for the FVP, the material to be capped was dredged from areas immediately adjacent to the section used for the FVP program (Fig. 1-2). Likewise, coordination with the New Haven operation was required to insure that the capping be with the desired sediment type and of the correct amount of material. The dredge sites for the capping sediment are shown in Figure 1-3.

Management of disposal at the Central Long Island Sound (CLIS) Disposal Site was also required to insure that all operations took place efficiently with no interference between projects. Figure 1-4 is a diagram of the CLIS site indicating specific disposal area survey grids established as part of the Disposal Area Monitoring System (DAMOS) program. The STNH-N, STNH-S and NORWALK grids were established to monitor previous capping operations in the area (Morton, 1979, 1981). The Mill/Quinnipiac River (MQR) grid was established to monitor a similar capping operation (Morton, 1982), but the site was also used during the period of this study to dispose of a small quantity of Black Rock material which was subsequently capped by a large quantity of New Haven silt.

The FVP site was established in the northeast corner of the CLIS site to conduct research studies of uncapped contaminated sediment from Black Rock Harbor as a joint project between the Corps of Engineers and EPA. Low contaminant level sediments from New Haven Harbor, outer Black Rock Harbor and other small projects in the area were all disposed at the "SP" buoy prior to and during the period of this study.

The selection of the two Cap Site grids for this program was based on several criteria, including:

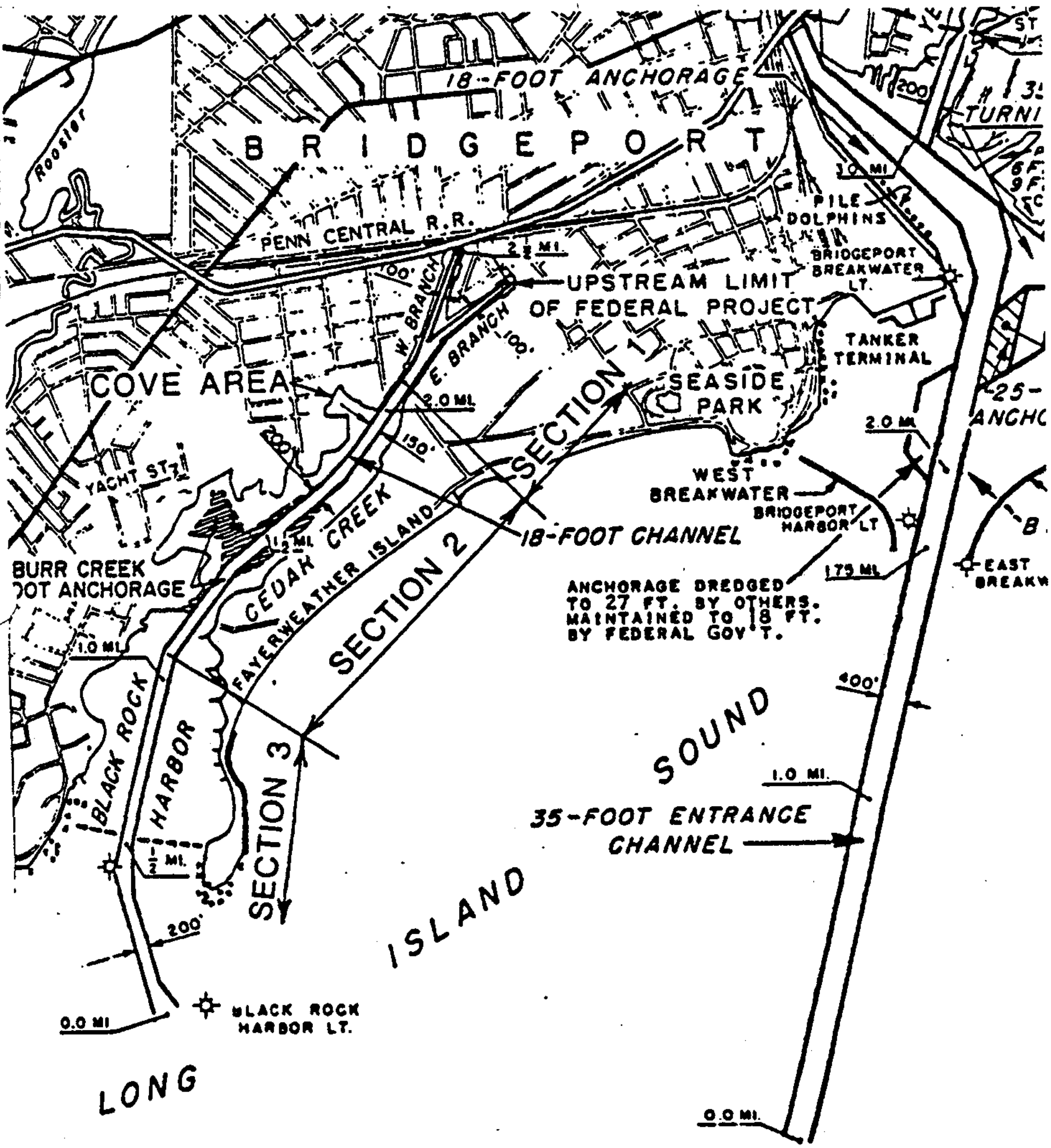

18-FOOT ANCHORAGE
BRIDGEPORT
Rooster
PENN CENTRAL R.R.
UPSTREAM LIMIT OF FEDERAL PROJECT
W. BRANCH
E. BRANCH
COVE AREA
YACHT ST.
SEASIDE PARK
SECTION 1
SECTION 2
SECTION 3
CEDAR CREEK
FAYERWEATHER ISLAND
18-FOOT CHANNEL
WEST BREAKWATER
BRIDGEPORT HARBOR LT
PILE DOLPHINS
BRIDGEPORT BREAKWATER LT.
TANKER TERMINAL
TURNI
25-
ANCHO
EAST BREAKW
BURR CREEK
OOT ANCHORAGE
ANCHORAGE DREDGED TO 27 FT. BY OTHERS. MAINTAINED TO 18 FT. BY FEDERAL GOV'T.
BLACK ROCK HARBOR
BLACK ROCK HARBOR LT.
LONG ISLAND SOUND
35-FOOT ENTRANCE CHANNEL
0.0 MI
1/2 MI.
1.0 MI
1 1/2 MI.
2.0 MI.
2 1/2 MI.
3.0 MI.
1.75 MI.
200'
150'
100'
400'

FIGURE 1-2

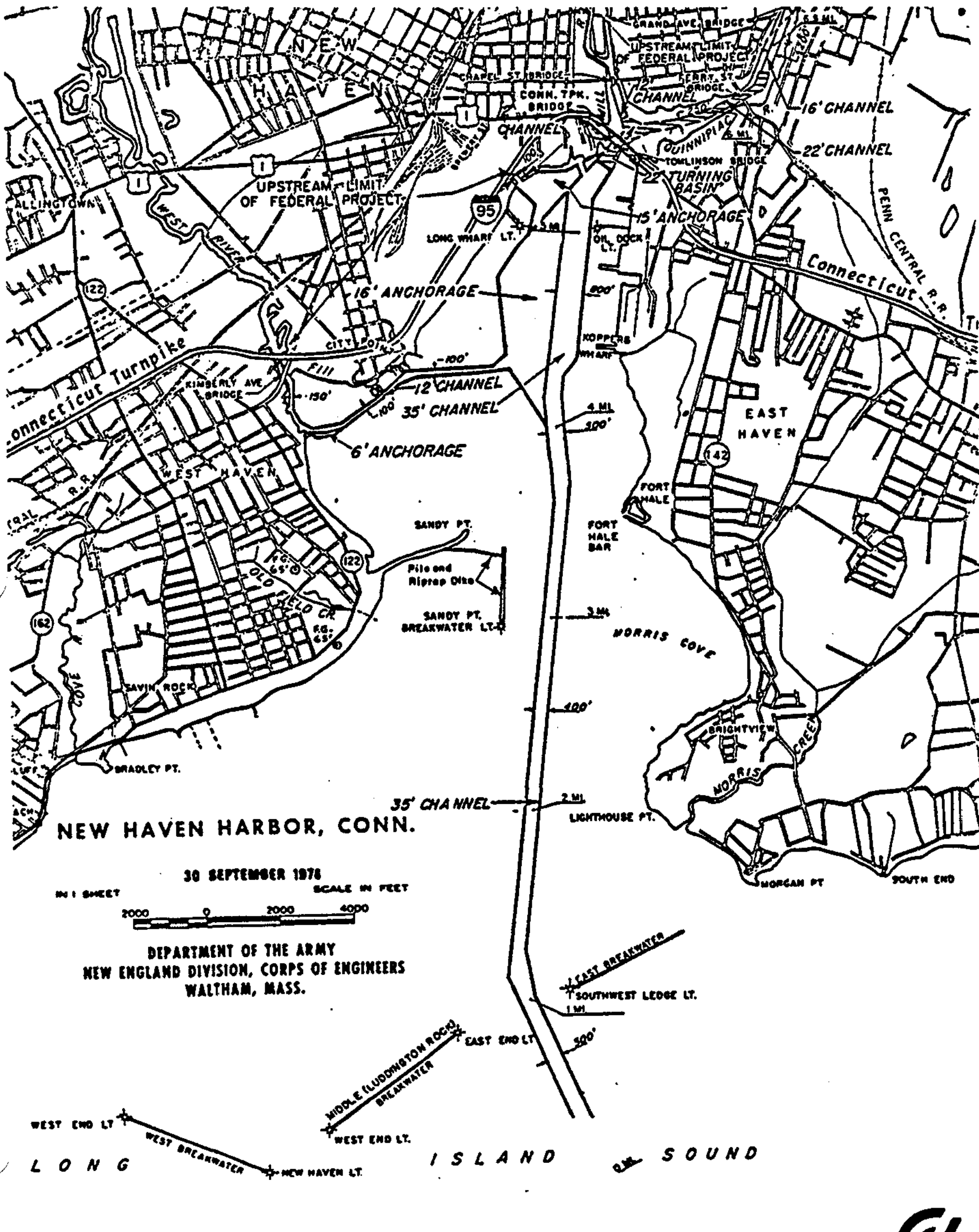

NEW HAVEN HARBOR, CONN.
30 SEPTEMBER 1976
SCALE IN FEET
2000 0 2000 4000
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.
NEW HAVEN
WEST HAVEN
EAST HAVEN
ALLINGTOWN
UPSTREAM LIMIT OF FEDERAL PROJECT
16' CHANNEL
22' CHANNEL
15' ANCHORAGE
16' ANCHORAGE
12' CHANNEL
35' CHANNEL
6' ANCHORAGE
TURNING BASIN
QUINNIPIAC R.
WEST RIVER
CONN. TPK. BRIDGE
CHAPEL ST. BRIDGE
GRAND AVE. BRIDGE
FERRY ST. BRIDGE
TOMLINSON BRIDGE
LONG WHARF LT.
OIL DOCK LT.
KOPPERS WHARF
Connecticut Turnpike
Connecticut R.R.
PENN CENTRAL R.R.
KIMBERLY AVE BRIDGE
CITY POINT
Fill
SANDY PT.
Pile and Riprap Dike
SANDY PT. BREAKWATER LT.
OLD FIELD CR.
SAVIN ROCK
BRADLEY PT.
FORT HALE
FORT HALE BAR
MORRIS COVE
MORRIS CREEK
BRIGHTVIEW
LIGHTHOUSE PT.
MORGAN PT
SOUTH END
EAST BREAKWATER
SOUTHWEST LEDGE LT.
EAST END LT
MIDDLE (LUDDINGTON ROCK) BREAKWATER
WEST END LT
WEST BREAKWATER
NEW HAVEN LT
LONG ISLAND SOUND

FIGURE 1-3

CHART SCALE: 1/15000

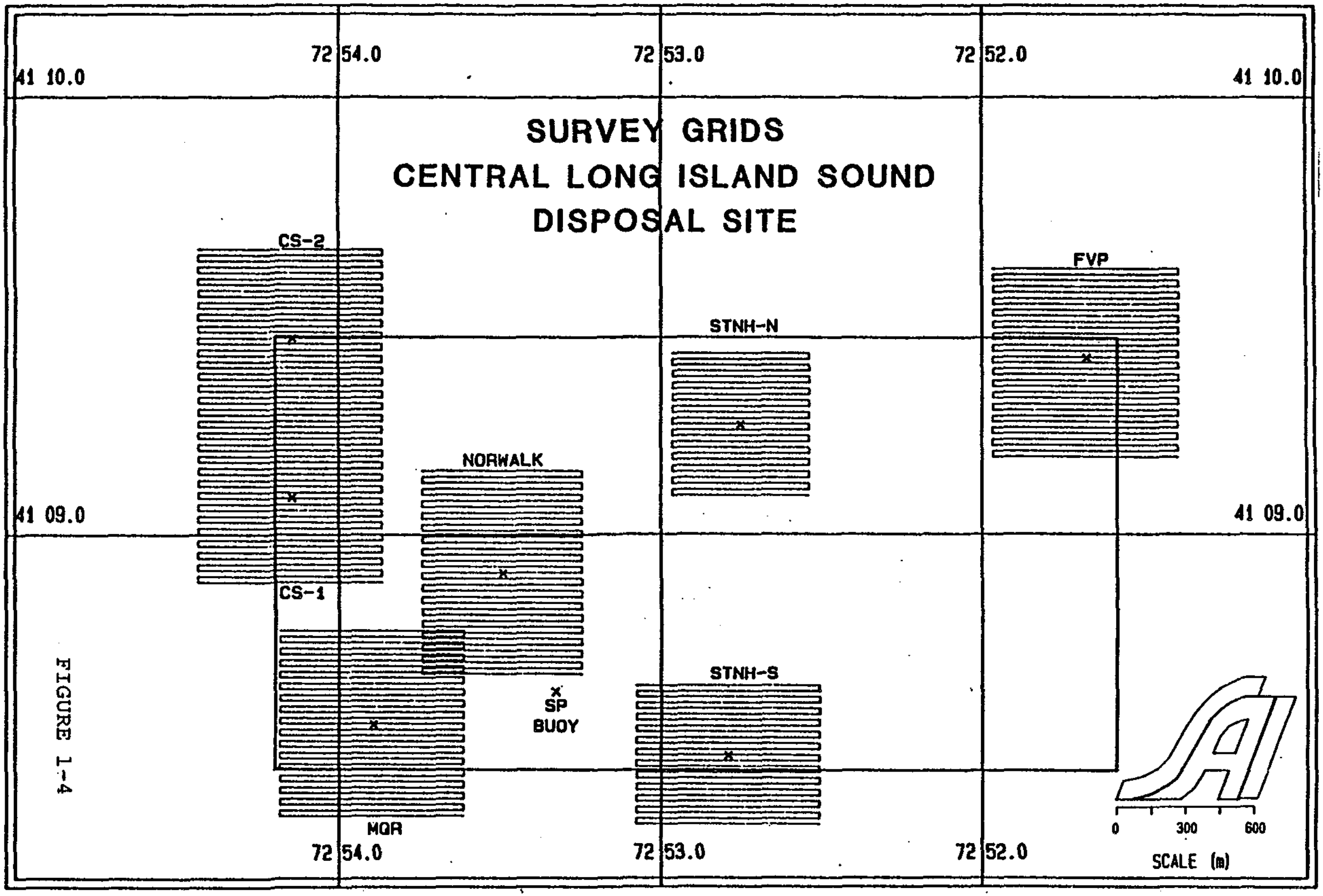


FIGURE 1-4

- natural bottom with no previous record of disposal
- flat bottom for precision bathymetric survey studies
- sufficiently removed from other sites to reduce potential for contamination by ongoing projects
- location within the CLIS site to maintain the consistent disposal management policy of the New England Division

As stated above, the capping operation was conducted by depositing material from Black Rock Harbor at each of the sites and then covering the resulting deposit with sediment from New Haven Harbor. At Cap Site #1, the capping material was silt, that was similar in composition to that disposed of at the MQR site, while at Cap Site #2, sand from the outer reaches of the channel was used as the capping material.

2.0 MEASUREMENT PROCEDURES AND INSTRUMENTATION

The objective of this capping program is to provide the Corps of Engineers with sufficient information and a logical framework within which to make decisions as to the suitability of specific disposal sites for dredged material and operating procedures for capping operations. The approach used to achieve this objective consists of acquisition of in-situ measurements on an active capping operation using existing procedures and instrumentation and interpretation of those measurements in terms of specific parameters and theories to assess the viability of such procedures. The following sections provide basic information on the procedures and instrumentation used to obtain the field measurements of the program.

2.1 In-Situ Sediment Volume and Distribution Measurements

In order to assess the effectiveness of capping operations at an open water disposal site, a mass balance approach must be used. Both the Central Long Island Sound (Morton, 1979) and New York Bight (O'Connor & O'Connor, 1982) studies have concluded that normal background energy levels are insufficient to cause significant erosion and transport of dredged material. Consequently, any changes that take place can be expected to be associated with extreme storm events, or in open ocean environments, with long period swell conditions.

Because of the sporadic nature of sediment erosion and transport, rates of erosion cannot be determined simply by in-situ measurement of hydrodynamic and sediment parameters. Rather, continuous monitoring of changes in dredged material volume with time provided a more accurate measure for long term assessments. Consequently, procedures for remote monitoring of disposal mounds to detect changes in volume due to disposal operations and sediment movement over the long term have been developed and used with some success throughout New England as part of the DAMOS program (Morton, 1981, 1983).

There are, however, potential error sources involved with this procedure that are related to the effects of density on the calculation of mass balance and to measurement errors associated with the hydrographic techniques used. Consequently, use of this procedure on this program serves two purposes; one is to monitor mass balance, and the other is to evaluate those error sources and reduce their impact, as much as possible, through correlation with geotechnical properties of the dredged material.

The procedures used to measure mass balance and long-term volume changes are based on hardware systems and software programs designed to produce extremely precise replicate surveys, so that small changes in topography can be determined. These data are then used to evaluate sediment accumulation during disposal, sediment movement after deposition within the vicinity of the mound, or total loss of material from the disposal site.

Prior to the disposal of dredged material at Cap Sites #1 and #2, a survey grid was established at each site consisting of 29 transects, 800 meters long oriented in an east-west direction and spaced 25 meters apart. When conducting the surveys, range data from a Del Norte positioning system with an accuracy of ±1m are input to a computer which then provides steering information to assist the helmsman in maintaining the ship's position relative to the survey grid. Since precision data are required for this work, surveys are only made on calm days so that steering errors are less than 5 meters on either side of a given transect. This navigational precision is necessary for comparing replicate surveys since slight errors in position can cause large errors in depth over sloping bottoms.

Data acquisition is controlled by the sampling rate of the Del Norte Trisponder unit which is nominally one position measurement per second. Depth measurements are obtained from a Raytheon 719 fathometer with a digitizing unit and they are recorded on magnetic disk with corresponding time and position information.

Analysis of bathymetric data is accomplished through the generation of depth sections along the transect lanes. Since each transect is reproducible with a positional accuracy of better than 5 meters, these sections provide a means of evaluating the precision of the survey technique, as well as small scale changes in topography. All depths on these sections are corrected for sound velocity, draft and tidal height. Assuming no signficant change (i.e. deposition or erosion) in the depth of the ambient bottom at some distance from the mound, the precision of the depth measurements between successive surveys can be evaluated by comparing the depths at the extremities of the transect.

Following development of the vertical sections, the data are inserted into a grid pattern for further analysis. This grid pattern is established such that each grid block is centered on a transect lane, with a north-south length equal to the lane spacing (25 m), and an east-west length equal to one half the lane spacing (12.5 m). This convention is applied to all surveys, even though it is possible to establish a finer grid pattern by sampling more frequently along the transect direction. The finer grid pattern would, however, introduce a bias into the data since the resolution between lanes cannot be improved.

All depth measurements falling within the area of each grid block are averaged and a mean depth is assigned to each grid location. The matrix of depths is then used to develop a contour chart of the entire survey area.

Calculations of volume difference between successive surveys are accomplished by comparison of the gridded data. The difference in depth (ΔZ) of each cell between successive surveys is determined by subtraction and then multiplied by the area of the cell to determine the net change in volume. These volume changes are then summed along transects and over the entire grid to determine the total volume change.

The precision of the depth measurement must be extremely high to achieve an accurate volume estimate because small changes in depth are multiplied by the area of the survey. In order to increase this precision, additional corrections are made based on the assumption that no significant changes in depth occur on the natural bottom beyond the extremities of the disposal mound. To make these corrections, a least squares computation comparing all depths on the margins of both surveys is made to determine a best fit between successive surveys. Small differences resulting from errors in tide, sound velocity or draft corrections are thus accounted for and the baselines of successive surveys are accurately aligned with each other. Corrections of this type, while always very small, are important for increasing the resolution of the volume difference technque.

The errors in determing the topographic volume relative to a baseline have been evaluated through a calculation of the standard error based on the standard deviation of the depth measurement. A conservative estimate of the precision in depth measurement by echo sounding which accounts for ship motion, navigation, correction factors, topographic changes, etc. is $\pm$20 cm for each point. It should be pointed out that this $\pm$20 cm is a random error that exists for a single measurement, but which is drastically reduced by a factor of 1/ N (where N = the number of measurements) when considering and comparing an entire survey.

Using this figure for the standard deviation of all depths within a grid cell, and assuming that the standard deviations of all cells are approximately equal, the error for the total survey can be expressed as:

$$\epsilon_v = \frac{A\,\sigma_i}{\sqrt{M(n-1)}}$$

where

A = area of survey = 700 x 800 = 3.6 x $10^5 m^2$

M = number of cells
= 64 x 29 = 1856

n = number of measurements in each cell
= 6 (approximately)

σ_i = Standard deviation of individual depth measurement
= 0.2m

therefore,

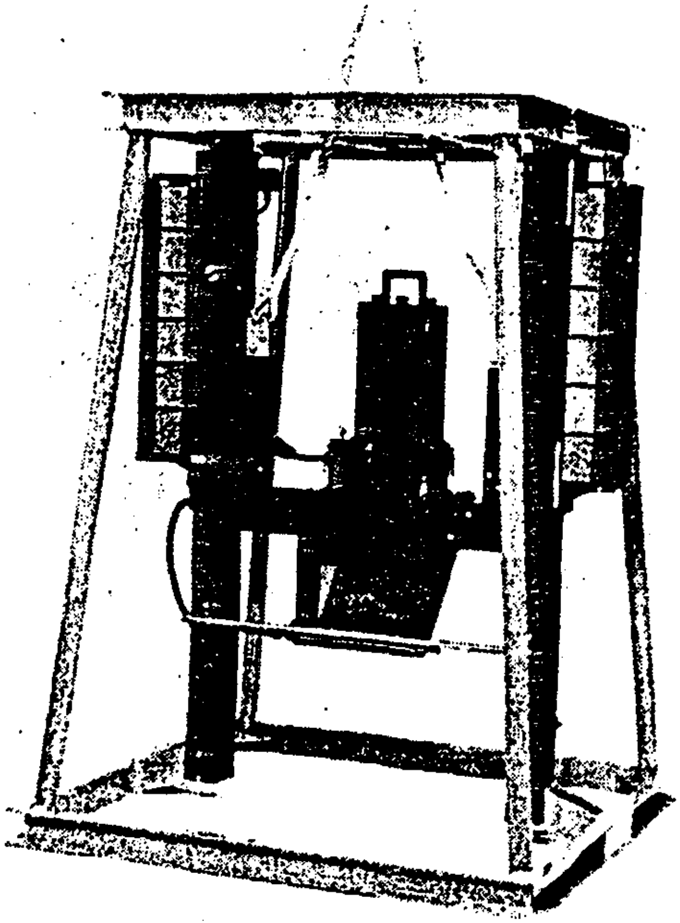
ϵ_v = $1160 m^3$

Since a depth difference (ΔZ), between successive surveys, is determined for each grid cell, a contour program can be applied to the difference data and a contour difference plot generated which provides information on the distribution of changes in depth resulting from the accumulation or loss of sediment volume.

Although the replicate bathymetric surveys provide a reasonable approach to remote sensing of disposal mound stability over time, they are somewhat restricted in their ability to detect small vertical changes in depth ($\pm$20 cm) on a point by point basis. Therefore, while they can define the extent of the disposal mound and the total volume of material present, the bathymetric survey should not be used to delineate the spread of material. The classic description of dredged material dispersion following disposal from a scow (Gordon, 1974) includes convective descent, which creates a mound at the disposal point, surrounded by an apron of finer material with decreasing thickness at greater distances from the point of impact. As this apron becomes finer, detection by acoustic measurement becomes impossible and other methods must be used.

For this study, three techniques were used to evaluate the distribution of material; diver observations, the REMOTS interface camera, and side scan sonar. Diver observations provide a unique capability to combine subjective observations and discrete measurements to obtain an understanding of sediment distribution and behavior, but have the limitation of restricted coverage and poor navigation control. The REMOTS camera (Fig. 2-1) (Germano, 1983) provides vertical photographic images of the sediment/water interface to a nominal depth of 18 cm and can be used to map specific parameters such as dredged material thickness, surface boundary roughness, oxidation depth, modal grain size and other more general information related to benthic biology, including faunal succession and bioturbation effects. The primary advantages of the REMOTS camera are its ability to accurately measure small thicknesses of dredged material over the fringe areas efficiently with excellent navigation control and replication of measurements. The side scan sonar provides a capability for assessing the overall physical characteristics of the disposal sites, and can detect and display relative differences in surface sediment density. The side scan sonar is particularly effective in displaying the areal distribution of dredged material within the disposal site. By combining these three approaches to measurement of sediment volume and distribution at the disposal site, an accurate and complete knowledge of in-situ conditions can be developed for application to other disposal areas and operations.

Diver observations were conducted with transect lines deployed across the disposal site using the navigation control system aboard the R/V UCONN. These lines, marked at specified incremental distances, then provided position information for divers to determine the spatial distribution of dredged material. Underwater photographs were obtained to document surface conditions and observations were recorded in diver logs for



REMOTS CAMERA

FIGURE 2-1

comparison with other measurements.

REMOTS measurements were made using the navigational control system to establish stations on a grid over the disposal site and three replicate observations were made at each station. Measurements of boundary roughness, camera prism penetration depth, and the positive redox area in the sediment, as seen in profile, were taken from the black and white negatives. These measurements were accomplished with the Measuronics LMS tm Image Analysis System. Negatives were used instead of positive prints in order to avoid changes in image density that can accompany printing a positive image. The image analysis system is capable of detecting 256 grey scale values while density slicing an image. Data on grain-size estimates, evidence of surface erosion, and faunal information were determined from 8 x 10 inch positive prints. At this magnification, the resulting print is 1.5 times real scale.

The range of grain-size (exclusive of shells and shell fragments) is estimated from the photographs by overlaying a grain-size comparator which is of the same scale. The comparator was prepared by photographing a series of Udden-Wentworth size classes through the profile camera (equal to or less than coarse silt up to granule and larger sizes). Seven grain-size classes are on this comparator. The lower limit of optical resolution of the photographic system is about 62 microns, allowing recognition of grain sizes equal to, or greater than, coarse silt. The accuracy of this method has been documented by comparing our REMOTS estimates with grain-size statistics determined from laboratory sieve analysis.

The boundary roughness values represent the maximum topographic relief measured over the width of the optical window of the profile camera which is fixed at 12.75 cm.

If there is oxygen in the overlying water column, the near surface natural sediment will have a high reflectance value relative to anoxic sediment underlying it. This is because the oxidized surface sediment contains ferric hydroxide (an olive color when associated with organic particles), while the hydrogen sulphide sediments below this oxygenated layer are grey to black. Although the high reflectance value of the surface layer is talked about in this report as the "oxidized layer", some sulphate reduction can take place in micro-anaerobic environments (interiors of fecal pellets or diatom frustules) within this ferric hydroxide zone. The boundary between light colored ferric hydroxide surface sediment and underlying grey to black sediment is called the redox potential discontinuity (RPD). In areas where dredged material is present, this oxidized layer is covered with reduced sediment and the thickness of dredged material can be readily measured.

The areas of positive (aerobic) and negative (anoxic) RPD are determined with the Measuronics LMS System by density-slicing reflectance values. The area of the oxidized layer can then be divided by 12.75 (the prism window width) to obtain a mean depth for the RPD. In the absence of a bioturbating fauna, the RPD depth is less than 0.5 cm thick in organic-rich muds, while mature bottom sediments have RPD depths greater than 3 cm. A seasonal change in the RPD depth has been observed related to temperature effects on bioturbation rates; however, this is quite small. The RPD depth is given special attention in photograph analysis as it is a sensitive indicator of the presence of dredged material, within station patchiness, bioturbation activity, and deposition/erosion environments.

In order to efficiently characterize conditions at a given station within the disposal site, a multi-parameter habitat index has been constructed to quantify habitat quality. Habitat quality is defined relative to two end-member standards. The lowest value is given to those bottoms which have low, or no dissolved oxygen in the overlying water, no apparent macrofaunal life, and methane gas present within the sediment (Rhoads and Germano, 1982). The habitat index for such a condition is minus 10. At the other end of the scale, an aerobic bottom with a deeply depressed RPD, evidence of a mature macrofaunal assemblage, and no apparent methane gas bubbles at depth will have a habitat index of plus 11. The habitat index is arrived at by summing the subset indices presented in Table 2-1.

Although not directly related to geophysical properties, the successional stage of the benthic infauna is important for assessing the habitat index. A detailed discussion of the stage of succession relative to REMOTS images is given in Rhoads and Germano (1982). This paper deals with primary succession, i.e. faunal colonization of a new or recently disturbed sedimentary surface, such as an active disposal site. In general, pioneering species are smaller, have shorter life spans and do not depress the RPD as much as species associated with a mature undisturbed bottom.

Although diving, REMOTS and sidescan data all provide excellent information concerning the distribution of material over the bottom, the replicate bathymetric survey technique remains as the most viable approach to remote measurement of sediment volume. However, in order to apply this technique to mass balance calculation, an equally accurate measure of dredged volume must be determined and an understanding of the changes in sediment density which occur during dredging and disposal must be available. Furthermore, a knowledge of post-disposal compaction of the dredged material is required to accurately evaluate long-term stability. The following sections describe our approach to addressing these problems through use of a Nuclear Density Probe, erosion/compaction stakes, and dual frequency sonar measurements in Black Rock Harbor.

2.2 Nuclear Density Probe

A major effort of this program has been an assessment of the accuracy, reliability and practical application of a Model 3565 Nuclear Density Probe, manufactured by Troxler Electronic Laboratories Inc. Since sediment density is known to be closely

TABLE 2-1

Parameters Used to Determine Habitat Index
From REMOTS Images

PLANIMETERED RPD AREA	INDEX VALUE
0-10 cm^2	1
10.1-20.0	2
20.1-30.0	3
30.1-40.0	4
40.1-50.0	5
50.1	6

CHEMICAL PARAMETERS	INDEX VALUE
Methane present	-2
No/low dissolved O_2	-4

SUCCESSIONAL STAGE	INDEX VALUE
(Primary Succession)	
Azoic	-4
Stage 1	1
Stage 1-2	2
Stage 2	3
Stage 2-3	4
Stage 3	5

SUCCESSIONAL STAGE	INDEX VALUE
(Secondary Succession)	
Stage 1 on a Stage 3	5^{I}
Stage 2 on a Stage 3	5^{II}

HABITAT INDEX = Total of all subset indices related to other geotechnical properties of sediments, use of the probe could provide valuable insight into changes in sediment properties caused by the dredging and disposal operations. In order to accomplish this work, SAI personnel were required to attend a course in the handling of radioactive material and, as a result, obtained licenses for operation of the system. When this was completed, the unit was delivered and initial measurements were conducted in April, 1983.

The Nuclear Density Probe works on the principle of measuring backscattered gamma radiation emitted from a Cesium 137 radioactive source that is mounted at the base of a stainless steel rod. When this rod penetrates the sediment, the intensity of backscattered radiation is a function of the density of the material. Since the radioactive source is continually decaying, the instrument must be calibrated each time it is used by measuring the backscatter intensity in a liquid of known density.

In practice, this calibration is accomplished by taking a series of standard counts in a container of water and measuring the density of the water with a laboratory grade hydrometer. The density measured by the hydrometer is then input to the microprocessor via the instrument control module and then used to calibrate observed counts for determination of actual density measurements.

Measurement stability and drift are two major factors that must be evaluated to insure that the probe will remain in calibration. The stability of the probe is determined by taking the ratio of the standard sample period of the backscatter counts to the mean number of counts per sampling period. If this ratio is less than .35, the instrument is considered stable. The drift of the unit is measured in a similar manner by obtaining two groups of standard count measurements separated in time. The ratio of the difference between these two measurements and their mean is expressed as a percentage of the drift rate. If the drift rate is less than 1%, the drift is normal and can be accounted for when calculating density over a significant time period. Examples of stability and drift tests, made during a typical sampling operation, are presented in Table 2-2 and they indicate that the probe that was used on this project is well within specifications.

After replicated calibration counts have been obtained, the probe is used to make a series of density measurements according to the procedures described in Figure 2-2. At each sample location, the probe is inserted into the sediment, nominally at .5m increments, and three fifteen second counts are made at each depth increment to determine density. At the completion of sampling, a second calibration is made using the hydrometer procedure and instrument drift is calculated for application to the density measurements.

Analysis of the data consists of simple statistical procedures that determinee the mean and standard deviation for all replicate counts within a given depth increment. This mean

Table 2-2

STATISTICAL STABILITY TEST

TEST NUMBER	DENSITY STANDARD COUNTS	
1	3518	(NORM)
2	3519	"
3	3523	"
4	3507	"
5	3503	"
6	3512	"

$\overline{X} = 3513.67$

$\overline{X} = 59.28$ $\sigma = 7.69$

$$\text{Ratio} = \frac{7.69}{59.28} = 0.13 \longrightarrow \text{Instrument is stable}$$

INSTRUMENT DRIFT TEST

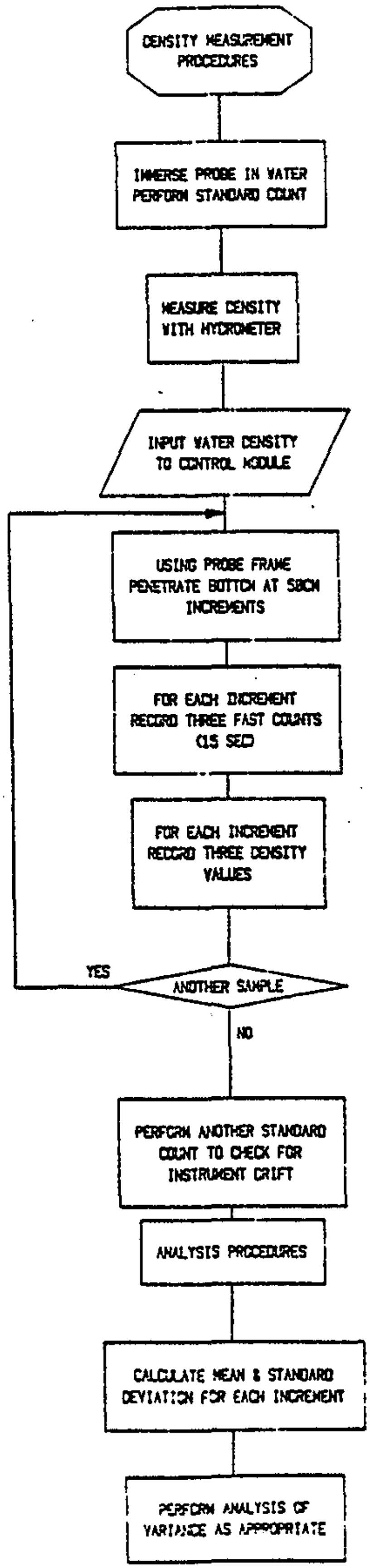
TEST NUMBER	DENSITY STANDARD COUNTS
1	3515
2	3500
3	3495
4	3494
5	3518

$\overline{X} = 3504.40$ $\sigma = 11.33$

Total Average = (3513.67 + 3504.40)/2 = 3509.04

Difference = 3513.67 - 3504.40 = 9.27

$$\text{Drift} = \frac{9.27}{3509.04} \times 100 = 0.26\%$$



SEDIMENT DENSITY MEASUREMENT PROCEDURE

FIGURE 2-2

value is then considered a data point for application to studies of density and other geotechnical parameters.

An important aspect of the program to examine sediment density as it relates to capping operations was the requirement to obtain data at the disposal sites in up to 20 meters of water. Diver operation of the probe was not feasible, due to the requirement for a large number of sample locations and the necessity for accurate placement of the probe. In order to obtain these measurements from shipboard, a frame was designed for multiple station sampling while at the same time controlling the depth of penetration so that vertical profiles of density could be obtained.

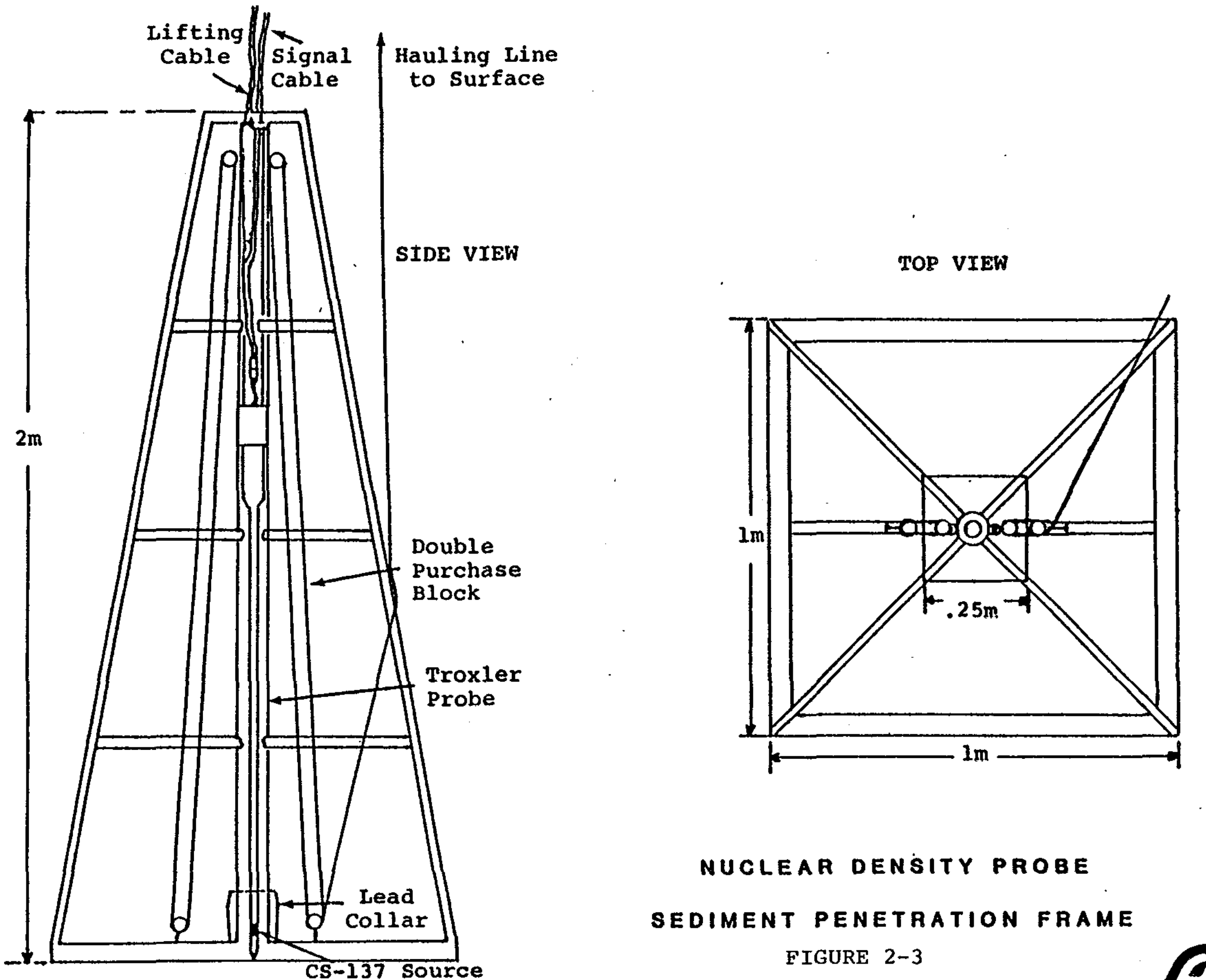
The frame, shown in Figure 2-3, consisted of a broad wooden base with a four sided framework of angle iron, 2 meters high, which supported a pipe that was slotted on both sides to hold the nuclear density probe. The probe and its associated stainless steel rod and cable were inserted into the pipe and attached to a collar with tongs extending beyond the surface of the pipe for attachment of a block and tackle rig. Surrounding the base of the pipe was a lead collar that shielded the radioactive source when the probe was on deck. A double purchase block and tackle rig was installed within the frame using Kevlar line to reduce stretch. This Kevlar line was lead to the surface and, when the frame was lowered to the bottom, provided the necessary force to penetrate the probe into the bottom. Since a 4:1 purchase was used, each 0.5m of penetration equalled 2m of line at the surface. In order to determine the total amount of penetration that occurred, a marker was inserted in the slot of the tube which would indicate the maximum depth of penetration at each station.

Two extremely different sediment types had to be considered when designing this probe; the soft mud of Black Rock Harbor and the hard sand of the New Haven outer channel. Consequently, the base of the support frame was provided with two removable wooden flaps, which provided a large surface area to prevent sinking into the soft mud. Conversely, these flaps were removed and lead weights added to the base of the frame to provide sufficient weight for penetration into the hard sand.

Diver observations of the frame during preliminary tests indicated that penetration occurred as expected and that the frame generally remained upright without sinking into the soft sediment to any significant degree. Tracking of the penetration marker generally indicated penetration equal to that measured through tension on the Kevlar line. However, on occasion, when measuring the sand cap, it became apparent that the frame lifted rather than the probe penetrating, causing the unit to tip over.

2.3 Additional Instrumentation

Although the instrumentation described above provided most of the data used in this report, additional instrumentation



NUCLEAR DENSITY PROBE

SEDIMENT PENETRATION FRAME

FIGURE 2-3

was required to generate supporting information.

Most of the work accomplished on this program was conducted from the R/V UCONN, a 65 foot "T" boat converted for research by the University of Connecticut. She is fitted with hydraulic winches and booms for over the side operations and has sufficient lab space for electronic instrumentation. The UCONN was supported by the "EAST PASSAGE", a 26 foot Mon Ark workboat which was used for sampling within the harbors and to support diving operations at the disposal sites.

All navigation control for surveys, sediment sampling and REMOTS photography was provided by the SAI Navigation and Data Acquisition System, a computerized control unit interfaced to a Del Norte 540 microwave positioning system. The SAI system provides real time video displays of ship position relative to designated lanes or locations which substantially enhance the capability of the ship's helmsman to steer survey lanes within ±5 meters and to obtain replicate sediment samples within ±10 meters. This precision in ship control is an essential requirement for this program since the disposal mounds are quite small and spatial variability in measured parameters is relatively large. Using calibration techniques established under the DAMOS program, recorded position accuracies within the CLIS disposal site are ±1-2 meters.

A Klein Side Scan Sonar was used to evaluate the distribution of dredged material over the Cap Sites, and to assess potential interference from other disposal operations. The system consisted of a 100kHz towfish, nominally positioned 10 meters above the bottom, and connected to a standard Klein wet paper recorder. The range scale was set to 75 meters and surveys were conducted over lanes 1000 meters long with a spacing of 100 meters (Fig. 2-4).

Sediment sampling at the disposal sites was accomplished using a stainless steel Smith-MacIntyre grab sampler, or a 3 meter long gravity corer supplied by the R/V UCONN. All samples were stored at 4°C and all cores were kept in a vertical orientation until sliced at the NED sediment lab.

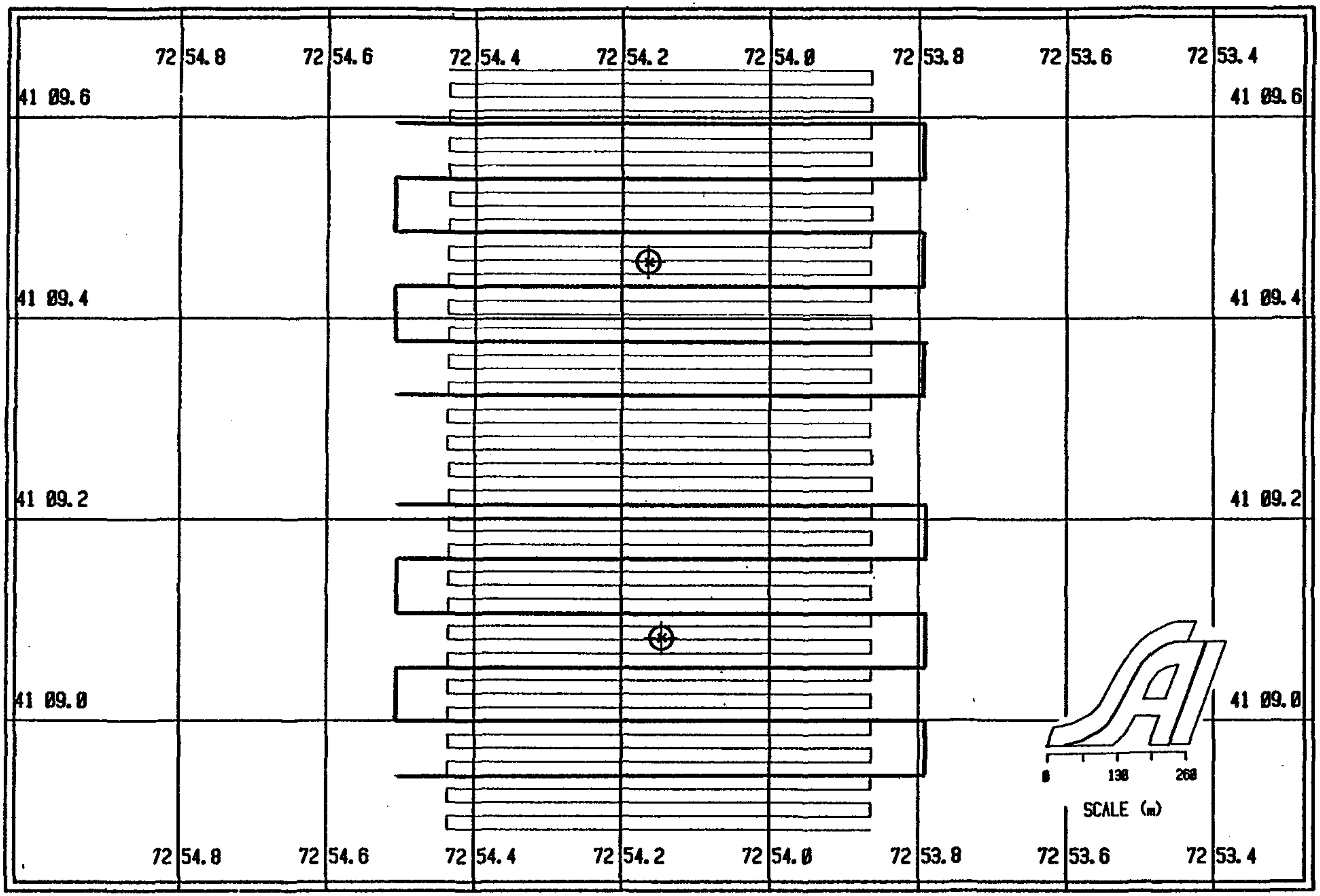


Figure 2-4. Survey lanes at Cap Sites 1 and 2. Dark lines indicate side scan; light lines represent bathmetry.

3.0 MONITORING OF DISPOSAL AND CAPPING OPERATIONS

As described in Section 1 of this report, concurrent dredging and disposal operations from harbors on the North Shore of Long Island Sound during the Spring of 1983 created a unique opportunity to examine environmental impacts of dredged material disposal in open water and to assess potential management procedures for control of disposal operations. Although a significant portion of the research conducted at the Central Long Island Sound Site during this period was not directly associated with the capping program, much of the data have direct relevance to interpretation of results at the cap sites and will be discussed in this section.

The proposed sequence of disposal operations at the CLIS site (Fig. 1-4) during the spring of 1983 was established as follows:

- Disposal of 20-30,000m^3 of contaminated Black Rock sediment from section 1 (Fig. 1-2) at a taut-wire buoy at MQR
- Disposal of approximately 55,000m^3 of contaminated Black Rock sediment from section 2 (Fig. 1-2) at a taut-wire buoy at FVP
- Concurrent disposal of approximately 1 million m^3 of New Haven silt at MQR under Loran-C control
- Disposal of approximately 25,000m^3 of contaminated Black Rock sediment from areas immediately adjacent to Section 2 at a taut-wire buoy at Cap Site #1
- Disposal of approximately 30,000m^3 of camtaminated Black Rock sediment from areas immediately adjacent to Section 2 at a taut-wire buoy at Cap Site #2
- Disposal of approximately 60,000m^3 of New Haven silt under Loran-C control at Cap Site #1
- Disposal of approximately 30,000m^3 of New Haven sand under Loran-C control at Cap Site #2
- Disposal of approximately 16,000m^3 of Black Rock sediment from Section 3 at the "SP" buoy

This sequence was established by the New England Division and managed by coordination between contractors and disposal inspectors. Disposal position control was accomplished using two procedures; point dumping at a taut-wire buoy, or use of a computerized Loran-C system. The taut-wire buoy system was used for disposal of contaminated sediments where the primary objective was to reduce the spread of material for future capping operations.

The Loran-C system was used to spread the capping material over a larger area and to distribute the large volume of material dredged from New Haven Harbor to prevent excessive shoaling at one point.

The taut-wire buoy design was the same as that used on previous deployments at the CLIS site (Morton, 1982). A schematic of the mooring design is shown in Figure 3-1. The advantages of the counterweight design, used here, over elastic tether moorings are the increased strength which means that the buoys can survive some contact with the disposal scows, and the ability to move from one point to another without dismantling the entire mooring. Since bottom depths within the CLIS site are all within one meter, the same buoy was used for point dumping of Black Rock sediment at the MQR, CS#1 and CS#2 sites. The buoys were deployed from the R/V UCONN using the SAI Navigation System at a point 25 meters north of the center of the survey grid. Disposal crews were then instructed to dump as close to the south side of the buoy as possible so that the mounds were formed in the center of the survey.

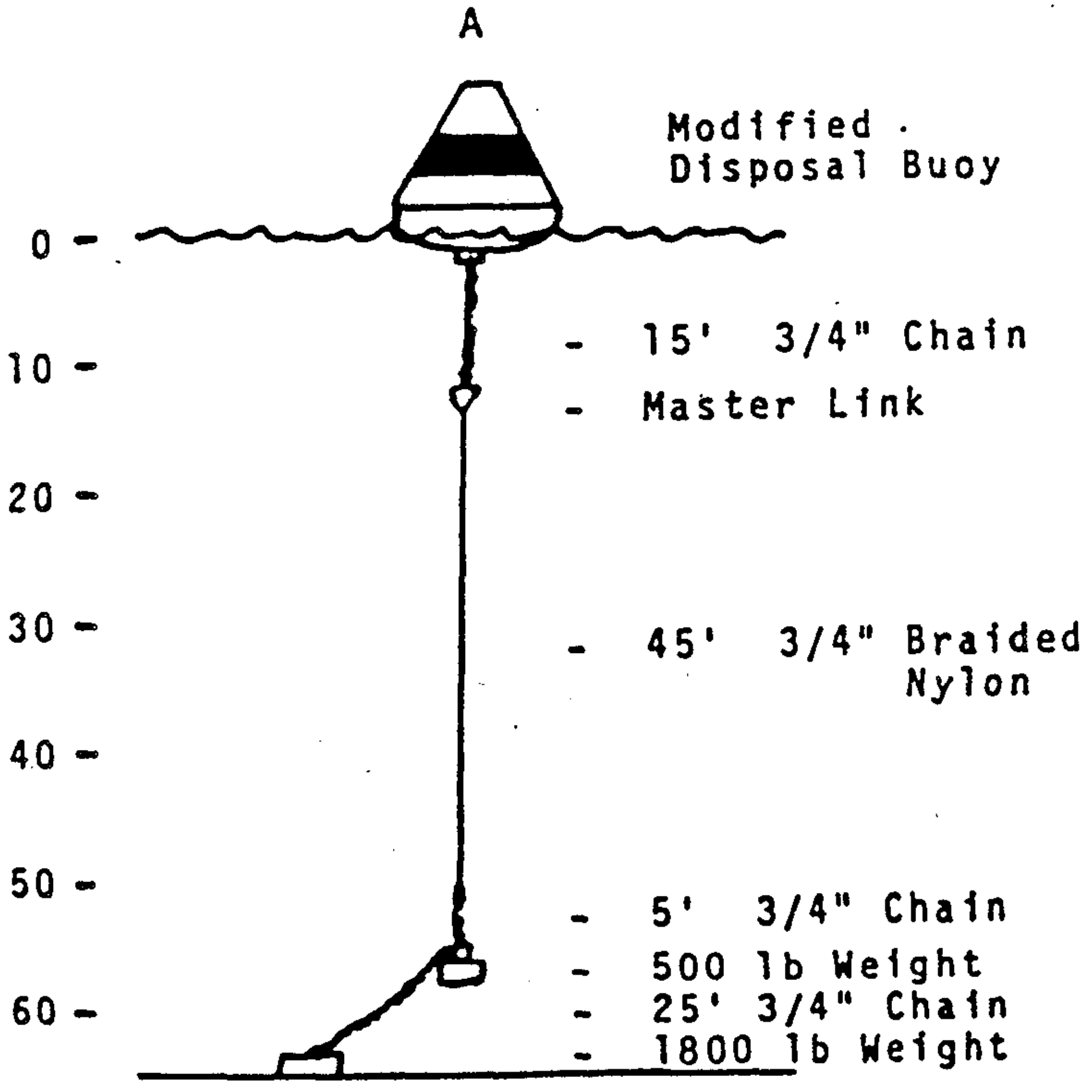
The Loran-C control was a special modification of the SAI Navigation System designed to position the disposal scows as accurately as possible so that a controlled distribution of dredged material could be developed. Schematic diagrams of the system are presented in Figures 3-2a and b. The system configuration for the New Haven project consisted of two scow units and a single display unit aboard the tug. Each scow system was comprised of a Micrologic Loran-C, a VHF transmitter, and rechargeable batteries. The system aboard the tug had an Apple II microcomputer interfaced to a VHF receiver. The computer generated a display similar to that shown in Figure 3-3, to provide the helmsman with range and bearing to the designated disposal point, and a visual representation of the scows track relative to that point. The disposal location for each scow could be input either automatically or manually, depending on requirements. Each time a scow was dumped, a permanent record of the actual location was recorded on magnetic disk. This Loran-C system was used for disposal of New Haven material at the MQR site and for control of capping operations at the CS#1 and CS#2 sites.

3.1 Baseline Conditions

Prior to disposal, each of the designated sites was surveyed to provide baseline information for comparison with post-disposal conditions. The following sections describe the information determined during those surveys.

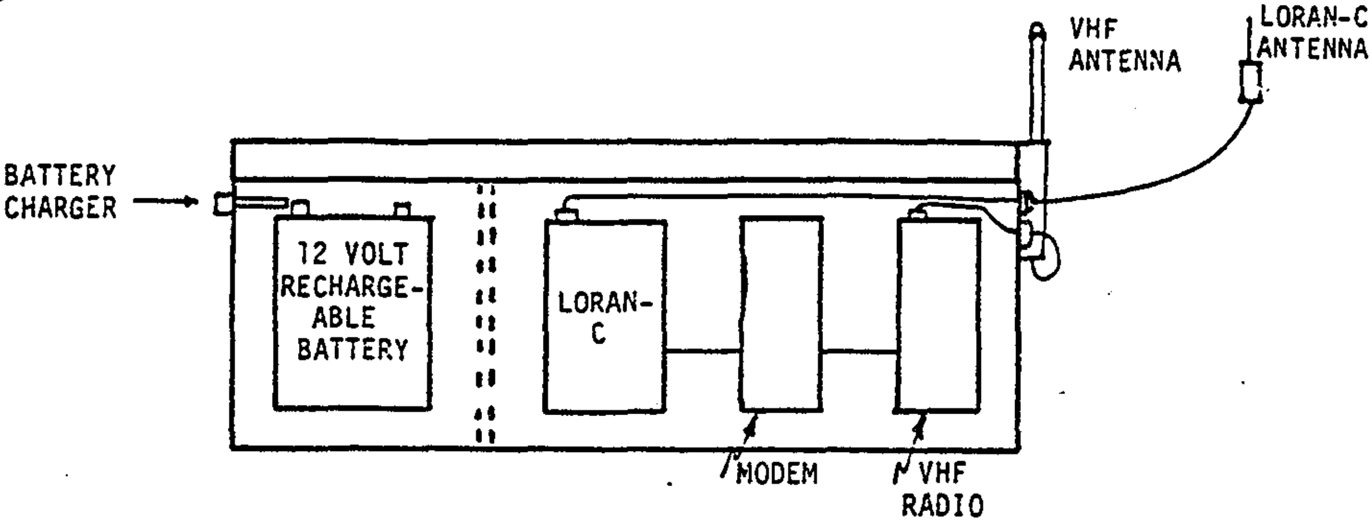
3.1.1 Cap Site #1

A baseline bathymetric survey (Fig. 3-4) of Cap Site #1 was conducted on 7 April, 1983, which indicated a relatively flat bottom sloping only 0.5m from north to south over the survey

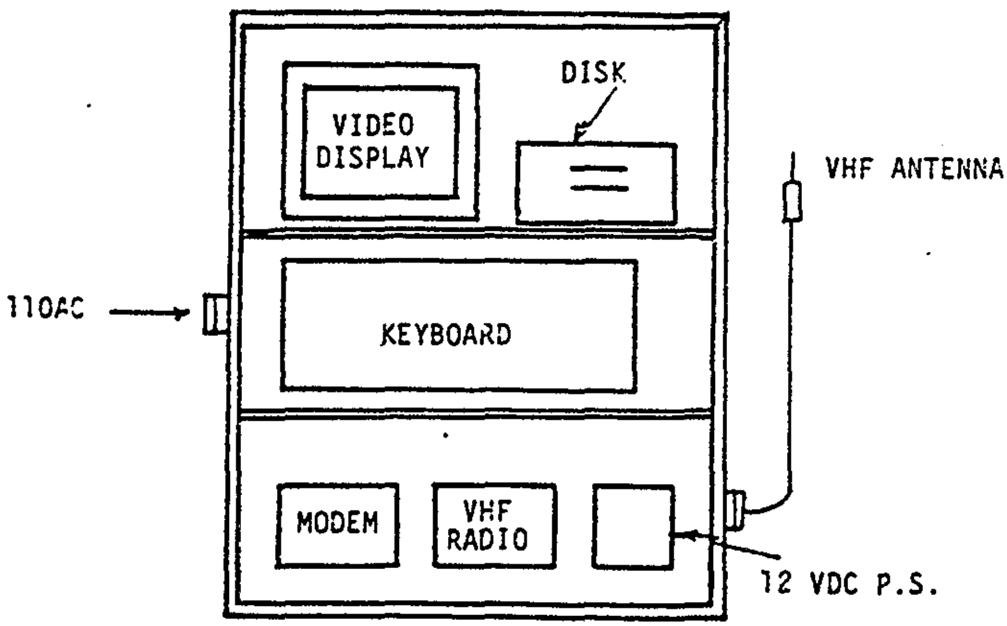


TAUT WIRE BUOY

Figure 3-1



SCOW LOCATED LORAN-C TELEMETERING SYSTEM



TUG LOCATED COMPUTER DISPLAY

FIGURE 3-2a

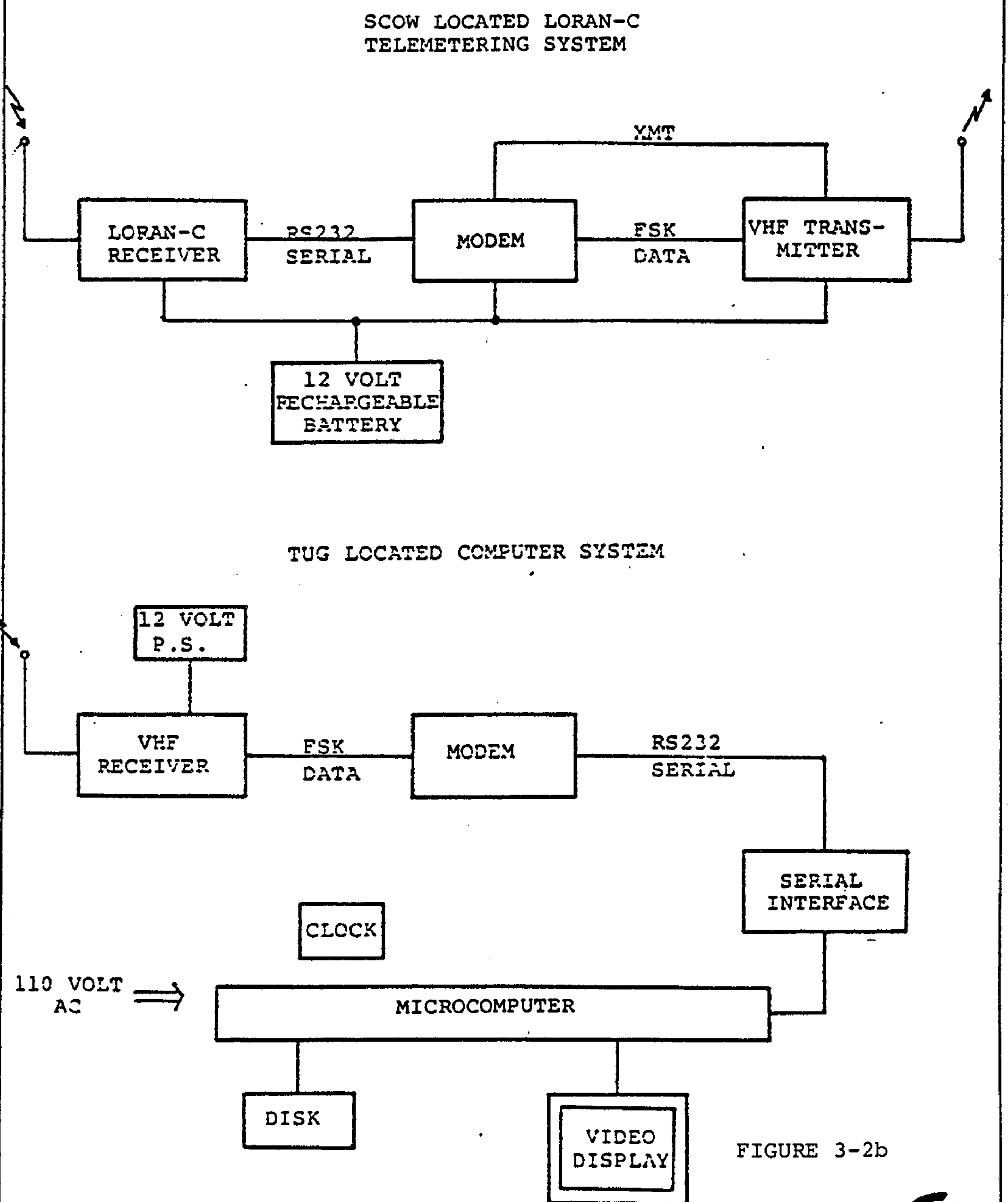
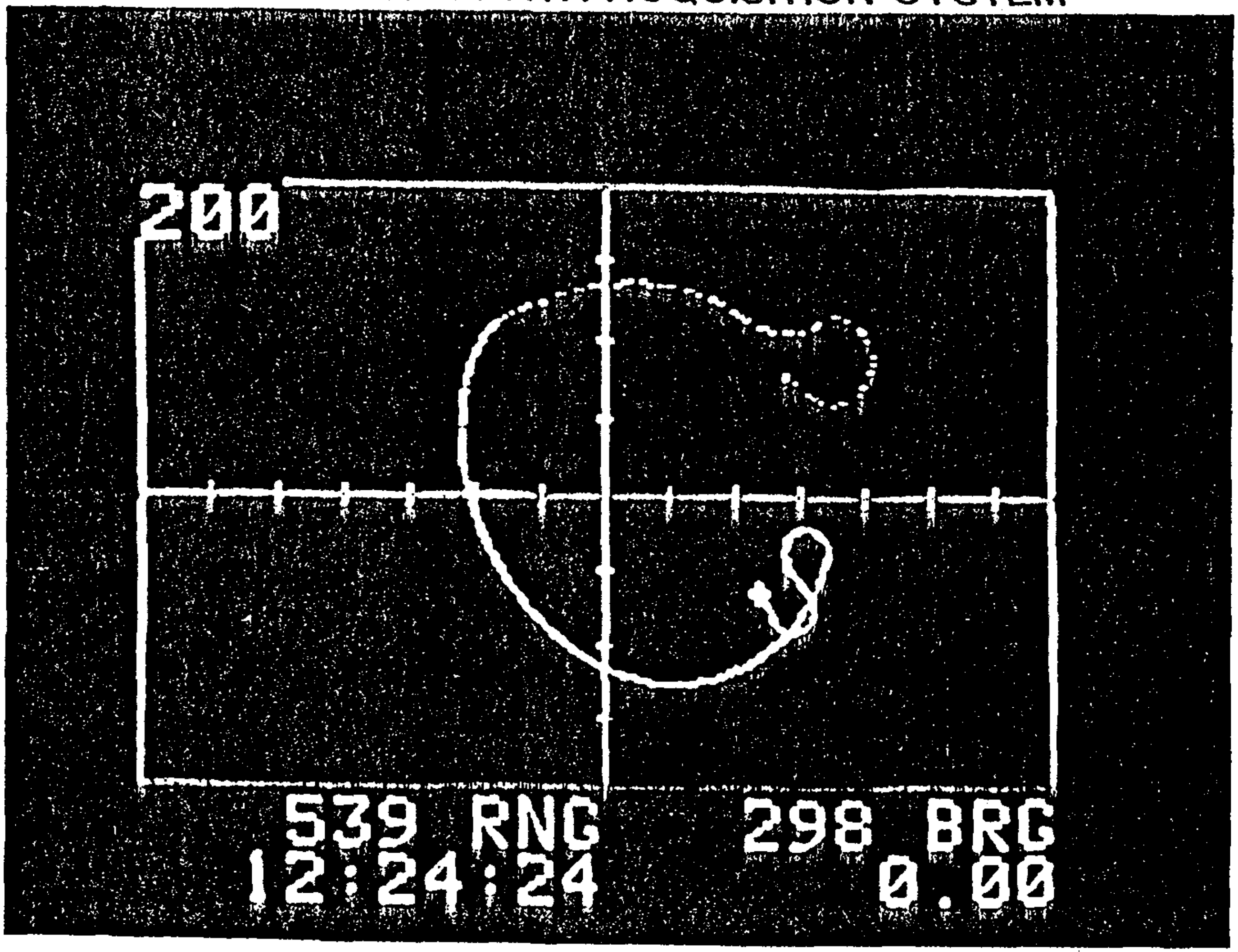

SCOW LOCATED LORAN-C
TELEMETERING SYSTEM
XMT
LORAN-C
RECEIVER
RS232
SERIAL
MODEM
FSK
DATA
VHF TRANS-
MITTER
12 VOLT
RECHARGEABLE
BATTERY
TUG LOCATED COMPUTER SYSTEM
12 VOLT
P.S.
VHF
RECEIVER
FSK
DATA
MODEM
RS232
SERIAL
SERIAL
INTERFACE
CLOCK
110 VOLT
AC
MICROCOMPUTER
DISK
VIDEO
DISPLAY

FIGURE 3-2b

IENCE APPLICATIONS, INC.

SAI

NAVIGATION & DATA ACQUISITION SYSTEM



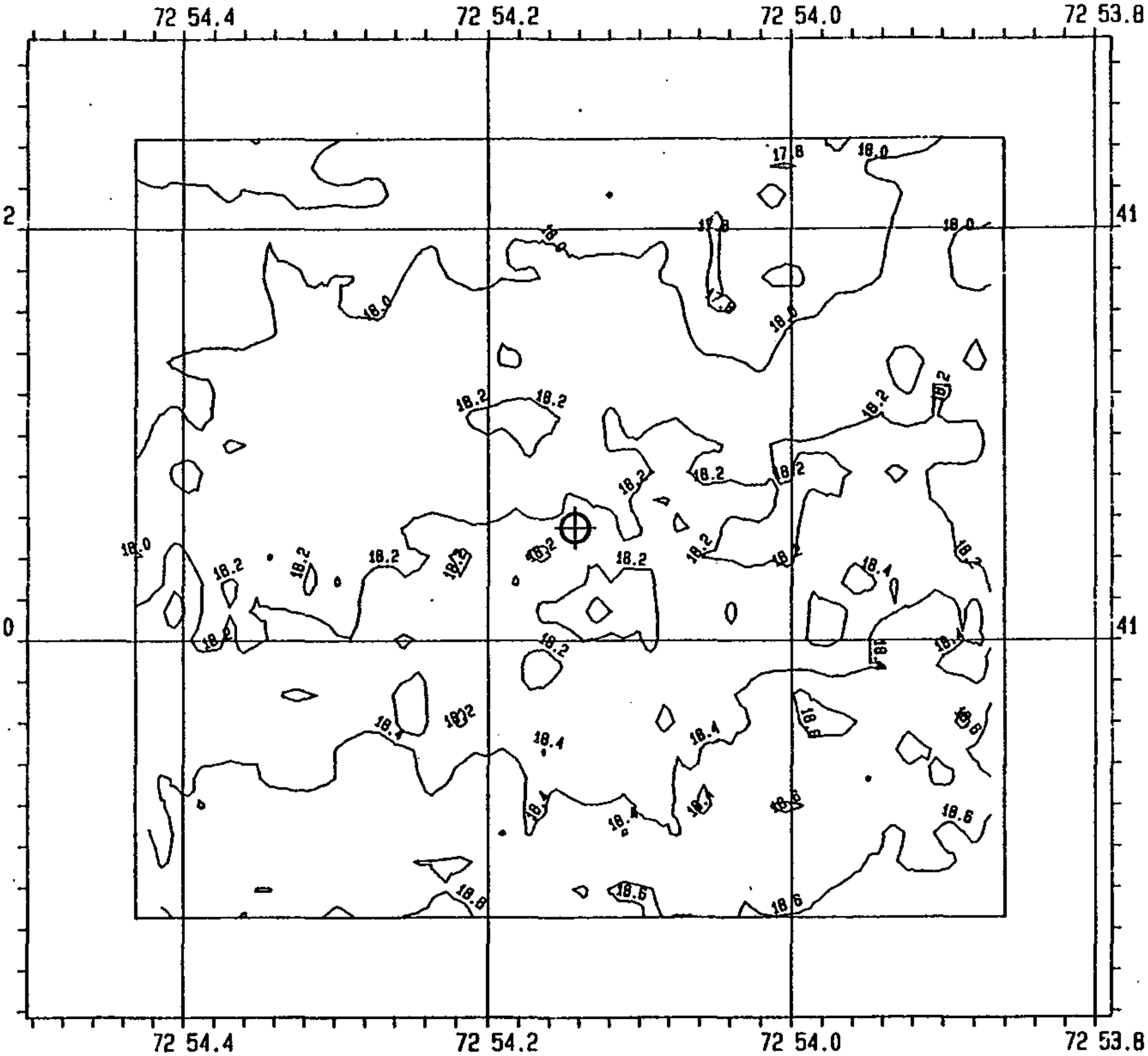
REPRESENTATIVE VIDEO DISPLAY

FIGURE 3-3

CAP SITE #1 PRE-DISPOSAL

APRIL 1983

FIGURE 3-4



0 80 160

SCALE (m)

area. However, due to scheduling and weather problems, this survey was made a few days after disposal operations began and a slight elevation is apparent in the south center of the survey.

A side scan sonar survey conducted on the same data indicated a predominantly soft, silty bottom interspersed with concentrations of rough, high reflectance sediment (Fig. 3-5). The frequency of occurrence for these high reflectance areas increases toward the east in the general area of permit disposal operations at the "SP" buoy and the previous Norwalk disposal operation. At the extreme east of the survey, the entire surface is composed of high reflectance material (Fig. 3-6).

Previous experience with side scan sonar records in this area (Morton, 1982) and other disposal sites (Menzie et al, 1982) has indicated that dredged material, and particularly that which has recently been disposed of, produce this high reflectance signature regardless of the grain size of the sediment. If the dredged material is of a similar fine grained texture as the surrounding material, this high reflectance contact tends to diminish with time as the sediment is reworked into the surface expression similar to the surrounding deposits.

In the area immediately south of the disposal buoy (Fig. 3-7), dredged material on the bottom results in another area of high reflectance with crater signatures also observed by Menzie et al (1982) characteristic of the location of actual dumping. The cratering most likely results from initial impact of disposed material on natural bottom producing a sidewards displacement of sediment and some penetration into the bottom. The combination of bathymetric and side scan data obtained at the site supported observations from the research vessel that initial disposal operations were not tightly controlled through dumping with the buoy immediately north of the scow. The importance of this control was re-emphasized to Corps inspectors, and future disposals were much closer to the buoy.

3.1.2 Cap Site #2

Cap Site #2 was established 700m north of Cap Site #1 to provide a site for capping with sand material. The baseline survey (Fig. 3-8) indicates a more complex topography than the CS#1 site, but still maintains a slope with a depth difference of one meter from north to south across the site. A shoal area with a topographic relief of one meter is also present in the northeast corner of the site. Sediment samples in that area were of a coarse sand, indicating the possible presence of previous disposal in the area. No side scan records were obtained prior to disposal at CS#2, however, subsequent surveys revealed an original bottom very similar to that observed at Cap Site #1, but with more frequent high reflectance areas and complete high reflectance on the east and northeast margins. Based on these results, it is apparent that both Cap Sites have potential influence from previous disposal operations on the east side of the area. It is important to note that side scan surveys extend beyond the bathymetric survey grids and include areas not considered in other analysis procedures.

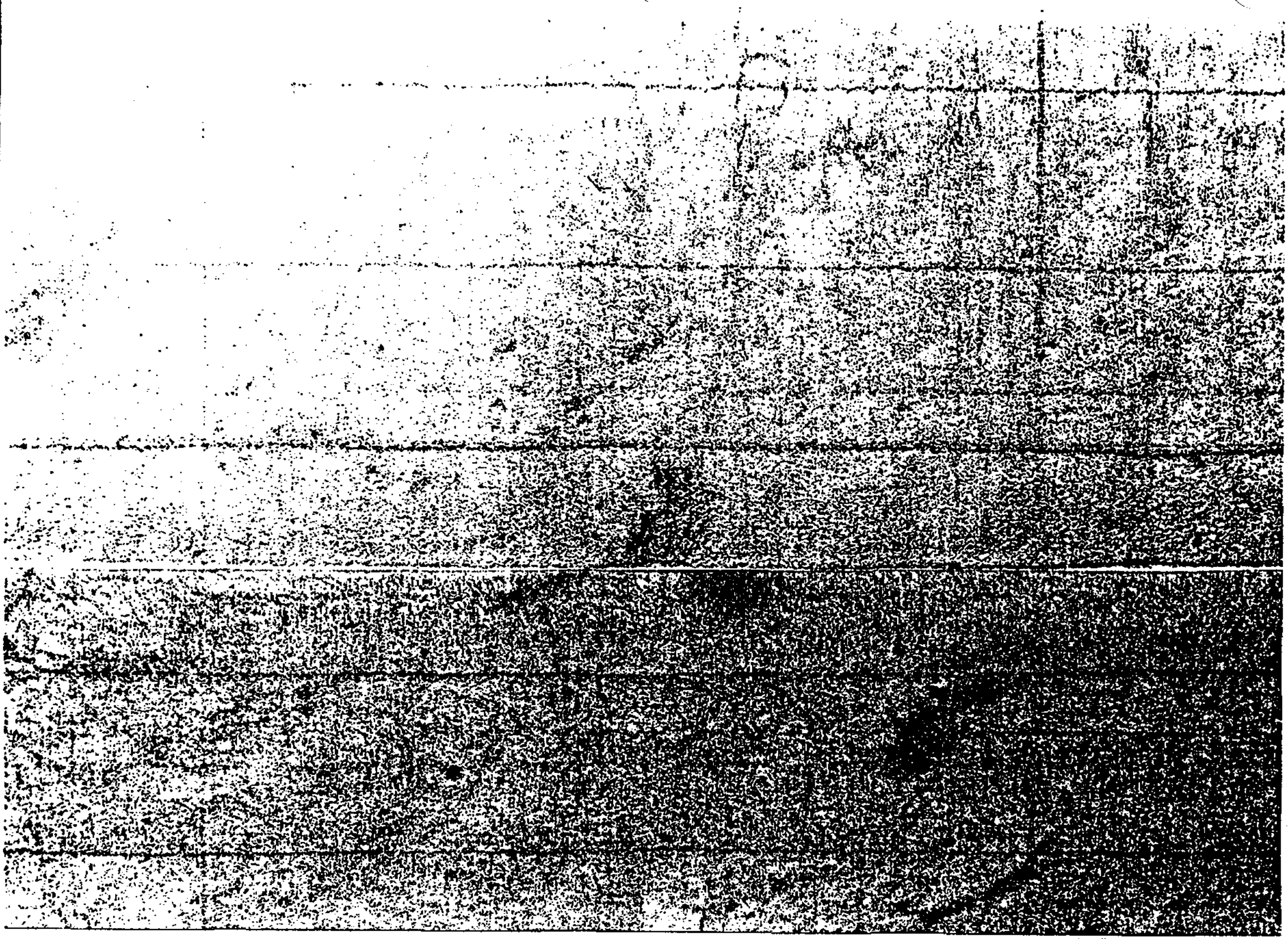


Figure 3-5. Ambient bottom conditions at CS#1.

Figure 3-6. High reflectance material from Norwalk disposal operations.

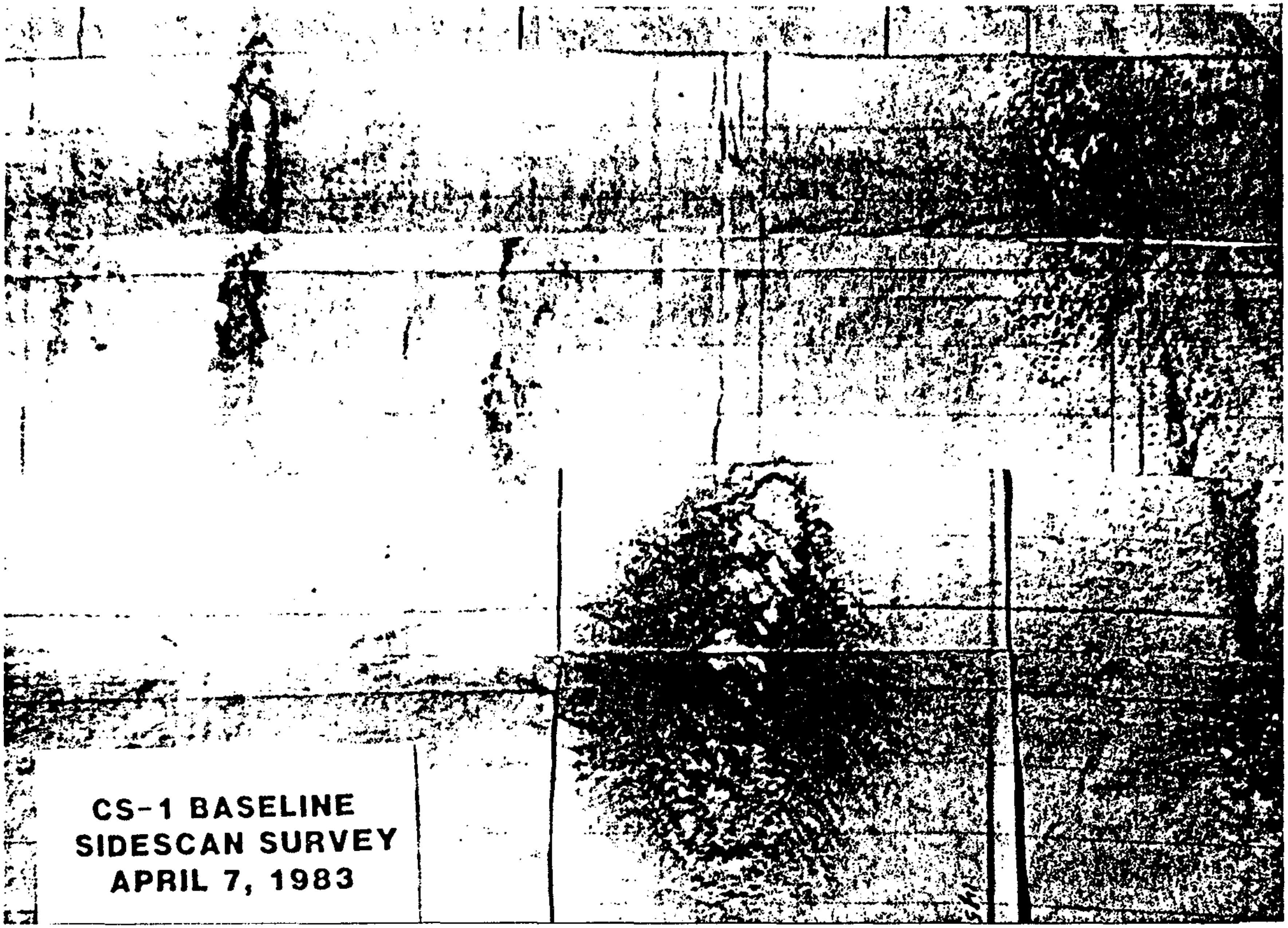
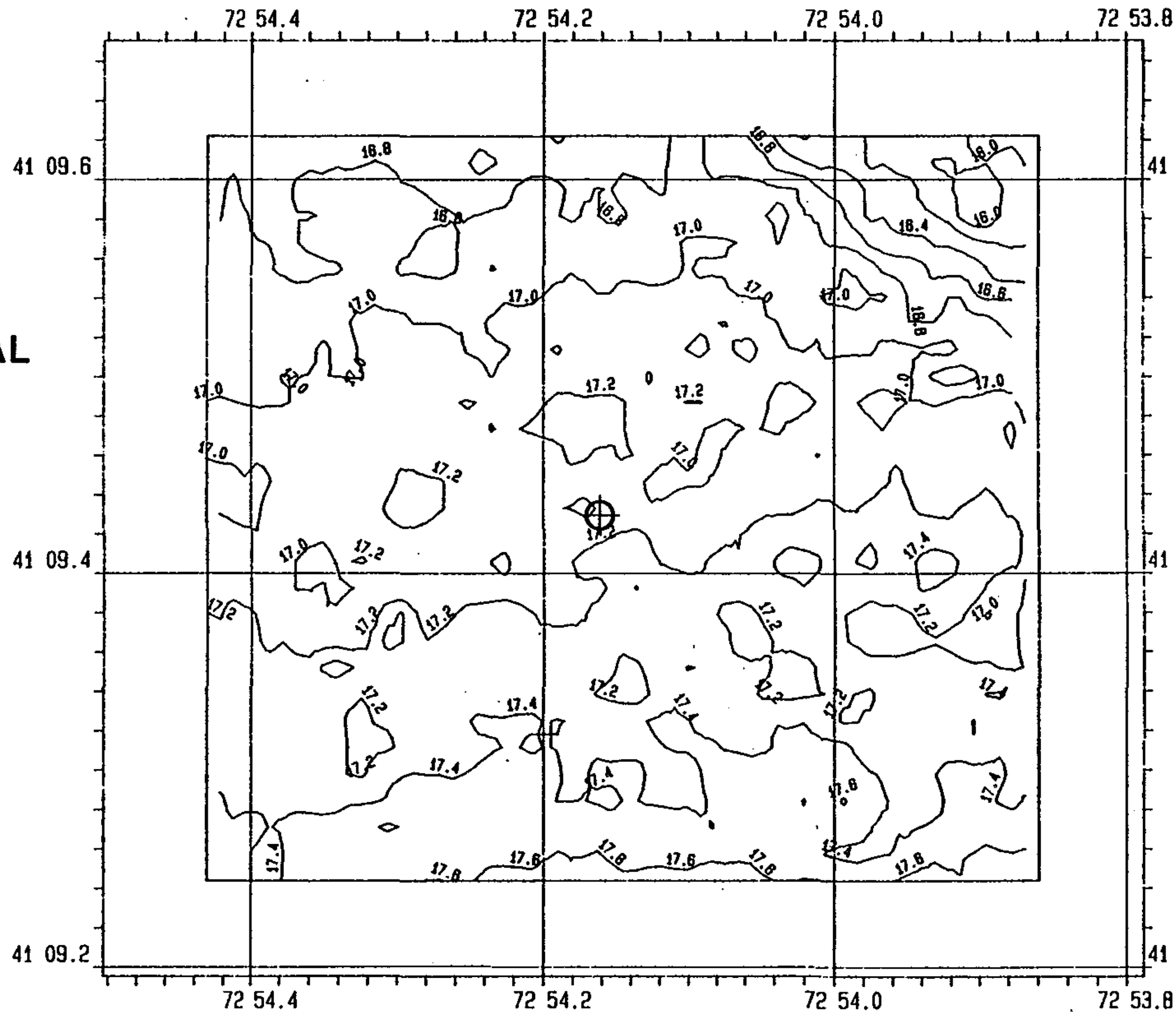


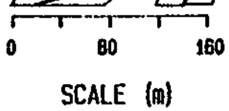
Figure 3-7. Dredged material deposited south of the disposal buoy.

CAP SITE #2 PRE-DISPOSAL

APRIL 1983

FIGURE 3-8





3.1.3 REMOTS Observations at CS#1 and CS#2

A REMOTS photographic survey was conducted over both cap sites on April 6, 1983. Eleven stations were sampled at each site with 200 meter spacing over an orthogonal grid. Four replicate sediment profile photographs were taken at each station and three exposures (chosen at random) were measured for baseline parameters with the Measuronics Image Analysis System in the manner described earlier.

The major modal grain size for all station replicates was 4Φ , a coarse silt. The range of grain size, exclusive of shell debris, was 4Φ -3Φ (silt-clay to very fine sand) with the exception of replicate 1 at station 200N (CS#2) which had some fine sand (2Φ) present.

Both cap sites have a positively skewed boundary roughness frequency distribution (Fig. 3-9a). The major mode at CS#1 is 0.41-0.80cm while the major mode at CS#2 is 0.81-1.20cm. The major modal RPD depth for CS#1 is 4.1-4.5cm and the frequency distribution appears to be symmetrical about this mode (Fig. 3-9b). This RPD depth mode is equivalent to the major RPD mode observed on natural, undisturbed bottom at the CLIS-REF station in March 1983 (MSI, 1983).

The RPD at Cap Site #2 has a major mode at 3.1-3.5cm and a minor mode at 5.1-5.5cm. This frequency histogram represents either a bimodal distribution or positively skewed normal distribution. The small sample size does not allow determination of the exact nature of this frequency distribution. Bimodal RPD distributions represent patchy mosaics of shallow and deep RPD values where the low values represent recently disturbed bottoms which occur in an otherwise undisturbed area characterized by higher RPD values.

Figure 3-10 is a map of the mean RPD depth at both capping sites. With the exception of station 400E, all RPD values at CS #1 are greater than 4.2cm, while only three station means at CS#2 are above this value, indicating possible disturbance of the sea floor in the recent past.

Habitat indices for each station sampled at the two cap sites are presented in Figure 3-11. Values of 10 and 11 are representative of areas with undisturbed seafloor. In contrast, colonized dredged material disposal areas generally have habitat indices in the range of 1 to 7 with most values falling within the frequency class 4-5. The ambient bottom can also have habitat indices with these values which are caused by local natural disturbances such as current scour or predation activity. Cap Site #1 has only one station (all three replicates of station 400E) which falls within the 4-5 class, while Cap Site #2 has values of 5 at three stations (200N-200E, 200E and 400E). In general, the distribution of habitat index values at the two study sites suggests that CS#1 has a higher habitat value than CS#2, and that the northeastern quadrant of CS#2 (stations 200N-200E, 200E and 400E) are particularly low in their habitat

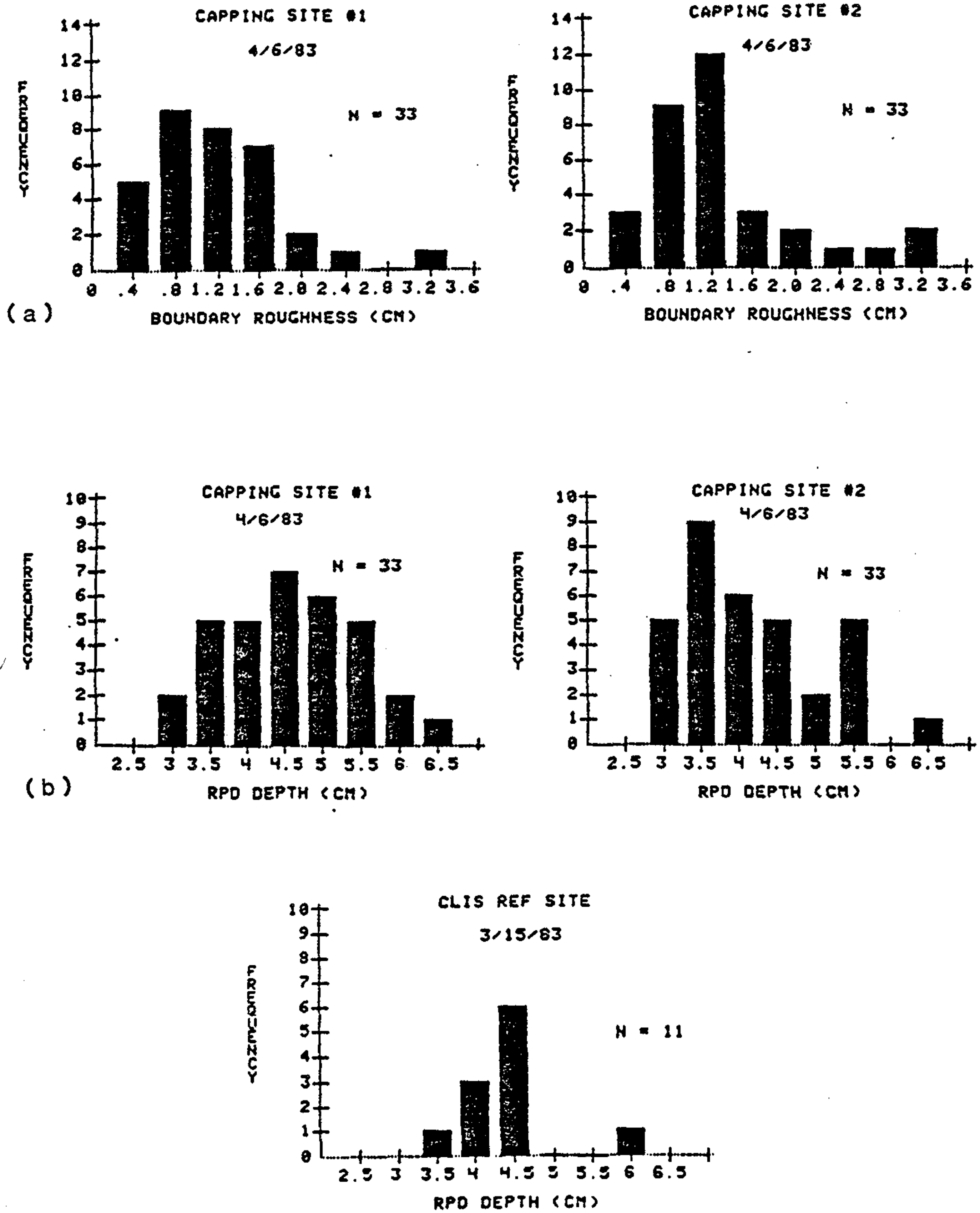


FIGURE 3-9 Pre Disposal Boundary Roughness and RFD Depth for Cap Sites 1 and 2.

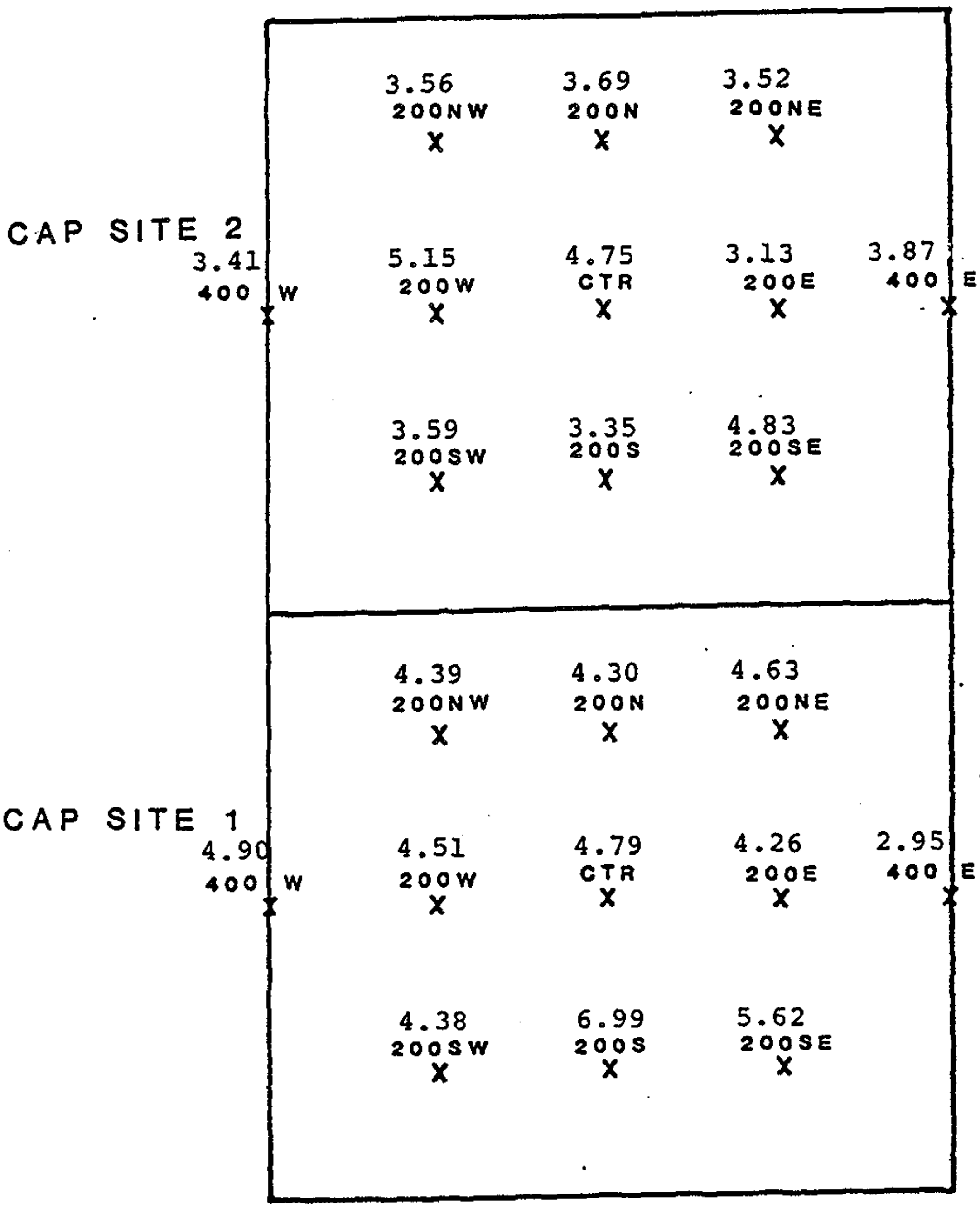


FIGURE 3-10 Pre-disposal mean RPD Depth at CS#1, CS#2

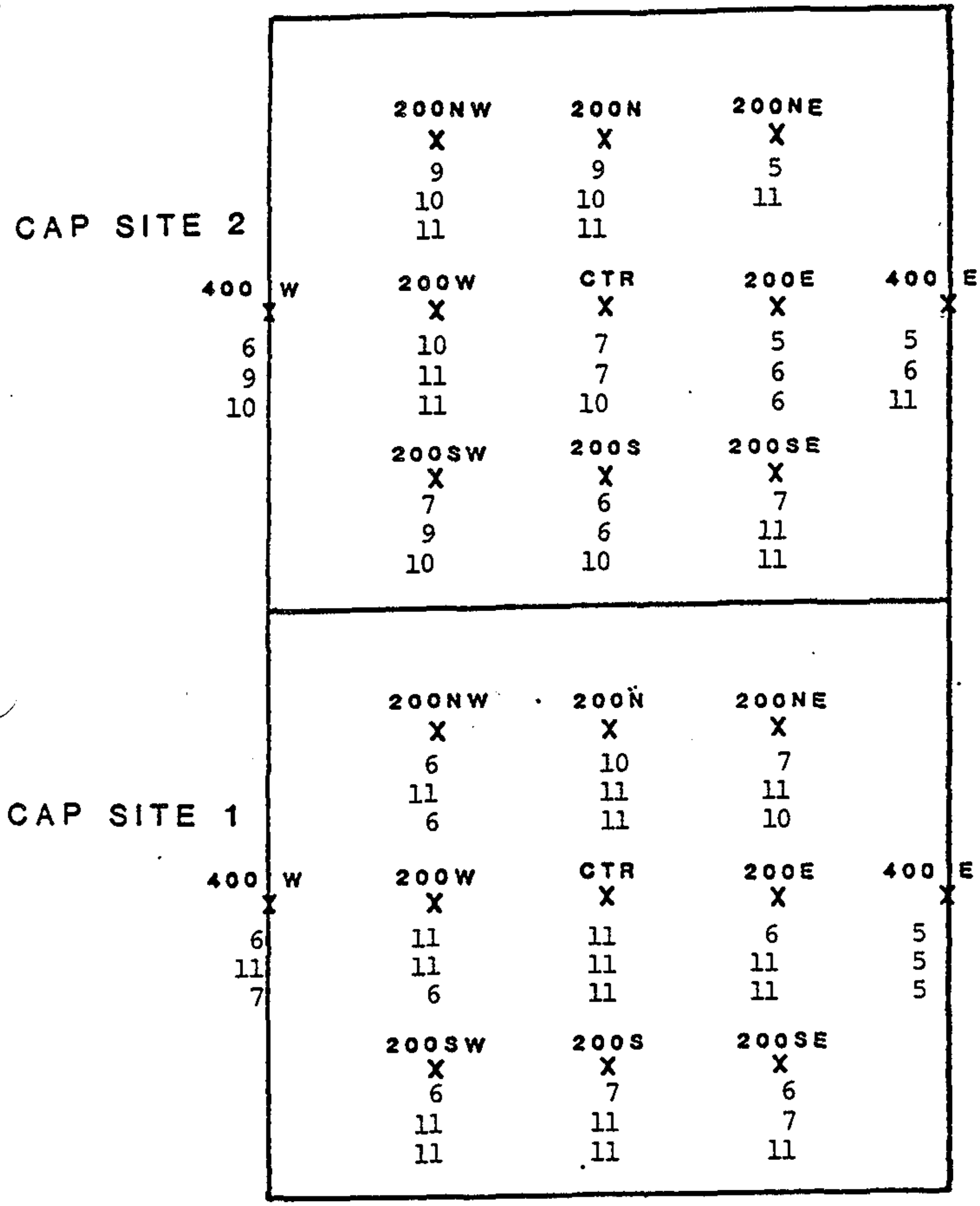


FIGURE 3-11 Maps of habitat indices for CS-1 and CS-2. Vaues for each replicate are plotted. Vaues of 10 and 11 represent undisturbed bottoms occupied by high-order successional stages and a deeply oxidized surface sediment. Values of 5 represent recently disturbed habitats.

indices, indicating a disturbance has taken place there in the recent past. This disturbance patch contributes to the apparent bimodality of the RPD depth frequency distribution shown in Figure 3-9a.

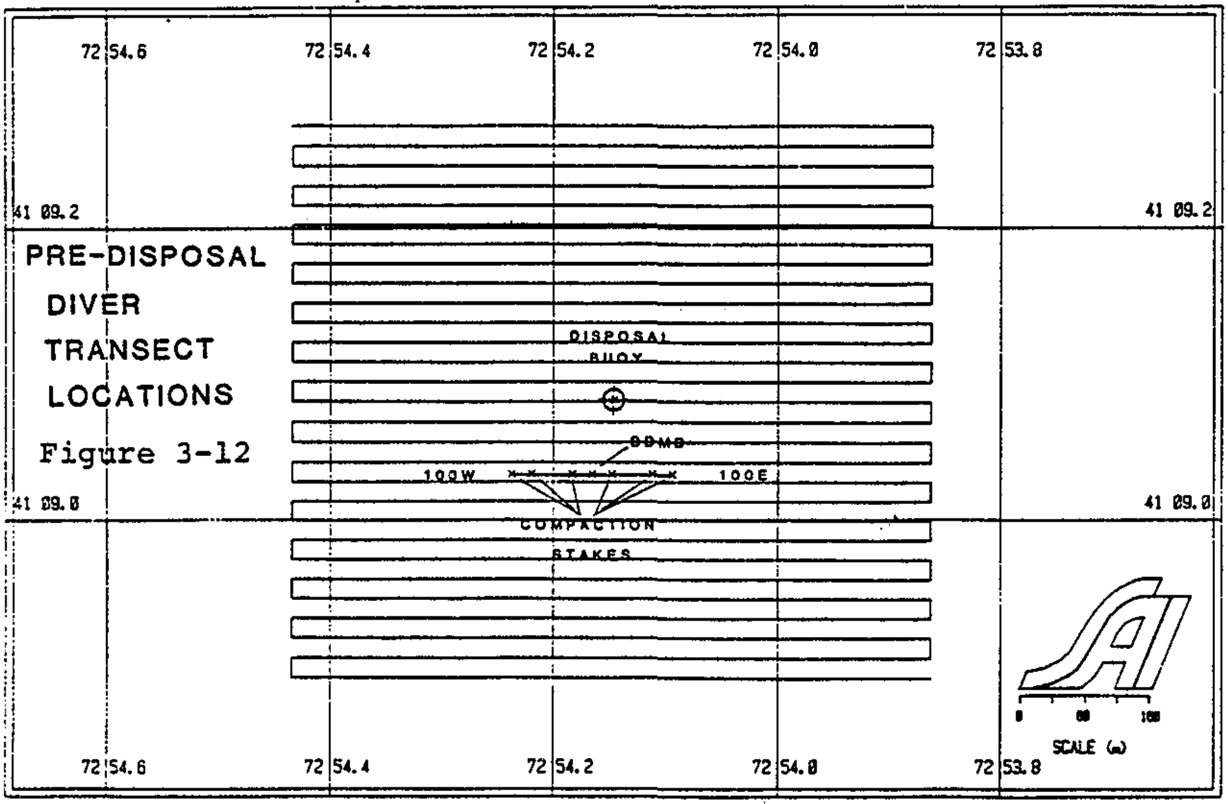
3.1.4 Diving Observations at CS#1 and CS#2

In order to observe baseline conditions at the cap sites and to deploy instrumentation for post-disposal, in-situ measurement of dredged material accumulation, compaction and erosion, a series of five dives at CS#1 and seven dives at CS#2 were made between April 8 and April 18, 1983. Initial dives involved deployment of a 200m long transect array oriented in an east-west direction across the center of each site (Fig. 3-12). The array consisted of a Bottom Deflection Measurement Device (BDMD) located at the center of the transect and four erosion/compaction stakes at distances of 25 and 75 meters east and west of the center. A 200m long transect line marked at 5m intervals was tied to the BDMD and anchored with pipe anchors immediately south of the erosion/compaction stakes (Fig. 3-13).

The BDMD was a 3 meter long steel pipe, welded to a 1.5 square meter plate placed on the surface of the sediment. An acoustic target was then fixed by divers at the top of the pipe so that differences in depth between a known location and the BDMD could be measured over time, thus reflecting changes in the depth of the initial surface following disposal of dredged material. Figure 3-14 provides an example of baseline measurements of the BDMD with the Raytheon 719 fathometer on a comparatively rough day. It is readily apparent that the measurements of the minimum depth on the BDMD are essentially equal to 14.8m (48.7 ft), while the depth of the reference bottom located using the SAI Navigation System at a point 450m southwest of the disposal site is 17.6m with a standard deviation of $\pm$14cm ($\pm$.46 ft). Whether or not such measurements are sufficiently accurate to detect bottom deflection was to be determined on subsequent measurements following disposal.

The erosion/compaction stakes were 3 meter long PVC tubes, 5cm in diameter, and marked at 10cm intervals. The tubes were threaded into 1.5meter PVC anchors imbedded in the natural bottom. These stakes were to be used following disposal to measure the thickness of dredged material and to monitor post-disposal changes in sediment thickness. Previous erosion stakes placed in dredged material have indicated, under normal conditions, that no net loss of material, due to erosion, is taking place on disposal mounds in the CLIS site (Morton, 1982). However, since these stakes were placed after disposal in the dredged material, no measurement of compaction was possible. On this program, the stakes anchored in the bottom permit assessment of compaction as well as erosion through post-disposal monitoring of sediment thickness.

Based on visual observations along the transect lines at Cap Site #1, the sediment surface was cohesive, flat and featureless near the ends with small clay clumps and gray



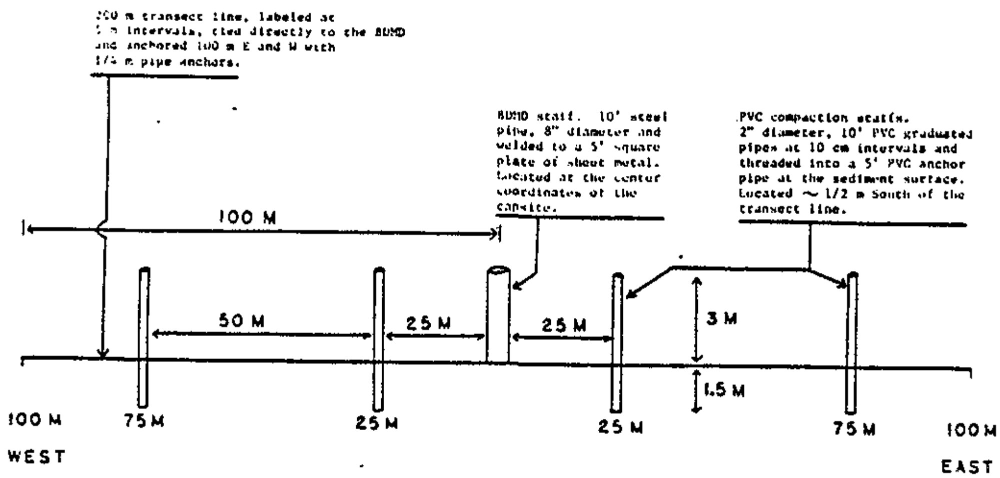


Figure 3-13. Baseline Transect Array at Capsites 1 and 2.

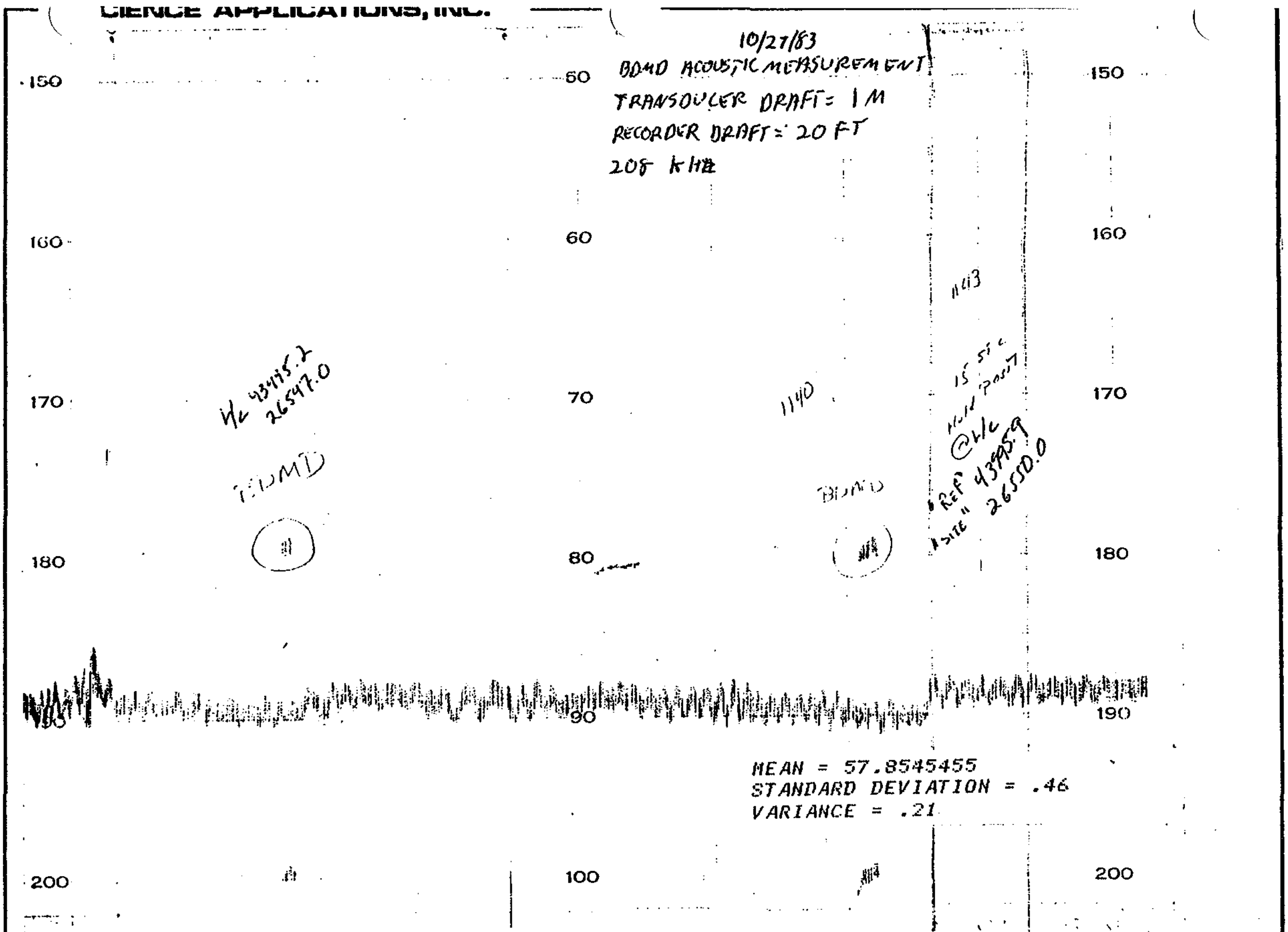


FIGURE 3-14 BDMD Baseline Measurements.

sediment indicative of dredged material near the center due to active disposal. Less than 5% of the total surface sediment contained incorporated shell hash material. Surface shell hash may be attributed to recent feeding activity by the *Asterias forbessii* and *Cancer irroratus* that were observed during the dive. Bioturbation in the area, from surface tracking and self-burial, is attributed to *Cancer irroratus*, *Pagurus longicarpus* and *Limulus polyphemus* activity. At Cap Site #2, the sediment surface was also cohesive, flat, and relatively featureless with an oxygenated surface layer of 3-5mm. Observable shell fragments accounted for less than one percent of the total sediment surface and may be attributed to minimal feeding activity by *Asterias forbesii* and *Cancer irroratus*. Bioturbation was evident, as tracking, over the entire surface by crabs and starfish, and as small decapod burrows. Unlike Cap Site #1, there was no indication of recent disposal activity at this site.

Photographs from the two cap sites indicate a natural undisturbed bottom (Fig. 3-15) composed of a fine oxygenated silt with the hydroid *Corymorpha* present in large numbers. A typical decapod burrow indicating extensive bioturbation activity is shown in Figure 3-16. Figure 3-17 shows an erosion/compaction stake threaded into its anchor with the transect line located immediately adjacent to the station.

3.1.5 MQR Baseline Conditions

During the spring of 1982, sediment from the Mill River in New Haven was deposited at the MQR site and capped with additional material from the Quinnipiac River. The mound created by the capping operation is readily apparent in Figure 3-18 as an elliptical shaped elevation with axes of 300m and 180m and a maximum elevation of approximately 1.5m. Prior to disposal of New Haven sediment, a replicate survey of the site was conducted in December 1982. Figure 3-19 shows the results of that survey and conditions of the site immediately before initiation of the present project. Very little change had occurred over this period, indicating a stable containment situation.

3.1.6 FVP Baseline Conditions

A major effort was made under the Field Verification Program to define the baseline conditions at the FVP site in some detail. The results of that study are presented in a New England Division Technical Report (Morton et al, 1982) and are summarized here for comparison with data from cap site surveys.

A detailed bathymetric survey was conducted over an area 800 x 800 meters square centered at the designated disposal point to form a baseline for future measurement of dredged material volume and to identify any significant topographic features in the study area. These data, presented in Figure 3-20, indicate the expected lack of topography characteristic of the CLIS site. Although there are no significant topographic features present, a gentle slope to the south is evident as the

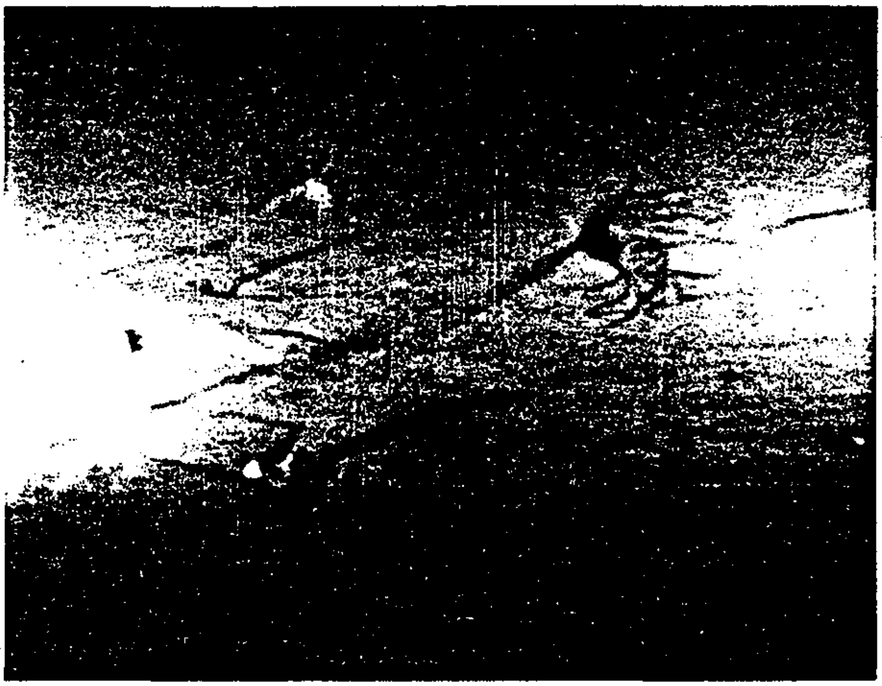


FIGURE 3-15 Natural bottom CS #2, Coryomorpha

FIGURE 3-16 Decapod Burrow

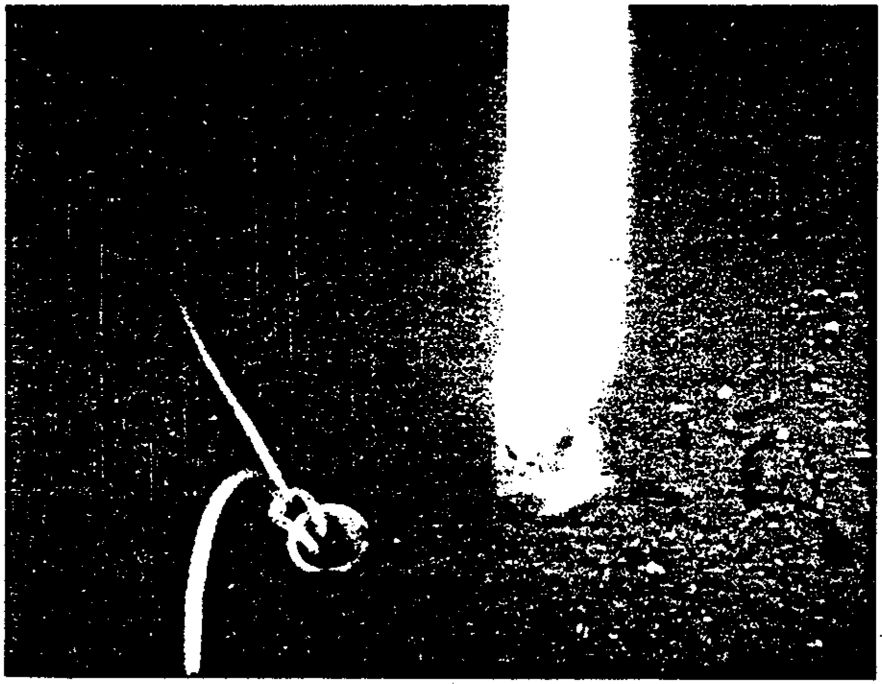


FIGURE 3-17 Erosion/Compaction Stake

MQRDS

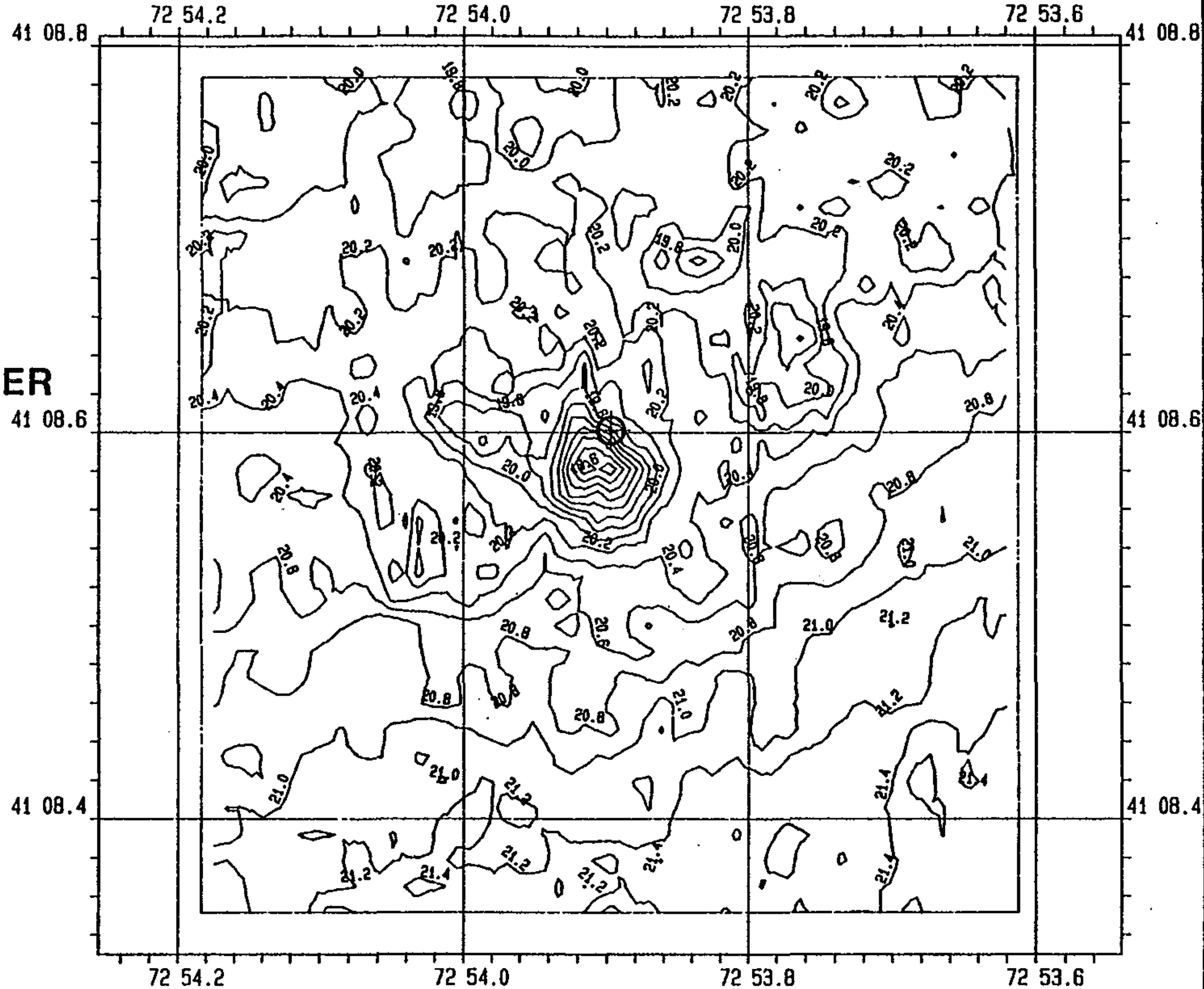
POST-QUINNIPIAC RIVER

JUNE 1982

FIGURE 3-18

0 80 160

SCALE (m)

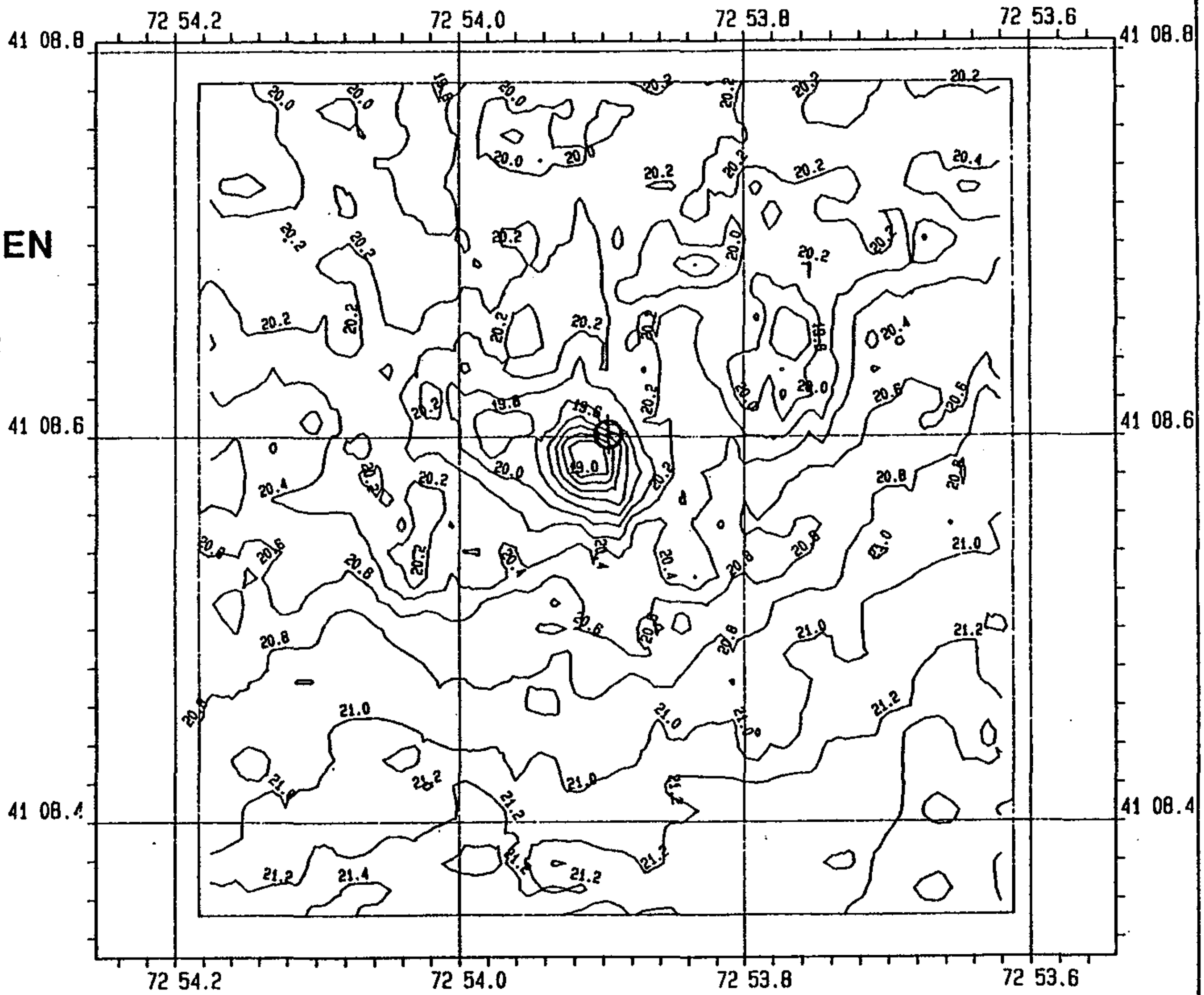


MQRDS

PRE- NEW HAVEN

DECEMBER 1982

FIGURE 3-19



0 80 160

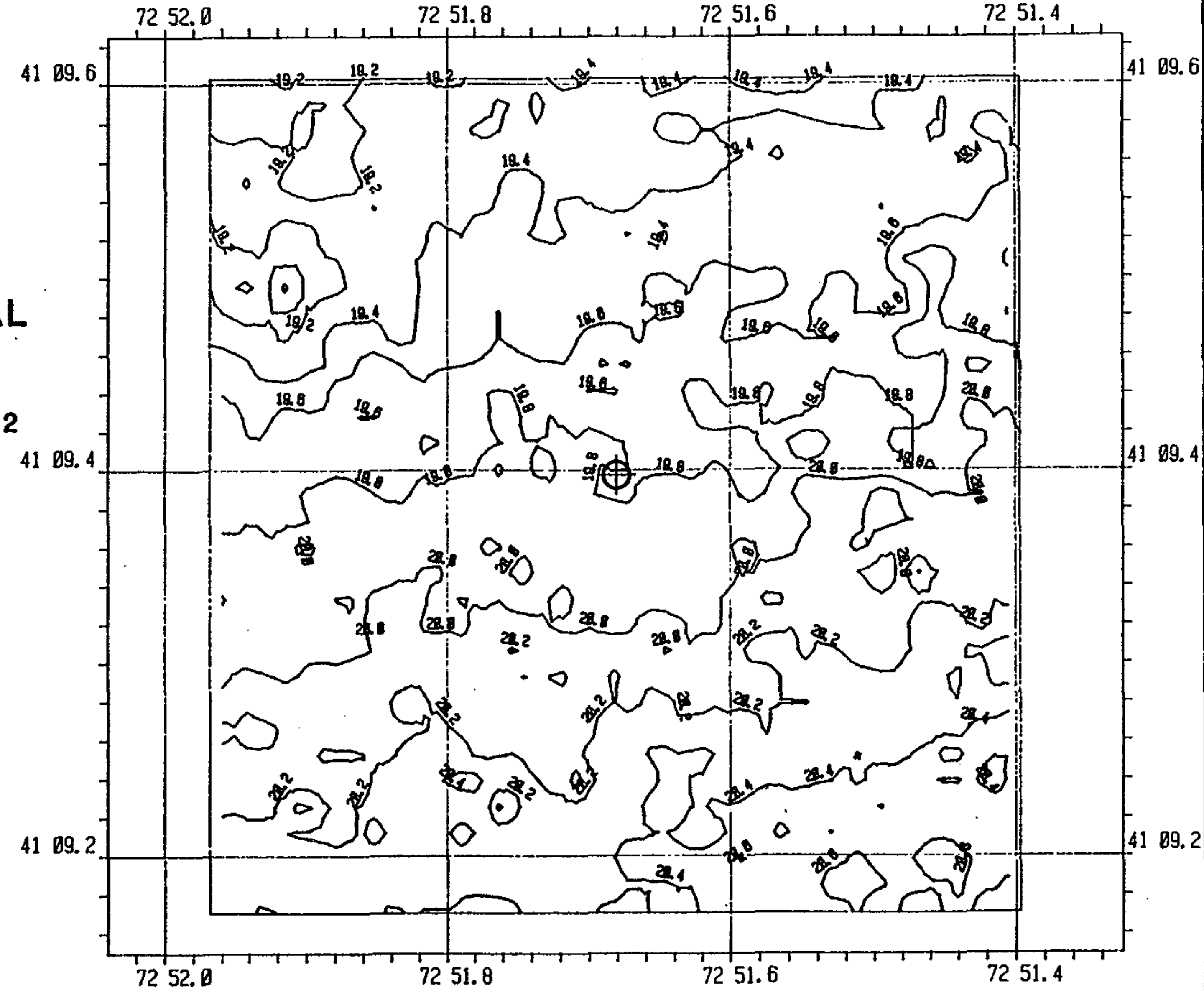
SCALE (m)

FVP

PRE-DISPOSAL

DECEMBER 1982

FIGURE 3-20



0 80 160

SCALE (m)

depth increases from 19.5 to 20.5 meters over the survey area.

Although bathymetric surveys can identify significant topographic features, more extensive data are required because changes in bottom conditions can occur which do not have a topographic expression. Consequently, a side scan sonar survey was conducted over a larger area to map any apparent differences in bottom type and to locate any indications of previous disposal in the site. The area surveyed by side scan was centered at the designated disposal point and consisted of 11 lanes, 1000m long, spaced 200m apart.

The survey revealed a major change in bottom conditions from the western margin of the site toward the east. On the western edge, the bottom was much more variable with frequent patches of strong reflecting sediment and obvious detritus. Toward the east the reflectance of the surface sediment decreased, there were fewer detritus outcrops, and the bottom was dominated by a series of troughs oriented in an east-west direction that was parallel to the tidal current flow.

Figure 3-21 shows a typical record from the western region which displays the random distribution of targets that were spread over the bottom. These records indicate a continual spillage and debris from disposal operations taking place over a long period of time. Such conditions appear common in the vicinity of disposal points where a standard approach lane is designated, as was the case with the Stamford/New Haven project.

Figure 3-22 shows bottom conditions resulting from an older dumping operation. The circular impact zones and increased reflectivity associated with the deposits have been identified in other areas, particularly in Buzzards Bay (Menzie et al, 1982). Figure 3-23 is located on the eastern side of the survey area, and is characterized by the relatively strong reflections from a series of troughs or furrows in an east-west direction. These troughs oriented parallel to the dominant tidal flow direction were not observed on previous surveys of the CLIS site, including the cap sites. They have been identified in other tidal regions where deposition of fine grained sediments was occurring.

Formation of the furrow features is thought to be the result of two factors: helical secondary flow patterns and localized abrasion or scour around coarser particles. The helical flow patterns have been shown to develop in well-mixed bottom boundary layers associated with short-term, non-steady tidal flows similar to those that occur in Long Island Sound.

Based on these records, the bottom in the vicinity of the designated disposal point appeared to be uniform and typical of natural sediment throughout the CLIS site. The presence of disposal debris and previous disposal sites in the western part of the survey resulted in a shift of the designated FVP disposal point to the north and east. The significance of the mud furrows at the FVP site is not known at this time, however future work is expected through other programs to evaluate their role in

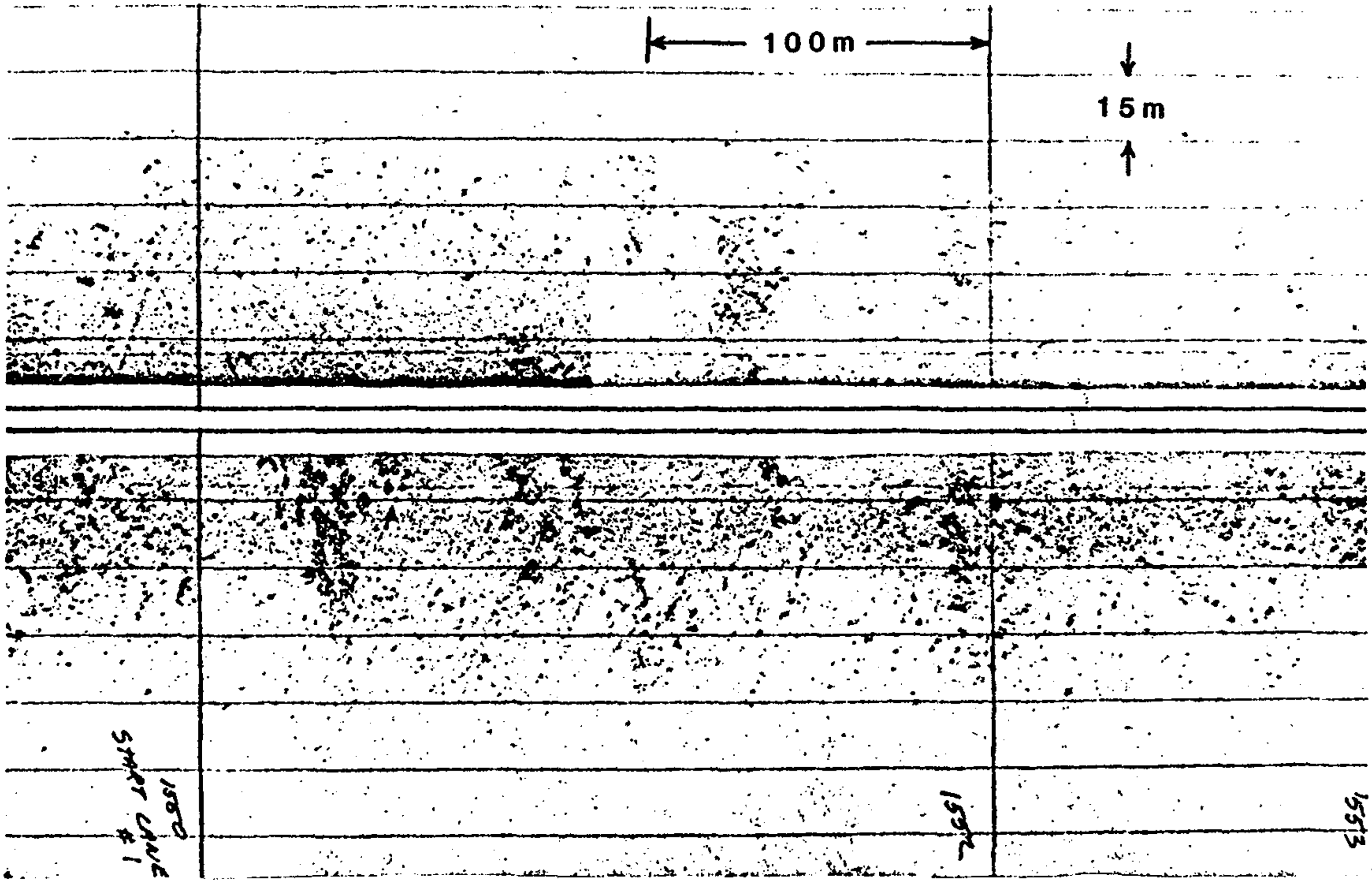


FIGURE 3-21 FVP SIDESCAN: Western Area
Representative signature of debris associated with disposal at other sites.

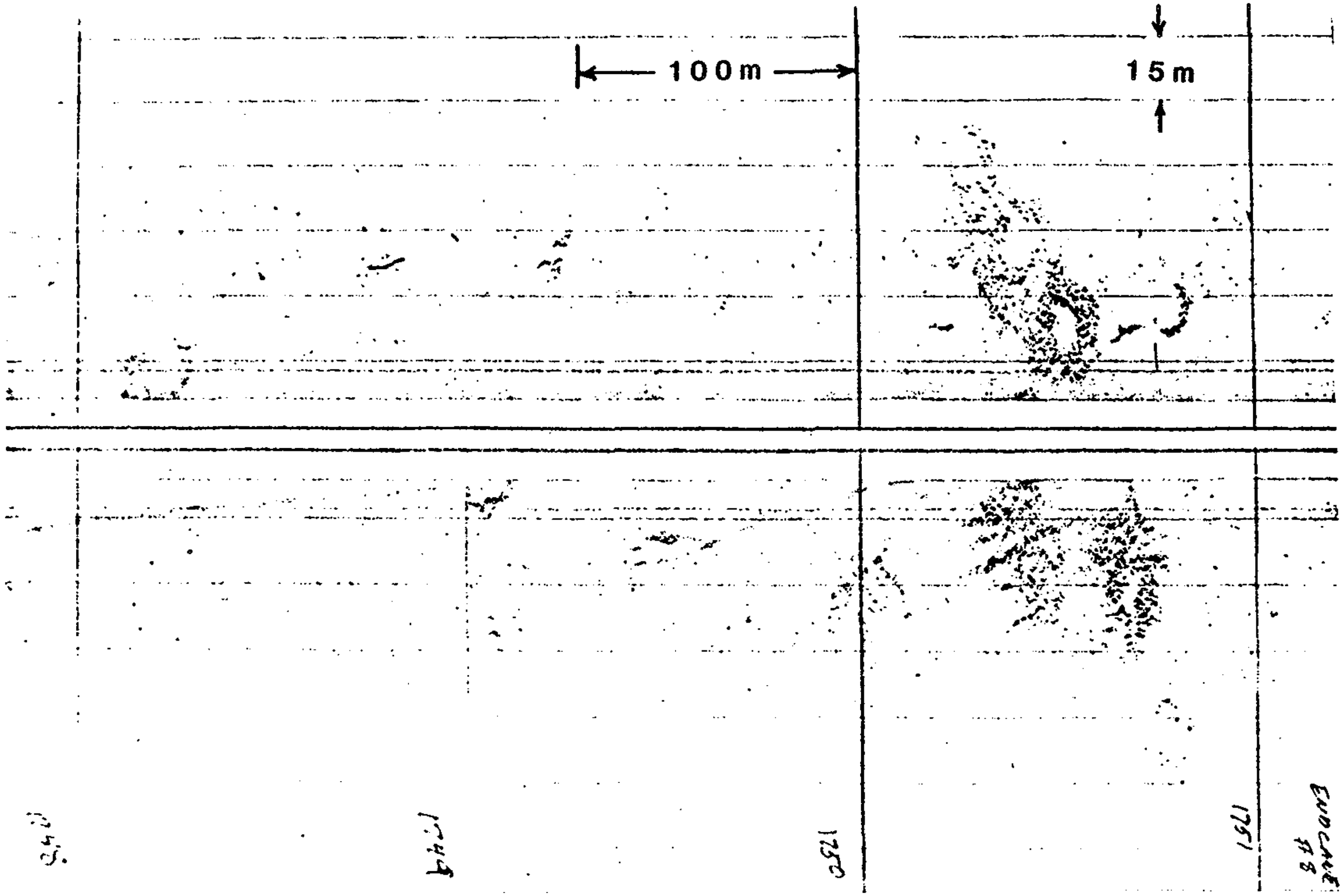


FIGURE 3-22 FVP SIDESCAN: Disposal area
Representative signature of disposal event

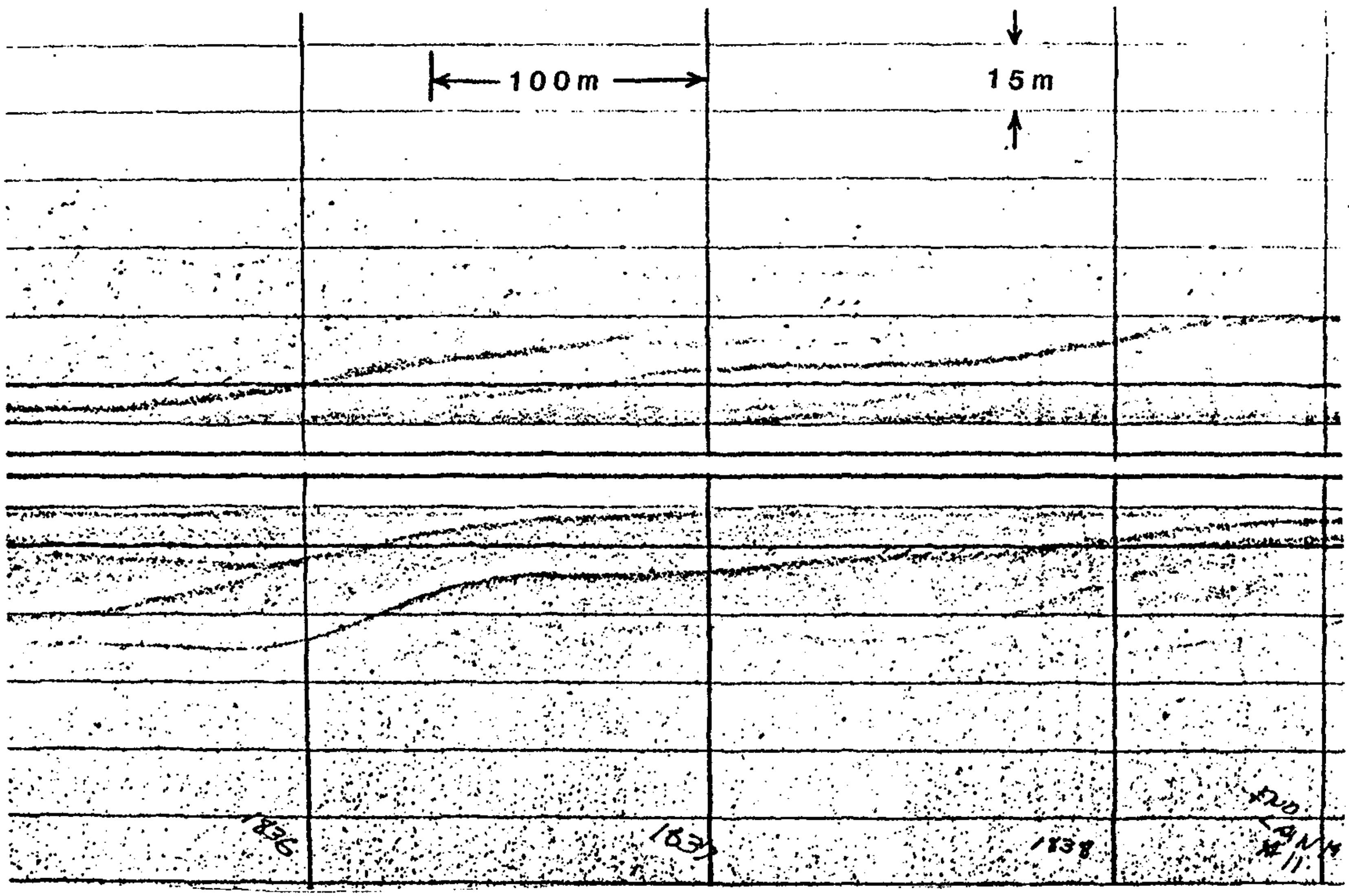


FIGURE 3-23 FVP SIDESCAN: Eastern Area
Representative signature of Mud furrow topography

sediment dynamics of the disposal site.

Two REMOTS surveys were conducted at the FVP site prior to disposal. On the first survey in August, 1982, 51 stations were sampled and based on the results, 15 stations were determined as representative of the area. These fifteen stations were sampled in March 1983 to evaluate seasonal differences. The results of these surveys indicated a sediment that was similar to natural material at CS#1 and CS#2; a fine silt clay with a well-mixed surface layer exhibiting an RPD depth greater than 4cm. There was no seasonal difference between the RPD depth (Fig. 3-24), however, there was an increase in bottom roughness values indicating more erosional features, which may be related to greater turbulence due to winter storms. Habitat indices at the FVP site were slightly higher than those at the cap sites, indicating less disturbance due to recent disposal activities. Consistent values from 9 to 11 suggest a mature seafloor with good habitat quality.

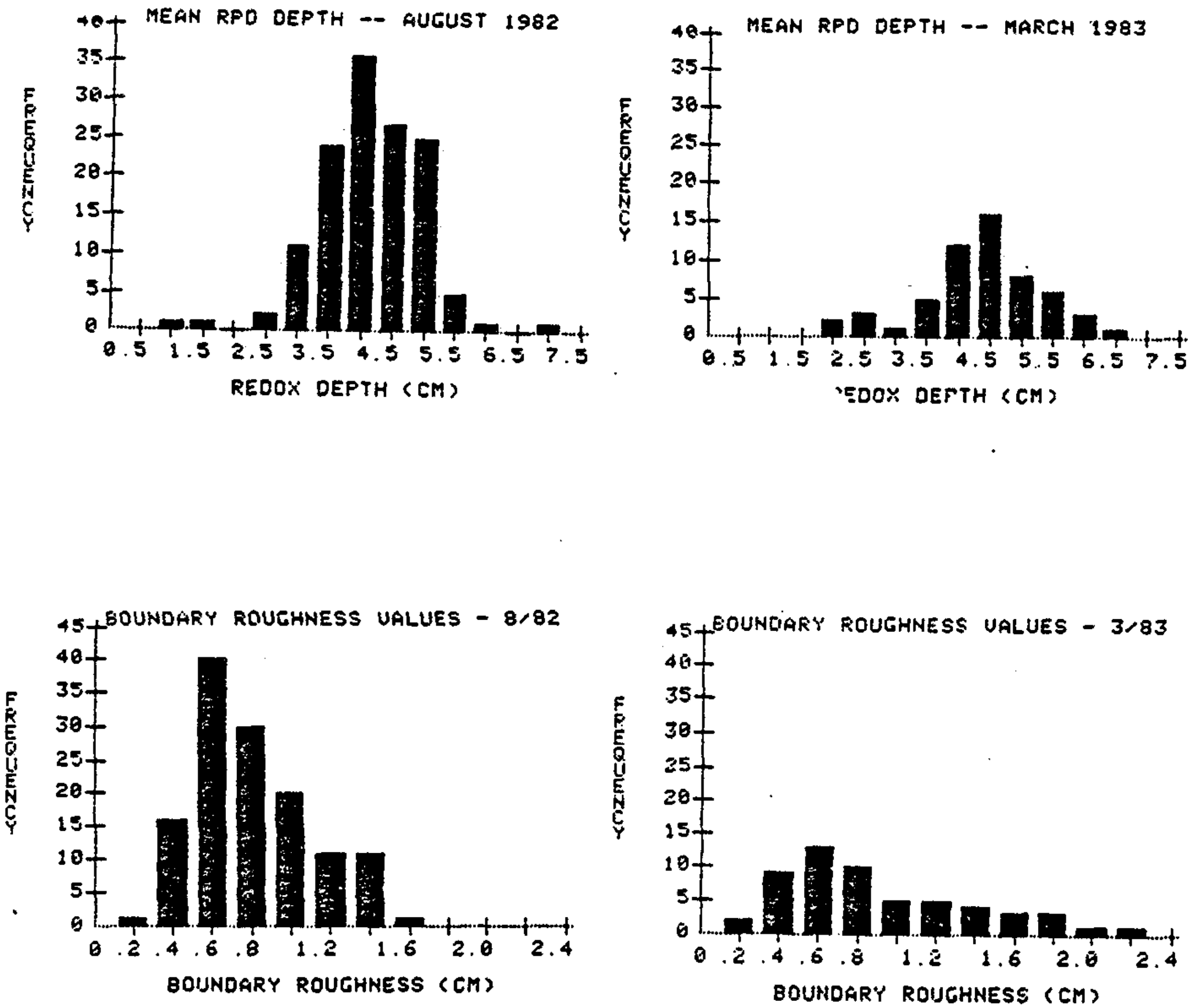
Diving observations at the FVP site support the observation of a mature, undisturbed natural bottom. The bottom was consistently made up of soft muddy sediment that was similar to other areas of the Central Long Island Sound Site. Divers were not able to distinguish the troughs observed on the sidescan record, but they did notice concentrations of detritus in depression zones similar to that observed in other areas.

The hydroids, *Corymorpha pendula*, were ubiquitous over the entire region, as expected from earlier studies. This species continues to be a unique indicator of dredged material distribution.

3.1.7 Summary of Baseline Conditions

Based on the results of previous and ongoing studies at the CLIS disposal site, the baseline conditions of the cap site locations can be evaluated in terms of the entire region. In general, the two sites appear to be more recently disturbed than other areas within the CLIS site, however, not to the extent that measurements taken as part of the capping program will be severely impacted. The natural bottom throughout the cap site area generally has habitat indices greater than 9, indicative of a mature, undisturbed sediment surface. However, some areas in the east and northeast sectors show decreased values in the same locations where side scan sonar records indicate that the bottom has been affected by previous disposal operations.

The flat bottom associated with the disposal sites provides a good basis for replicate bathymetric surveys and the oxidized surface layer of natural sediment provides a distinct boundary on REMOTS photographs to indicate the original bottom prior to disposal. Consequently, future measurements of dredged material thickness should be accurately accomplished. Diving operations were successful in deploying transects with BDMD's and erosion/compaction stakes at both sites.



COMPARISON OF RPD DEPTH AND BOUNDARY ROUGHNESS VALUES
BETWEEN AUGUST, 1982 AND MARCH, 1983 AT THE FVP SITE

FIGURE 3-24

Although most measurements were completed prior to disposal, some disposal of Black Rock material took place at Cap Site #1 prior to the bathymetric survey. Observations of the disposal by personnel aboard the R/V UCONN revealed that these operations were not tightly controlled near the disposal buoy. Consequently, corrections will be made in future surveys to accomodate for this material.

3.2 Interim Surveys

In order to provide data for management of disposal operations, interim surveys and measurements were made on all sites. These were particularly important at the cap sites to insure tight control of contaminated Black Rock material prior to capping. The following sections present the results of these surveys for each disposal site within the CLIS site.

3.2.1 Cap Site #1

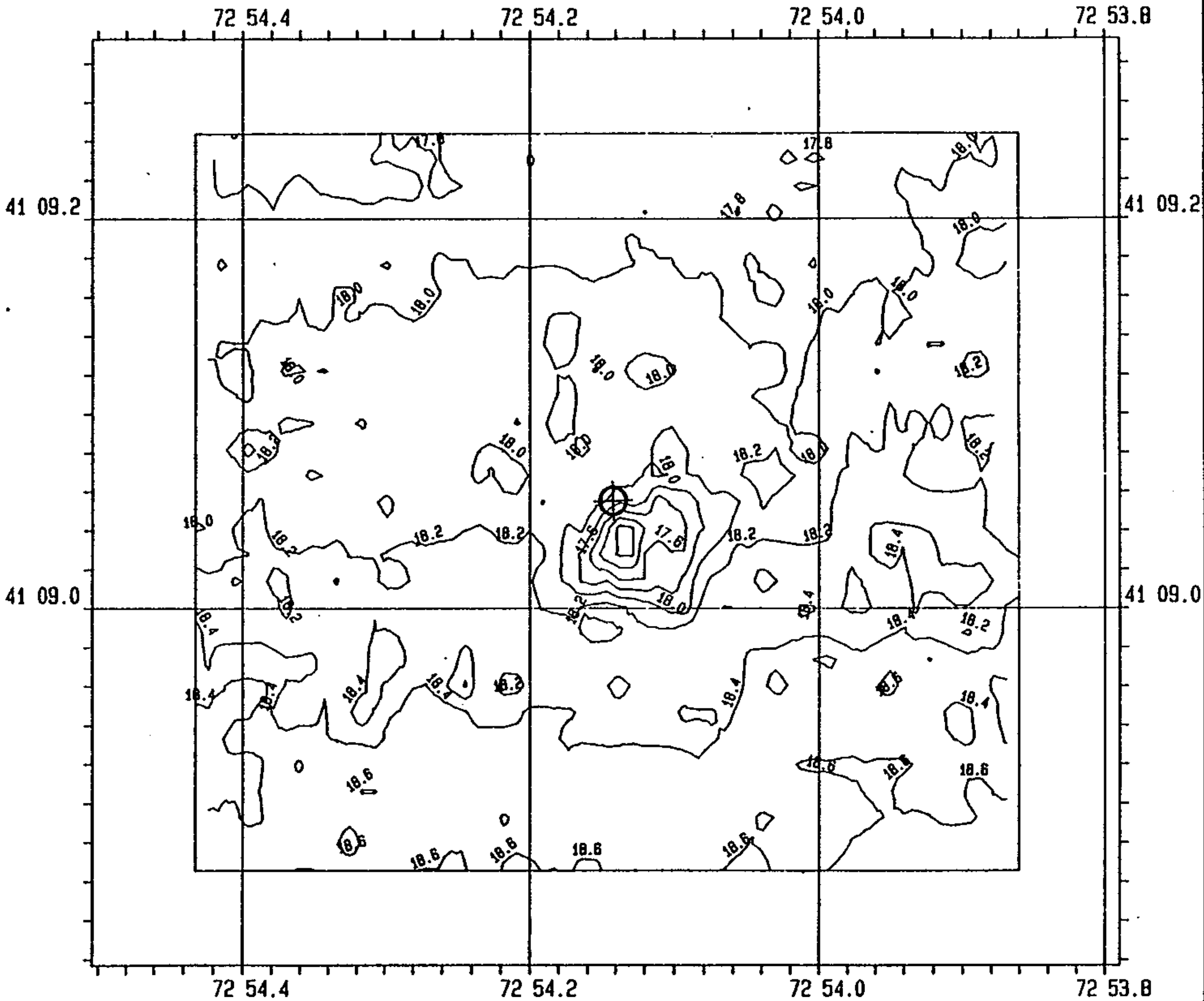
An interim bathymetric survey was conducted at Cap Site #1 on 28 April, 1983, following completion of Black Rock sediment disposal at the site. The results of that survey are presented in Figure 3-25, indicating development of a mound approximately 1 meter high with an average diameter of approximately 150 meters. A contour difference chart (Fig. 3-26) comparing this survey with the baseline data indicates similar conditions with most of the material located immediately southeast of the disposal buoy, but extending to the northeast. No topographic expression is evident from the material that was apparently disposed farther south of the buoy during the first stages of disposal.

Diving observations were conducted on 27 April to evaluate dredged material characteristics and to examine the condition of the BDMD and erosion/compaction stakes deployed prior to disposal. The sediment characteristics observed were typical of a post-disposal area. Cohesive, eroded clay and peat clumps, 0.3 - 1.0 meters in diameter, characterized the substrate. Their surface was consolidated and cohesive, yet current erosion was evident around the base of the more stable clumps. The clumps generally had a gray anoxic coloration and the surrounding sediment had a light brown oxygenated veneer (1-2 mm) over a black organic matrix, which was very soft and non-cohesive. The sediment surface consisted of less than 1% exposed shell fragments of oyster, scallop and clam, however, there was also some evidence of coarse material exposed on the mound. Considerable anthropogenic input, i.e. pipes and logs, were noted approximately 75m west of the BDMD. There was no evidence of bioturbation or infaunal colonization on areas covered with dredged material. No distinct conical central pile could be observed from the designated center of the BDMD. Areas northeast, south, and west of the center were flat and uniform, and there was no dredge material coverage along the first 10m of the east transect leg. At this point, dredged material coverage was approximately 1.5m at the BDMD and no declining slope was observed.

CAP SITE #1
PRE-CAPPING

APRIL 1983

FIGURE 3-25

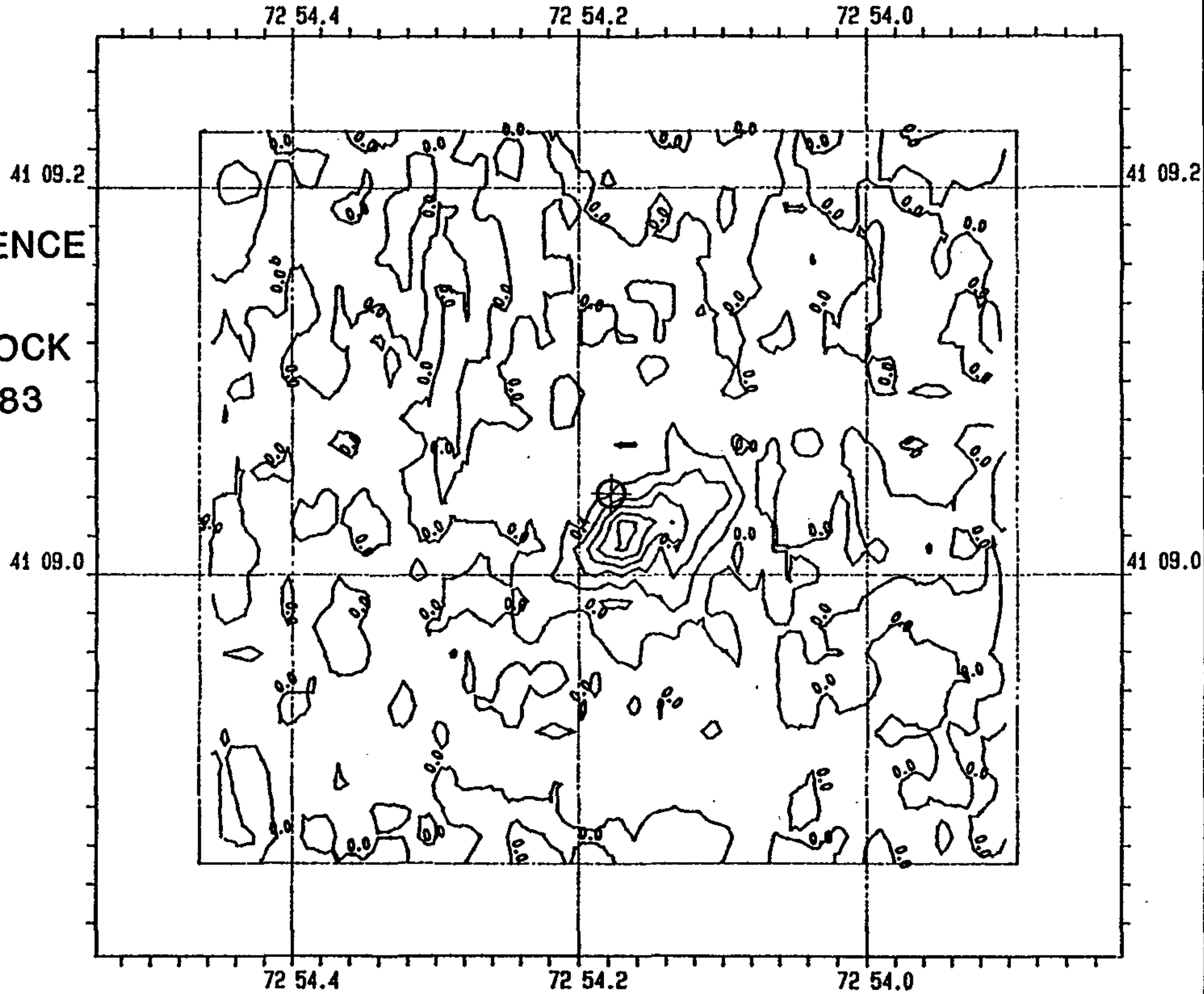


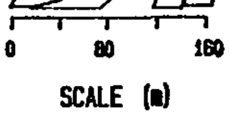
0 80 160

SCALE (m)

VOLUME DIFFERENCE
CAP SITE #1
POST-BLACK ROCK
7-28 APRIL, 1983

FIGURE 2-26





Figures 3-27 through 3-30 are representative photographs of dredged material observed at the cap site, following disposal of Black Rock material. Figure 3-27 is representative of the clay dumps observed on the site, while 3-28 indicates the presence of coarse sediment within the dredged material. Figures 3-29 and 3-30 reveal the presence of near shore shell fragments and debris within the dredged material. Only the BDMD and the first 10m of the eastern line of the erected transect array that was completed on 8 April 1983, were located during this study. Sweep searches were conducted for all the 10 foot PVC compaction stakes and none were successful. It must be assumed that either the array did not sustain direct impact by the barge loads and the stakes were sheared off by the resulting outward flow of material, or that the stakes may have been dislodged by commercial fishing traffic.

3.2.2 Cap Site #2

Following completion of disposal of Black Rock dredged material at Cap Site #1, the disposal buoy was moved to its Cap Site #2 position and further disposal took place at that point. During disposal at Cap Site #2, an interim survey was conducted on April 28, 1983 (Fig. 3-31). The contour chart of that survey revealed the formation of an elliptical mound approximately 60 cm thick at its maximum elevation and extending 250m on an east-west axis and 125m on a north-south axis. The contour difference chart (Fig. 3-32) verified the distribution of sediment close to the disposal buoy. Additional disposal continued after this survey until May 18th; consequently, the full distribution of Black Rock sediment at this site is unknown.

A side scan survey conducted over this site on May 11, 1983 produced results similar to those observed at Cap Site #1, however, the high reflectance areas associated with dredged material were more pronounced in the center of the site indicating satisfactory positioning of disposal operations. In addition, high reflectance areas were present in the east and northeast positions of the site, indicating some previous disposal.

Diving observations at this cap site also resulted in a loss of the erosion/compaction stakes although the BDMD was found intact at a later date. The sediment observed at this location was similar to that at Cap Site #1, and although no mounding or slope could be detected, the material was more prevalent in the vicinity of the disposal buoy.

3.2.3 MQR Site

Initial disposal at the MQR site in 1983 consisted of point disposal of a small quantity of sediment from Bridgeport and Black Rock Harbors, which was relatively high in heavy metals and organic content. This material was then capped by the large volume of sediment dredged from New Haven Harbor.

Based on the results of previous capping operations

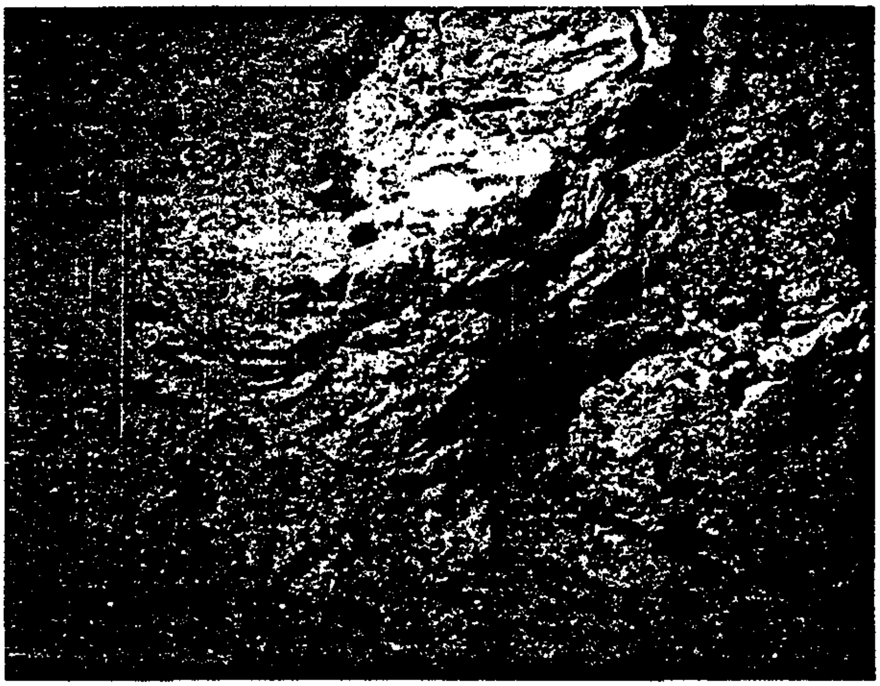


FIGURE 3-27 Cap Site #1 Interim Survey
Fractured clay clump subject to erosion following deposition.

FIGURE 3-28 Cap Site #1 Interim Survey
Evidence of coarse grained sediment in
Black Rock dredged material.

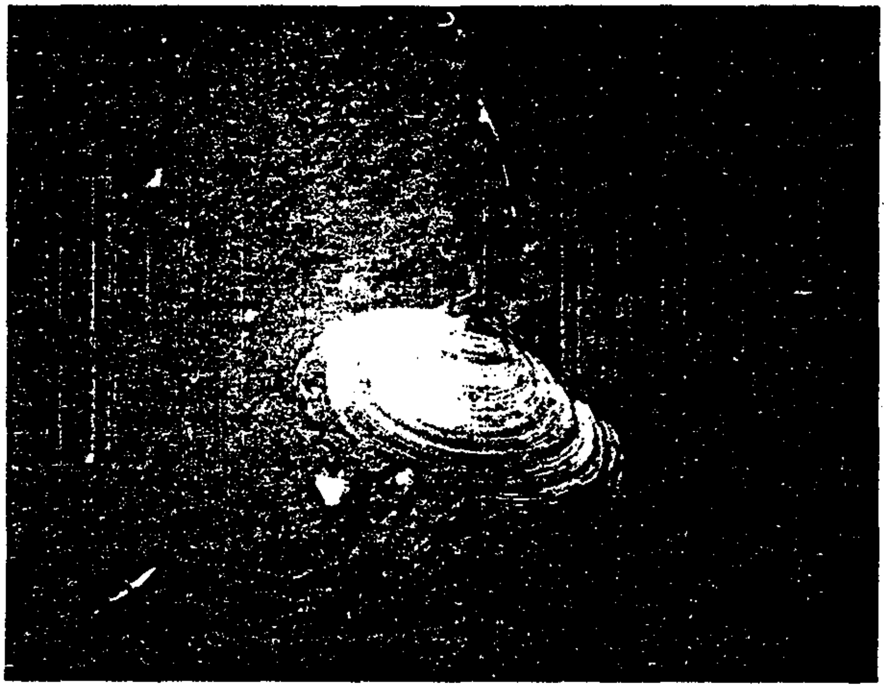


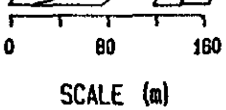
FIGURE 3-29 Cap Site #1 Interim Survey
Mya arrenaria shell indicative of shell material transport within dredged material.

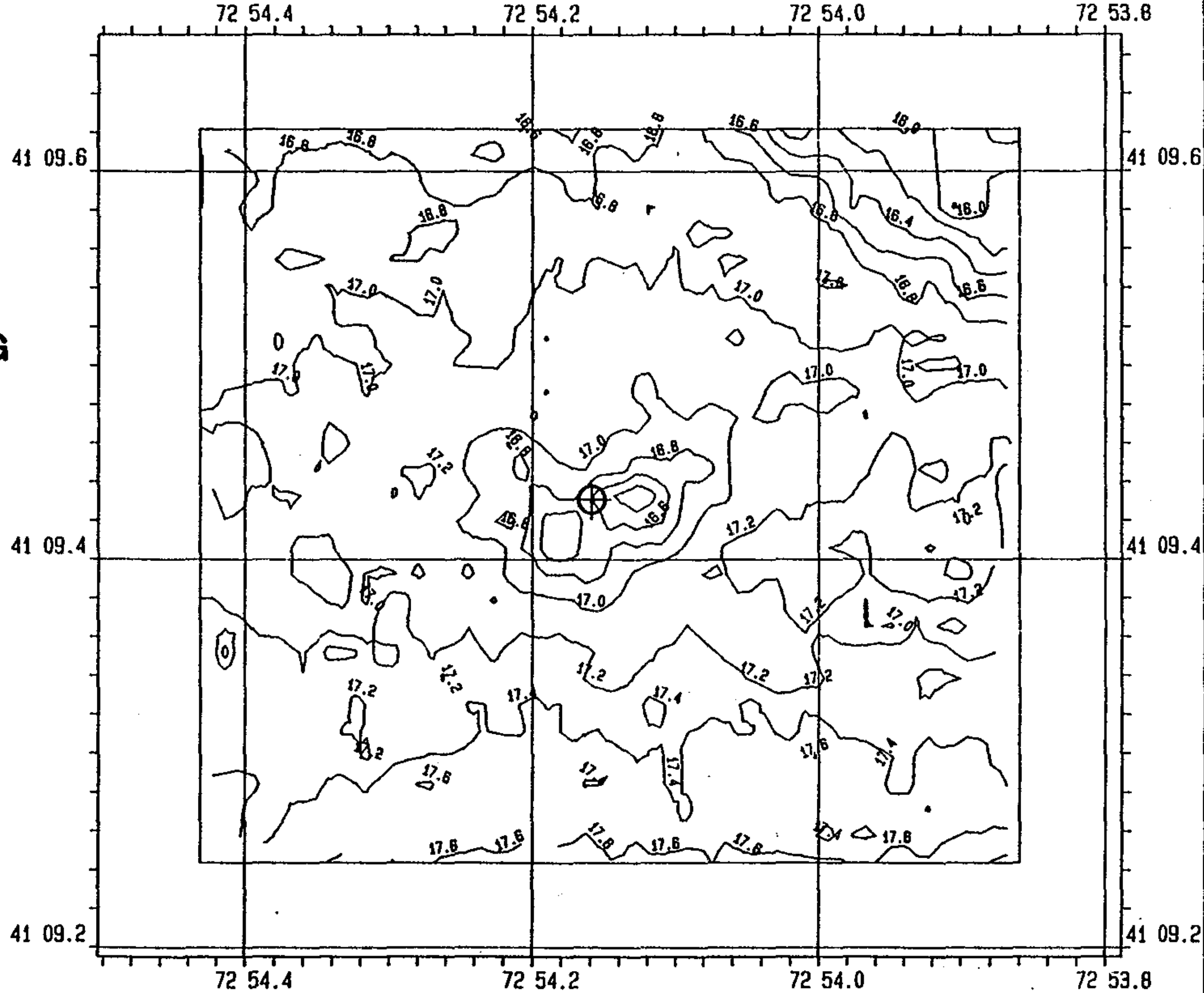
FIGURE 3-30 Cap Site #1 Interim Survey
Wood debris deposited as part of Black
Rock dredged material.

CAP SITE #2
PRE-CAPPING

APRIL 1983

FIGURE 3-31

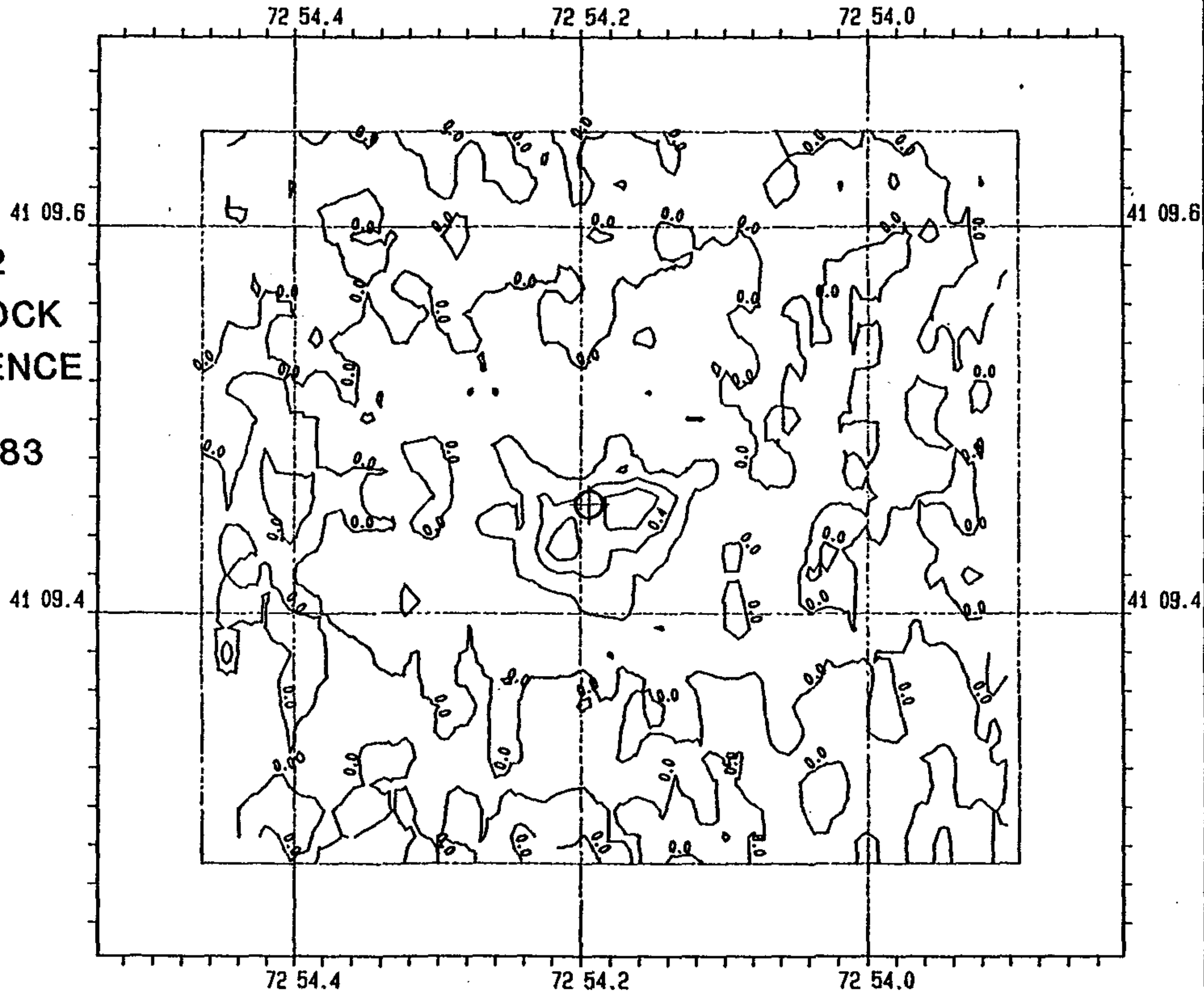




CAP SITE #2
POST BLACK ROCK
VOLUME DIFFERENCE

7-28 APRIL,1983

FIGURE 3-32



0 80 160

SCALE (m)

with New Haven material, and because of the large volume of sediment to be dredged, a Loran-C controlled navigation system was used to spread the capping sediment over a larger area rather than develop a steep sided mound using point dumping procedures. This disposal control system, as described earlier, was programmed with ten different disposal points arranged concentrically at distances of 80 and 120 meters from the center of the site. By sequencing through these points, the dredged material was spread evenly over the bottom and a record of each disposal was obtained.

Although some problems were experienced due to loss of Loran-C signals, (at which time disposal took place at the "SP" buoy) the system was successful in distributing the dredged material over the designated area. Figure 3-33 is a contour chart of an interim bathymetric survey conducted on May 6, 1983. At this time, approximately 70% of the dredging had been completed and the mound at the MQR site had expanded to a roughly circular configuration with a diameter of 400m and an average thickness of approximately two meters.

Following completion of the bathymetric survey, a series of grab samples were obtained on N-S and E-W transects across the mound. As in previous capping operations, the thickness of dredged material decreased rapidly beyond the flanks of the mound to a 1-2cm layer at distances of 400m from the center of the site. Traces of material were present, however, at distances up to 1000 meters, particularly on the west transect.

In summary, the disposal of New Haven material at the MQR site was accomplished efficiently and effectively so that a large volume of material was disposed of in a relatively small area. A uniform cover was provided without creating a steep-sloped conical mound, which would have been more susceptible to wave action and, consequently, less stable as a cap. Based on this survey, controlled distribution of disposal points appeared to be an effective method for placement of capping material.

3.2.4 FVP Site

Disposal of contaminated Black Rock sediment was carefully monitored at the FVP site through a series of interim surveys. The first of these, on 28 April, 1983, was conducted to assess the conditions of the site, as the first loads of sediment were deposited. The results of this survey (Fig. 3-34) indicated that a small mound had formed in the vicinity of the disposal buoy and, therefore, that additional disposal should create the desired mound.

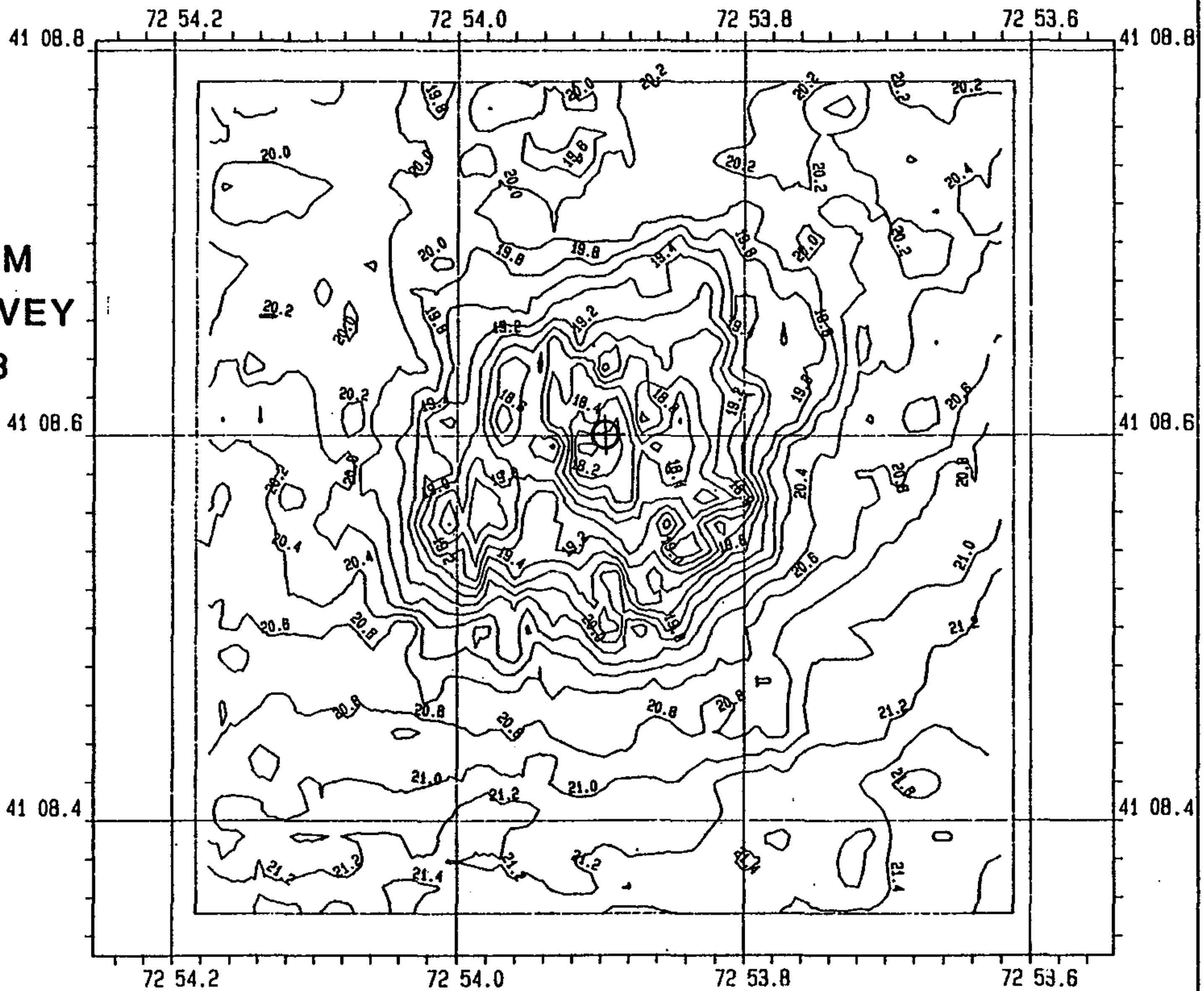
A second interim bathymetric survey and associated side scan survey were conducted on May 5, 1983, after the disposal of approximately 35,000m^3 of dredged material had been completed. The results of this survey (Fig. 3-35) were also satisfactory as a small mound approximately 150m in diameter had formed at the buoy with a topographic relief of more than one meter. Sediment

CLIS
MQR INTERIM
DISPOSAL SURVEY
MAY 1983

FIGURE 3-33

0 80 160

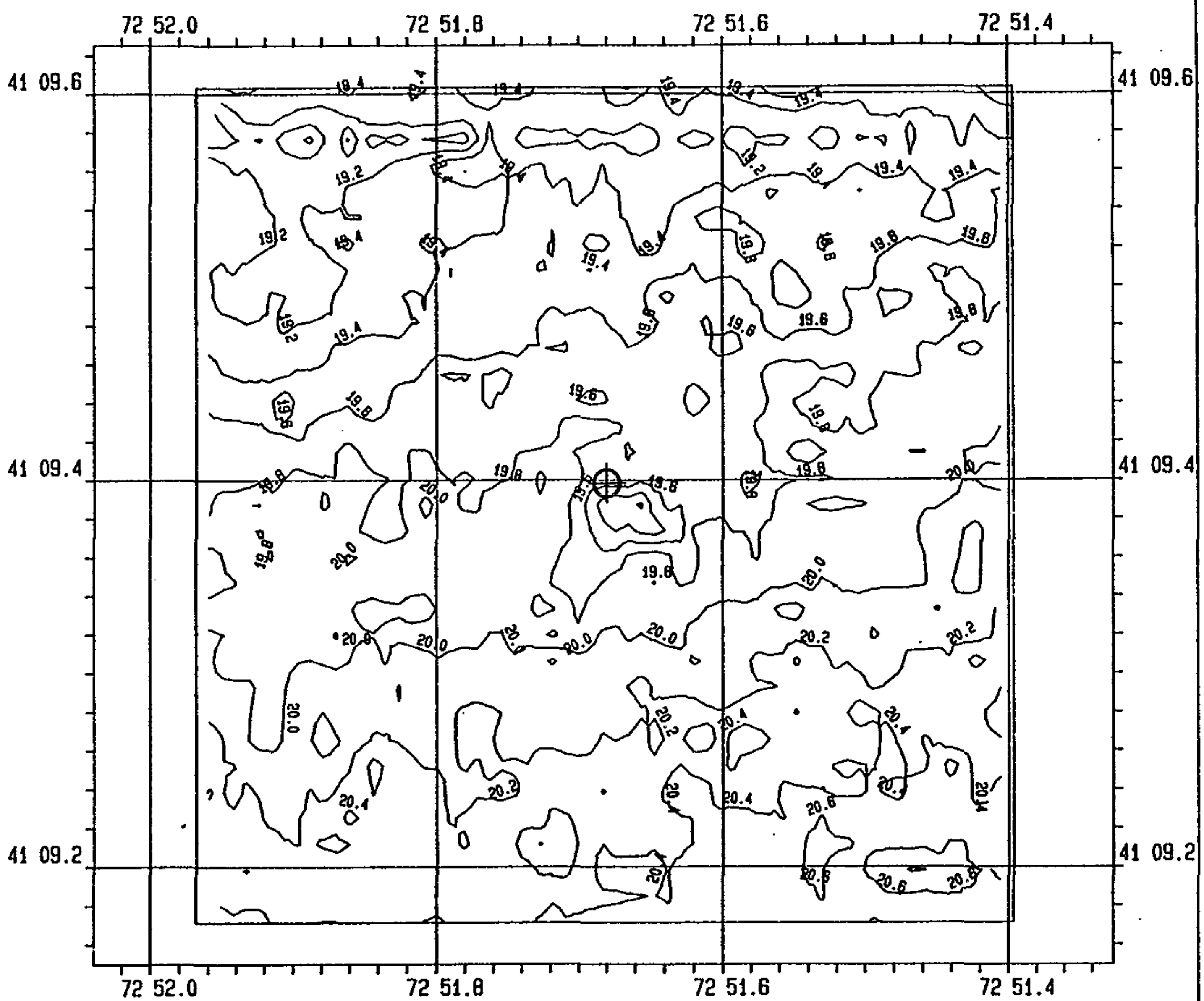
SCALE (m)



FVP INTERIM

APRIL 1983

FIGURE 3-34



0 80 160

SCALE (m)

FVP

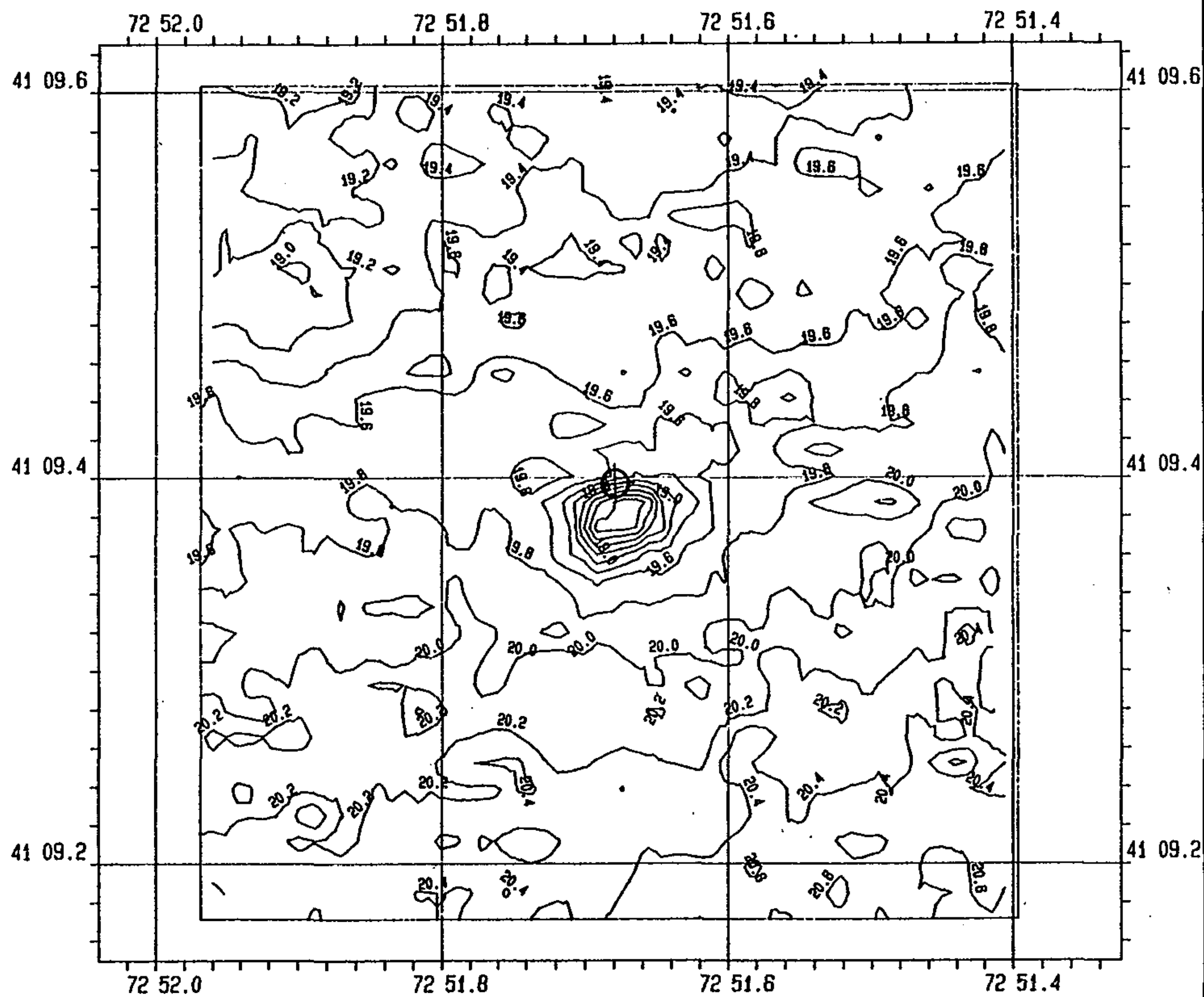
INTERIM

MAY 1983

FIGURE 3-35

0 80 160

SCALE (m)



samples taken at the same time revealed a covering of several centimeters thickness which extended out to a range of 200m on the east and slightly farther on the west side of the mound. This covering consisted of fine black organic silt with a high water content and low cohesiveness. The sediment appeared to be quite fluid and in the process of mixing with the natural fluff layer at the site.

A side scan survey, conducted on the same day, revealed some interesting results. The mound created by the disposal operation was conspicuous as a region of high reflectance superimposed on the natural mud furrows at the site (Fig. 3-36). An interesting feature is also shown in Figure 3-37, indicating an area of high reflectance created by scow leakage after disposal. The record follows the usual track of scows at they leave the disposal point heading south and then turning and proceeding west. It is puzzling that only one track can be seen, since if this were a common phenomenon, more examples would be present. However, if such leakage does occur, then it is a mechanism for dispersion of some amount of contaminants even if the point dumping operation is generally successful.

3.2.5 Summary of Interim Conditions

The primary objective of the interim surveys at all sites was to evaluate the condition of Black Rock sediment during disposal to insure that distribution over the bottom could be sufficiently controlled to permit future capping operations. In general, the results indicated that such an operation would be feasible since relatively small mounds were created at all locations. Some caution should be exercised, however, since the sediment appeared to be a combination of typical dredged material with cohesive gray clumps and coarse grained sediment that was interspersed with a soft, non-cohesive matrix with the potential to spread over larger areas. However, evidence from side scan surveys and sediment samples from the FVP site indicate that such spreading is not significantly more extensive than that observed on previous disposal operations at this site (Morton, 1979). Measurements at the MQR site indicated that New Haven sediment dumped using a Loran-C controlled system could be spread evenly over a relatively large area in a manner that would be suitable for capping operations.

In summary, the interim surveys supported the expected conditions and indicated that capping of contaminated Black Rock Harbor sediment with New Haven material was a feasible operation.

3.3 Post-Disposal Surveys

Immediately following completion of dredging and disposal, a series of surveys were conducted to assess the results of the disposal operations and to establish a new baseline for post-disposal monitoring procedures. The following sections present the results of these studies.

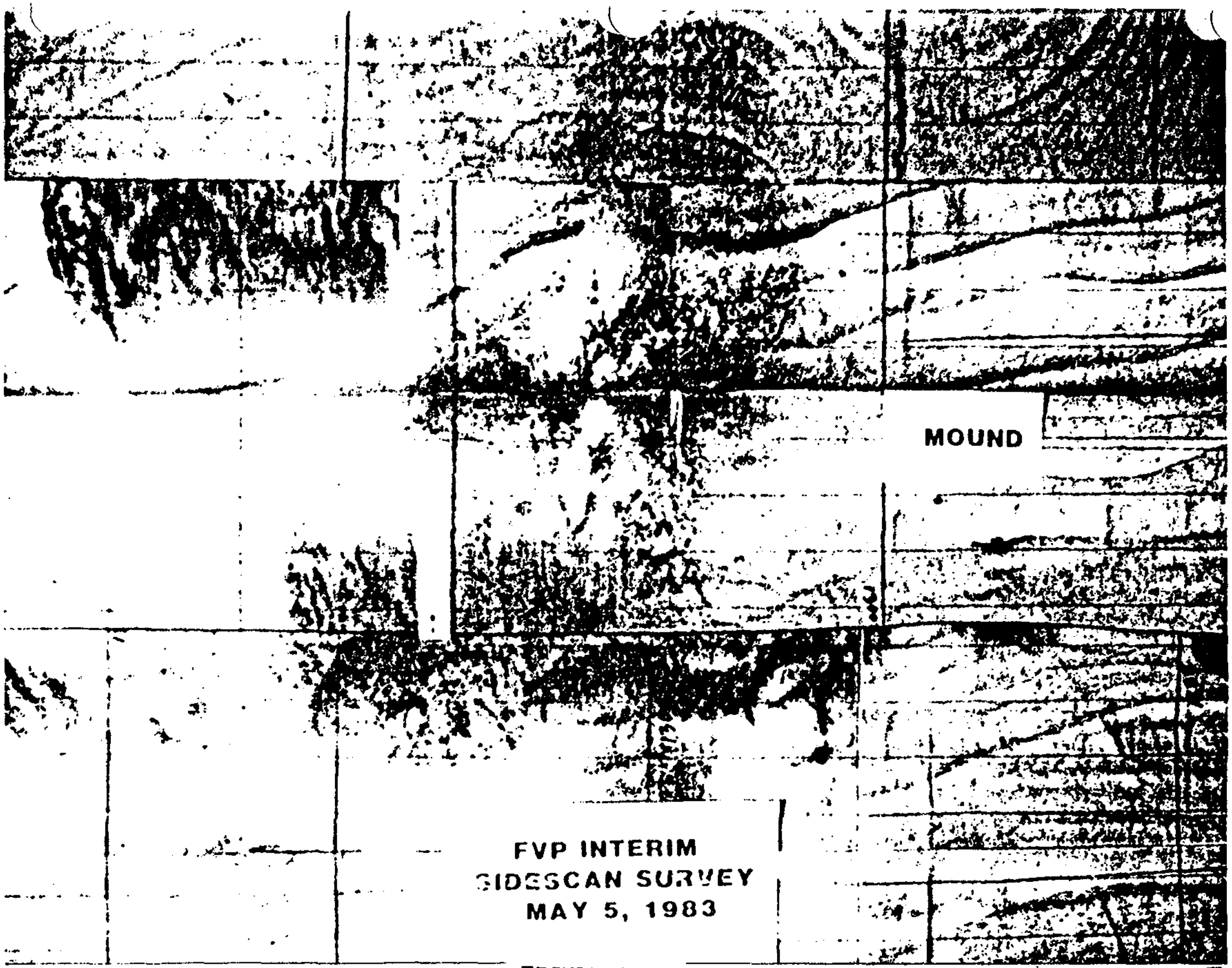


FIGURE 3-36

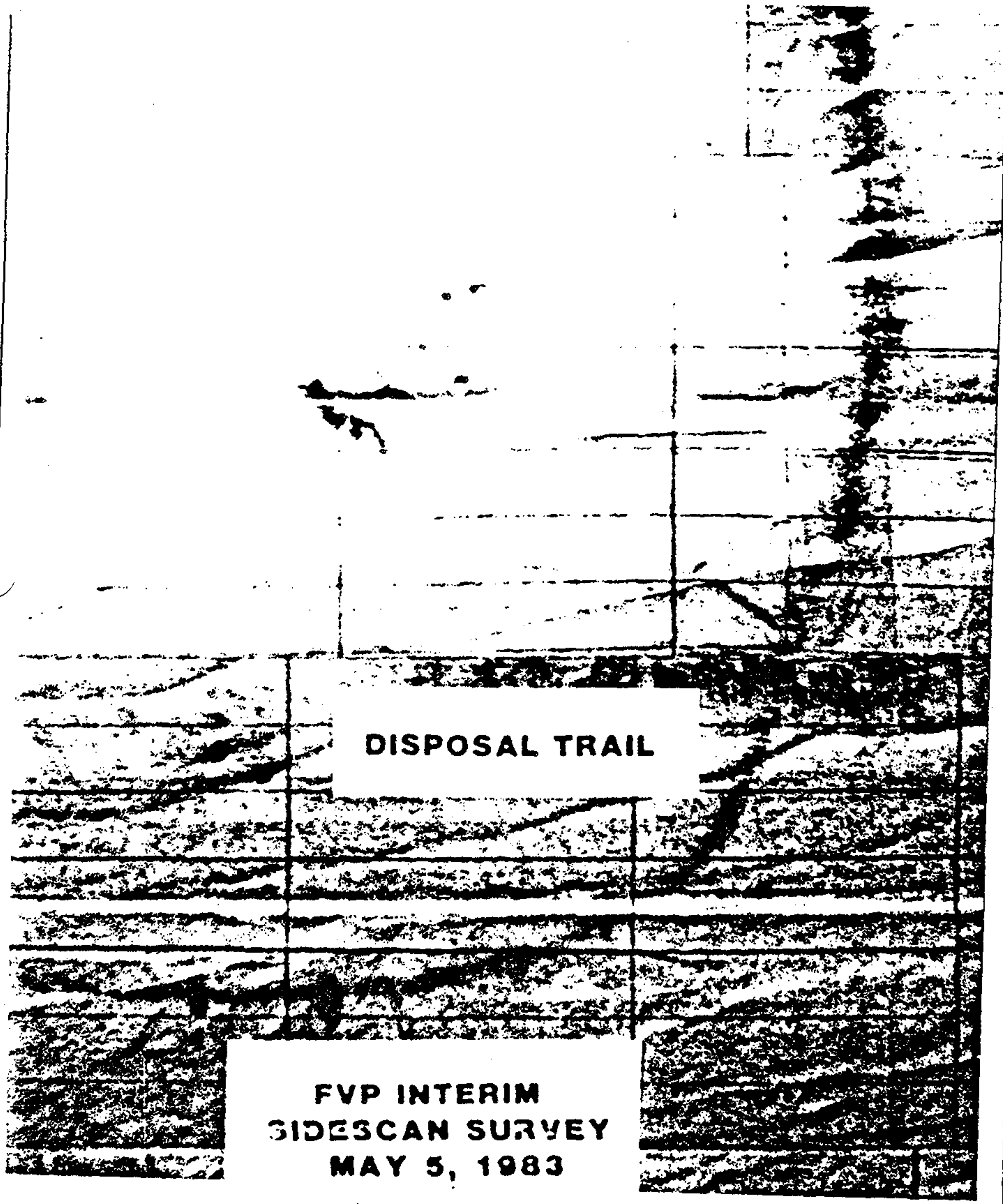


FIGURE 3-37

3.3.1 Cap Site #1

Capping operations designed to cover Black Rock Harbor sediment at Cap Site #1 with silt from the upper portion of New Haven Harbor were conducted over a period from April 18 to May 23, 1983. Disposal took place with the same large scows and Loran-C disposal control systems used at the MQR site. However, since the mounds created by the point dumping of Black Rock material were quite small, a decision was made to input only one disposal location to the computer. Assuming a random distribution of errors about this point, it was felt that adequate distribution of capping material would be accomplished.

Figure 3-38 presents the designated disposal point and the actual location of specific disposal events to develop a cap from New Haven material. From this chart it is readily apparent that nearly all disposal took place to the southwest of the designated site, not in a random pattern as expected.

An explanation for this phenomenon may be related to the fact that the scows were approaching the point from the north and may have overshot the destination prior to disposal. However, most of these errors are on the order of 100m or more, and do not appear consistent with previous operations. Although a reason for this affect cannot be fully determined, the fact that disposal generally took place to the southwest is reflected in the sediment distribution determined from a post-disposal monitoring survey during June 1983 (Fig. 3-39).

From this survey and the contour difference chart (Fig. 3-40), derived from a comparison of the June and April surveys, the deposition of cap material to the southwest of the Black Rock sediment can be clearly seen. The resulting mound is approximately 250 meters in diameter in a southwest-northeast direction and 175 meters on a perpendicular axis. However, the NE 50 meter segment of the mound is essentially unchanged in depth indicating that no significant coverage in that area was accomplished. Based on these data, insufficient capping of Black Rock material, particularly on the eastern margins of the mound, has occurred.

A side scan survey of the area provides little additional information relative to the distribution of material as there are no significant differences between the acoustic reflection of the Black Rock and New Haven dredged material. However, Figure 3-41 does indicate the restricted distribution of side scan signal indicating that most of the disposal material remains in a relatively small area.

Diving observations at Cap Site #1 indicated that general sediment conditions three weeks after the last disposal operations were atypical of recently dumped material. The sediment surface was a flat, featureless, soft, oxidized mud with only a patchy distribution of 10-100cm clay clumps, and 1 year old scallop shells. The top 1cm of sediment was easily suspended by agitation and below 2-3cm was aerobic black in color. Below

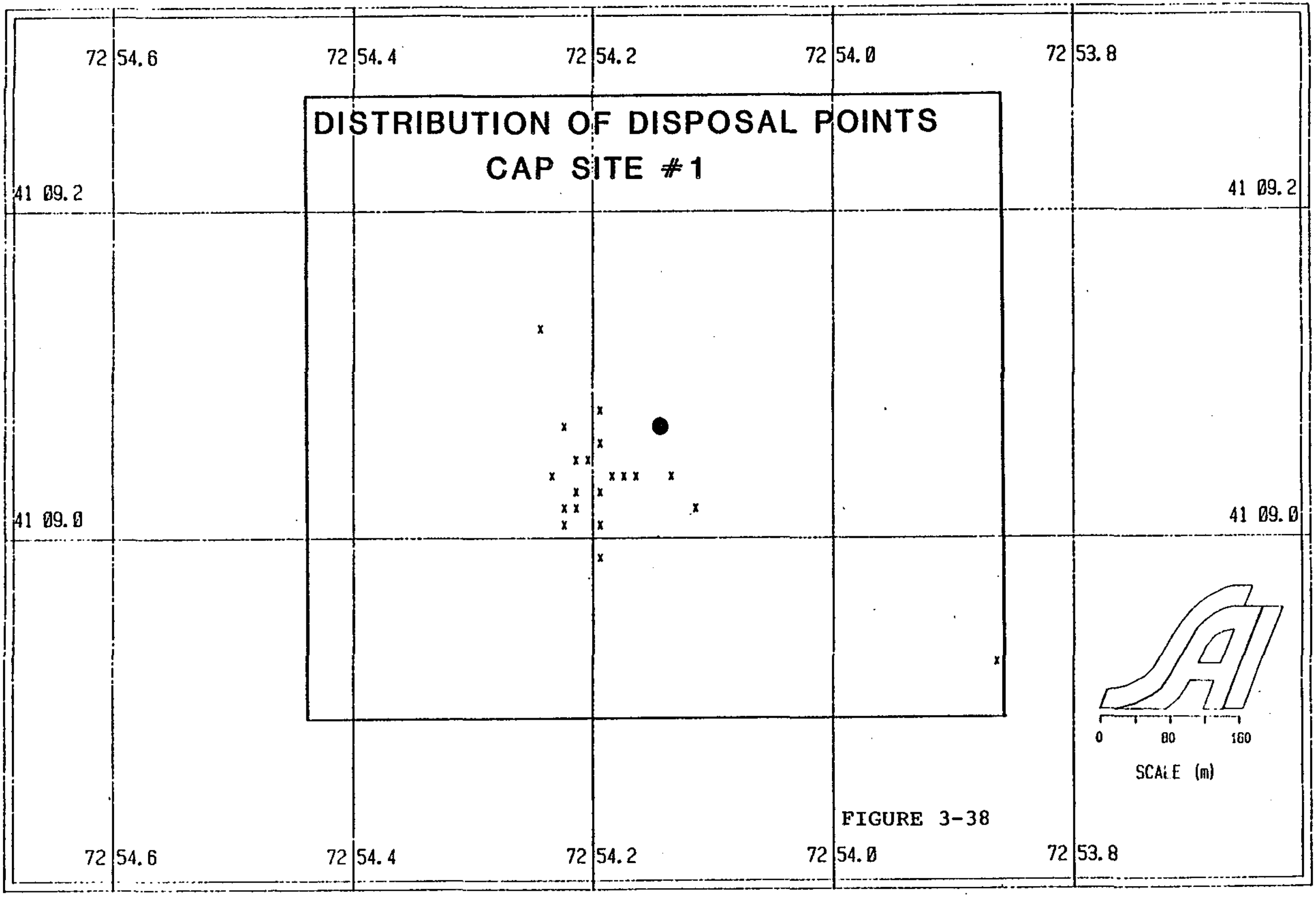
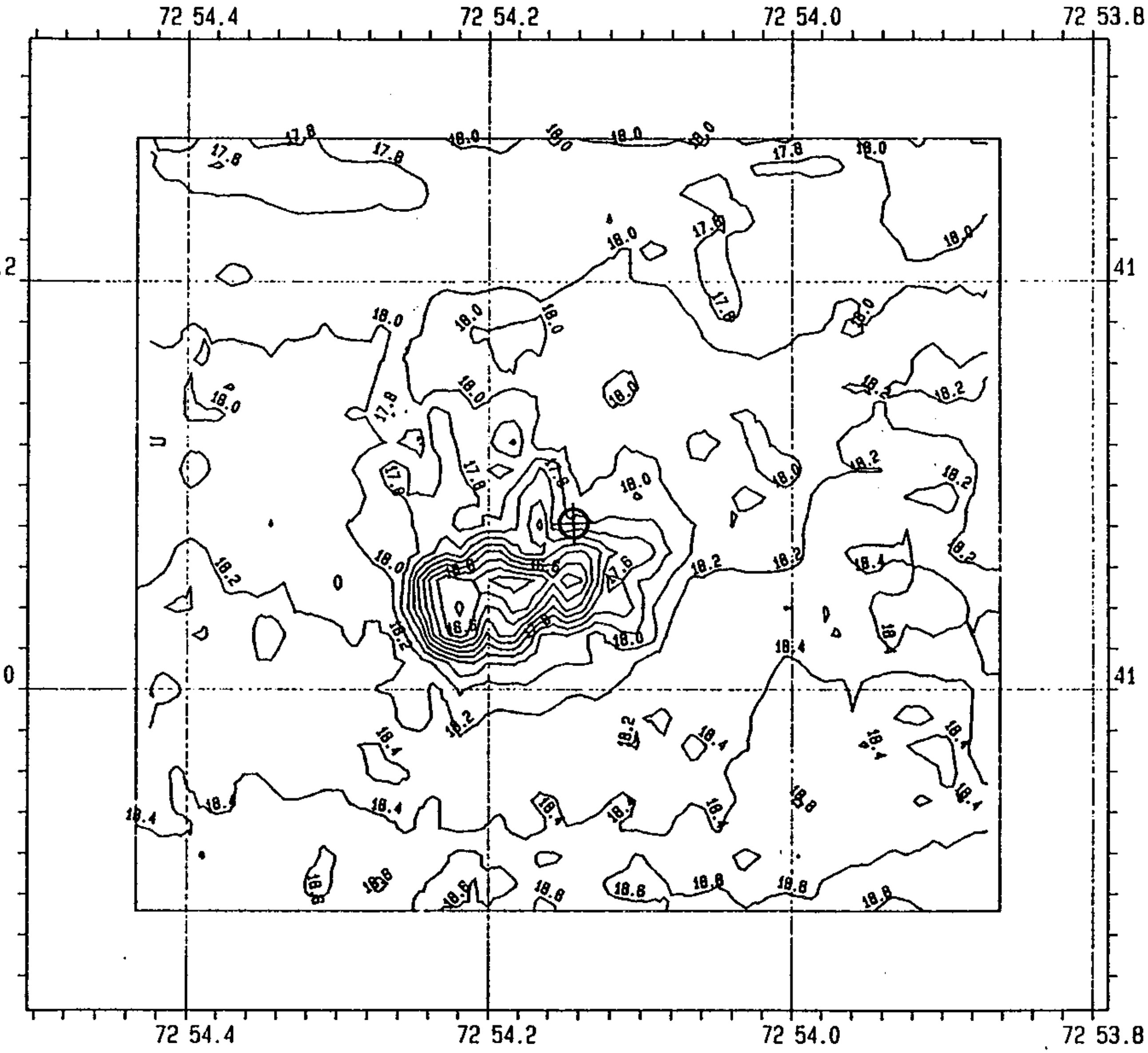

DISTRIBUTION OF DISPOSAL POINTS
CAP SITE #1
72 54.6
72 54.4
72 54.2
72 54.0
72 53.8
41 09.2
41 09.0
0
80
160
SCALE (m)

FIGURE 3-38

CAP SITE #1 POST-DISPOSAL

JUNE, 1983

FIGURE 3-39

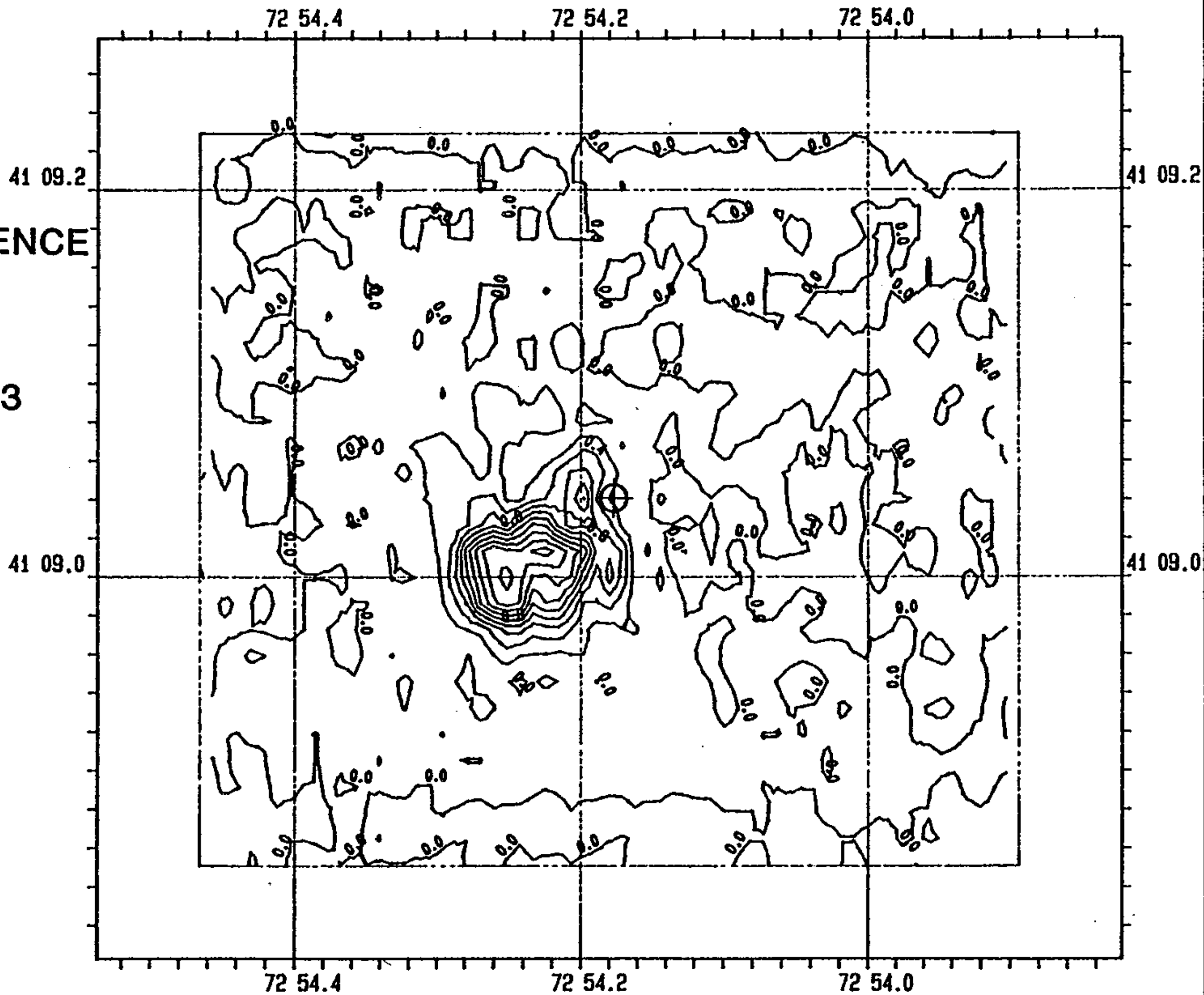


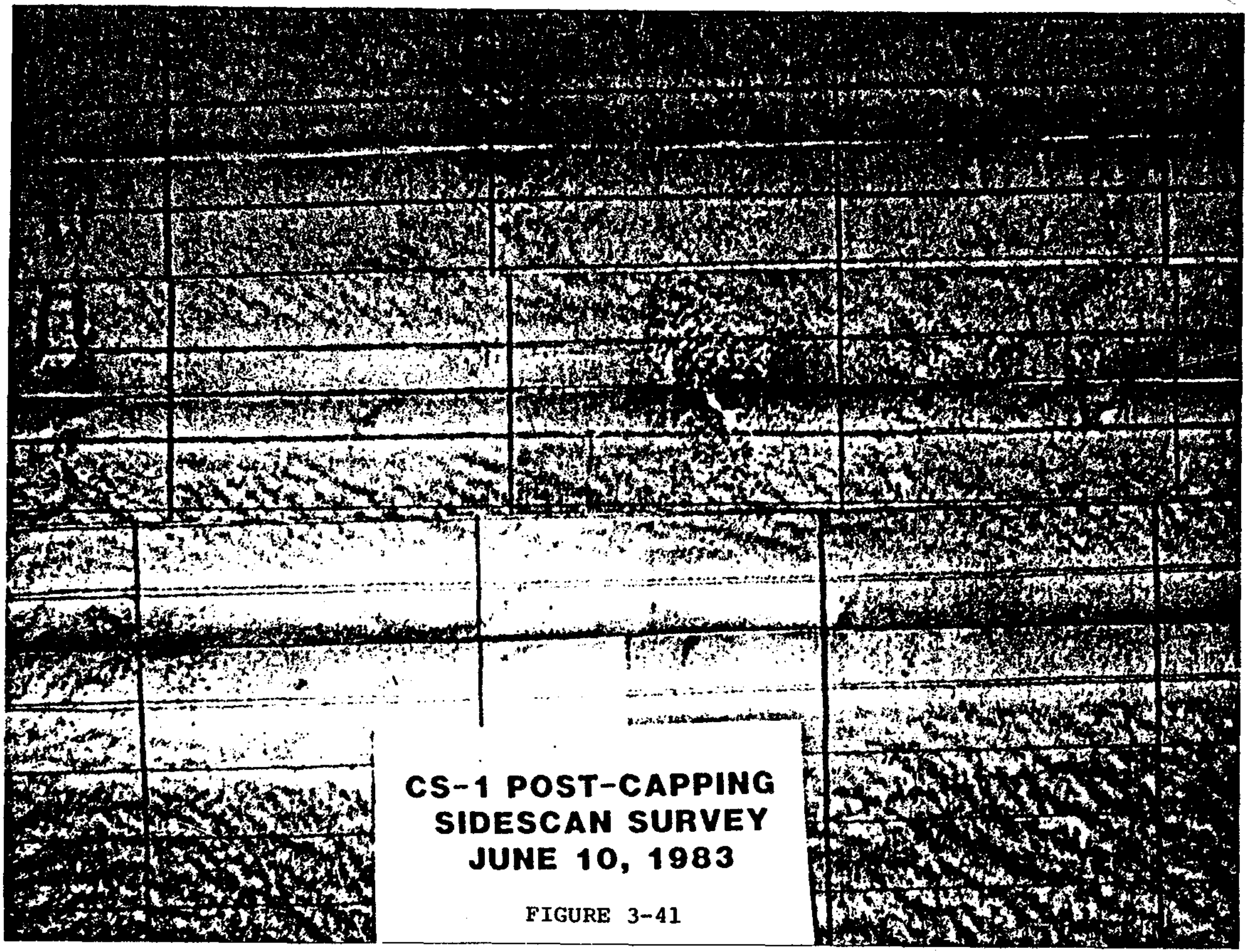
SCALE (m)

0 80 160

VOLUME DIFFERENCE
CAP SITE #1
CAPPING
APRIL-JUNE, 1983

FIGURE 3-40





CS-1 POST-CAPPING SIDESCAN SURVEY JUNE 10, 1983

FIGURE 3-41

2cm, the sediment was cohesive. There was no apparent bioturbation at this stage. A typical description of recently dumped material would consist of more topographic relief, composed of clay clumps interspersed with a fine matrix of dredged material. Based on these observations, dives were probably conducted over uncapped Black Rock sediment.

On 29 June 1983, five weeks after completion of the capping phase at this disposal site, an erosion stake array was deployed at the center of the site (Fig. 3-42). A 75m east/west transect line was positioned over the sediment with 25m east of the center and 50m west of the center. Seven 1 meter, 3.8cm diameter erosion stakes were positioned at the locations shown in the figure so that exactly 30cm were above the sediment/water interface and 70cm were driven into the sediment. After this deployment, the BDMD pole was located 10m north and 15m east of the center of the erosion stake array.

3.3.2 Cap Site #2

A similar situation developed at Cap Site #2 as a result of disposal operations conducted in the same manner as those at Cap Site #1. Figure 3-43 presents a series of disposal events occurring during capping operations from May 30 through June 3, 1983. A similar pattern of disposal to the southwest occurs, however, the errors are not as large as those described at Cap Site #1. This is probably because the disposal buoy was still in place during this period and served as a reference for tug operators. Radio communication with the Corps inspector aboard the ship confirmed that the disposal position output by the computer was correctly located south of the buoy, so it is clear that the offset in location is not due to Loran-C calibration error. During capping operations at CS #2, some problems developed with operation of the Loran receivers; consequently, when this occurred, disposal was accomplished using the buoy as a reference. This resulted in better control of cap placement compared to CS #1, but fewer disposal events were recorded by the computerized system.

The results of capping with sand from the outer portion of New Haven Harbor are presented as a contour chart in Figure 3-44 and a contour difference chart in Figure 3-45. As in the Cap Site #1 situation, most of the material has been deposited south and west of the disposal point and although there is coverage over the entire Black Rock deposit, it is only 20-40cm thick on the eastern borders while it may be as much as 1.4 meters thick on the western margin. The resulting mound is roughly shaped as an equilateral triangle, pointing south from the disposal point with sides approximately 250 meters in length.

A post-capping side scan survey also revealed conditions similar to Cap Site #1 with the mound identified as a very strong reflector (Fig. 3-46) in the center of the survey. The strong reflectance associated with sand deposits and the cratering characteristic of disposal operations were evident on

CAPSITE 1

FINAL TRANSECT ARRAY
29 JUNE 1983

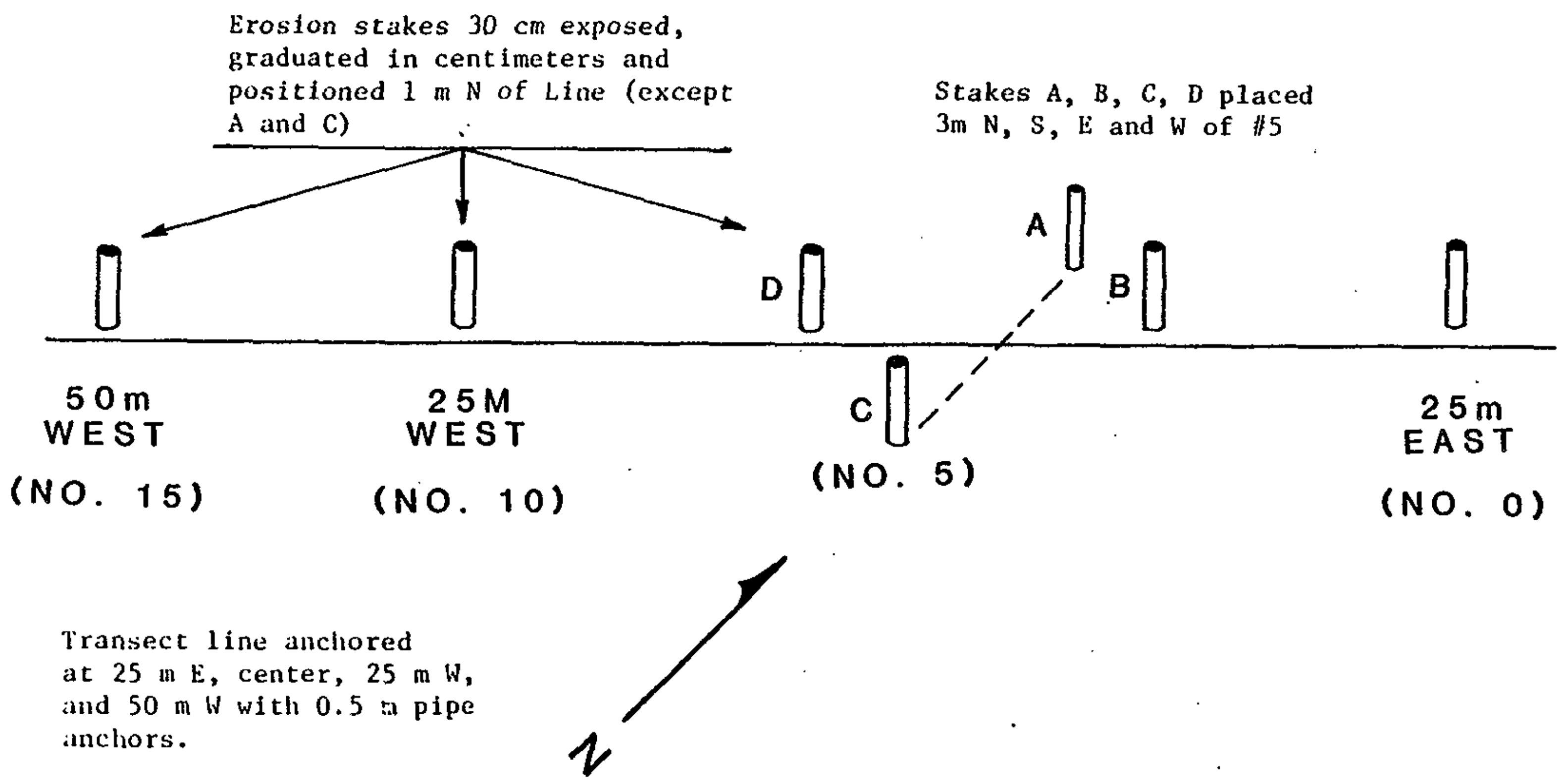
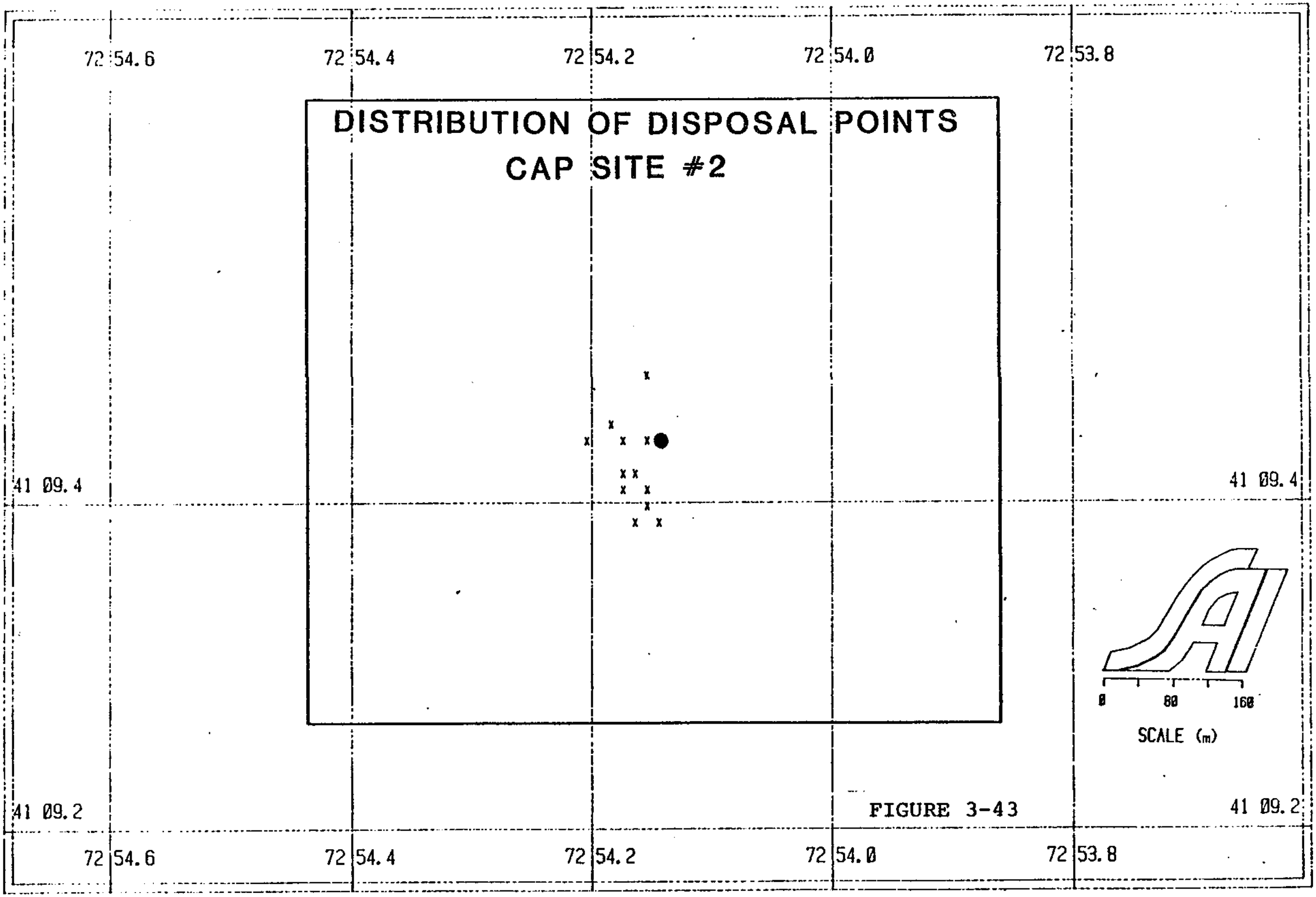


FIGURE 3-42



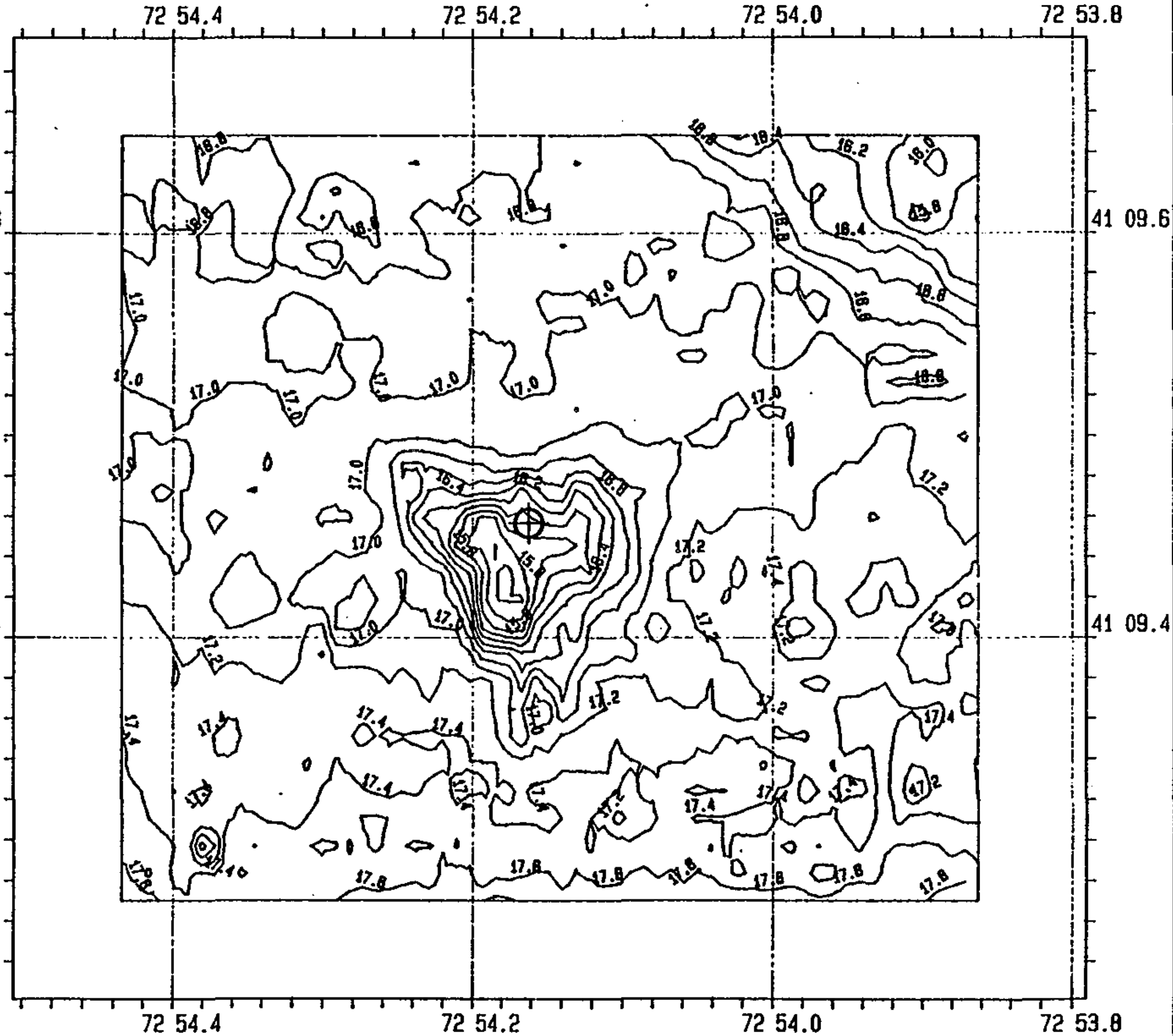
DISTRIBUTION OF DISPOSAL POINTS
CAP SITE #2

FIGURE 3-43

CAP SITE #2 POST DISPOSAL

JUNE, 1983

FIGURE 3-44



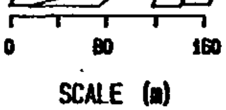
0 80 160

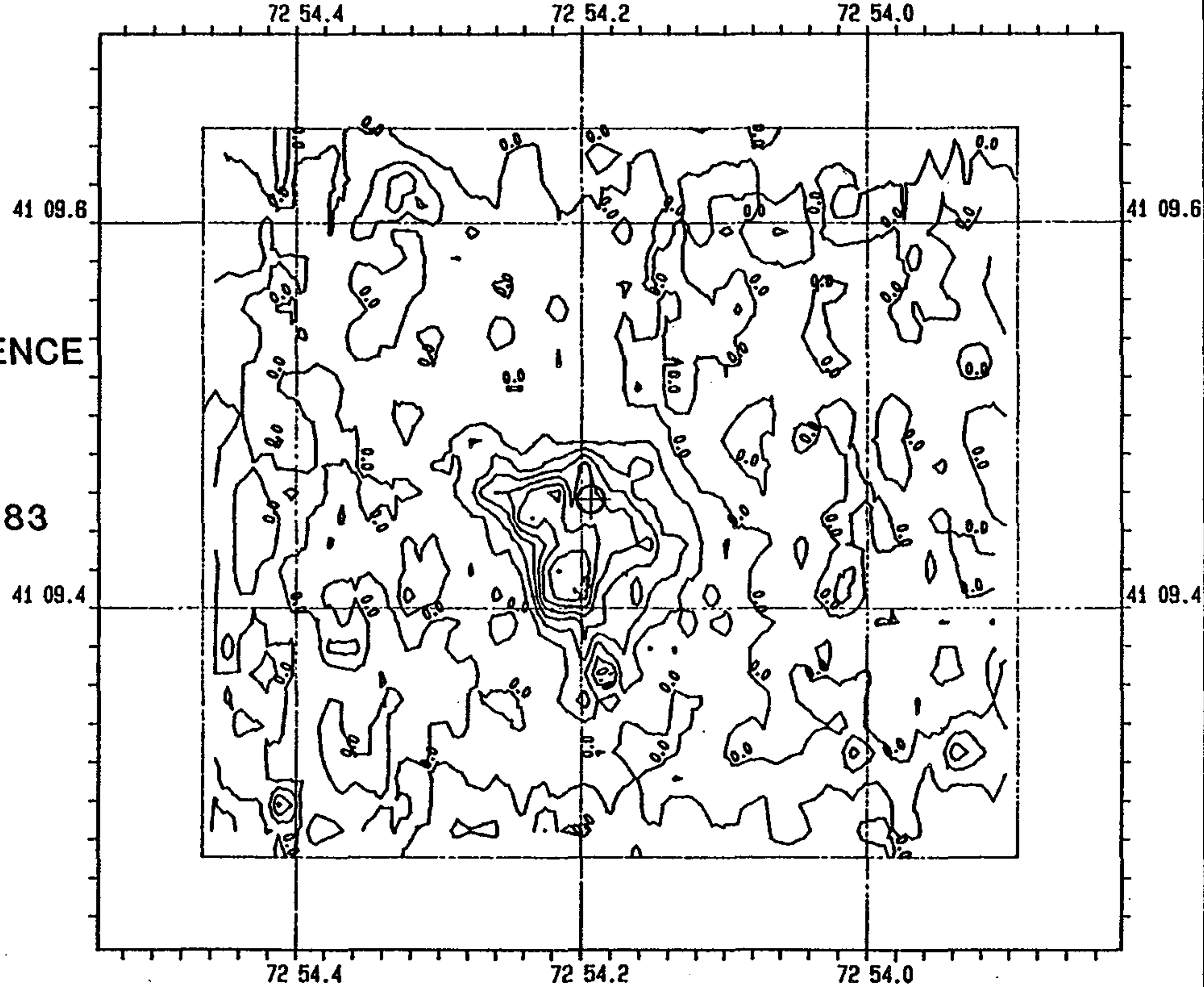
SCALE (m)

CS #2
VOLUME DIFFERENCE
CAPPING

APRIL-JUNE,1983

FIGURE 3-45





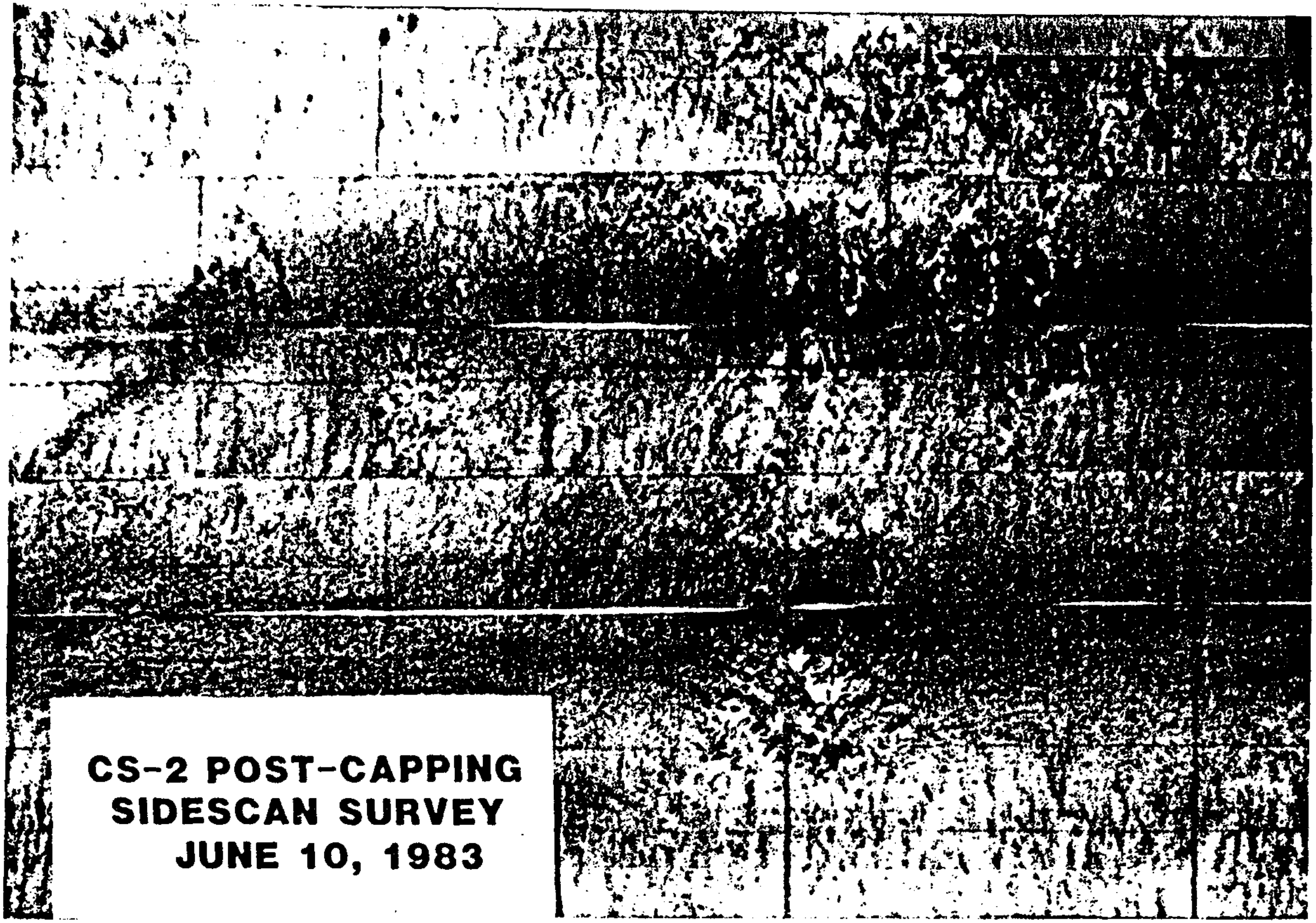


FIGURE 3-46

this record, providing supporting evidence of a relatively small aerial distribution of the mound.

Diver observations at this site indicated that sediment surface conditions near the center of the site consisted of 2cm of fine sand over a layer of hard sandy gravel. The fine sand had obvious current ripples running north/south, with a crest to crest period of 5-8cm and 2-3cm trough. This sediment type was not uniform over the whole center of the site. Surface distribution of shell fragments, clay clumps and anthropogenic input was patchy, but prominent during every diver transect. Shell hash was incorporated into both clay and sand material. Some randomly distributed clay clumps, 10-30cm in length, were of high organic content (black in color), with a 2mm brown oxidized veneer. Anthropogenic input included wood debris, scraps of metal and clothing. General topography of the site was marked by rapid 1-2m changes in slopes. The only obvious bioturbation of the sediment was at the periphery of the dredge spoil where four lobster burrows were observed under a 30-foot piling and Asterias forbesii was observed during foraging activity.

An erosion array was deployed on 22 June 1983 for monitoring over the long term post-disposal period. A 50m line was positioned due west from the BDMD and one meter long erosion stakes were driven into the sediment to a depth of 70cm at the positions indicated in Figure 3-47. These erosion stakes are PVC pipes graduated in centimeters so that they can be read during future diver surveys.

3.3.3 REMOTS Observations at CS#1 and CS#2

A REMOTS photographic survey was obtained at both cap sites following completion of disposal to assess the distribution of material and to evaluate the thickness of capping deposits over Black Rock sediment. On June 13, 1983, 11 stations were sampled at each cap site. These were the same stations occupied in the pre-disposal survey of April 6, 1983 (Fig. 3-10). The results of this initial survey were used to determine additional stations so that the second survey, made on June 14, was able to cover the full perimeter of the dumped area. On June 14, 1983, 36 additional stations were sampled, making a total of 58 stations (Fig. 3-48). One sample was taken at each station to determine the thickness of Black Rock sediment and the overlying cap material. Thicknesses exceeding the length of the REMOTS prism window are indicated on subsequent figures by a " > " preceeding the penetration value for that station. All of the flank regions of the mounds were less than 19cm deep; therefore, an accurate map of most of the disposal stratigraphy could be developed.

The pre-disposal surface was recognized by the presence of an oxidized (high reflectance) mud buried below the low reflectance Black Rock harbor sediment. The sandy material from CS#2 was also easily recognized as its grain-size was much coarser than the silt-clay of the underlying Black Rock material (Fig. 3-49a). The cap material at CS#1 was "clean" mud, which was visually indistinguishable from the underlying Black Rock

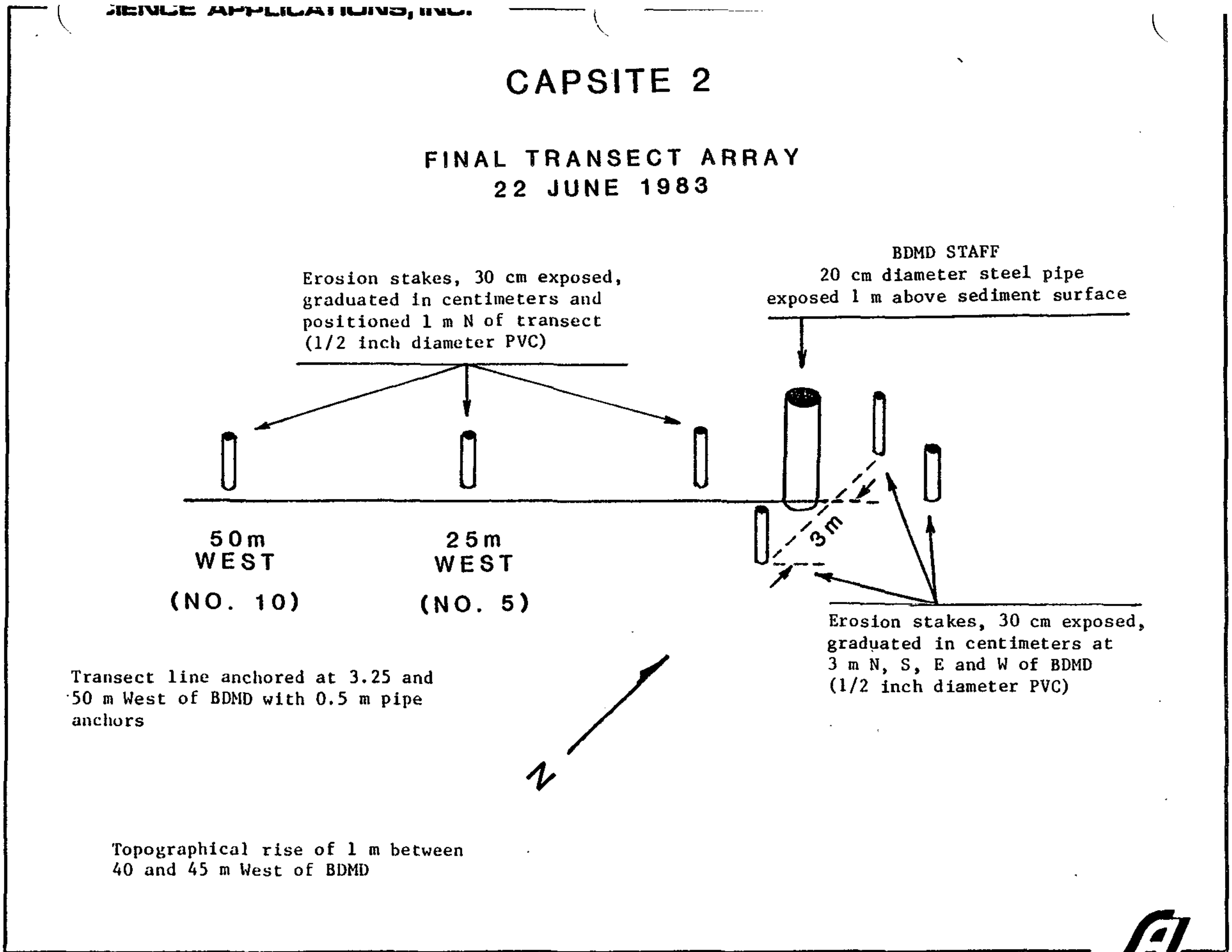
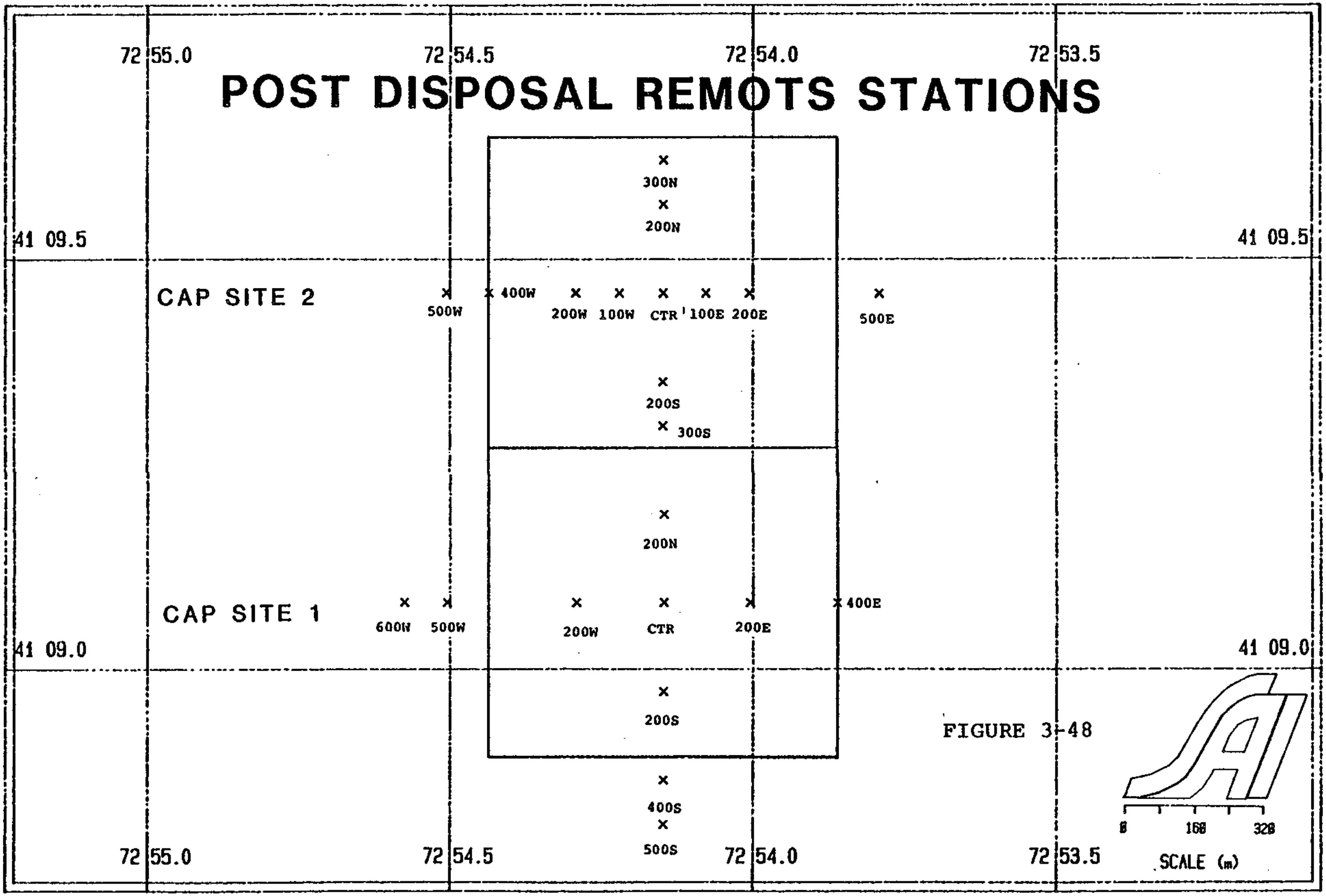

IENCE APPLICATIONS, INC.
CAPSITE 2
FINAL TRANSECT ARRAY
22 JUNE 1983
Erosion stakes, 30 cm exposed, graduated in centimeters and positioned 1 m N of transect (1/2 inch diameter PVC)
BDMD STAFF
20 cm diameter steel pipe exposed 1 m above sediment surface
3m
50m WEST (NO. 10)
25m WEST (NO. 5)
Erosion stakes, 30 cm exposed, graduated in centimeters at 3 m N, S, E and W of BDMD (1/2 inch diameter PVC)
Transect line anchored at 3.25 and 50 m West of BDMD with 0.5 m pipe anchors
N
Topographical rise of 1 m between 40 and 45 m West of BDMD

FIGURE 3-47


POST DISPOSAL REMOTS STATIONS
72 55.0
72 54.5
72 54.0
72 53.5
41 09.5
41 09.5
CAP SITE 2
300N
200N
500W
400W
200W
100W
CTR
100E
200E
500E
200S
300S
200N
CAP SITE 1
600W
500W
200W
CTR
200E
400E
41 09.0
41 09.0
200S
400S
500S
FIGURE 3-48
0
160
320
SCALE (m)
72 55.0
72 54.5
72 54.0
72 53.5

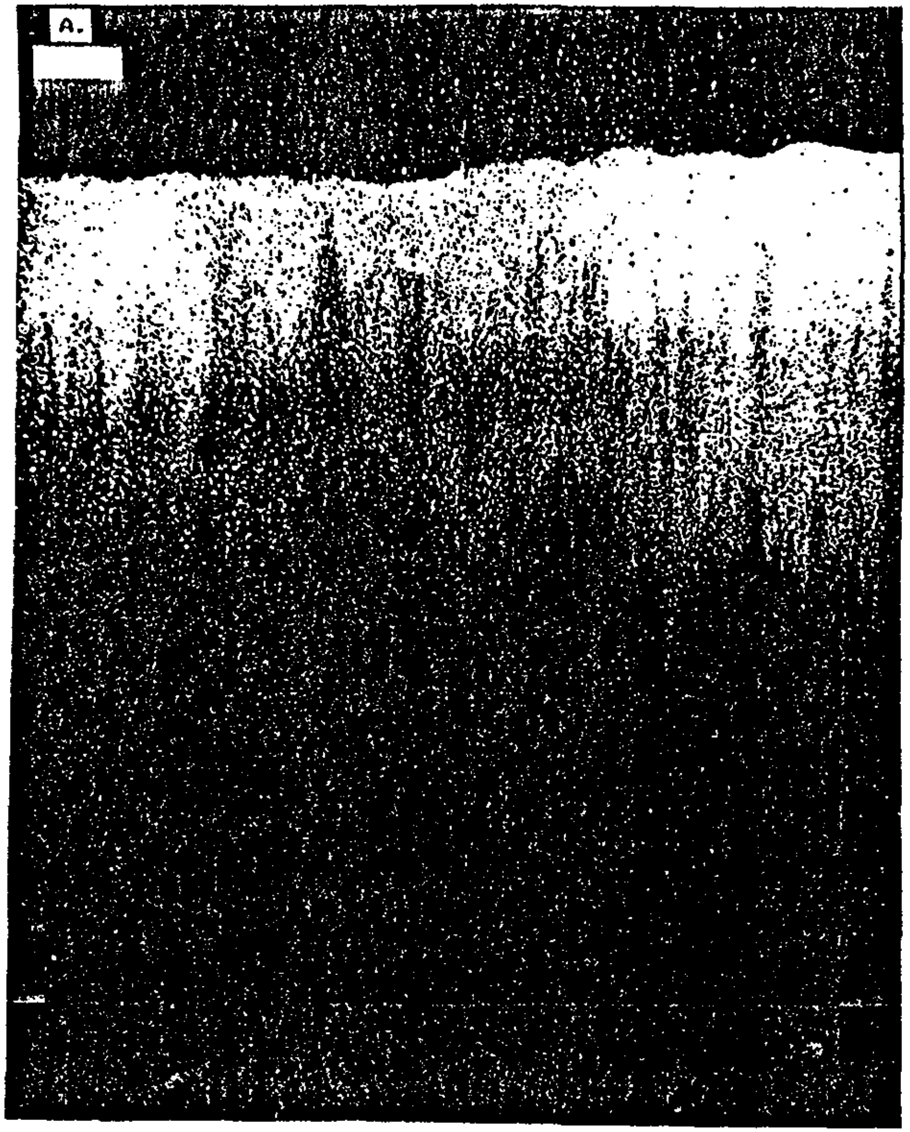


FIGURE 3-49a Remots photograph of station 200N showing sand cap at surface and underlying sediment (black layer). Below this layer is the buried redox of the predisposal surface. Bar in upper left hand corner equals 1 cm.

CS#2

B.

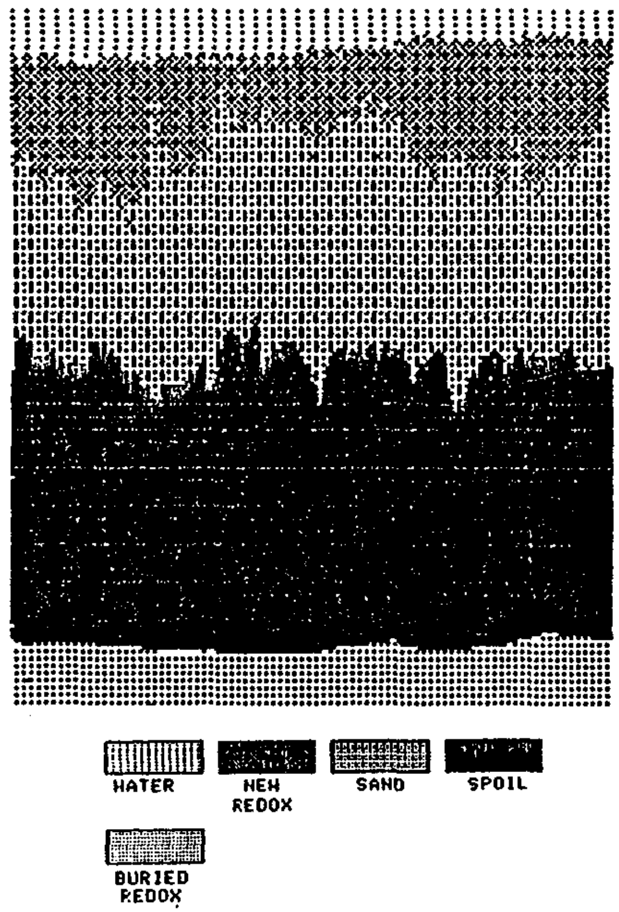


FIGURE 3-49b Computer density-sliced image of the Remots photograph shown in (A). Note that the density-sliced image has removed the vertical streaking caused by the Remots prism entering the bottom.

sediment. Thickness measurements of the sand cap and Black Rock sediment were made with the Measuronics LMS Image Analysis System (Fig. 3-49b) to the nearest millimeter. These measurements represent the average thickness of the units of interest in each photograph. Areas and perimeters of Black Rock sediment and capping materials were also measured from the isopleth maps generated from thickness data with the LMS System.

Figure 3-50a gives disposed material thickness at each station within CS#1 (n=27), and Figure 3-50b is a contour map of those values. The thickness values and contours for CS#1 represent the thickness of both the Black Rock sediment and capping material, since it is impossible to separate these two materials based on their reflectance values.

Figure 3-51a shows Black Rock sediment thickness and sand cap thickness values for each CS#2 station (n=31), and Figure 3-51b is a contour map of the Black Rock material. The perimeter of the zero isopleth, and area of the 0-2cm contour interval, depend heavily on interpretation of the REMOTS photo from station 400E. This appears to be an area which has experienced recent disturbance either through disposal or erosion. The boundary roughness is high (2.3cm), no sand is present, and the characteristically black (low reflectance) Black Rock harbor silt-clay is apparently not present. The sediment observed at station 400E is a high reflectance mud; however, the origin of the sediment is unknown. This deposit may represent New Haven silt designated for disposal at the CS#1, MQR or "SP" sites, or may be a remnant of previous disposal at the Norwalk disposal site as indicated by the high reflectance values observed on the side scan records in this area. Until further data are available, this sediment has arbitrarily been eliminated from consideration as Black Rock material.

Figure 3-51c is an isopleth map of the sand capp thickness. The grain-size composition of the underlying Black Rock sediment is uniformly a silt-clay ($<4\Phi$). The capping sand appears to be uniformly spread over the surface and is easily detected in the REMOTS photos because of its markedly different texture and reflectance value (Fig. 3-47a).

In summary, the REMOTS data provde information on overall spread of dredged material from Black Rock harbor, indicating results similar to those obtained at the FVP site, where sediment samples during the interim surveys indicated material present to a radius of 2-300 meters from the disposal point. In addition, these data permit an assessment of the effectiveness of the sand cap in covering the Black Rock material, and indicate that a uniform cover of 2-4cm on the flanks of the CS#2 mound has been achieved with greater thickness near the center of the site. A limitation of the REMOTS and other visual measurements is the lack of discrimination between Black Rock and New Haven sediment at Cap Site #1. Under those conditions, sediment sampling and subsequent chemical analysis remain the only method for distinguishing such material.

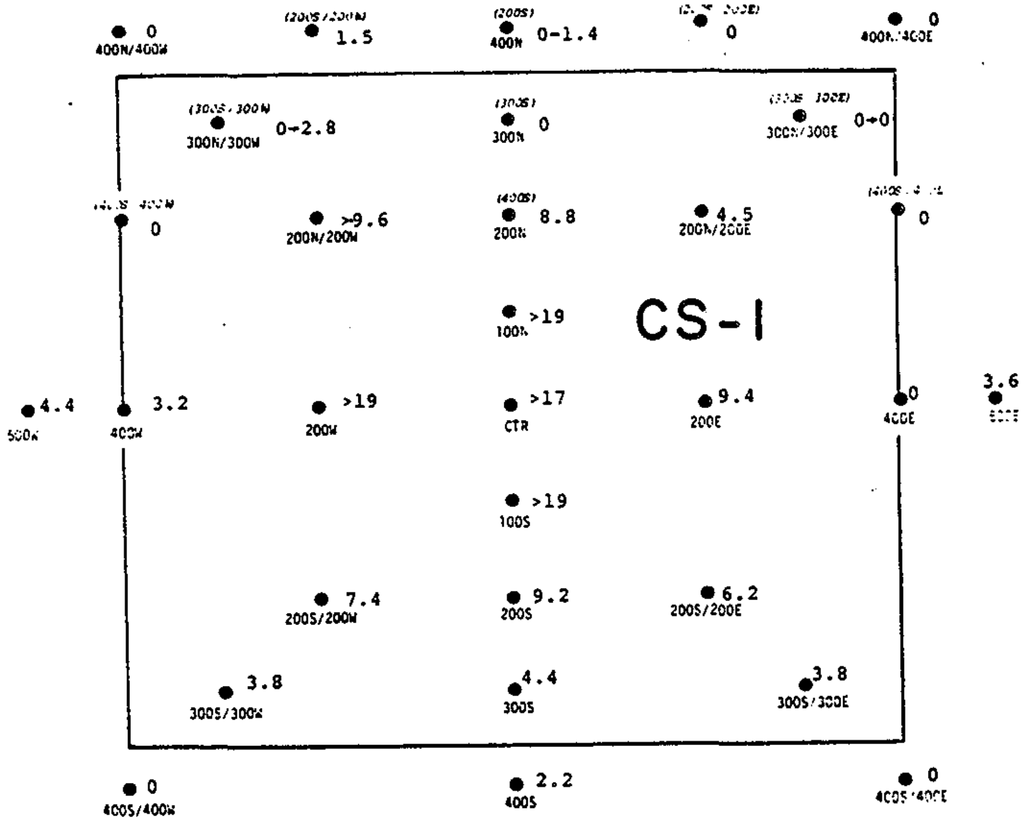


FIGURE 3-50a Station locations (from CS-1 center in meters) and thickness of dredge material. Values in centimeters. One photo per station, except for the 3 stations where two values are printed.

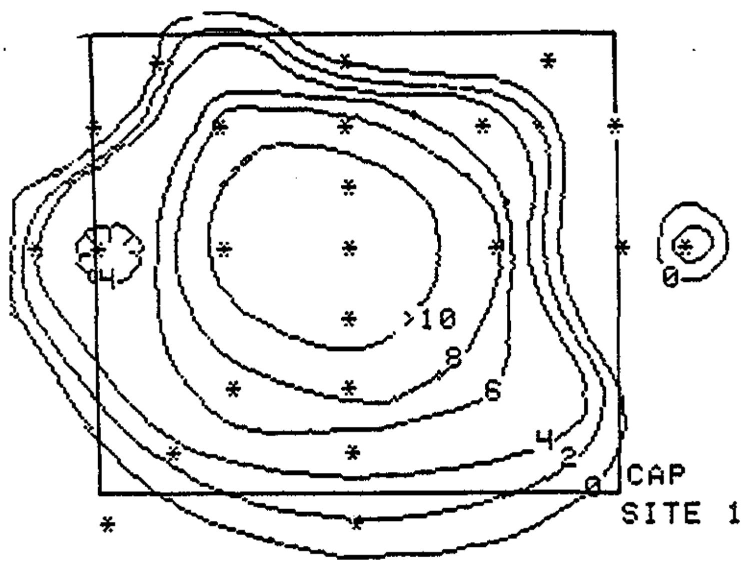


FIGURE 3-50b Isopleth map of dredge material thickness, (in centimeters) at CS-1. Contour interval is 2 cm.

CS-2

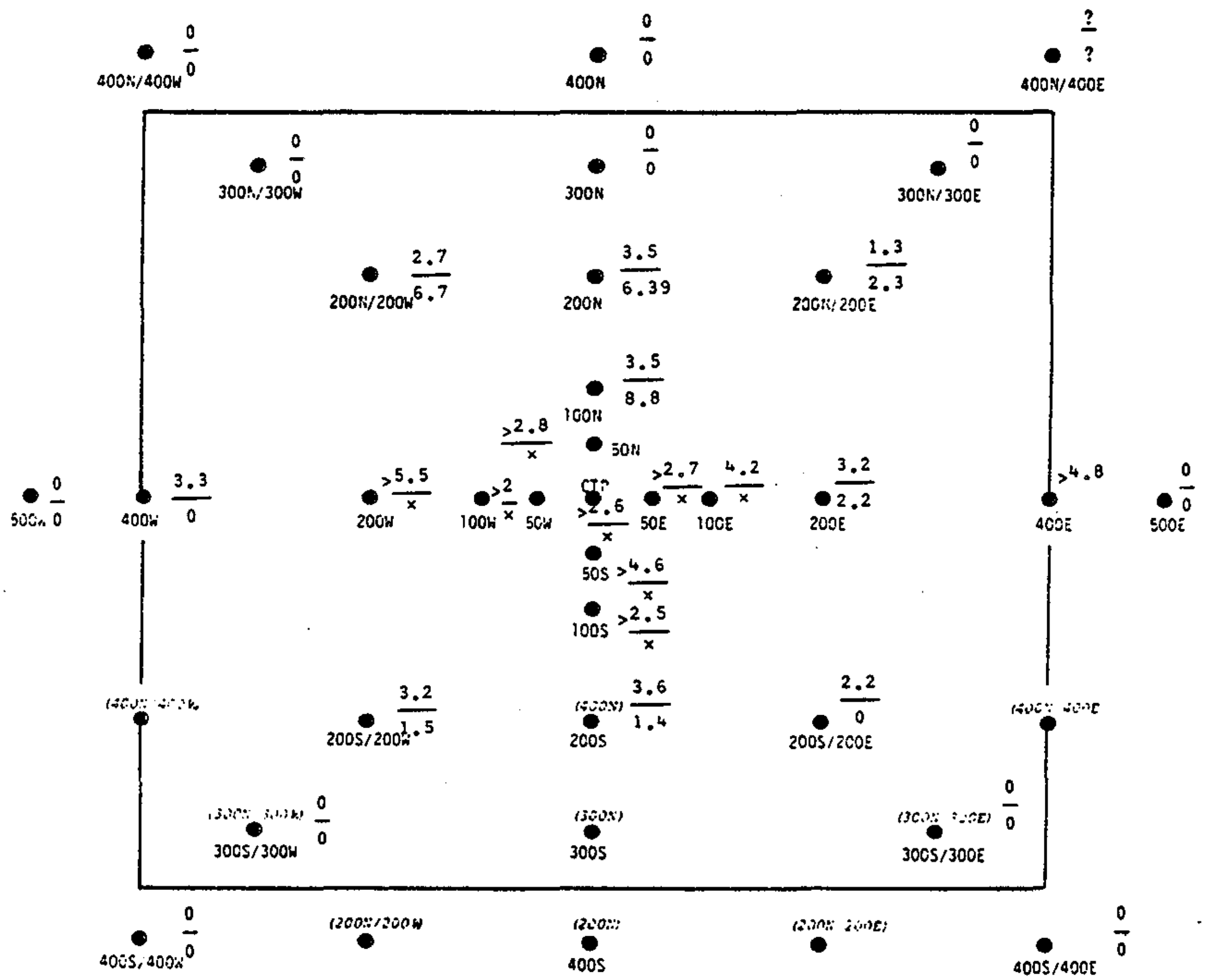


FIGURE 3-51a Station locations (from CS-2 center in meters) with thickness (in centimeters) of sand cap (numerator) over thickness (cm) of Black Rock material (denominator). Values of material thick ness given as (x) are unknown due to size limit of camera prism or inadequate penetration.

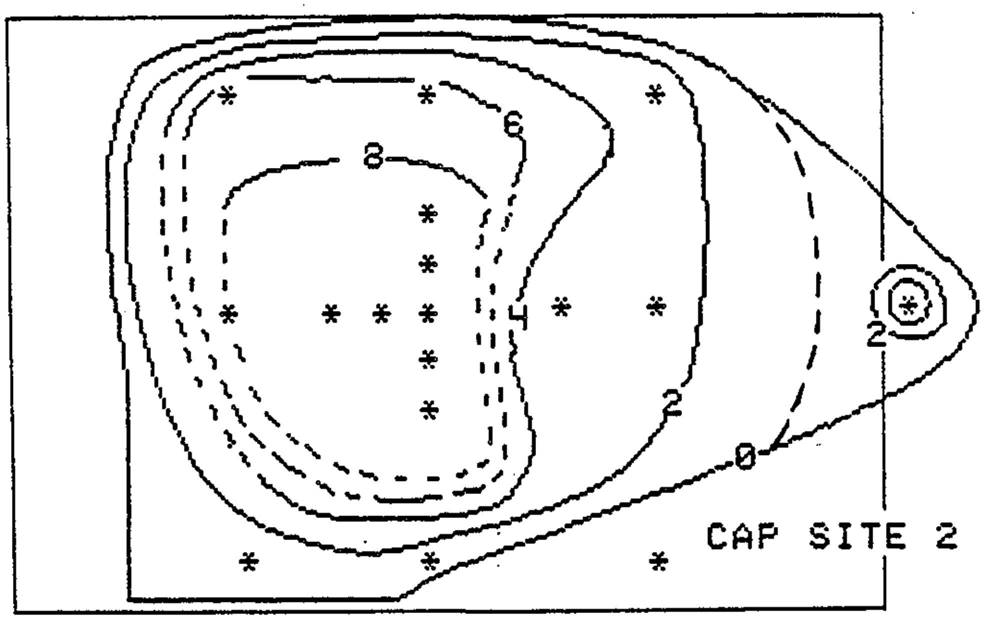


FIGURE 3-51b Isopleth map of Black Rock sediment thickness (in cm). Contour interval is 2 cm. Dashed line denotes probable extent of Black Rock Material.

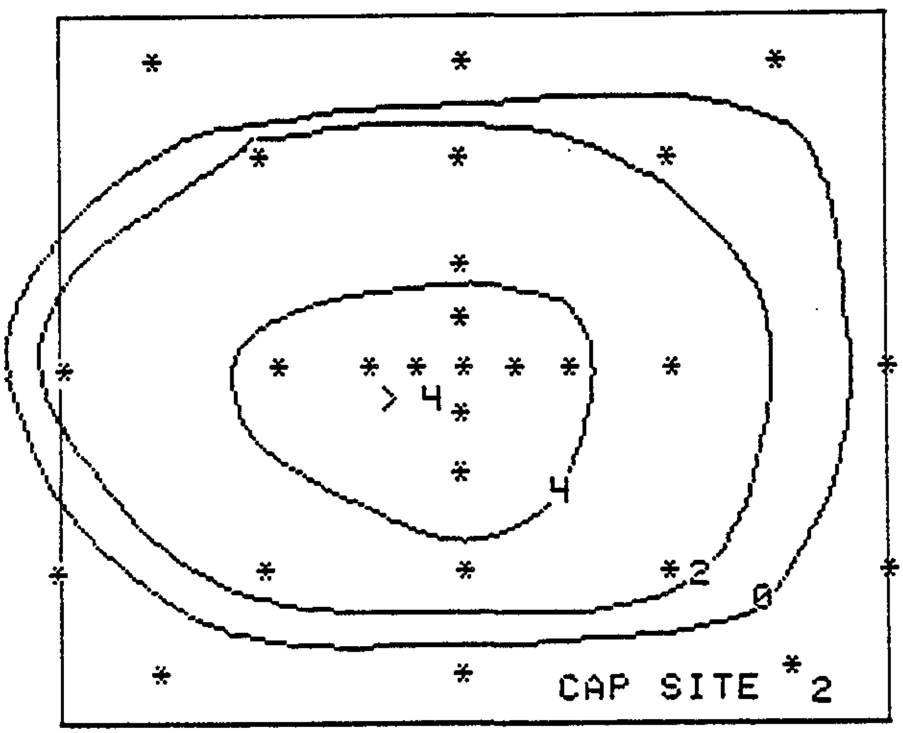


FIGURE 3-51c Isopleth map of sand cap thickness (in cm) at CS-2. Contour interval is 2 cm.

3.3.4 MQR Site

Disposal of New Haven material at the MQR site took place entirely under control of the Loran-C disposal system described earlier. Figure 3-52 presents the actual location of dumping events relative to the ten locations designated for disposal. Although the individual events are evenly spread over the site, it is apparent that most disposal occurred south of the designated points in a manner similar to that observed at the cap sites. Consequently, disposal at the MQR site produced a well defined circular mound approximately 450 meters in diameter and 2-3 meters thick (Fig. 3-53).

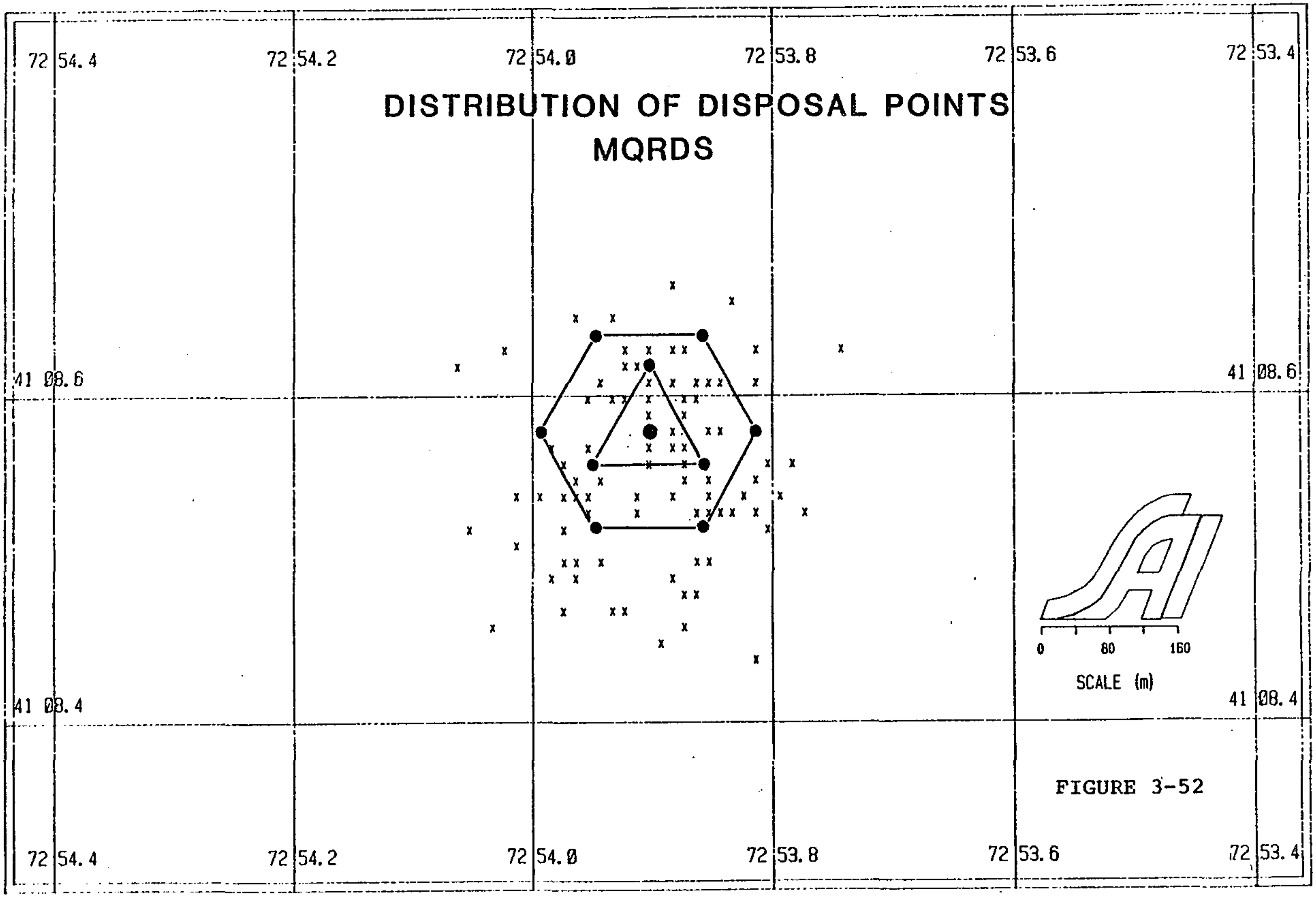
Although REMOTS photographs were not taken at this site, sediment samples obtained immediately after disposal consisted of a soft, high water content, black organic silt which, while predominantly contained in the mound at the center of the site, could be traced to distances of 800m in an east-west direction and 400m in a north-south direction.

3.3.5 FVP Site

Disposal of contaminated Black Rock sediment at the FVP site was tightly controlled through a taut-wire moored buoy and the resulting deposit (Fig. 3-54) was relatively small, approximately 200m by 100m, with the major axis oriented in an east-west direction. When viewed on the contour difference chart (Fig. 3-55), the topographic expression is slightly larger with a thin layer of material extending along a NE/SW direction. The maximum thickness of the mound is approximately 1.8 meters. Side scan sonar records over the site indicated similar conditions as those observed during the interim survey with the mound defined by an area of strong reflections masking the east-west troughs prevalent throughout most of the survey. The trail of material extending south and west remained as an obvious feature of the record.

Sediment samples and diver observations of the FVP mound indicated that the center portion of the Black Rock material consisted of a mixture of coarse grained materials including a gray sand, cohesive gray, clay clumps up to 50cm in diameter, and a matrix of soft, high water content black organic silt with a strong odor and obvious presence of oil and grease. At a relatively short distance from the center (100-150m), the thickness of this material was reduced substantially to a layer several centimeters thick, which was composed of a fine grained black organic silt, with virtually no coarse material, but a continued high water content and a strong odor. At distances approaching 400m from the center, this layer had thinned to a slight veneer over the natural bottom, and the margin of visible dredged material was between 400 and 500 meters in the east-west, and 300-400 meters in the north-south directions.

Three REMOTS surveys were made at the FVP site following completion of disposal operations. The first, on May 24, sampled the entire suite of 52 stations occupied on the

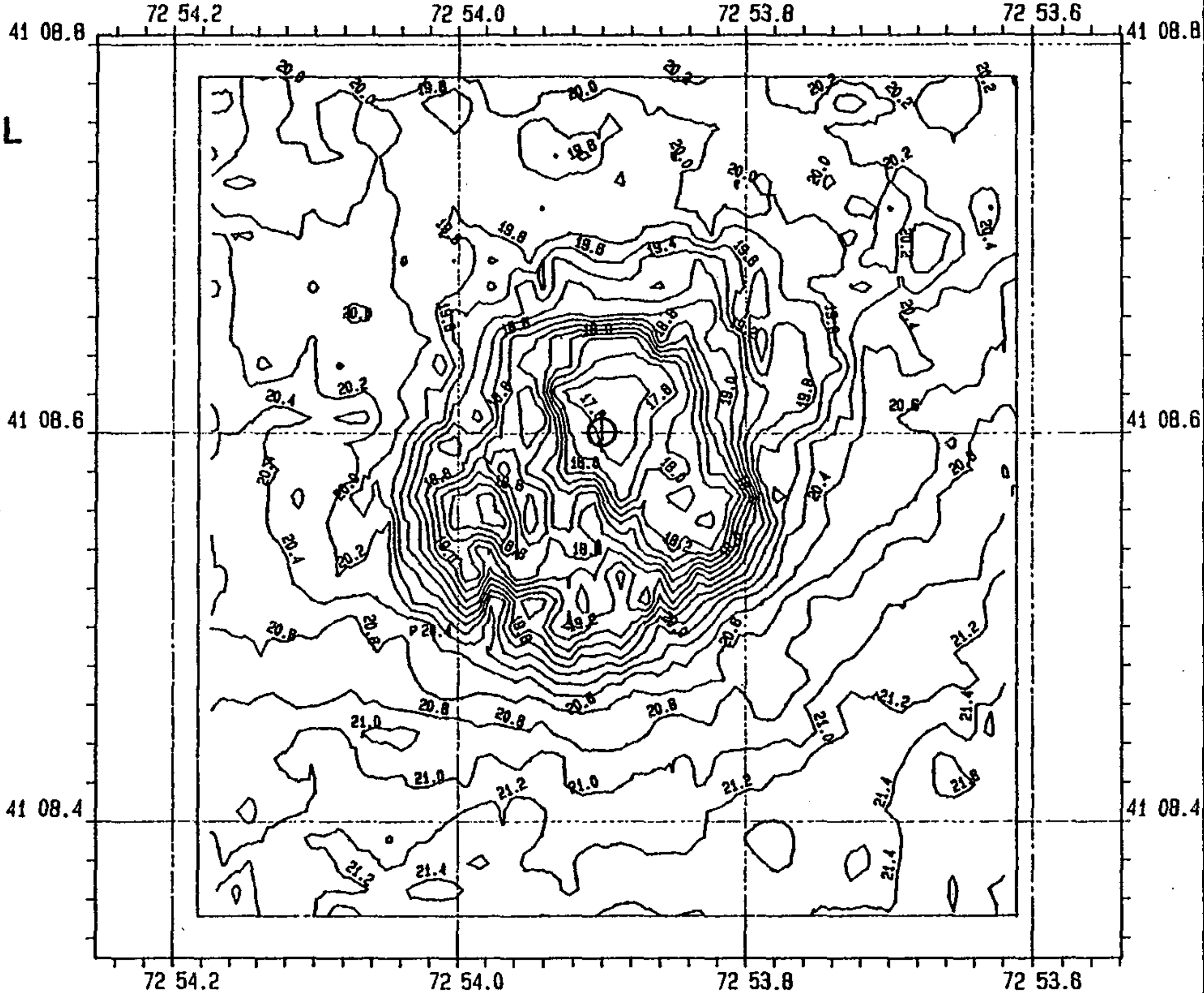


DISTRIBUTION OF DISPOSAL POINTS
MQRDS
72 54.4
72 54.2
72 54.0
72 53.8
72 53.6
72 53.4
41 08.6
41 08.4
0
80
160
SCALE (m)

FIGURE 3-52

POST-DISPOSAL
MQR
JUNE, 1983

FIGURE 3-53

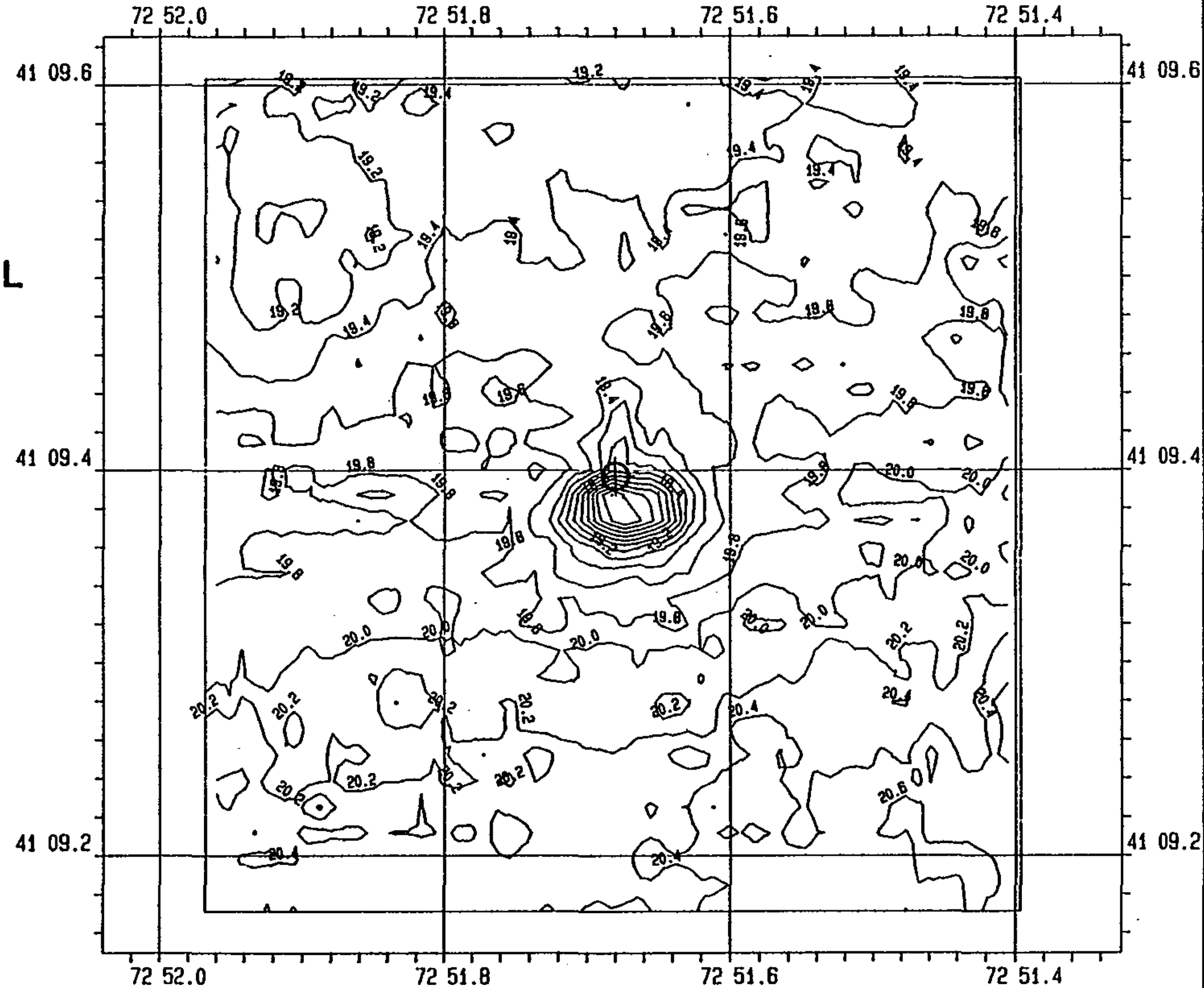


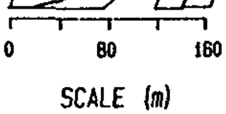
0 80 160
SCALE (m)

FVP
POST-DISPOSAL

MAY 1983

FIGURE 3-54



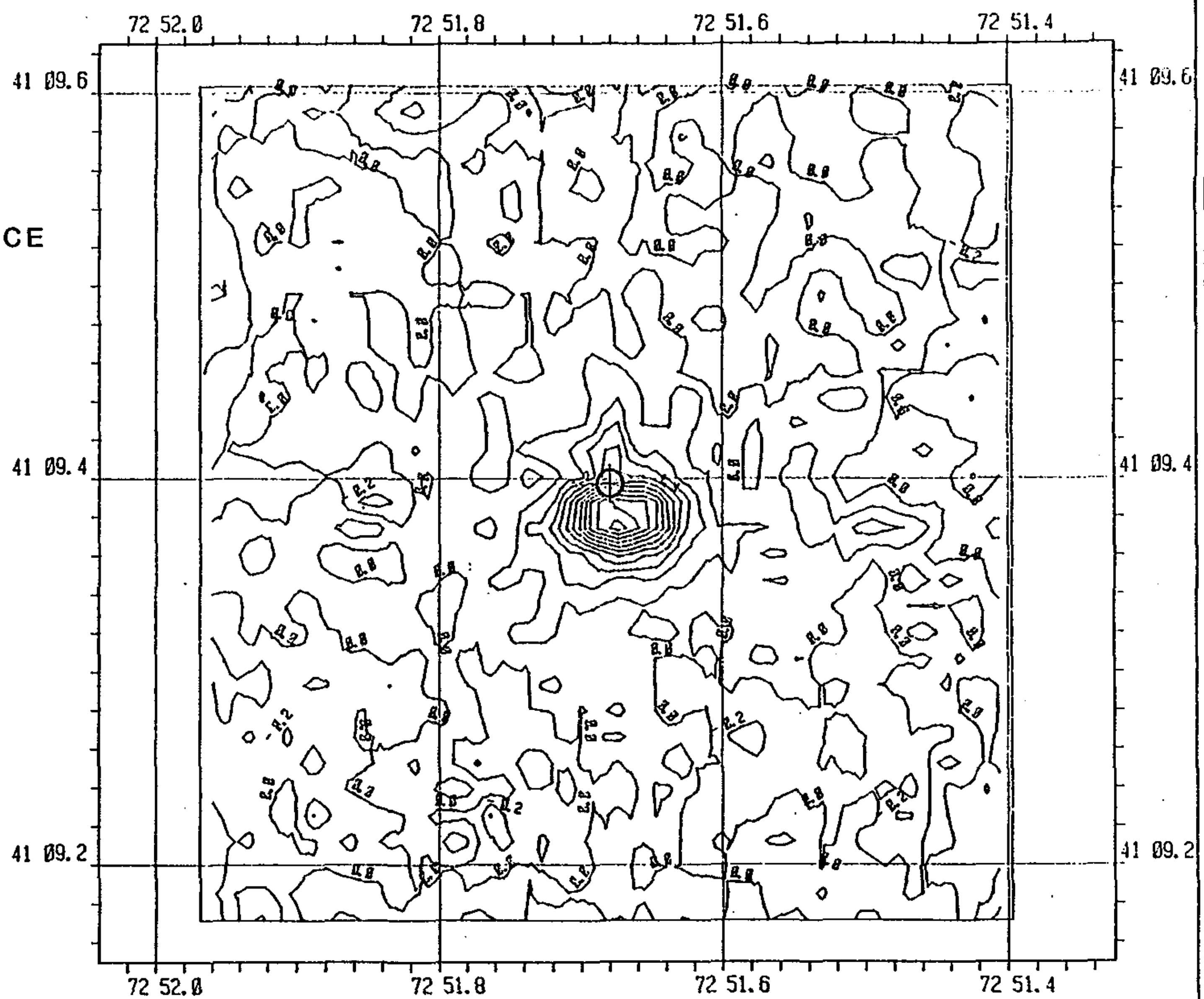


FVP

VOLUME DIFFERENCE

DEC82-19 MAY83

FIGURE 3-55



0 80 160

SCALE (m)

original baseline survey, while the second and third surveys, on May 26 and June 13, sampled a grid of 20 stations with replicate photographs to determine within station variability. Thickness of dredged material was measured using the same techniques described for the cap sites.

A contour map of Black Rock sediment thickness at the FVP site is given in Figure 3-56. Eleven additional stations were added along the east-west transect line to obtain a more accurate positioning of the zero thickness isopleth. This chart shows an area of $7.36 \times 10^5 m^2$, affected by dredged material; however, a major uncertainty in this map exists in the position of the boundary on the west side of the FVP site. This area is shown as a cross-hatched pattern in Figure 3-56, and occupies an area of $1.49 \times 10^5 m^2$. Black Rock material in this area is patchily distributed with some station replicates showing the presence of dumped material while other replicates shown a "normal" bottom. Furthermore, since this area extends to the west into areas with previous disposal, identification of Black Rock material is less certain. The RPD depth also provides an excellent indication of dredged material distribution as shown in Figure 3-57. The area containing RPD depths less than 3.74 is outlined on this chart, since sediment within this boundary contains an abnormally thin redox which is characteristic of newly disturbed bottoms. The critical value of 3.74cm is based on the June 13, 1983 data for the CLIS-REF station, which had a mean value of 3.74. The surveys of the FVP site in August 1982 and March 1983 also showed that the ambient seafloor has RPD depths greater than 3.0cm, with the major mode being about 4cm.

If the RPD map of Figure 3-57 is compared to the sediment thickness chart (Fig. 3-56), the 3.74cm deep RPD boundary contour is nearly coincident with the zero thickness contour. Although redox depths are, in this case, dependent on the presence or absence of Black Rock material, their measurement from REMOTS images is independently made and therefore we use these two parameters as separate criteria for the identification of disturbed seafloor at the FVP site.

Finally, the habitat indices as determined by the REMOTS camera are presented in Figure 3-58. All stations affected by Black Rock material have indices less than 8 and most station fall below an index of 5. The modal index is 2.

Stations located outside of the impacted area have values greater than 5, and the distribution is bimodal with peaks at 7 and 11. This bimodal distribution mainly reflects whether or not a station replicate contained evidence of only pioneering species (lower value) or also displayed subsurface feeding voids characteristic of mature infauna (higher value).

Baseline studies in August 1982 and March 1983 showed the area of the FVP site to have habitat indices ranging from 10-11. The frequency distribution of habitat indices for post-disposal conditions are comparable to the distribution shown for other DAMOS disposal sites within Long Island Sound.

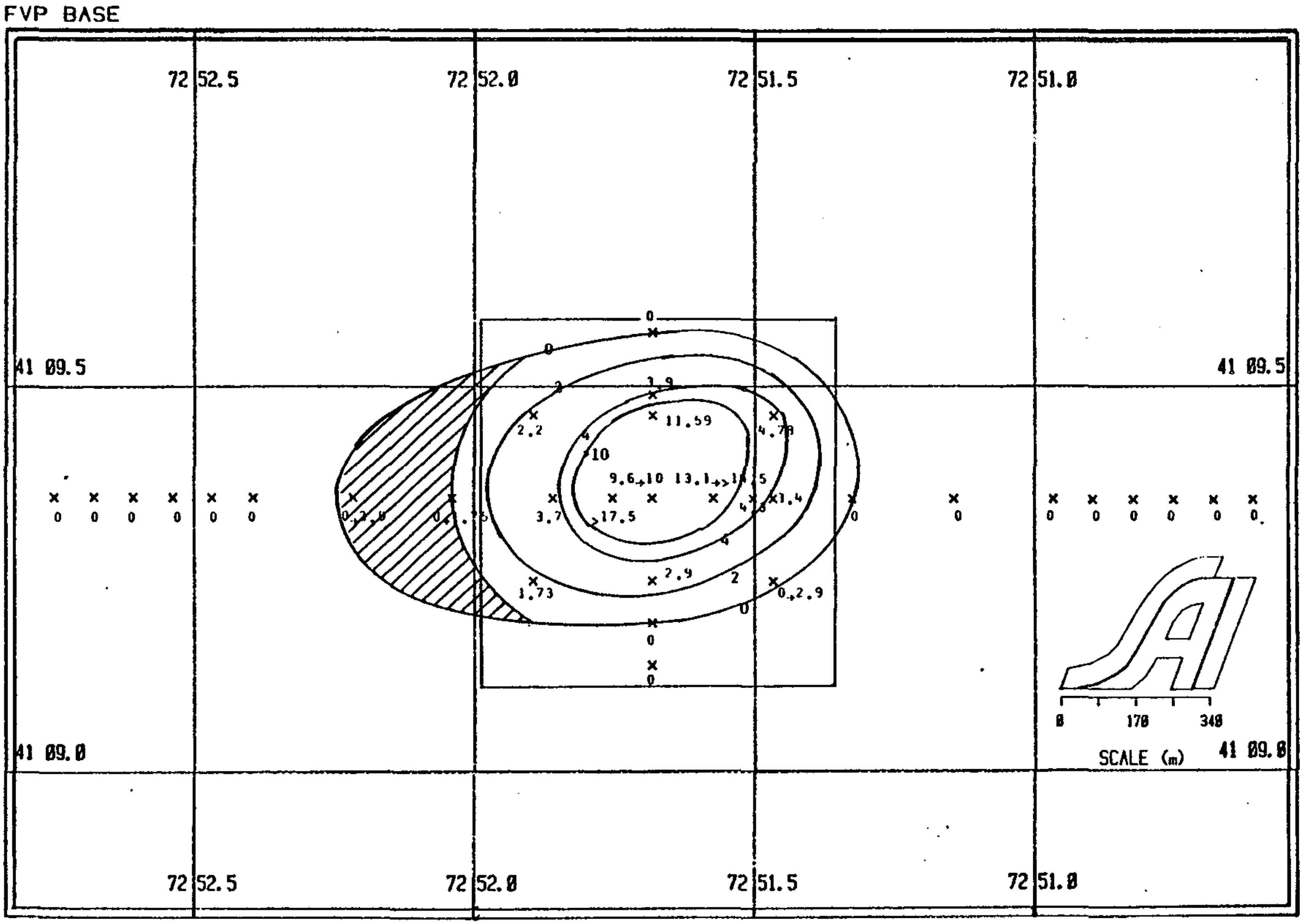


FIGURE 3-56 Thickness of Black Rock Dredge Material at the FVP Site.

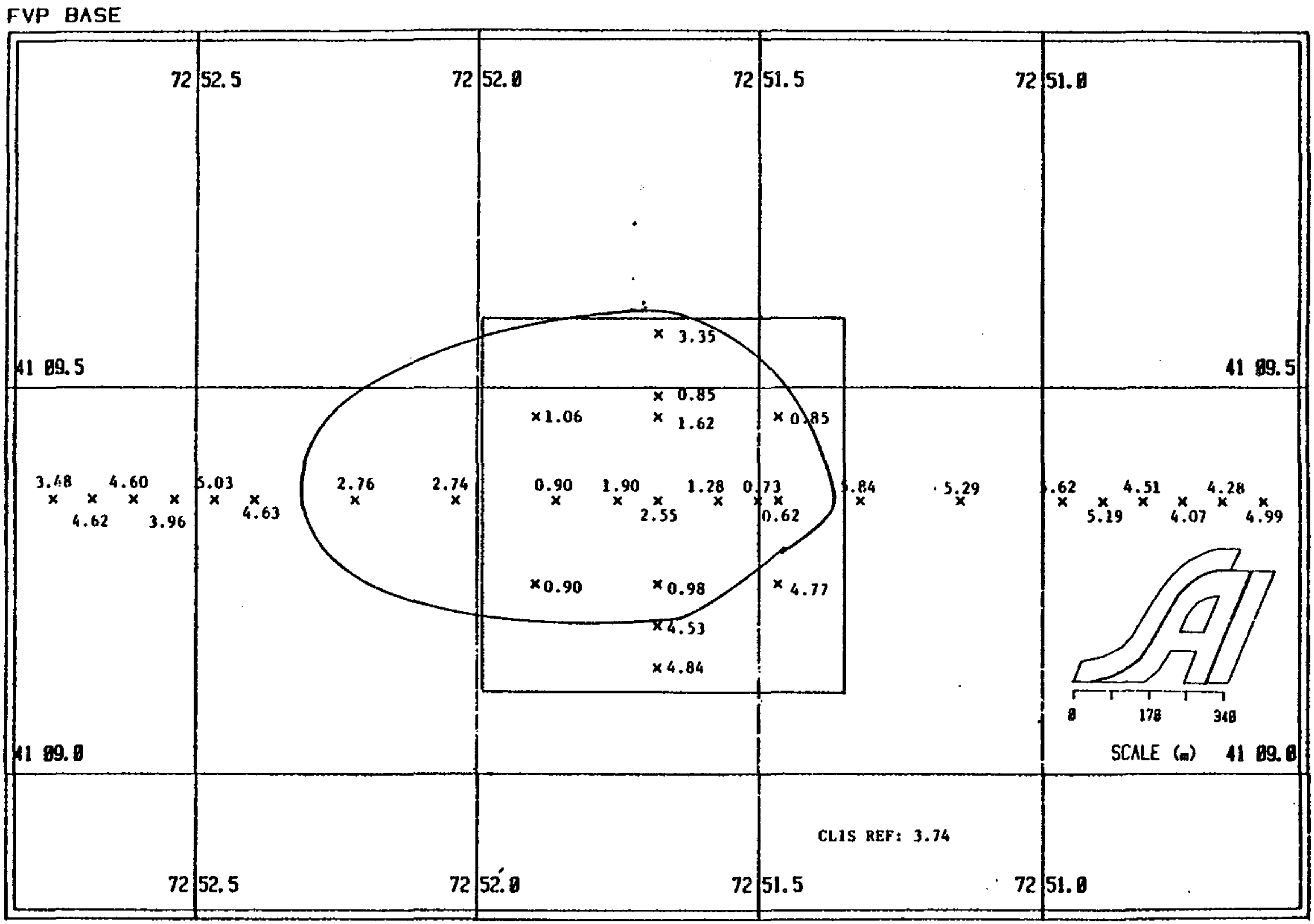


FIGURE 3-57. Depth of the Redox Potential Discontinuity FVP Site - Post Disposal.

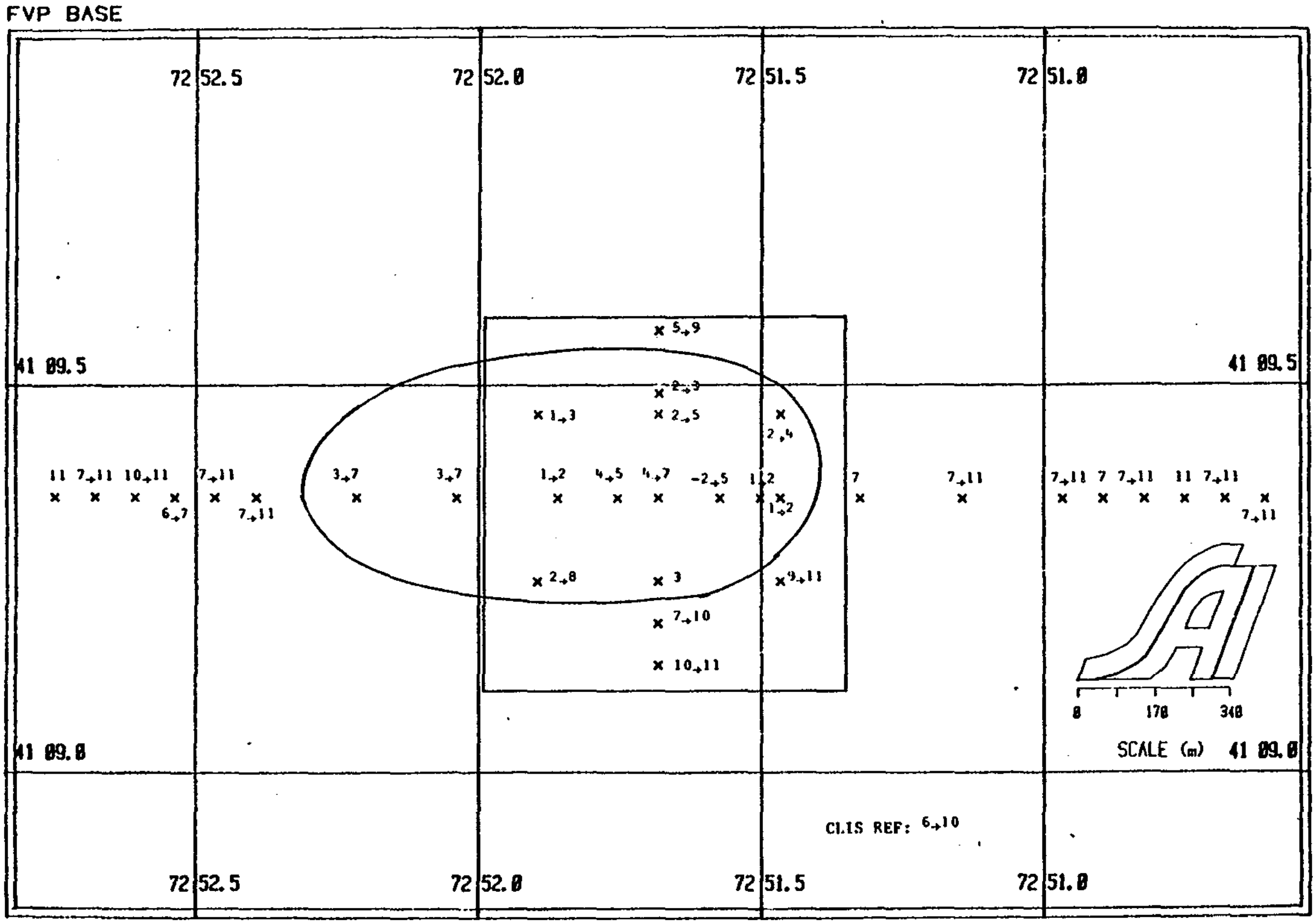


FIGURE 3-58 Habital Indices at the FVP Site - Post Disposal.

3.3.6 Summary of Post-Disposal Conditions

The results of the capping operations were not successful in fully covering Black Rock material, particularly at the CS#1 location. Although complete coverage was attained at the CS#2 site, the thickness of sand material on the eastern border was less than desirable, and may not be adequate to insure capping following post-disposal reworking and bioturbation. The reasons for this are primarily related to disposal control problems which resulted in deposition of both the silt and sand caps to the south and west of the desired location. The causes of this lack of control are not entirely clear, but it is obvious that when conducting small scale capping operations, extreme care in disposal position and frequent monitoring of results are required to insure coverage. In the future, scows with capping material should approach the disposal point from the same direction as those dumping the contaminated material, and at least one interim survey should be conducted during the capping operation to assess the distribution of material.

In spite of these problems, studies of capping parameters can still be conducted since the geotechnical properties of the sediments remain unchanged and some effective capping has taken place at both sites. It appears that disposal of New Haven material at the MQR and Black Rock sediment at the FVP sites was successful, and that important data concerning the behavior of the respective sediment types under controlled dredging and disposal conditions can be applied to the capping project.

Special care must be taken to insure that influence from previous or ongoing disposal operations do not affect the results of this study. In particular, the presence of Norwalk and "SP" disposal sites to the east may have been detected in side scan and REMOTS data and interpretation of results should consider this information.

3.4 Post-Disposal Monitoring

The effectiveness of capping operations depends to a large extent on the long-term stability of the sediment placed at the disposal site to cover the contaminated sediment. Consequently, post-disposal monitoring of these sites is of critical importance to evaluate the success of the procedure. The following sections provide a summary of post-disposal monitoring results during the summer and fall of 1983.

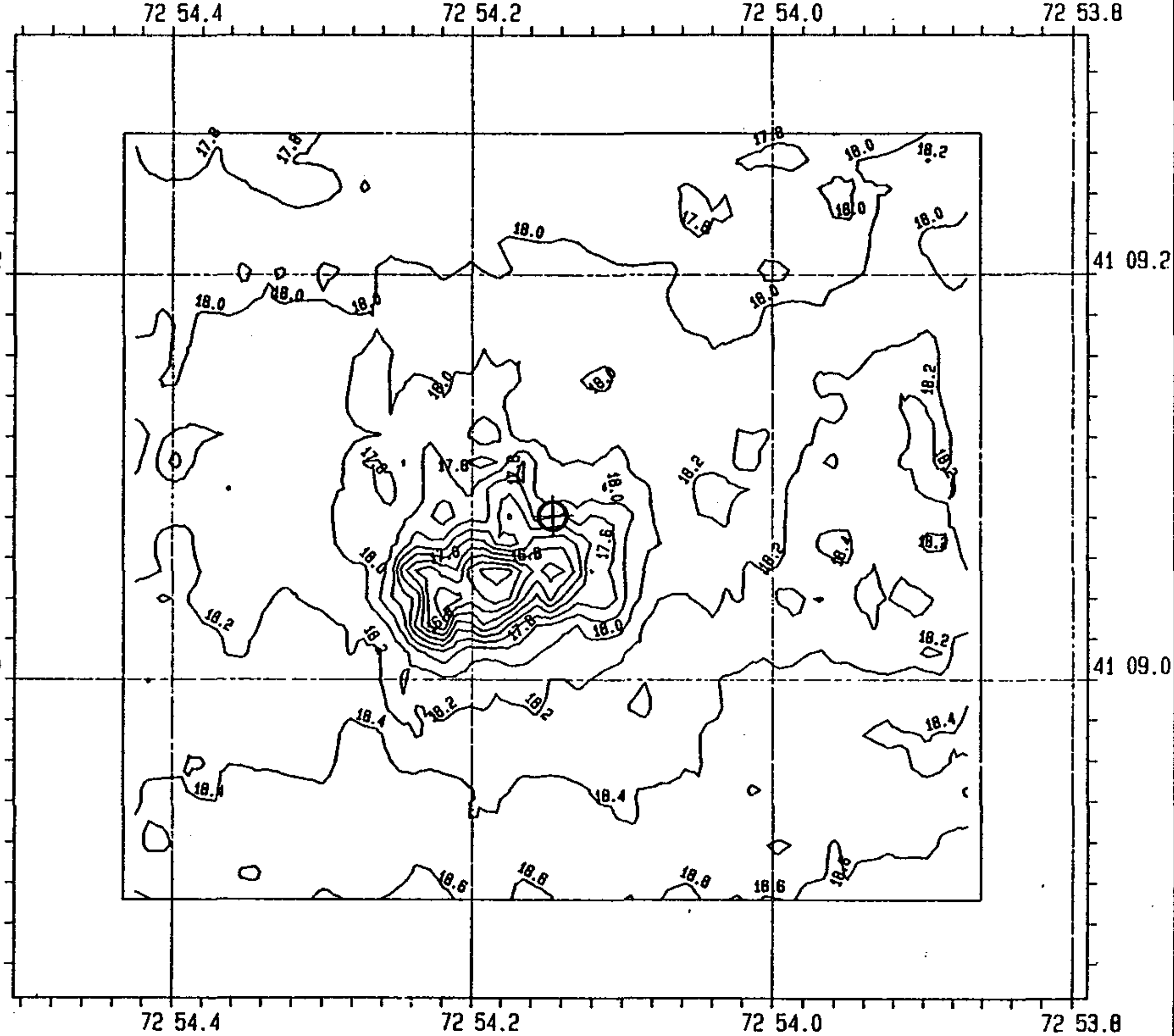
3.4.1 Cap Site #1

A replicate bathymetric survey of the Cap Site #1 area was conducted on August 23, 1983, which resulted in the contour chart shown in Figure 3-59. A comparison with the post-disposal survey from June, 1983 indicates no apparent changes in the shape of the mound, and the contour difference chart (Fig. 3-60) indicates virtually no difference over the entire survey.

CAP SITE #1 POST-DISPOSAL MONITORING

AUGUST 1983

FIGURE 3-59

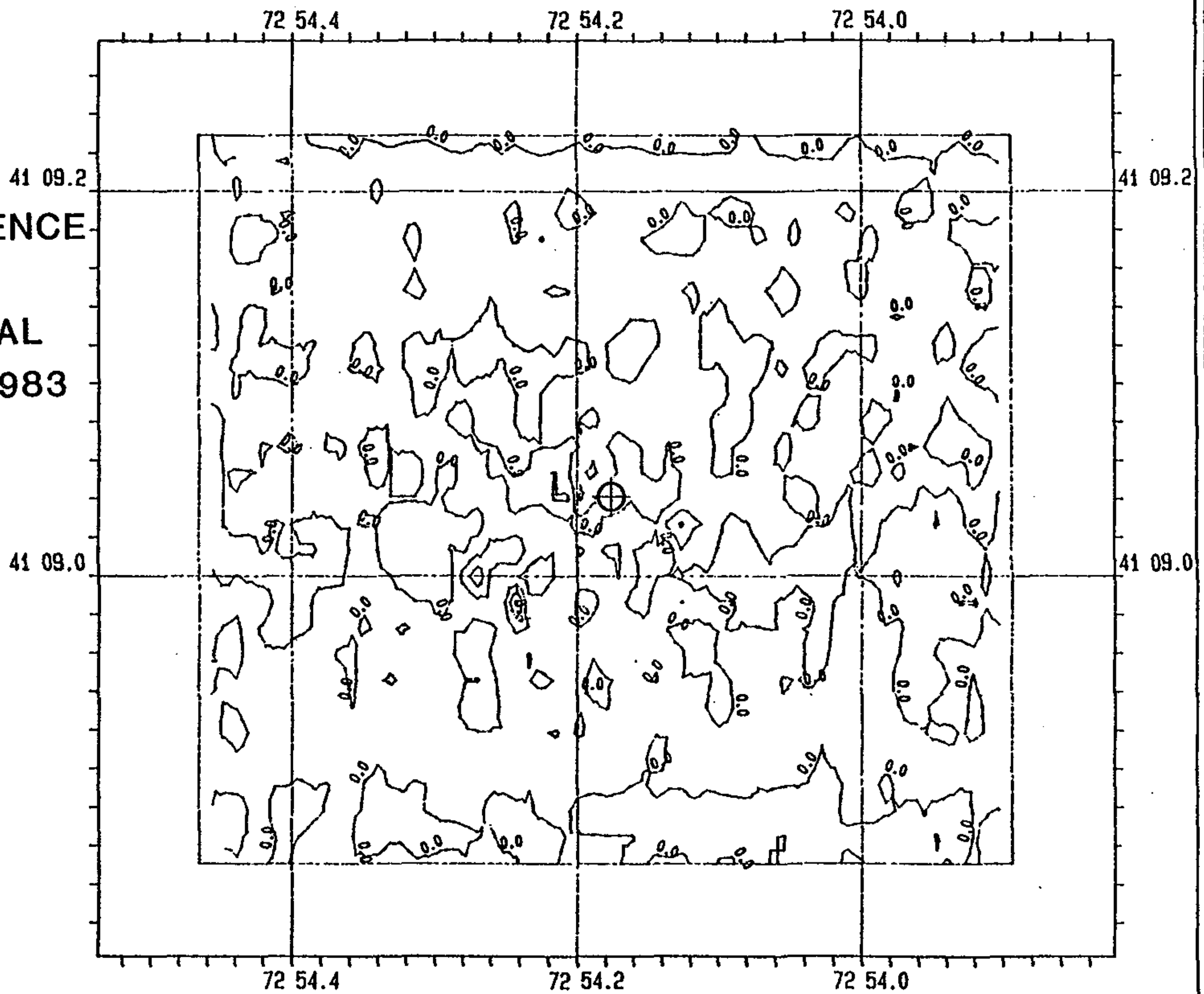


0 80 160

SCALE (m)

VOLUME DIFFERENCE
CAP SITE #1
POST-DISPOSAL
JUNE-AUGUST, 1983

FIGURE 3-60



0 80 160

SCALE (m)

Sediment samples and diver observations on the site revealed a smooth sediment surface with an oxidized layer beginning to form in the upper portion of the sediment column After four weeks, there had been no change in the erosion stake readings, thus indicating that there is no observable monthly erosion by this type of disposal material during the early summer season.

3.4.2 Cap Site #2

A similar survey at Cap Site #2 was conducted on the same day to assess stability of the sand cap. The contour chart (Fig. 3-61) shows some change from the June survey, and the difference chart (Fig. 3-62) indicates an area of depression relative to the post-disposal survey near the west center portion of the cap at the point of highest elevation and greatest thickness. Based on these data alone, we cannot at this time relate this change in depth to either erosion or compaction of the mound.

Diver observations of sediment surface conditions at this site revealed heavy natural deposition since the sandy New Haven dredge material was used to cap the Black Rock Harbor sediments. At this date, a flocculent 2cm layer of soft sediment was present over a hard sand/gravel layer. At mid-day flood current of 13cm/sec (0.25kt), this sediment condition created a bottom visibility of only 1 meter. Some eroding clay clumps, presumably of the Black Rock Harbor dredge material, were observed at a 1 per 5m^2 density with patchy distribution. This provides evidence of thin or incomplete capping operations with the New Haven material. The average clay clump was approximately 25cm in diameter and light brown in color due to an approximately 2mm oxidized veneer. One clay clump had an obvious peat constituent with what look like *Spartina* rhizoids eroding through one side. No biological activity was associated with the clay clumps, but substantial amounts of motile species were seen nearby on the recent natural sediment. The general topography was flat except for an area of steep (1:5) westerly slope that was encountered halfway along the transect. The divers did not follow down this slope, but it was estimated to be an elevation change greater than 3 meters. Anthropogenic deposits in this area were represented by a piece of a steel rod, chunks of wood to 0.5m long and derelict fishing gear and rope. No erosion/compaction stakes were found on the site, and therefore, measurements could not be made at this time.

3.4.3 REMOTS Observations at CS#1 and CS#2

On August 29 and 30, 1983, 22 stations at Cap Site #1 and #2 were sampled with three replicate photographs at each station. Methods of analysis of the resulting REMOTS images were conducted as described in previous sections.

The major mode for boundary roughness values at each site is 0.8cm; the majority of the roughness elements at the sediment surface at both sites are due to biogenic sediment reworking. The few high values observed at each site are from

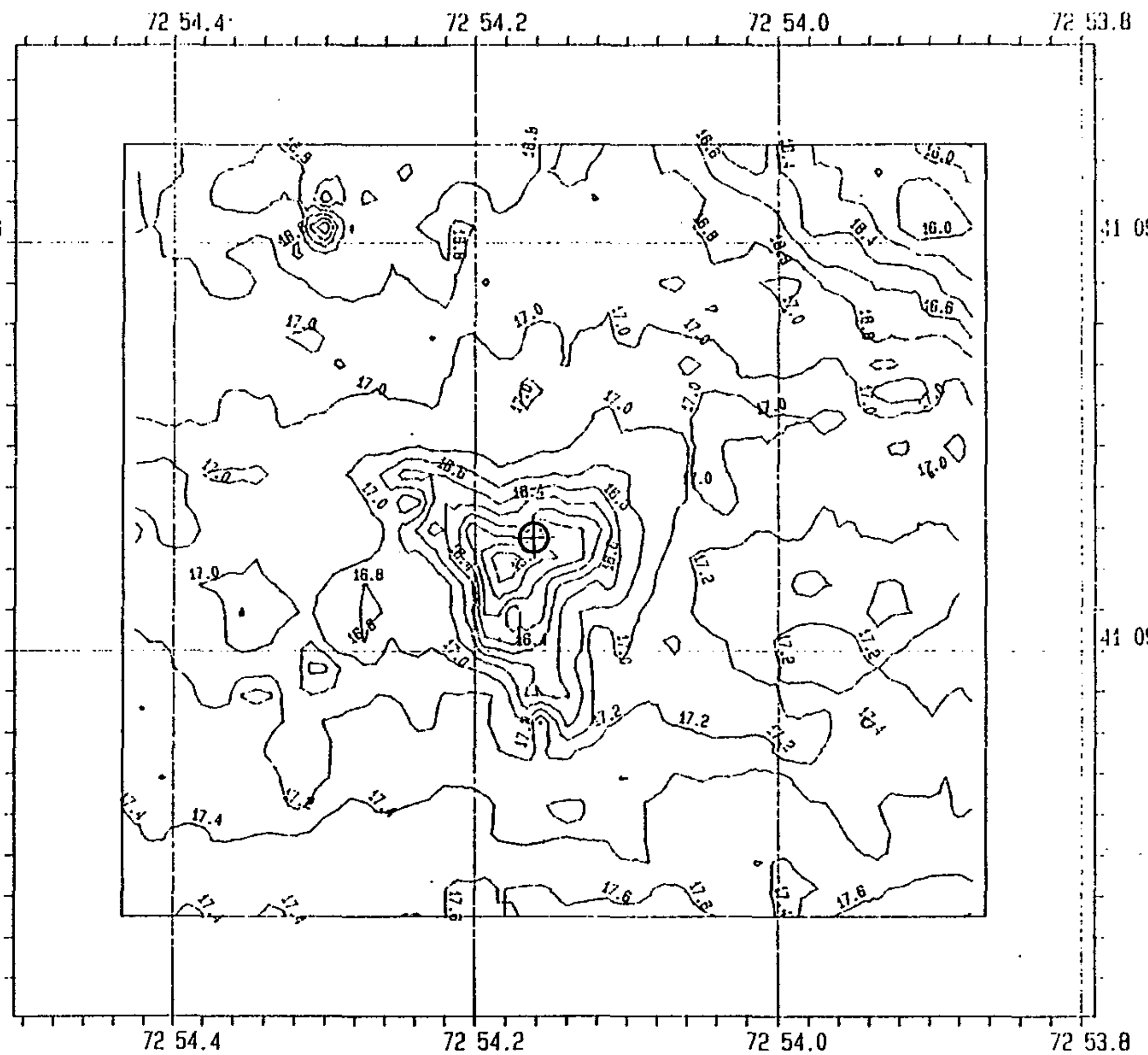
CAP SITE #2 POST-DISPOSAL MONITORING

AUGUST 1983

FIGURE 3-61

0 80 160

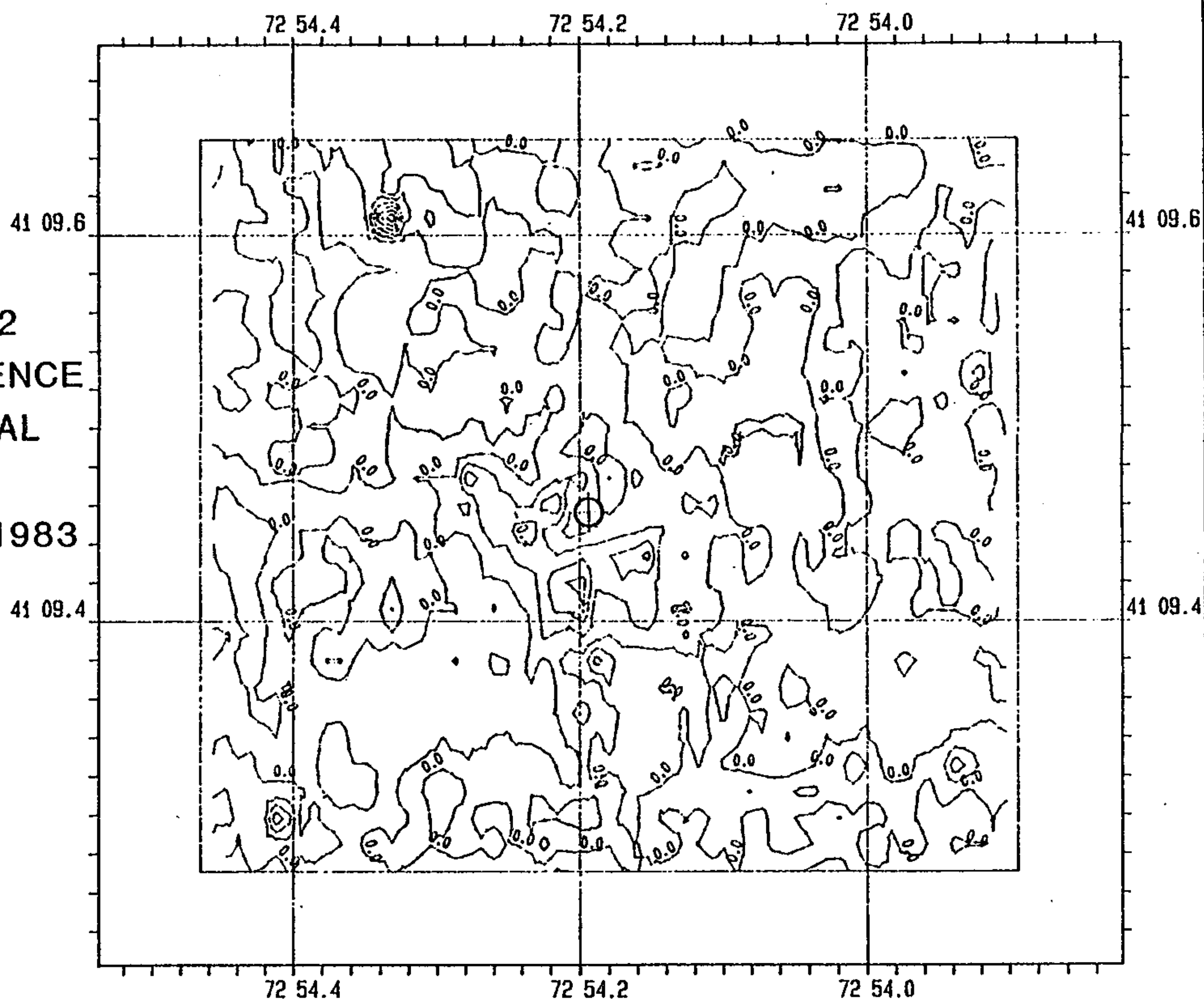
SCALE (m)



CAP SITE #2
VOLUME DIFFERENCE
POST-DISPOSAL

JUNE-AUGUST, 1983

FIGURE 3-62



0 80 160
SCALE (m)

stations where physical scour is evident. Some stations on the flanks of the mound at Cap Site #2 have a "chaotic" sedimentary fabric. Figure 3-63 shows such a "chaotic" fabric consisting of buried cohesive mud clasts mixed in with overlying sand.

The grain size distribution for stations at Cap Site #1 is essentially unchanged from the last survey in June. All stations have major modes in the silt-very fine sand (>4Φ - 3Φ) range. The limits of the sand cover at Cap Site #2 are the same as reported earlier. The range of grain size still exists (a 3Φ - 1Φ I sand layer overlying a 4Φ - 3Φ silt); however, 5 stations at Cap Site #2 show a surface layer of mud approximately 2cm thick overlying and admixed into the sand cap. Figure 3-64a and b show sediment profile photographs from 200W at Cap Site #2 in June and August. The top photo, taken in June, has a layer of sand greater than 4cm thick, while the bottom photograph in August shows a 2cm thick layer of mud on top of the sand cap. Reduced sediment can be seen at depth underneath this middle sand layer. This areal extent of this newly deposited mud layer is found mainly on the western side of the mound, where the contour difference chart has shown a decrease in the thickness of the material. Such a deposit may suggest settling of the mound, since erosion sufficent to produce such a decrease would not permit accumulation of such deposits in the same area.

In the two months following disposal, both cap site areas were significantly improved in benthic habitat quality. Figure 3-65 compares values at each station for depth of the redox potential discontinuity (RPD) and Figure 3-66 compares habitat indices for both sites between June and August, 1983.

Frequency distributions of mean RPD depth and habitat index values for both sites in August are shown in Figure 3-67. The major mode for RPD depth and habitat indices are one class interval greater at Cap Site #1 than at Cap Site #2; most of the area of Cap Site #1 has been bioturbated to a depth of 3-3.5cm. Most stations at Cap Site #2 are not reworked to as great a depth below the sediment-water interface. This may be related to the physical resistance that the comparatively larger sand grains offer to bioturbating organisms, as well as qualitative differences in colonizing species. Comparing these values with values obtained in June, the rate of increase in the depth of the RPD is approximately one centimeter per month. This is within the expected range of reworking rates for Long Island Sound benthos, given the high water temperatures and correspondingly increased metabolic activity of the infauna during the summer months.

By combining the volume difference results with the REMOTS observations, it is possible to assess the effectiveness of the sand cap in isolating Black Rock material from the colonizing benthos. Because the maximum depth of the RPD at Cap Site #2 is about 3cm, the area of the sand cap greater than 4cm thick can be considered as having effectively isolated the underlying material from the infauna. This represents about 20% of the total area covered by sand at Cap Site #2. A portion of

FIGURE 3-63 Sediment profile photograph at Cap Site 2, Station 200 S showing chaotic sedimentary fabric.

A

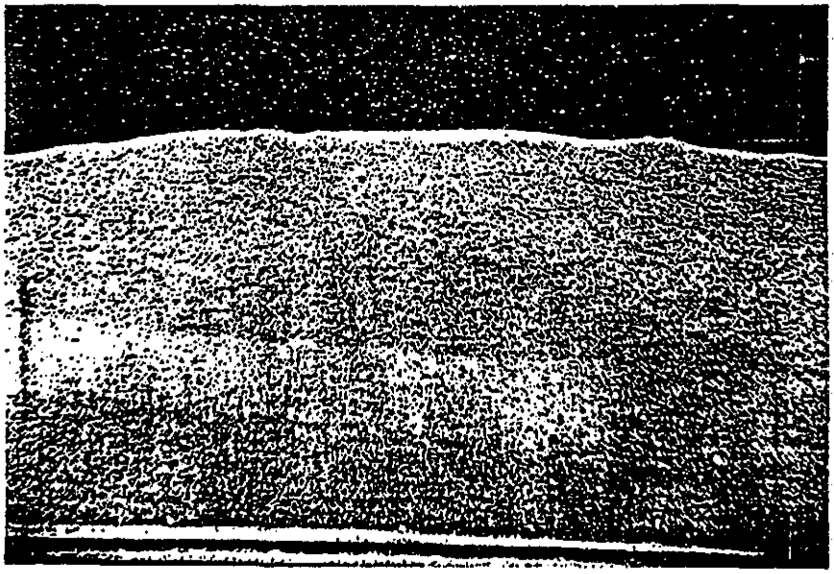


FIGURE 3-64a Sediment profile photography at Cap Site 2, Station 200 W taken June, 1983. Note the 4 cm thick sand layer at the sediment surface.

B

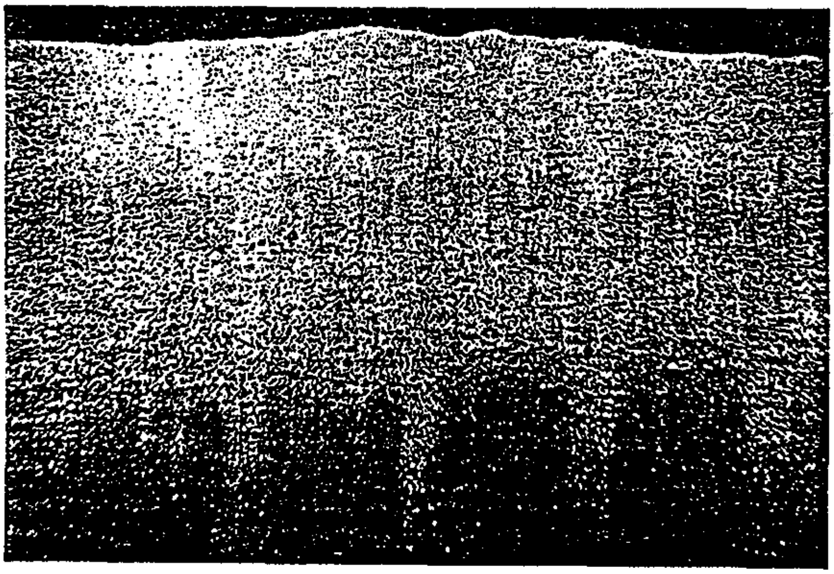
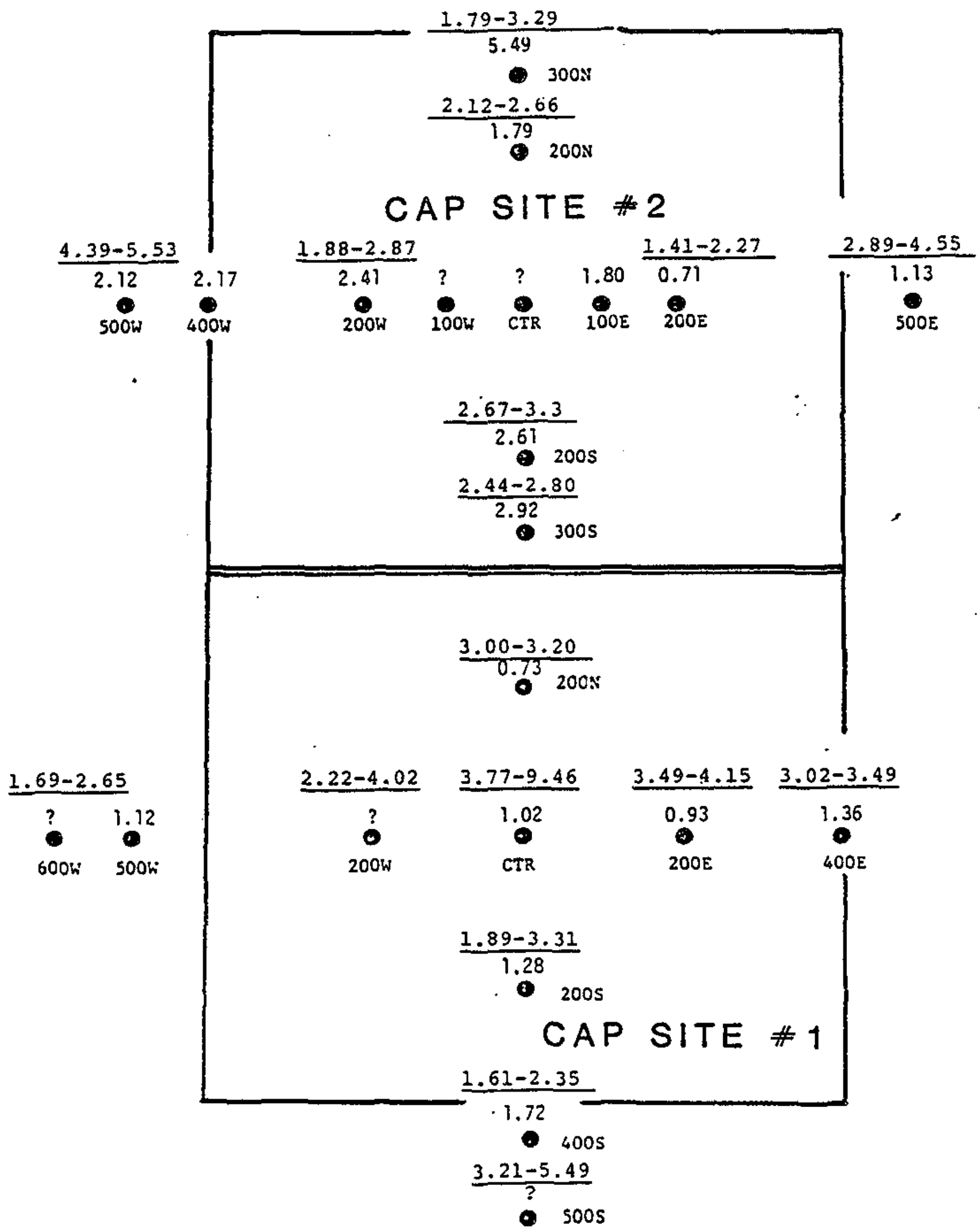
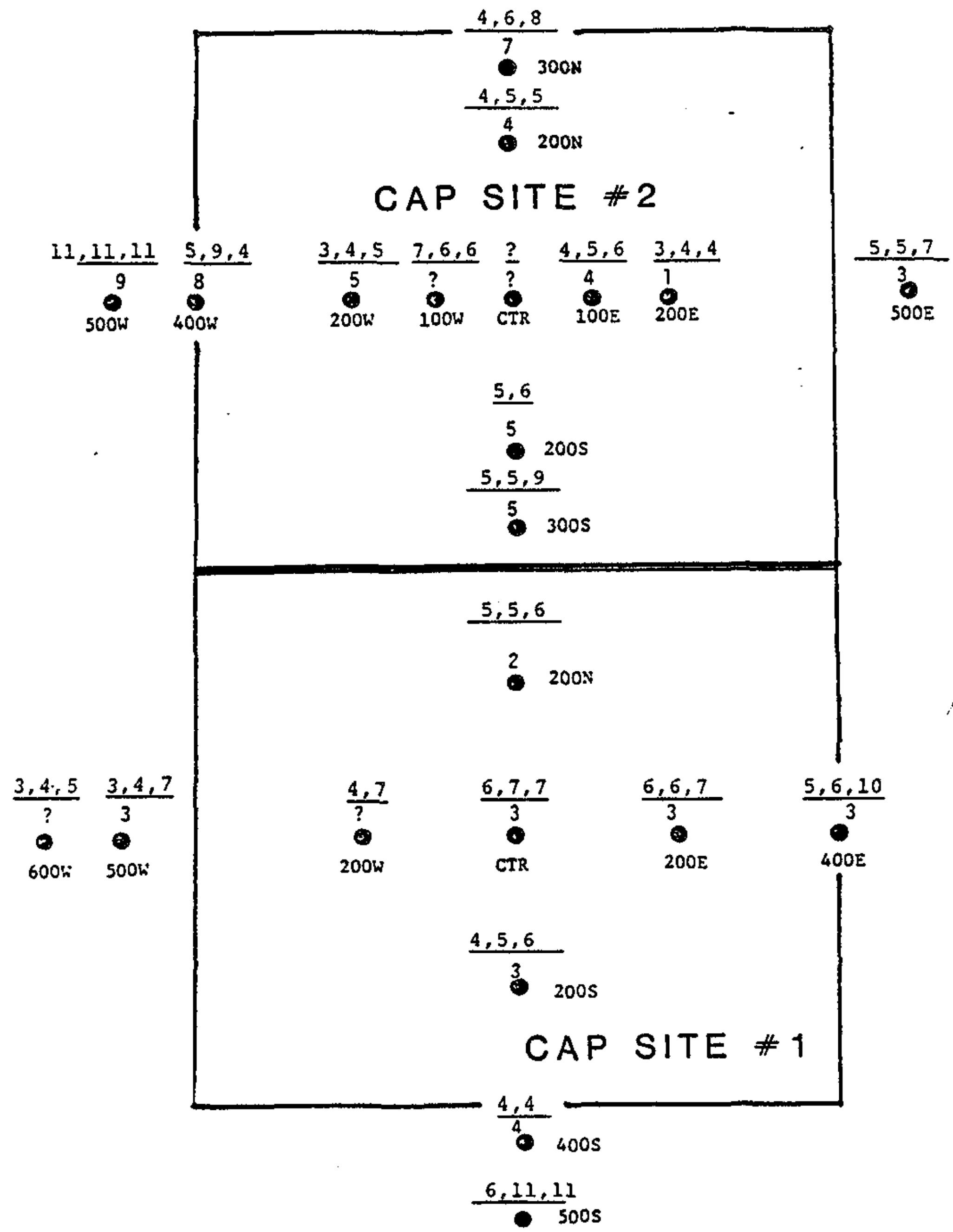


FIGURE 3-64b Sediment profile photograph from this same station taken August, 1983. The 2 cm thick layer of mud at the sediment surface is easily distinguished from the middle sand layer (the former sediment surface). Reduced, anoxic sediment can be seen at depth.



RPD DEPTH $\frac{\text{AUG}}{\text{JUN}}$ 1983

FIGURE 3-65



HABITAT INDEX - $\frac{\text{AUG}}{\text{JUN}}$ 1983

FIGURE 3-66

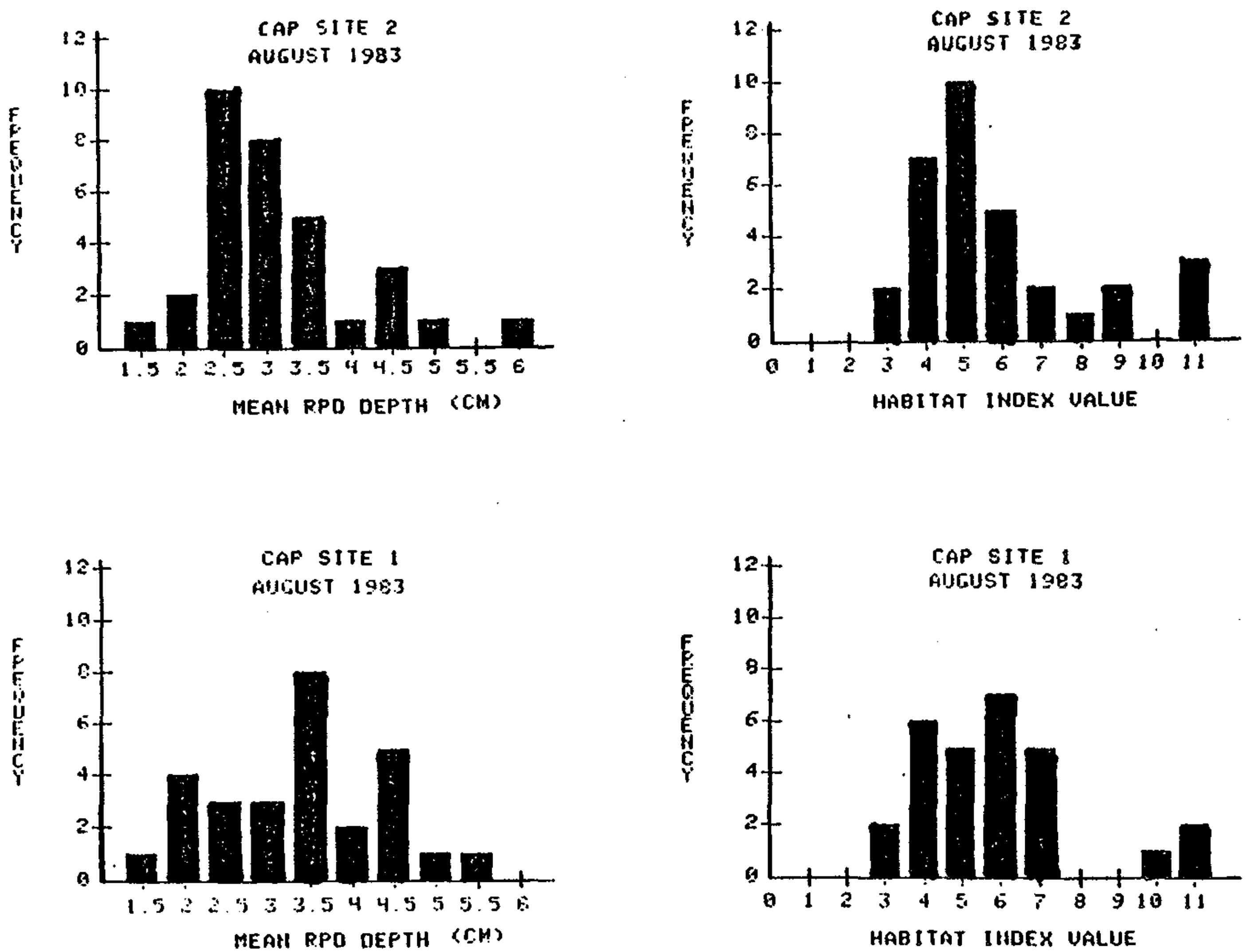


FIGURE 3-67 Post Disposal Frequency Distribution of RPD Depth and Habital Indices for Cap Sites 1 and 2.

the remaining 80% of the sand cap has areas where the depth of the RPD exceeds the thickness of the sand layer. By overlaying and digitizing the two contour maps of sand cap thickness and RPD depth, it is possible to determine the area of bottom where the infauna have penetrated the sand cap and are exposed to the underlying sediment. Figure 3-68 shows the two contour maps for sand cap thickness and RPD depth at Cap Site #2, as well as a map delimiting the areas where the RPD depth exceeds the thickness of the sand cap. This area represents approximately 31% of the total area of the sand cap at Cap Site #2, which has been penetrated by colonizing organisms. However, it is important to note that the thickness of Black Rock material in these areas is quite small, generally less than 2cm (Fig. 3-51b).

3.4.4 MQR Site

No post-disposal monitoring of the MQR site has taken place since June 1983. Future monitoring will be conducted as part of the DAMOS program on a semi-annual basis.

3.4.5 FVP Site

Extensive post-disposal monitoring has taken place at the FVP site at more frequent intervals through the summer and fall of 1983. Replicate bathymetric surveys were conducted on June 21, July 19, and August 26, 1983. Contour charts for these surveys are presented as Figures 3-69, 3-70, and 3-71, respectively. All of these surveys show very little change in the topography of the disposal mound, however, the volume difference chart comparing the baseline post-disposal condition in May with the July survey (Fig. 3-72) showed a slight decrease in depth at the center of the mound. A later comparison between the July and August surveys (Fig. 3-73), showed no change whatsoever. As in the case of other mounds, this appears to have been an initial reworking and settling of the mound, with no significant erosion and transport of material occurring.

Side scan records over this period showed a general decrease in the intensity of the reflected signal associated with the disposal mound. This can be attributed to general reworking of the sediment and deposition of fine material on the surface of the disposal mound. This phenomenon was also observed by divers who noted the development of an oxidized surface layer and initial reworking of the blanks of the mound by large epifauna, and the usual infauna associated with the Central Long Island Sound area.

REMOTS surveys at the FVP site have provided some important results relative to conditions of Black Rock material with time. Both the RPD depth and the Habitat Index values have improved over the summer. RPD depths increased at a rate of .6cm/month since June, reaching an average depth of 2.77cm in areas impacted by Black Rock dredged material. This is still lower than natural bottom conditions (approximately 4cm), but a significant improvement with time. Likewise, the Habitat Index has improved from a value of about 3 during June to 5 during

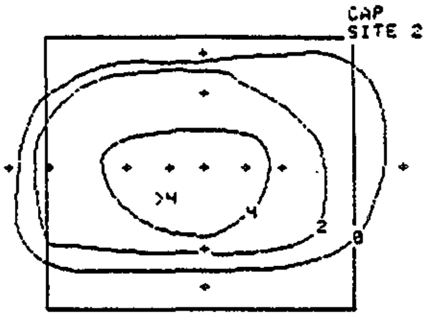


FIGURE 3-68a
Contour map of sand cap thickness.

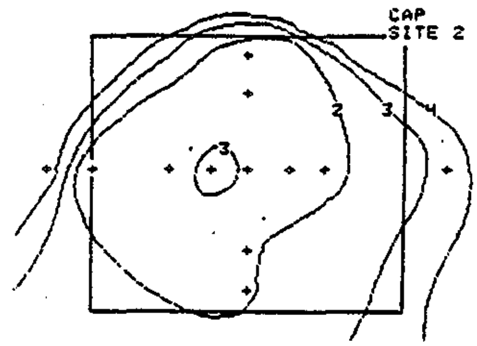


FIGURE 3-68b
Contour map of RPD Depth.

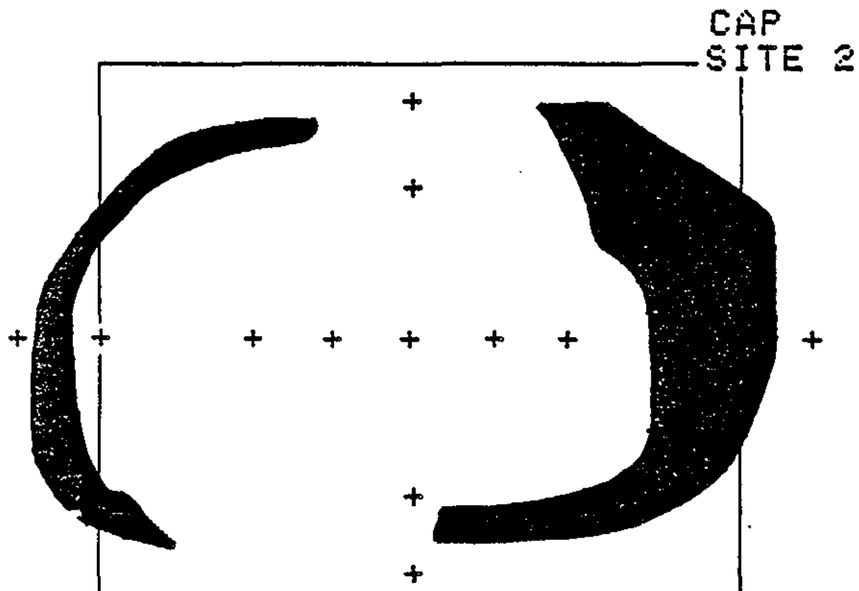


FIGURE 3-68c
Shaded area indicates areas where infauna have penetrated sand cap and are exposed to the underlying Black Rock Material.

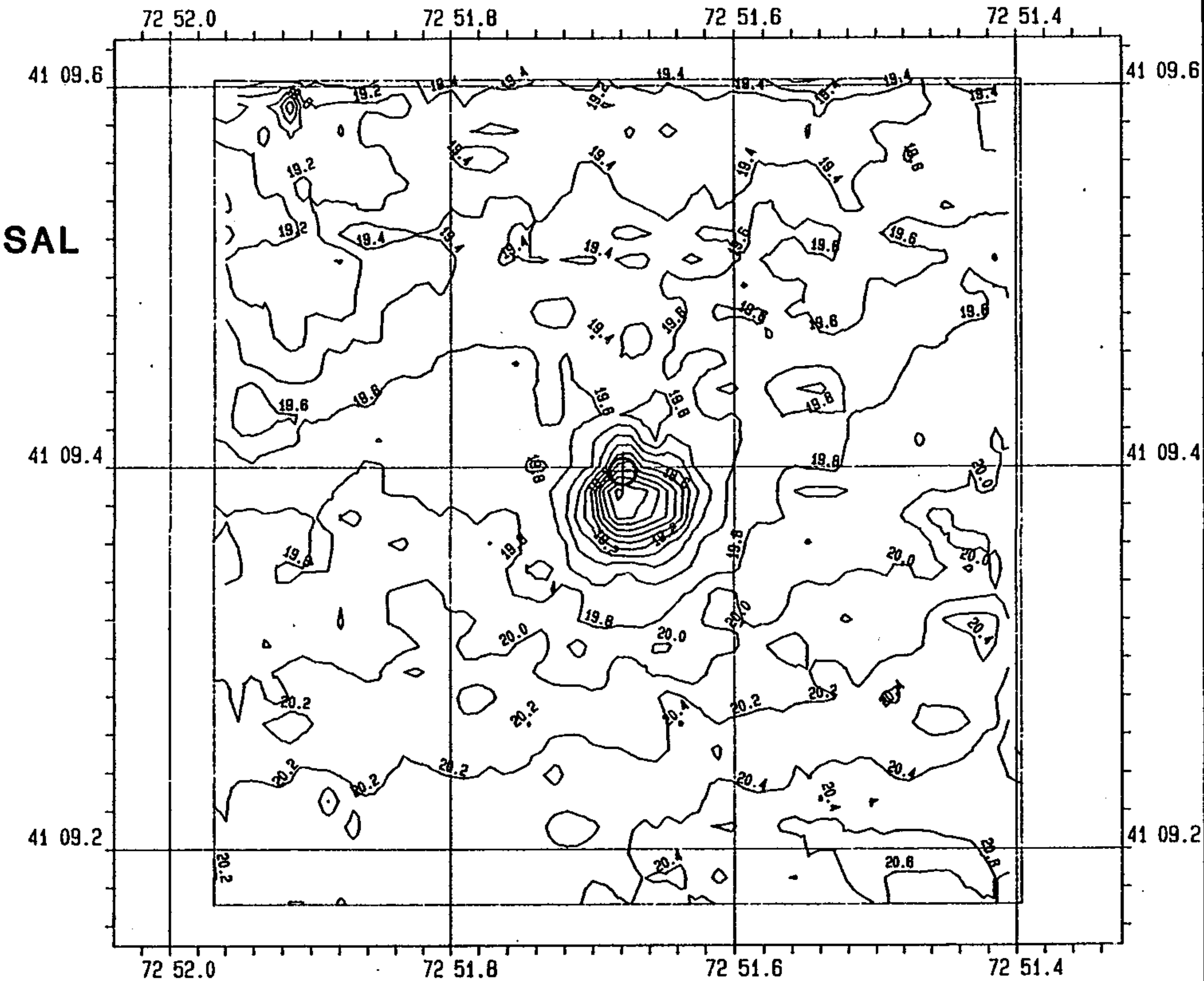
FVP
POST-DISPOSAL

JUNE 1983

FIGURE 3-69

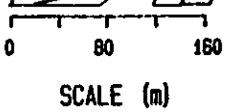
0 80 160

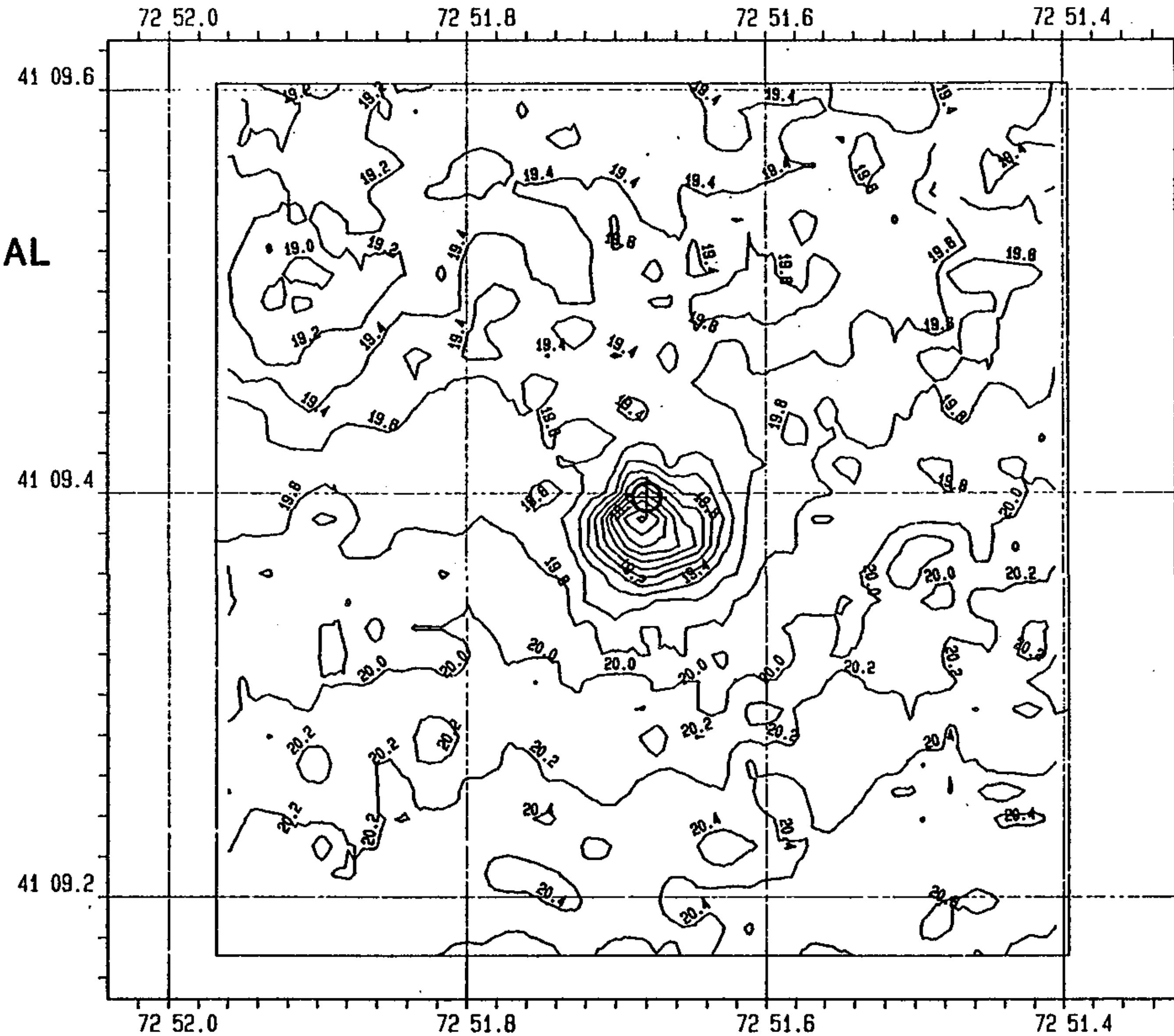
SCALE (m)



FVP
POST-DISPOSAL
JULY, 1983

FIGURE 3-70





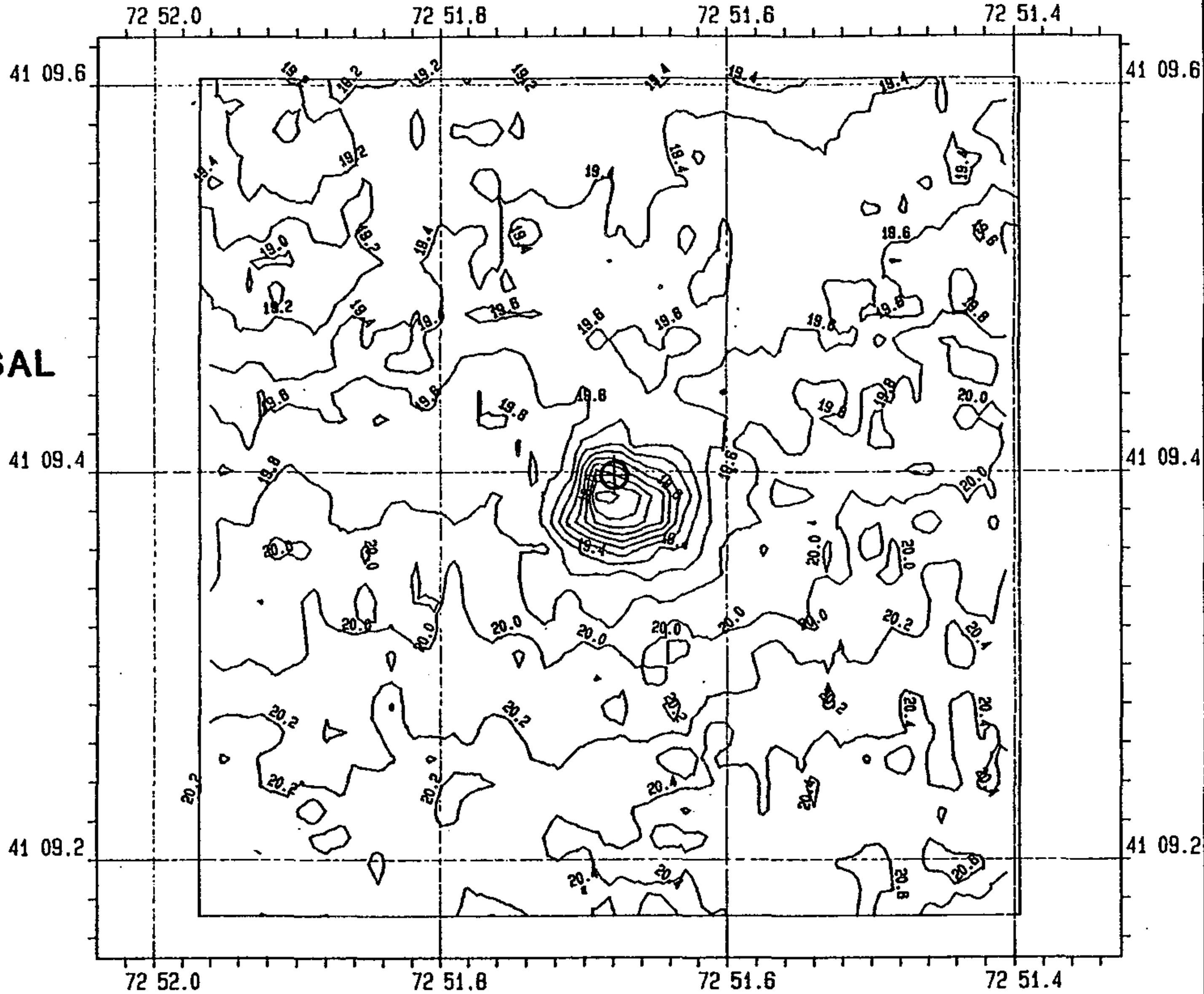
FVP POST-DISPOSAL MONITORING

AUGUST 1983

FIGURE 3-71

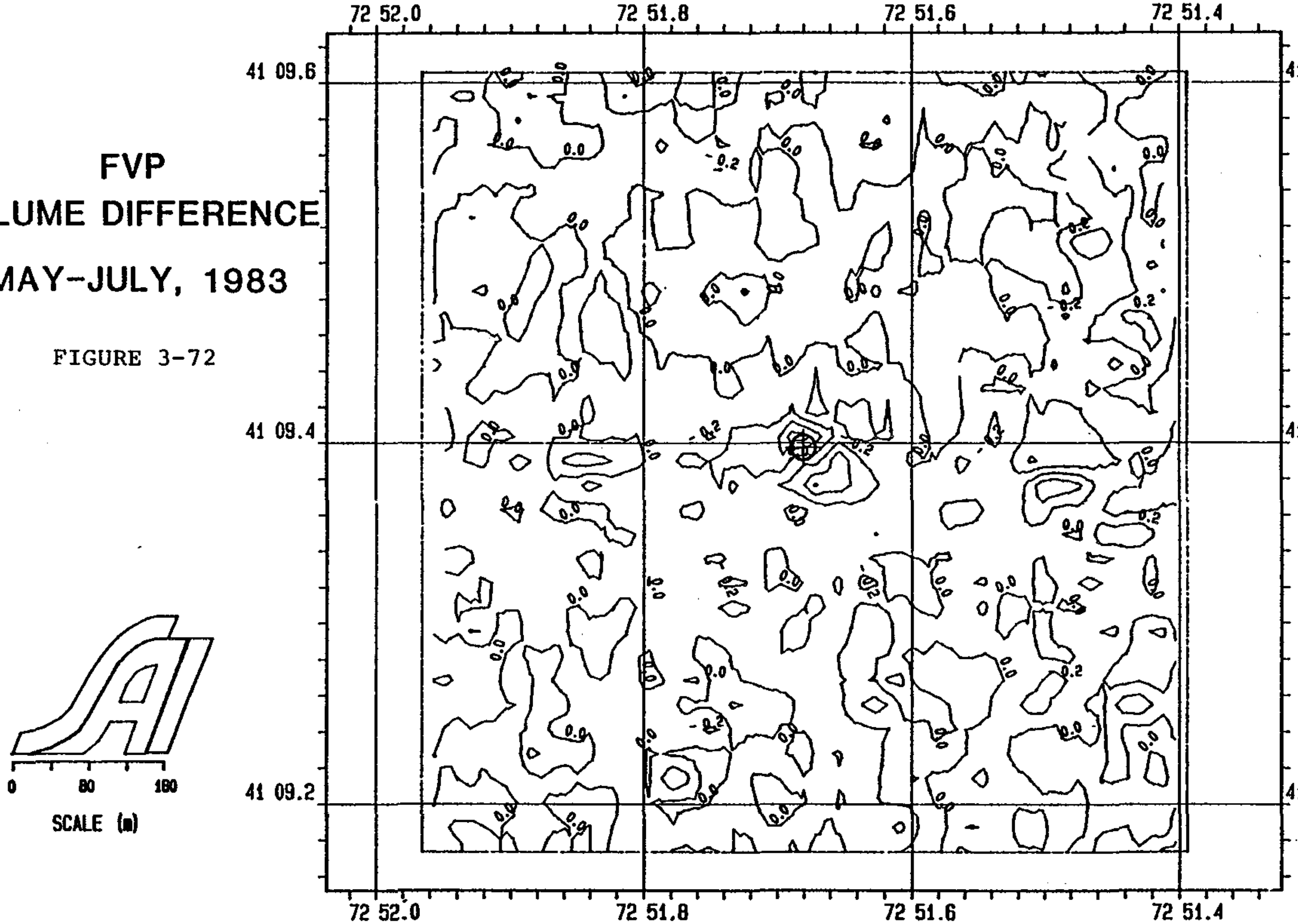
0 80 160

SCALE (m)



FVP
VOLUME DIFFERENCE
MAY-JULY, 1983

FIGURE 3-72

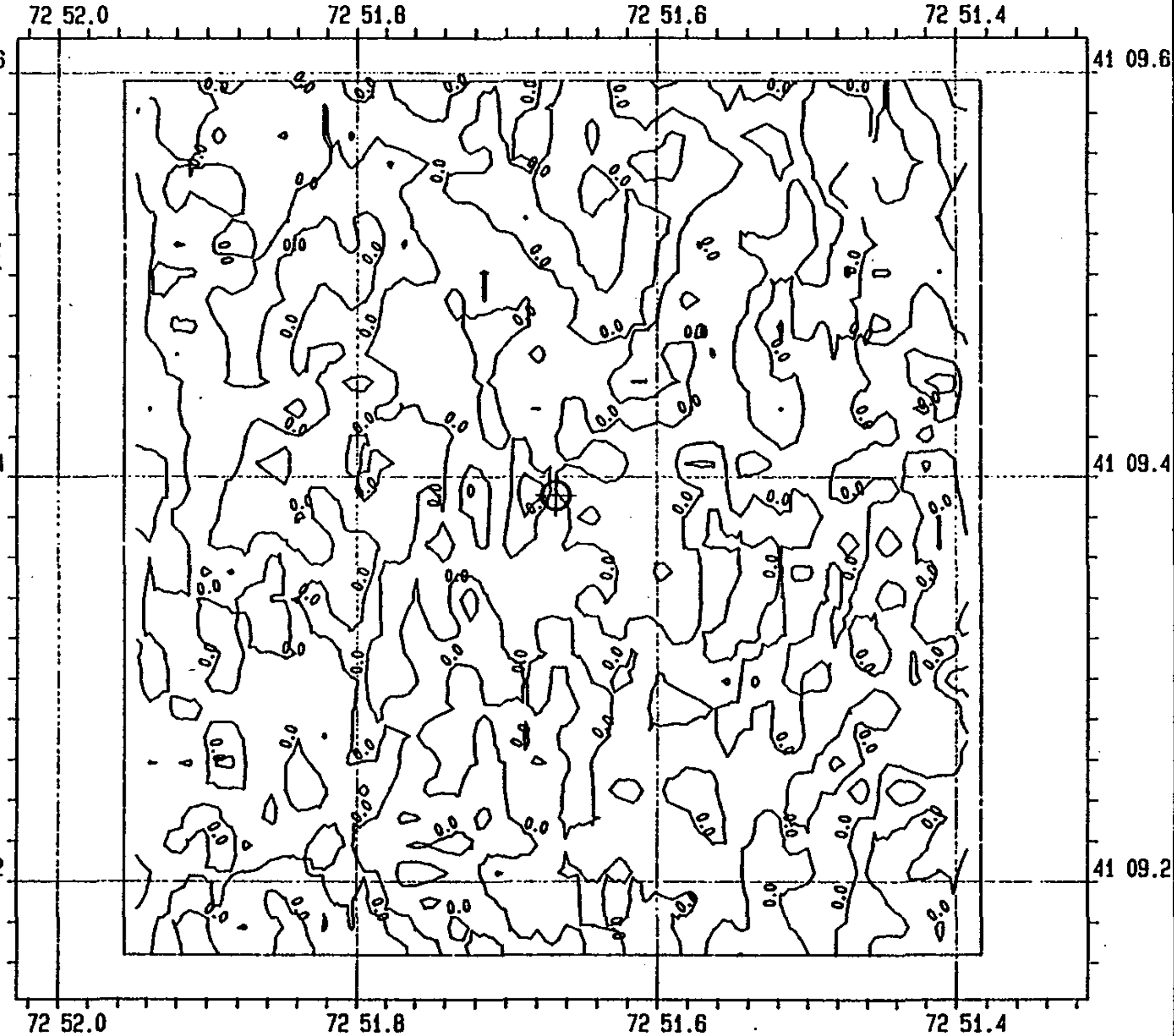


FVP
VOLUME DIFFERENCE
JULY-AUGUST, 1983

FIGURE 3-73

0 80 160

SCALE (m)



August, primarily because of the progressive oxidation caused by the infaunal deposit feeders.

There are no indications of significant spreading of Black Rock sediment. In fact, the margins of the mounds become less discernible and appear to recede toward the center of the mound as bioturbation and natural deposition combine to mix natural sediment with Black Rock material. These processes result in a deposit with no detectable layering. Although the margins can no longer be detected with the REMOTS camera, it is important to note that the contaminants remain at that site and are available for interaction with the infauna.

3.4.6 Summary of Post-Disposal Monitoring

As expected from previous studies at the CLIS site (Morton, 1983), no significant erosion or transport of dredged material has occurred after completion of disposal operations. However, it must be considered that the summer months do not produce the storms and associated wave action which migh cause erosion during the winter months. All sites, including the FVP site, where Black Rock sediment was fully exposed to the environment, are adjusting to existing environmental conditions through recolonization, deposition of natural sediments, and reworking through bioturbation. Continued monitoring should be conducted through the winter months to assess long-term changes in sediment parameters and to determine cap stability in the presence of winter storms.

4.0 GEOTECHNICAL MEASUREMENTS

The geotechnical properties of dredged material were studied as part of an overall assessment of the geophysical aspects of capping operations for several reasons. Although some work has been done evaluating the conditions of dredged material at the disposal site, very little information is known about the changes the material undergoes as it is removed from its original location, transported to the disposal site and dumped on the bottom. These changes could have significant effects on such parameters as the spread and distribution of sediment at the disposal site, the strength of the material to support a cap, the stability of the cap and the accuracy and viability of monitoring procedures following disposal.

Measurements of geotechnical parameters were made to meet the following objectives:

- determine the changes in sediment properties associated with the dredging and disposal operation
- determine the impact of those changes on capping procedures in terms of the ability to cap contaminated materials and the integrity of the cap in isolating contaminants over a long period of time
- develop guidelines defining limits for application of different sediment types to capping procedures
- determine how changes in geotechnical properties affect the accuracy of monitoring procedures, in particular the effects of density changes, compaction and consolidation on volume measurements
- determine the effectiveness of in-situ sediment density measurements as a method for estimating other geotechnical parameters and defining sediment properties for disposal management decisions
- evaluate the accuracy, reliability and effectiveness of the Troxler Nuclear Density Probe as an instrument for in-situ measurement of sediment density

Although most of the emphasis on this program was centered on capping operations at two locations in the Central Long Island Sound disposal site (CLIS), additional data were obtained from other ongoing projects in the area as part of the Disposal Area Monitoring System (DAMOS). Figure 1-1 is a diagram of the CLIS site and the specific disposal area survey grids examined under this and other parts of the DAMOS program. Cap sites #1 and #2 were selected for this program based on several criteria, including:

- natural bottom with no previous record of disposal
- flat bottom for precision bathymetric survey studies
- sufficiently removed from other sites to reduce potential for contamination of results by ongoing projects
- conduct disposal operations within the CLIS site to maintain the consistent disposal management policy of the New England Division

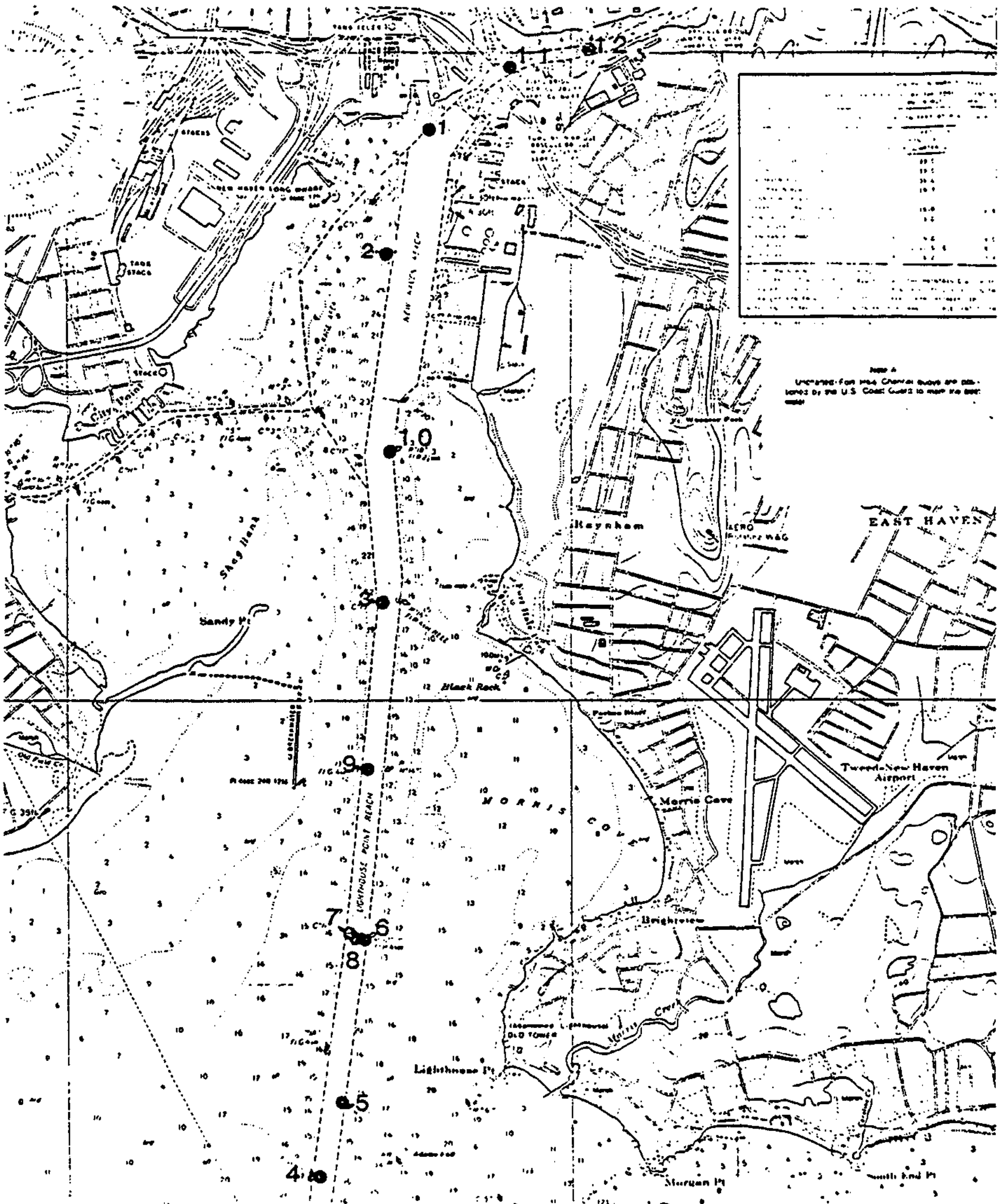
The capping operations were coordinated with other disposal programs at the Field Verification Program (FVP) site in the northeast corner and the Mill-Quinnipiac River (MQR) site in the southwest corner of the CLIS disposal site. Relatively contaminated material from Black Rock Harbor was deposited at the FVP site and silt from New Haven Harbor was deposited at the MQR site during the period of this study. The capping study was conducted using similar material, in that Black Rock sediment from the same area as the FVP material was dumped at each of the cap sites and then covered with sediment from New Haven Harbor. At Cap Site #1 the capping material was silt similar in composition to that dumped at the MQR site, while at Cap Site #2, sand from the outer reaches of the channel was used as the capping material. Bathymetric charts of the resulting mounds were presented in the previous section. Although some influence of dredged material from the Norwalk and "SP" disposal sites was observed on the eastern margins of the capping sites, the side scan and REMOTS data obtained during this study requires that this information be considered during interpretation of results.

4.1 Nuclear Density (ND) Probe Measurement Results

The nuclear density probe was used extensively during this study in an attempt to provide baseline information on the nature of sediment density variability in harbor sediments, in the loaded scows and at the disposal site. The following sections provide a summary of data obtained during this study; interpretation of results will be considered in a later section using other data sources as well as this information.

4.1.1 New Haven Harbor

A transect of twelve stations was made covering the entire length of the New Haven channel in April, 1983, at the locations shown in Figure 4-1. The results of these measurements are given in Table 4-1, and presented in Figure 4-2. The first portion of data was obtained by divers inserting the probe into the bottom, and the latter portion of data was obtained by free falling the probe into the bottom. Consequently, depth of penetration is not well known for the latter set of data.



DENSITY MEASUREMENT STATIONS
NEW HAVEN HARBOR
APRIL 1983

FIGURE 4-1

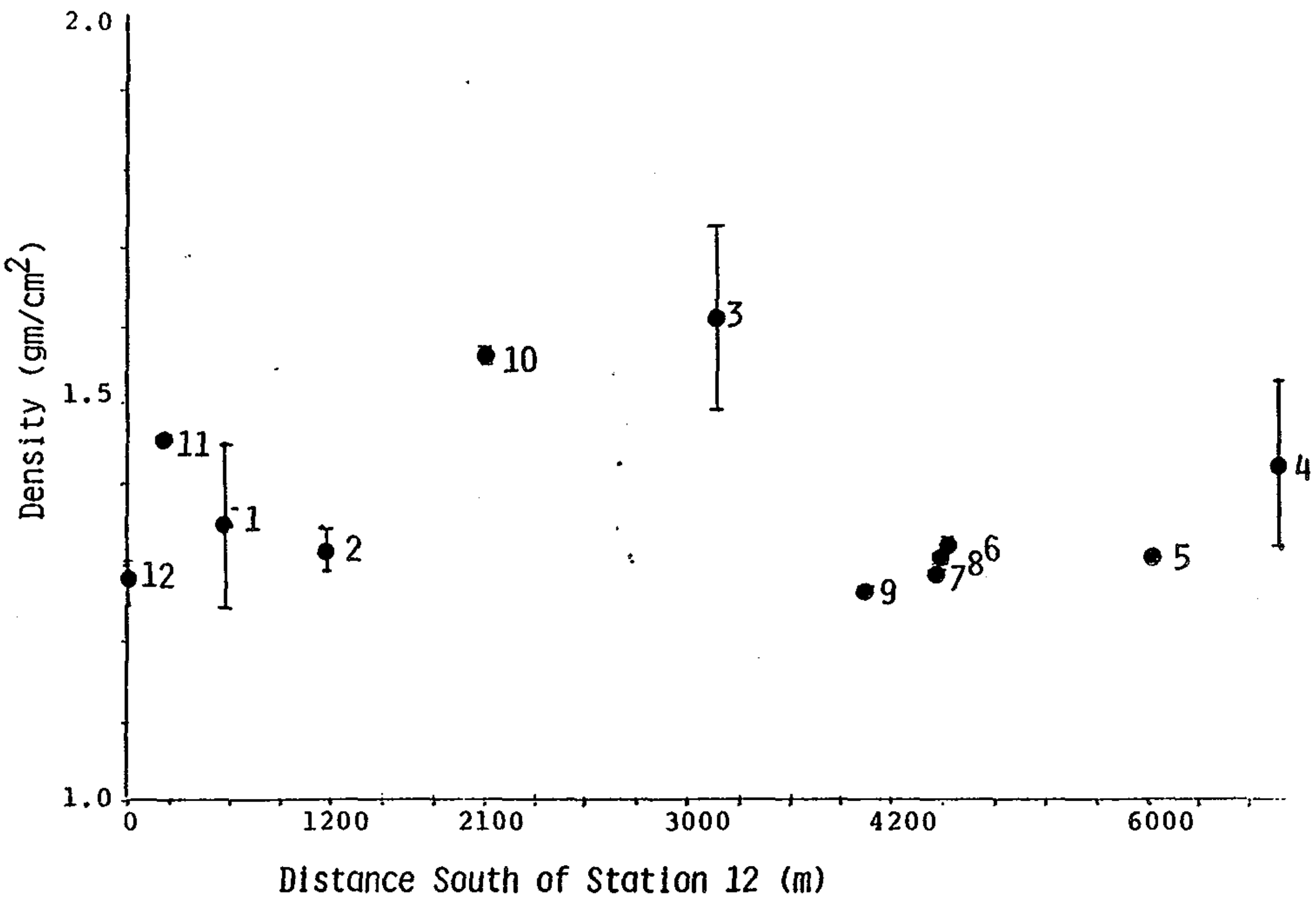
New Haven Harbor
Sediment Density Measurements
April, 1983

STA #	DENSITY	STA#	DENSITY
12	1.194	9	1.263
	1.374		
	1.274		
	$\bar{X}$ = 1.281		
	= 0.090		
11	1.453		
1	1.444	6,7,8	1.335
	1.187		1.284
	1.355		1.311
	1.459		= 1.31
	$\bar{X}$ = 1.36325		= .0255
	σ = .12491		
2	1.158	5	1.318
	1.195		
	1.229		
	1.248		
	$\bar{X}$ = 1.2075		
	σ = .039619		
		4	1.356
			1.286
10	1.577		1.575
	1.566		1.494
	$\bar{X}$ = 1.5715		= 1.42775
	σ = .00665		= .13078
3	1.428		
	1.599		
	1.725		
	$\bar{X}$ = 1.584		
	σ = .1491		

SUMMARY

Mean Density ($\bar{X}$) = 1.368
Standard Deviation (σ) = .119

TABLE 4-1



DENSITY DISTRIBUTION
NEW HAVEN HARBOR
APRIL 1983

FIGURE 4-2

The results indicate no significant trend in density in spite of significant changes in sediment composition from an extremely soft mud near the head of the harbor to sand near the mouth (NED, 1980). It should be noted, however, that dredging of the upper portion of the harbor had already been conducted at this time and, therefore, measurements were probably obtained in natural sediment as opposed to maintenance material.

Measurements were also taken in scows recently filled with sediment dredged from the vicinity of the scrap metal piers located on the east side of the harbor and from the turning basin off Long Wharf. The results of these measurements are represented in Table 4-2. Dredged material in both scows was substantially less dense on the average than material in the harbor, however, both scows showed an increase in density with depth and for Scow #1 the sediment density at the bottom of the scow approached the density of in-situ sediment.

For the type of sediment being dredged, the addition of water during the dredging process reduces the overall density of material transported to the disposal site, however, a significant portion of material is relatively undisturbed, sinks to the bottom of the scow and is transported to the disposal site intact. Because of time constraints and electronic problems with the probe, no additional scow measurements were made within New Haven Harbor.

4.1.2 Black Rock Harbor

A series of density measurements were made within Black Rock Harbor after dredging was completed. The measurement locations are shown in Figure 4-3 and the results are presented in Table 4-3 and Figure 4-4. The smaller numbers in Figure 4-3 are locations of core samples obtained prior to dredging operations. (Unfortunately, the ND probe was not available during the pre-dredge coring study.)

An interesting aspect of the Black Rock Harbor measurements was definition of the sediment water interface. When pushing the probe into the bottom there was no obvious increase in resistance coinciding with an increase in density which would indicate a discrete surface. Later investigations with a dual frequency sonar further substantiated such observations through detection of a substantial "fluff" layer. Figure 4-5 presents a record of the Black Rock harbor bottom made with a 27 kHz system which shows a sediment layer with a distinct low reflectance which lies between peaks of sediment with higher reflectance. Likewise, Figure 4-6 is a dual frequency trace through the same region which indicates an extensive fluff layer, approximately .5m thick as measured by the 200 kHz system, overlying more dense material observed by the 3.5 kHz signal.

In order to relate density measurements made under these conditions, the probe was lowered at equal increments of .3m and the sediment surface was arbitrarily defined as the level at which a significant increase in density occurred. In most

Table 4-2

Sediment Density Measurements
in
Dredge Material Disposal Scows
New Haven Harbor

Scow #1
Scrap Metal Piers
April, 1983

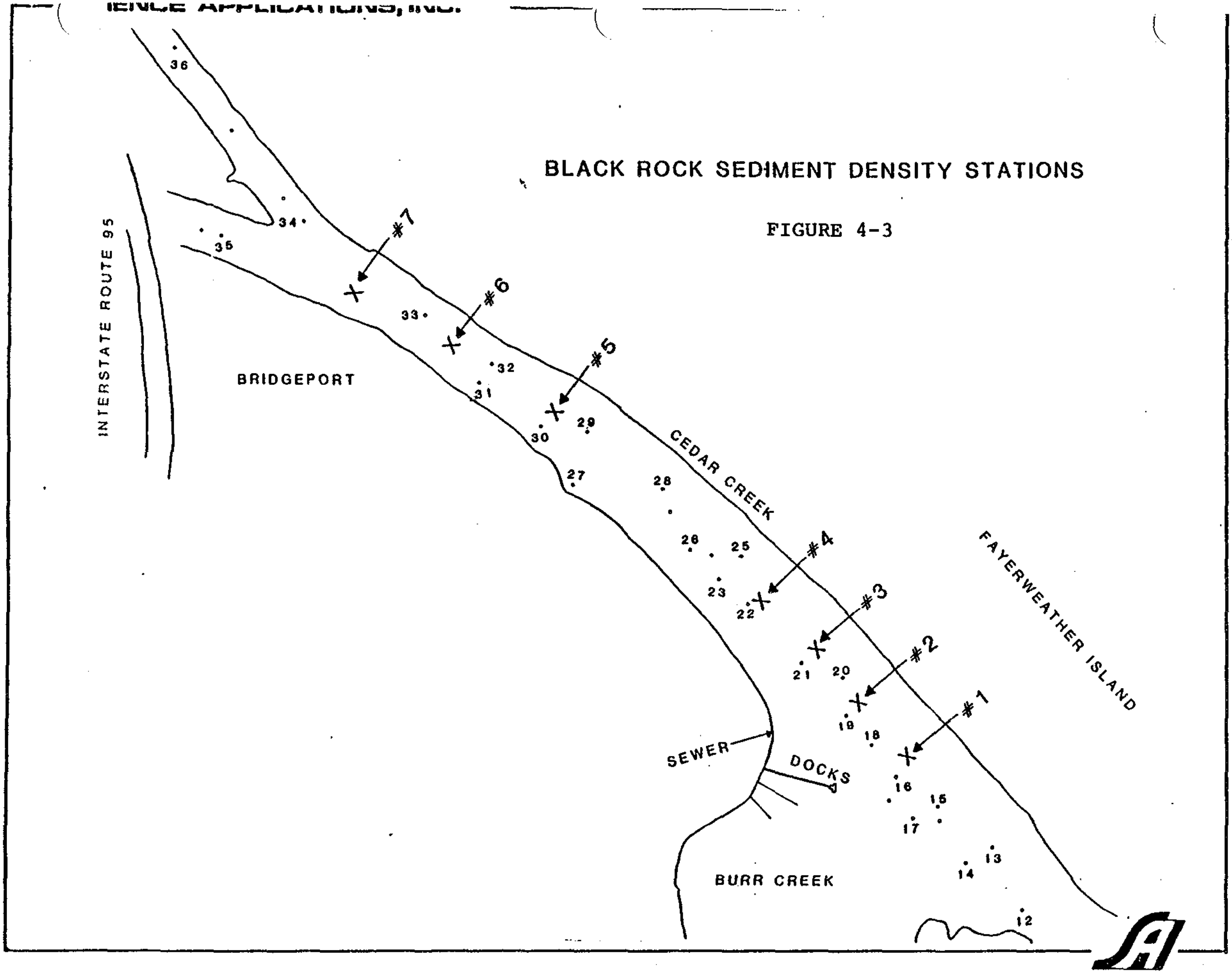
Depth (m)	Density
1.0	1.095
2.0	1.242
2.5	1.242
3.0	1.262
4.0	1.321
4.3	1.318

$\bar{X}$ = 1.250
σ = .077

Scow #2
Turning Basin
May, 1983

Depth (m)	Density
.5	1.131
1.0	1.180
1.5	1.184
2.0	1.186
2.5	1.190
3.0	1.197

$\bar{X}$ = 1.181
σ = .025



BLACK ROCK SEDIMENT DENSITY STATIONS

FIGURE 4-3

Table 4-3

Sediment Density Measurements
Black Rock Harbor
June, 1983

Sta #	Depth	Density
1	-1.8	1.017
	- .3	1.032
	0	1.168
	.3	1.212
	1.5	1.191
2	- .9	1.013
	- .3	1.018
	- .1	1.059
	0	1.148
	.9	1.198
	1.2	1.334
	1.5	1.286
	1.8	1.295
	2.0	1.327
3	-1.5	1.018
	- .9	1.019
	- .3	1.021
	0	1.135
	.3	1.154
	.6	1.180
	.9	1.215
	1.2	1.285
	1.5	1.489
4	-2.0	1.019
	- .6	1.036
	0	1.209
	.3	1.206
	.6	1.763
	.9	1.807
5	-2.0	1.022
	- .6	1.022
	0	1.146
	.3	1.187
	.6	1.209
	.9	1.191
	1.5	1.187
6	- .6	1.024
	- .3	1.088
	0	1.246
	.3	1.165
	.6	1.185
	1.2	1.342
7	- .9	1.016
	- .6	1.016
	- .3	1.084
	0	1.231
	.3	1.313
	.6	1.275
	.9	1.587

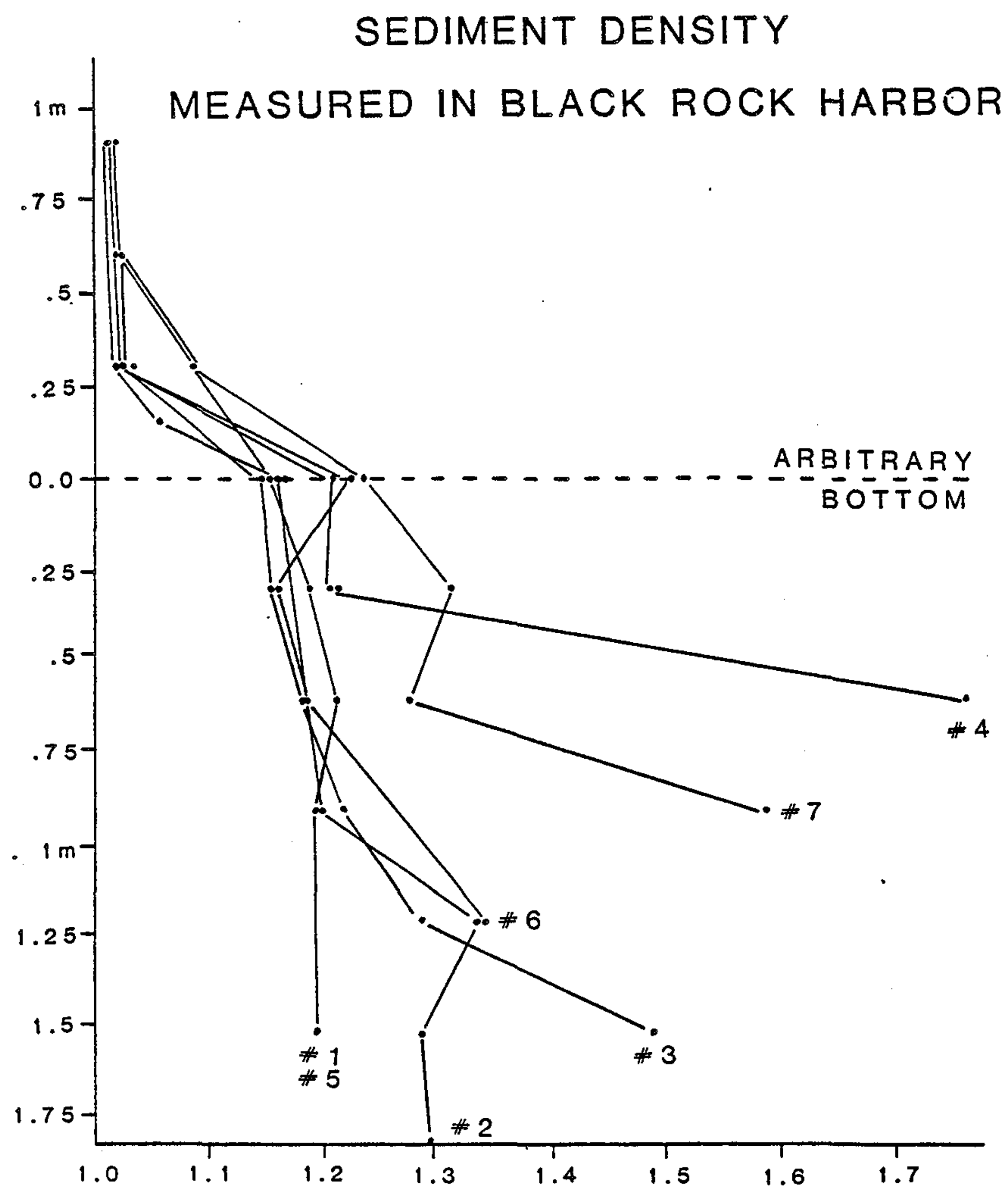
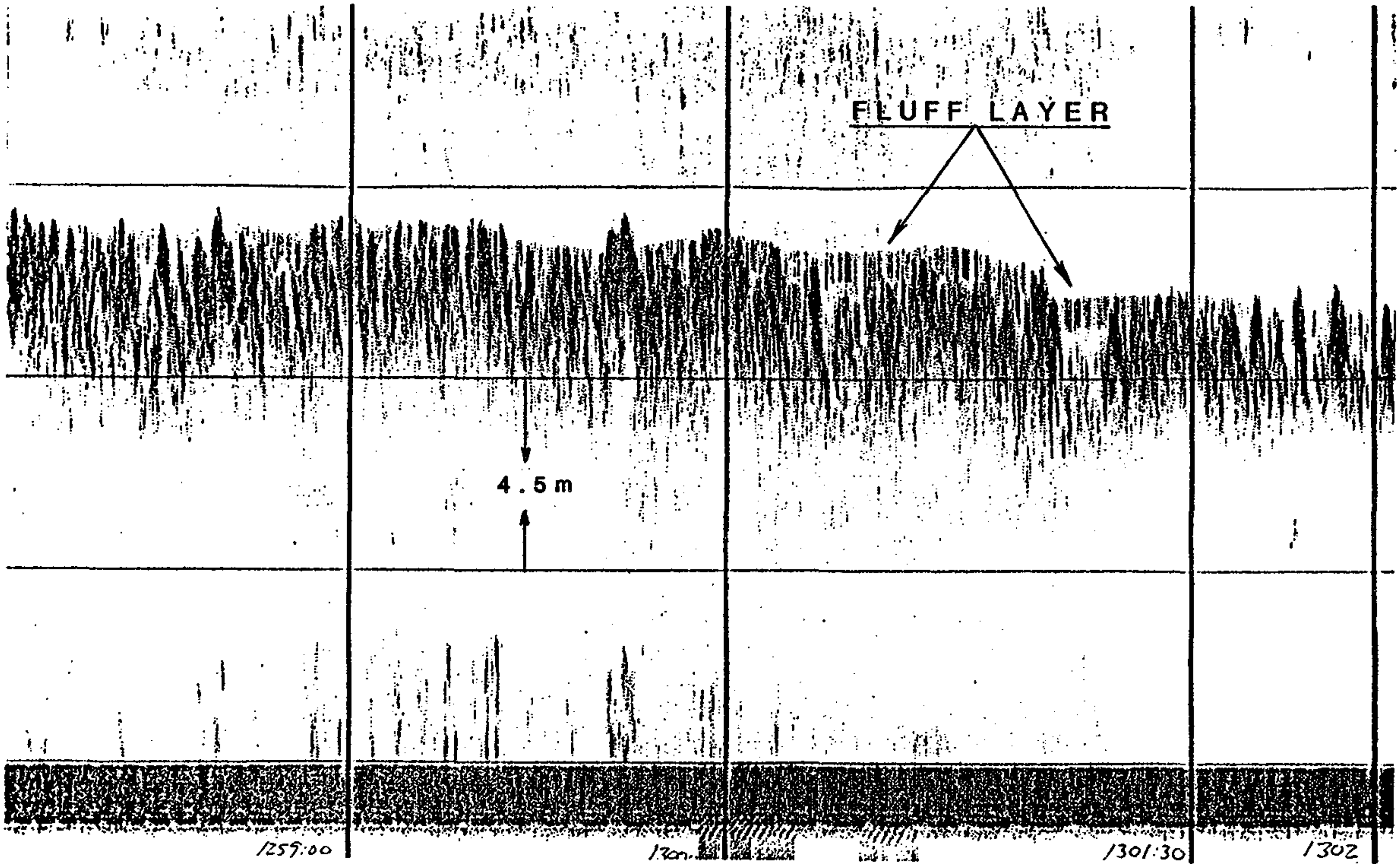

SEDIMENT DENSITY
MEASURED IN BLACK ROCK HARBOR
1m
.75
.5
.25
0.0
.25
.5
.75
1m
1.25
1.5
1.75
ARBITRARY
BOTTOM
4
7
6
1
5
3
2
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7

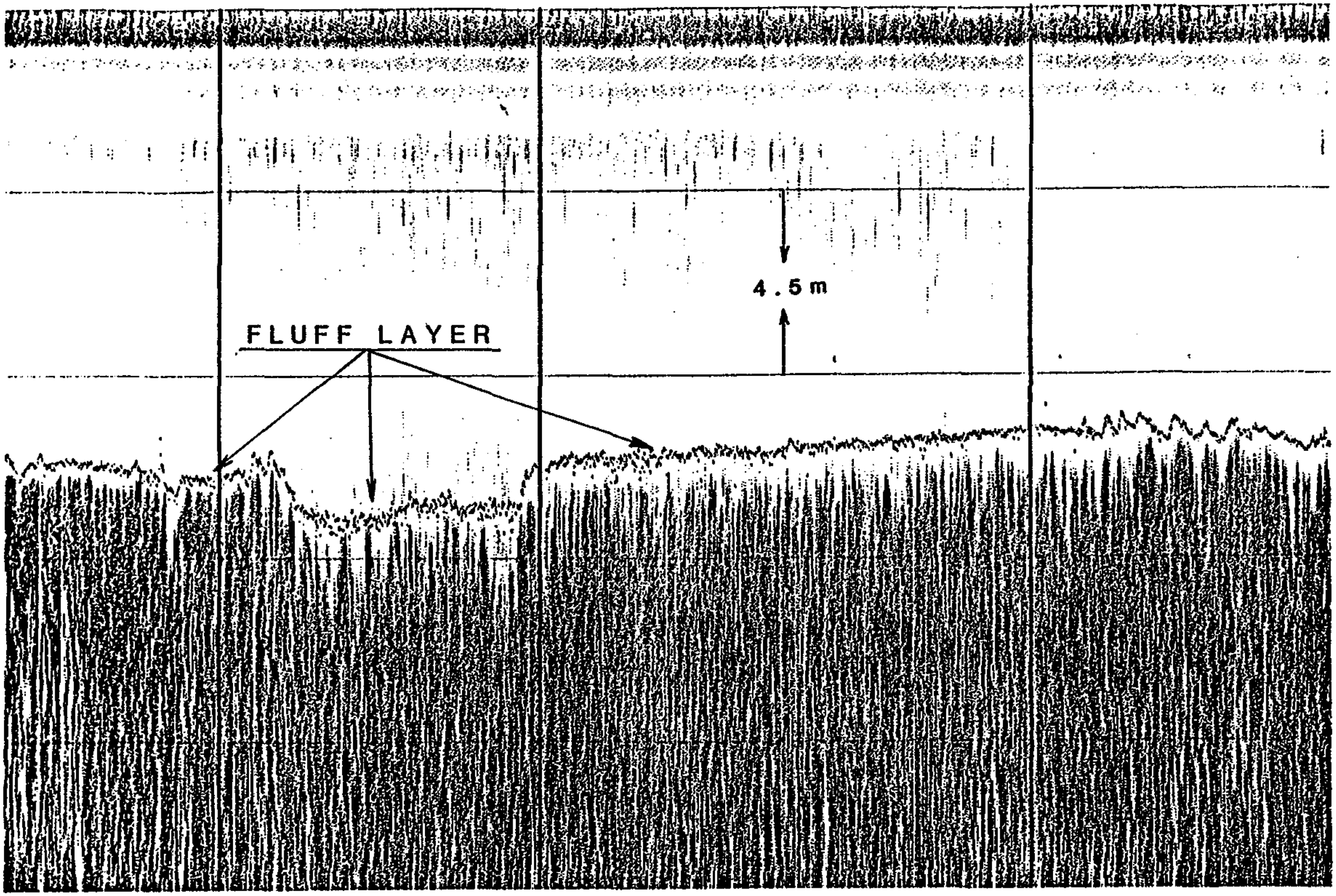
FIGURE 4-4



27KHz SONAR TRACE

BLACK ROCK HARBOR

FIGURE 4-5



3.5/200 KHz
DUAL FREQUENCY SONAR TRACE
BLACK ROCK HARBOR

FIGURE 4-6

cases, this increase was at least .1 gm/cm3, however in some samples such as #2, #6 and #7, the increase was more gradual, indicating the presence of a fluff layer. There was also a marked increase in density with depth in these measurements. Measurements less than 50 cm from the sediment/water interface averaged 1.193 g/cm^3 while those greater than 50cm averaged 1.33 g/cm^3. This upper value is close to the mean of 1.20 for the density of samples obtained prior to dredging and analyzed by laboratory methods as shown in Table 4-4. The sediment below 50 cm is significantly more dense and probably represents undisturbed material. From these data, it is readily apparent that the dredged material from Black Rock Harbor consisted of a significant amount of low density sediment slurry, some of which remained as a fluff layer and some of which was obviously transported to the disposal site in the scows. Furthermore, it is apparent from the sub-bottom profiles in Figures 4-5 and 4-6 that more dense material was also dredged.

In addition to density measurements, grain size and Atteburg limits were also determined for these samples. Atteburg limits are engineering parameters used to test the plasticity of sediments. These results indicate that Black Rock sediments have high plasticity, and are composed of fine silt with extremely high liquid limits. This is probably associated with the high organic content of the sediment.

Sediment density measurements were obtained from three scow loads during the dredging of Black Rock Harbor. The results of these measurements, presented in Table 4-5, show relatively low density material in one scow load, while others showed a higher density more typical of maintenance material.

In summary, the sediments from Black Rock Harbor were less dense than sediments from New Haven (1.20 versus 1.37 gm/cm^3); however, once dredged and placed in the disposal scows, there appeared to be a vertical layering of material according to density in each of the three scows and frequently relatively large differences between the mean density measured for entire scow loads and the mean density of the individual stations.

4.1.3 Disposal Site

The density probe was also deployed at the disposal sites to assess the changes in density that occurred during the disposal operation. The penetration frame was used to sample transects across the mounds developed at Cap Sites #1 and #2 and the FVP site. Each station was sampled by placing the frame on the bottom and inserting the probe in 50cm increments. The results of the measurements are presented in Tables 4-6 through 4-11. The FVP data are presented in this report, since they represent uncapped Black Rock material and give added insight to the interpretation of the Cap Sites.

Background density levels for natural sediment in the area averaged 1.378 gm/cm^3 with a 0.5 gm/cm^3 increase in

Table 4-4

Black Rock Harbor
Pre-Dredging Geotechnical Properties

Sta #	Density	Mean Grain Size	Liquid Limit	Plastic Limit	Plasticity Index
16	1.18	.012	213	76	137
17	1.24	.043	147	55	92
18	1.15	.012	204	77	127
19	1.17	.014	209	73	36
20	1.15	.010	210	78	32
21	1.18	.039	202	84	118
22	1.16	.009	204	76	128
23	1.16	.013	186	69	117
24	1.19	.012	195	75	120
25	1.19	.015	155	63	92
26	1.28	.048	123	54	69
27	1.23	.021	158	63	95
28	1.16	.035	210	68	142
29	1.24	.031	122	52	69
30	1.26	.035	126	54	72
31	1.17	.014	192	73	119
32	1.17	.015	199	69	130
33	1.33	.043	142	55	87
$\bar{X}=$	1.20	.023	177	67	99
$\sigma=$	.08	.014	33	10	33

Table 4-5

Sediment Density Measurements
Black Rock Harbor Disposal Scow
May, 1983

DEPTH	SCOW #1 DENSITY	SCOW #2 DENSITY	SCOW #3 DENSITY
.5m	1.119	1.173	1.224*
1.0m	1.159	1.183	1.168
1.5m	1.182	1.230	1.212
2.0m	1.192	1.222	1.196
=	1.174	1.202	1.200

$\overline{X} = 1.191$
$\sigma = .029$

FPV DISPOSAL SITE

25N
1.471
1.685
1.776 (1.0^{+})

25W	CTR	25E	50E	100E	200E	400E
1.430	1.395	1.354	1.279	1.357	1.430	1.433
1.494	1.436	1.427	1.397	1.387	1.487	1.374
1.420	1.487	1.493	1.455	1.489	1.409	1.452

25S
1.377
1.474
1.448

(PROFILE INCREMENTS 50CM EXCEPT WHERE NOTED)

POST DISPOSAL
DENSITY MEASUREMENT PROFILES
AT THE FVPDISPOSAL SITE
JUNE 17, 1983

Table 4-6

CS-1 DISPOSAL SITE

25N
1.241
1.303
1.390

200W	100W	50W	25W	CTR	25E	50E	100E	200E
1.347	1.239	1.259	1.265	1.264	1.341	1.356	1.324	1.536
1.444	1.263	1.241	1.251	1.254	1.371	T.O.	1.470	1.361
1.347	1.264	1.250	1.269	T.O.	1.463	T.O.	1.458	1.412

25S
1.251
1.296
1.386

T.O. = PROBE STAND TIPPED OVER

(PROFILE INCREMENTS 50CM
EXCEPT WHERE NOTED)

POST CAPPING
DENSITY MEASUREMENT PROFILES
AT THE CS-1 DISPOSAL SITE
JUNE 17, 1983

Table 4-7

CS-2 DISPOSAL SITE

25N

1.881
1.635
1.949

200W	100W	75W	25W	CTR	25E	50E	100E	200E
1.358	1.714	1.556	1.831	1.750	1.690	1.680	1.805	1.591
1.389	1.623	1.556	1.620	1.530	1.638	1.413	1.518	1.364
1.427	1.641	1.314	1.468	1.446	1.574	1.504	1.408	1.407
	1.557 (1.8)							

25S

1.893
1.738
1.690

(PROFILE INCREMENTS 50CM EXCEPT WHERE NOTED)

POST CAPPING

DENSITY MEASUREMENT PROFILES
AT THE CS-2 DISPOSAL SITE

JUNE 17, 1983

Table 4-8

FVP DISPOSAL SITE

50W	CTR
	25N
	1.345
	1.346
	1.411
50W	**CTR**
1.411	1.403
1.457	1.432
1.394	1.452
	25S
	1.372
	1.365
	1.436
	1000S
	1.387
	1.367
	1.431

POST DISPOSAL
SEDIMENT DENSITY PROFILES
FVP DISPOSAL SITE
OCTOBER 18, 1983

Table 4-9

CAP SITE #1

		25N	
		1.239	
		1.254	
		1.317	
	25W	CTR	25E
	1.259	1.263	1.292
	1.266	1.253	1.460
	1.263	1.321	1.539
1000W		25S	
1.368		1.251	
1.367		1.377	
1.422		1.417	
1.312			
1.370			
1.372			
1.322			
1.322			
1.372			
1.400			

POST DISPOSAL
SEDIMENT DENSITY PROFILES
CAP SITE #1
OCTOBER 18, 1983

Table 4-10

CAP SITE #2

1000W		CTR	25E
		1000N	
		1.398	
		1.442	
		1.485	
		25N	
		1.890	
		1.746	
		1.631	
1000W		**CTR**	**25E**
1.366		1.791	1.585
1.381		1.816	1.637
1.399		1.717	1.555
		25S	
1.352		1.827	
1.385		1.473	
1.411		1.385	
1.362			
1.404			
1.403			

POST DISPOSAL
SEDIMENT DENSITY PROFILES
CAP SITE #2
OCTOBER 18, 1983

Table 4-11

density over the 1.5 m of penetration. Density levels on the disposal mounds were markedly different. The FVP mound was characterized by sediment densities on the order of 1.4 to 1.5, Cap Site #2 with a predominance of sand from 1.5 to 1.8, and Cap Site #1 with more normal values of 1.25 to 1.3. The density values have remained consistent within each mound over the period from June to October, consequently it is apparent that these differences are a result of the respective dredging and disposal operations and not post disposal phenomena.

Although further interpretation requires additional data, it is readily apparent that density measurements may provide significant insight toward understanding the processes that may be affecting disposal and capping operations in the marine environment.

4.2 Coring Operations

During July, 1983, 15 gravity cores were obtained at the Central Long Island Sound Disposal site, sampling the disposal mounds created at the FVP, Cap Site #1 and Cap Site #2 disposal points. A summary of the core locations and their overall lengths is presented in Table 4-12. Charts of the core locations are presented in Figure 4-7a, b and c, and graphic presentations of core lithology are presented in Figures 4-8 to 4-22.

Typical natural bottom sediment in the disposal area consists of a cohesive silty-clay, with relatively low water content, and is generally light gray in color. This sediment was found at the base of all cores and apparently extends for several meters without much variability.

In spite of the low density, high water content, organic rich silt, that was characteristic of the upper layers of Black Rock Harbor sediment, a typical core from the FVP site contained relatively coarse sand, with large amounts of organic detritus present. This material was predominant throughout the mound area, but at distances from 100 to 400 m from the disposal point, the sediment is finer and more similar to typical harbor material.

Cores taken from Cap Site #1, show a somewhat different situation. Here the silt from New Haven has behaved in a manner similar to that which occurred during the Stamford-New Haven operation. A relatively thick mound of dredged material has formed and is composed of cohesive silt material that appears quite stable.

At the present time, it is impossible to distinguish Black Rock sediment from New Haven material on the basis of visual observations, since both are black organic silts. Sediment samples have been taken from these cores and are presently being analyzed at the New England Division to insure that material at the base of the silt layer is in fact Black Rock sediment and that the top portion is New Haven silt.

Table 4-12

Summary Data For
Gravity Cores From
Central Long Island Sound Disposal Site
July, 1983

Disposal Site	Location	Core Length	Black Rock Thickness	New Haven Thickness
FVP	CENTER	142 cm	86 cm	
	50N	155 cm	44 cm	
	100S	230 cm	10 cm	
	100E	129 cm	28 cm	
	100W	129 cm	18 cm	
CAP SITE #1	CENTER	210 cm		97*cm
	50N	140 cm		89 cm
	75S	122 cm		86 cm
	50E	162 cm		99 cm
	100W	172 cm		86 cm
CAP SITE #2	CENTER	121 cm	35.6 cm	50.8 cm
	25N	150 cm	2 cm	85 cm
	50S	127 cm	9 cm	60 cm
	50E	177 cm	12 cm	41 cm
	75W	173 cm	5 cm	74 cm

*Boundary between Black Rock and New Haven sediment cannot be distinguished through lithology

FVP POST-DISPOSAL

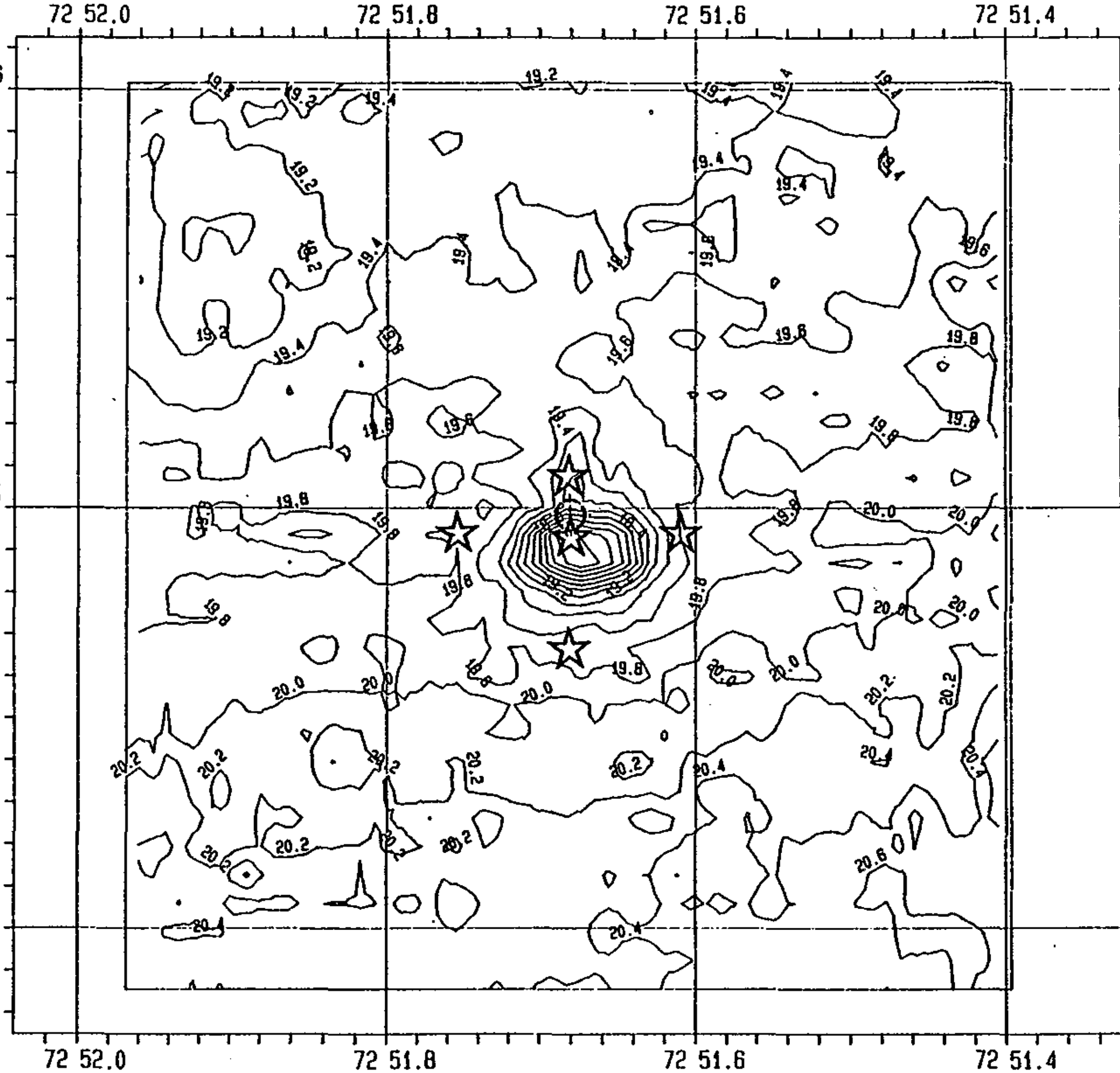
MAY 1983

☆-CORE LOCATION

FIGURE 4-7a

0 80 160

SCALE (m)



CAP SITE #1
POST-CAPPING

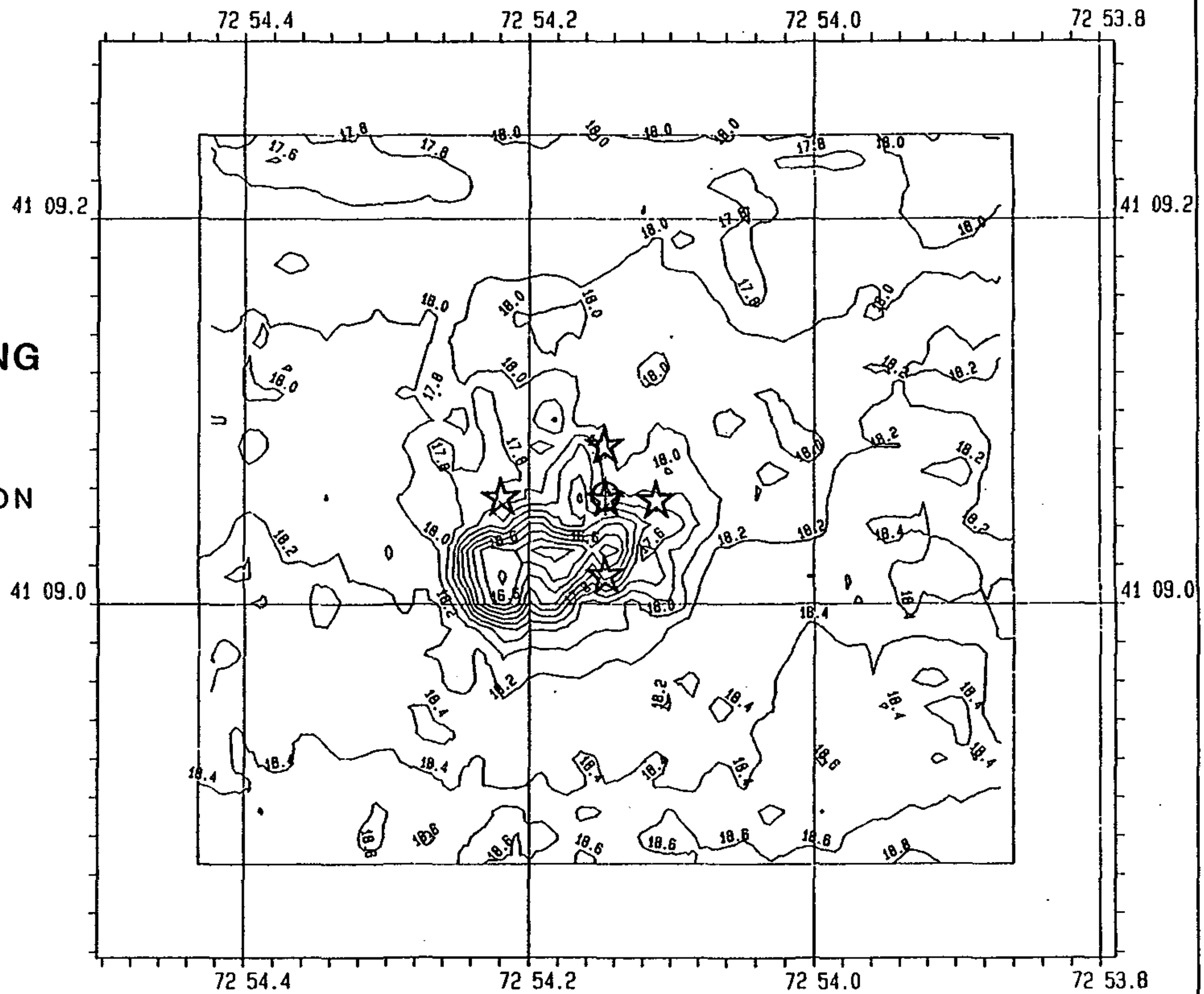
JUNE 1983

☆-CORE LOCATION

FIGURE 4-7b

0 80 160

SCALE (m)

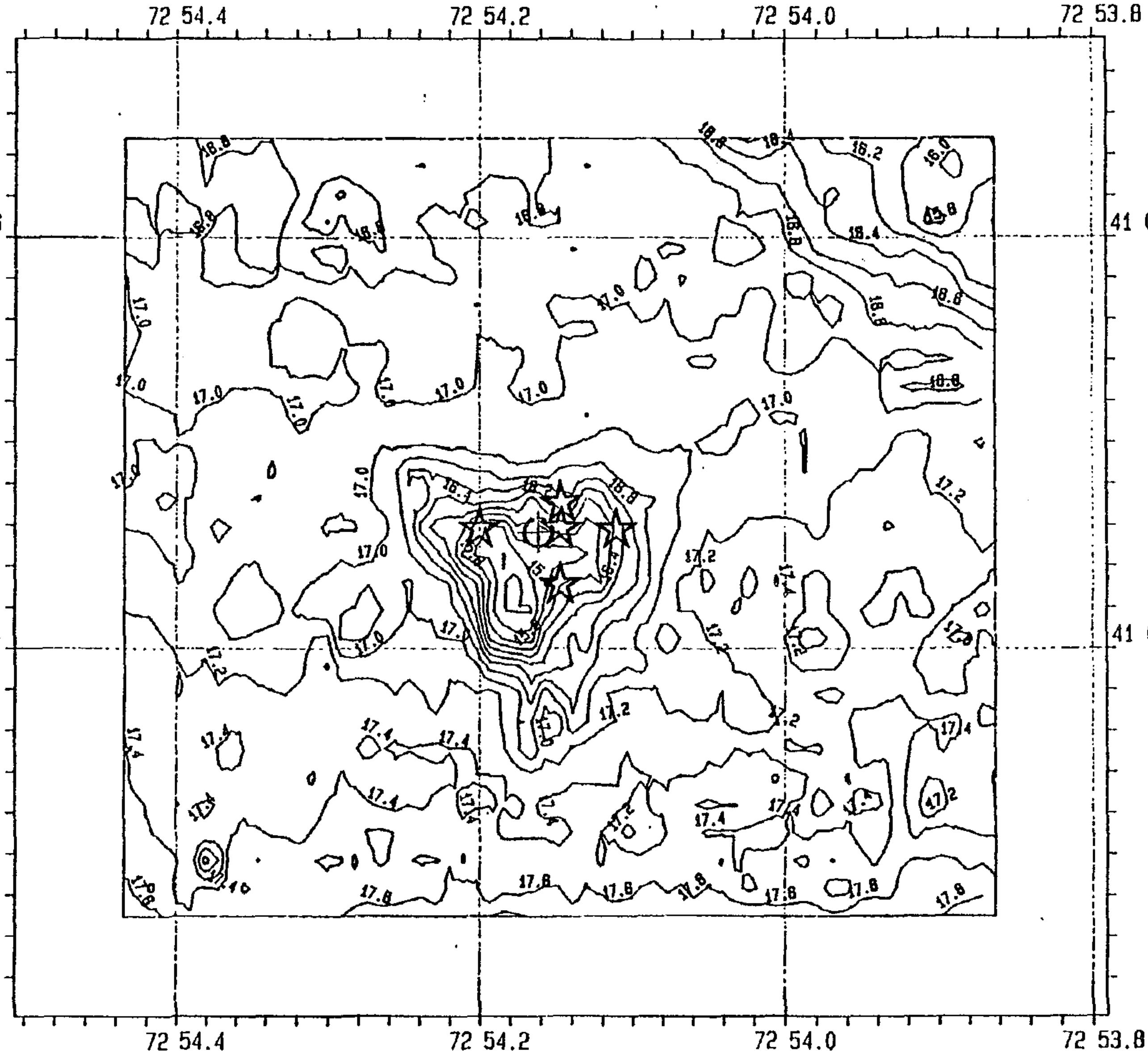


CAP SITE #2 POST DISPOSAL

JUNE, 1983

☆-CORE LOCATION

FIGURE 4-7c



0 80 160

SCALE (m)

Sediment Cores

Sampled By Science Applications, Inc.

July 1983

Depth
(cm)

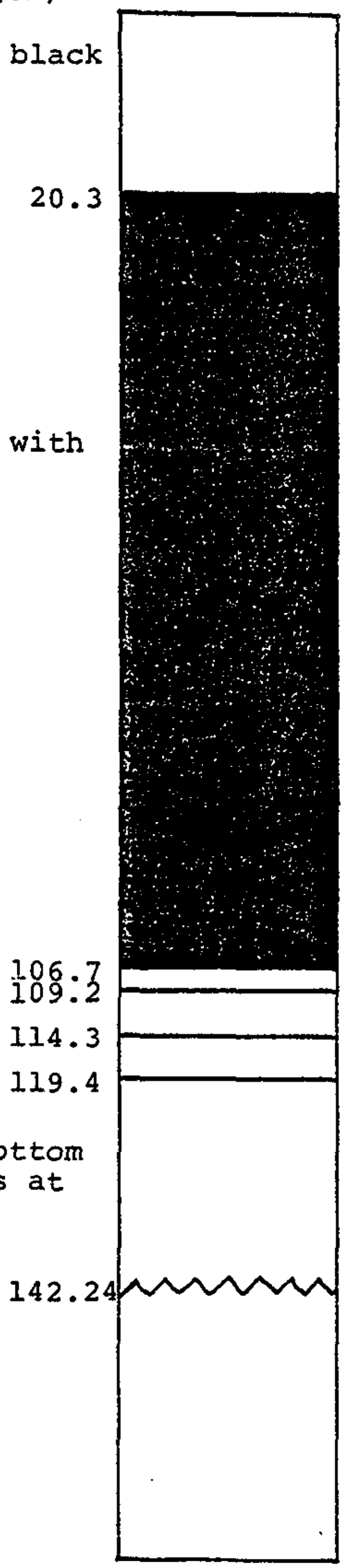
rmixed grey and black
, fairly coarse
es

ular black silt with
ng odor

ular sand layer
n silt

k silt

silt natural bottom
shell fragments at
5 cm



Field Log No. ______

Site FVP

Location Center

Date Sampled July 1983

Length of Core 142.2 cm

Diameter 6.5 cm

1 cm = 8 cm of core

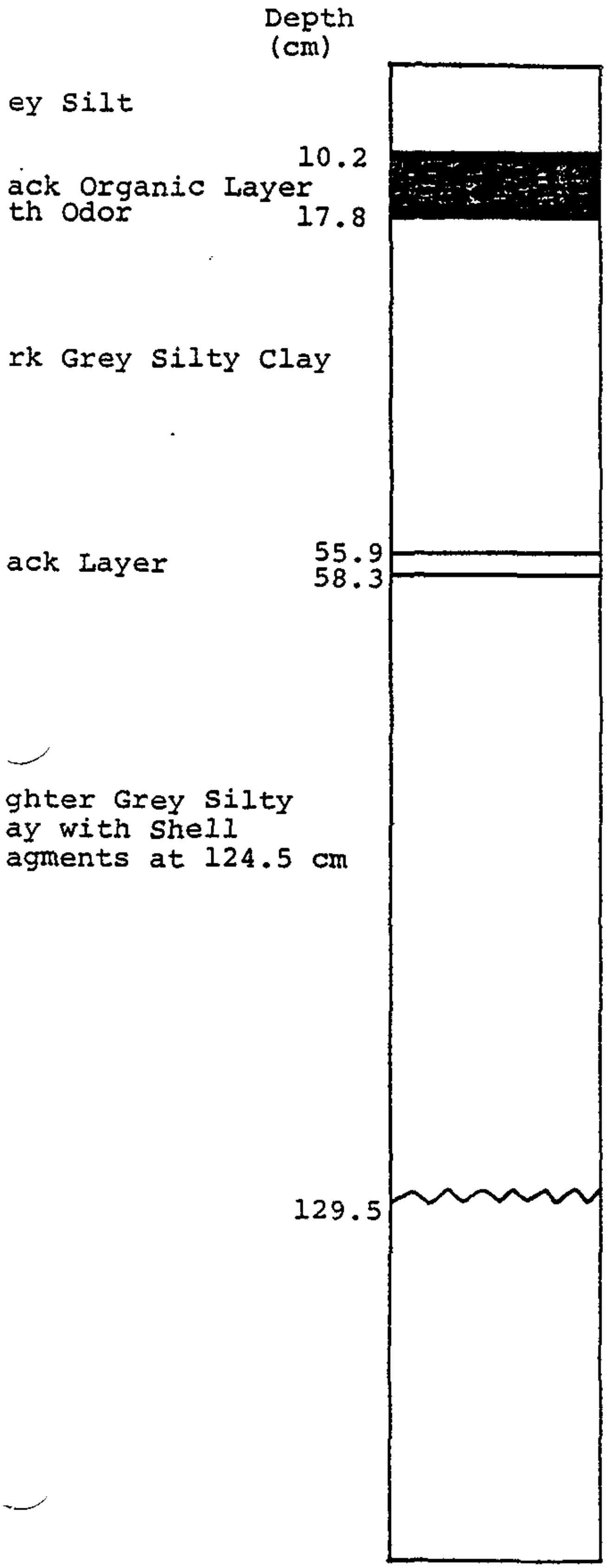
Darkened area indicates
dredged material

Figure 4-8

Sediment Cores

Sampled By Science Applications, Inc.

July 1983



Field Log No. __________

Site FVP

Location 100 West

Date Sampled July 1983

Length of Core 129.5 cm

Diameter 6.5 cm

1 cm = 8 cm of core

Darkened area indicates dredged material.

Figure 4-9

Sediment Cores

Sampled By Science Applications, Inc.

July 1983

ey Silt Grade to

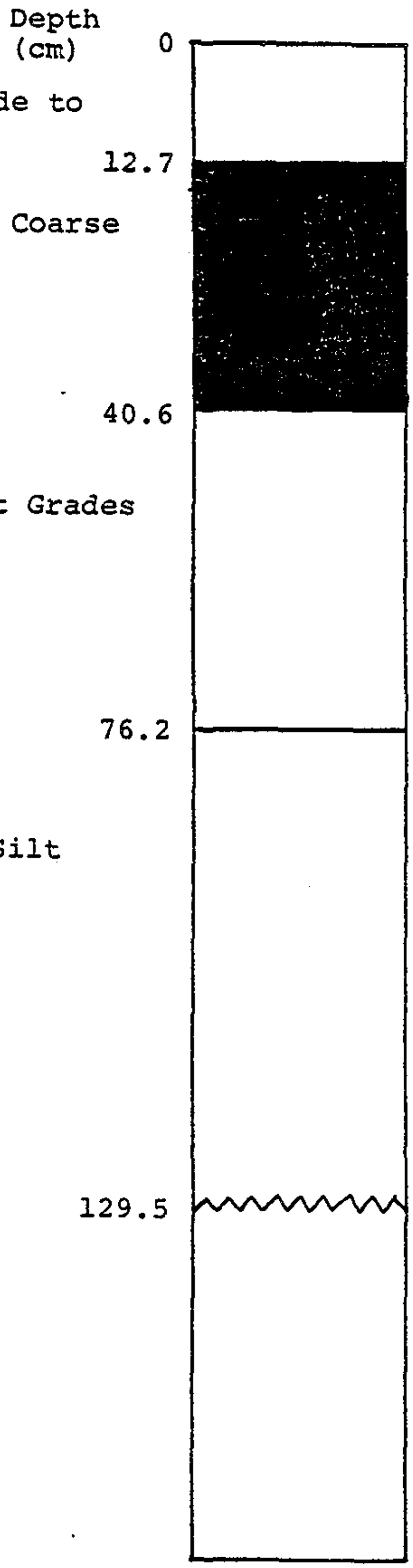
ack Organic Coarse
.t Grades

To

:k Grey Silt Grades

To

ghter Grey Silt



Field Log No. ______________

Site FVP

Location 100 East

Date Sampled July 1983

Length of Core 129.5 cm

Diameter 6.5 cm

1 cm = 8 cm of core

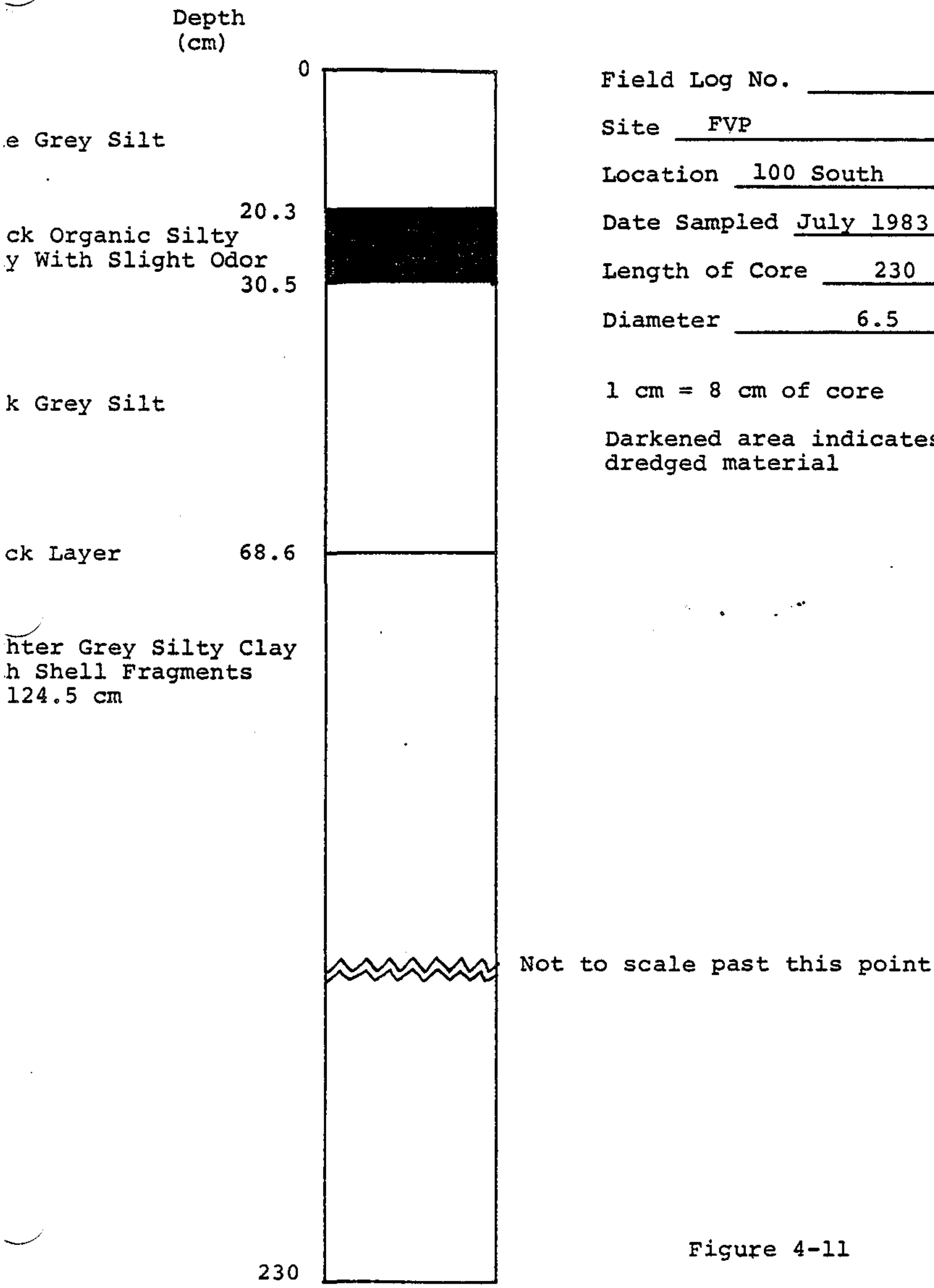
Darkened area indicates dredged material

Figure 4-10

Sediment Cores

Sampled By Science Applications, Inc.

July 1983



Field Log No. ______

Site FVP

Location 100 South

Date Sampled July 1983

Length of Core 230 cm

Diameter 6.5 cm

1 cm = 8 cm of core

Darkened area indicates dredged material

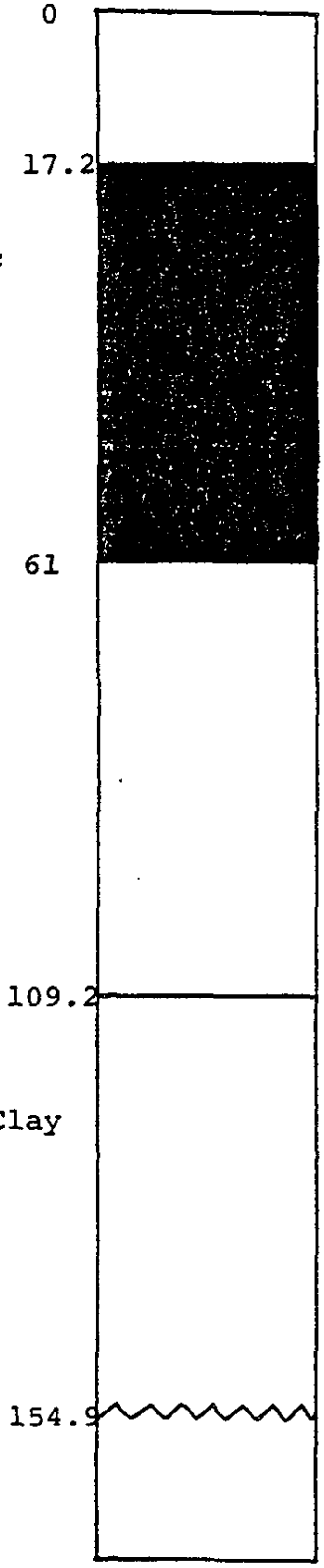
Figure 4-11

Sediment Cores

Sampled By Science Applications, Inc.

July 1983

Depth (cm)



ermixed Grey and
ck Silt

rse Black Organic
t with Odor

ck Fine Silt

ural Grey Silty Clay

Field Log No. ____________

Site FVP

Location 50 North

Date Sampled July 1983

Length of Core 154.9 cm

Diameter 6.5 cm

1 cm = 8 cm of core

Darkened area indicates dredged material

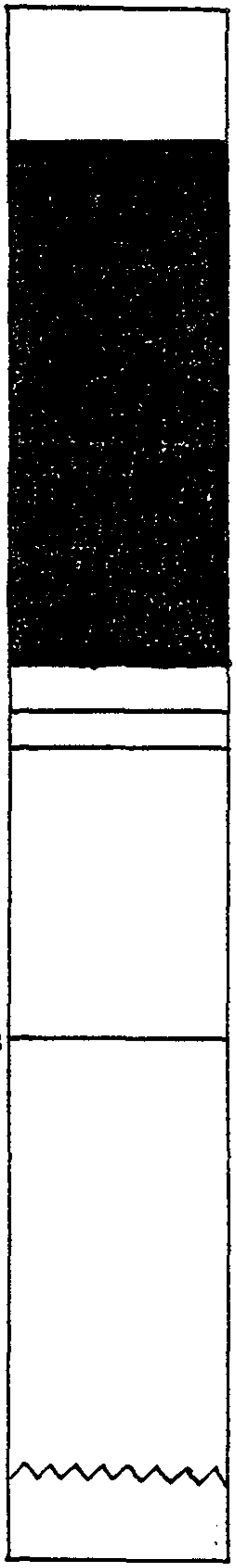
Figure 4-12

Sediment Cores

Sampled By Science Applications, Inc.

July 1983

Depth (cm)



0
:ermixed Black and
:y Silt Grades
to

15.2
ıck Organic Silt, No
ır.

to

43.2
:ermixed Black and
:y Silt

63.5
.ck Organic Clay Silt

73.7
y Coarser Brown Silt

78.7
.lt Layer

82.6
'k Grey Sandy Silt
:h Shell Fragments

114.3
y Clay Natural Bottom

162.6

Field Log No. ______________

Site CS-1

Location 50 East

Date Sampled July 1983

Length of Core 162.6 cm

Diameter 6.5 cm

1 cm = 8 cm of core

Darkened area indicates dredged material

Figure 4-13

Sediment Cores

Sampled By Science Applications, Inc.

July 1983

Depth
(cm)

0

ey Clay

10.2

ack Organic Silt with
gh H_2O Content

27.7

ack Organic Silt,
anular with Occasional
yer of Grey Silt

124.5

yers of Brown and
ack Silt Grades to

ey Natural Bottom

210

Field Log No. ______

Site CS-1

Location Center

Date Sampled July 1983

Length of Core 210 cm

Diameter 6.5 cm

1 cm= 8 cm of core

Darkened area indicates
dredged material

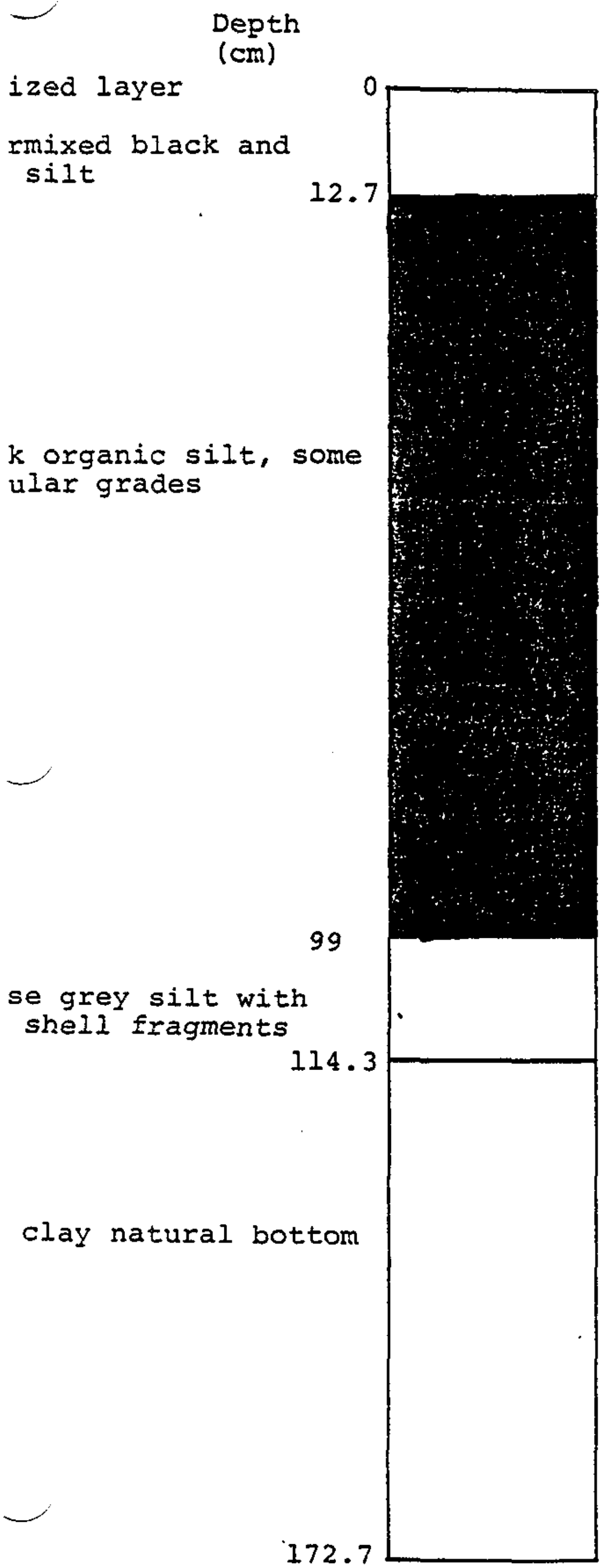
Not to scale past this point

Figure 4-14

Sediment Cores

Sampled By Science Applications, Inc.

July 1983



Field Log No. ____________

Site CS-1

Location 100 West

Date Sampled July 1983

Length of Core 172.7 cm

Diameter 6.5 cm

1 cm = 8 cm of core

Darkened area indicates dredged material

Figure 4-15

Sediment Cores

Sampled By Science Applications, Inc.

July 1983

Depth
(cm)

Description	Depth (cm)
	0
lack Silt	
	10.2
rey Silt Grades o	
	17.8
lack Organic Silt	
	104.1
ark grey clay gets oarser at bottom	
	121.9

Field Log No. ____________

Site CS 1

Location 75 South

Date Sampled July 1983

Length of Core 121.9 cm

Diameter 6.5 cm

1 cm = 8 cm of core

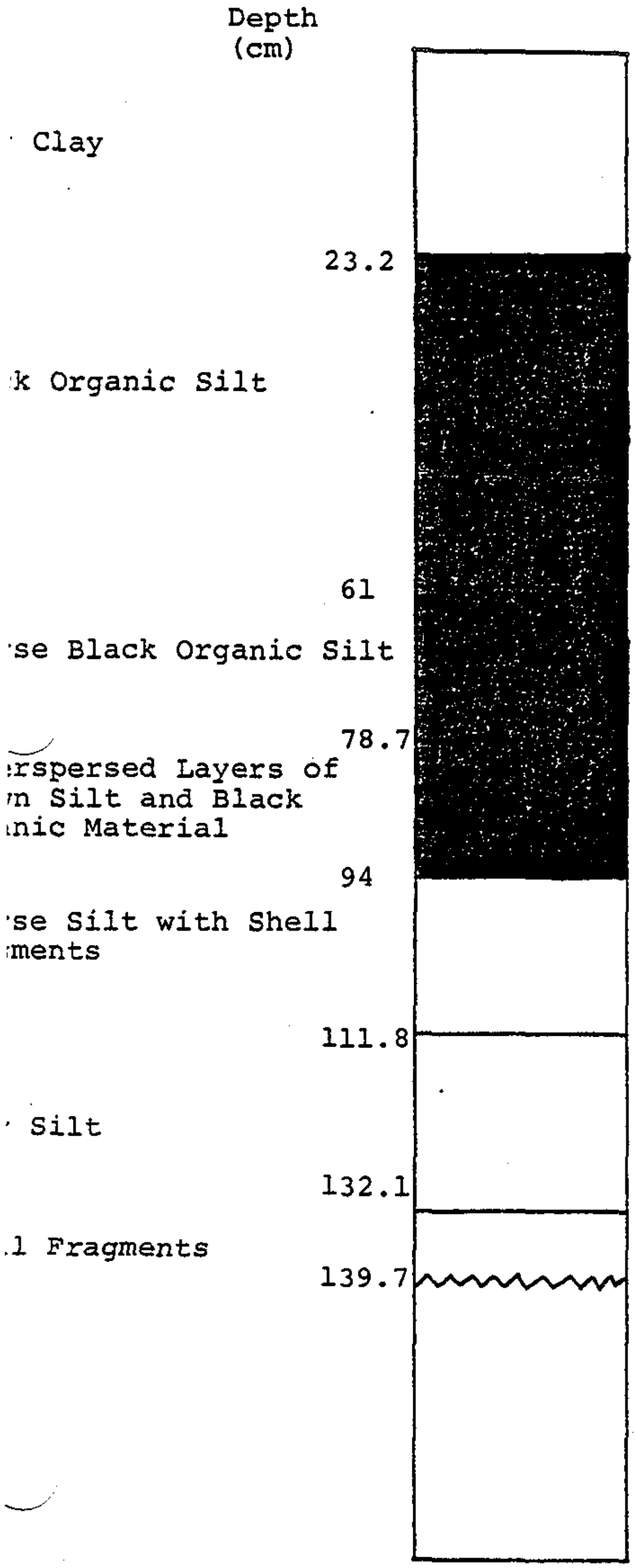
Darkened area indicates dredged material

Figure 4-16

Sediment Cores

Sampled By Science Applications, Inc.

July 1983



Field Log No. ____________

Site CS-1

Location 50 North

Date Sampled July 1983

Length of Core 139.7 cm

Diameter 6.5 cm

1 cm = 8 cm of core

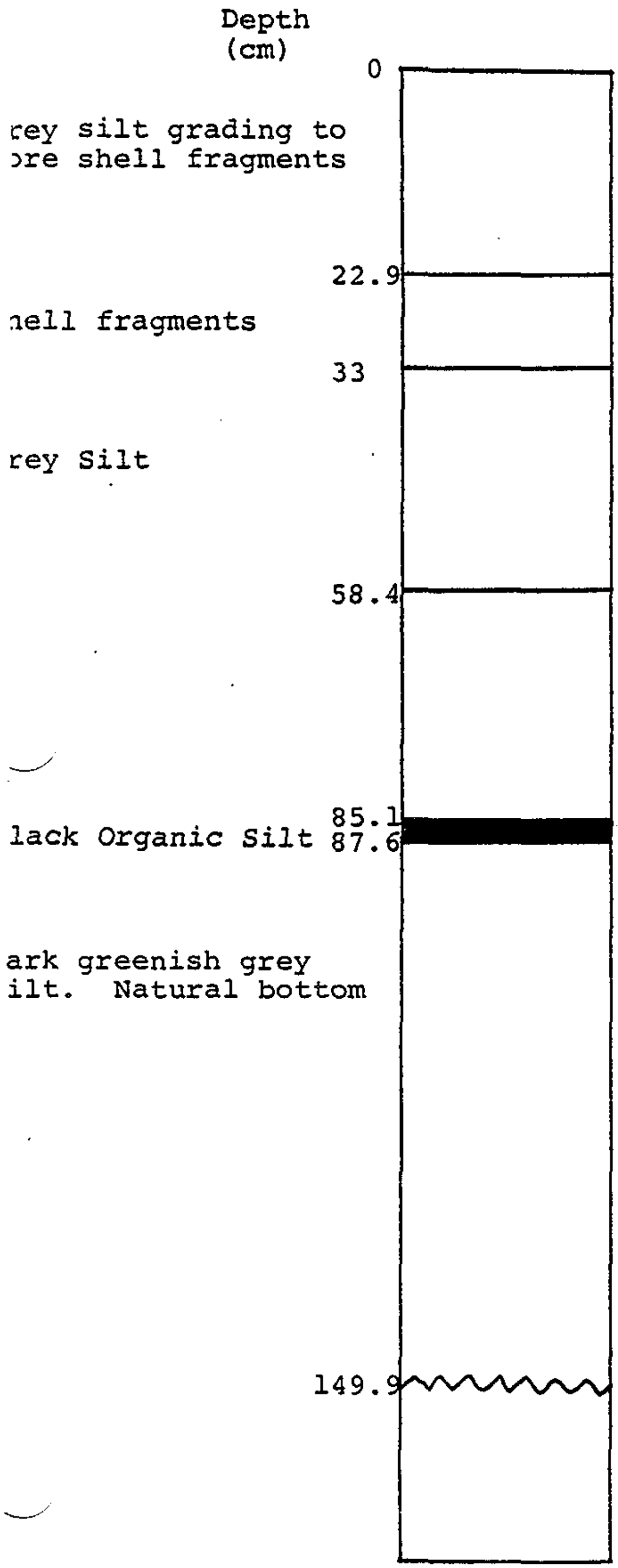
Darkened area indicates dredged material

Figure 4-17

Sediment Cores

Sampled By Science Applications, Inc.

July 1983



Field Log No. ______________

Site CS - 2

Location 25 North

Date Sampled July 1983

Length of Core 149.9 cm

Diameter 6.5 cm

1 cm = 8 cm of core

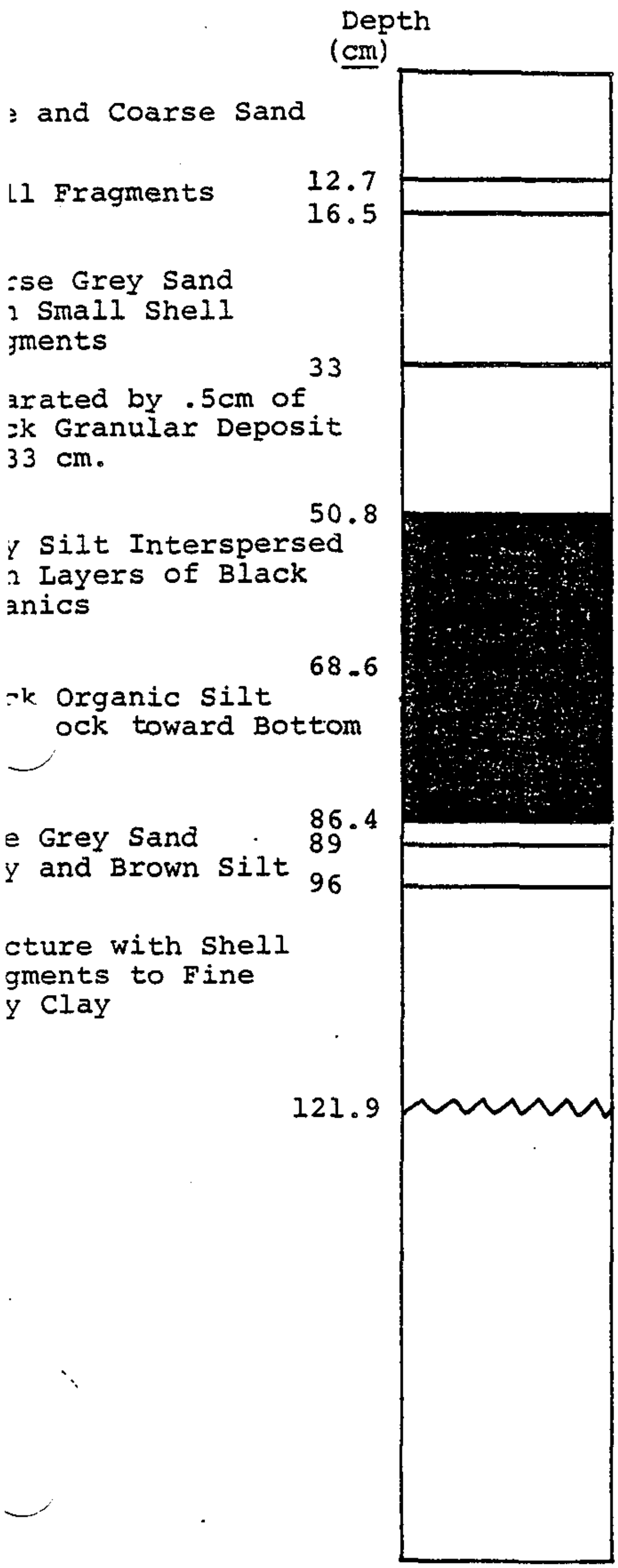
Darkened area indicates dredged material

Figure 4-18

Sediment Cores

Sampled By Science Applications, Inc.

July 1983



Field Log No. ________

Site CS-2

Location Center

Date Sampled July 1983

Length of Core 121.9 cm

Diameter 6.5 cm

1 cm = 8 cm of core

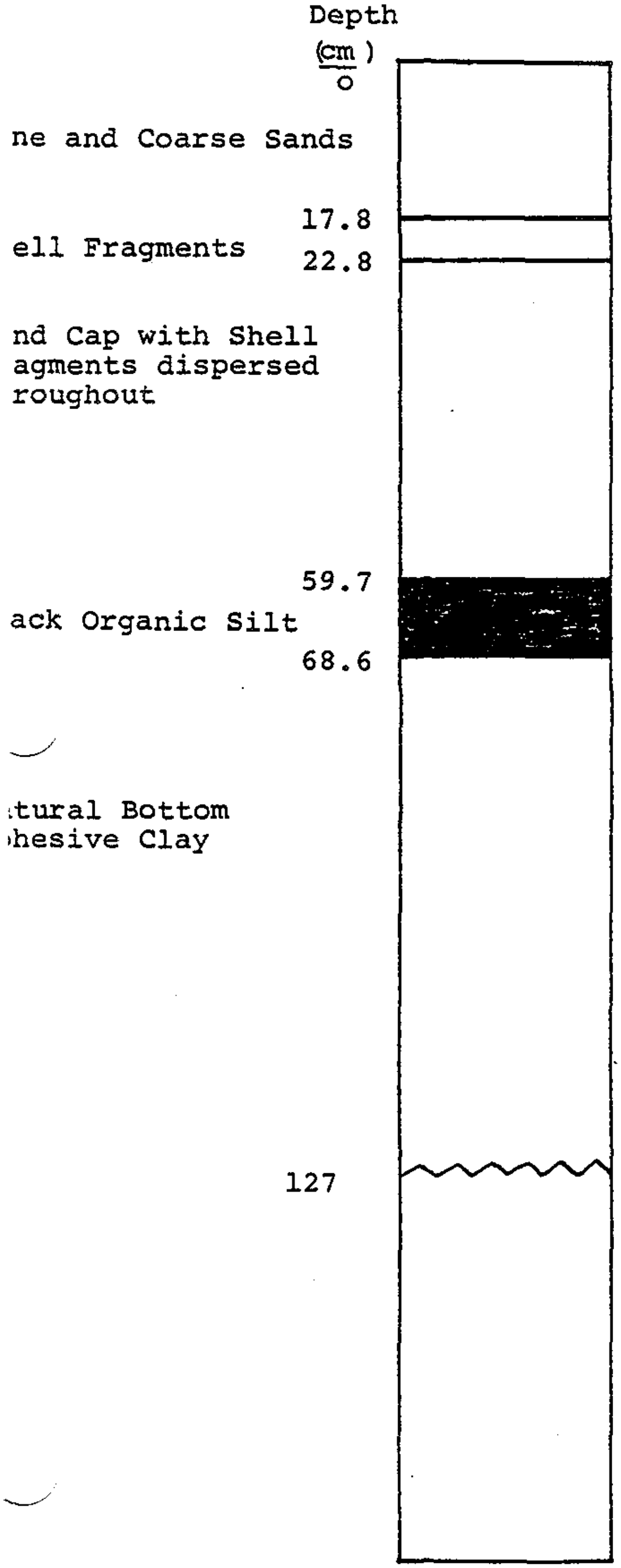
Darkened area indicates dredged material

Figure 4-19

Sediment Cores

Sampled By Science Applications, Inc.

July 1983



Field Log No. ______

Site CS-2

Location 50 South

Date Sampled July 1983

Length of Core 127 cm

Diameter 6.5 cm

1 cm = 8 cm of core

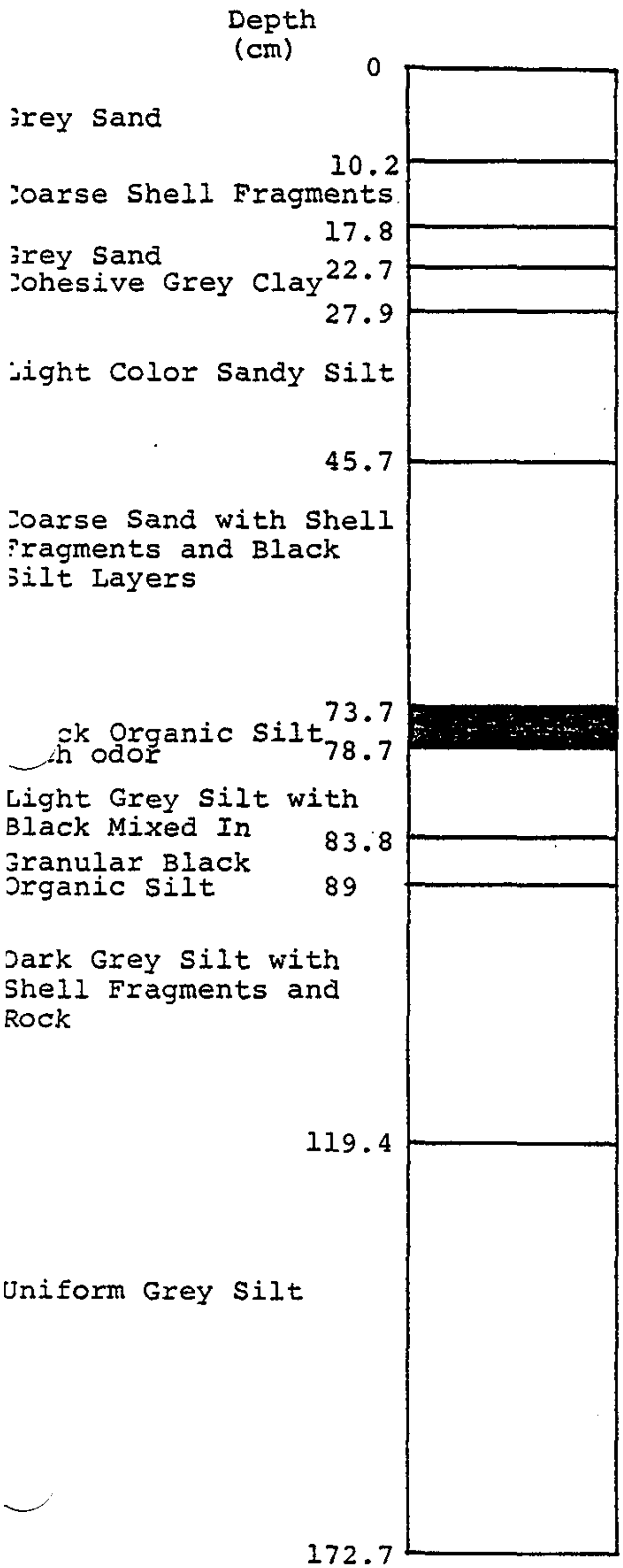
Darkened area indicates dredged material

Figure 4-20

Sediment Cores

Sampled By Science Applications, Inc.

July 1983



Field Log No. ____________

Site CS-2

Location 75 West

Date Sampled July 1983

Length of Core 172.6 cm

Diameter 6.5 cm

1 cm = 8 cm of core

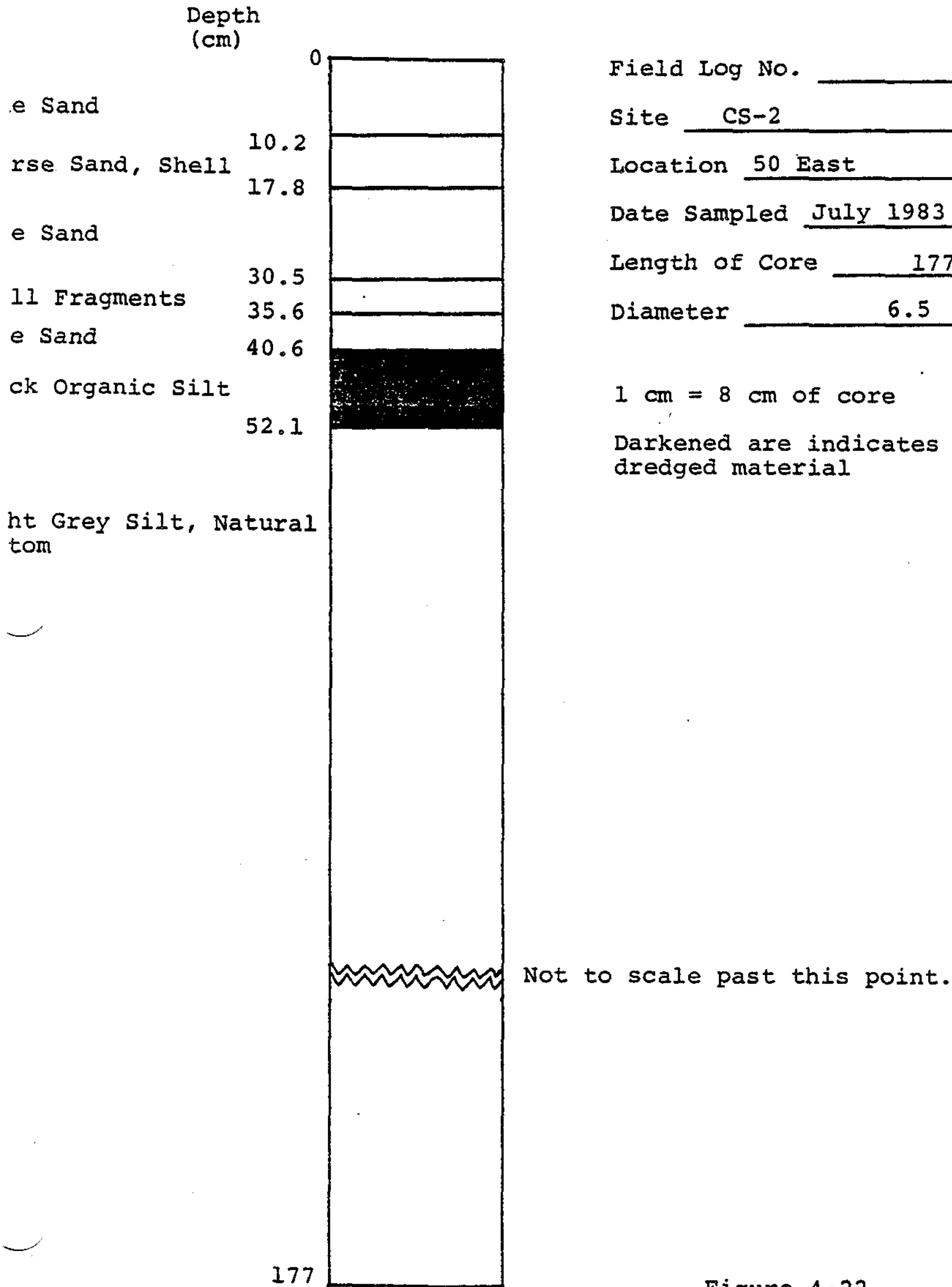
Darkened area indicates dredged material

Figure 4-21

Sediment Cores

Sampled By Science Applications, Inc.

July 1983



Field Log No. ______________

Site CS-2

Location 50 East

Date Sampled July 1983

Length of Core 177 cm

Diameter 6.5 cm

1 cm = 8 cm of core

Darkened are indicates dredged material

Figure 4-22

The cores taken through the sand cap at Cap Site #2 indicate that the cap is in place and, in most cases, is more than .5m thick and composed of coarse sand and shell fragments. The layer of Black Rock material is clearly visible beneath the sand, however, the thicknesses observed are all less than 40cm in all cores.

Table 4-13 presents a comparison of Black Rock sediment thickness measured prior to capping in April, 1983 (Fig. 3-32), and that measured in the cores. In all cases, the thicknesses in the cores are substantially less than those measured by bathymetric techniques, which raises several questions concerning the behavior of the Black Rock material during capping, such as:

- Has the material mixed with the sand cap during or after disposal?
- Has it been compacted?
- Did the same phenomenon occur at Cap Site #1 or at the Stamford/New Haven sites?

At the present time, these questions remain unanswered, but they must be addressed to insure the validity and feasibility of capping relatively unconsolidated, high water content organic silts. The cores taken during this program were not examined in terms of geotechnical parameters which could give answers to these questions. Future work should address these questions through a combination of remote measurements and geotechnical analysis of undisturbed samples.

It is known from previous sampling in the area that the layering described beneath the observed dredge material is typical of natural deposits in the area, however, changes in the geotechnical properties of the Black Rock material and its behavior in response to capping with both sand and silt require more extensive study. More cores are needed that can be analyzed for chemical content to define the origin and amount of intermixing of sediments under the different types of cap material, then studied in terms of geotechnical parameters to assess changes and responses due to capping operations.

4.3 Geotechnical Measurements

Prior to the coring program, an opportunity arose to obtain samples from the disposal sites to assess the geotechnical properties in terms of their effect on disposal in general and capping operations in particular.

During June 1983, fourteen surface samples were acquired at Central Long Island Sound disposal site using a Smith-MacIntyre grab sampler. After a grab sample was obtained, a thin wall plastic tube with a 6.5 cm diameter and 15 cm length was pressed into the sample to recover sufficient quantity of sediment for geotechnical testing. These tube samples were capped and kept in refrigerated storage. The samples were taken

Table 4-13 Comparison of Black Rock Sediment

Station	Bathymetric Thickness	Core Thickness	Difference
CS-2 Center	50cm	35cm	-15cm
CS-2 50E	40cm	12cm	-28cm
CS-2 25N	30cm	2cm	-28cm
CS-2 50S	40cm	9cm	-31cm
CS-2 75W	20cm	5cm	-15cm

Thickness determined from Pre-Capping Bathymetric Measurements and Post-Capping Core Samples from the three mounds studied under this project; the Field Verification Program (FVP) mound which is composed of contaminated Black Rock Harbor spoil and the two capped mounds designated as CS#1 and CS#2 which are capped with silt and sand respectively.

The objective of this study was to determine the physical and engineering properties of these mound samples for purposes of classifying the sediments and evaluating strength and compression behavior. This geotechnical information will provide a basis for material balance analyses during dredge material disposal monitoring and for predicting mass deformation of mounds under the affect of their own weight and as a result of storm wave loading.

4.3.1 Testing Program

Each of the samples was subjected to a series of classification tests including determination of water content, Atterberg limits, particle size gradation, undrained strength and unit weight. In addition, several selected samples were subjected to consolidation and direct shear tests and organic matter content determination. These samples were selected to be representative of Black Rock sediment, cap material and natural bottom sediments in order to obtain strength and compression data for these different sediment types. Testing generally conformed to standard ASTM procedures except for the preparation of the extremely soft sediments for direct shear and consolidation testing, since there are no ASTM procedures for handling and trimming during soft sediment testing.

Since all of the samples were from the surface of the mound and adjacent seafloor, they had very high water contents and an almost fluid-like consistency. As a result, there was some sediment-fluid separation during storage and sloshing of sediment within the core liner during transit. These samples would be classified as very disturbed for purposes of engineering properties determination. While disturbed samples from the mounds may be justified for geotechnical testing on the basis that the mounds are composed of a very recently deposited disturbed sediment mass, the natural bottom sediments probably exhibit some aging affects which were destroyed during sampling and handling. Consequently the laboratory strength and compression properties and some index properties for natural bottom sediments may not be fully representative of in-situ properties.

Because all of the samples were soft, it was impossible to extrude the sediment from the core liner and have it support its own weight. The procedure for strength and consolidation testing consisted of pouring or spooning the soft sediment into the testing apparatus and subjecting it to high frequency vibrations while unconfined so the sediment would flow, thus, minimizing the presence of air voids in the specimen. This method of preparation was found to have little affect on soil-fluid separation or densification of clays, but does result in a more homogeneous test specimen than trimming with a wire saw. However, it tends to further destroy any stress history affects that may have existed in the sediment. Some densification occurred for sand sample CS2-CTR.

If future coring studies are conducted, samples will be obtained with a gravity core and maintained in an undisturbed state for subsequent analysis. The engineering properties of these sediments, while difficult to measure, are of prime importance for assessing the behavior of dredged material during disposal and capping. Further development of procedures and testing protocols are required and more samples for replication of results are required to obtain more confidence in test results.

4.3.2 Results of Geotechnical Tests

Although the sediment samples were only about 15 cm long, many samples contained two distinct sediment types such as cap material over Black Rock sediment or Black Rock over natural bottom sediment. When a sample was extruded from the tube and identified as being layered, the sample layers were separated and index properties tests were performed on each portion depending upon the quantities of sediment present. Several samples, therefore, contain two sets of index property data - one for each layer.

The test data for each sample are summarized in Table 4-14 a, b and c. The location of each sample is designated by a mound designation and location on the mound.

There is a considerable amount of sediment property variability in Table 4-14 because of the many different sediment types sampled. However, many of the index and engineering property test results correlate well with the particle size distribution. Although other correlations probably exist, they are not visibly obvious for the small number of samples that were tested. A brief summary of each of the parameters includes:

- Water Content

  The measured water contents are observed to vary significantly within a sample when more than one value of water content is determined, probably as a result of disturbance and solid segregation during storage. The values reported in Table 4-1 are average values. These water contents correlated fairly well with the amount of silt and clay in each sample. The greater the amount of silt and clay the greater the natural water content measured. There also appears to be a direct correlation between water content and organic matter content.

TABLE 4-14a

GEOTECHNICAL PROPERTIES OF SEDIMENTS AT THE FVP SITE

Sample	Desc.	Water Content W_n	Liquid Limit W_l	Plastic Limit W_p	Grain Size Sand/Silt/Clay (%)	Undr. Strength S_u (T/m^2)	Wet Mass (g/ml) Density	Organic Matter Content %	$s/\bar{\sigma}$ ratio	Compr. Index C_c	Swell Index C_s	Coef. Consol C (cm^2/min)
FVP 400E	Ol-gry silt with clay & some sand	119.4	92.8	40	5.3/70.1/24	.098	1.40	6.1	0.52	0.82	0.16	5.5×10^{-2}
FVP 200E	Blk silty sand (B.R.)	150.0	119.1	23	21.6/55.4/23		1.33					
	Ol-Gry clayey silt	104.0		44.2	2.6/68.4/29	.15	1.44					
FVP 100E	Blk Organic Silty Sand (B.R.)	125.9	60.1	52.1	63.8/24.2/12.	.064	1.38	7.8		0.75	0.125	2.6×10^{-2}
FVP 50E	Blk Silty Sand with some clay	117.5	71.1	33.9	44.1/37.9/18	.096	1.40					
FVP CTR	Silty Sand - some shells (B.R.)	99.5		36.4	63.6/22.4/14.	.11	1.45	7.4	0.40			
	Blk Silty - sand(cap?)	62.8	56.9	22.8	57.6/32.4/10	N.A.	1.62	5.5				

TABLE 4-14B

GEOTECHNICAL PROPERTIES OF SEDIMENTS AT THE CAP SITE #1

Sample	Desc.	Water Content w_n	Liquid Limit w_l	Plastic Limit w_p	Grain Size Sand/ Silt/ Clay (%)	Undr. Strength S_u (T/m^2)	Wet Mass Density (g/ml)	Organic Matter Content %	$s/\bar{\sigma}$ ratio	Compr. Index C_c	Swell Index C_s	Coef. Consol C (cm^2/min)
CS-1 200E	Dk. Ol. clayey silt	127.6	107.8	39.5	5/60/35	.12	1.38		0.49			
CS-1 100E	10cm Blk. silt material (B.R.)	152.0	120.9	55.6	22.5/50.5/27	.17	1.33	8.7		0.87	0.17	4.8×10^{-2}
	2 cm Gry clayey silt	157.5	127.1	22.8			1.32					
CS-1 50E	Blk Clayey Silt Material (B.R.)	167.0	151.2	62.3	3.2/61.8/35	.12	1.31					
	Ol.Clayey Silt	164.0	132.9	66.7	4.4/63.6/32		1.31					
CS-1 Ctr	Blk Clayey Silt w/some Sand (cap)	153.2	103	62.7	16.0/53/31		1.33	7.4	0.42	0.59	0.13	4.8×10^{-2}

TABLE 4-14c

GEOTECHNICAL PROPERTIES OF SEDIMENTS AT THE CAP SITE #2

Sample	Desc.	Water Content W_n	Liquid Limit W_l	Plastic Limit W_p	Grain Size Sand/Silt/Clay (%)	Undr. Strength S_u (T/m^2)	Wet Mass Density (g/ml)	Organic Matter Content %	$s/\bar{\sigma}$ ratio	Compr. Index C_c	Swell Index C_s	Coef. Consol C (cm^2/min)
CS-2 200E	Ol Silt/clay w/some sand (cap)	109.5	76.8	38.6	12.8/58.2/29	.27	1.42		0.52	0.67	0.09	5.2×10^{-2}
	Blk Sandy-silt material	88		36.7	40.7/46.3/13		1.50	6.9				
CS-2 100E	Ol Gry Sand w/some silt (cap)	30.9			83.8/10.2/6	N.A.	1.91					
	Blk. Organic	83.5		31.5	61.0/26/13	.22	1.51					
CS-2 50E	Sand w/silt and shell hash	26.2			92.6/5.4/2	N.A.	1.98	1.4				
CS-2 CTR	Lt. Ol. Sand w/some silt & Shells	24.8			80.8/16.2/3	N.A.	1.99	1.3	0.72	0.04	0.01	6×10^{-2}

- Atterberg Limits

  The liquid and plastic limits were run on the fraction of solids passing the No. 200 sieve. These properties also correlate directly with the amount of silt and clay in the sample. The differences between the liquid and plastic limits, called the plastic index, show that the Black Rock sediments are of moderate to high plasticity and are typical of published values for slightly organic silty dredge material. However, all values here are substantially lower than those measured in the pre-dredging samples. Most of the cohesive samples have water contents that are greater than the liquid limit, which shows that they behave as fluid for all practical purposes.

- Grain Size

  Most samples show a large fraction of the particles in the silt-size range. This reflects the relation of these sediments to typical soils in the Connecticut area. The amount of particles in the clay size range tends to be smaller than the amount in the silt size range. Eight of the samples are largely sand, including four samples of capping sand from mound CS#2, and four from the center of the FVP mound.

- Undrained Shear Strength

  The undrained shear strength of cohesive samples was measured with a NGI fall-cone penetrometer. The soft fluid-like behavior of the samples is reflected in the low strength values, reported as tons per square meter (1 T/m^2=1g/cm^2).

- Wet Mass Density

  The values of mass density in tons per cubic meter were computed from measured specific gravity and void ratio measurements. They are typically low and indicative of the high water contents of the samples. These densities are close to the minimum values expected for this type of soil.

- Organic Matter Content (OMC)

  The percent organic matter was determined by heating the sample to 500°C in a muffle furnace. The loss of weight was attributed solely to combustion of organic matter. The results show that the dredge material contains a moderate quantity of organic matter (5 to 9%) and the sand cap at CS#2 has a low value of less than 2%. With the few number of samples measured, it is impossible to determine a difference between Black Rock and New Haven sediment at this time based on Organic Matter Content.

- Direct Shear Data

The results of the direct shear tests are reported as a ratio of shear strength, S, to effective consolidation stress. These data represent a partially drained shear condition and can be used conservatively in design as the tangent of the drained friction angle. The reason for the uncertainty in strength is due to the specified method of testing, i.e. direct shear with partial drainage. Triaxial testing requires using less disturbed and stiffer samples than obtained for this study, but should be considered in future work.

- Compression Index (C_c)

The Compression Index of a sediment is a measure of the stress-strain properties of the soil, using a loading (increasing load) mode in a device that allows only vertical displacement.

As shown in the table, the compression indices are quite high and fall in a narrow range for both dredge material and natural bottom samples containing large amounts of silt and clay. The sand cap sample from CS#2 has a compression index that is lower than the other samples by an order of magnitude and is typical of sand.

- Swell Index (C_s)

The Swell Index is a measure of a sediments ability to expand or increase in void ratio due to a decrease in applied stress (unloading).

- Coefficient of Consolidation (C_v)

The coefficient of consolidation is a property that indicates the speed with which the sediment mound will settle when subjected to an imposed load. The greater the coefficient of consolidation, the faster the settlement will occur. In this test program, the values of C_v tended to increase slightly with increasing applied stress. The values of C_v reported in Table 4-1 are average values for the range of applied stress (about 0.03 to 4.0 kg/cm^2).

4.3.3 Summary of Geotechnical Test Data

There is considerable variability in the engineering properties of the sediment tested in this study, which reflects a heterogeneous sediment composition of the mound and possibly mixing of cap, mound and natural bottom sediments during deposition. The mound sediments are primarily organic silts with variable sand and clay fractions. Sediment strengths are very low as a result of high water contents of the surface grab samples and, as a result, these fluid-like samples exhibited considerable disturbance, possible from sampling, handling and storage. The potential for compression (consolidation) is generally moderate to high with both mound and natural bottom sediments having about the same compression indices. Further work is needed to assess the impact of this compressibility on mass balance calculations and more emphasis must be placed on the properties of the sea floor to evaluate the potential volume changes.

4.4 Summary of Geotechnical Measurements

The geotechnical measurements made during the past year have provided some important insights into assessing the geophysical aspects of dredge material disposal particularly related to capping of high water content, organic silts. It is apparent that low density harbor sediments are not as easily managed as more cohesive silts and sands. Significant differences between mounds developed from these sediment types were observed.

There appears to be a differentiation and possibly a loss of low density material during the dredging, transport and disposal operation which results in a coarser, more dense mound at the disposal site. There is certainly evidence, based on the fluff layer observed at Black Rock Harbor (Fig. 4-5 and 4-6) that a substantial amount of fine material remains at the dredging site. Furthermore, the vertical density gradients within the scows indicate that this differentiation is maintained during transport. This would result in a more significant turbidity flow along the bottom following disposal, thus creating a coarse, cohesive and dense mound surrounded by flanks of low density, non-cohesive, high water content fine sediment extending as a thin deposit for several hundred meters.

This type of dredged material contrasts sharply with the more cohesive material such as the silt from New Haven Harbor, which tends to maintain the integrity of the sediment and produce steeper, thicker mounds with less unconsolidated material on the flanks. Such factors in addition to defining the behavior of the material during disposal affect the ability to support a capping operation. Not only does the spatial distribution play an important role in defining the area to be covered, but evidence derived from the coring operations indicates that the capping procedure may induce further spreading or mixing with the cap material.

Certainly further work is required to define those geotechnical properties of harbor sediments that affect these parameters in terms of open water disposal and capping. The Nuclear Density Probe, remote sensing surveys, in-situ measurements and sediment testing have all answered specific questions regarding the behavior of this dredged material in a capping operation. They have also created new questions based on the observations, and more work is needed to understand these phenomena.

5.0 DEVELOPMENT OF A CLASSIFICATION SCHEME FOR SELECTION OF CAPPING AS A DREDGED MATERIAL DISPOSAL ALTERNATIVE

Application of capping procedures to a given disposal situation requires that the specific parameters defining the sediments being considered and potential disposal sites to be used meet certain criteria to insure a successful operation. At the present time, these criteria are not well defined and a logical decision making process is not in place to assess whether capping is an appropriate and feasible disposal alternative for a specific project. The purpose of the classification scheme to be discussed in this section is to begin development of such a decision making process based on both theoretical considerations and the observed field data discussed in earlier sections.

Designation of capping as a disposal alternative requires a knowledge of three major parameters:

- The geotechnical properties of the contaminated sediment to be capped and how they affect the behavior of the material during the initial disposal and capping operation.
- The geotechnical properties of the capping sediment and how they affect the ability of the material to cover and isolate the contaminated sediment over the long-term.
- The environmental parameters of the disposal site and how they will interact with the dredged material to insure a long-term stable situation.

There are many other project and region specific parameters that also must be considered, such as:

- equipment type and availability
- distance from the dredging site to the disposal point
- operational guidlines for disposal operations
- affect of disposal on surrounding biota
- impact on fisheries

However, these are related to determining whether or not open water disposal in general is feasible and not specifically concerned with capping, and will not be considered at this time.

The approach taken to develop a classification scheme for determining the feasibility of capping is to use the results of past studies, to place boundaries on important parameters, to insure the permitting agency that the decision made is safely within acceptable limits of environmental risk. When those boundaries for one or more parameters are approached or exceeded, then the agency would have the option of rejecting capping as an alternative or conducting field observations to determine whether or not the particular sediment or disposal site is appropriate for capping.

Using this technique, theoretical models, which obviously have limitations, can be employed to evaluate conditions and predict future consequences well within their accuracy range. These will provide a framework for logical decisions based on theory where practical and supported by field observations where necessary. Wherever possible, the classification scheme will apply the results of previous studies, no develop new computations to assess parameters, thus keeping the application of the decision process as simple as possible.

By the completion of this project, the classification scheme should be in the form of a simple computer program supported by an operators manual which will request certain parameters relative to sediment properties and disposal site environmental conditions. These parameters will be entered through a menu format and processed to provide probability curves relative to specific capping criteria such as:

- expected distribution of contaminated sediment following disposal
- expected thickness of cap as a function of sediment volume and location
- expected erosion rate of cap material

and other parameters to be determined.

As discussed earlier in this report, additional information is required for evaluation and prediction of the effects and interactions of geotechnical properties on the behavior of dredged material during open water disposal. Such factors as water depth, dredging technique, disposal control, sediment density, cohesiveness, etc. must all be considered and evaluated based on previous experience. That has been the thrust of this first year of field study under this program, and although progress has been made, more work is required to generate significant input to the classification scheme.

Consequently, most of the effort relative to this part of the program during the past year has centered on understanding and developing procedures for assessing the environmental effects on capped deposits and quantifying the parameters affecting the long-term stability of the capping material. During the next year, more effort will be placed on quantifying the behavior of dredged material based on geotechnical properties, so that, during the final year of the program, the classification scheme will be operational and available for verification on existing capping operations.

5.1 Physical Processes Affecting Capped Deposits

Since the long-term stability of the capped deposit is the primary goal of the capping operations, the factors affecting stability of the mound must be addressed in detail. Mound stability can be characterized by the following processes:

1) settling of the mound,

2) horizontal spreading of the mound,

3) slumping and shearing of the mound,

4) settling of the cap into the underlying material,

5) mixing of the cap and the underlying material, and

6) erosion of the cap or mound.

These processes can be broken into two categories according the the controlling mechanisms. The first four processes deal with changes in the structure of the mound and are primarily dependent on the geotechnical properties of the sediments and the mound structure itself. Mixing of the cap and underlying material and erosion of the mound are primarily controlled by the environmental conditions of the site and can be determined via sediment transport calculations.

All six processes are dependent upon both the environmental conditions of the site and the geotechnical properties of the sediments; however, the sediment transport processes are more sensitive to the environmental conditions and the mound structure change processes to the geotechnical properties of the sediments. Consequently, the sediment transport processes can be used to classify the suitability of a site; while the mound structure changes can be used to classify the suitability of contaminated and capping dredged materials regarding a specific mound shape or height.

For capping to be a viable method of isolating contaminated disposal materials from the surrounding environment, no significant erosion or mixing of the mound should occur over a long time period. Consequently, disposal sites suitable for capping are low energy regions with little or no current velocity. Although current velocity will certainly be a factor input to the classification scheme, its effect, standing alone, is certain to be negligible. However, when generated by storm events, the mean current velocity can have an important effect. However, it is the passage of low pressure atmospheric disturbances over the disposal area that is certain to have the most profound effect on disposal mound stability and these disturbances must be considered. Reasonable estimates of storm effects can be determined using site specific parameters and theoretical calculations. These estimates can then be input to a sediment transport model implemented on a computer to estimate the rate of erosion of cap material as a function of storm intensity. The frequency of intensity can then be used to predict long term stability of the mound.

Working toward development of such a procedure, a current literature review has been completed and applied to the capping situation, along with identifying some of the potential problems of such an approach. This section of the report presents a detailed discussion of the development and utilization of the sediment transport model, including potential problem areas that must be acknowledged in order for the disposal site classification criteria to be useful.

Because of the major underlying role of sediment transport in the erosion and transport of dredged material, a short description of the physical processes involved in sediment transport will be given. Sediment transport consists of two natural physical processes: first particles are entrained into the water column and after entrainment, they are transported by the motions of the water column until they settle out. While the particles are entrained in the water column, there are two modes of suspension, bedload and suspended load. These modes of suspension are shown in Figure 5-1. The bedload is defined as "the concentrated sediment that moves on or in close proximity to the bottom, maintained in a dispersed state by grain-to-grain contacts" (Komar, 1976). Particles actually "transported within the water column, maintained above the bottom by the turbulence of the water" are considered the suspended load (Komar, 1976). Usually, particles which enter the suspended load are quickly dispersed; whereas particles in the bedload travel only short distances. In spite of this, the suspended load is generally responsible for only a small portion of the transport; most of it is accounted for by bedload transport, due to the much higher sediment concentrations.

Sediment transport is caused by a combination of wave and current motions. The wind blowing across the water surface exerts a force which has a two-fold effect. As in Figure 5-1, waves are generated and propagate in the direction of the wind and a wind-driven current is created; however, because of local bathymetric effects, the wind-driven current may be in a different direction than the wind. This wind-driven current, when combined with the tidal and non-tidal currents comprises the total current. Due to the relatively long period of the tide and other currents as compared to the fluctuations of the wave orbital velocities, the total current is viewed as a 'steady' velocity. Both the total 'steady' current and wave orbital velocities have near-bottom components which exert forces on the bottom. However, due to the boundary shear stress associated with the wave velocities, the force exerted by a wave will be much greater than the force exerted by a 'steady' current of the same magnitude. On the contrary, the fluctuating nature of the

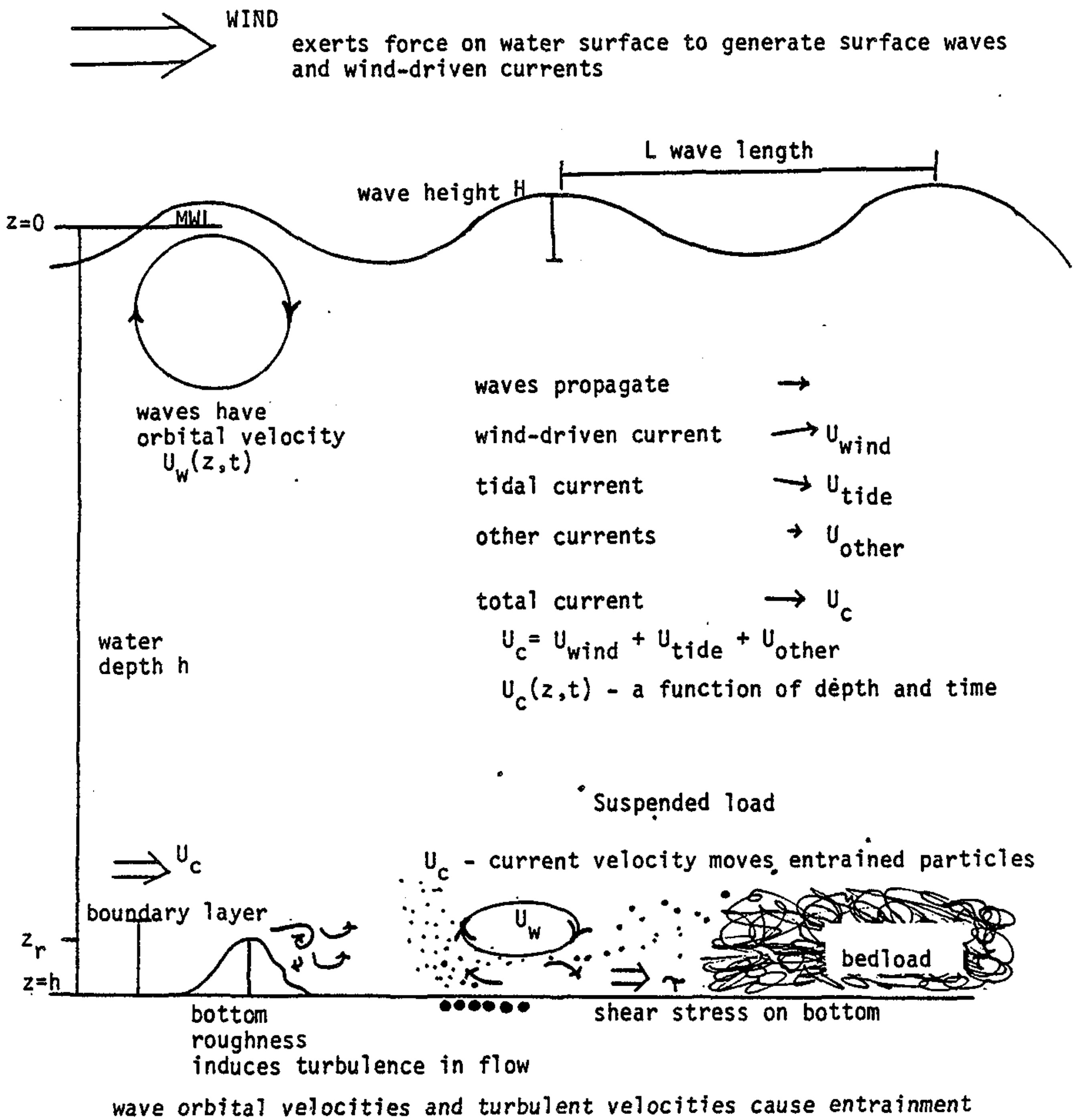


FIGURE 5-1 Physical Processes Involved in Sediment Transport

wave velocities is not well suited for transport, as opposed to the 'steady' current, which can efficiently transport particles even though it may be of a much smaller magnitude than the wave velocities. Thus the wave orbital velocities effectively 'stir' the bottom, entraining particles which are then carried along by the 'steady' current flow. Both the wave induced velocities and the currents are potentially ineffective by themselves, but they can combine to bring about transport of the sediment particles.

There are other factors involved in this entrainment process, notably the weight of the sediment particles and effects on the current and wave velocities. The grain size and sediment density determine the particle's weight, which is important in the entrainment process. Usually a distribution of both grain size and density are present in the sediment; consequently, it is quite possible for some of the smaller, lighter particles to be affected and not the larger, heavier particles. Velocity effects are also important factors and are affected by: 1) the water depth, 2) turbulence generation, and 3) bottom shear stress. Wave orbital velocities decrease with the water depth; in relatively deep water, the bottom effects of wave orbital velocities may be minimal for a certain set of conditions which would erode and transport material in shallower water. The effects of turbulence generation and bottom shear stress are complex, with higher levels of turbulence being generated over a rough bottom than over a smooth bottom, Figure 5-1. This turbulence can increase entrainment due to the generation of shear velocities associated with the roughness elements. This effect, however, is only a part of the total bottom shear stress effect on the velocities.

Through boundary layer dynamics, the bottom shear stress and near-bottom velocities become interdependent. As the velocities come in contact with the bottom, they exert a shear stress on the bottom. This shear stress requires energy and effectively decreases the velocities creating a boundary layer adjacent to the bottom. Within this boundary layer, the velocities are a function of the shear stress. Friction caused by velocities flowing along the bottom characterize this shear stress. The amount of friction, which affects the velocities, is determined by the velocities and the roughness or friction factor of the bottom. Thus the near-bottom velocities and the bottom shear stress are coupled through the bottom friction and both affect the amount of sediment transport.

The sediment transport process is further complicated at the onset of transport, due to the dynamic nature of some of the parameters and the effects of transport itself. The entrained sediment effectively increases the bottom roughness enhancing the bottom shear stress. However, the bottom roughness can also decrease due to erosion of the roughness features. Similarly, the water depth is dynamic and will increase as transport occurs. Another dynamic feature is due to the particle's weight. As mentioned earlier, only a portion of the sediment may be subject to transport due to weight considerations. Usually the larger heavier particles will be left behind, forming a 'lag' deposit. This lag deposit may 'protect' the underlying sediment from further erosion. Due to many factors, once transport is initiated, its dynamic nature further complicates and often accelerates the processes.

5.2 Literature Review

A significant amount of work has been done to define and quantify the sediment transport process. The present state-of-the-art formulations can quantitatively predict the sediment transport within an order of magnitude of accuracy. These formulations account for the processes described above for non-cohesive sediments. Similar formulations have been made for cohesive sediments; however, they are not as well developed or comprehensive as the non-cohesive theories.

The initial efforts evaluating sediment transport were made by Shield's (1936), concentrating on determination of the threshold of motion for cohesionless sand in steady unidirectional flow. He developed the Shield's criteria which relates the Reynold's number to the shear stress at the onset of sediment motion. Bagnold (1946) also empirically related the near-bottom motion to the onset of sediment motion. He then developed a model of sediment transport for both steady and oscillatory flow (Bagnold, 1963). Einstein (1972), however, was the first to develop an analytic form for the empirical relations of sediment transport and the flow conditions, relating bedload to flow intensity. Wang and Liang (1974) used Einstein's work to develop a model of sediment transport due to waves at a constant water depth. Another sediment transport model which ignored wave effects was developed by Lepitit and Hauguel (1978). The work of Shields, Bagnold and Einstein provided a basis for future sediment transport calculations, however, these early models were inadequate because they ignored the effects of bottom roughness.

The efforts were then split with some investigators concentrating specifically on obtaining data such as: Sternberg and Larsen (1975) in the open ocean, Davies and Wilkenson (1978) in shallow water, Kana and Ward (1980) during storms, and a review of the data is given by Grant and Madsen (1978), and other investigators such as Komar and Miller (1974), who qualitatively determined the threshold of sediment motion with waves. Madsen and Grant (1976) made quantitative estimates of the shear stress on the transport due to both waves and currents. They later included the effects of a rougher bottom in the shear stress calculation. In addition, they incorporated the effects of the interactions between the waves and currents (Grant & Madsen, 1981). Using Grant and Madsen's work as a basis, Vincent et al, (1982) developed a sediment transport rate formula and an estimate of the suspended load. They evaluated these against observations of sediment transport during storm conditions with good results.

All of the studies above were oriented toward cohesionless sediments. The primary investigation for cohesive sediments were done by Partheniades (1965), who measured flow rates for deposition and erosion of cohesive soils. He noticed the threshold flow rate for deposition was significantly lower than the threshold rate of erosion. He then developed formulations of erosion and deposition in terms of concentration similar to the state-of-the-art for cohesionless sediments at that time, but included a factor for the inter-particle cohesion (Partheniades, 1972).

Although there are detrimental effects resulting from ignoring the cohesion of silt and clay particles in dredge material, the formulation by Vincent et al, (1982) based on Grant and Madsen's (1979, 1981) was chosen to be most applicable for calculations of sediment transport in this case. A simple disposal site classification scheme which uses the results of their work to quantitatively predict the sediment transport resulting from storms is described in the next section.

5.3 Sediment Transport Model Description

The sediment transport model calculates the bedload transport according to the physical characteristics of the site and typical storm values for waves and currents in the area. The frequency of storms is combined with the sediment transport resulting from storms to obtain a probabilistic estimate of the sediment transport due to storms as a function of time. Since not all storms will cause transport, the frequency of transport becomes non-linear. The occurrence of transport is primarily dependent on the bottom wave orbital velocities and the low frequency or 'steady' currents. These observations are based on and included in the theories of Grant and Madsen (1982; 1979) for bottom shear stress and Vincent et al. (1982) for bedload transport, which reflect the present state-of-the-art of sediment transport estimation. Using these theories, an order of magnitude estimate is presently attainable for a sediment transport prediction.

Figure 5-2 presents a flow chart of the sediment transport model applied to the classification scheme. Site specific wave and current data for a given storm intensity, along with the joint frequency of occurrence and the physical characteristics of the disposal site are used to calculate the bottom shear stress. The resulting bottom shear stress and the physical properties of the bottom sediment are used to calculate the sediment transport. Once sediment transport occurs, the bottom shear stress must be recalculated to include the effects of sediment entrainment on that parameter. Finally, the sediment transport rate for a storm of the specified intensity is calculated using the modified version of the bottom shear stress. The resulting sediment transport for the storm is combined with the frequency of occurrence for such a storm to generate a frequency of transport. These steps are repeated using data from different levels of storm intensity and corresponding frequency of occurrence to obtain the final product, the total from the site as a function of time in years.

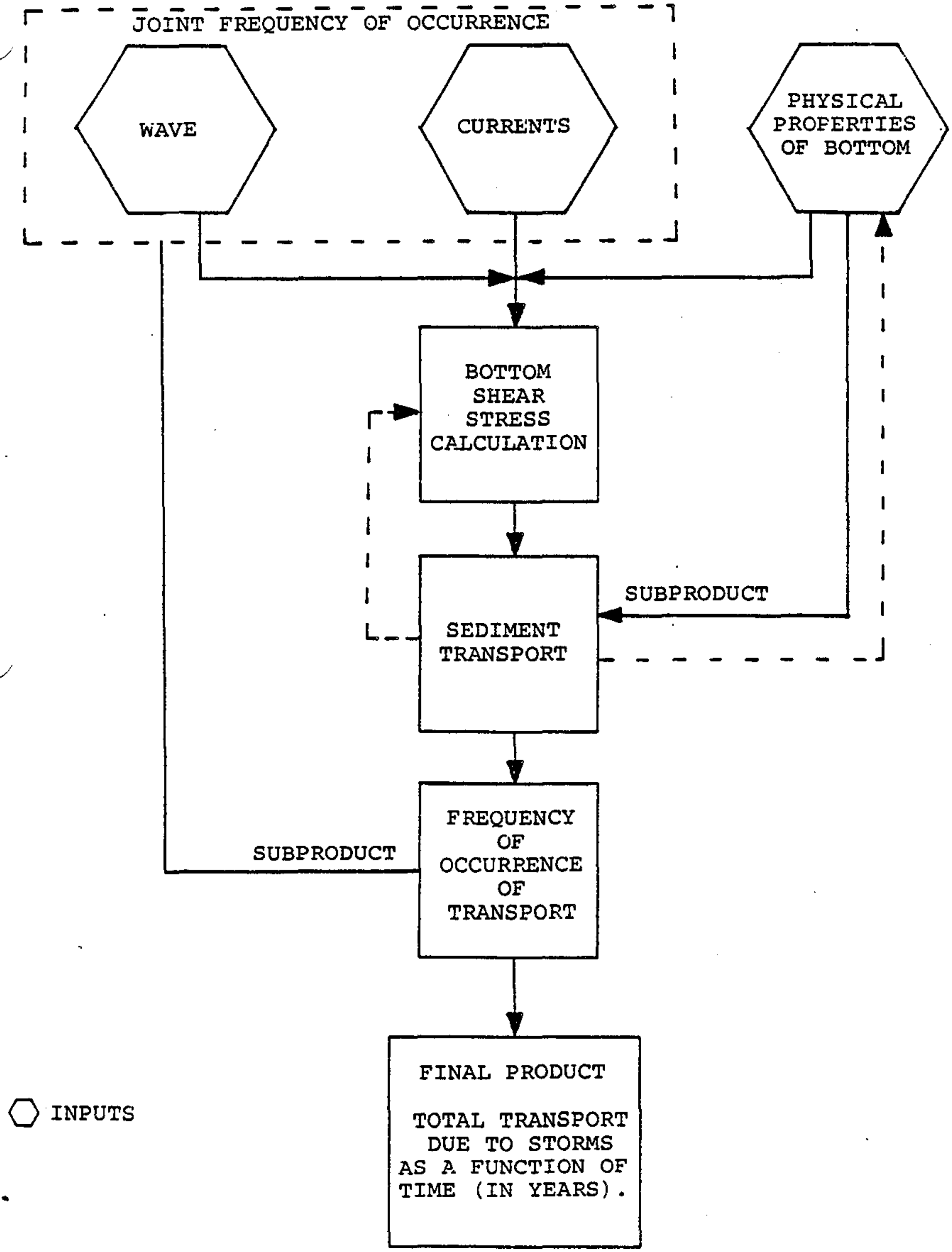


FIGURE 5-2 Sediment Transport Model for Capping Classification Scheme

5.3.1 Input Data

Two types of input data are required: storm data and the physical characteristics of the bottom, including the proposed disposal mound. These inputs are summarized in Table 5-1. The waves and currents generated by typical storm intensities along with the frequency of occurrence and duration of the storm are needed to satisfy the storm data requirement. For the physical characteristics of the bottom, water depth and the bathymetry of the area are required and the sediment density and grain size of the cap and/or dredged material are needed. Since these data must be supplied by the user, a more detailed explanation along with a list of sources is given below and in Table 5-2.

Descriptions of storms of various intensities and durations must be specified according to their frequency of occurrence such as a 1, 5, 10, or 20 year storm. (A 5 year storm represents the worst storm probabilistically expected within a 5 year period.) Climatological summaries prepared by NOAA and the Army Corps of Engineers provide general meteorological information for public use. A description of a storm pertinent to this scheme consists of the waves and wind-driven, tidal and non-tidal currents.

To describe the waves sufficiently, the wave height, period and direction must be specified either from observations or through hindcast from wind data. There are several sources for wave data observations, as seen in Table 5-2, including NOAA, the Army Corps of Engineers, local sources, and ship's records. NOAA has compiled a "Summary of Synoptic Meterological Observations" (SSMO) for the North American coasts, which provides monthly and yearly frequencies of wind speed and direction, wave heights and wave periods. A sample wave data tabulation is shown in Figure 5-3. This type of report is readily available for certain areas through the National Technical Information Service (NTIS). Both NOAA and the Army Corps of Engineers (COE) are presently initiating studies of the wave climate by deploying wave buoys at specific sites along the east, west, Gulf, and Alaskan coasts. A national data center has been proposed to archive these data and make them available to the public.

For the past twenty years, wave data has been collected by the COE for certain portions of the Atlantic coast for verification of their wave hindcast models. A sample of these data collected at Buzzards Bay, Massachusetts is shown in Figure 5-4. Similarly, wave observations from ships provide a data base representing over one hundred years. An example of wave data obtained from ship's logs is shown in Figure 5-5. These observations have been collected on tape (the TDF-11 series) and are available for general use from the National Climatic Center in Asheville, North Carolina. The observations mentioned above are primarily in deep water at sites which may not be near enough to a proposed site to be representative of its conditions. It is preferable to have direct observations at or near the proposed site, but these are not always available.

Required Input Data for the Disposal Site Classification Scheme

Data Type	Specific Parameters
Storm Data	Statistic of Occurance and Duration Wave Height, Period, and Direction Wind-Driven Current Velocities or Wind Speed and Direction Tidal Currents
Physical Characteristics:	
of Bottom	Bedforms (i.e. ripples, holes, etc.)
of Dredged Material	Sediment Density Distribution Grain Size Distribution
of Site Topography	Water Depth Bathymetry of Area

TABLE 5-1 Required Input Data for the Disposal Site Classification Scheme

Input Data Sources

Statistics of Occurance and Duration (for the storm)
- Observations by NOAA or the Army Corps of Engineers

Wave Height, Period and Direction (with frequency of occurance)
- Observations by NOAA or the Army Corps of Engineers
- Ship's Observations
- Local Measurements
- Hindcast from Storm Winds

Wind-Driven Currents
- Local Observations
- Hydrodynamic Estimate of Wind-Driven Flow

Wind Speed and Direction (with duration and frequency of occurance)
- Climatological Summaries
- National Weather Service Coastal Stations

Tidal Currents
- Local Observations
- NOS Tidal Current Tables

Bedforms
- Photography
- Sidescan

Sediment Density Distribution
- In Situ Sampling

Grain Size Distribution
- In Situ Sampling

Water Depth and Bathymetry of Area
- Charts
- Bathymetric Survey

TABLE 5-2 Sources for the Required Input Data

PERIOD: (OVER-ALL) 1963-1970 OCTOBER AREA 0015 ATLANTIC CITY

TABLE 18 (CONT) 38.7N 72.0W

PCT FREQ OF WIND SPEED (KTS) AND DIRECTION VERSUS SEA HEIGHTS (FT)

S

HGT	1-3	4-10	11-21	22-33	34-47	48+	PCT
<1	.3	.9	*	.0	.0	.0	1.3
1-2	.2	1.0	.9	.0	.0	.0	2.7
3-4	*	.8	1.2	.1	.0	.0	2.3
5-6	.0	.1	1.0	.1	.0	.0	1.1
7	.0	.1	.4	.1	*	.0	.6
8-9	.0	.0	.1	.1	.0	.0	.2
10-11	.0	.0	.1	.1	.0	.0	.2
12	.3	.0	.1	*	.0	.0	.1
13-16	.0	.0	*	.1	.0	.0	.1
17-19	.0	.0	.0	.0	*	.0	*
20-22	.0	.0	.0	.0	*	.0	*
23-25	.0	.0	.0	.0	.0	.0	.0
26-32	.0	.0	.0	.0	.0	.0	.0
33-40	.0	.0	.0	.0	.0	.0	.0
41-48	.0	.0	.0	.0	.0	.0	.0
49-60	.0	.0	.0	.0	.0	.0	.0
61-70	.0	.0	.0	.0	.0	.0	.0
71-86	.0	.0	.0	.0	.0	.0	.0
87+	.0	.0	.0	.0	.0	.0	.0
TOT PCT	.0	3.3	3.0	.7	.1	.0	6.7

SW

HGT	1-3	4-10	11-21	22-33	34-47	48+	PCT
<1	.1	.7	*	.0	.0	.0	.8
1-2	.1	2.1	1.2	.0	.0	.0	3.3
3-4	.0	1.2	2.1	.4	.0	.0	3.6
5-6	.0	.2	1.4	.2	.0	.0	1.7
7	.0	.1	.3	.3	.0	.0	.7
8-9	.0	.0	.2	.3	*	.0	.5
10-11	.0	.0	.1	.1	*	.0	.2
12	.0	.0	*	.1	.0	.0	.1
13-16	.0	.0	*	*	*	.0	.1
17-19	.0	.0	.0	.0	*	.0	*
20-22	.0	.0	.0	.0	.0	.0	.0
23-25	.0	.0	.0	.0	.0	.0	.0
26-32	.0	.0	.0	.0	.0	.0	.0
33-40	.0	.0	.0	.0	.0	.0	.0
41-48	.0	.0	.0	.0	.0	.0	.0
49-60	.0	.0	.0	.0	.0	.0	.0
61-70	.0	.0	.0	.0	.0	.0	.0
71-86	.0	.0	.0	.0	.0	.0	.0
87+	.0	.0	.0	.0	.0	.0	.0
TOT PCT	.2	4.2	5.3	1.2	.1	.0	11.0

W

HGT	1-3	4-10	11-21	22-33	34-47	48+	PCT
<1	.2	.7	.1	.0	.0	.0	1.0
1-2	*	1.8	1.6	.0	.0	.0	3.4
3-4	.0	1.2	2.5	.2	.0	.0	4.0
5-6	.0	.6	1.6	.2	.0	.0	2.3
7	.0	.0	.2	.2	.0	.0	.4
8-9	.0	.0	.2	.2	*	.0	.4
10-11	.0	.0	.1	.1	*	.0	.1
12	.0	.0	.1	.1	*	.0	.1
13-16	.0	.0	.1	.1	*	.0	.3
17-19	.0	.0	.0	.0	*	.0	.1
20-22	.0	.0	.0	.0	.0	.0	.0
23-25	.0	.0	.0	.0	.0	.0	.0
26-32	.0	.0	.0	.0	.0	.0	.0
33-40	.0	.0	.0	.0	.0	.0	.0
41-48	.0	.0	.0	.0	.0	.0	.0
49-60	.0	.0	.0	.0	.0	.0	.0
61-70	.0	.0	.0	.0	.0	.0	.0
71-86	.0	.0	.0	.0	.0	.0	.0
87+	.0	.0	.0	.0	.0	.0	.0
TOT PCT	.2	4.0	8.4	1.3	.2	.0	12.1

NW

HGT	1-3	4-10	11-21	22-33	34-47	48+	PCT	TOTAL PCT
<1	.1	.4	*	.0	.0	.0	.5	
1-2	*	1.9	1.0	.0	.0	.0	2.9	
3-4	.0	.6	2.1	.5	.0	.0	3.3	
5-6	.0	.2	2.7	.8	.1	.0	3.8	
7	.0	.1	1.2	1.0	.1	.0	2.4	
8-9	.0	.0	.3	.8	.1	.0	1.2	
10-11	.0	.0	.2	.5	.1	.0	.8	
12	.0	.0	.1	.1	*	.0	.3	
13-16	.0	.0	.1	.1	.1	.0	.2	
17-19	.0	.0	.0	.1	.1	.0	.2	
20-22	.0	.0	.0	.1	.1	.0	.1	
23-25	.0	.0	.0	.0	.0	.0	.0	
26-32	.0	.0	.0	.0	.0	.0	.0	
33-40	.0	.0	.0	.0	.0	.0	.0	
41-48	.0	.0	.0	.0	.0	.0	.0	
49-60	.0	.0	.0	.0	.0	.0	.0	
61-70	.0	.0	.0	.0	.0	.0	.0	
71-86	.0	.0	.0	.0	.0	.0	.0	
87+	.0	.0	.0	.0	.0	.0	.0	
TOT PCT	.2	3.4	7.8	3.8	.6	*	15.7	99.7

WIND SPEED (KTS) VS SEA HEIGHT (FT)

HGT	0-3	4-10	11-21	22-33	34-47	48+	PCT	TOT OBS
<1	4.3	5.3	.5	.0	.0	.0	10.1	
1-2	.8	14.4	8.6	.0	.0	.0	23.7	
3-4	.3	9.3	10.1	2.6	.0	.0	22.1	
5-6	*	2.1	12.4	2.9	.1	.0	17.9	
7	.0	.4	3.3	5.5	.3	.0	9.6	
8-9	.0	.1	2.0	2.4	.3	.0	4.7	
10-11	.0	.0	.9	1.9	.2	.0	3.0	
12	.0	.0	.3	.6	.1	*	1.0	
13-16	.0	.0	*	1.2	.1	.0	1.3	
17-19	.0	.0	*	.1	.2	.0	.4	
20-22	.0	.0	.0	*	.1	.0	.2	
23-25	.0	.0	.0	.0	.0	.0	.0	
26-32	.0	.0	.0	.0	.0	.0	.0	
33-40	.0	.0	.0	.0	.0	.0	.0	
41-48	.0	.0	.0	.0	.0	.0	.0	
49-60	.0	.0	.0	.0	.0	.0	.0	
61-70	.0	.0	.0	.0	.0	.0	.0	
71-86	.0	.0	.0	.0	.0	.0	.0	
87+	.0	.0	.0	.0	.0	.0	.0	
TOT PCT	5.6	31.7	49.2	19.0	1.6	*	100.0	2333

PERIOD: (OVER-ALL) 1949-1970 TABLE 19

PERCENT FREQUENCY OF WAVE HEIGHT (FT) VS WAVE PERIOD (SECONDS)

PERIOD (SEC)	<1	1-2	3-4	5-6	7	8-9	10-11	12	13-16	17-19	20-22	23-25	26-32	33-40	41-48	49-60	61-70	71-86	87+	TOTAL	MEAN HGT
<6	3.6	15.4	17.7	9.0	2.8	1.1	.4	*	.2	*	.0	.0	.0	.0	.0	.0	.0	.0	.0	2881	3
6-7	.1	1.6	6.3	7.7	4.8	2.9	1.3	.5	.5	.1	.1	*	.0	.0	.0	.0	.0	.0	.0	1532	6
8-9	*	.4	1.0	2.3	2.3	1.6	1.2	.7	.8	.2	.1	*	.0	.0	.0	.0	.0	.0	.0	827	8
10-11	.0	.2	.4	.4	.7	1.1	.6	.6	.7	.1	.1	*	*	.0	.0	.0	.0	.0	.0	191	9
12-13	.0	.0	.2	.1	.2	.3	.1	.2	.3	*	.0	.0	*	.0	.0	.0	.0	.0	.0	76	9
>13	.5	*	.3	.1	.4	.1	.2	.1	.2	*	.0	.0	.0	.0	.0	.0	.0	.0	.0	46	12
INDET	3.3	1.0	1.3	.4	.3	.3	.2	.1	*	.0	.1	*	.1	.0	.0	.0	.0	.0	.0	403	2
TOTAL	416	1093	1572	1111	659	438	234	136	157	77	18	8	7	0	0	0	0	0	0	3876	5
PCT	7.1	18.6	26.8	18.9	11.2	7.5	4.0	2.3	2.7	.9	.3	.1	.1	.0	.0	.0	.0	.0	.0	100.0	

Figure 5-3. Sample Wave Data- a page from the Synoptic Summary of Meterological Observations

GAGE OBSERVATIONS SUMMARY FOR 16 MONTHS FEB 64 THROUGH DEC 65

PERIOD (SECS) HEIGHT (FT)

PERIOD (SECS)	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13 +	TOT.*	CUM. TOT.*	ROW AVG.*
.0 - 1.9	34															1000	.00
2.0 - 2.4																1000	.00
2.5 - 2.9																1000	.00
3.0 - 3.4	2	4	1	1											8	1000	1.65
3.5 - 3.9	9	22	9	3	2										45	992	1.77
4.0 - 4.9	10	46	12	15	4	6	2								98	946	2.33
5.0 - 5.9	13	60	39	19	4	6	2	1							168	849	2.35
6.0 - 6.9	12	62	49	31	7	8	1	1							178	701	2.48
7.0 - 7.9	16	41	45	20	8	10	8	1							150	523	2.59
8.0 - 8.9	21	40	43	16	8	6	2								143	373	2.38
9.0 - 9.9	17	30	18	10	6	6	2		1		1				96	230	2.51
10.0 - 10.9	5	22	10	8	8	4	2	2	1		1				66	134	3.10
11.0 - 11.9	4	7	6	6	5	4	1			1					33	69	3.25
12.0 - 12.9	2	4	2	4	2	2				1			1		19	36	4.14
13.0 - 13.9	1	1	2	1	2										8	17	3.36
14.0 - 14.9	1	2			1		1		1	1	1				9	9	6.98
TOTAL	144	343	239	131	55	51	16	7	5	4	3		1				2.47
CUM. TOTAL	1000	856	513	275	144	88	37	21	14	9	5	2	1				
COL. AVG.	7.55*	6.97	7.33	7.30	9.49	7.86	8.17	9.00	9.96	11.20	11.50	13.50	12.50	12.50	7.80		

AVERAGE SIG. HEIGHT = 2.86 FT AVERAGE WAVE PERIOD = 7.39 SEC*
VARIANCE OF SIG. HEIGHT = 2.89 FT SQ VARIANCE OF WAVE PERIOD = 5.27 SEC SQ*
STANDARD DEVIATION OF HEIGHT = 1.70 FT STANDARD DEVIATION OF PERIOD = 2.30 SEC*

RESULTS OBTAINED FROM 7-MINUTE PEN AND INK RECORDS TAKEN WITH A PRESSURE WAVE GAGE LOCATED AT COAST GUARD LIGHT
* CALMS ARE OMITTED.

FIGURE 5-4 Sample Wave Data- Observations for Buzzard's Bay by the Army Corps of Engineers (CERC)

SEASON= YEAR

HGT= 14.

PERIOD	SE	SSE	SOU	SSW	SW
8.	0.0136	0.0136	0.0136	0.0169	0.0068
10.	0.0	0.0	0.0102	0.0136	0.0339
12.	0.0	0.0	0.0068	0.0237	0.0169
14.	0.0	0.0	0.0102	0.0136	0.0102
16.	0.0068	0.0034	0.0136	0.0034	0.0305
0.	0.0	0.0	0.0	0.0	0.0

HGT= 12.

PERIOD	SE	SSE	SOU	SSW	SW
8.	0.0	0.0136	0.0102	0.0203	0.0203
10.	0.0102	0.0034	0.0102	0.0136	0.0068
12.	0.0	0.0	0.0068	0.0068	0.0102
14.	0.0068	0.0	0.0034	0.0	0.0034
16.	0.0	0.0	0.0068	0.0068	0.0068
0.	0.0	0.0	0.0	0.0	0.0

HGT= 10.

PERIOD	SE	SSE	SOU	SSW	SW
8.	0.0136	0.0136	0.0407	0.0440	0.0745
10.	0.0068	0.0068	0.0271	0.0169	0.0440
12.	0.0034	0.0068	0.0068	0.0034	0.0068
14.	0.0034	0.0102	0.0	0.0034	0.0034
16.	0.0068	0.0	0.0	0.0068	0.0169
0.	0.0034	0.0	0.0034	0.0	0.0

HGT= 8.

PERIOD	SE	SSE	SOU	SSW	SW
8.	0.0271	0.0373	0.0983	0.0915	0.1389
10.	0.0102	0.0068	0.0237	0.0203	0.0576
12.	0.0034	0.0	0.0068	0.0068	0.0102
14.	0.0	0.0	0.0102	0.0	0.0068
16.	0.0068	0.0	0.0102	0.0068	0.0136
0.	0.0	0.0	0.0	0.0	0.0068

HGT= 6.

PERIOD	SE	SSE	SOU	SSW	SW
8.	0.1050	0.1220	0.2541	0.2346	0.4032
10.	0.0169	0.0271	0.0271	0.0237	0.0373
12.	0.0068	0.0102	0.0	0.0169	0.0102
14.	0.0068	0.0	0.0034	0.0034	0.0
16.	0.0034	0.0034	0.0136	0.0203	0.0169
0.	0.0	0.0034	0.0034	0.0068	0.0

HGT= 4.

PERIOD	SE	SSE	SOU	SSW	SW
8.	1.0369	0.8199	2.2302	2.6495	2.9205
10.	0.0712	0.0339	0.0983	0.0949	0.1152
12.	0.0169	0.0102	0.0407	0.0136	0.0169
14.	0.0034	0.0136	0.0237	0.0102	0.0136
16.	0.0610	0.0305	0.1660	0.1728	0.2609
0.	0.0068	0.0068	0.0407	0.0136	0.0339

FIGURE 5-5 Sample Wave Data- taken from ship's records for the area bounded by 70° and 80° W longitude and 40° and 50° N latitude

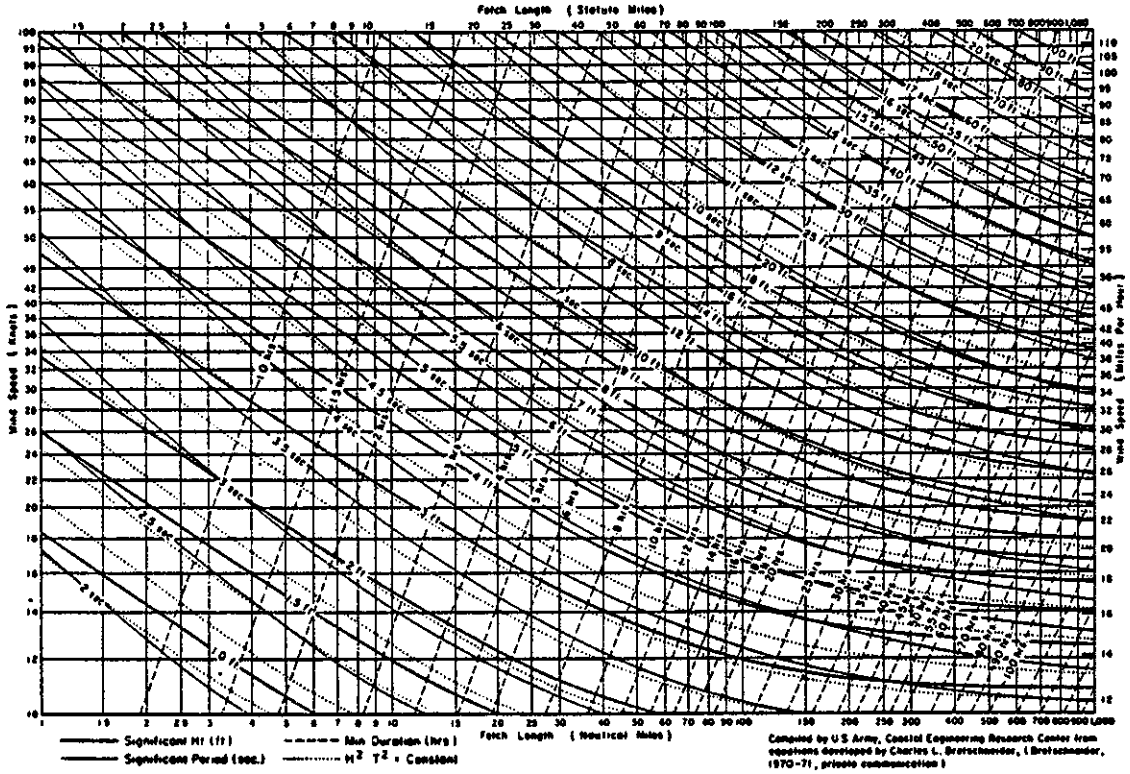
Occasionally, local studies have been made by academic or other organizations. Using the Central Long Island Sound Site as an example, two nearby areas - Stratford Shoals and Six Mile Reef - are presently being studied by the Marine Sciences Institute of the University of Connecticut. These areas lie on either side of the Central Long Island Sound Site, approximately 8-10 miles distant in approximately half the water depth. After extrapolation for the water depth difference, they are applicable to that site and are being studied for that reason. If observations are not available, the wave height, period, and direction can be predicted using a hindcast scheme such as Bretschneider's (Fig. 5-6). The Army Corps of Engineers has also compiled hindcast estimates for significant wave information through its Wave Information Studies of U.S. Coastlines done by the Waterways Experiment Station (WES). An example of hindcast estimations are presented in Figure 5-7. Any of these sources may be used as needed to provide the required data and it will be the user's responsibility to assess the data base relative to the proposed disposal site.

The sources for the wind-driven current information are less numerous and are generally available only from local measurements or hydrodynamic estimates based on wind observations. Long-term local current measurements are preferred, but a literature search must be conducted in order to determine the extent of data available. If the specific storm dates and associated wind data are known, the wind-driven current can be determined from the current record. If the data are not available, an estimate can be made using a hydrodynamic model of the wind-driven circulation based on wind observations. A simple method for calculating the flow due to wind stress is presented in Figure 5-8. This calculation requires wind velocity observations, which are readily available from climatological summaries, as was shown in Figure 5-3, or through the National Weather Service Coastal Station network.

In addition, tidal current velocities over at least several cycles of the tide can be used for the tidal currents. These data can be obtained either from local observations or the National Ocean Survey tidal charts (Fig. 5-9). The waves, tidal currents and wind-driven current specify the environmental conditions that determine transport; therefore, representative values of these parameters during storms are required to characterize a storm for sediment transport prediction.

Direct observations of the total current from current meters occasionally exist, but these observations are not commonly made near the bottom (within one meter). The best type of data are obtained from sources studying sediment transport such as Vincent (1982), and should be used whenever available.

The physical characteristics of the bottom and of the capped dredged material mound are also required. Since the cap material would be the sediment entrained, the grain size and density of the cap should be used. In-situ sampling should be used to acquire these values if possible. The bottom roughness



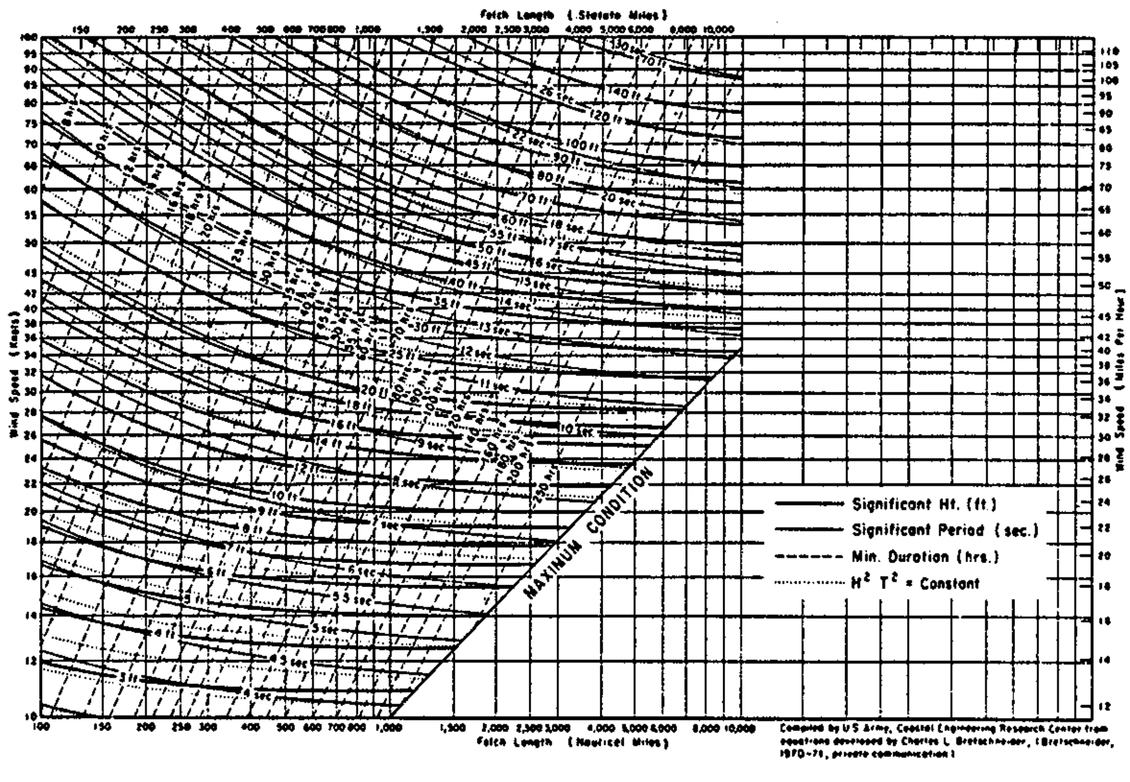


FIGURE 5-6 Sample Wave Data- Table developed by Bretschneider to predict wave height and period using wind speed and fetch

STATION 2 FOR ALL DIRECTIONS IN SEASON 4
PERCENT OCCURENCE(X100) OF HEIGHT AND PERIOD FOR ALL DIRECTIONS

HEIGHT(METRES)	PERIOD(SECONDS)															TOTAL
	0.0-2.9	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-24.9	25.0-26.9	27.0-28.9	29.0-30.9	
0. - 0.49	34	213	.	192	47	.	.	.	.	.	.	.	1	.	.	487
0.50 - 0.99	14	627	112	656	335	28	.	.	.	.	.	.	.	.	.	1772
1.00 - 1.49	3	46	607	631	370	79	9	.	.	.	.	.	.	.	.	1745
1.50 - 1.99	.	.	407	419	279	107	10	2	.	.	.	.	.	.	.	1224
2.00 - 2.49	.	.	143	404	247	134	21	1	.	.	.	.	.	.	.	950
2.50 - 2.99	.	.	14	614	177	181	29	2	.	.	.	.	.	.	.	1017
3.00 - 3.49	.	.	1	626	105	124	33	.	.	.	.	.	.	.	.	889
3.50 - 3.99	.	.	.	483	91	72	31	.	.	.	.	.	.	.	.	677
4.00 - 4.49	.	.	.	209	131	27	36	6	.	.	.	.	.	.	.	409
4.50 - 4.99	.	.	.	82	173	13	23	11	.	.	.	.	.	.	.	302
5.00 - 5.49	.	.	.	40	144	6	4	4	.	.	.	.	.	.	.	198
5.50 - 5.99	.	.	.	25	87	6	1	.	.	.	.	.	.	.	.	119
6.00 - 6.49	.	.	.	12	46	21	.	.	.	.	.	.	.	.	.	79
6.50 - 6.99	.	.	.	4	25	21	1	.	.	.	.	.	.	.	.	51
7.00 - 7.49	.	.	.	1	14	12	.	.	.	.	.	.	.	.	.	27
7.50 - 7.99	.	.	.	1	4	8	.	.	.	.	.	.	.	.	.	13
8.00 - 8.49	.	.	.	.	1	2	.	.	.	.	.	.	.	.	.	3
8.50 - 8.99	.	.	.	.	2	3	.	.	.	.	.	.	.	.	.	5
9.00 - 9.49	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	2
9.50 - 9.99	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
10.00 -10.49	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
10.50 -10.99	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1
11.00 -11.49	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	1
11.50 -11.99	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1
12.00 -12.49	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
12.50 -12.99	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
13.00 -13.49	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
13.50 -13.99	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
14.00 -14.49	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
14.50 -14.99	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0
TOTAL	51	886	1284	4399	2278	849	200	26	0	0	0	0	1	0	0	

1:20

1:40

1:80

STATION 2 AVERAGE HS(METRES)= 2.2 LARGEST HS(METRES)= 11.7 TOTAL CASES= 14720. SEASONAL %= 25.2

FIGURE 5-7 Sample Wave Data- Hindcast Estimations by the Army Corps of Engineers

The wind-driven current velocity, V, at the near-bottom is directly related to the surface wind shear stress, the duration of the wind, and the depth of the water

$$V = \tau\ t / (h\ p)$$

where:
- t = duration of the wind
- h = water depth
- p = water density.

The wind stress can be calculated from an estimate of the drag of the wind on the water surface, according to the equation

$$\tau = C_{d10}\ p_a\ U_{10}\ |U_{10}|$$

where:
- C_{10} = drag coefficient
- p_a = air density
- u_{10} = wind velocity 10 m above the surface.

The drag coefficient has been empirically determined as a function of the wind speed,

$$C_{d10} = 0.00063 + 0.00000066\ |U_{10}|.$$

(Carl Amos, 1983: personal communication)

FIGURE 5-8 . Sample Wind-Driven Current Determination

THE RACE, LONG ISLAND SOUND, 1983

F-Flood, Dir. 295° True E-Ebb, Dir. 100° True

JANUARY

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
1	0025	0341	4.1E
Sa	0643	0937	4.1F
	1241	1606	4.7E
	1923	2211	4.0F
2	0119	0435	4.1E
Su	0741	1029	3.9F
	1336	1702	4.5E
	2017	2304	3.9F
3	0214	0533	4.0E
M	0841	1128	3.6F
	1432	1759	4.2E
	2113		
4		0002	3.6F
Tu	0311	0631	3.9E
	0944	1228	3.3F
	1531	1855	3.9E
	2211		
5		0101	3.4F
W	0409	0731	3.7E
	1050	1333	3.0F
	1633	1956	3.5E
	2311		
6		0205	3.2F
Th	0509	0832	3.6E
	1155	1443	2.7F
	1736	2057	3.3E
7	0011	0306	3.0F
F	0608	0933	3.5E
	1259	1552	2.6F
	1840	2155	3.1E
8	0110	0410	2.9F
Sa	0706	1028	3.5E
	1358	1653	2.6F
	1941	2252	3.0E
9	0205	0509	2.8F
Su	0800	1124	3.6E
	1453	1751	2.6F
	2037	2345	2.9E
10	0257	0558	2.8F
M	0848	1211	3.6E
	1542	1838	2.6F
	2127		
11		0032	2.9E
Tu	0345	0643	2.7F
	0933	1258	3.6E
	1627	1921	2.7F
	2211		
12		0118	2.9E
W	0428	0724	2.7F
	1013	1341	3.6E
	1708	2000	2.7F
	2251		
13		0201	2.9E
Th	0509	0757	2.7F
	1052	1422	3.5E
	1746	2033	2.6F
	2329		
14		0242	2.8E
F	0548	0828	2.6F
	1129	1459	3.5E
	1822	2101	2.6F
15	0005	0321	2.8E
Sa	0625	0904	2.6F
	1205	1538	3.4E
	1856	2134	2.6F

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
16	0040	0400	2.8E
Su	0701	0942	2.5F
	1242	1616	3.2E
	1930	2209	2.6F
17	0117	0438	2.7E
M	0738	1022	2.5F
	1320	1651	3.1E
	2003	2248	2.6F
18	0154	0514	2.7E
Tu	0818	1104	2.4F
	1400	1727	2.9E
	2039	2331	2.6F
19	0234	0552	2.7E
W	0903	1149	2.3F
	1444	1802	2.7E
	2119		
20		0015	2.5F
Th	0317	0637	2.7E
	0952	1240	2.2F
	1532	1849	2.6E
	2203		
21		0102	2.5F
F	0405	0729	2.7E
	1048	1331	2.2F
	1627	1942	2.5E
	2254		
22		0155	2.6F
Sa	0458	0828	2.9E
	1148	1429	2.2F
	1726	2049	2.5E
	2350		
23		0250	2.7F
Su	0555	0929	3.1E
	1250	1528	2.4F
	1829	2152	2.7E
24	0050	0349	2.9F
M	0654	1031	3.5E
	1350	1627	2.7F
	1932	2254	2.9E
25	0150	0447	3.2F
Tu	0754	1129	3.8E
	1447	1728	3.0F
	2032	2351	3.3E
26	0250	0544	3.5F
W	0851	1223	4.2E
	1542	1824	3.4F
	2129		
27		0046	3.7E
Th	0347	0640	3.8F
	0947	1315	4.6E
	1634	1918	3.8F
	2224		
28		0141	4.0E
F	0443	0736	4.1F
	1041	1409	4.8E
	1724	2012	4.0F
	2317		
29		0233	4.3E
Sa	0537	0829	4.2F
	1134	1459	4.9E
	1814	2103	4.2F
30	0009	0325	4.4E
Su	0631	0921	4.2F
	1227	1551	4.8E
	1905	2153	4.2F
31	0100	0417	4.4E
M	0726	1014	4.0F
	1319	1642	4.6E
	1955	2245	4.0F

FEBRUARY

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
1	0152	0511	4.3E
Tu	0822	1108	3.7F
	1412	1735	4.2E
	2047	2336	3.7F
2	0244	0605	4.0E
W	0921	1205	3.3F
	1507	1828	3.8E
	2141		
3		0031	3.4F
Th	0338	0702	3.8E
	1022	1303	2.9F
	1603	1926	3.4E
	2238		
4		0129	3.0F
F	0434	0759	3.5E
	1125	1407	2.5F
	1704	2025	3.0E
	2337		
5		0230	2.7F
Sa	0532	0859	3.3E
	1229	1517	2.3F
	1806	2122	2.7E
6	0038	0335	2.5F
Su	0631	0958	3.2E
	1330	1625	2.2F
	1909	2223	2.6E
7	0137	0437	2.4F
M	0727	1053	3.2E
	1426	1726	2.3F
	2009	2317	2.6E
8	0232	0535	2.4F
Tu	0820	1148	3.2E
	1517	1815	2.4F
	2101		
9		0008	2.7E
W	0322	0623	2.5F
	0907	1233	3.3E
	1602	1900	2.5F
	2146		
10		0055	2.8E
Th	0407	0700	2.5F
	0950	1317	3.4E
	1643	1937	2.6F
	2226		
11		0137	2.9E
F	0448	0737	2.6F
	1029	1358	3.5E
	1720	2008	2.7F
	2303		
12		0217	3.0E
Sa	0526	0808	2.7F
	1107	1435	3.5E
	1755	2035	2.8F
	2338		
13		0256	3.0E
Su	0602	0842	2.7F
	1143	1513	3.4E
	1827	2105	2.8F
14	0011	0331	3.1E
M	0637	0919	2.8F
	1219	1549	3.3E
	1858	2141	2.9F
15	0046	0407	3.1E
Tu	0712	0956	2.8F
	1256	1622	3.2E
	1929	2216	2.9F

Day	Slack Water Time h.m.	Maximum Current Time h.m.	Maximum Current Vel. knots
16	0121	0443	3.1E
W	0749	1037	2.7F
	1334	1651	3.1E
	2003	2257	2.8F
17	0158	0516	3.1E
Th	0831	1120	2.6F
	1416	1723	2.9E
	2041	2340	2.8F
18	0240	0557	3.1E
F	0918	1208	2.5F
	1502	1808	2.8E
	2125		
19		0029	2.7F
Sa	0328	0648	3.0E
	1013	1301	2.4F
	1556	1903	2.6E
	2218		
20		0122	2.7F
Su	0423	0751	3.0E
	1115	1358	2.3F
	1657	2015	2.6E
	2318		
21		0221	2.7F
M	0525	0901	3.2E
	1221	1501	2.4F
	1804	2126	2.7E
22	0026	0323	2.8F
Tu	0630	1007	3.4E
	1327	1605	2.6F
	1910	2235	3.0E
23	0133	0426	3.1F
W	0734	1108	3.8E
	1428	1709	3.0F
	2014	2334	3.4E
24	0238	0529	3.4F
Th	0836	1207	4.2E
	1524	1809	3.4F
	2113		
25		0032	3.8E
F	0337	0629	3.8F
	0934	1259	4.5E
	1617	1905	3.8F
	2207		
26		0126	4.2E
Sa	0432	0725	4.0F
	1028	1352	4.7E
	1707	1955	4.1F
	2259		
27		0217	4.5E
Su	0526	0817	4.2F
	1120	1441	4.8E
	1755	2045	4.2F
	2349		
28		0307	4.6E
M	0617	0906	4.2F
	1211	1530	4.7E
	1843	2133	4.2F

Time meridian 75° W. 0000 is midnight. 1200 is noon.

FIGURE 5-9 Sample Tidal Current Data- a page from the NOS tidal charts which can be used to determine the tidal current velocity of the site must also be described, i.e. bedforms and ripples, and bathymetry, and can be determined using sidescan or photographic techniques. Bathymetric charts or standard nautical charts can be used to describe depths in the study area. Water depth should be adjusted according to the height of the proposed mound, which may be estimated from historical data based on the volume of material to be deposited at the site.

After compiling the most representative values available for these several parameters described above, the computations of the sediment transport model can begin, starting with the bottom shear stress calculation.

5.3.2 Bottom Shear Stress Calculation

The bottom shear stress, (τ), as a function of time is primarily a function of the fluid density, ρ, the near bottom wave orbital velocity, U_w, a combined current and wave friction factor, f_{cw}, and the relative angle of the current velocity with the waves, θ_c, as described by:

$$\tau(t) = 0.5 \rho f_{cw} U_w^2 \left| \sin(\omega t + \theta_c) \right| \sin(\omega t + \theta_c)$$

The shear stress calculation is complicated because of the interaction between the shear stress and the near-bottom velocity via the bottom friction factor. To calculate the bottom shear stress, the velocities must be known, however, to know the velocities within the bottom boundary layer, the shear stress must be known. This type of problem is best solved using an iterative approach, such as the following proposed by Grant and Madsen (1979). Their approach divides the bottom shear stress calculation into five steps, as seen in Figure 5-10, with only the fourth step being iterative. The bottom shear stress derived from this calculation is then input to the sediment transport calculation.

5.3.3 Sediment Transport Calculation for a Specific Storm

The sediment transport is a function of the bottom shear stress via the Shield's parameter. The basic determination of the instantaneous sediment transport rate, q(t), is dependant only on the near-bottom velocity, U_{cw}, and the excess Shield's parameter, , according to:

$$q(t) = 0.09 \ (\psi(t) - \psi_c) \ U_{cw}$$

(Vincent et al., 1982).

The excess Shield's parameter is the exceedence of the maximum Shield's parameter over the critical Shield's parameter, where the critical Shield's parameter signifies the onset of sediment motion. (The critical Shield's parameter is empirically derived.)

BOTTOM SHEAR STRESS CALCULATION

Define Characteristic Parameters

↓

Estimate a Value for the Bottom Roughness

↓

Estimate the Near Bottom Wave and Current Velocities and the Separation Angle

↓

Iteratively Solve for Four Interdependent Parameters

1) the ratio of the near bottom current and wave velocities
2) the separation angle for the current and wave velocities
3) the ratio of the bottom roughness to the excursion amplitude of a fluid particle
4) the ratio of the near bottom specification height to the bottom roughness

↓

Calculate the Bottom Shear Stress

FIGURE 5-10

The bottom shear stress and the friction factor affect the transport rate via the Shield's parameter, as characterized by

$$\tau(t) = 0.5\rho f_{cw} (U_c \cos\omega t + U_c)$$

(Vincent et al., 1982).

This transport rate is first integrated over a wave cycle and then over the duration of the storm to yield the sediment transport per unit area for a storm.

The formulation for the sediment transport calculation is much more straightforward than that of the bottom shear stress. The approach outlined by Vincent et al. (1982) and based on Grant and Madsen (1979) was used.

The basic steps of the formulation are outlined in Figure 5-11. First, the maximum Shield's parameter is determined using the velocity values obtained in the bottom shear stress calculation. The critical Shield's parameter is then obtained empirically. If the maximum Shield's parameter does not exceed the critical value, transport will not occur for this set of input conditions and the calculations for a storm of that intensity are complete. If the maximum exceeds the critical Shield's parameter, transport will occur. Since sediment transport affects the bottom roughness parameter (Grant and Madsen, 1982), the bottom roughness must be recalculated along with the bottom shear stress and the Shield's parameters at the onset of sediment transport. Once this has been done, the instantaneous sediment transport rate per unit area can be calculated. This rate must be integrated over a wave cycle to obtain the average instantaneous sediment transport rate per unit area per wave cycle. This rate is again integrated over the duration of the storm to obtain the sediment transport per unit area per storm.

5.3.4 Sediment Transport Model Results

The sediment transport per unit area as a function of time is the final output of the sediment transport portion of the classification scheme. The sediment transport can be converted to a depth loss and, by normalizing this value by the proposed mound height, the final output is a percent loss per unit area as a function of time. This can be presented in the form shown in Figure 5-12. (This figure was drawn by speculation for a hypothetical site.) The percent loss for a site should have this general appearance, with the slope of the line depending on the degree of storm impact. If the site is affected by 5 year storms, there would be an increase in the curve every five years. Superimposed on this steady increase are larger increases corresponding to 10, 20, and 50 year storms (or the equivalent). From Figure 5-12, a 'lifetime' for this site could be estimated, in this case, 80 years. However, it must be remembered that this is a probabalistic curve and if a major 20 or 40 year storm

CALCULATIONS OF SEDIMENT TRANSPORT FOR A SPECIFIC STORM

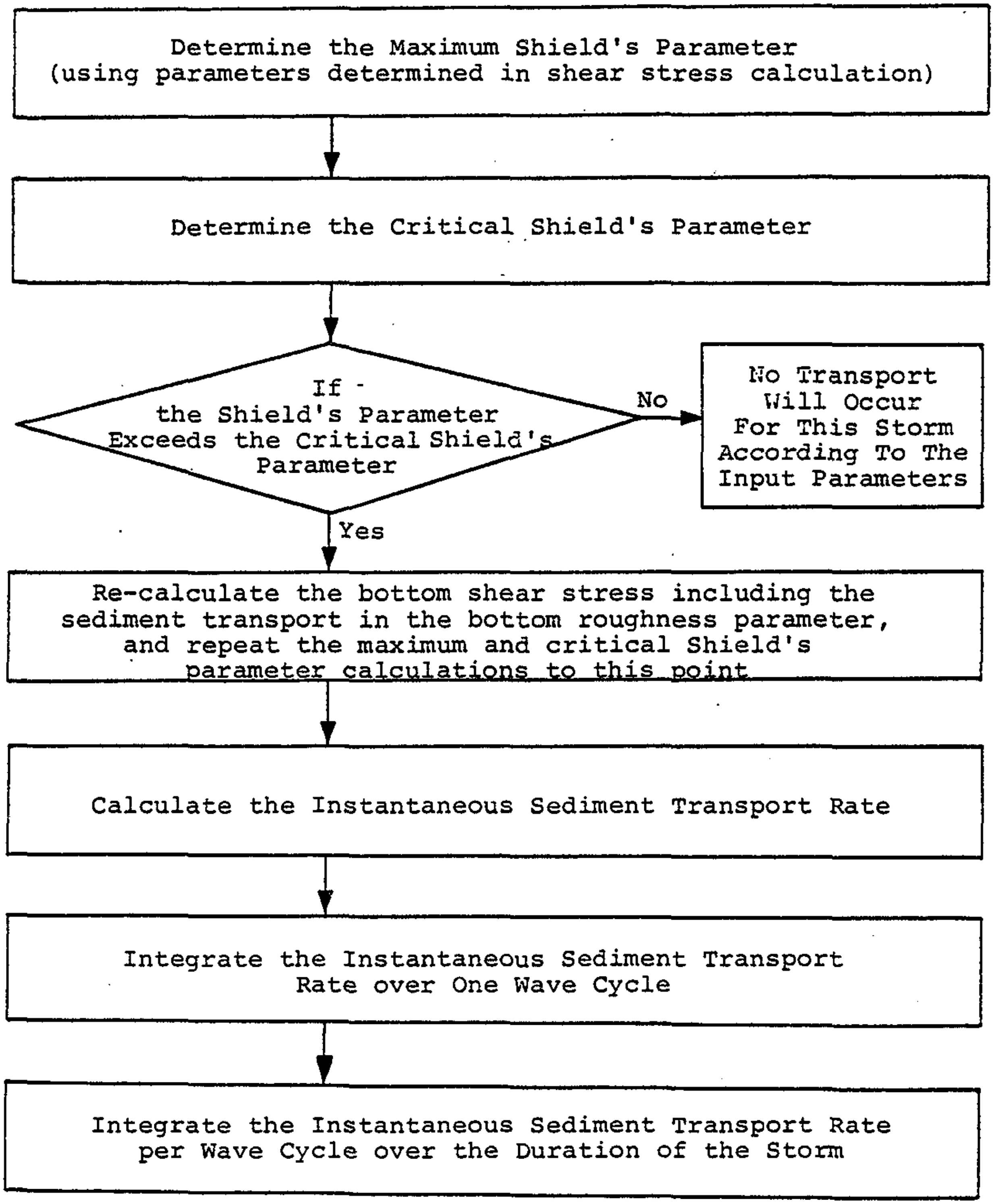


FIGURE 5-11

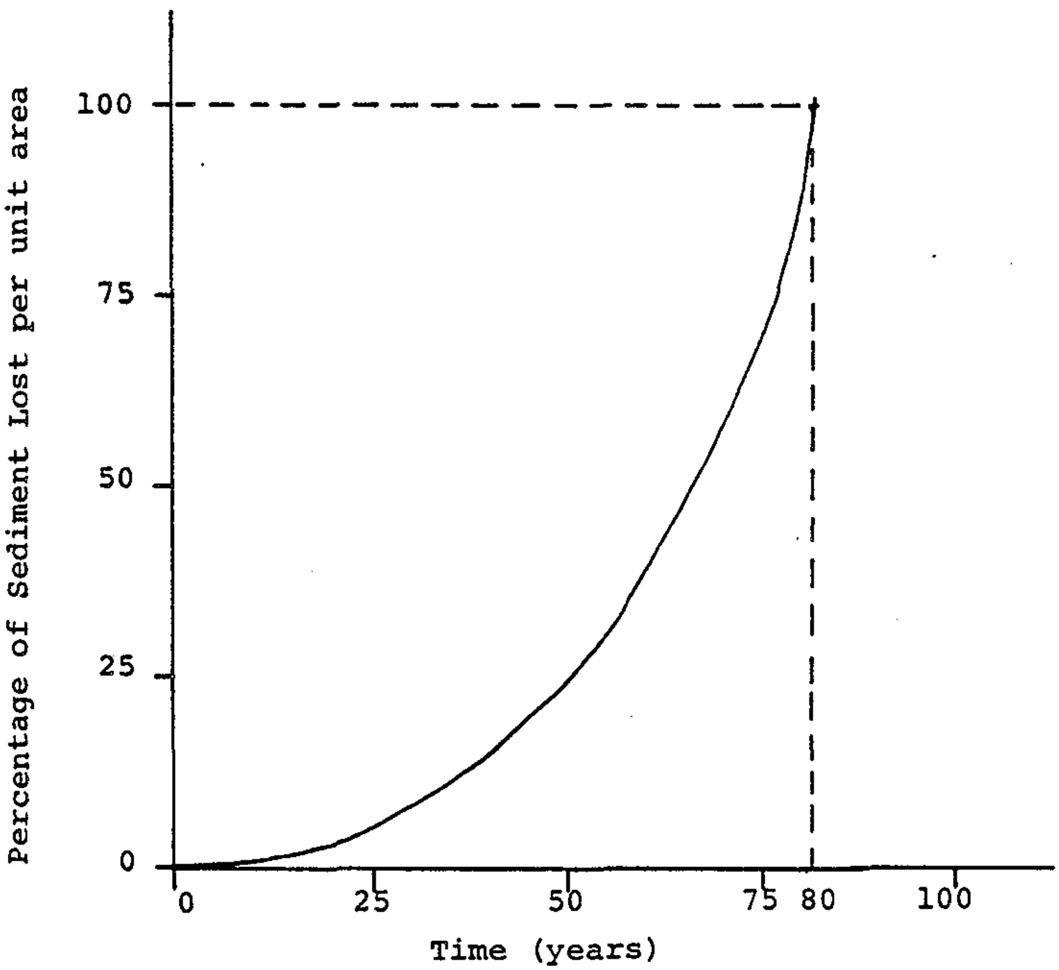


FIGURE 5-12 Sample Disposal Site Classification Scheme Output

occurred at the start of the period, conditions at the site might be drastically altered and require attention.

5.3.5 Sediment Transport Model Assumptions

There are three potential sources of errors due to assumptions in sediment transport models: 1) reliability of the input data, 2) uncertainties in the sediment transport formulation, and 3) neglect of portions of the physics. In each of these areas, uncertainties exist or assumptions were made which are potential error sources. Overall, the primary error source, however, is the uncertanty in the sediment transport formulae, which were derived from empirical relations. These empirical relations are based on limited data mainly gathered in laboratory flume experiments for non-cohesive sediments such as coarse sand. These formulae alone limit the degree of accuracy to an order of magnitude. This does not imply, however, that reliable predictions cannot be made. The capability does exist for accurate preditions of this type, since many of the effects of the errors are small, and average out making the overall estimation sufficiently accurate for the decisions required here.

The primary potential for error of the sediment transport model itself is the reliability of the theories and formulae. First those of Grant and Madsen (1982, 1979) for determination of shear stress under waves and currents and the effect of sediment transport on the effective bottom roughness and secondly the calculation of sediment transport by Vincent (1982). Both of these theories have been empirically verified, but not for all types of conditions. Grant and Madsen's work, particularly, has been verified primarily using coarse sands in laboratory flume studies. Although this applies directly to most of the capping material, its application to the silty or muddy sediment that is characteristic of dredged material is questionable. Vincent's relations were verified against storm data with good agreement, which was one of the primary criteria for their selection.

Other sources of error due to the theoretical formulation are the interdependent nature of the parameters in the formulation of the shear stress, which has already been discussed, and the dynamic nature of the parameters. The sediment density, grain size, and bottom roughness are assumed to be constant with time while in reality they are dynamic with the onset of sediment transport. This dynamic nature could be considered part of the physics of the problem which is being neglected.

Other potential error sources which may impact the problem are:

1) lack of knowledge of cohesive forces within the sediment,

2) lack of knowledge of suspended load transport,

3) disregard for non-linear breaking wave effects,

4) no change in the water depth due to the storm,

5) no change in the bathymetry of the area for a long period of time,

5.4 Final Form of the Classification Scheme

Upon completion of this program, the classification scheme will consist of:

1) a set of computer models capable of predicting behavior of different sediment types under different conditions and calculating parameters of mound stability

2) a set of interpretation tables to evalute the output of the models

3) a user's manual for operating the models and interpreting the results.

When it is necessary to evaluate a potential capping project, the models will be run depending upon the specific needs of the user. It will be his responsibility to obtain the necessary data for operation of the program.

5.5 Model Verification and Sensitivity Analysis

Once the models have been developed, they need to be verified against a test case and a sensitivity analysis should be made. Since a significant amount of observations and measurements have been made in Central Long Island Sound and with Black Rock material, they will be used for the first verification test case. Upon successful completion of this test case, two other cases with their respective materials will be run. A site in deeper and more open water should be selected to verify the models for those conditions.

After verification, a sensitivity analysis will be made for the models. This type of analysis determines the sensitivity of a model to typical magnitude changes of its parameters. A sensitivity analysis may show that typical values for changes in the consolidation ratio show an order of magnitude less change than typical values for the sediment density. Using this information, a user's reaction would be two-fold. First, he would place more emphasis on obtaining accurate estimates of the density when operating the model. Secondly, he would probably be able to disregard most changes in the consolidation ratio and concentrate his effort on the effect of changes in density on his data.

5.6 Summary

The development of a classification scheme to assist in decisions relative to capping operations is progressing well. Sediment transport models applied to the stability of cap material at a specific site have been developed to the point where implementation of the computer software can begin. Further work is needed to define the parameters associated with geotechnical properties and their effect on dredged material distribution and behavior, however, the basic inputs and formulas for development of mound stability criteria have been defined and can be implemented.

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APPENDIX I

SUMMARY OF DISPOSAL OPERATIONS
AT THE
CENTRAL LONG ISLAND SOUND
DISPOSAL SITE

SPRING, 1983

(Operations designated as unknown were not clearly recorded in disposal logs.)

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

---- DISPOSED AT : : 0 UNKNOWN ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
04-26-83	UNKNOWN	NHAV UPPER	3701	2830
04-26-83	UNKNOWN	NHAV UPPER	3703	2831
04-28-83	UNKNOWN	NHAV UPPER	3700	2829
04-28-83	UNKNOWN	NHAV UPPER	3701	2830
04-28-83	UNKNOWN	NHAV UPPER	3702	2831
04-29-83	UNKNOWN	NHAV UPPER	3700	2829
04-29-83	UNKNOWN	NHAV UPPER	3701	2830
------ T O T A L S FOR NHAV UPPER				
			25908	19809
------ T O T A L S FOR UNKNOWN				
			25908	19809

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

- - DISPOSED AT : : 1 CS #1 - - - -

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
04-06-83	CS #1	BLKRK REACH 1 NORTH	1420	1086
04-06-83	CS #1	BLKRK REACH 1 NORTH	1500	1147
04-06-83	CS #1	BLKRK REACH 1 NORTH	1501	1148
04-06-83	CS #1	BLKRK REACH 1 NORTH	3000	2294
04-07-83	CS #1	BLKRK REACH 1 NORTH	1450	1109
04-07-83	CS #1	BLKRK REACH 1 NORTH	3000	2294
04-08-83	CS #1	BLKRK REACH 1 NORTH	1420	1086
04-08-83	CS #1	BLKRK REACH 1 NORTH	1500	1147
04-08-83	CS #1	BLKRK REACH 1 NORTH	3000	2294
04-09-83	CS #1	BLKRK REACH 1 NORTH	1200	918
04-09-83	CS #1	BLKRK REACH 1 NORTH	3000	2294
- - - - - - T O T A L S FOR BLKRK REACH 1 NORTH				
			21991	16814
04-10-83	CS #1	BLKRK REACH 3 SOUTH	1350	1032
- - - - - - T O T A L S FOR BLKRK REACH 3 SOUTH				
			1350	1032
04-06-83	CS #1	NHAV UPPER	3700	2829
04-18-83	CS #1	NHAV UPPER	3499	2675
04-18-83	CS #1	NHAV UPPER	3501	2677
04-18-83	CS #1	NHAV UPPER	3700	2829
04-19-83	CS #1	NHAV UPPER	3700	2829
05-17-83	CS #1	NHAV UPPER	3700	2829
05-18-83	CS #1	NHAV UPPER	3698	2827
05-18-83	CS #1	NHAV UPPER	3699	2828
05-18-83	CS #1	NHAV UPPER	3700	2829
05-18-83	CS #1	NHAV UPPER	3701	2830
05-18-83	CS #1	NHAV UPPER	3702	2831
05-19-83	CS #1	NHAV UPPER	3698	2827
05-19-83	CS #1	NHAV UPPER	3699	2828
05-19-83	CS #1	NHAV UPPER	3701	2830
05-19-83	CS #1	NHAV UPPER	3702	2831
05-20-83	CS #1	NHAV UPPER	3699	2828
05-20-83	CS #1	NHAV UPPER	3700	2829
05-20-83	CS #1	NHAV UPPER	3701	2830
05-21-83	CS #1	NHAV UPPER	3700	2829
05-22-83	CS #1	NHAV UPPER	3699	2828
05-22-83	CS #1	NHAV UPPER	3700	2829
05-22-83	CS #1	NHAV UPPER	3701	2830

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

-- DISPOSED AT : : 1 CS #1 ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
05-23-83	CS #1	NHAV UPPER	3700	2829
05-23-83	CS #1	NHAV UPPER	3701	2830
----- T O T A L S FOR NHAV UPPER				
			88401	67590
04-11-83	CS #1	UNKNOWN BLKRK	1450	1109
04-11-83	CS #1	UNKNOWN BLKRK	1550	1185
04-11-83	CS #1	UNKNOWN BLKRK	3000	2294
04-12-83	CS #1	UNKNOWN BLKRK	1500	1147
04-12-83	CS #1	UNKNOWN BLKRK	3000	2294
04-13-83	CS #1	UNKNOWN BLKRK	1500	1147
04-13-83	CS #1	UNKNOWN BLKRK	2000	1529
04-13-83	CS #1	UNKNOWN BLKRK	3000	2294
04-14-83	CS #1	UNKNOWN BLKRK	3000	2294
04-15-83	CS #1	UNKNOWN BLKRK	1500	1147
04-15-83	CS #1	UNKNOWN BLKRK	1501	1148
----- T O T A L S FOR UNKNOWN BLKRK				
			23001	17586
--- T O T A L S FOR CS #1				
			134743	103023

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

-- DISPOSED AT : : 2 CS #2 ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
05-15-83	CS #2	UNKNOWN	2000	1529
------ T O T A L S FOR UNKNOWN				
			2000	1529
04-18-83	CS #2	BLKRK REACH 1 NORTH	1500	1147
04-19-83	CS #2	BLKRK REACH 1 NORTH	1400	1070
04-19-83	CS #2	BLKRK REACH 1 NORTH	1800	1376
04-19-83	CS #2	BLKRK REACH 1 NORTH	3000	2294
04-20-83	CS #2	BLKRK REACH 1 NORTH	1400	1070
04-20-83	CS #2	BLKRK REACH 1 NORTH	2790	2133
04-21-83	CS #2	BLKRK REACH 1 NORTH	1300	994
04-21-83	CS #2	BLKRK REACH 1 NORTH	1330	1017
04-21-83	CS #2	BLKRK REACH 1 NORTH	2800	2141
04-22-83	CS #2	BLKRK REACH 1 NORTH	2550	1950
04-23-83	CS #2	BLKRK REACH 1 NORTH	2700	2064
04-23-83	CS #2	BLKRK REACH 1 NORTH	2800	2141
------ T O T A L S FOR BLKRK REACH 1 NORTH				
			25370	19397
04-24-83	CS #2	BLKRK REACH 1 SOUTH	1800	1376
04-25-83	CS #2	BLKRK REACH 1 SOUTH	1330	1017
04-25-83	CS #2	BLKRK REACH 1 SOUTH	1800	1376
04-25-83	CS #2	BLKRK REACH 1 SOUTH	2800	2141
04-26-83	CS #2	BLKRK REACH 1 SOUTH	1800	1376
04-26-83	CS #2	BLKRK REACH 1 SOUTH	2750	2103
------ T O T A L S FOR BLKRK REACH 1 SOUTH				
			12280	9389
05-15-83	CS #2	BLKRK REACH 3 SOUTH	2125	1625
05-17-83	CS #2	BLKRK REACH 3 SOUTH	1850	1415
05-17-83	CS #2	BLKRK REACH 3 SOUTH	2825	2160
05-18-83	CS #2	BLKRK REACH 3 SOUTH	1650	1262
------ T O T A L S FOR BLKRK REACH 3 SOUTH				
			8450	6461
05-30-83	CS #2	NHAV OUTER	2500	1912

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

-- DISPOSED AT : : 2 CS #2 ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
05-30-83	CS #2	NHAV OUTER	3000	2294
05-30-83	CS #2	NHAV OUTER	3250	2485
05-31-83	CS #2	NHAV OUTER	3449	2637
05-31-83	CS #2	NHAV OUTER	3450	2638
05-31-83	CS #2	NHAV OUTER	3451	2639
05-31-83	CS #2	NHAV OUTER	3650	2791
06-01-83	CS #2	NHAV OUTER	3350	2561
06-01-83	CS #2	NHAV OUTER	3450	2638
06-01-83	CS #2	NHAV OUTER	3750	2867
06-02-83	CS #2	NHAV OUTER	2850	2179
06-02-83	CS #2	NHAV OUTER	3450	2638
06-02-83	CS #2	NHAV OUTER	3850	2944
06-03-83	CS #2	NHAV OUTER	3850	2944
06-03-83	CS #2	NHAV OUTER	3851	2944
06-03-83	CS #2	NHAV OUTER	3852	2945
TOTALS FOR NHAV OUTER			55003	42055
TOTALS FOR CS #2			103103	78831

-- DISPOSED AT : : 3 MORDS ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
04-01-83	MORDS	BLKRK REACH 1 NORTH	1500	1147
04-01-83	MORDS	BLKRK REACH 1 NORTH	2900	2217
04-02-83	MORDS	BLKRK REACH 1 NORTH	1490	1139
04-02-83	MORDS	BLKRK REACH 1 NORTH	1520	1162
04-04-83	MORDS	BLKRK REACH 1 NORTH	1500	1147
04-05-83	MORDS	BLKRK REACH 1 NORTH	2710	2072
04-05-83	MORDS	BLKRK REACH 1 NORTH	2800	2141
04-06-83	MORDS	BLKRK REACH 1 NORTH	1420	1086
04-06-83	MORDS	BLKRK REACH 1 NORTH	1500	1147
TOTALS FOR BLKRK REACH 1 NORTH			17340	13258
03-21-83	MORDS	BLKRK REACH 3 SOUTH	1300	994
03-22-83	MORDS	BLKRK REACH 3 SOUTH	1300	994
03-22-83	MORDS	BLKRK REACH 3 SOUTH	2800	2141
03-23-83	MORDS	BLKRK REACH 3 SOUTH	3000	2294
03-24-83	MORDS	BLKRK REACH 3 SOUTH	2800	2141
03-25-83	MORDS	BLKRK REACH 3 SOUTH	3000	2294
03-26-83	MORDS	BLKRK REACH 3 SOUTH	1100	841
03-26-83	MORDS	BLKRK REACH 3 SOUTH	1300	994
03-26-83	MORDS	BLKRK REACH 3 SOUTH	2700	2064
03-27-83	MORDS	BLKRK REACH 3 SOUTH	1500	1147
03-28-83	MORDS	BLKRK REACH 3 SOUTH	1300	994
03-28-83	MORDS	BLKRK REACH 3 SOUTH	3000	2294
03-29-83	MORDS	BLKRK REACH 3 SOUTH	2800	2141
03-30-83	MORDS	BLKRK REACH 3 SOUTH	1500	1147
03-30-83	MORDS	BLKRK REACH 3 SOUTH	2800	2141
TOTALS FOR BLKRK REACH 3 SOUTH			32200	24620
03-30-83	MORDS	NHAV UPPER	3700	2829
03-30-83	MORDS	NHAV UPPER	3701	2830
04-01-83	MORDS	NHAV UPPER	3700	2829
04-01-83	MORDS	NHAV UPPER	3701	2830
04-02-83	MORDS	NHAV UPPER	3700	2829
04-02-83	MORDS	NHAV UPPER	3701	2830
04-02-83	MORDS	NHAV UPPER	3702	2831
04-02-83	MORDS	NHAV UPPER	3703	2831
04-02-83	MORDS	NHAV UPPER	3704	2832
04-02-83	MORDS	NHAV UPPER	3705	2833

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

-- DISPOSED AT : : 3 MORDS ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
04-02-83	MORDS	NHAV UPPER	3706	2834
04-03-83	MORDS	NHAV UPPER	3700	2829
04-03-83	MORDS	NHAV UPPER	3701	2830
04-03-83	MORDS	NHAV UPPER	3702	2831
04-04-83	MORDS	NHAV UPPER	3698	2827
04-04-83	MORDS	NHAV UPPER	3699	2828
04-04-83	MORDS	NHAV UPPER	3700	2829
04-04-83	MORDS	NHAV UPPER	3701	2830
04-04-83	MORDS	NHAV UPPER	3702	2831
04-05-83	MORDS	NHAV UPPER	3700	2829
04-05-83	MORDS	NHAV UPPER	3701	2830
04-05-83	MORDS	NHAV UPPER	3702	2831
04-05-83	MORDS	NHAV UPPER	3703	2831
04-06-83	MORDS	NHAV UPPER	3699	2828
04-06-83	MORDS	NHAV UPPER	3700	2829
04-06-83	MORDS	NHAV UPPER	3701	2830
04-07-83	MORDS	NHAV UPPER	3500	2676
04-07-83	MORDS	NHAV UPPER	3699	2828
04-07-83	MORDS	NHAV UPPER	3700	2829
04-07-83	MORDS	NHAV UPPER	3701	2830
04-08-83	MORDS	NHAV UPPER	3699	2828
04-08-83	MORDS	NHAV UPPER	3700	2829
04-08-83	MORDS	NHAV UPPER	3701	2830
04-08-83	MORDS	NHAV UPPER	3702	2831
04-08-83	MORDS	NHAV UPPER	3703	2831
04-09-83	MORDS	NHAV UPPER	3699	2828
04-09-83	MORDS	NHAV UPPER	3700	2829
04-09-83	MORDS	NHAV UPPER	3701	2830
04-09-83	MORDS	NHAV UPPER	3702	2831
04-10-83	MORDS	NHAV UPPER	3699	2828
04-10-83	MORDS	NHAV UPPER	3700	2829
04-11-83	MORDS	NHAV UPPER	3700	2829
04-11-83	MORDS	NHAV UPPER	3701	2830
04-12-83	MORDS	NHAV UPPER	3700	2829
04-13-83	MORDS	NHAV UPPER	3500	2676
04-13-83	MORDS	NHAV UPPER	3700	2829
04-13-83	MORDS	NHAV UPPER	3701	2830
04-13-83	MORDS	NHAV UPPER	3702	2831
04-14-83	MORDS	NHAV UPPER	3500	2676
04-14-83	MORDS	NHAV UPPER	3501	2677
04-15-83	MORDS	NHAV UPPER	3700	2829
04-17-83	MORDS	NHAV UPPER	3500	2676
04-22-83	MORDS	NHAV UPPER	3698	2827
04-22-83	MORDS	NHAV UPPER	3700	2829

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

-- DISPOSED AT : : 3 MQRDS ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
04-22-83	MQRDS	NHAV UPPER	3702	2831
04-22-83	MQRDS	NHAV UPPER	3703	2831
04-23-83	MQRDS	NHAV UPPER	3699	2828
04-23-83	MQRDS	NHAV UPPER	3700	2829
04-23-83	MQRDS	NHAV UPPER	3701	2830
04-24-83	MQRDS	NHAV UPPER	3700	2829
04-24-83	MQRDS	NHAV UPPER	3701	2830
04-25-83	MQRDS	NHAV UPPER	3698	2827
04-25-83	MQRDS	NHAV UPPER	3699	2828
04-25-83	MQRDS	NHAV UPPER	3700	2829
04-26-83	MQRDS	NHAV UPPER	3704	2832
04-26-83	MQRDS	NHAV UPPER	3705	2833
04-27-83	MQRDS	NHAV UPPER	3700	2829
04-27-83	MQRDS	NHAV UPPER	3701	2830
04-30-83	MQRDS	NHAV UPPER	3699	2828
04-30-83	MQRDS	NHAV UPPER	3700	2829
04-30-83	MQRDS	NHAV UPPER	3701	2830
05-01-83	MQRDS	NHAV UPPER	3700	2829
05-01-83	MQRDS	NHAV UPPER	3701	2830
05-02-83	MQRDS	NHAV UPPER	3699	2828
05-02-83	MQRDS	NHAV UPPER	3700	2829
05-02-83	MQRDS	NHAV UPPER	3701	2830
05-02-83	MQRDS	NHAV UPPER	3702	2831
05-03-83	MQRDS	NHAV UPPER	3699	2828
05-03-83	MQRDS	NHAV UPPER	3700	2829
05-03-83	MQRDS	NHAV UPPER	3701	2830
05-03-83	MQRDS	NHAV UPPER	3702	2831
05-04-83	MQRDS	NHAV UPPER	3700	2829
05-06-83	MQRDS	NHAV UPPER	3700	2829
05-06-83	MQRDS	NHAV UPPER	3701	2830
05-06-83	MQRDS	NHAV UPPER	3702	2831
05-07-83	MQRDS	NHAV UPPER	3700	2829
05-07-83	MQRDS	NHAV UPPER	3701	2830
05-07-83	MQRDS	NHAV UPPER	3702	2831
05-07-83	MQRDS	NHAV UPPER	3703	2831
05-08-83	MQRDS	NHAV UPPER	3699	2828
05-08-83	MQRDS	NHAV UPPER	3700	2829
05-08-83	MQRDS	NHAV UPPER	3701	2830
05-09-83	MQRDS	NHAV UPPER	3699	2828
05-09-83	MQRDS	NHAV UPPER	3701	2830
05-09-83	MQRDS	NHAV UPPER	3702	2831
05-09-83	MQRDS	NHAV UPPER	3703	2831
05-10-83	MQRDS	NHAV UPPER	3699	2828
05-10-83	MQRDS	NHAV UPPER	3700	2829

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

-- DISPOSED AT : : 3 MORDS ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
05-10-83	MORDS	NHAV UPPER	3701	2830
05-11-83	MORDS	NHAV UPPER	3698	2827
05-11-83	MORDS	NHAV UPPER	3699	2828
05-11-83	MORDS	NHAV UPPER	3700	2829
05-11-83	MORDS	NHAV UPPER	3701	2830
05-12-83	MORDS	NHAV UPPER	3700	2829
05-12-83	MORDS	NHAV UPPER	3701	2830
05-13-83	MORDS	NHAV UPPER	3698	2827
05-13-83	MORDS	NHAV UPPER	3699	2828
05-13-83	MORDS	NHAV UPPER	3700	2829
05-13-83	MORDS	NHAV UPPER	3701	2830
05-13-83	MORDS	NHAV UPPER	3702	2831
05-14-83	MORDS	NHAV UPPER	3699	2828
05-14-83	MORDS	NHAV UPPER	3700	2829
05-14-83	MORDS	NHAV UPPER	3701	2830
05-15-83	MORDS	NHAV UPPER	3699	2828
05-15-83	MORDS	NHAV UPPER	3700	2829
05-15-83	MORDS	NHAV UPPER	3701	2830
05-16-83	MORDS	NHAV UPPER	3698	2827
05-16-83	MORDS	NHAV UPPER	3699	2828
05-16-83	MORDS	NHAV UPPER	3700	2829
05-16-83	MORDS	NHAV UPPER	3701	2830
05-17-83	MORDS	NHAV UPPER	3699	2828
05-17-83	MORDS	NHAV UPPER	3700	2829
05-17-83	MORDS	NHAV UPPER	3701	2830
T O T A L S FOR NHAV UPPER			454170	347252
03-10-83	MORDS	UNKNOWN BLKRK	2700	2064
03-11-83	MORDS	UNKNOWN BLKRK	1150	879
03-11-83	MORDS	UNKNOWN BLKRK	2700	2064
03-14-83	MORDS	UNKNOWN BLKRK	1850	1415
03-15-83	MORDS	UNKNOWN BLKRK	1000	765
03-15-83	MORDS	UNKNOWN BLKRK	2800	2141
03-19-83	MORDS	UNKNOWN BLKRK	1133	866
03-20-83	MORDS	UNKNOWN BLKRK	1100	841
03-20-83	MORDS	UNKNOWN BLKRK	2800	2141
03-31-83	MORDS	UNKNOWN BLKRK	3000	2294
04-17-83	MORDS	UNKNOWN BLKRK	1350	1032
04-17-83	MORDS	UNKNOWN BLKRK	1500	1147
04-17-83	MORDS	UNKNOWN BLKRK	2940	2248
05-19-83	MORDS	UNKNOWN BLKRK	1200	918

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

- - DISPOSED AT : : 3 MQRDS - - - -

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
05-19-83	MQRDS	UNKNOWN BLKRK	1925	1472
- - - - - - T O T A L S FOR UNKNOWN BLKRK				
			29148	22286
03-31-83	MQRDS	UNKNOWN NHAV	3600	2753
03-31-83	MQRDS	UNKNOWN NHAV	3700	2829
03-31-83	MQRDS	UNKNOWN NHAV	3701	2830
03-31-83	MQRDS	UNKNOWN NHAV	3702	2831
- - - - - - T O T A L S FOR UNKNOWN NHAV				
			14703	11242
- - - - - - T O T A L S FOR MQRDS				
			547561	418658

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

-- DISPOSED AT : : 4 FVP ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
04-06-83	FVP	BLKRK REACH 1 NORTH	1350	1032
04-06-83	FVP	BLKRK REACH 1 NORTH	1360	1040
04-06-83	FVP	BLKRK REACH 1 NORTH	2790	2133
T O T A L S FOR BLKRK REACH 1 NORTH			5500	4205
04-27-83	FVP	BLKRK REACH 1 SOUTH	1450	1109
04-27-83	FVP	BLKRK REACH 1 SOUTH	2800	2141
T O T A L S FOR BLKRK REACH 1 SOUTH			4250	3249
04-28-83	FVP	BLKRK REACH 2 NORTH	1388	1061
04-28-83	FVP	BLKRK REACH 2 NORTH	1800	1376
04-28-83	FVP	BLKRK REACH 2 NORTH	2200	1682
04-28-83	FVP	BLKRK REACH 2 NORTH	2350	1797
05-07-83	FVP	BLKRK REACH 2 NORTH	1300	994
05-07-83	FVP	BLKRK REACH 2 NORTH	1900	1453
05-07-83	FVP	BLKRK REACH 2 NORTH	2940	2248
05-08-83	FVP	BLKRK REACH 2 NORTH	1200	918
05-08-83	FVP	BLKRK REACH 2 NORTH	1900	1453
05-08-83	FVP	BLKRK REACH 2 NORTH	1901	1454
T O T A L S FOR BLKRK REACH 2 NORTH			18879	14435
04-26-83	FVP	BLKRK REACH 2 SOUTH	945	723
04-29-83	FVP	BLKRK REACH 2 SOUTH	1350	1032
04-29-83	FVP	BLKRK REACH 2 SOUTH	1450	1109
04-29-83	FVP	BLKRK REACH 2 SOUTH	1750	1338
04-29-83	FVP	BLKRK REACH 2 SOUTH	2580	1973
04-30-83	FVP	BLKRK REACH 2 SOUTH	2700	2064
05-06-83	FVP	BLKRK REACH 2 SOUTH	1550	1185
05-06-83	FVP	BLKRK REACH 2 SOUTH	1750	1338
05-09-83	FVP	BLKRK REACH 2 SOUTH	800	612
05-09-83	FVP	BLKRK REACH 2 SOUTH	2790	2133
05-10-83	FVP	BLKRK REACH 2 SOUTH	628	480
05-10-83	FVP	BLKRK REACH 2 SOUTH	1350	1032
05-11-83	FVP	BLKRK REACH 2 SOUTH	750	573

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

--- DISPOSED AT : : 4 FVP ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
------ T O T A L S FOR BLKRK REACH 2 SOUTH				
			20393	15592
05-01-83	FVP	BLKRK REACH 3 NORTH	1330	1017
05-01-83	FVP	BLKRK REACH 3 NORTH	1350	1032
05-01-83	FVP	BLKRK REACH 3 NORTH	2760	2110
05-05-83	FVP	BLKRK REACH 3 NORTH	1600	1223
05-05-83	FVP	BLKRK REACH 3 NORTH	2600	1988
05-12-83	FVP	BLKRK REACH 3 NORTH	1450	1109
05-13-83	FVP	BLKRK REACH 3 NORTH	1750	1338
------ T O T A L S FOR BLKRK REACH 3 NORTH				
			12840	9817
05-02-83	FVP	UNKNOWN BLKRK	2460	1881
05-04-83	FVP	UNKNOWN BLKRK	850	650
05-04-83	FVP	UNKNOWN BLKRK	1750	1338
05-14-83	FVP	UNKNOWN BLKRK	1625	1242
05-14-83	FVP	UNKNOWN BLKRK	1750	1338
------ T O T A L S FOR UNKNOWN BLKRK				
			8435	6449
------ T O T A L S FOR FVP				
			70297	53748

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

-- DISPOSED AT : : 5 SP ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
05-29-83	SP	UNKNOWN	540	413
------ T O T A L S FOR UNKNOWN				
			540	413
03-30-83	SP	NHAV UPPER	3700	2829
04-06-83	SP	NHAV UPPER	3700	2829
04-14-83	SP	NHAV UPPER	3700	2829
04-14-83	SP	NHAV UPPER	3701	2830
04-15-83	SP	NHAV UPPER	3501	2677
04-15-83	SP	NHAV UPPER	3700	2829
04-15-83	SP	NHAV UPPER	3701	2830
04-16-83	SP	NHAV UPPER	3500	2676
04-17-83	SP	NHAV UPPER	3699	2828
04-17-83	SP	NHAV UPPER	3700	2829
04-17-83	SP	NHAV UPPER	3701	2830
04-19-83	SP	NHAV UPPER	3500	2676
04-20-83	SP	NHAV UPPER	3700	2829
04-20-83	SP	NHAV UPPER	3701	2830
04-21-83	SP	NHAV UPPER	3699	2828
04-21-83	SP	NHAV UPPER	3700	2829
04-21-83	SP	NHAV UPPER	3701	2830
04-21-83	SP	NHAV UPPER	3702	2831
04-21-83	SP	NHAV UPPER	3703	2831
04-23-83	SP	NHAV UPPER	3699	2828
04-23-83	SP	NHAV UPPER	3701	2830
04-24-83	SP	NHAV UPPER	3700	2829
04-27-83	SP	NHAV UPPER	3900	2982
04-28-83	SP	NHAV UPPER	3700	2829
04-29-83	SP	NHAV UPPER	3700	2829
05-01-83	SP	NHAV UPPER	3700	2829
05-02-83	SP	NHAV UPPER	3700	2829
05-03-83	SP	NHAV UPPER	3700	2829
05-04-83	SP	NHAV UPPER	3700	2829
05-04-83	SP	NHAV UPPER	3701	2830
05-07-83	SP	NHAV UPPER	3700	2829
05-10-83	SP	NHAV UPPER	3700	2829
05-11-83	SP	NHAV UPPER	3700	2829
05-12-83	SP	NHAV UPPER	3700	2829
05-12-83	SP	NHAV UPPER	3701	2830
05-12-83	SP	NHAV UPPER	3702	2831
05-13-83	SP	NHAV UPPER	3700	2829
05-16-83	SP	NHAV UPPER	3700	2829

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

-- DISPOSED AT : : 5 SP ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
05-17-83	SP	NHAV UPPER	3700	2829
05-23-83	SP	NHAV UPPER	3700	2829
05-26-83	SP	NHAV UPPER	3699	2828
05-26-83	SP	NHAV UPPER	3701	2830
05-27-83	SP	NHAV UPPER	3699	2828
05-27-83	SP	NHAV UPPER	3701	2830
05-28-83	SP	NHAV UPPER	3699	2828
05-28-83	SP	NHAV UPPER	3700	2829
05-28-83	SP	NHAV UPPER	3701	2830
05-29-83	SP	NHAV UPPER	3699	2828
05-29-83	SP	NHAV UPPER	3700	2829
05-29-83	SP	NHAV UPPER	3701	2830
		T O T A L S FOR NHAV UPPER	184613	141153
06-02-83	SP	BRIDGEPORT	900	688
06-04-83	SP	BRIDGEPORT	1000	765
		T O T A L S FOR BRIDGEPORT	1900	1453
05-20-83	SP	UNKNOWN BLKRK	2720	2080
05-22-83	SP	UNKNOWN BLKRK	1350	1032
05-22-83	SP	UNKNOWN BLKRK	2370	1812
05-25-83	SP	UNKNOWN BLKRK	1050	803
05-25-83	SP	UNKNOWN BLKRK	1125	860
05-25-83	SP	UNKNOWN BLKRK	1250	956
05-25-83	SP	UNKNOWN BLKRK	1400	1070
05-26-83	SP	UNKNOWN BLKRK	900	688
05-26-83	SP	UNKNOWN BLKRK	1500	1147
05-28-83	SP	UNKNOWN BLKRK	1100	841
05-28-83	SP	UNKNOWN BLKRK	1350	1032
		T O T A L S FOR UNKNOWN BLKRK	16115	12321
05-24-83	SP	UNKNOWN NHAV	3699	2828
05-24-83	SP	UNKNOWN NHAV	3701	2830
05-25-83	SP	UNKNOWN NHAV	3699	2828
05-25-83	SP	UNKNOWN NHAV	3701	2830

DISPOSAL AREA MONITORING SYSTEM (DAMOS)
DREDGE MATERIAL DISPOSAL RECORD
CENTRAL LONG ISLAND SOUND (CLIS) DISPOSAL AREA

--- DISPOSED AT : : 5 SP ----

DATE	DISPOSAL SITE	MATERIAL SOURCE	YARDS^3	METERS^3
06-04-83	SP	UNKNOWN NHAV	3200	2447
06-06-83	SP	UNKNOWN NHAV	3700	2829
06-06-83	SP	UNKNOWN NHAV	3701	2830
------ T O T A L S FOR UNKNOWN NHAV			25401	19421
------ T O T A L S FOR SP			228569	174761
---------------- G R A N D T O T A L S			1110181	848829

APPENDIX II

SUMMARY OF MONITORING OPERATIONS AT THE CENTRAL LONG ISLAND SOUND DISPOSAL SITE DURING 1982 - 1983

SCHEDULE OF EVENTS

DATE	STATION	SURVEY OPERATIONS
12/7/82	FVP	Baseline Diver Operations Baseline Sediment Grabs Baseline Underwater TV
12/8/82	FVP	Baseline Sediment Grabs Baseline Underwater TV
12/10/82	FVP	Baseline Bathymetric Survey
12/11/82	MQR	Pre-Disposal Condition Survey
12/13/82	MQR	Sediment Samples
1/26/83	MQR	REMOTS Survey
2/1/83	Black Rock	Harbor Sampling Program
2/28/83	FVP	Deploy Mussel Cages
3/1/83	FVP	Deploy Diver Transect Lines
3/4/83	FVP	Sediment Sampling Diver Observations
	MQR	Deploy Disposal Buoy
3/15/83	FVP	Deploy Disposal Buoy REMOTS Survey
4/6/83	CS#1	Baseline Sediment Samples Baseline REMOTS Survey Deploy BDMD Deploy MQR Buoy at CS#1
	CS#2	Baseline REMOTS Survey
4/7/83	CS#1	Baseline Bathymetric and Side Scan Surveys
	CS#2	Baseline Bathymetric and Side Scan Surveys
4/8/83	CS#1	Deploy Diver Transect Lines
	CS#2	Deploy BDMD
4/18/83	CS#2	Deploy CS#1 Buoy at CS#2 Deploy Diver Transect Lines

SCHEDULE OF EVENTS (CONT.)

DATE	STATION	SURVEY OPERATIONS
4/22/83	FVP	Mussel Operations
4/23/83	FVP	Water and Sediment Samples
4/26/83	FVP	Side Scan Survey
4/27/83	CS#1	Diver Observations
	CS#2	Diver Observations
		Density Probe Measurements
4/28/83	FVP	Bathymetric and Side Scan Survey
	CS#1	Bathymetric and Side Scan Survey
	CS#2	Bathymetric and Side Scan Survey
5/5/83	FVP	Bathymetric and Side Scan Survey
		Sediment Sampling
		Diver Observations
5/6/83	MQR	Bathymetric Survey
	CS#1	Diver Observations at BDMD
	FVP	Diver Observations
5/10/83	CS#2	Sediment Samples
	MQR	Sediment Samples
	NHAV	Density Probe Measurements
5/11/83	CS#2	Bathymetric and Side Scan Survey
	CS#1	Diving Operations at BDMD
5/18/83	CS#2	Diver Observations
	FVP	Diver Observations
5/19/83	FVP	Bathymetric and Side Scan Survey
5/23/83	FVP	Water and Sediment Samples
5/24/83	FVP	REMOTS Survey
		Diver Observations
5/25/83	CS#2	Density Probe Measurements
	FVP	Diver Observations
		Remove Disposal Buoy
5/26/83	FVP	REMOTS Survey

SCHEDULE OF EVENTS (CONT.)

DATE	STATION	SURVEY OPERATIONS
5/31/83	Black Rock	Fluff Layer Study
6/1/83	Black Rock	Post-Dredging Sediment Sample
6/2/83	FVP	Sediment Sampling
		Mussel Sampling
6/3/83	FVP	Side Scan Survey
		Sediment Sampling
		Diver Observations
6/7/83	FVP	Mussel Sampling
		Diver Observations
6/8/83	CS#1	Bathymetric Survey
	CS#2	Bathymetric Survey
6/9/83	MQR	Bathymetric Survey
		Sediment Samples
	CS#2	Sediment Samples
6/10/83	CS#2	Side Scan Survey
	CS#1	Side Scan Survey
		Sediment Sampling
	FVP	Side Scan Survey
6/13/83	FVP	REMOTS Survey
	CS#1	REMOTS Survey
	CS#2	REMOTS Survey
6/14/83	CS#2	Additional REMOTS Stations
	CS#1	Additional REMOTS Stations
6/16/83	FVP	Sediment Sampling
	CS#1	Density Probe Measurements
		Diver Observations at BDMD
	CS#2	Diver Observations at BDMD
6/17/83	FVP	Density Probe Measurements
	CS#1	Density Probe Measurements
		Diving Operations
	CS#2	Density Probe Measurements
		Diving Operations

SCHEDULE OF EVENTS (CONT.)

DATE	STATION	SURVEY OPERATIONS
6/21/83	FVP	Bathymetric Survey
	CS#2	Density Probe Measurements
	CS#1	Density Probe Measurements
7/13/83	FVP	Sediment Sampling
7/14/83	FVP	Sediment Sampling
	CS#1	Diver Observations
7/15/83	FVP	Diver Observations
7/19/83	FVP	REMOTS Survey
7/20/83	FVP	Density Probe Measurements
	CS#1	Density Probe Measurements
		Bathymetric Survey
7/21/83	FVP	Sediment Sampling
7/26/83	FVP	Sediment Sampling
7/27/83	FVP	Side Scan Survey
	CS#1	Diving Operations
7/28/83	FVP	Gravity Core Sampling
	CS#1	Gravity Core Sampling
	CS#2	Gravity Core Sampling
8/2/83	CLIS	Comprehensive Bathymetric Survey
8/3/83	CLIS	Comprehensive Bathymetric Survey
8/22/83	FVP	Sediment Sampling
8/23/83	CS#2	Bathymetric Survey
	CS#1	Bathymetric Survey
8/26/83	FVP	Bathymetric Survey
8/29/83	FVP	REMOTS Survey
8/30/83	CS#1	REMOTS Survey
	CS#2	REMOTS Survey
	FVP	Diving Operations

SCHEDULE OF EVENTS (CONT.)

DATE	STATIONS	SURVEY OPERATIONS
8/31/83	FVP	Diving Observations
9/8/83	CLIS	Side Scan Survey
10/18/83	CS#1	Density Probe Measurements
	CS#2	Density Probe Measurements