Monitoring Surveys at the
Field Verification Program (FVP)
Disposal Site in 1985

Disposal Area Monitoring System DAMOS

Contribution 52
August 1988

US Army Corps
of Engineers
New England Division

MONITORING SURVEYS AT THE FIELD VERIFICATION PROGRAM (FVP) DISPOSAL SITE IN 1985

CONTRIBUTION #52

AUGUST 1988

Report No.
SAIC- 87/7512&C62

Contract No. DACW33-86-D-0004
Work Order No. 6

Submitted to:

Regulatory Branch
New England Division
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254-9149

Submitted by:

J.H.Parker
E.C. Revelas
Science Applications International Corporation
Admiral's Gate, 221 Third Street
Newport, RI 02840
(401) 847-4210

US Army Corps of Engineers
New England Division

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (CONT.)

1.0 INTRODUCTION

Through the Disposal Area Monitoring System program (DAMOS), the New England Division of the Corps of Engineers has been supporting a joint EPA-COE project at the Central Long Island Sound (CLIS) disposal site since March 1982. A description of the Field Verification Program (FVP), the baseline surveys and subsequent disposal site selection have been presented in DAMOS Contribution #23 (SAIC, 1982). To briefly summarize the conclusions of that report, the FVP site (Figure 1-1) at the northeast corner of the CLIS open water disposal area (41°9.39'N, 72°51.75'W) is characterized by a flat, gently sloping topography with the typical central Long Island Sound mud bottom. The disposal site was considered to be very homogenous and typical of natural sediments in the region (i.e., silt-clay with subordinate modes of fine to coarse sand). These conclusions were reached based on sediment chemistry, diver observations and the analysis of REMOTS® photographs. Suspended sediment measurements indicated that the potential impact on the FVP site of other proposed disposal operations in the southwest corner of the CLIS disposal area would be negligible.

Previous DAMOS operations have occurred in three phases: the pre-disposal surveys, the disposal operation itself, and the immediate post-disposal surveys that were conducted through September 1983. The study included bathymetry and side scan sonar measurements, diver observations, suspended sediment measurements, REMOTS® profiling, sediment chemistry, sediment density probe measurements and visual observations of cores, and were reported in DAMOS Contribution #46, Volume II, Section III (SAIC, 1984).

This report describes the monitoring studies conducted since December 1984 utilizing bathymetric surveys conducted on 21 March and 22 October 1985, and REMOTS® photography conducted on 22 March, 26 June, and 23 October 1985.

2.0 BATHYMETRY

A survey grid (Figure 2-1) was established consisting of 33 transects, 800 meters long oriented in an east-west direction and spaced 25 meters apart. All navigation control for surveys and REMOTS® photography was provided by the SAIC Navigation and Data Acquisition System, a computerized control unit interfaced to a Del Norte 540 microwave positioning system. The SAIC 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 comparison of the contoured bathymetric charts of the FVP site in March 1985 (Figure 2-2) and October 1985 (Figure 2-3) indicates slightly greater depths (approximately 10 cm) occurring on the mound during the October survey. Vertical depth profiles for both surveys for the lanes where the mound is located reveal the lack of any significant changes in bathymetry (Figure 2-4). Because an increase in depth of 10 cm is less than the level detectable by the system when the combined errors in depth recording and navigation are considered, it is difficult to conclude that an actual increase in depth has occurred. Due to the small area covered by the mound, the volume of material involved in a 10 cm change in depth would also be quite small. The depths at the mound compare well with those found during the September 1984 survey where the minimum water depth at the peak of the mound was also approximately 18.3 meters.

An analysis of the volume difference between the surveys conducted in March and October indicated no significant change in volume. Over the entire 800 x 800 meter area of the survey, the accuracy for detecting changes in volume within the 95% confidence limit (given the total accumulated errors due to fathometer accuracy, vessel speed, vertical motion due to wave interference, survey lane spacing, etc.) was ± 9852 m^3. The volume difference was calculated to be -5244 m^3, well within the non-significant range. An additional calculation was made of the volume difference between a smaller survey conducted during the CLIS survey in August 1985 and the October 1985 survey. Because of the reduced area of the survey, the accuracy for detecting volume change within the 95% confidence limits was ± 4462 m^3. The calculated change in volume was 50 m^3, again indicating no significant gain or loss of volume between August and October.

3.0 REMOTS® Sediment-Profile Photography

The purpose of the October 1985 FVP REMOTS® survey was to monitor potential change in the sediment characteristics of the dredged material mound, to document the process of benthic infaunal successional recovery of the FVP disposal site, and to monitor changes in the ambient fauna and sediments adjacent to the FVP site. This survey was conducted 29 months after the disposal operation, and one month after Hurricane Gloria. Hurricane Gloria moved through central Long Island Sound on 27 September, 1985 with maximum wind speeds of 145-161 km/h (90-100 mph). This extremely high energy event was capable of disturbing the seafloor throughout the CLIS disposal area. The REMOTS® data obtained in October were examined with this consideration.

The results of the October survey were also compared with the June and March FVP REMOTS® data to provide an assessment of changes in benthic conditions at the FVP site during 1985.

3.1 Methods

On 23 October, twenty-one stations were occupied at the FVP disposal site, corresponding to those which have been monitored since the June 1984 FVP REMOTS® survey. The twelve central stations (Figure 3-1) were considered to be located on the main dredged material mound or mound flanks based on REMOTS® and bathymetric surveys conducted immediately after the FVP disposal operation. The remaining nine stations located off the dredged material mound were classified as edge and ambient stations. Three REMOTS® images were obtained at each FVP station, and twenty REMOTS® images were obtained from the CLIS reference site (CLIS-REF).

Methods of REMOTS® image interpretation have been described in DAMOS Contribution #23 (SAIC, 1982) and are not repeated here.

3.2 Results

The distribution and thickness (cm) of apparent dredged material layers at the FVP site (Figure 3-1) were comparable to those observed in previous surveys.

All stations showed an apparent grain-size major mode of >4 phi (silt-clay), with subordinate fractions of 3 and 2 phi (very fine to fine sand). A layer of fine sand (3-2 phi) continued to be observed at station CTR (Figure 3-2). This sand layer has been observed since the January 1984 REMOTS® survey and has been interpreted as being a lag deposit resulting from current washing of the mound apex. For the first time, sand and shell lag deposits were also evident at stations 150E and 100W, indicating more widespread current scouring of the central disposal mound area. This was apparently a result of Hurricane Gloria.

In June, approximately 80% of the FVP REMOTS® photos exhibited patches of reduced sediment and/or reduced mud clasts at or near the sediment-water interface. This material seemed to represent locally eroded Black Rock sediment which had recently been redistributed over the site as far as 1000E and 1000W. This material was not observed at CLIS-REF, and it had not been observed in previous FVP surveys. In the October survey, approximately 50% of the FVP images showed patches of reduced material at the interface (Figures 3-2 and 3-3). As in June, this material was distributed within the entire survey grid at the FVP site (Figure 3-1); moreover, reduced sediments were evident at the interface in two of the twenty CLIS-REF images

(Figure 3-4). The wide-spread distribution of reduced material suggests recent local erosion on a much broader scale, an apparent result of Hurricane Gloria.

The frequency distributions of boundary roughness values for the dredged material mound, edge and ambient stations, and the CLIS-REF site were similar for all three areas, with the major mode for small-scale topographic relief being 0.8 cm (Figure 3-5). Boundary roughness values have increased significantly in all three areas since the June survey (Mann-Whitney U-tests, $p < 0.05$; Figure 3-6). This represents the first change in small-scale topographic relief at the site since December 1984. Both seasonal changes in the rates of biogenic reworking and physically-induced surface erosional and depositional events can result in changes in boundary roughness. The boundary roughness observed in this survey appeared to be physically induced; again, it was apparently related to the influence of Hurricane Gloria. Many images revealed erosional features such as mud clasts and exposed worm tubes (Figure 3-7).

There were no remarkable spatial trends or patterns in the distribution of mean apparent RPD depths at the FVP site in October (Figure 3-8). The average RPD depth was 2.39 cm at mound stations, 1.95 cm at edge and ambient stations, and 2.04 cm at CLIS reference; the frequency distributions of RPD values for these three areas all have a major mode of 2 cm (Figure 3-9). The October RPD depths did not vary significantly among the mound, edge and ambient and CLIS reference stations. However, at all three areas RPD values showed a decrease from March to June and from June to October 1985 (Figure 3-10).

The decrease in RPD depths at the mound stations between June and October was not statistically significant; however, the mound station values were significantly shallower in June than in March (Mann-Whitney U-test, $p < 0.05$). Edge and ambient RPD depths have significantly decreased since June (Mann-Whitney U-tests, $p < 0.05$). Moreover, RPD depths at edge and ambient stations have decreased progressively throughout the past year (the March and June average RPD values equaled 4.33 and 2.90 cm, respectively). At CLIS-REF, RPD depths were also significantly less than in June (Mann-Whitney U-test, $p < 0.001$).

The atypically shallow RPD depths observed at both the reference and grid stations during the October survey were largely a result of the physical disturbance caused by Hurricane Gloria. Several REMOTS® photos revealed oxygenated surface sediment layers which appeared to be truncated (Figure 3-11). Scour by bottom currents probably resulted in erosion of surface sediment layers over large areas of the Sound, especially in shallower regions. Near-surface, biogenically reworked sediments are susceptible to erosion due to their low shear strength, increased porosity and high water content. In the center of the disposal area, this scouring resulted in some images lacking or exhibiting very shallow redox layers; highly reduced dredged material that was formerly underlying aerated sediment was evident at the sediment-water interface (Figure 3-12). In adjacent ambient regions, evidence of significant surface erosion was indicated by the presence of methane. Methanogenesis occurs at depth in the sedimentary column whenever pore-water sulphate is exhausted. In central Long Island Sound, methane production usually occurs below the REMOTS® prism penetration depth (15-20 cm; Needell et al., 1987); methane has not been observed previously at the FVP site. In this survey, station 1000E showed a relatively shallow RPD and sedimentary methane pockets (Figure 3-13). These features suggest that a notable amount (5-10 cm) of surface sediments had recently been removed.

While Hurricane Gloria represented a major physical disturbance to the entire central Long Island Sound region prior to the October survey, the trend of decreasing RPD depths observed at FVP from March to June suggests that the disposal site had been subject to disturbance factors in the months preceding the storm. The relatively shallow RPD depths exhibited in June at both mound as well as edge and ambient stations were attributed at the time to localized erosion and redistribution of the dredged material mound. It is also possible that this area was beginning to experience adverse effects related to the development of near-bottom hypoxia. At CLIS-REF, the extensive DAMOS sampling which occurred over the two years prior to the October survey represents another disturbance factor which must be considered. Past sampling at this station by U.S. EPA personnel from the Narragansett Environmental Research Laboratory (ERLN) involved the removal of relatively large volumes of sediment for chemical analyses and for collection of organisms for body burden analyses. The use of precision navigation for deployment of the various sampling devices means that a relatively small area of the bottom was subjected to intense disturbance at regular intervals. Because of this, it is difficult to determine unequivocally how much of the disturbance seen at the reference station in October was attributable solely to the effects of the hurricane and how much was attributable to the long-term disturbance from the FVP and DAMOS sampling efforts. The current DAMOS sampling procedure of using more than one reference area should alleviate this potential source of ambiguity when interpreting results from future surveys.

Twenty-eight percent of the mound station replicates exhibited Stage III assemblages; this compares with 35% of the edge and ambient replicates and 30% of the CLIS-REF replicates (Figure 3-14). The mound region exhibited relatively low abundances of Stage III seres throughout 1985, the highest level being 43% in March. Of edge and ambient replicates, 77% revealed Stage III infauna in March. This relative abundance decreased dramatically to 31% in June, and it remained at this low level in

August and October. This reversal in successional status could be related to both physical disturbance and surface erosion of the dredged material mound, as well as developing hypoxia in near-bottom waters throughout this region of the Sound. At CLIS-REF, the number of replicates that showed Stage III seres also decreased progressively throughout 1985 (March = 87%, June = 61%, August = 55%). In REMOTS® surveys prior to 1985, over 80% of the CLIS-REF replicates revealed Stage III seres. The most recent contributing factor to the "retrograde" status of CLIS-REF in October was Hurricane Gloria. However, by August (when CLIS-REF was surveyed during the CLIS disposal sites survey), the site already showed evidence of physical disturbance and retrograde infaunal succession. It is possible that in August this area was experiencing seasonal near-bottom hypoxia, a Sound-wide phenomenon. It again becomes impossible to determine the extent to which the retrograde status of the reference site in October can be attributed to either the hurricane, seasonal hypoxia or the long-term combined sampling effort of both DAMOS and the FVP investigations by ERLN.

The REMOTS® Organism-Sediment Indices (OSI) mapped at the various FVP stations and at the CLIS-REF station (Figure 3-15) represent the lowest observed since the first post-disposal FVP survey; this reflects both the extremely shallow RPD depths and the low-order successional status. While the frequency distributions of OSI values did not vary significantly between the three regions surveyed in October (Figure 3-16), there is a trend of decreasing OSI values during 1985 (Figure 3-17). Each area exhibited a broad range of OSI values indicative of the extreme patchiness in benthic conditions. This patchiness was evident in June at the mound and edge and ambient stations. At CLIS-REF, the patchiness in OSI values began to develop in June and was most notable in October.

Overall, the FVP site was significantly disturbed in 1985. This downturn in benthic conditions began subsequent to the March survey, but it was clearly evident by June. The September hurricane apparently enhanced the retrograde condition of the benthic system. However, it is unclear how much of the system disturbance measured by the various REMOTS® parameters (successional stage, RPD depth, OSI, and boundary roughness) is due solely to the storm. At CLIS-REF, the site was markedly disturbed by August, possibly as a result of near-bottom hypoxia and/or oversampling. The fact that some disturbance might be attributable to over-sampling at the traditional CLIS-REF station reinforces the new sampling protocol of using more than one reference area.

4.0 SUMMARY AND CONCLUSIONS

One month prior to the October REMOTS® survey, Hurricane Gloria moved through central Long Island Sound. This report has documented the effects of the hurricane on the FVP disposal site in October, and these results have been compared with the March and June 1985 FVP REMOTS® data to provide an assessment of long-term changes in benthic conditions.

Although the FVP site consisted predominately of silt-clay sediments, thin sand layers were evident at stations CTR, 150E and 100W. This material represents lag deposits which indicate current scouring of the central mound area. In addition, patches of reduced sediment were evident at or near the sediment-water interface in many of the REMOTS® images from both FVP and CLIS-REF. Small-scale topographic relief has also increased throughout the region for the first time since December 1984. All these features indicate recent seafloor erosion, an apparent result of Hurricane Gloria.

The apparent RPD depths observed in this survey were the lowest observed at FVP and CLIS-REF since the monitoring program began. Again, this is partially attributable to the effects of Hurricane Gloria; a number of images revealed truncated redox layers indicating that aerated surface layers had been removed by erosion. However, even prior to the Hurricane, RPD values in June were relatively shallow throughout the FVP site. This suggests that the region was experiencing disturbance factors during much of 1985. At the CLIS-REF station, it is proposed that one potential major disturbance factor was the intense FVP-DAMOS sampling program over the previous two years.

Low-order successional infauna dominated the FVP and CLIS-REF sites. The abundance of Stage III infauna at FVP has been relatively low throughout 1985. While the most recent contributing factor to this "retrograde" status was Hurricane Gloria, it is also possible that at certain times the area experienced near-bottom hypoxia as part of a Sound-wide phenomenon. At CLIS-REF, the progressive decrease in the number of high-order successional stages indicates that the area has changed relative to its historical status due to one or more of the disturbance factors discussed above.

Reflecting the shallow RPD depths and low-order successional status, the Organism-Sediment Indices observed at FVP and CLIS-REF in October 1985 were extremely low. By June, both the FVP site and CLIS-REF were exhibiting evidence of disturbance. This marked a reversal of a trend which started with the first post-disposal REMOTS® survey in May 1983 and continued through March 1985, during which time there appeared to be a convergence of benthic conditions between the FVP disposal site and CLIS-REF. Although the origins of this reversal are unclear, localized erosion of the disposal mound and the development of seasonal near-bottom hypoxia are possible explanations. Subsequently, the strong disturbance effects of Hurricane Gloria have enhanced the retrograde conditions at the

FVP site as well as at CLIS-REF.

While the hurricane caused physical disturbance of the seafloor in central Long Island Sound, it did not result in changes in the height of the disposal mound at FVP. The region-wide erosion and redistribution of sediment was apparently restricted to near-surface layers (i.e., $\leq$ 10 cm); a significant loss of volume was not apparent from the results of the bathymetric surveys at the FVP disposal mound. Due to the accumulation of errors associated with the fathometer, as well as with wave conditions during the survey and the ability to re-navigate the same survey lanes, the 5-10 cm layer which was eroded is not consistently detectable by acoustic profiling. The vertical profiles over the mound indicated an increase in depth of approximately 10 cm only in the lane crossing the mound apex. The volume difference calculation between the March and October surveys indicated an insignificant loss of volume over the entire site. An additional calculation between August and October also detected no loss of volume. Based on both the REMOTS® and bathymetric surveys, it must be concluded that the disturbance of the seafloor due to the hurricane involved only small volumes of material at the FVP mound.

REFERENCES

Needell, S. W., Lewis, A., and M. Coleman. 1987. Map Showing the Quaternary Geology of East Central Long Island Sound. USGS Misc. Field Study Map, MF-1939 (B).

SAIC, 1982. Site Selection and Baseline Surveys of the Black Rock Disposal Site for the Field Verification Program (FVP). DAMOS Contribution #23.

SAIC, 1984. DAMOS Disposal Area Monitoring System, Summary of Program Results 1981-1984. DAMOS Contribution #46 (SAIC Report #SAIC-84/7521&C46).

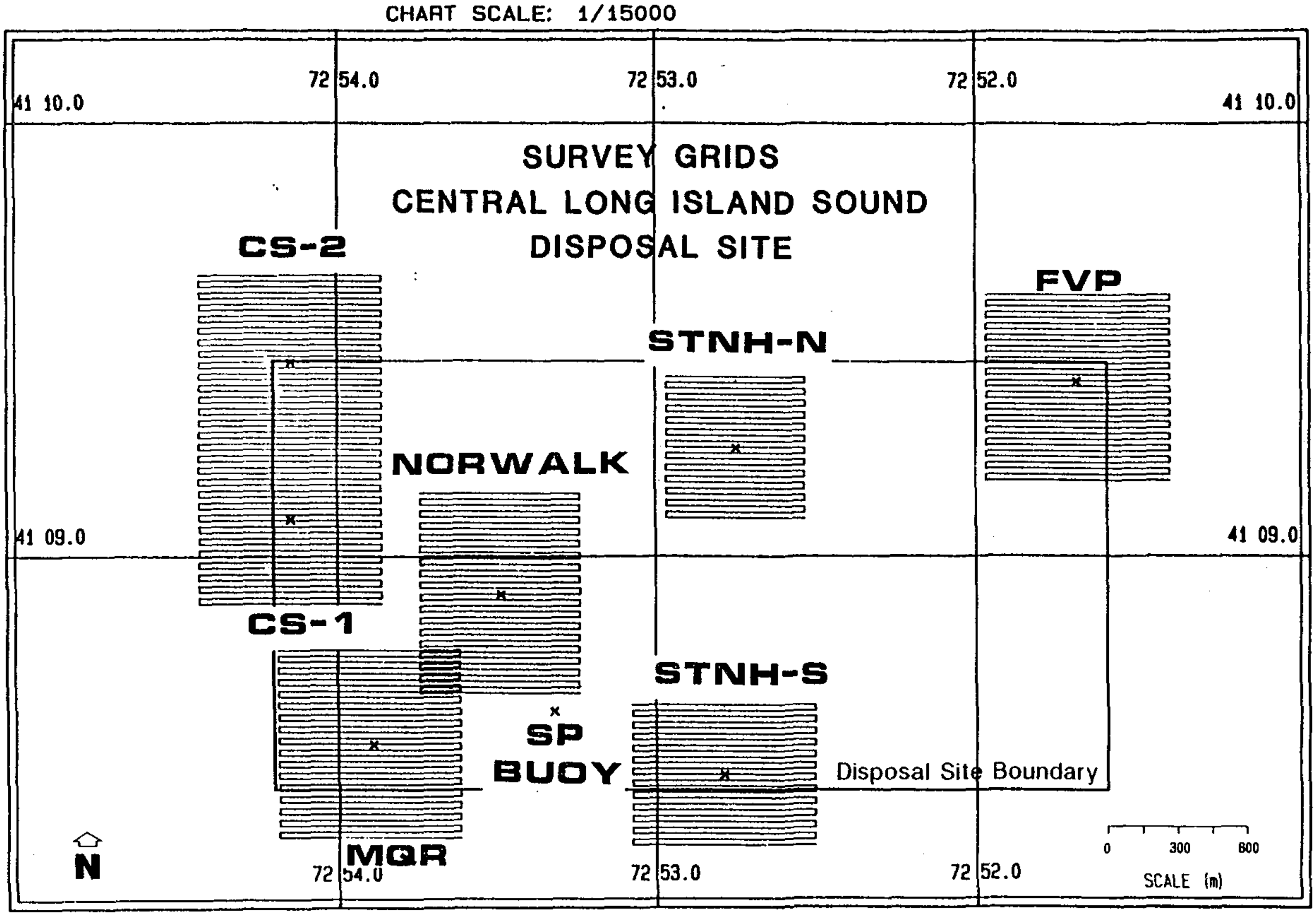

Figure 1-1. Surveys grids at Central Long Island Sound Disposal Site.

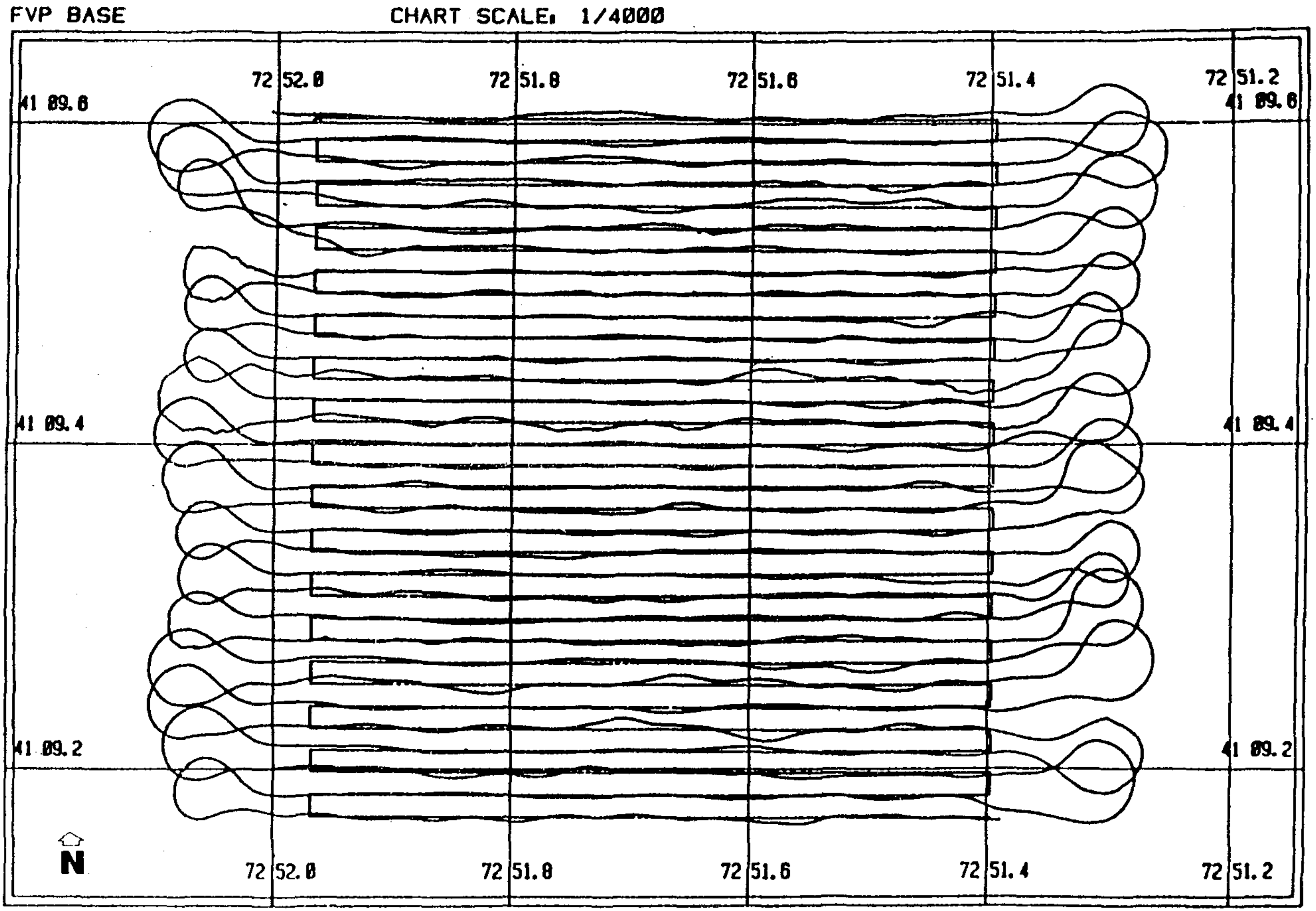

Figure 2-1. FVP bathymetric survey grid with a depiction of the actual ship track.

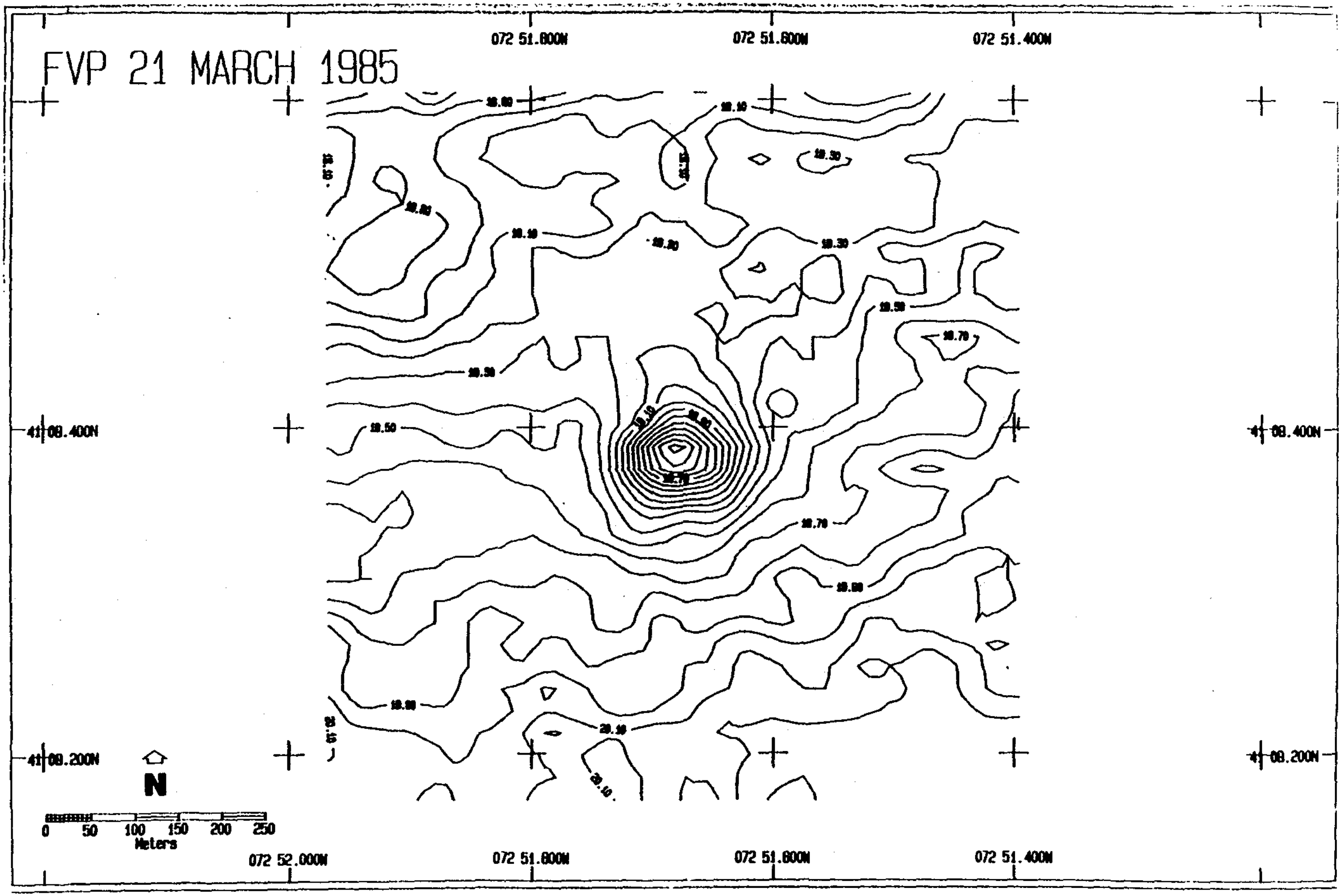

Figure 2-2. Contour bathymetric chart at FVP, 21 March 1985. Depth in meters.

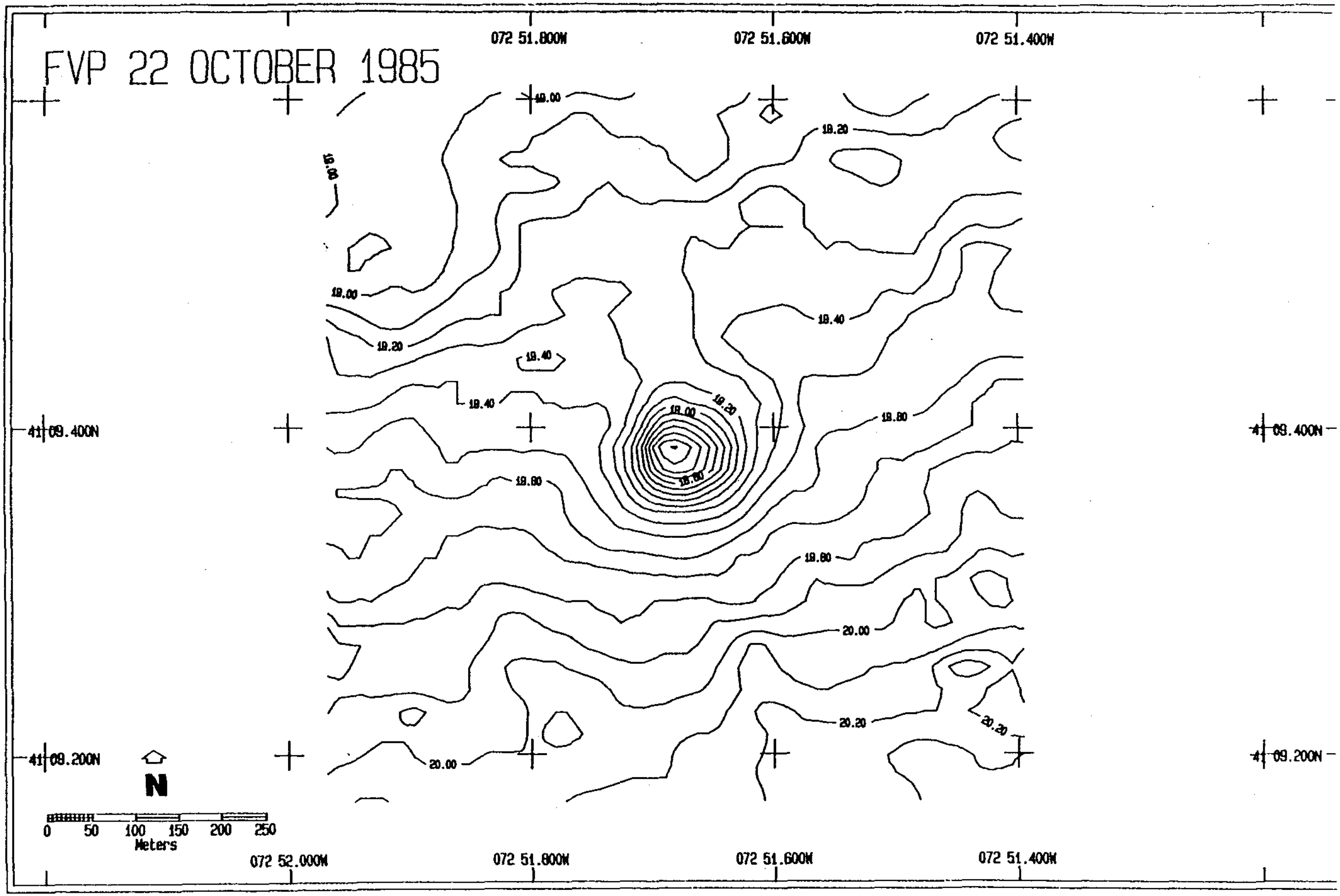

Figure 2-3. Contour bathymetric chart at FVP, 22 October 1985. Depth in meters.

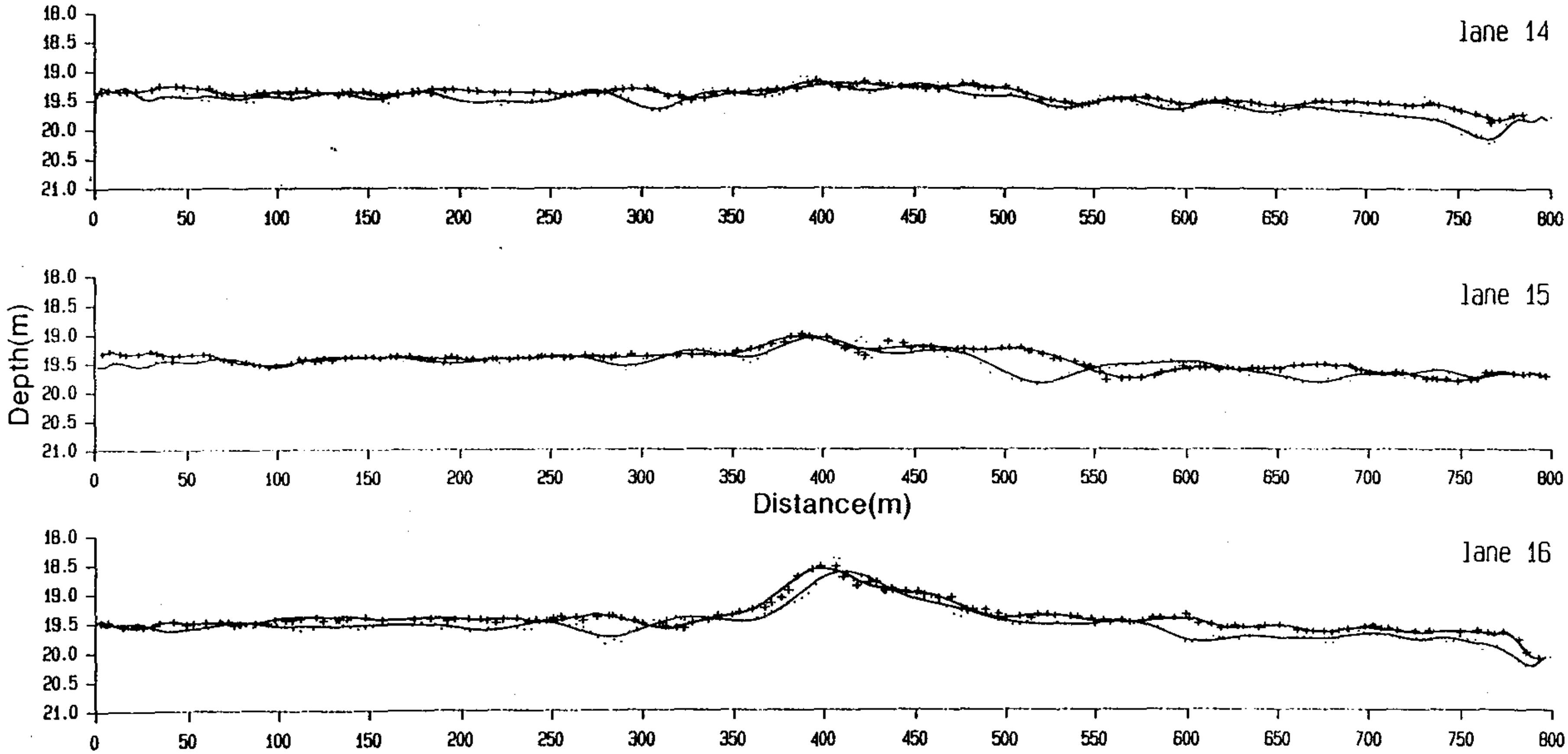

Figure 2-4. Vertical depth profiles for 21 March (•) and 22 October (+) 1985 bathymetric surveys.

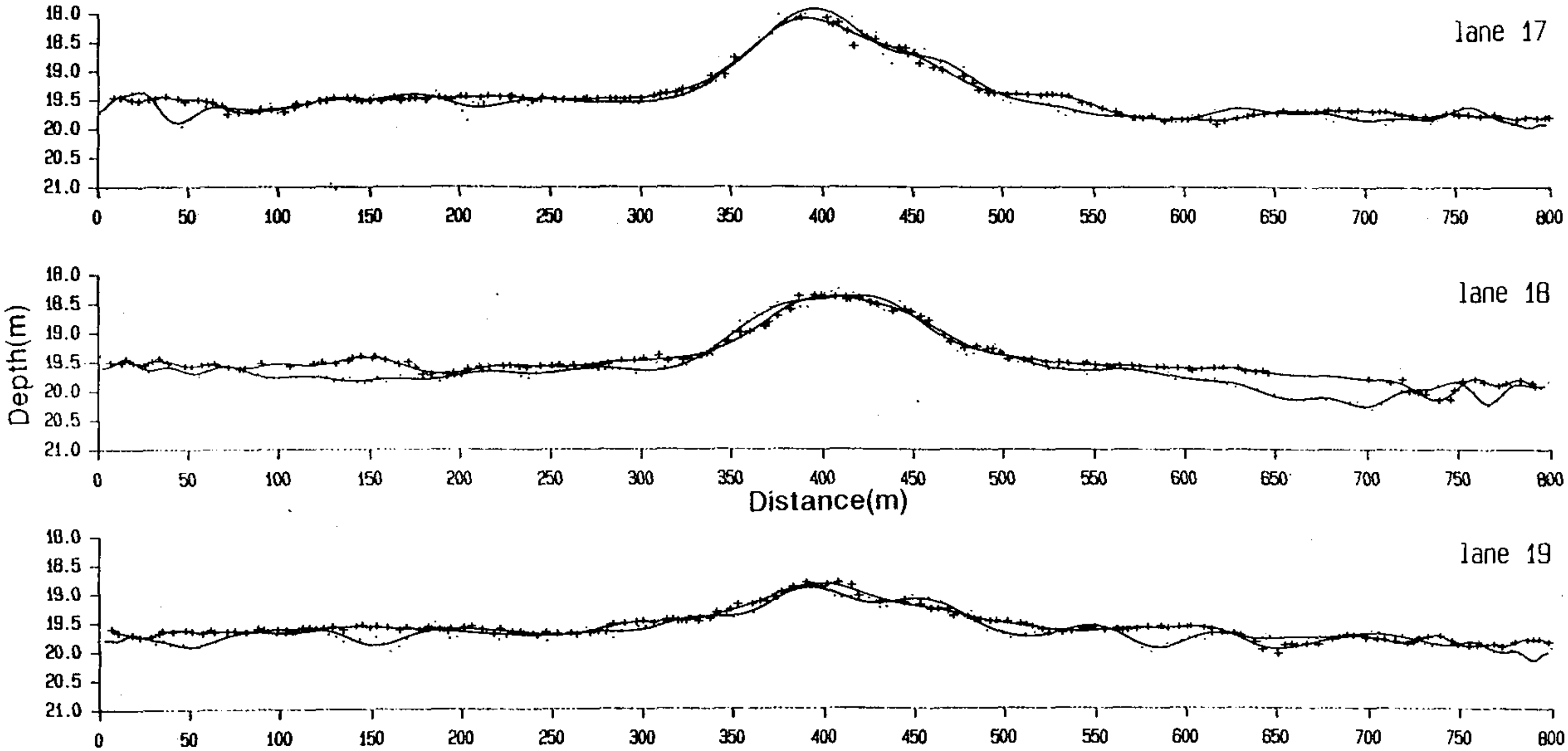

Figure 2-4. Continued.

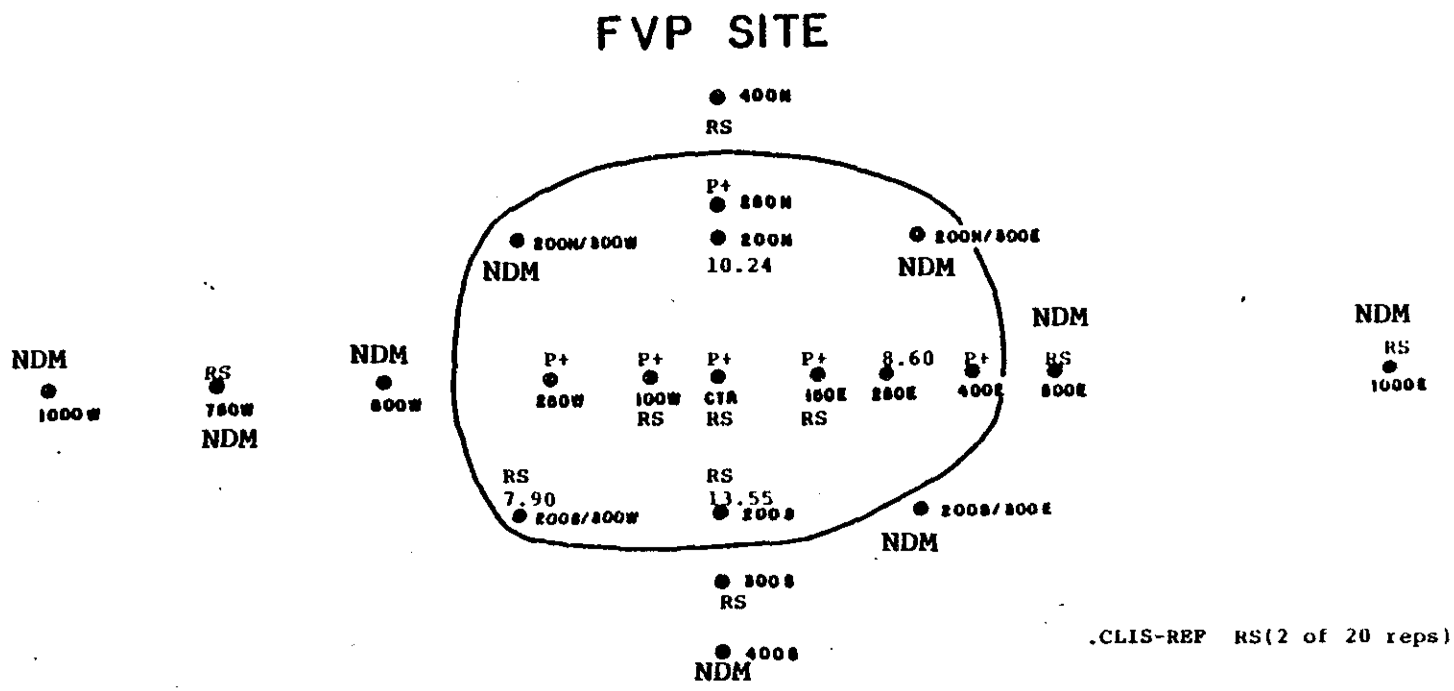

Figure 3-1. The apparent distribution and thickness (cm) of dredged material, averaged by station, at the FVP site in October 1985. The solid line encloses the twelve stations considered to be on the main dredged material mound or flanks as defined by REMOTES® and bathymetric surveys conducted immediately after the disposal operation in May of 1983.

P+ = dredged material thicker than REMOTS® window penetration

NDM = no detectable dredged material

RS = stations which show reduced sediment near the sediment-water interface

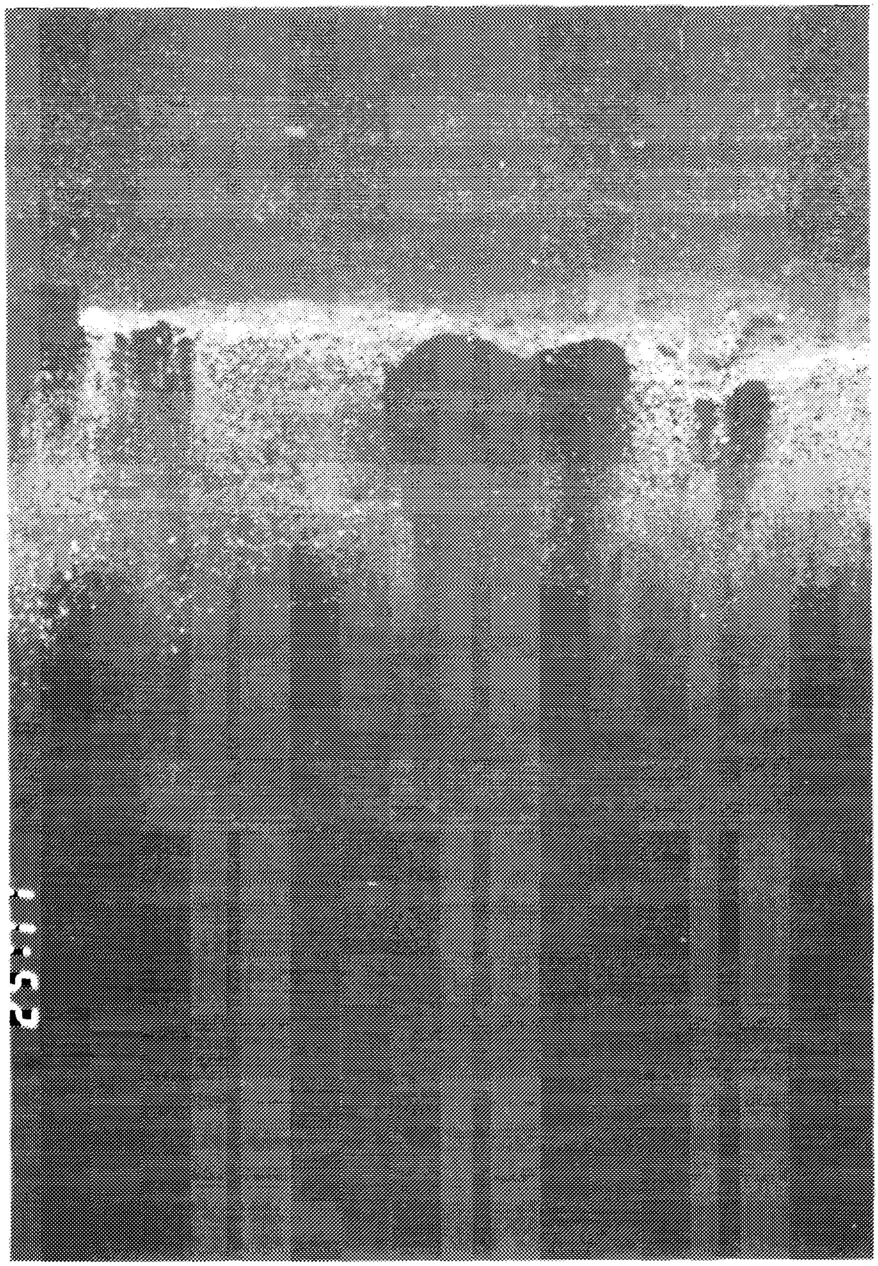

Figure 3-2. A REMOTS image from station CTR showing a fine sand layer overlying silt-clay. Also, note the patch of highly reduced sediment at the sediment-water interface. Scale = 1X.

Figure 3-3. A REMOTS image from station 200S showing patches of reduced sediment at the sediment-water interface. Also, note the mudclasts in the background at left edge of image. Scale ≈ 1X.

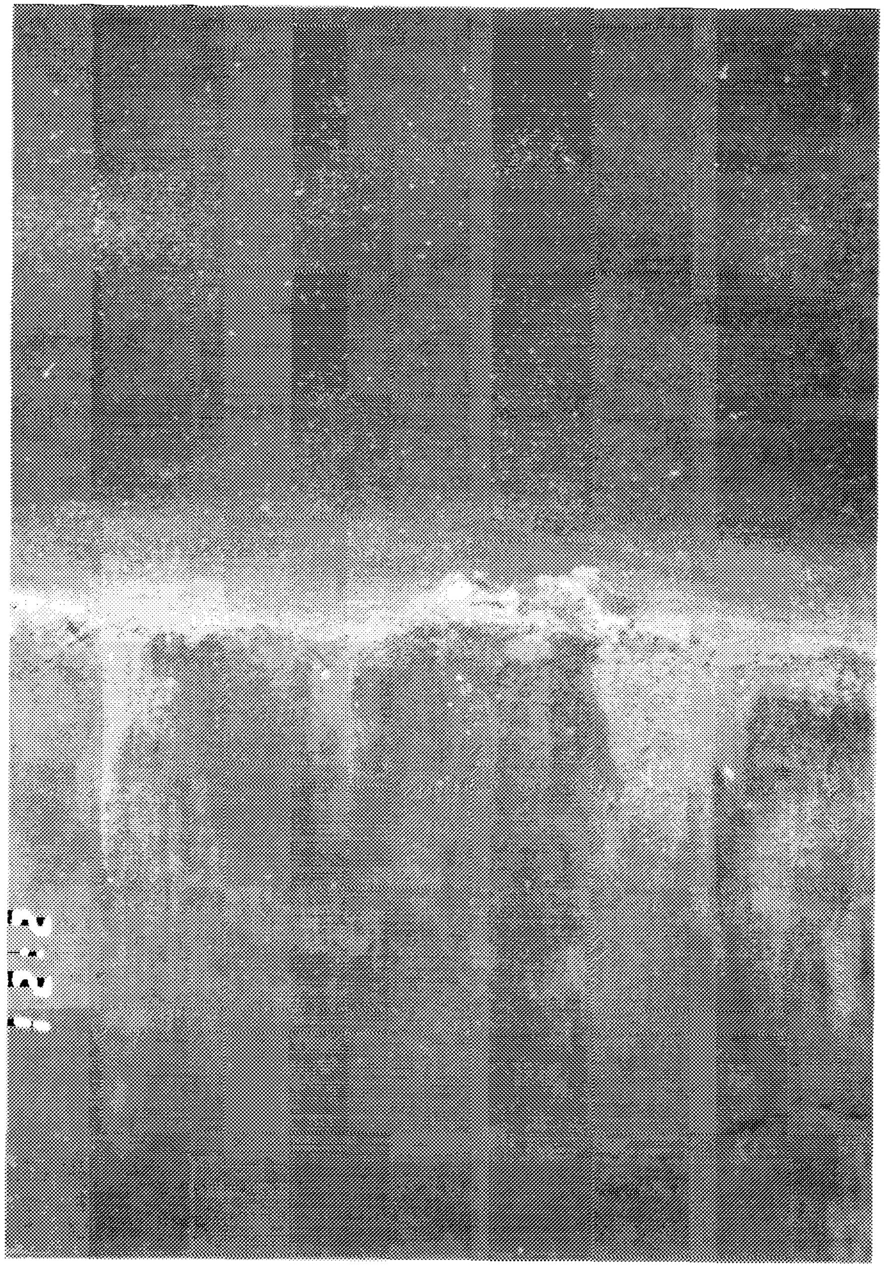

Figure 3-4. A REMOTS image from the CLIS-reference site showing reduced sediments near the interface. Mudclasts are also evident in the center of the image. Scale = 1X.

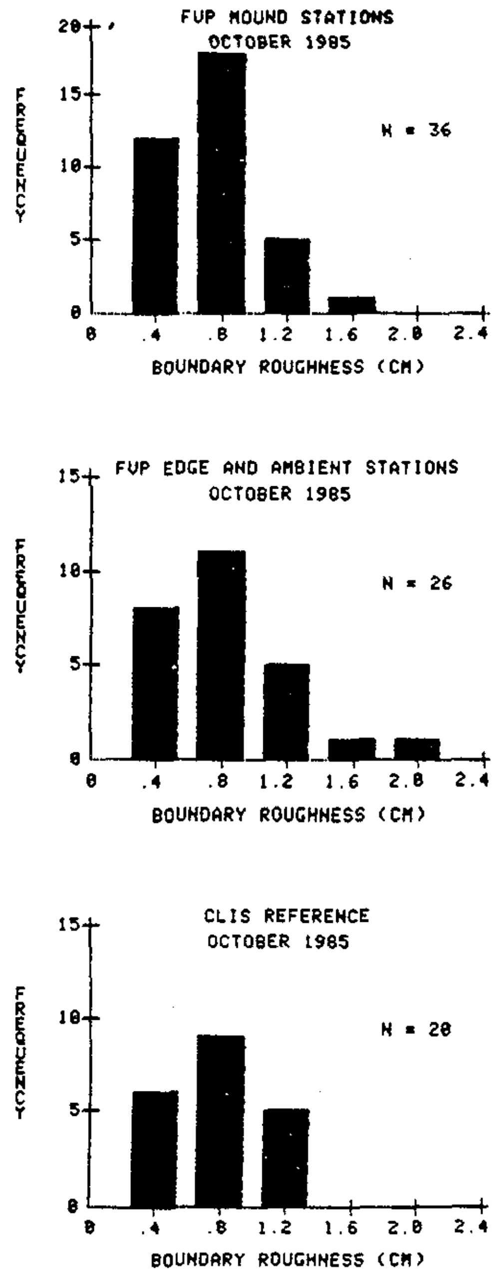

Figure 3-5. The frequency distributions of boundary roughness values for dredged material mound stations, edge and ambient stations, and the CLIS-REF site.

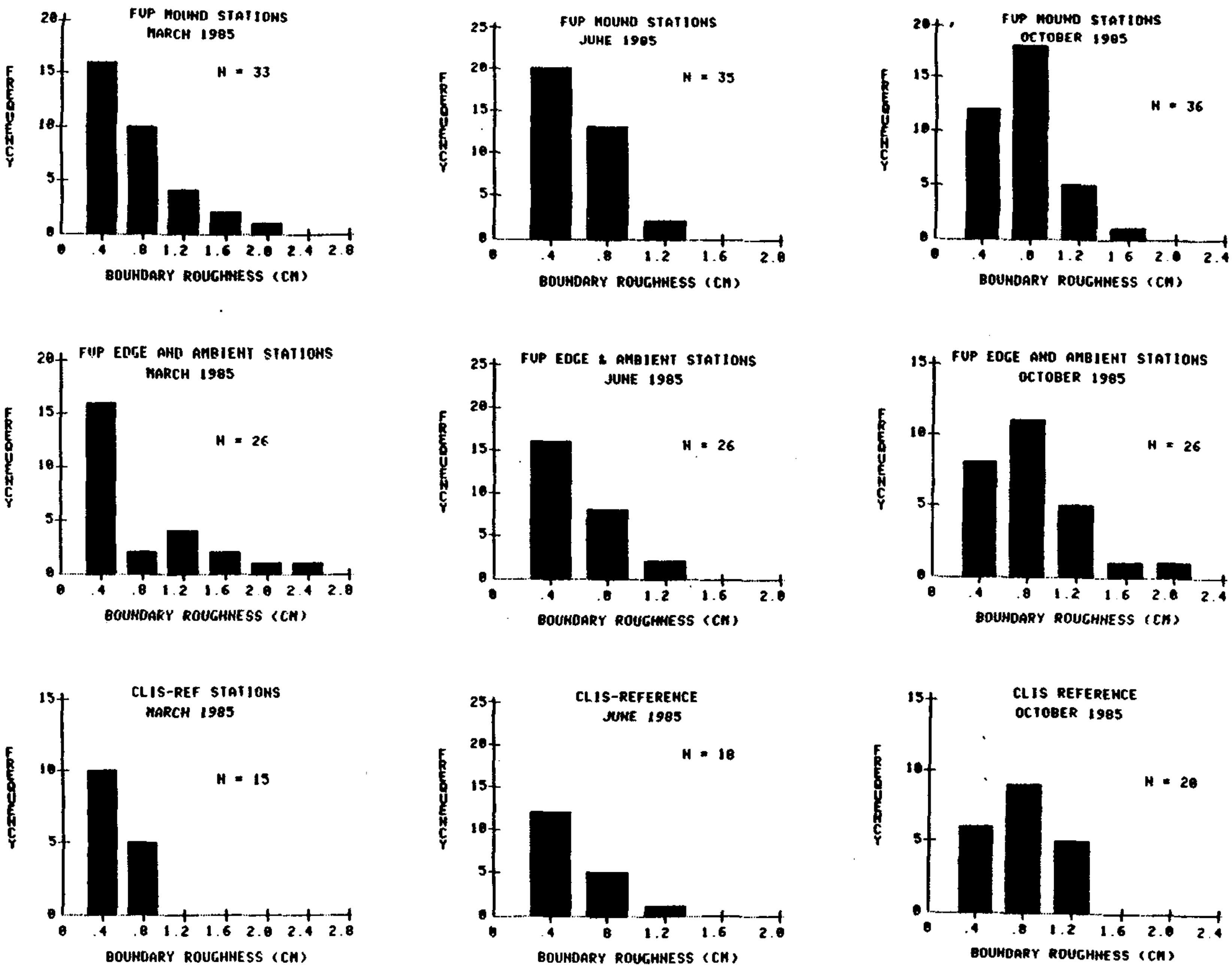

Figure 3-6. Boundary Roughness values at the FVP and CLIS-REF sites in 1985.

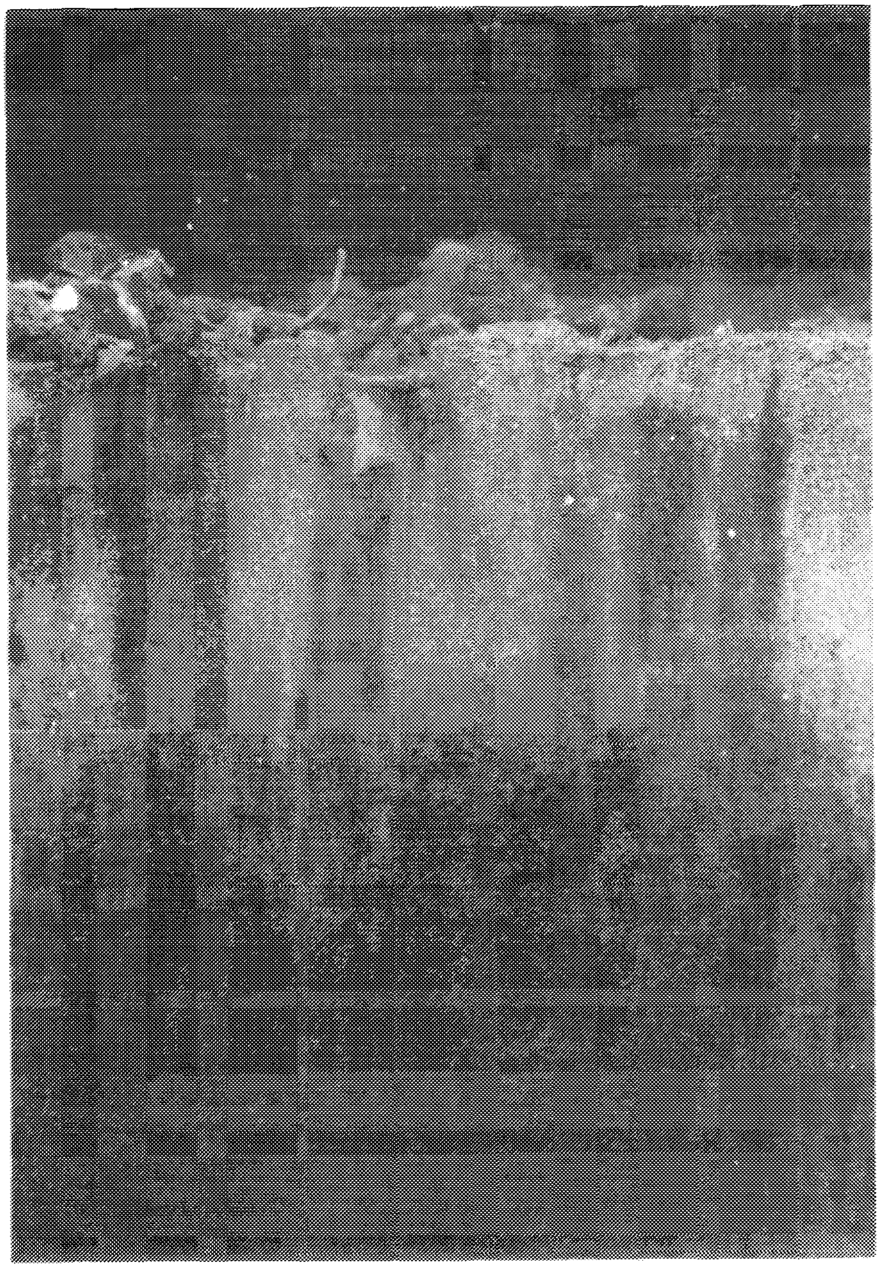

Figure 3-7. A REMOTS image from station 200S/300E showing evidence of erosion. Reduced and oxidized mud clasts litter the surface and an exposed worm tube is present in the center of the image. Scale = 1X.

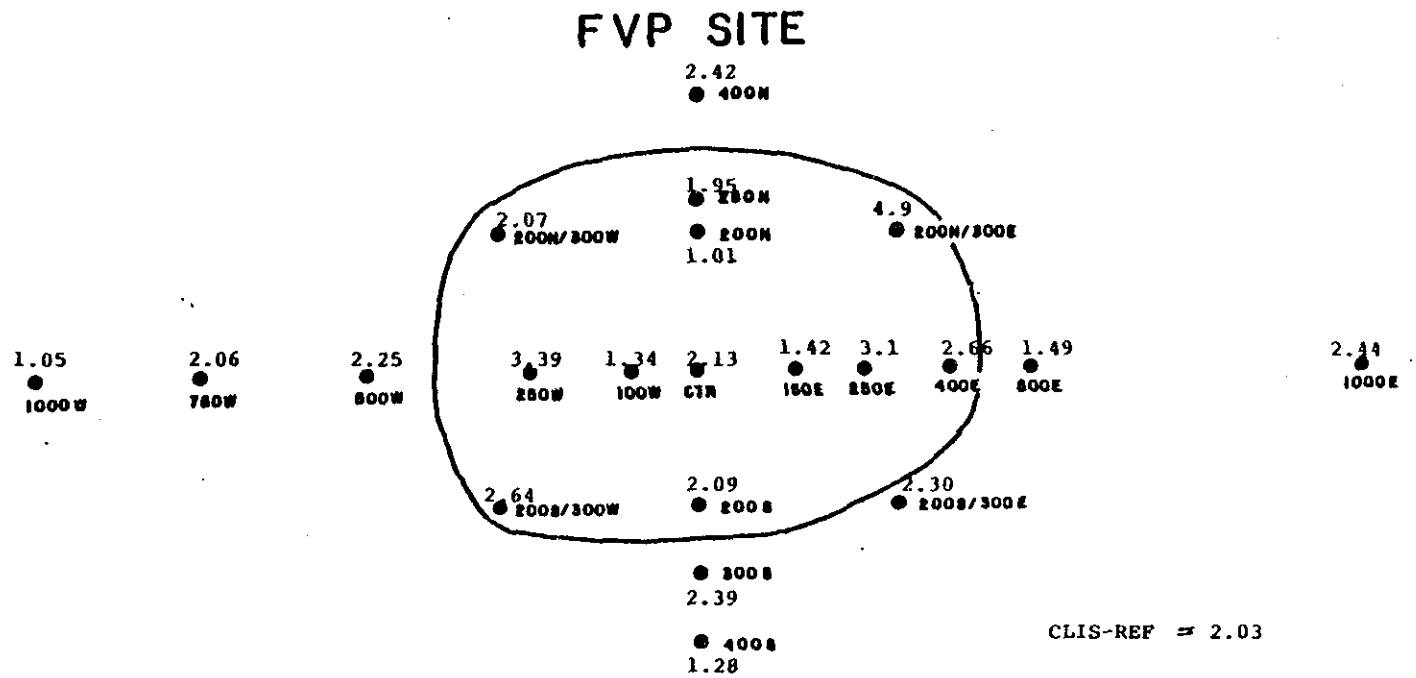

Figure 3-8. The distribution of mean apparent RPD depths (cm) at each REMOTS® station.

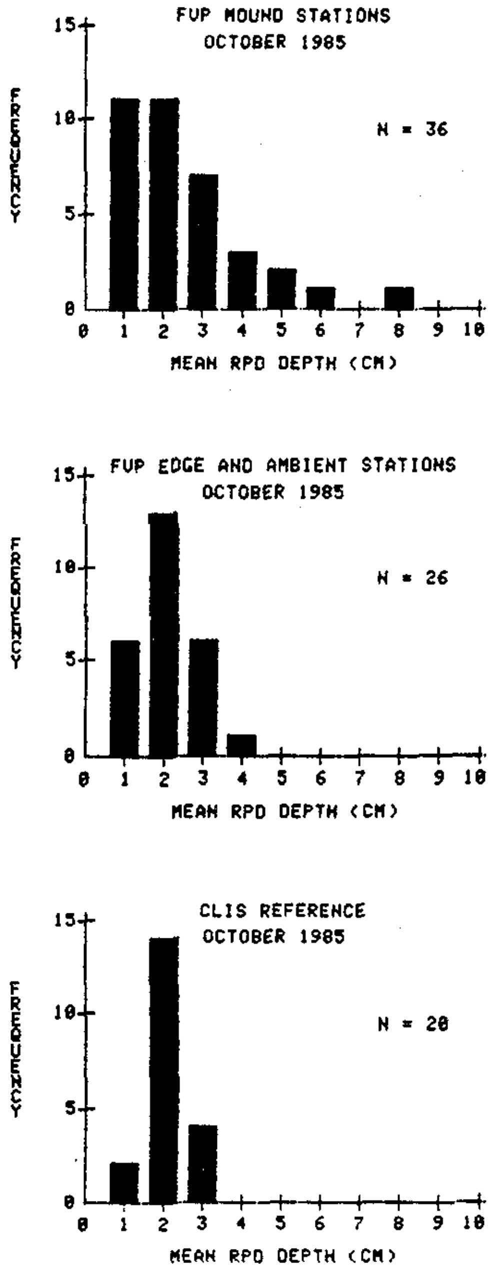

Figure 3-9. The frequency distributions of mean apparent RPD depths for mound, edge and ambient, and CLIS-REF stations.

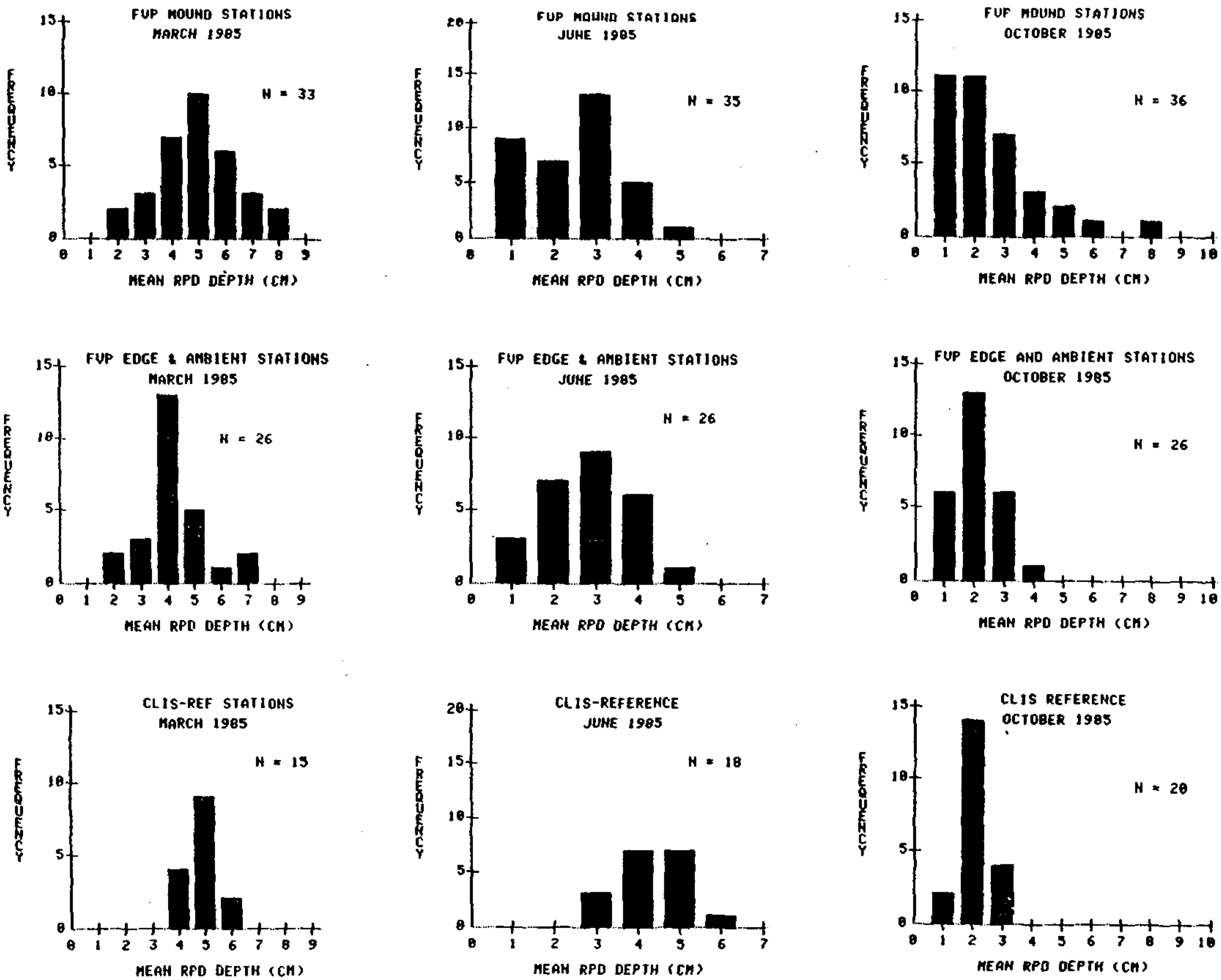

Figure 3-10. RPD values at the FVP and CLIS-REF sites in 1985.

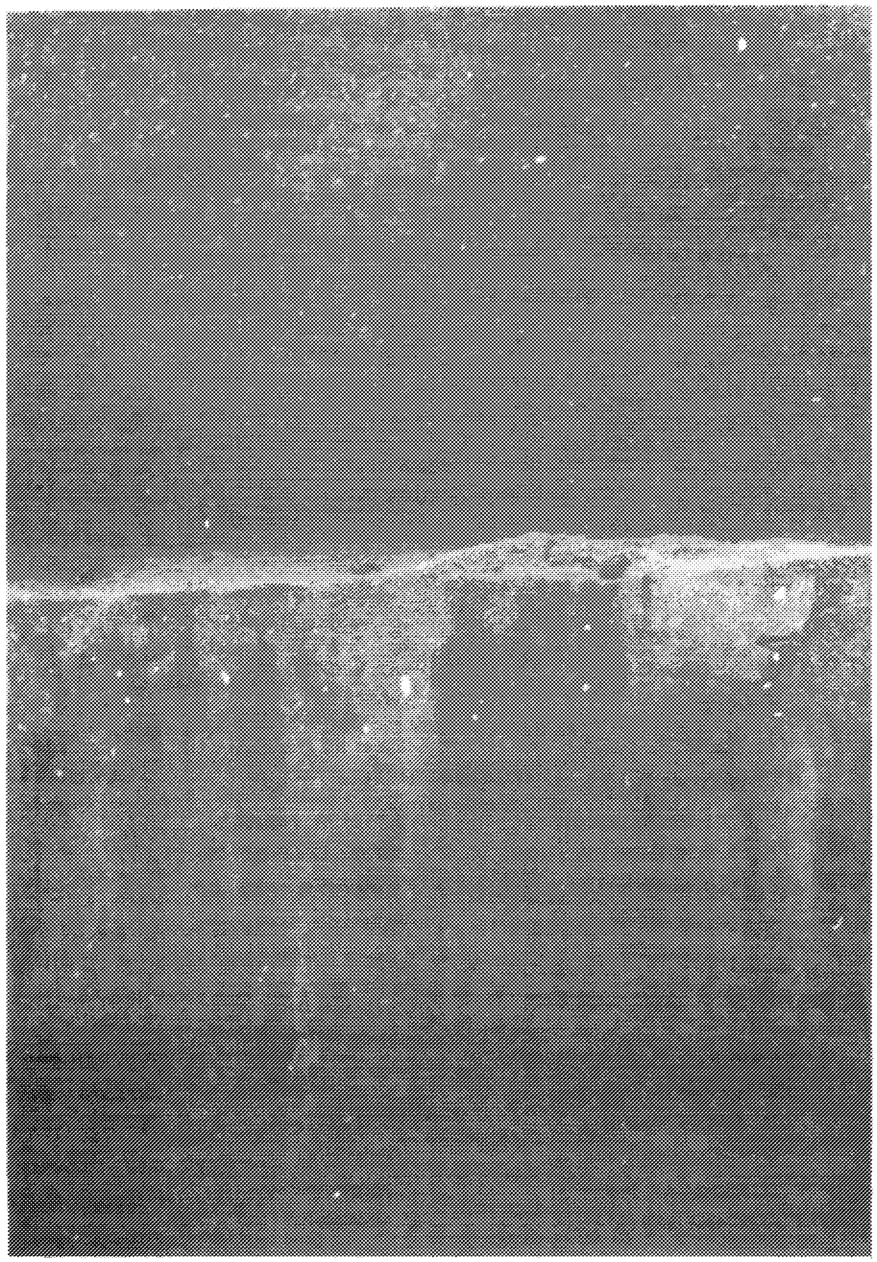

Figure 3-11. A REMOTS image from station 500E showing shallow RPD which appears to be truncated. This suggests that overlying oxidized material has recently been removed by bottom scour. Scale = 1X.

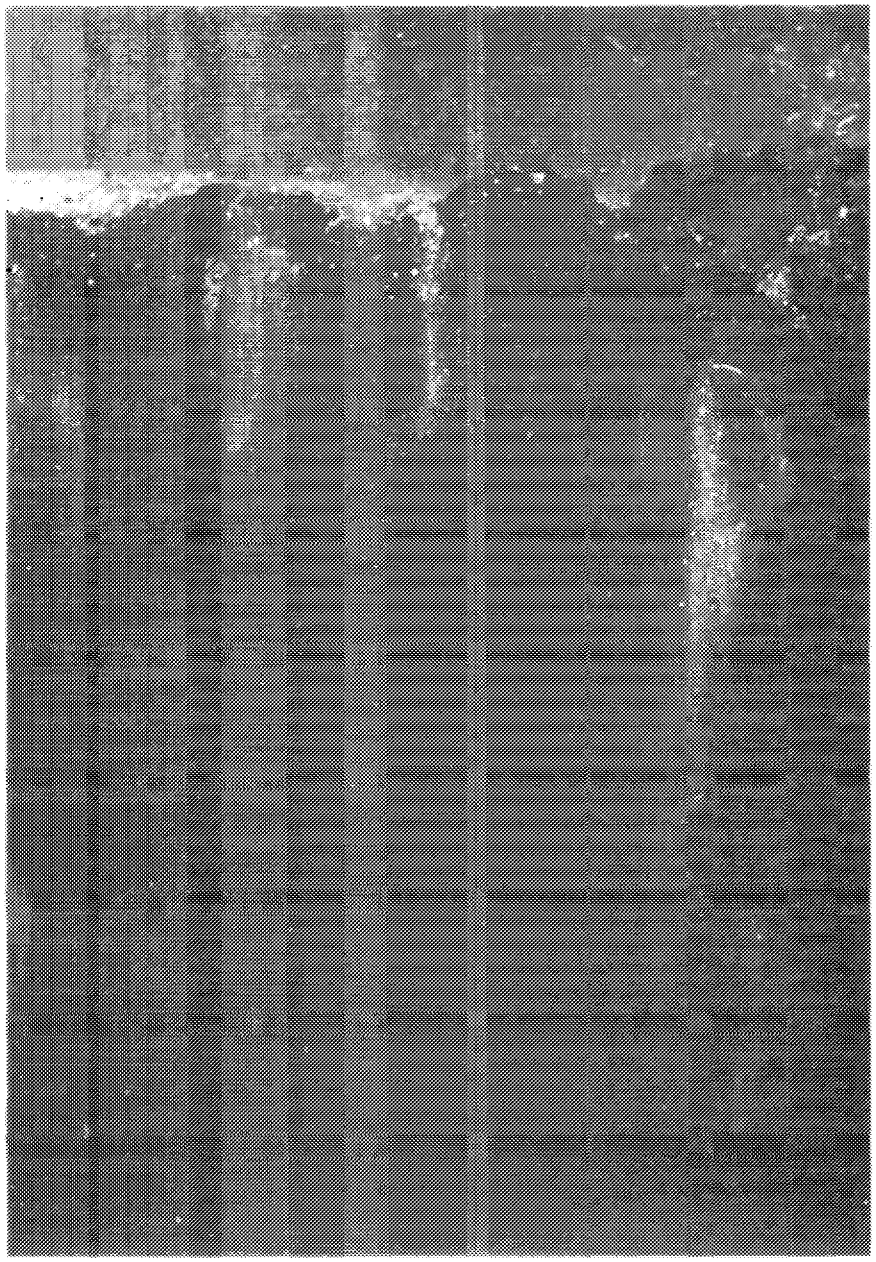

Figure 3-12. A REMOTS image from station CTR showing reduced dredged material at the interface. Apparently, oxidized surface sediments were completely removed by the severe bottom scour produced by Hurricane Gloria. Scale = 1X.

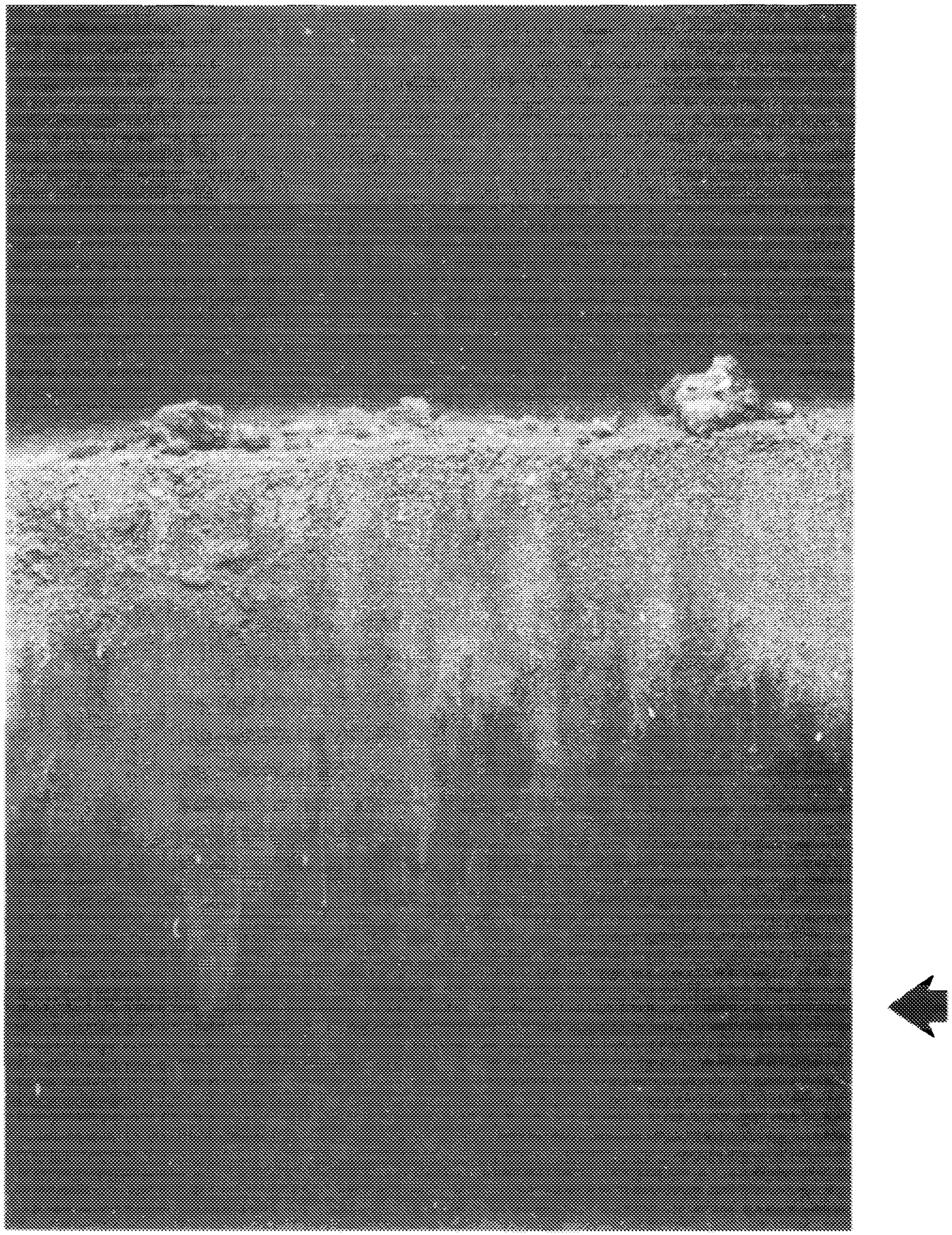

Figure 3-13. A REMOTS image from station 1000E showing an apparently truncated RPD, mud clasts, and methane gas pockets at depth (arrow). Scale = 1X.

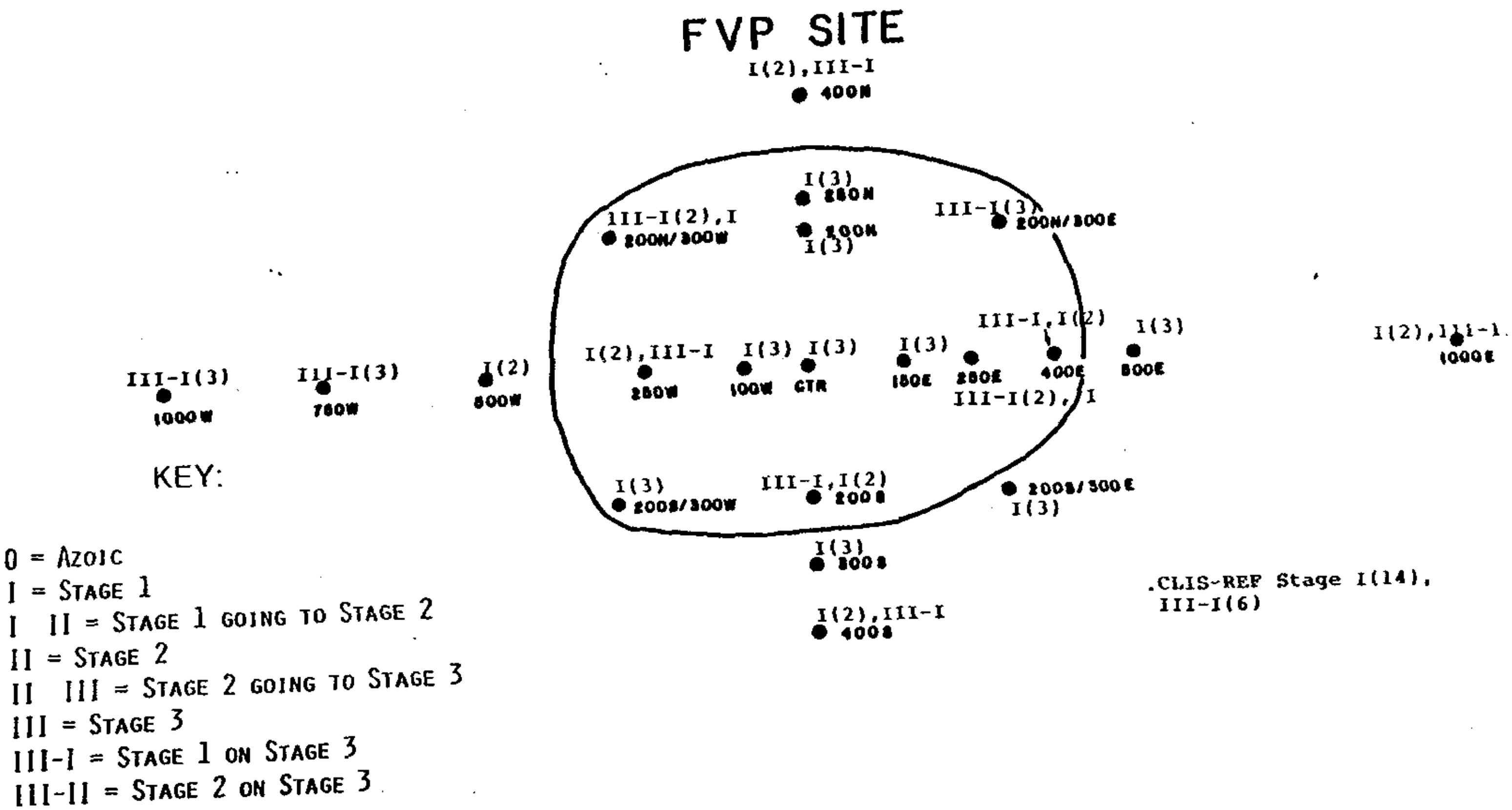

Figure 3-14. The mapped distribution of successional stages for all replicates in the October survey.

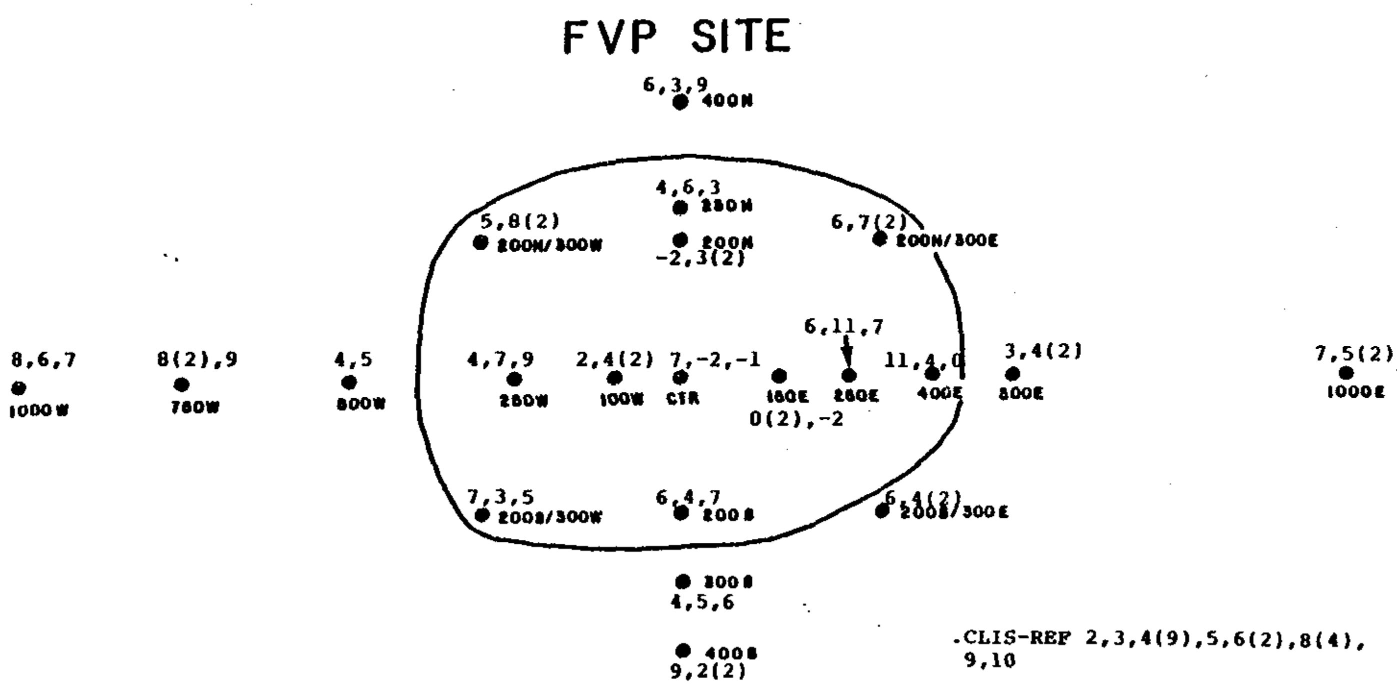

Figure 3-15. The distribution of Organism-Sediment Index values for all replicates in the October survey. The numbers in parenthesis indicate the number of replicates exhibiting a given OSI value at each station.

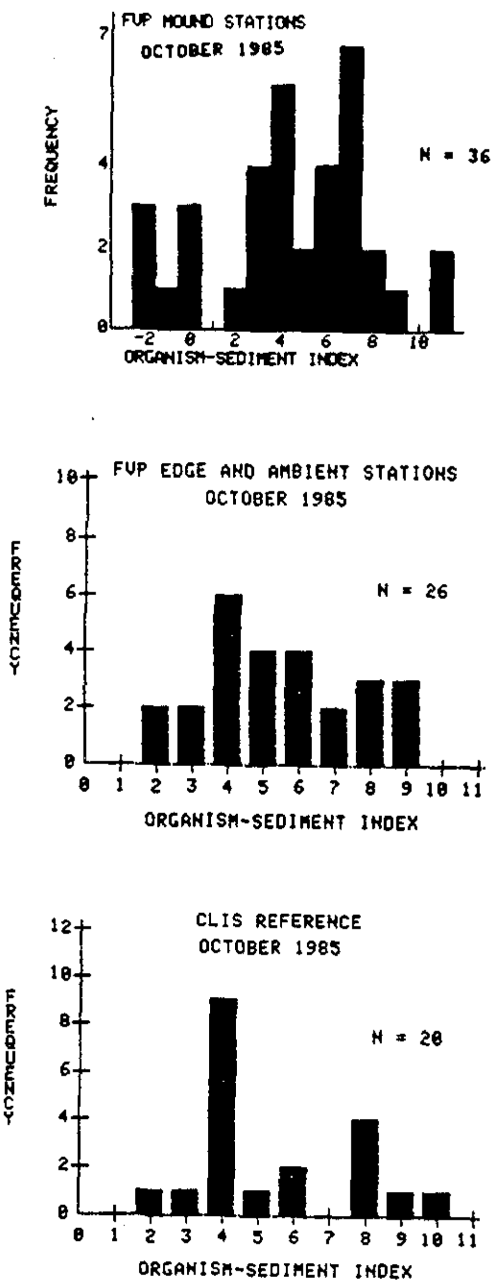

Figure 3-16. Organism-Sediment Index frequency distributions for the mound, edge and ambient, and CLIS-REF stations.

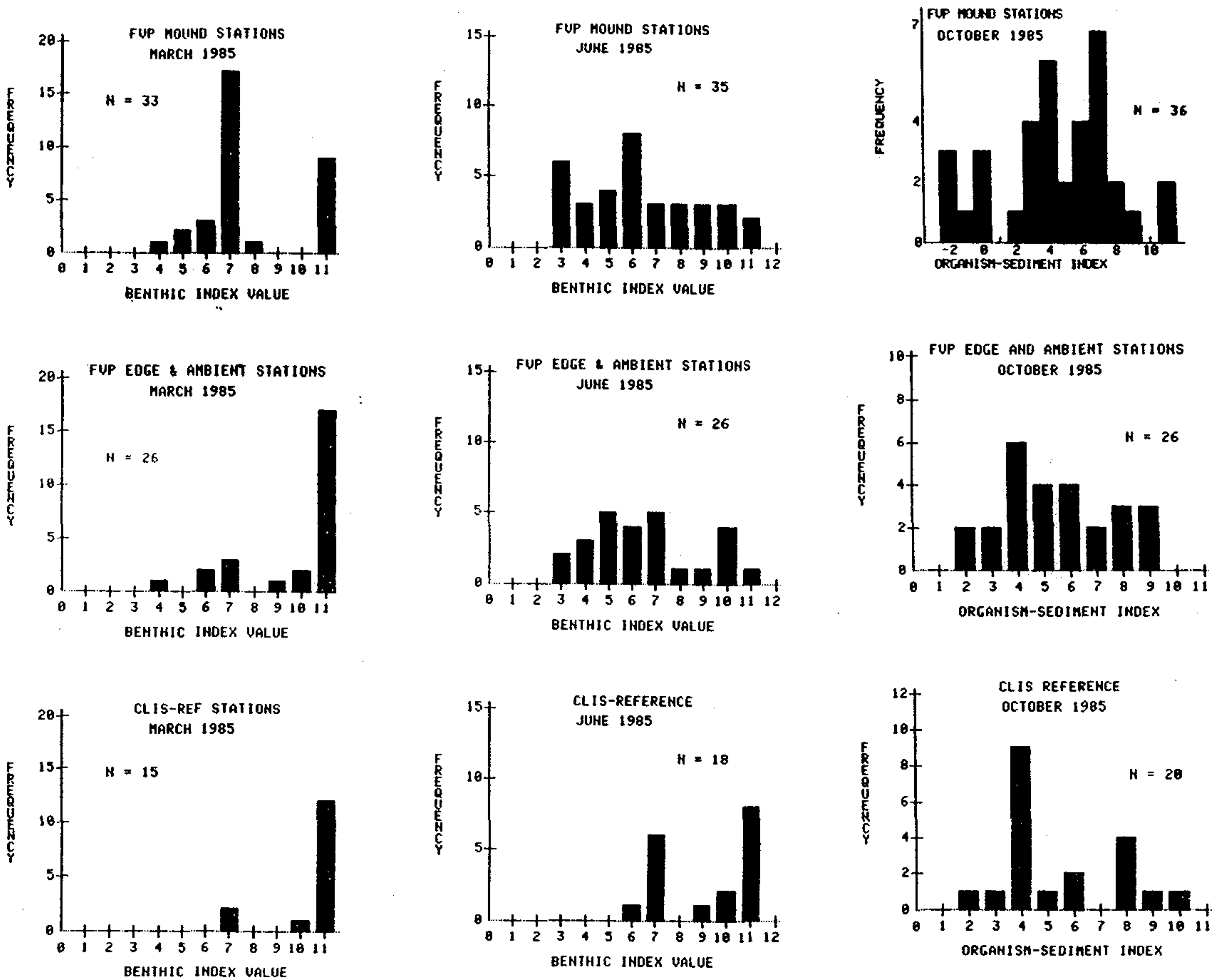

Figure 3-17. OSI values at the FVP and CLIS-REF sites in 1985.