Monitoring Cruise at the Massachusetts Bay
Disposal Site
November 1988 - January 1989

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13. ABSTRACT (Maximum 200 words)

The Massachusetts Bay Disposal Site (MBDS), referred to in previous studies as the Foul Area Disposal Site (FADS), is located at 42° 25.7 N and 70° 34.0 W.

Field operations were conducted at MBDS from 28 October to 18 January 1989, and consisted of precision bathymetric and REMOTS® sediment-profile bathymetric surveys around the point where the disposal buoy "FDA" was located during the 1987-88 and 1988-89 disposal seasons. At the "FDA" buoy at MBDS, dredged material deposited since the January 1987 bathymetric and REMOTS® surveys occurred as a circular mound, centered slightly east of the buoy, with gradually sloping sides and a maximum thickness of 0.3 meters at the apex. Based on changes in bathymetry, the radius of the mound was estimated to be between 50 and 100 meters, while the REMOTS® results extended the detected radius to 300 to 350 meters. Based on these combined results, it was estimated that 61,054 m^3 of dredged material had accumulated at the "FDA" buoy since January 1987. The disposal mound was situated well within the disposal site boundaries. The prediction that sediment disposed since the January 1987 surveys would add to the existing mound without increasing the diameter was confirmed.

A REMOTS® survey was performed at the "A" buoy to assess the benthic community recovery at this former disposal point. Although a minimal amount of dredged material was disposed at the "A" buoy since January 1987, it seemed to have little or no effect on the benthic conditions in this region. The RPD depths and OSI values were similar to those at the reference stations, and a high abundance of Stage III organisms was present. The prediction that the benthic community at the "A" buoy stations would have an abundance of Stage III taxa similar to the reference stations was confirmed. However, given the apparent lack of significant recent disturbance in this area, Stage I organisms did not occur in greater abundance compared to the reference stations.

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MONITORING CRUISE AT THE MASSACHUSETTS BAY DISPOSAL SITE NOVEMBER 1988 - JANUARY 1989

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US Army Corps
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New England Division

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1.0 INTRODUCTION

The Massachusetts Bay Disposal Site (MBDS), referred to in previous studies as the Foul Area Disposal Site (FADS), is located approximately 22 nautical miles (nm) east-northeast of the entrance to Boston Harbor and 12 nm south-southeast of Gloucester, Massachusetts. The site consists of a 2 nm diameter circle centered at 42° 25.7 N and 70° 34.0 W.

Field operations were conducted at MBDS from 28 October 1988 to 18 January 1989. The field operations consisted of precision bathymetric and REMOTS® sediment-profile photographic surveys around the point where the disposal buoy ("FDA") was located during the 1987-88 and 1988-89 disposal seasons (Figure 1-1). The last previous surveys occurred at this location in January 1987. The objective of the 1988-89 surveys was to delineate the distribution and thickness of the dredged material deposit resulting from disposal activities which have been on-going since the previous surveys. A second precision bathymetric survey was conducted over the entire MBDS disposal site to provide detailed bathymetric information for the entire area. A REMOTS® sediment-profile photographic survey also was performed at the "A" buoy to assess the benthic community recovery at this former disposal point.

The 1988 sampling plan at the MBDS "FDA" buoy was designed to verify the following predictions:

- sediment disposed during the 1987-88 and the first half of the 1988-89 disposal seasons would add to the existing sediment mound without increasing the size (diameter) of the previously detected mound, and
- the center of this deposit would be detectable with bathymetry

The REMOTS® survey at the "A" buoy was designed to verify the following predictions:

- the benthic community around the buoy would follow expected recolonization patterns with an abundance of Stage III organisms similar to the reference stations, and
- Stage I organisms would be present in higher densities than at the reference stations.

2.0 METHODS

2.1 Bathymetry and Navigation

The precision navigation required for all field operations was provided by the SAIC Integrated Navigation and Data Acquisition System (INDAS). This system uses a Hewlett-Packard 9920 series computer to collect position, depth, and time data for subsequent analysis as well as providing real-time navigation. Positions were determined to an accuracy of ±3 meters from ranges provided by a Del Norte Trisponder System. For the present survey, shore stations were established in Massachusetts at known benchmarks at Marblehead Light and Eastern Point Light. A detailed description of the navigation system and its operation can be found in DAMOS Contribution #48 (SAIC, 1985).

The depth was determined to a resolution of 3.0 cm (0.1 feet) using an Odom DF3200 Echotrac Survey Recorder with a narrow-beam 208 kHz transducer. The speed of sound was determined from the water temperature and salinity data measured by an Applied Microsystems CTD probe. The speed of sound and the transducer depth were entered into the fathometer to adjust the depth values being transmitted to the computer. During analysis, raw bathymetric data were standardized to Mean Low Water by correcting for changes in tidal height during the survey. A detailed discussion of the bathymetric analysis technique is given in DAMOS Contribution #48 (SAIC, 1985).

The bathymetric survey conducted at the MBDS "FDA" buoy on 4 November 1988 encompassed a 1200 x 1200 m grid with 25 m lane spacing, centered at coordinates 42° 25.095 N and 70° 34.423 W (Figure 1-1). This same grid was used in the previous bathymetric survey of this area in January 1987. Between 5 and 19 November 1988, the master bathymetric survey was conducted over a 4000 x 4000 m grid with 50 m lane spacing, centered at 42° 25.695 N and 70° 33.999 W (Figure 1-1).

2.2 REMOTS® Sediment-Profile Photography

REMOTS® photography was used to detect the distribution of thin (1 to 20 cm) dredged material layers, map benthic disturbance gradients, and monitor the process of infaunal recolonization on and adjacent to the disposal mounds at the "FDA" and "A" buoys. A detailed description of REMOTS® photograph acquisition, analysis, and interpretative rationale is given in DAMOS Contribution #60 (SAIC, 1989).

The REMOTS® stations occupied on 16-18 January 1989 at the "FDA" buoy were the same ones occupied during the last survey in January 1987. Three replicate photographs were obtained at each of 39 stations situated around the disposal buoy in a cross-shaped pattern. Stations were spaced 100 m apart and extended 600 m to the north, 800 m to the south, 900 m to the east, and 700 m to the west of center (Figure 2-1). Stations were also located in each of the four quadrants at 250 and 500 meters NE, NW, SE, and SW. Additionally, thirteen REMOTS® stations arranged in a cross-shaped pattern and spaced 100 m apart were occupied at each of three reference locations to allow comparisons between ambient and on-site conditions. These reference stations were located at 42° 22.7 N, and 70° 34.6 W (station FG23); 42° 20.0 N, and 70° 28.0 W (station SE-REF); and 42° 24.686 N, and 70° 32.814 W (station 18-17; Figure 2-1).

The REMOTS® stations around the "A" buoy were occupied on 11 and 16 January 1989; the station grid was centered at 42° 25.7 N and 70° 35.04 W. Three replicate photographs were obtained at each of 39 stations arranged in a cross-shaped pattern, identical to the grid used for the REMOTS® survey at the "FDA" buoy (Figure 2-1).

3.0 RESULTS

3.1 Bathymetry

A comparison of the November 1988 and January 1987 precision bathymetric surveys (Figures 3-1 and 3-2, respectively) revealed that an acoustically-detectable layer of dredged material had been deposited at the "FDA" buoy in the time between the two surveys. In November 1988, the minimum depth at the disposal point was approximately 88.50 meters (Figure 3-1), compared to a depth of 88.75 meters in January 1987 (Figure 3-2). A depth difference contour chart (Figure 3-3) indicates that the deposit had a maximum thickness of 0.3 meters and was centered slightly east of the buoy. Depth differences on the order of 20 cm (i.e., approaching the limits of detection in this comparison of the 1988 and 1987 surveys) occurred within a 50 to 100 meter radius of the center of the deposit.

For the 1200 x 1200 m survey area, comparison of the depth matrices from the 1987 and 1988 bathymetric surveys resulted in a volume difference calculation of 18,087 m^3 of material deposited since the January 1987 survey. Examination of the disposal logs indicated that an estimated 140,000 m^3 of material was deposited at this location between the January 1987 and November 1988 surveys.

The second precision bathymetric survey performed at MBDS provided detailed bathymetric data for the entire disposal site and revealed the overall topographical features (Figure 3-4). The disposal site is located in a trough running northwest to southeast, just to the southwest of Stellwagen Bank. Extreme changes in depth of up to 20 meters over a 60 meter distance were found on the slopes of the bank (Figure 3-5).

3.2 REMOTS® Sediment-Profile Photography

Dredged material layers presumed to be recently-deposited (i.e., since the January 1987 survey) were evident in the REMOTS® photographs from stations surrounding the disposal buoy (Figure 3-6). The precise boundaries of the "new" mound were difficult to determine due to the presence of relict dredged material at most of these same stations (Figure 3-7). This relict material was the result of disposal operations which have been ongoing at this location since November 1985.

The apparent "fresh" dredged material consisted of a chaotic mixture of silts, fine sands and sands intermixed with clay (Figure 3-8). The REMOTS® photographs from the stations located closest to the point of disposal (CTR, 100S, 100N, out to 200E, and out to 300W) showed over-consolidated clay clasts and occasional rock rubble at the surface which limited camera penetration (Figure 3-9). At other stations, the dredged material appeared to be less consolidated, exhibiting more stratification and allowing deeper camera penetration (Figure 3-10). At these stations, the mixture of silts, fine silts, and sands was less chaotic with only an occasional buried clay clast, reflecting heterogeneity in the composition of the disposed material. Again, the thickness of the recently-deposited layers often could not be measured accurately because of the lack of a clear marker between the "fresh" dredged material and underlying relict material.

The majority of REMOTS® grid and reference stations consisted of silt-clay sediments (≥4 phi, Figure 3-11). Many of the stations having either relict or fresh dredged material exhibited grain size major modes from fine sand (4-3 phi) to silt-clay (≥4 phi). The majority of small-scale surface boundary roughness values at the stations around the "FDA" buoy where dredged material was present ranged between 0.6 to 1.8 cm, while the majority of values at the reference stations ranged from 0.0 to 0.6 cm (Figure 3-12). Boundary roughness values at the "FDA" buoy stations having dredged material were significantly greater than those at the reference stations (Mann-Whitney U-test, $p < 0.001$). Not surprisingly, this greater surface boundary roughness reflected the physical bottom disturbance related to disposal operations.

The frequency distribution of mean apparent RPD depths for the "FDA" buoy stations where dredged material was present was right-skewed with a major mode at the 1.0 cm class interval, while the distribution of RPD depths for the reference stations showed a normal distribution with a major mode at the 5.0 cm class interval (Figure 3-13). The reference station RPD values were significantly deeper (Mann-Whitney U-test, $p < 0.001$). RPD depths less than 2.0 cm occurred at stations immediately around the buoy, generally corresponding to that area of the disposal site having recently-deposited dredged material (Figure 3-14).

Only three stations located at or near the point of disposal had evidence of only Stage I organisms (100N, CTR, 100S); Stage III taxa were evident at all but five of the reference stations (Figure 3-15). At the remainder of the disposal site stations, there was evidence of Stage III taxa (i.e., head-down deposit-feeding infauna) in at least one of the replicate photographs (Figure 3-16). In January 1987, 66% of the replicate photographs (N = 92) at the "FDA" buoy REMOTS® stations showed evidence of Stage III taxa, compared to 75% (N = 108) in the present survey. These proportions of Stage III taxa present in 1987 and 1989 were not found to be significantly different (Chi-squared Test, $p > 0.1$). However, at the reference stations, 68% of the 1989 replicates (N = 57) showed evidence of Stage III taxa, compared to 94% (N = 32) in January 1987. These proportions of Stage III taxa present were found to be significantly different (Chi-squared Test, $p < 0.01$).

The pooled reference station OSI values were significantly higher than those at the "FDA" buoy stations where dredged material was present (Mann-Whitney U-test, $p < 0.001$). The mapped distribution of OSI values confirms this statistic: OSI values less than or equal to +6 occurred at stations in the immediate vicinity of the disposal buoy (Figure 3-17). Frequency distributions also showed higher values at the reference stations (Figure 3-18). However, the OSI values for all stations at the disposal site and for the reference stations had not changed significantly since the January 1987 REMOTS® survey (Mann-Whitney U-test, $p = .0527$ for the disposal site and $p = .0608$ for the reference stations).

3.3 REMOTS® Sediment-Profile Photography at the "A" Buoy

It was estimated that 6,700 m^3 of dredged material were deposited at the "A" buoy since the January 1987 survey at MBDS. In most of the January 1989 REMOTS® photographs, it was difficult to determine whether the observed dredged material was fresh or relict (Figure 3-19). The photographs from eight of the stations showed no evidence of dredged material. Given the small volume of disposed sediment, most of the dredged material evident at the remainder of the stations was assumed to be relict.

All of the REMOTS® stations consisted of silt-clay sediments (≥ 4 phi). Boundary roughness values at the "A" buoy stations were significantly greater than those at the reference stations (Mann-Whitney U-test, $p < 0.001$); more values at the "A" buoy stations fell within the higher class intervals (Figure 3-20).

Mean apparent RPD depths at the "A" buoy stations were not significantly different from the reference stations (Mann-Whitney U-test, $p = 0.162$; Figure 3-21). Mean RPD depths less than 3.0 cm occurred at stations close to the buoy, corresponding to that area which most likely was affected by disposal operations during the past year (Figure 3-22).

None of the stations within the "A" buoy grid had only Stage I taxa present; all showed evidence of Stage III taxa in at least one of the replicate photographs (Figures 3-23). The Stage III taxa included head-down deposit-feeding infauna, as evidenced by feeding voids at depth, as well as relatively large, tube-dwelling polychaetes visible at the sediment surface (Figure 3-24). At the "A" buoy stations, 82% of the replicates showed evidence of Stage III taxa, compared to 68% at the reference stations.

The frequency distributions of OSI values at the "A" buoy and at the reference stations both had major modes at +11 (Figure 3-25); there was no significant difference between these two groups (Mann-Whitney U-test, $p = 0.686$). With the exception of station 300W, all the "A" buoy stations had OSI values greater than +6 (Figure 3-26).

4.0 DISCUSSION

The objective of the combined REMOTS® and precision bathymetric surveys was to delineate the extent and topography of the dredged material deposit resulting from disposal at the "FDA" buoy since the previous surveys in January 1987. As predicted, the bathymetric survey revealed an accumulation of dredged material within a 50 to 100 meter radius of the disposal buoy (Figure 3-3). The REMOTS® photographs confirmed the existence of dredged material layers beyond the boundaries determined by bathymetry. REMOTS® photography indicated that the roughly circular area around the buoy covered by recently-deposited (i.e., since the January 1987 survey) dredged material had an approximate radius of 300 to 350 meters (Figure 4-1). Some fresh dredged material probably occurred beyond this radius but, as was mentioned earlier, the precise boundaries of the new portion of the mound were difficult to determine due to the difficulties in distinguishing between fresh and "relict" dredged material layers at several of the stations on the mound flank. This coincides with the results found in the last REMOTS® survey in January 1987. In the previous survey, the radius of dredged material was determined to be approximately 350 to 400 meters, with no definitive boundary found to the north. This confirms the prediction that the sediment deposited at the buoy since the 1987 survey would add to the existing mound without increasing the diameter.

The REMOTS® results showed the new mound had a larger radius than indicated by the bathymetry results mainly because of the camera's ability to detect thin layers on the flanks of the deposit. Such layers were below the limits of detection by precision bathymetry and were therefore unaccounted for in the volume difference calculation. When the area representing the flanks of the mound was digitized and measured, it was found to occupy 306,908 m^2. A reasonable estimate for the average thickness of the fresh dredged material layers in this area was 14 cm, based on the actual thickness of such layers at several flank REMOTS® stations (see Figure 3-6). This results in an estimated volume of 42,967 m^3 of material on the mound flanks not accounted for in the bathymetric depth difference calculation. Adding this to the depth difference volume estimate of 18,087 m^3 results in a final total of 61,054 m^3 of dredged material detected on the bottom using the two techniques.

The final total volume estimate of 61,054 m^3 is less than the scow disposal log volume estimate of 140,000 m^3 of disposed material. The scow disposal log volume is assumed to be an overestimate due to the significant amount of interstitial water associated with the dredged material in the barges and the self-compaction of the material after it is disposed. Tavolaro (1984) determined an apparent decrease in volume of 40.7% when comparing the scow log volume and the volume estimated by comparing pre- and post-disposal bathymetric surveys in 30 meters of water. However, the Tavolaro study does not include estimates to account for the greater spreading of the material at increased depths, such as those at MBDS (average 88 to 92 meters). During disposal at MBDS, wider distribution of the falling sediment is expected because the greater depth offers more time for entrainment of water. This entrainment facilitates the dispersal of the more flocculent material which may be carried farther away by currents as a result of the increased descent time. Until a comprehensive mass balance study is performed at these greater depths and methods are developed to easily and accurately measure scow disposal volumes, attempts to reconcile the bathymetric volume difference and scow disposal log volume estimates almost certainly will result in a discrepancy. At other DAMOS disposal sites, dredged material volumes calculated from bathymetric data consistently have been less than the scow log volumes (SAIC, 1987 and SAIC, 1989).

Small-scale surface boundary roughness was significantly higher at the "FDA" disposal site stations compared to the reference stations, reflecting the physical bottom disturbance related to past and recent disposal activities. Likewise, RPD depths at the disposal site stations were significantly shallower than those at the reference stations. While Stage III taxa were present at the disposal site stations in a relatively high percentage of the REMOTS® photographs (75%), most of the Stage III organisms were also associated with Stage I taxa.

Stage III organisms appeared in a significantly higher percentage of REMOTS® photographs at the reference stations in 1987 than in 1989 (94% in 1987 and 68% in 1989). This most likely was due to a sampling artifact; only one reference area was sampled in 1987, with many replicate photographs from one location, while three reference areas were sampled in 1989 with much greater areal coverage. The 1987 reference data may be somewhat biased because only one reference location was sampled.

Although not significantly different, the percentage of Stage III organisms in replicate REMOTS® photos at the "FDA" buoy stations also showed an increase since the January 1987 survey (66% in 1987 compared to 75% in 1989) despite ongoing disposal activity. Likewise, overall site averages for mean RPD and OSI values increased over the same time period. These results suggest a steady recovery in the benthic ecosystem at the disposal site in the time between the two surveys.

The objective of the REMOTS® survey at the "A" buoy was to assess the benthic community recovery at this former disposal point. The REMOTS® survey showed evidence of dredged material at all but eight of the stations. Stage III taxa were present at the "A" buoy stations in a high percentage of the REMOTS® photographs (82%). This was higher than the percentage of Stage III taxa present at the reference stations (68%), demonstrating a fairly complete benthic ecosystem recovery at this disposal location. The prediction that Stage I organisms would be in greater abundance at the "A" buoy stations than at the reference stations was not confirmed, suggesting that the disposal impacts were not as great as expected. Given the small volume of material deposited, coupled with the healthy rate of recolonization at the "A" buoy since establishment of the "FDA" disposal location, there was not an increased abundance of opportunistic taxa at the "A" buoy.

5.0 CONCLUSIONS

At the "FDA" buoy at MBDS, dredged material deposited since the January 1987 bathymetric and REMOTS® surveys occurred as a circular mound, centered slightly east of the buoy, with gradually sloping sides and a maximum thickness of 0.3 meters at the apex. Based on changes in bathymetry, the radius of the mound was estimated to be between 50 and 100 meters, while the REMOTS® results extended the detected radius to 300 to 350 meters. Based on these combined results, it was estimated that 61,054 m^3 of dredged material had accumulated at the "FDA" buoy since January 1987. This was less than the disposal log estimate of 140,000 m^3 of disposed material, but such discrepancies are expected because of the inaccuracies of scow estimates, the compaction of the dredged material on the bottom following disposal, the significant amount of water associated with the dredged material in the barges, and greater spreading of the material in the deeper waters at MBDS. The disposal mound was situated well within the disposal site boundaries. The prediction that sediment disposed since the January 1987 surveys would add to the existing mound without increasing the diameter was confirmed.

A REMOTS® survey was performed at the "A" buoy to assess the benthic community recovery at this former disposal point. Although a minimal amount of dredged material was disposed at the "A" buoy since January 1987, it seemed to have little or no effect on the benthic conditions in this region. The RPD depths and OSI values were similar to those at the reference stations, and a high abundance of Stage III organisms was present. The prediction that the benthic community at the "A" buoy stations would have an abundance of Stage III taxa similar to the reference stations was confirmed. However, given the apparent lack of significant recent disturbance in this area, Stage I organisms did not occur in greater abundance compared to the reference stations.

6.0 REFERENCES

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SAIC. 1989. Monitoring Surveys at the New London Disposal Site, August 1985 - July 1986. US Army Corps of Engineers, New England Division, Waltham, MA. DAMOS Contribution #60 (SAIC Report # SAIC-86/7540&C60).

Tavolaro, J.F. 1984. Sediment budget study for clamshell dredging and ocean disposal activities in the New York Bight. Environ. Geol. Water Sci. 6 (3): 133-140.

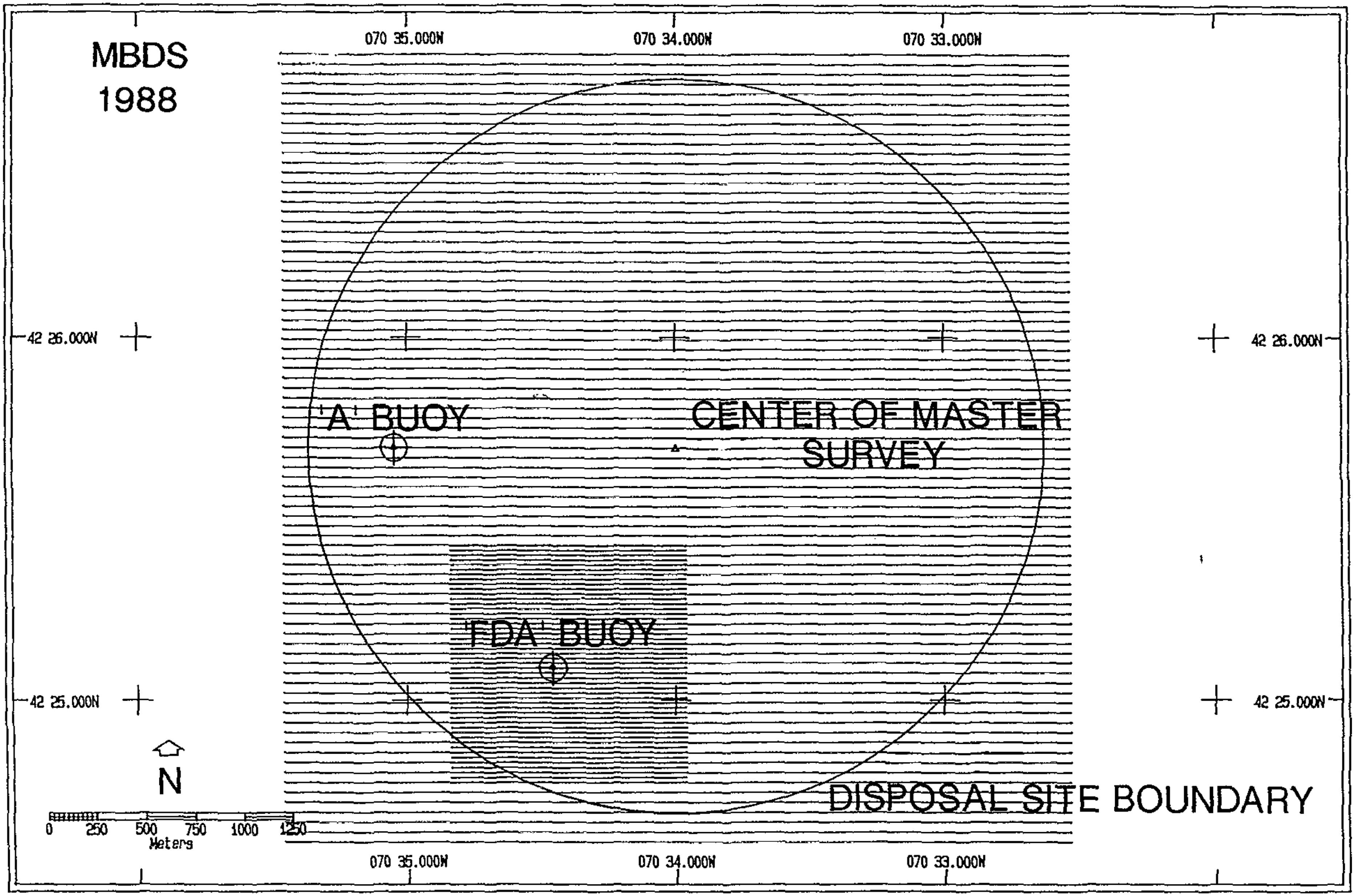


Figure 1-1. Map of bathymetric survey lanes used at MBDS, indicating the location of the "FDA" and "A" buoys, as well as the MASTER MBDS survey encompassing the entire area.

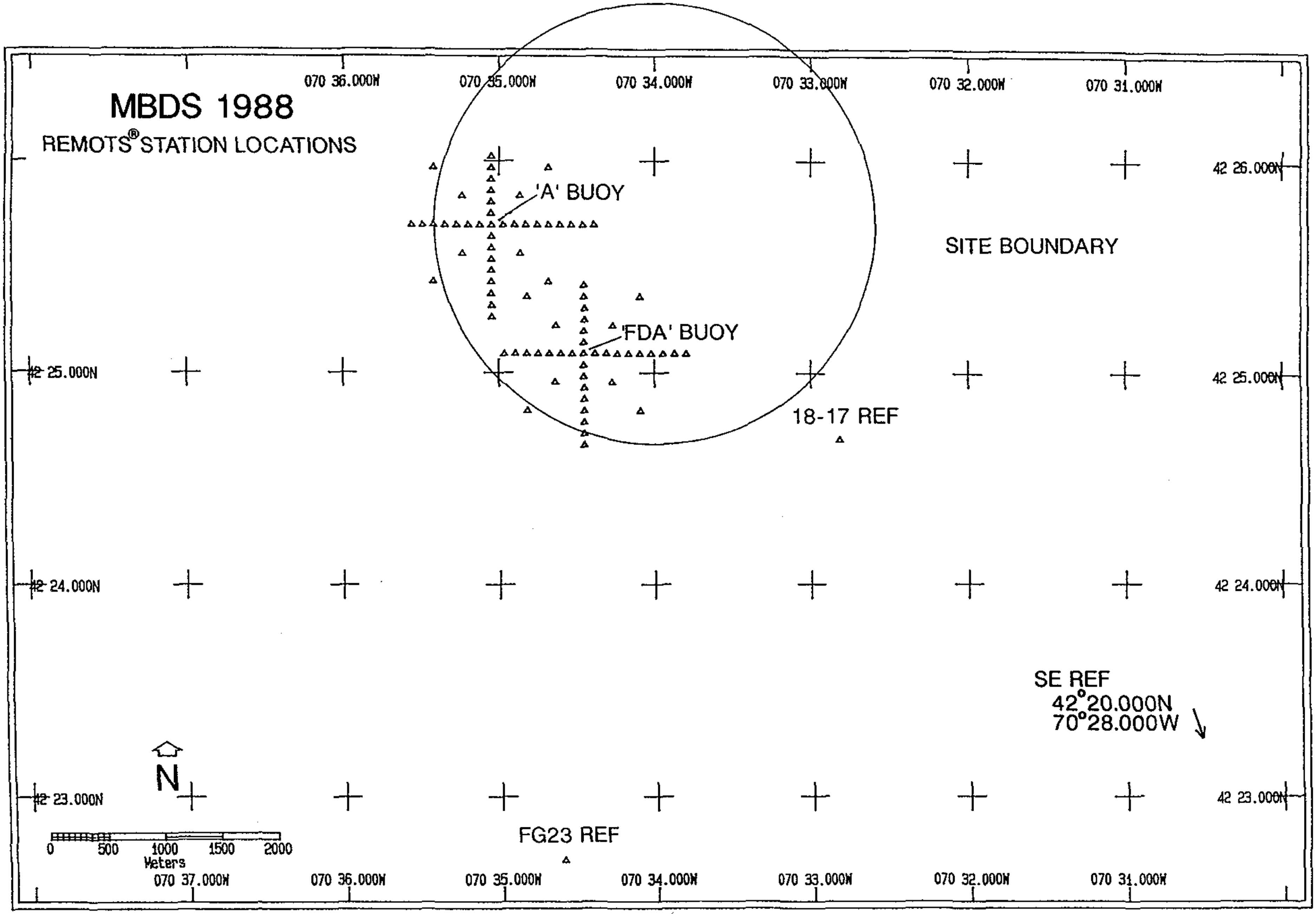


Figure 2-1. Location and designation of REMOTS® stations (triangles) at MBDS, January 1989. Cross-shaped grids with 100 m station spacing were used at the three outlying reference sites (FG23, SE-REF and 18-17).

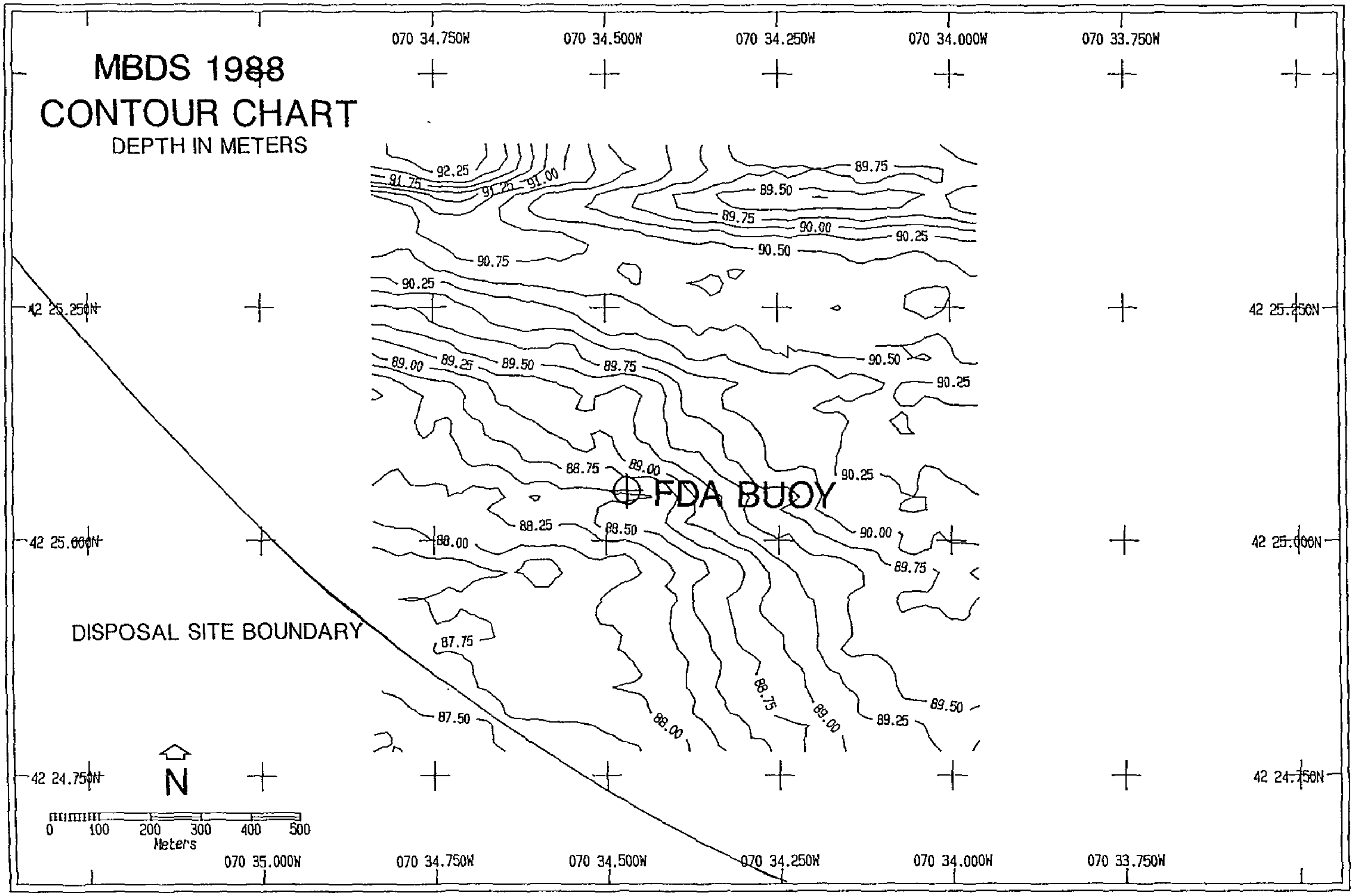


Figure 3-1. Bathymetric contour chart of the area surrounding the "FDA" buoy at MBDS, November 1988. The contour interval is 0.25 meters.

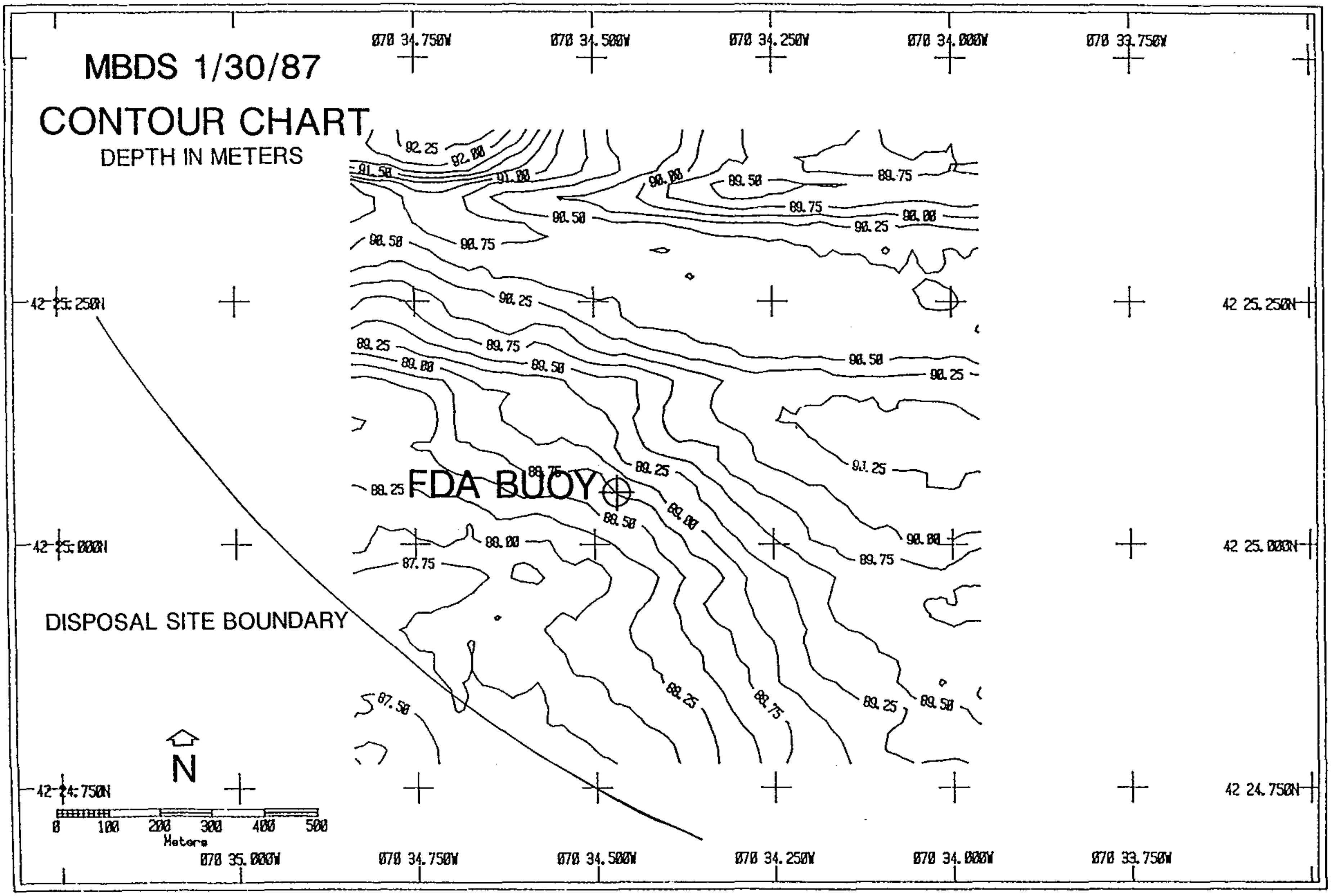


Figure 3-2. Bathymetric contour chart of the area surrounding the "FDA" buoy at MBDS, January 1987. The contour interval is 0.25 meters.

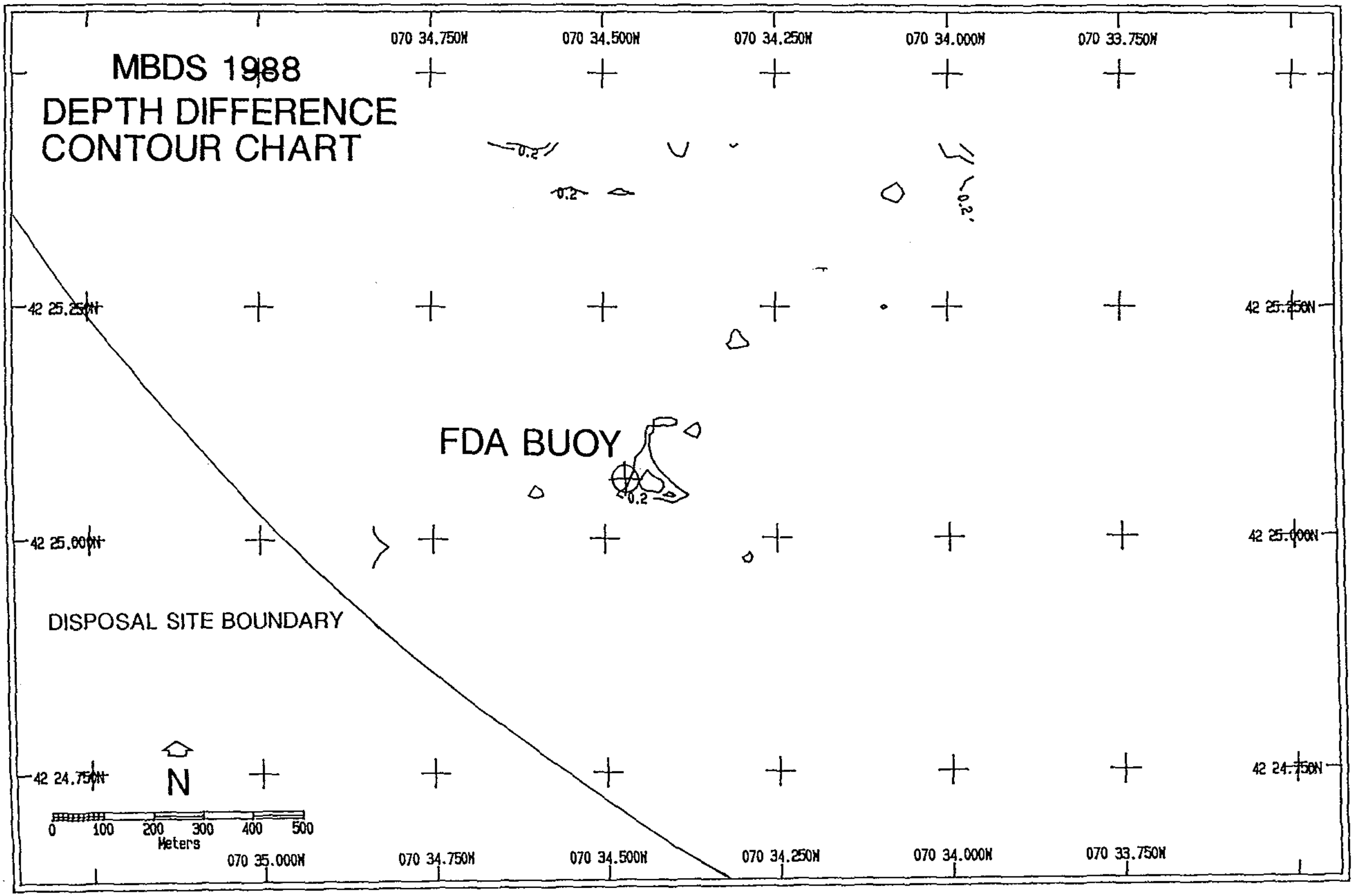


Figure 3-3. Depth difference (in meters) contour map based on comparison of the January 1987 and November 1988 precision bathymetric surveys at the "FDA" buoy.

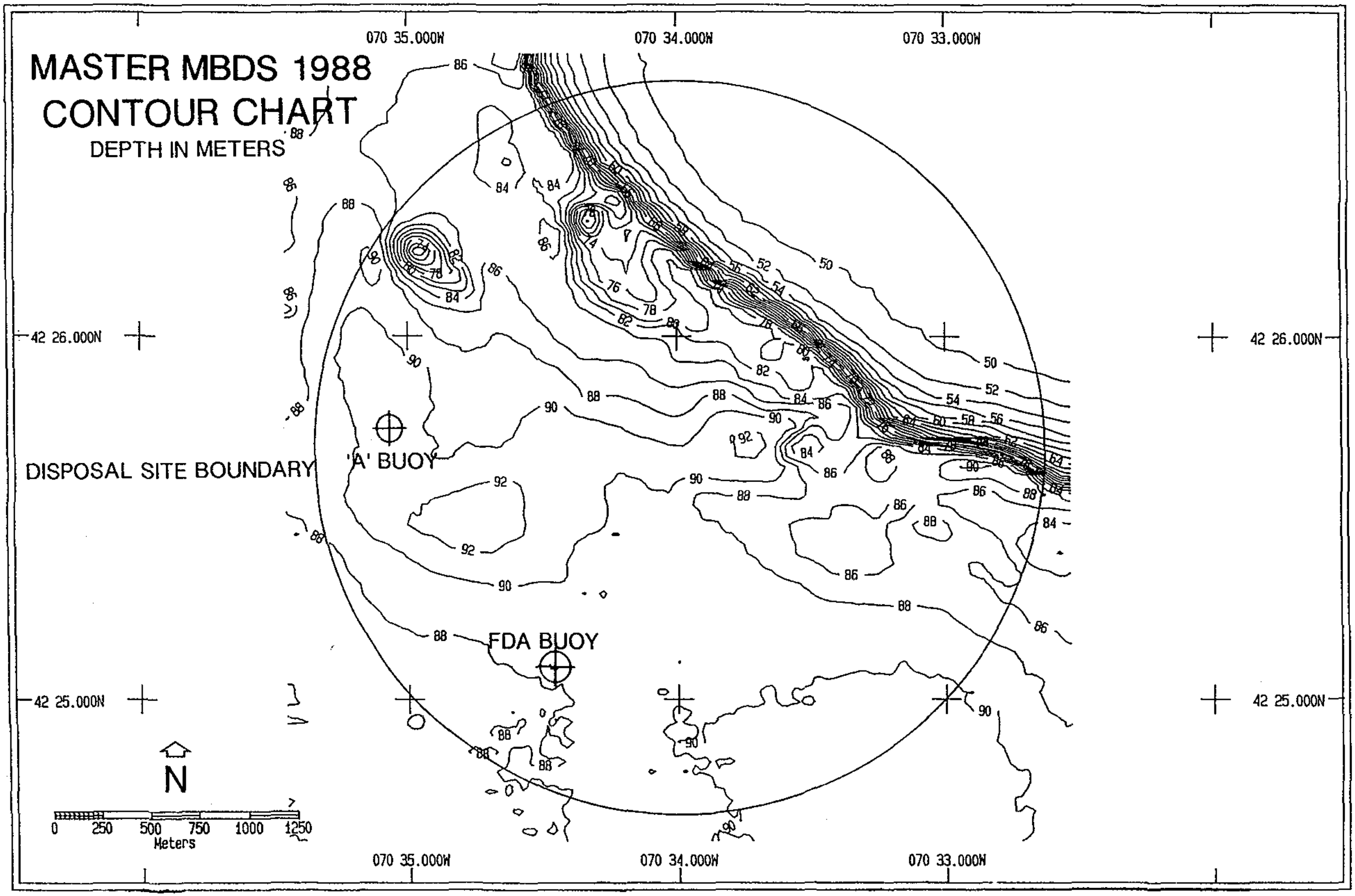


Figure 3-4. Bathymetric contour chart of the entire MBDS area, November 1988. Contour interval is 2.0 meters.

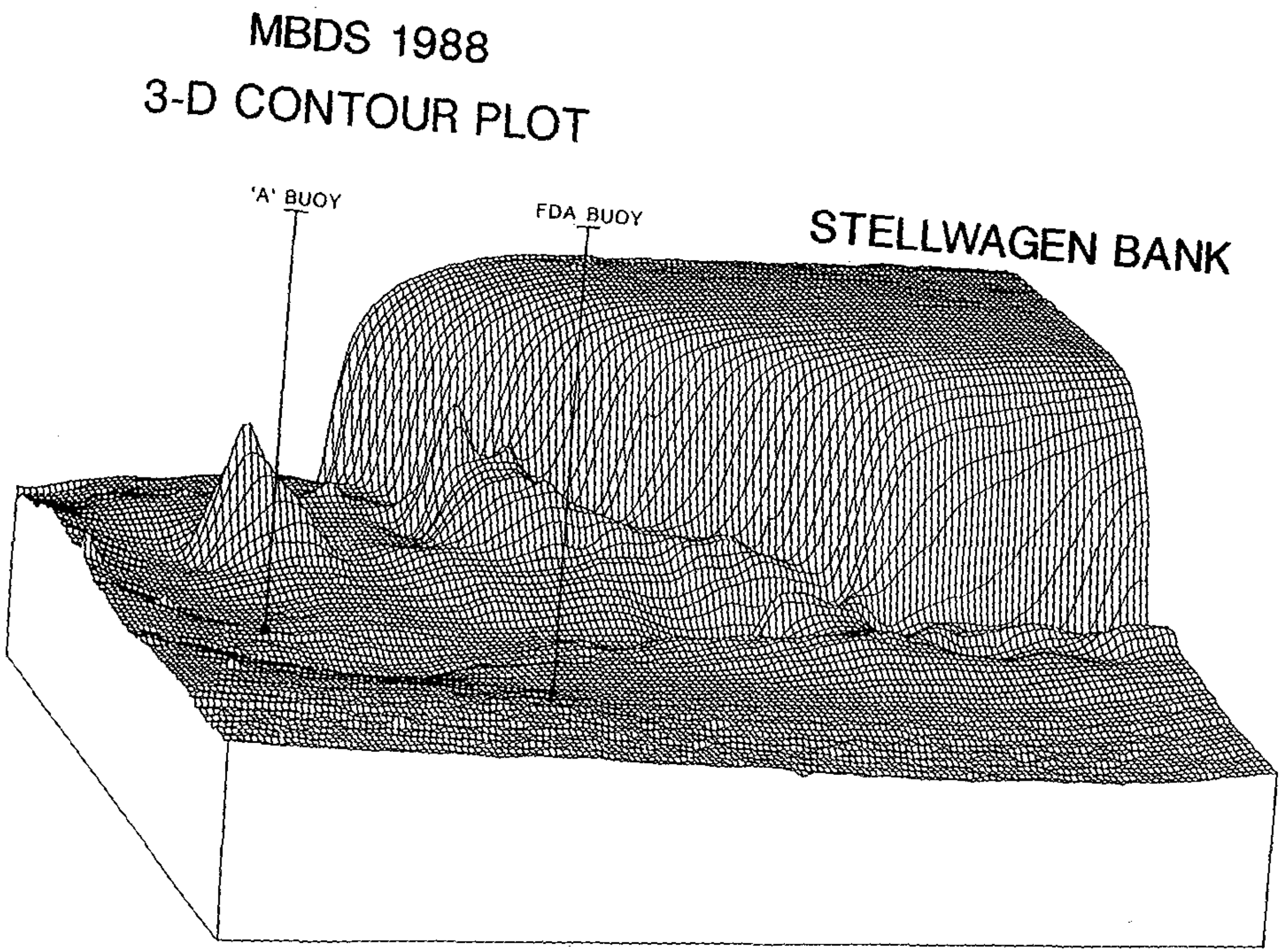


Figure 3-5. 3-D contour plot of the entire MBDS area, November 1988. The vertical exaggeration is 25X.

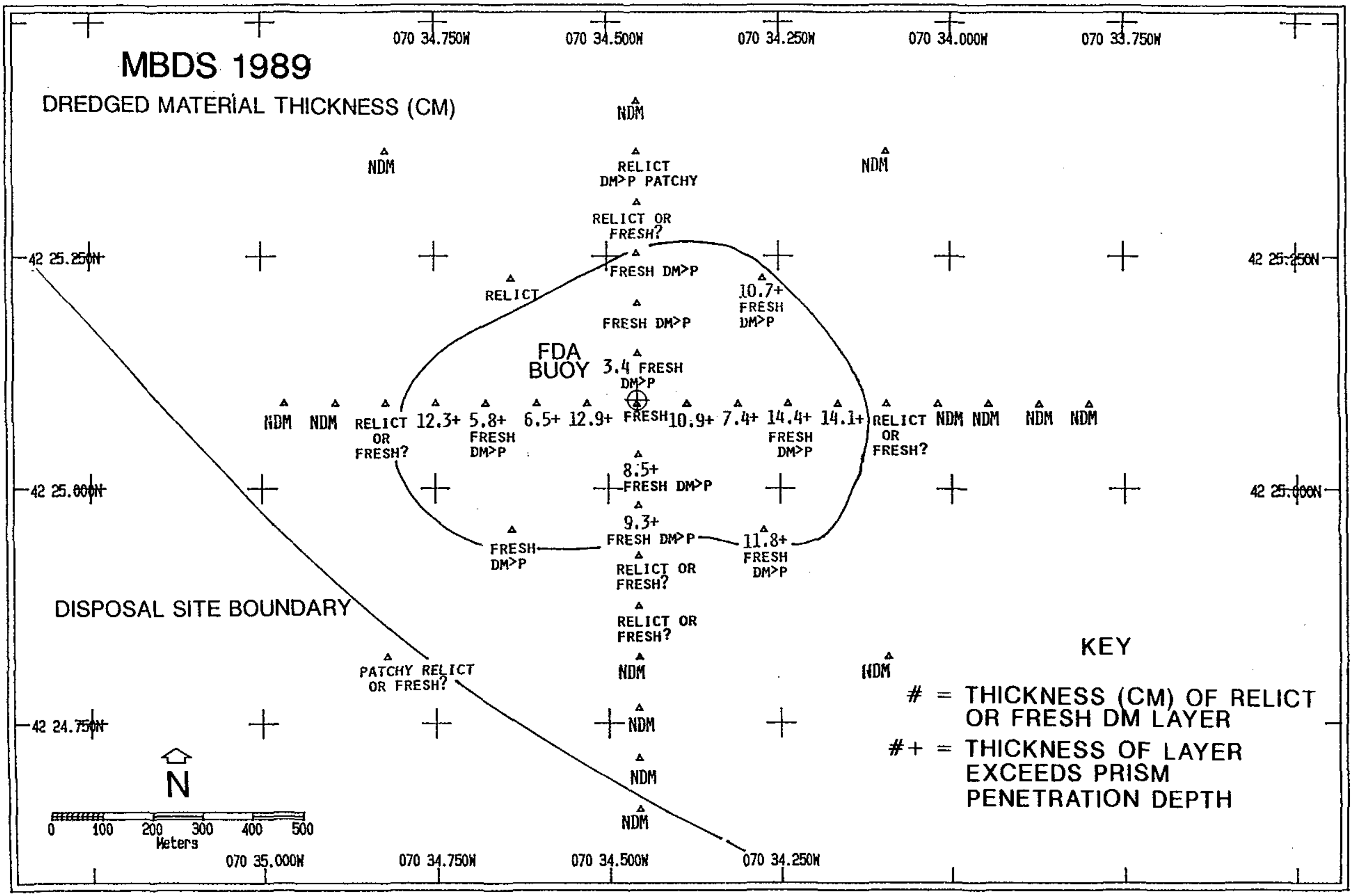


Figure 3-6. Map showing the distribution of dredged material based on REMOTS® photography at the "FDA" buoy, January 1989. The contour delimits the extent of dredged material deposited since the January 1987 survey (i.e., "fresh" dredged material).

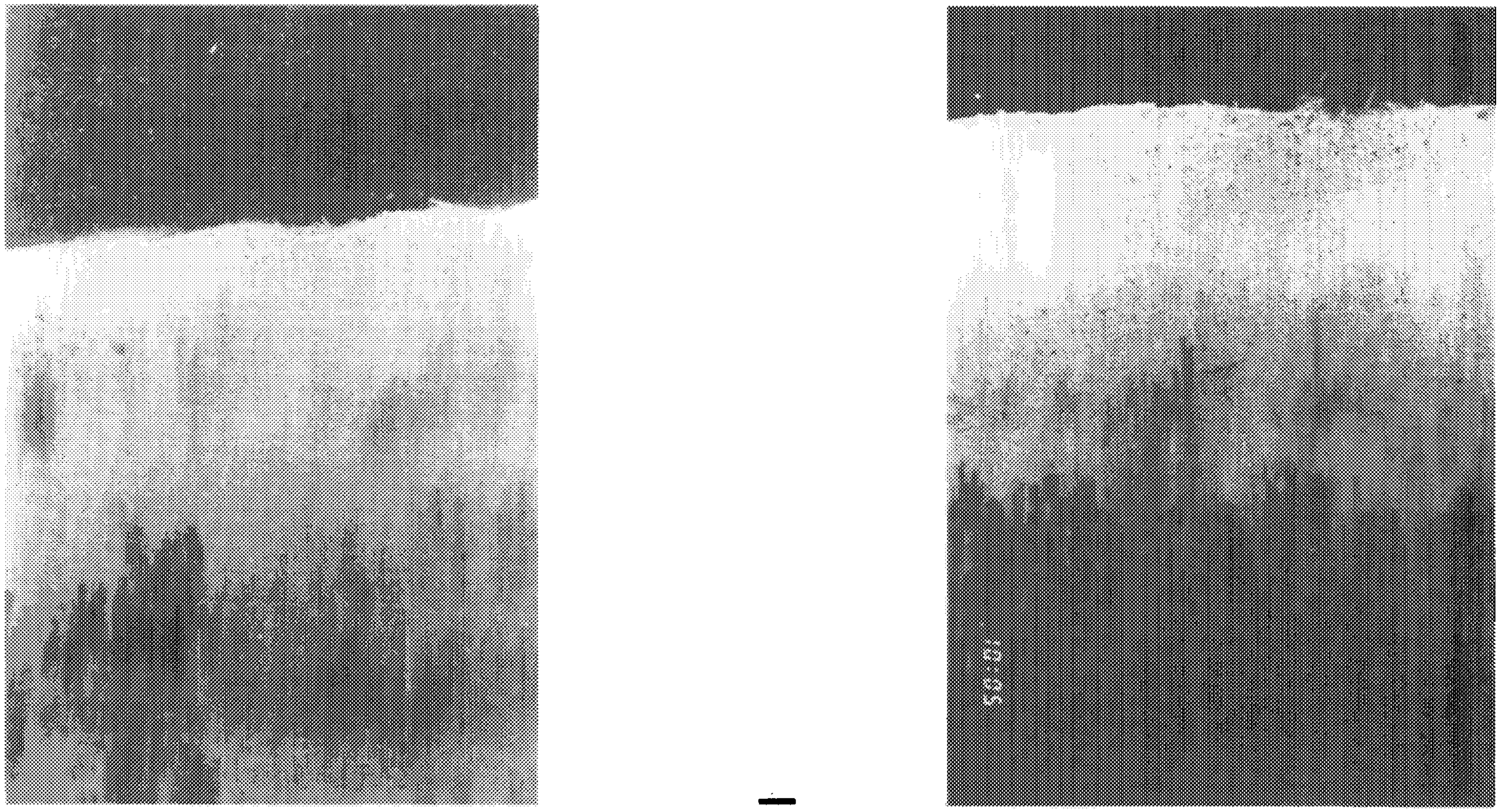
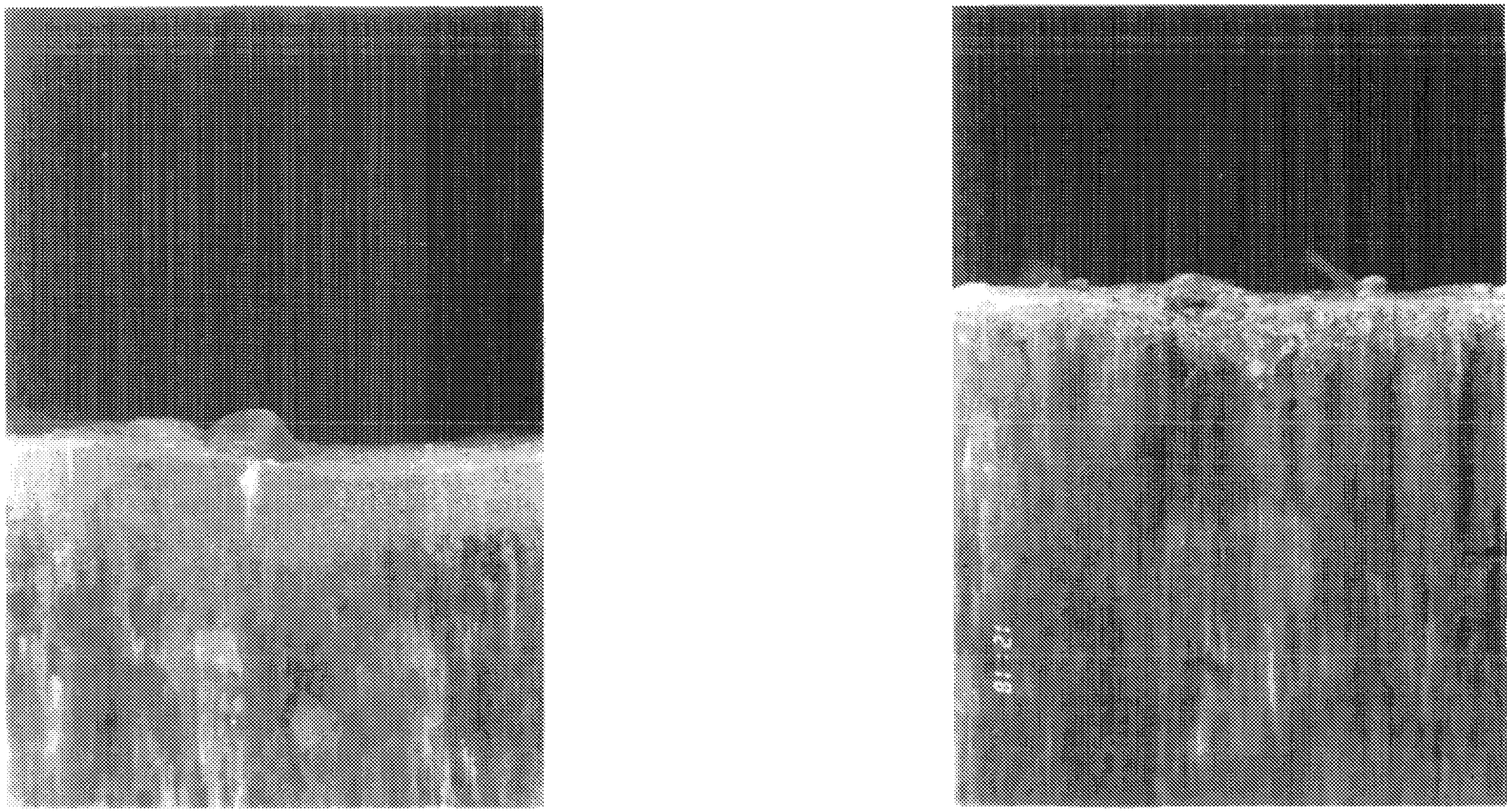


Figure 3-7. REMOTS® photographs from station 500E (A) and 300S (B) showing the presence of apparent relict dredged material on the flanks of the mound. Scale = 0.5X.



A 1 CM B

Figure 3-8. REMOTS® photographs from station 100E (A) and 200W (B) showing a "chaotic" mixture of silts, fine sands and sands intermixed with clay in the recently deposited dredged material. Scale = 0.5X

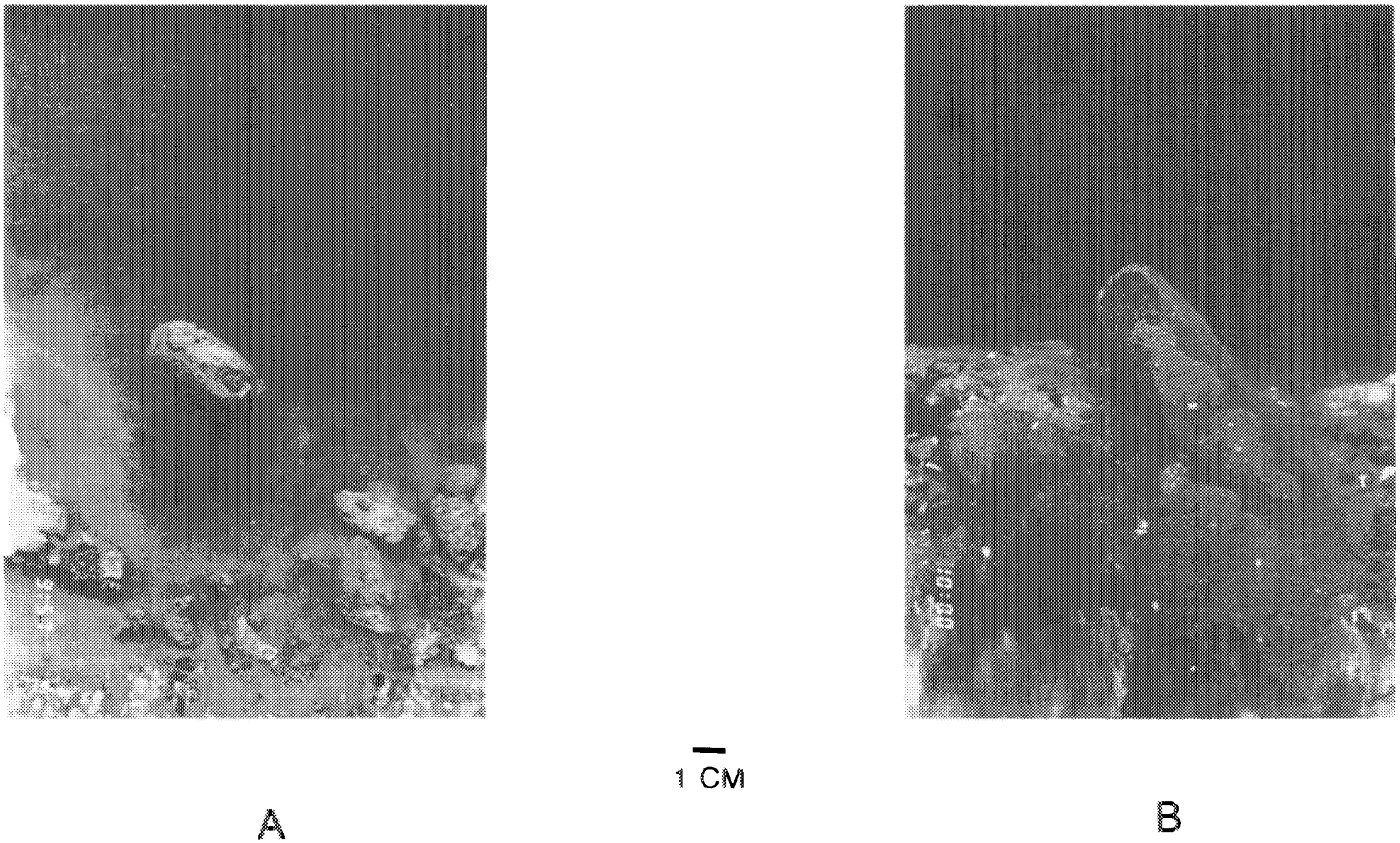


Figure 3-9. REMOTS® photographs from station CTR (A) and 100S (B) showing overconsolidated clay clasts and rubble at the surface and limited camera penetration. Scale = 0.5X.

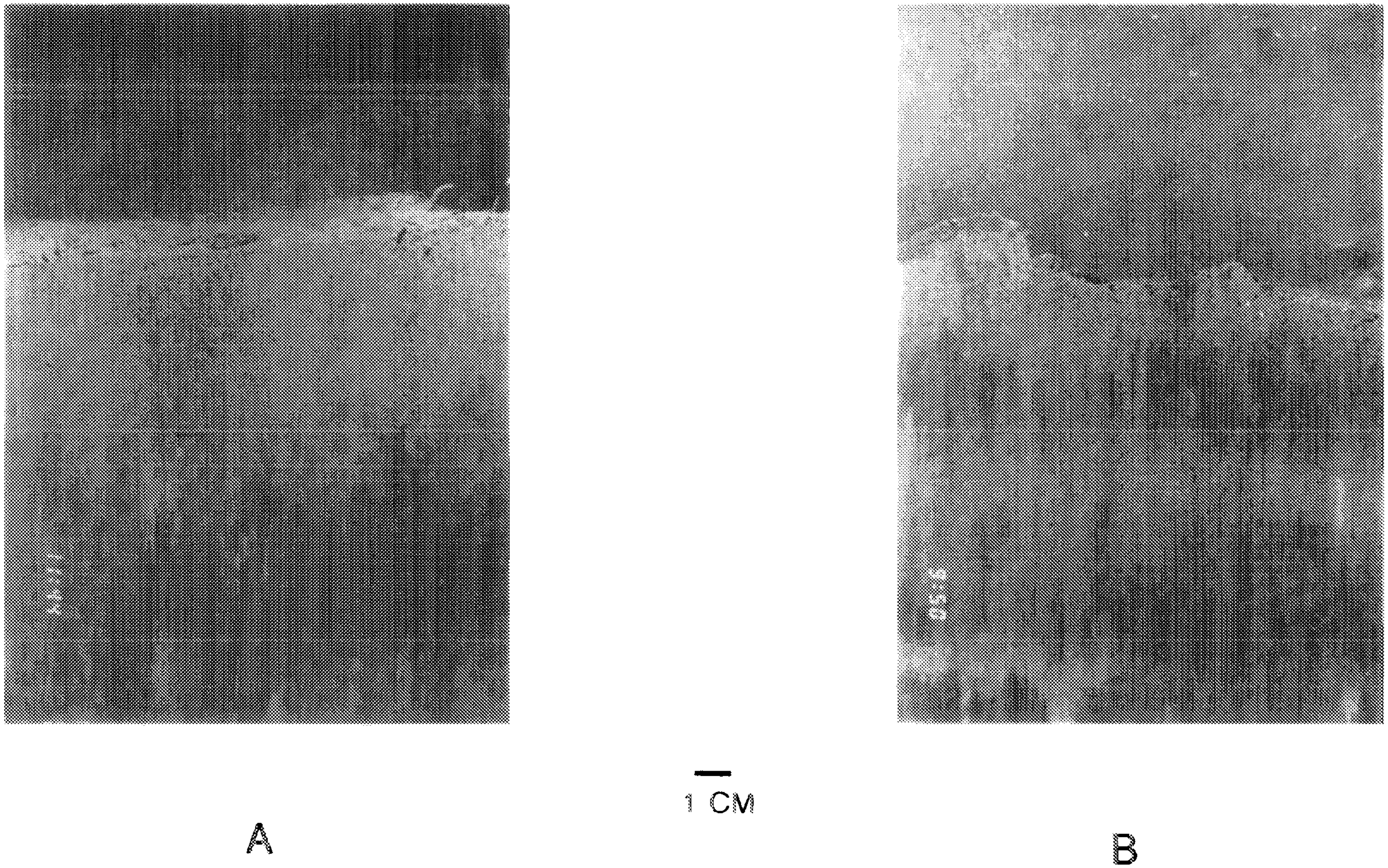


Figure 3-10. REMOTS® photographs from station 250SW (A) and 200N (B) showing less consolidation and deeper camera penetration with more stratification. Scale = 0.5X.

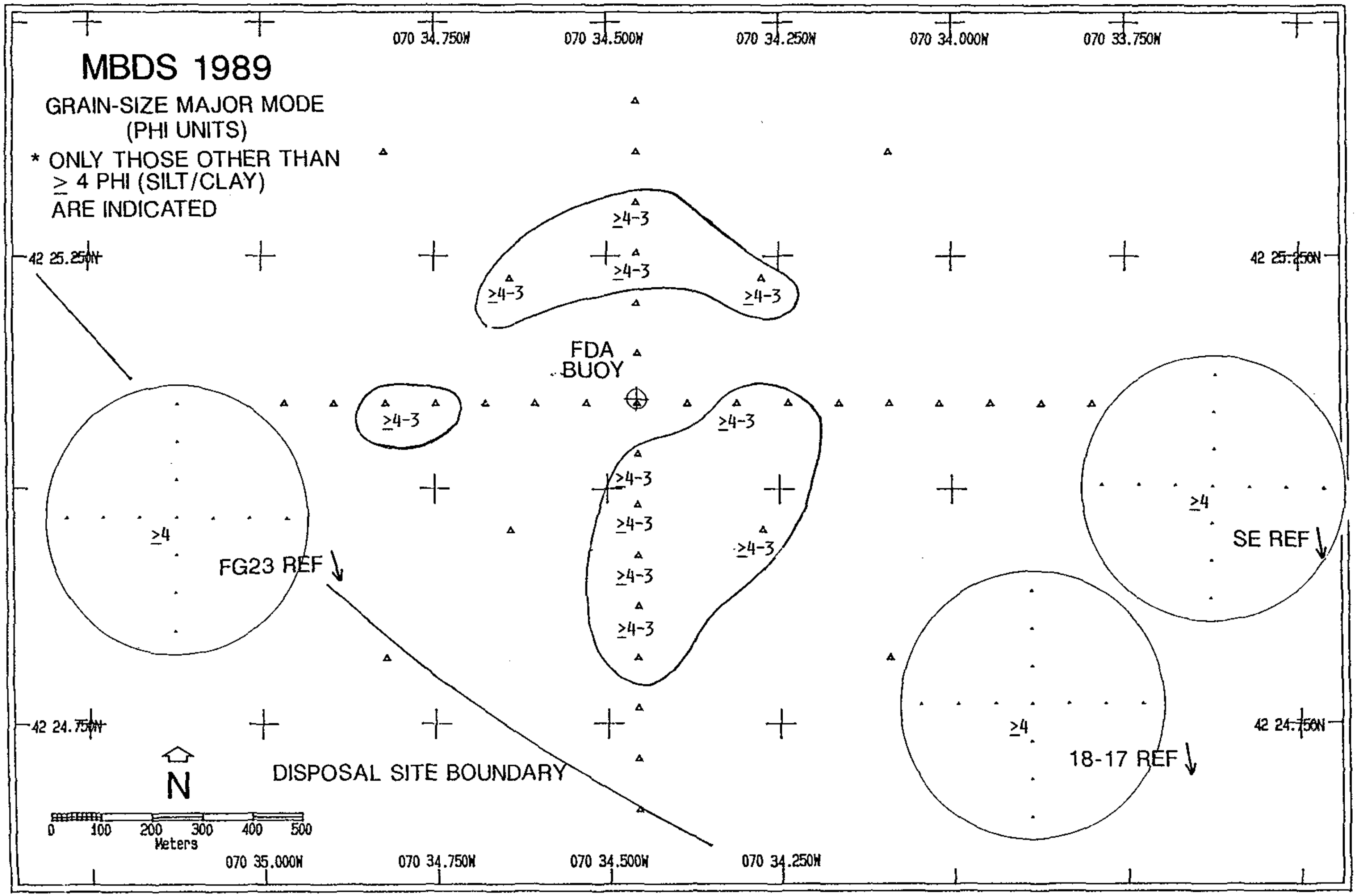


Figure 3-11. Map of sediment grain size major mode (in phi units) at FADS, January 1989.

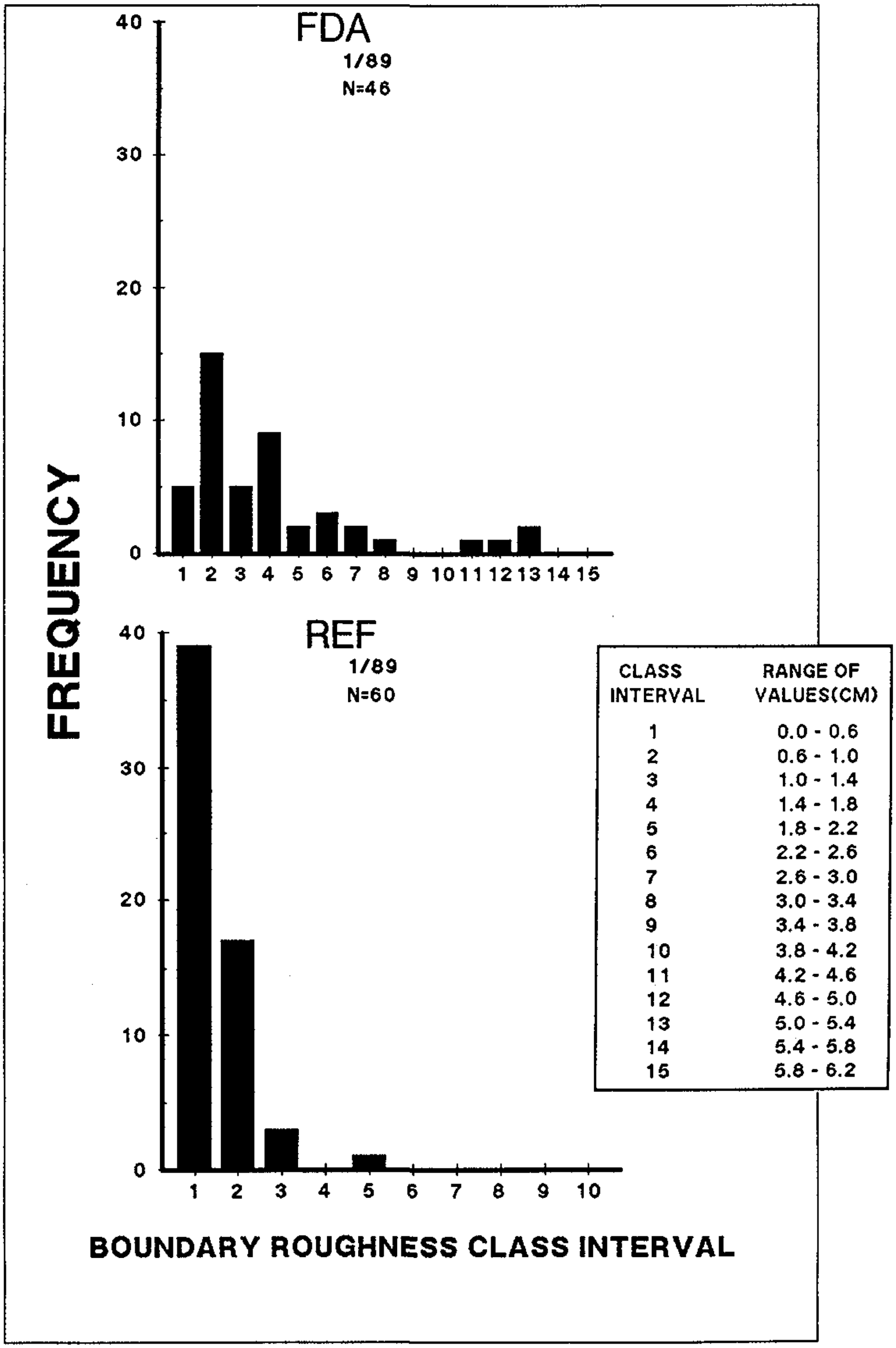


Figure 3-12. Frequency distribution of small-scale surface boundary roughness values for all replicates at the reference stations and at the FDA buoy stations where fresh dredged material was present, January 1989 (n = number of replicates).

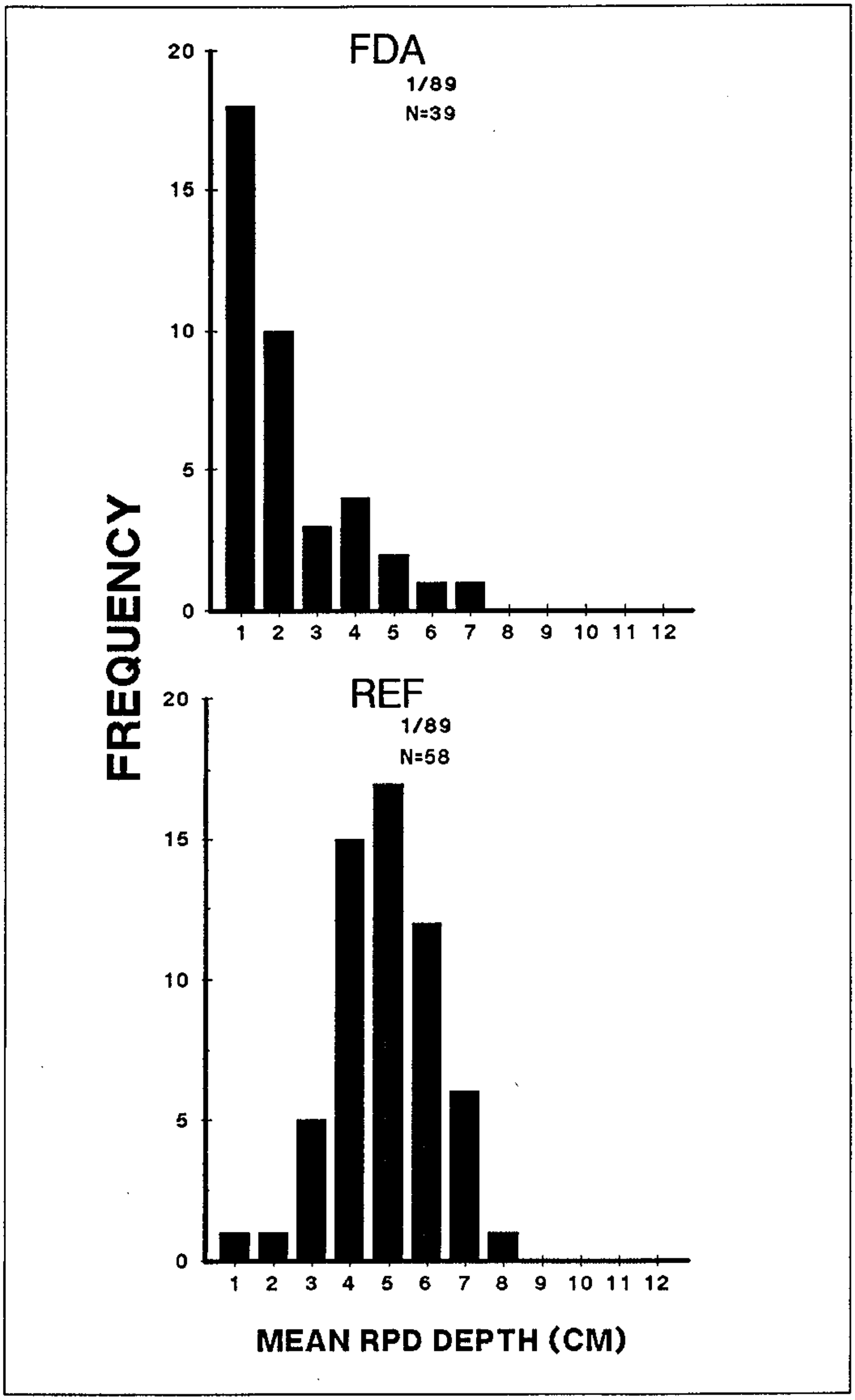


Figure 3-13. Frequency distributions of apparent RPD depths for all replicates at the reference stations and the FDA buoy stations where dredged material was present, January 1989.

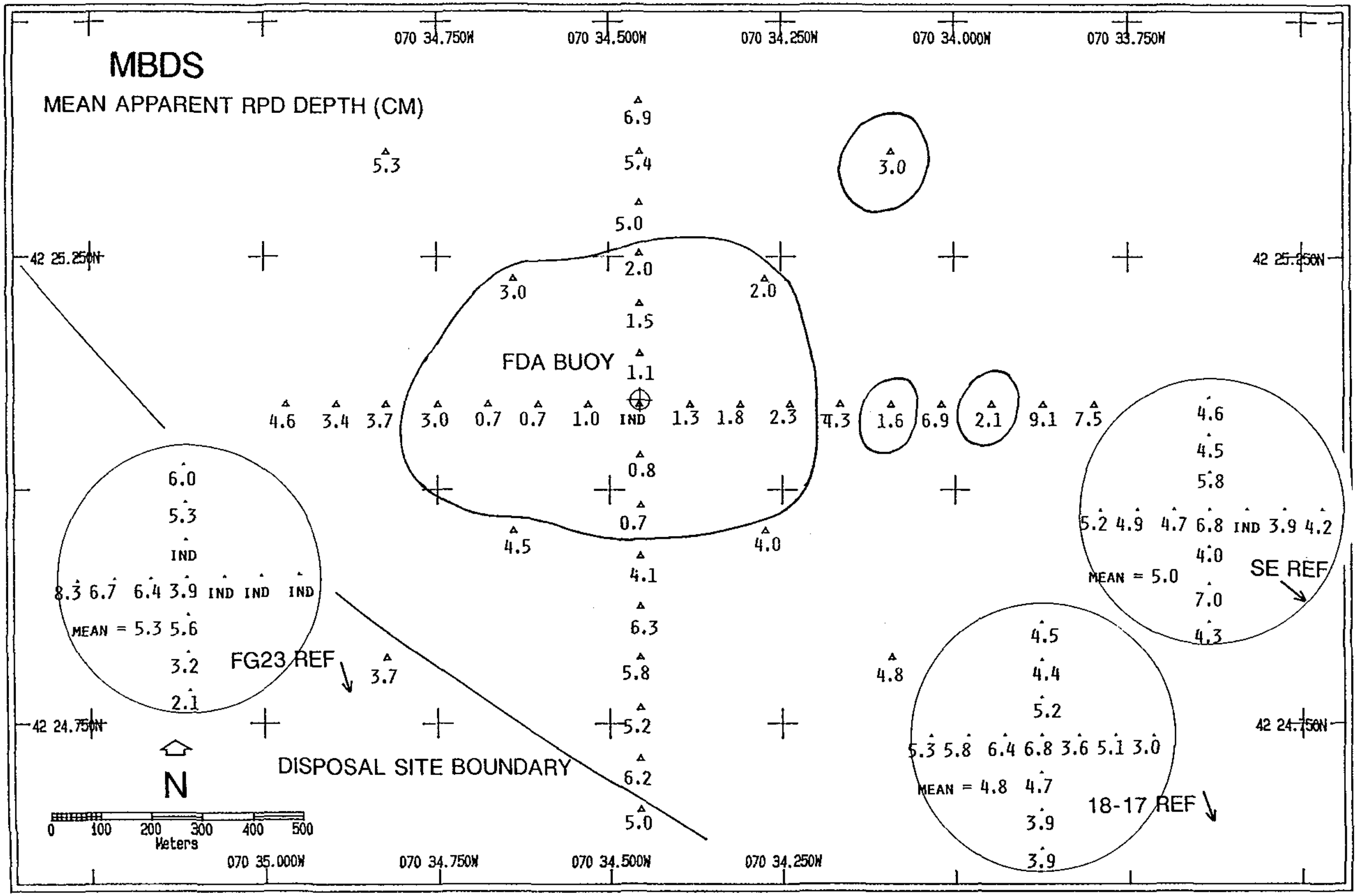


Figure 3-14. The mapped distribution of apparent RPD depths (cm), averaged by station, at the FDA buoy in January 1989. The contours delimit stations having mean apparent RPD depths ≤ 3 cm.

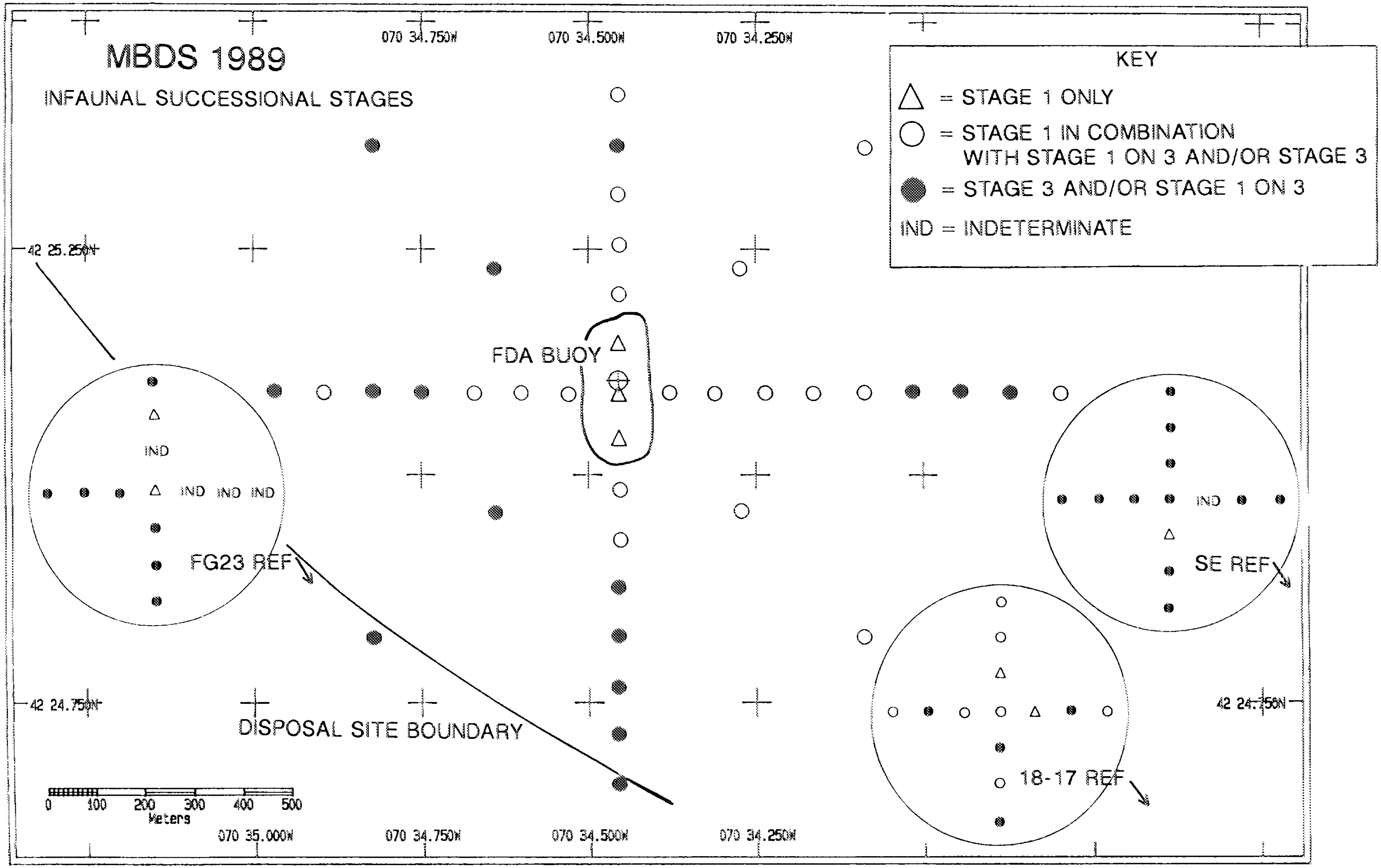
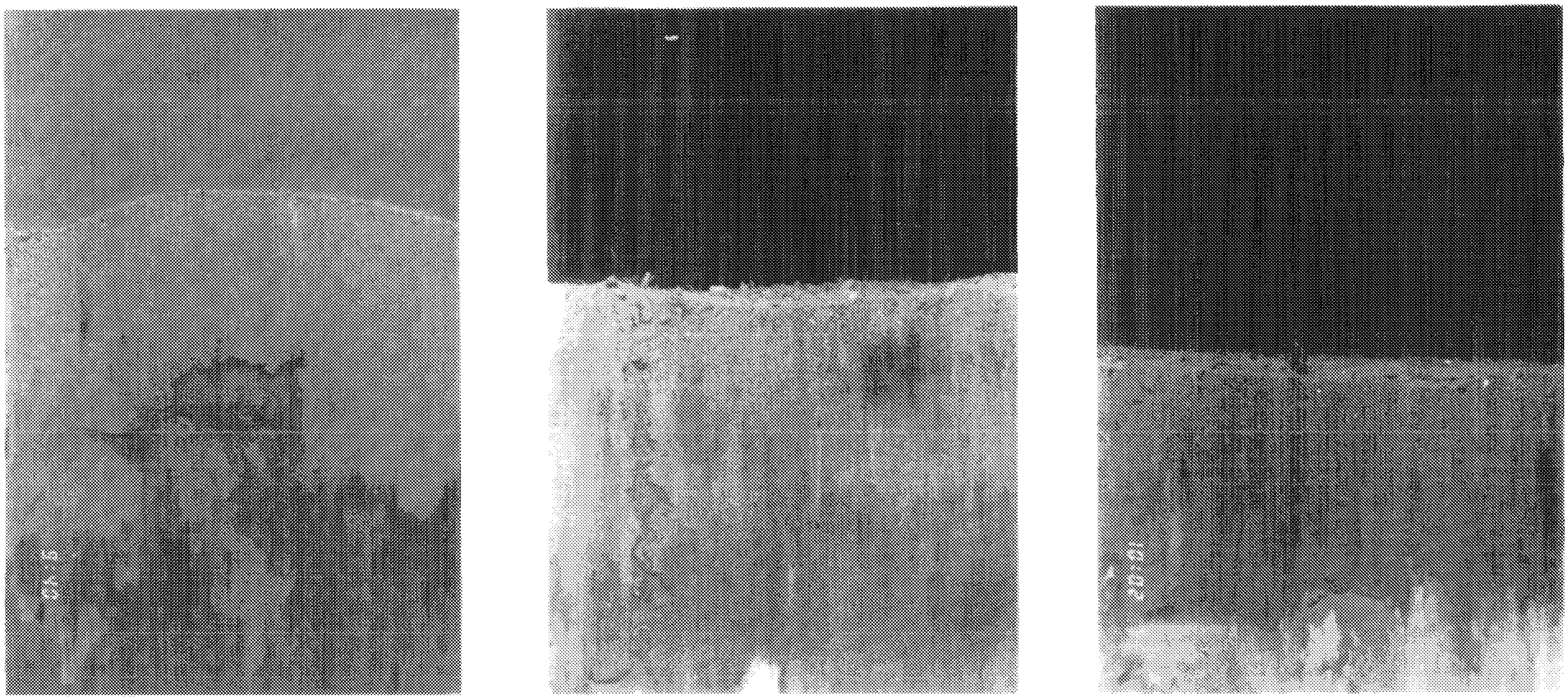


Figure 3-15. The mapped distribution of infaunal successional stages at the FDA buoy, January 1989. The contour delimits the disposal site stations where only Stage I seres were seen in the replicate REMOTS® photos.



A B C 1 CM

Figure 3-16. A large feeding void at depth indicates the presence of Stage III organisms at station 500N (A), while the REMOTS® photographs from station 300E (B) and 200S (C) show Stage I on III organisms at the disposal site. Scale = 0.5X.

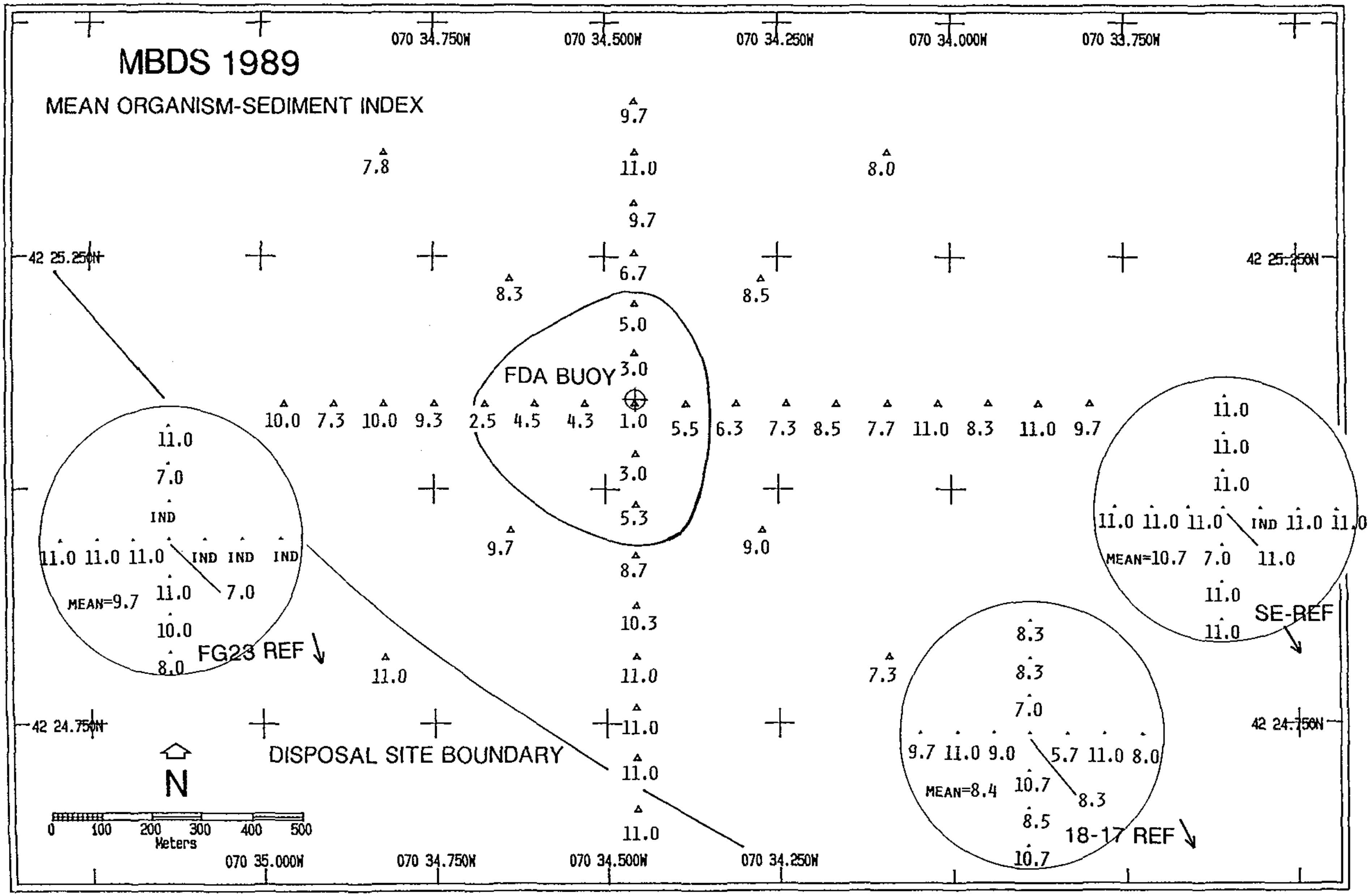


Figure 3-17. The distribution of Organism-Sediment Indices, averaged by station, at the FDA buoy in January 1989. The contour delimits stations having mean OSI values ≤ +6.

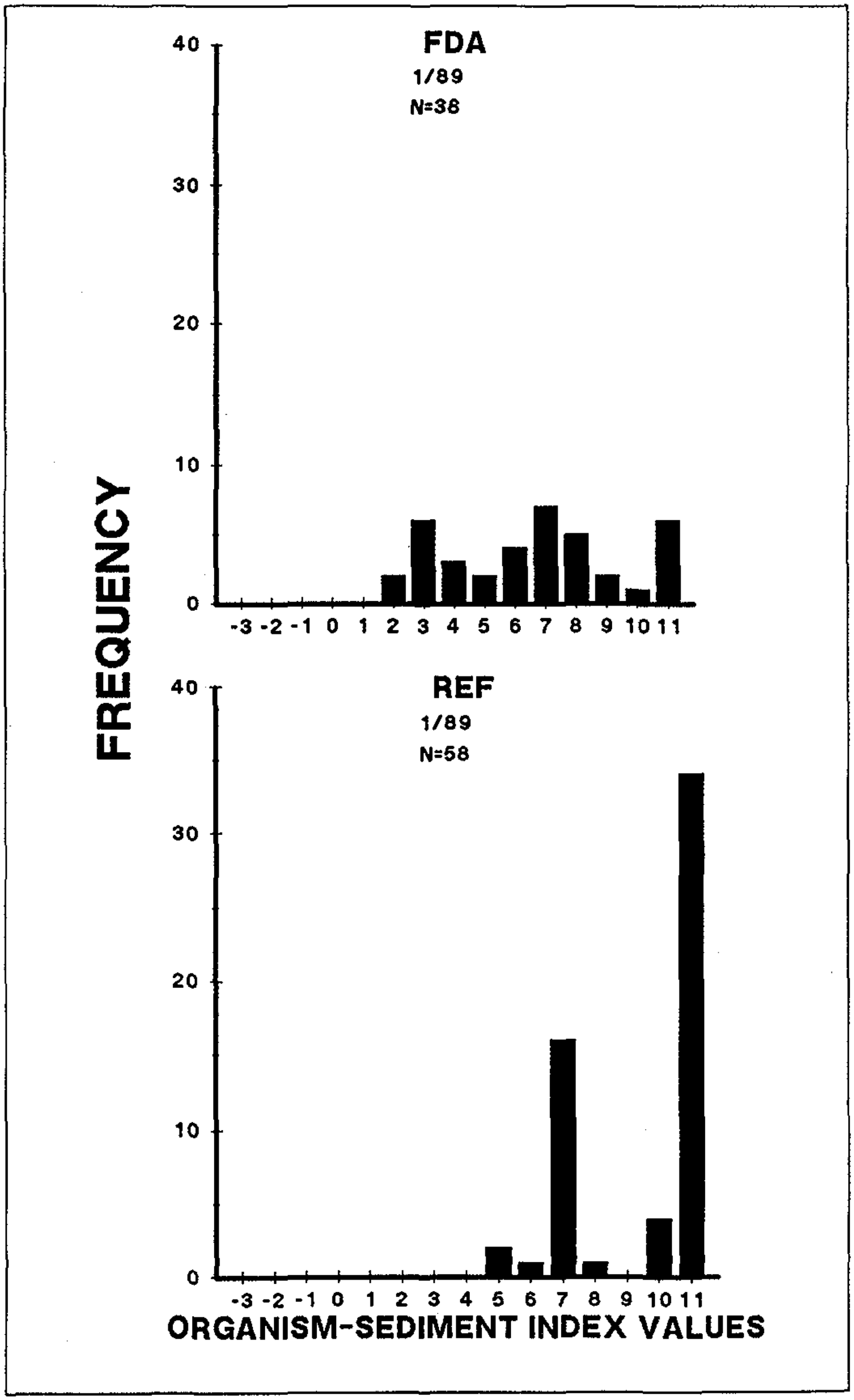
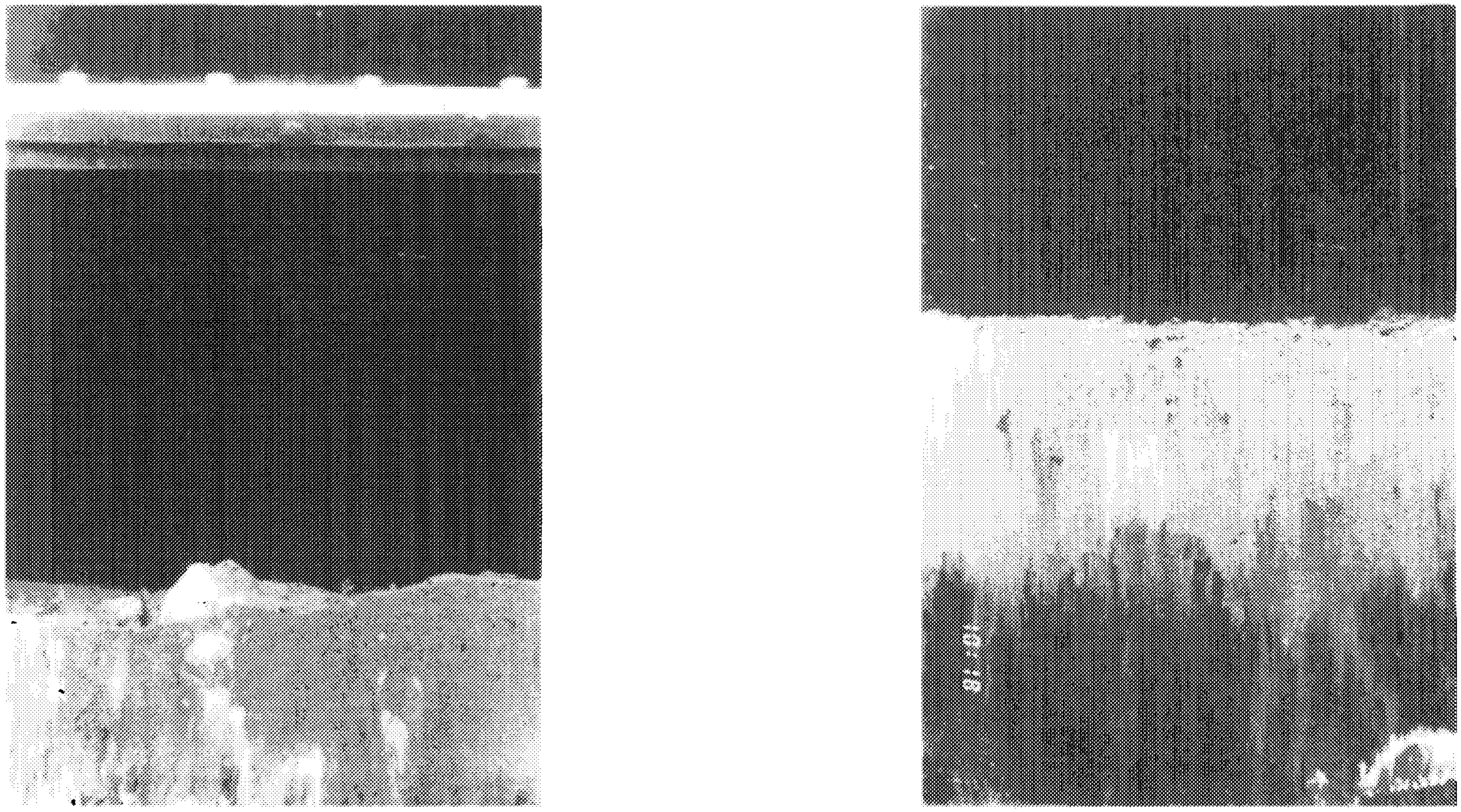


Figure 3-18. Frequency distributions of Organism-Sediment Indices for all replicates at the reference stations and at the disposal site stations where dredged material was present, January 1989.



1 CM

A B

Figure 3-19. REMOTS® photographs from station 200E (A) and 100E (B) showing the presence of dredged material with clay clasts evident at the surface and at depth. It is difficult to estimate how recently this light-colored, highly-consolidated material was deposited. Scale = 0.5X.

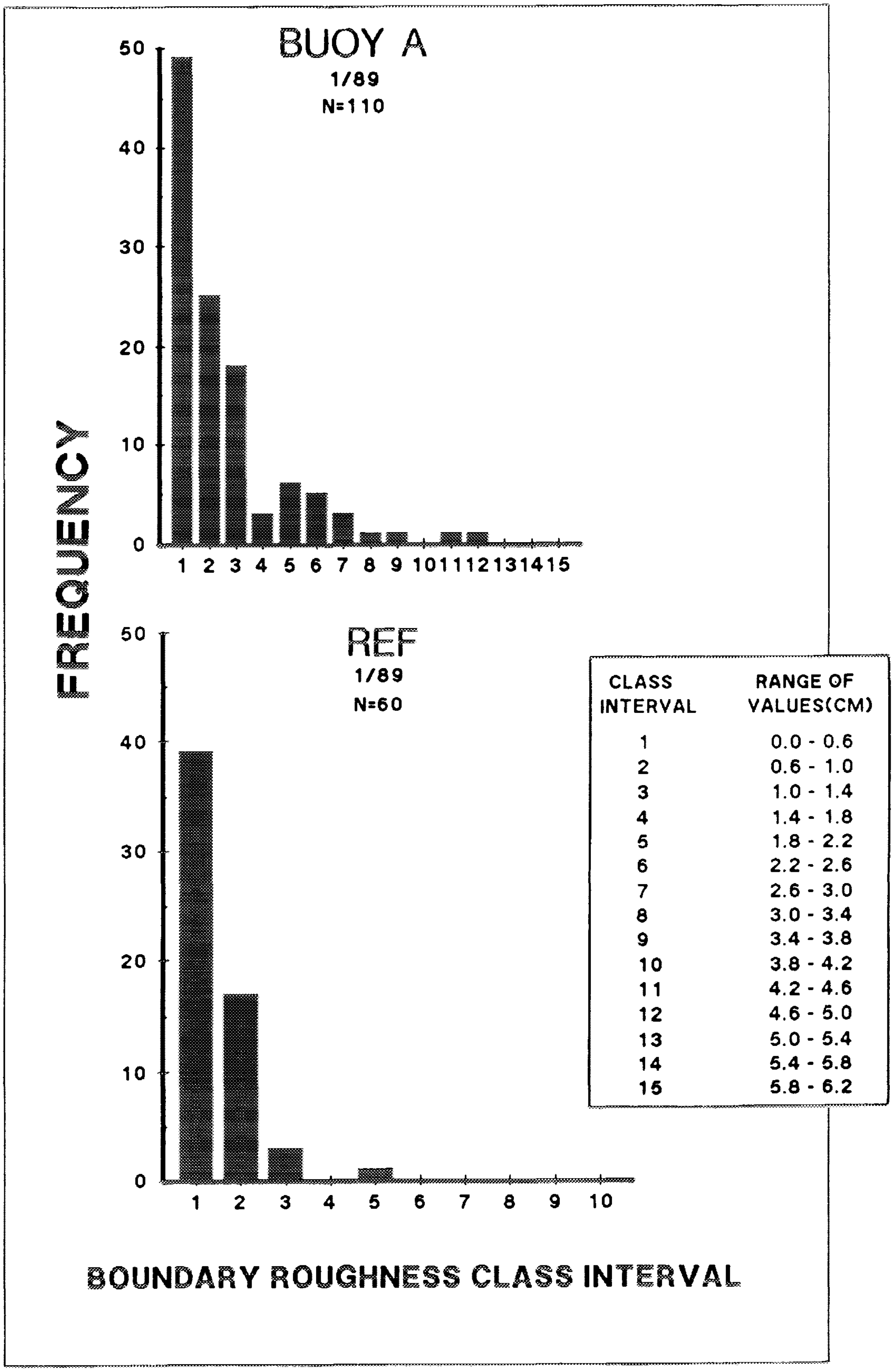


Figure 3-20. Frequency distributions of small-scale surface boundary roughness values for all replicates at both the "A" buoy and reference site stations at MBDS, January 1989.

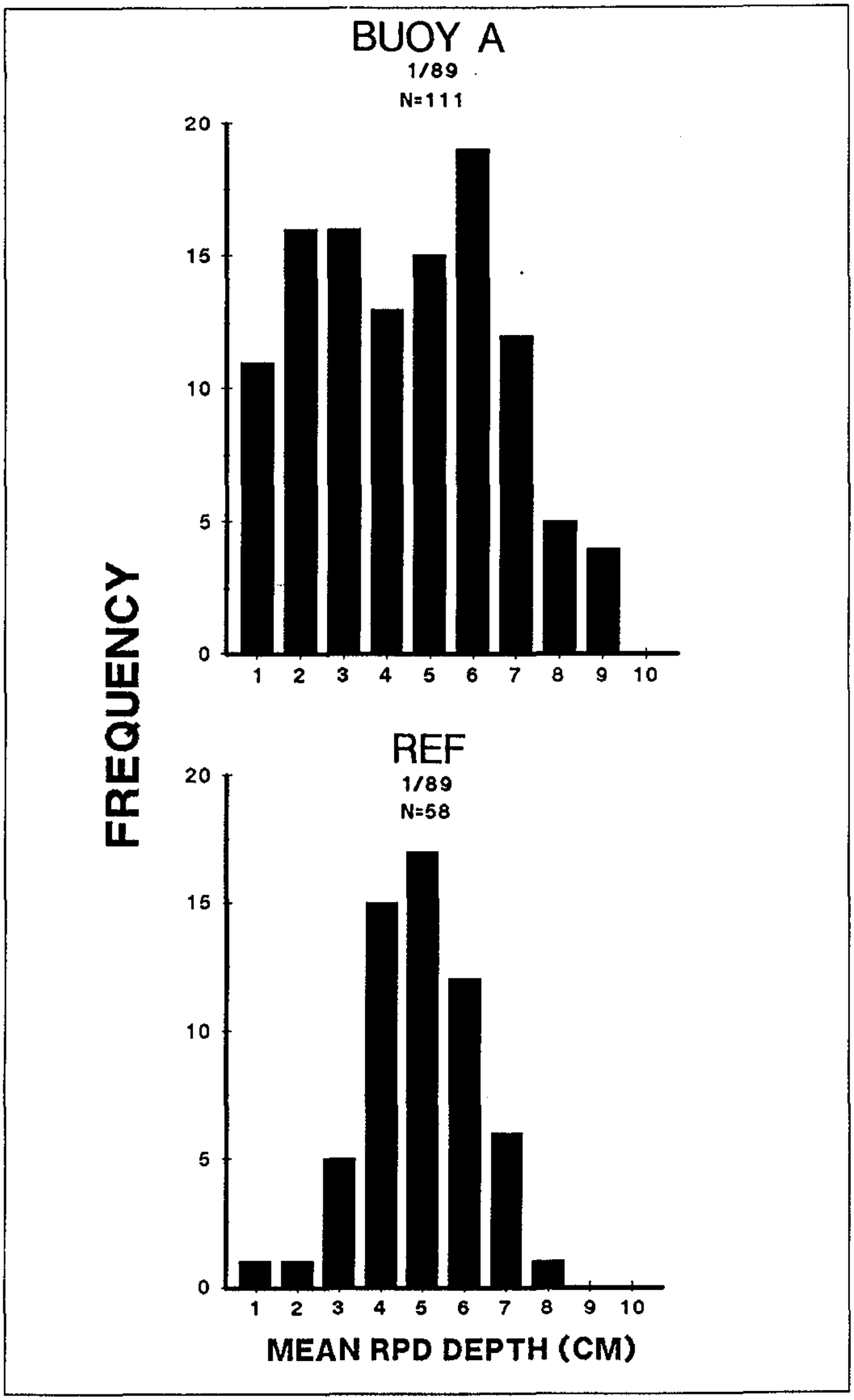


Figure 3-21. Frequency distribution of apparent RPD depths for all replicates at both the "A" buoy and reference site stations at MBDS, January 1989.

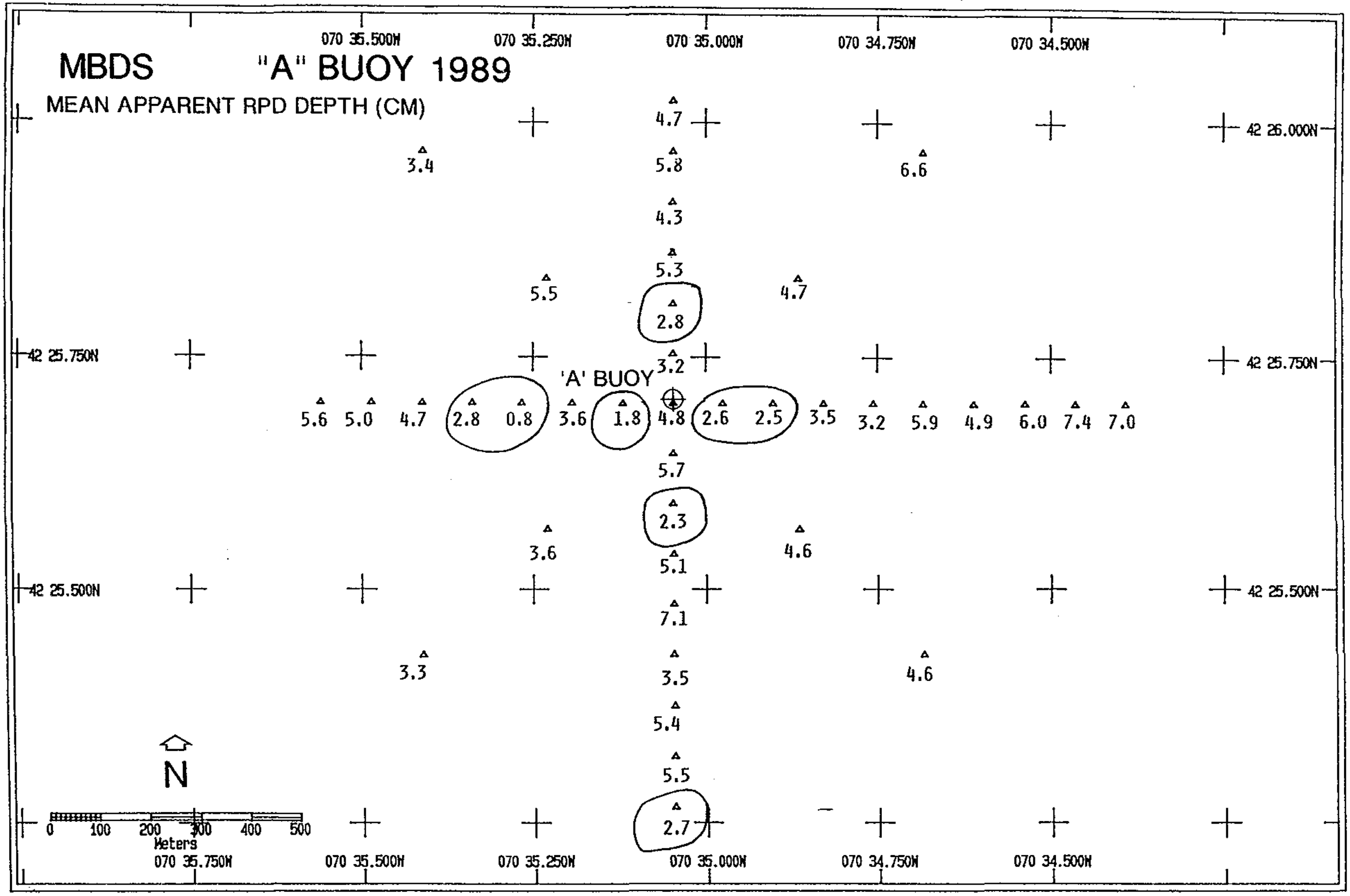


Figure 3-22. The mapped distribution of apparent RPD depths (cm), averaged by station, at the "A" buoy at MBDS, January 1989. The contours delimit stations having mean apparent RPD depths ≤ 3 cm.

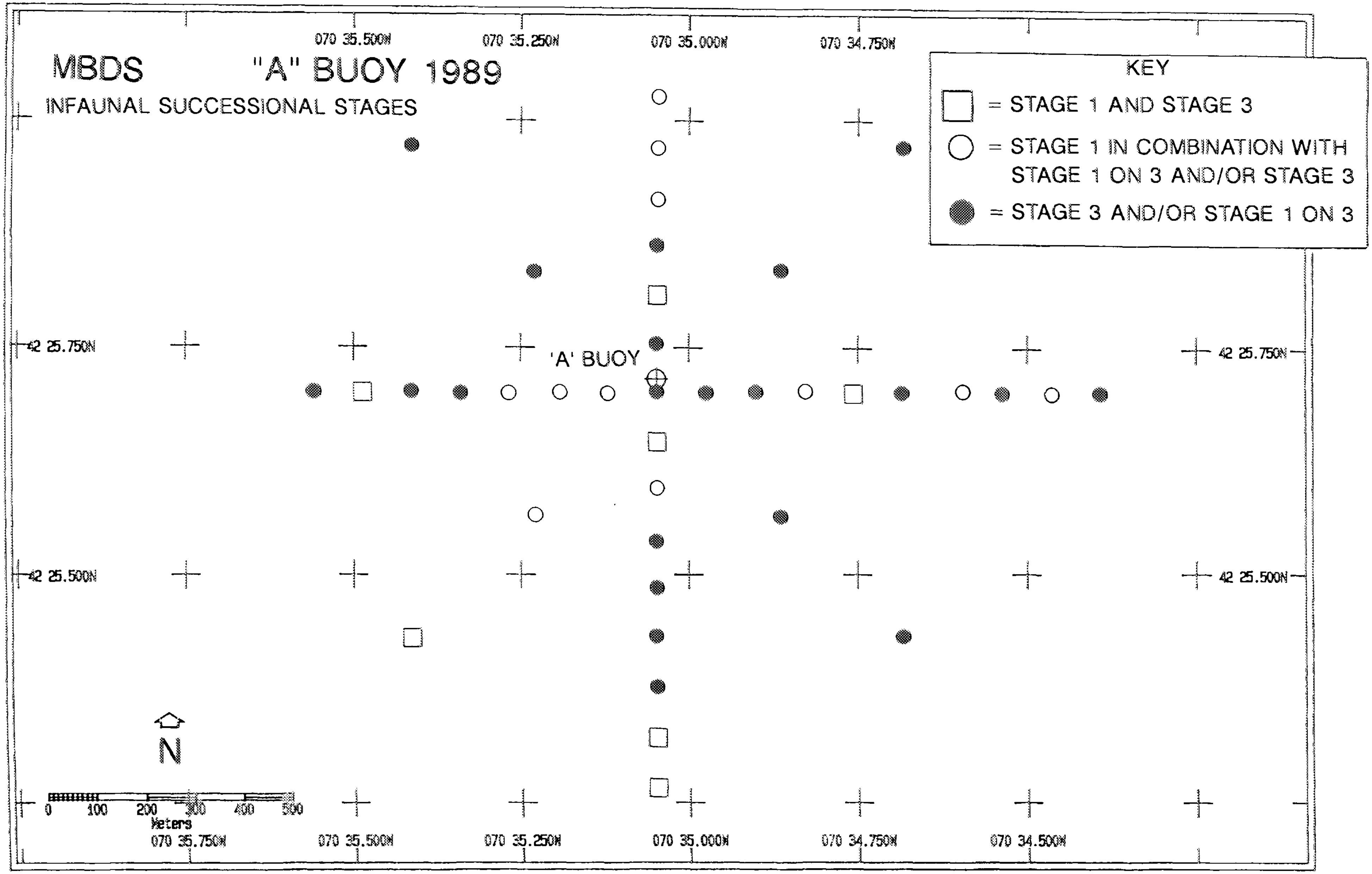
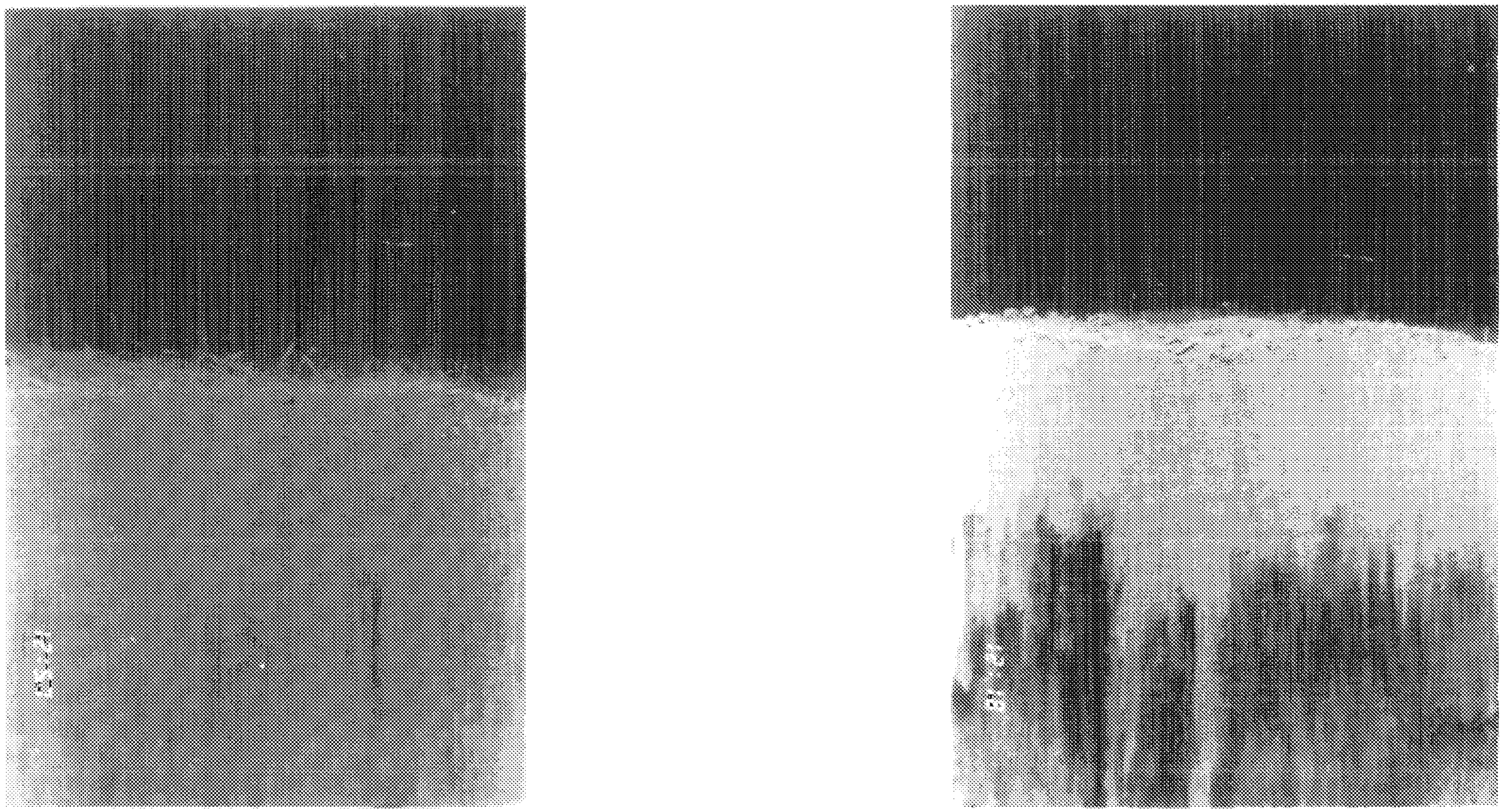


Figure 3-23. The mapped distribution of infaunal successional stages at the "A" buoy at MBDS, January 1989.



A 1 CM B

Figure 3-24. REMOTS® photographs from the vicinity of the "A" buoy showing dense Stage III tubes at the surface (photo A from station 800S) and surface tubes along with a feeding void at depth (lower right hand corner of photo B from station 250NW). Scale = 0.5X.

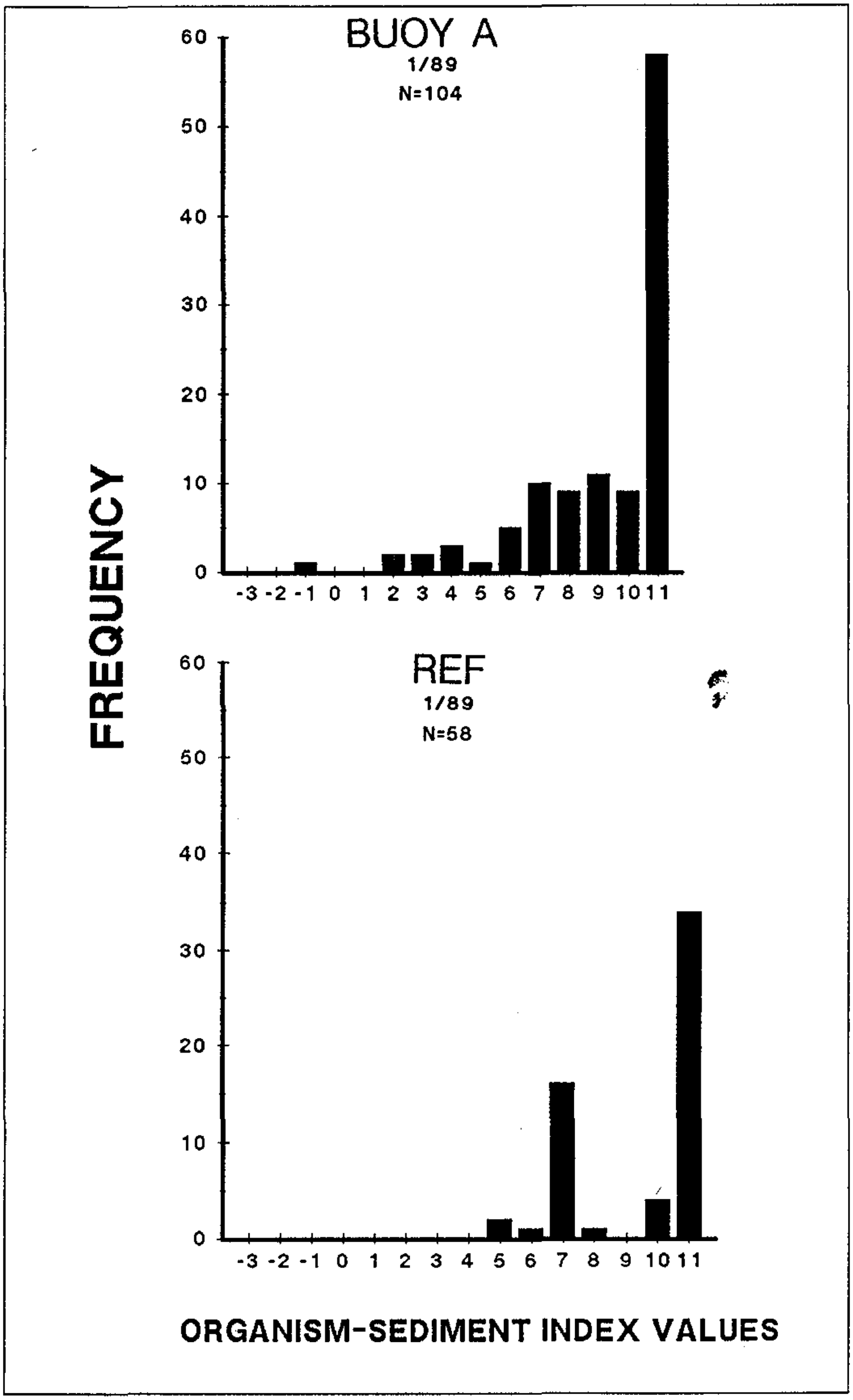


Figure 3-25. Frequency distributions of Organism-Sediment Indices for all replicates at both the reference and "A" buoy stations, January 1989.

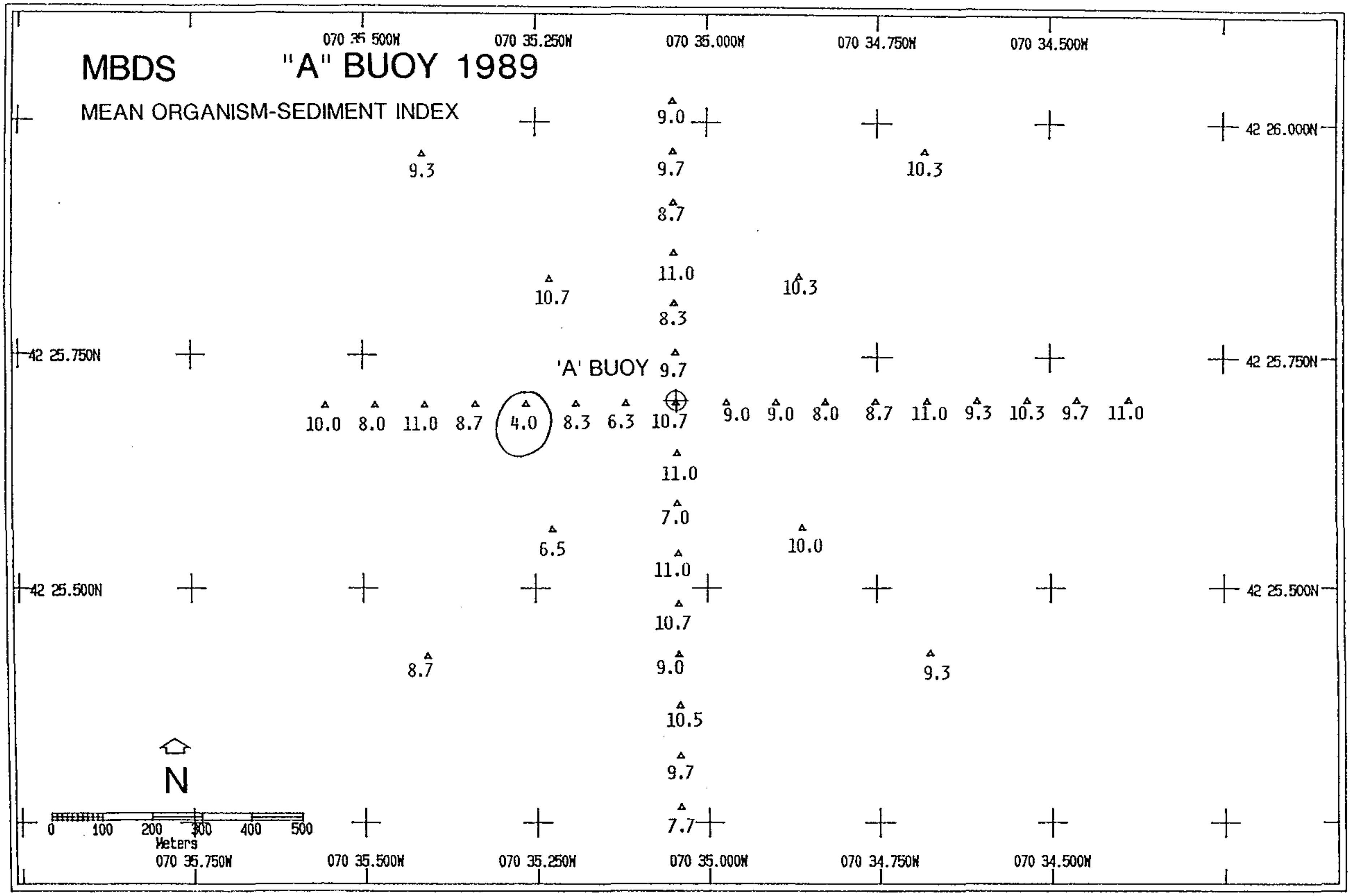


Figure 3-26. The distribution of Organism-Sediment Indices, averaged by station, at the "A" buoy at MBDS, January 1989. The contour delimits the single station (300W) having a mean OSI value ≤ +6.

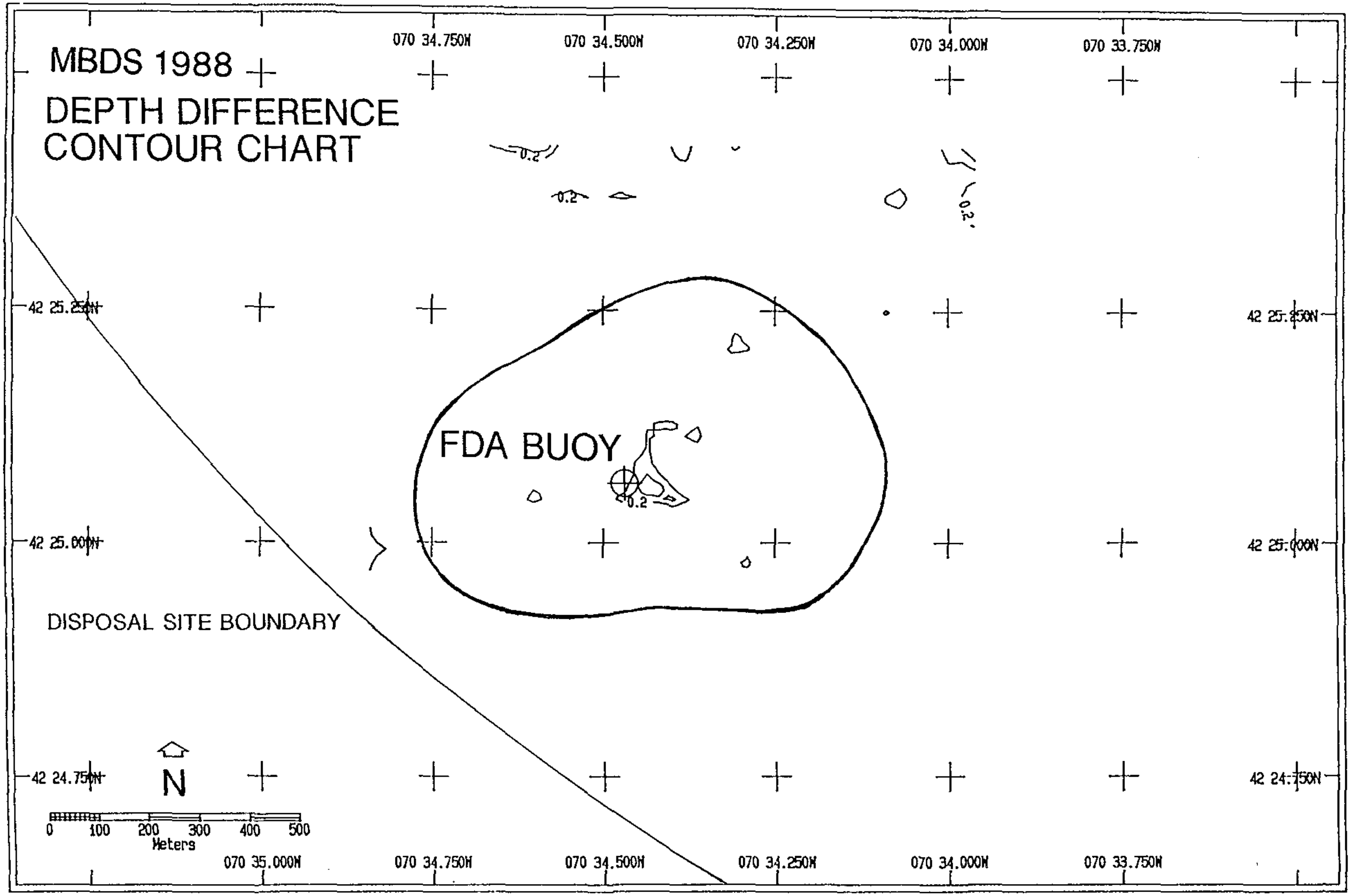


Figure 4-1. Depth difference contour chart with the thick contour line indicating the extent of recently-deposited dredged material around the "FDA" buoy as determined by REMOTS® photography (see Figure 3-6).