Monitoring Cruise at the Cape Cod Canal Disposal Site and Springhill Beach Site, March 1990 - April 1990

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The Cape Cod Canal serves as a major thoroughfare for recreational and commercial vessels transiting Massachusetts waters. For this reason, maintenance dredging of the east end of the Cape Cod Canal and improvement dredging of the East Mooring Basin were conducted by the U.S. Army Corps of Engineers during the spring of 1990. The fine grained sediments from these projects were released at the Cape Cod Canal Disposal Site (CCDS) and the sandier material was sent to Springhill Beach. The CCDS has been used periodically for similar dredging operations. The objective of disposal at Springhill Beach was to create a small feeder berm.

The fine grained material released at CCDS formed a mound 1.0 m in height within a 300 m radius of the "CCD" disposal buoy. A comparison of pre- and postdisposal bathymetry generated a volume difference of 21,823 m^3 (95% confidence limits of 10,739 m^3 and 32,908 m^3). This agreed closely with the barge log volume estimates of 15, 296 m^3. The REMOTS® survey, consisting of a 15 station east-west transect over a historic disposal mound at CCDS, showed recolonization by Stage II infauna near the mound center. No distinct dredged material layers were present anywhere along the transect. However, the continued effect of dredged material disposal was apparent at the center and eastern end of the survey while ambient conditions existed at the western end. Scouring and winnowing were evident at some stations near the mound center.

The depth difference analysis at the Springhill site revealed four distinct disposal mounds, ranging from 2.1 to 2.3 m in height. General shoaling and redistribution of sediments around the area of the individual disposal mounds were apparent. Barge disposal logs estimated 87,628 m^3 of material were deposited at the Springhill site. Volume calculations showed an estimated 83,972 m^3 (95% confidence limits of 67,736 and 98,208 m^3) of dredged material had accumulated, indicating barge log records for both the CCDS and Springhill sites were in good agreement with the survey calculations. Additional bathymetric surveys after a period of time (e.g., six months) could provide evidence as to whether or not the Springhill site is serving as a feeder berm for the beach area.

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EXECUTIVE SUMMARY

The Cape Cod Canal serves as a major thoroughfare for recreational and commercial vessels transiting Massachusetts waters. For this reason, maintenance dredging of the east end of the Cape Cod Canal and improvement dredging of the East Mooring Basin were conducted by the U.S. Army Corps of Engineers during the spring of 1990. The fine grained sediments from these projects were released at the Cape Cod Canal Disposal Site (CCDS) and the sandier material was sent to Springhill Beach. The CCDS has been used periodically for similar dredging operations. The objective of disposal at Springhill Beach was to create a small feeder berm.

The optimal management of both sites required pre- and postdisposal bathymetric surveys. These surveys were used to map the areal distribution of the dredged material and measure changes in depth before and after disposal. In addition, a REMOTS® sediment-profile photographic survey was conducted at CCDS to map the dredged material below the resolution of the acoustic bathymetric survey and assess the recolonization status of the historical disposal mound at the site.

The fine grained material released at CCDS formed a mound 1.0 m in height within a 300 m radius of the "CCD" disposal buoy. A comparison of pre- and postdisposal bathymetry generated a volume difference of 21,823 m^3 (95% confidence limits of 10,739 m^3 and 32,908 m^3). This agreed closely with the barge log volume estimates of 15,296 m^3. The REMOTS® survey, consisting of a 15 station east-west transect over a historic disposal mound at CCDS, showed recolonization by Stage II infauna near the mound center. No distinct dredged material layers were present anywhere along the transect. However, the continued effect of dredged material disposal was apparent at the center and eastern end of the survey while ambient conditions existed at the western end. Scouring and winnowing were evident at some stations near the mound center.

The depth difference analysis at the Springhill site revealed four distinct disposal mounds, ranging from 2.1 to 2.3 m in height. General shoaling and redistribution of sediments around the area of the individual disposal mounds were apparent. Barge disposal logs estimated 87,628 m^3 of material were deposited at the Springhill site. Volume calculations showed an estimated 83,972 m^3 (95% confidence limits of 67,736 and 98,208 m^3) of dredged material had accumulated, indicating that barge log records for both the CCDS and Springhill sites were in good agreement with the survey calculations. Additional bathymetric surveys after a period of time (e.g., six months) could provide evidence as to whether or not the Springhill site is serving as a feeder berm for the beach area.

1.0 INTRODUCTION

Maintenance dredging of the east end of the Cape Cod Canal and improvement dredging of the East Mooring Basin were conducted by the U.S. Army Corps of Engineers during the spring of 1990. The dredged material from this project was released at two locations. The fine grained dredged material (15,296 m^3) was brought to the Cape Cod Canal Disposal Site (CCDS) and the sandy sediments (87,628 m^3) were released off Springhill Beach. The CCDS is located in Cape Cod Bay approximately 3 nm northeast of Cape Cod Canal Buoy #1 (Figure 1-1). This site consists of a 1 nm diameter circle centered at 41° 49'N and 70° 25'W. Presently not considered a regional site, CCDS has been used periodically for canal and other dredging operations. The Springhill Beach site is located in East Sandwich, MA at approximate mean low water (MLW) depths of 4.5 to 10.5 m. The Springhill Beach site is 3.5 nm south southwest of CCDS (Figure 1-1).

Predisposal field operations began 19 March 1990 with the deployment of two marker buoys at the Springhill Beach Site and one buoy within CCDS. A predisposal bathymetric survey was done at CCDS on 22 March 1990, and at the Springhill Beach Site on 23 March 1990. After the dredged material was released at the sites, postdisposal surveys were conducted on 24 April at CCDS and on 24 and 25 April at Springhill. The pre- and postdisposal bathymetric surveys were conducted to determine changes in bathymetry due to the recent disposal.

An historic disposal mound exists at CCDS. It was most likely formed by the disposal of 228,735 m^3 of dredged material in 1980. A fifteen station REMOTS® sediment-profile photographic survey was conducted across the apex of this mound on 25 April to assess its infaunal recolonization status.

2.0 METHODS

2.1 Buoy Deployment

Marker buoys were deployed at the CCDS and Springhill Beach Sites to serve as navigational aids for disposal operations. Two small "lollipop" buoys were deployed at the Springhill Beach Site at a depth of 4.5 m MLW. The buoys were located at 41° 45.439'N, 70° 26.913'W and 41° 45.281'N, 70° 26.225'W along an axis running roughly parallel to the beach.

One marker buoy, "CCD", was deployed within CCDS at 41° 49.007'N and 70° 25.426'W (Figure 2-1). This location is approximately 600 meters west of the center of the CCDS in approximately 23 m of water.

2.2 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 at known benchmarks at Telegraph Hill, Sandwich, and Indian Hill, Plymouth. A detailed description of the navigation system and its operation can be found in the DAMOS QA/QC Plan (SAIC, 1990d).

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. During analysis, raw bathymetric data were adjusted for speed of sound and for changes in tidal height during the survey. A detailed discussion of the bathymetric analysis technique is also given in DAMOS QA/QC Plan (SAIC, 1990d).

The predisposal bathymetric survey, conducted at the "CCD" buoy on 22 March 1990, encompassed a 1200 x 1200 m grid with 25 m lane spacing, centered at coordinates 41° 49.000'N and 70° 25.430'W (Figure 2-1). The postdisposal CCDS survey, conducted on 24 April 1990, was extended an additional 300 meters to the east of the predisposal grid encompassing a 1200 x 1500 m grid with 25 m lane spacing (Figure 2-2).

The Springhill Beach predisposal bathymetric survey conducted on 23 March 1990 consisted of a 2000 x 1000 m grid with 25 m lane spacing (Figure 2-3). Survey lanes were oriented at a bearing of 288° true, running parallel to the axis defined by the two marker buoys deployed at the site. This same grid was used for the postdisposal Springhill Beach Site survey conducted on 24 and 25 April. The volume of accumulated material was calculated for both the Springhill Beach and CCDS sites.

2.3 REMOTS® Sediment-Profile Photography

REMOTS® photography was used to detect the distribution of thin (1 to 20 cm) dredged material layers and assess the progress of infaunal recolonization at and around the historical CCDS disposal mound. REMOTS® photograph acquisition, analysis, and interpretative rationale were described in detail in DAMOS Contribution #60 (SAIC, 1989).

REMOTS® stations were occupied on 25 April. Three replicate photographs were obtained at each of 15 stations (Figure 2-4) situated along an east-west transect through the center of the historical CCDS disposal mound as determined from analysis of the postdisposal bathymetric data. Stations were spaced 50 m apart and extended 350 m east and west of the designated mound center located at 41° 49.189'N and 70° 24.947'W (Figure 2-2).

3.0 RESULTS

3.1 Bathymetry

3.1.1 Cape Cod Canal Disposal Site

Analysis of the predisposal bathymetry at the CCDS revealed a portion of what appeared to be an historical disposal mound in the northeast corner of the survey grid (Figure 3-1). The postdisposal CCDS survey was extended 300 m eastward in order to delineate more clearly the boundary of this mound (Figure 3-2). Postdisposal analysis indicated the minimum depth of this mound was 19.3 m, approximately 4 m in height compared to ambient water depths of 23 m.

All analyses of depth differences between pre- and postdisposal surveys were calculated using only that 1200 x 1200 m region which was included in both pre- and postdisposal survey grids. The depth difference contour plot (Figure 3-3) indicated that the majority of the dredged material was deposited within a 300 m radius of the "CCD" buoy, with the greatest change in depth occurring approximately 150 m southwest of the buoy. At this point, predisposal survey depths of 22.8 m were reduced to a depth of 21.8 m in the postdisposal survey, indicating a maximum detected thickness of deposited material of 1.0 m. The broadest region of accumulation was evident within 100 m north of the buoy. Depth decreased 0.7 m, from 23.3 m in the predisposal survey to 22.6 m in the postdisposal survey.

Comparison of the depth matrices from the pre- and postdisposal bathymetric surveys resulted in a volume calculation of 21,823 m^3 with 95% confidence limits of 10,739 and 32,908 m^3. Examination of barge logs indicated that an estimated 15,296 m^3 of material were deposited at this site during the time between the two surveys.

3.1.2 Springhill Beach Site

Analyses of pre- and postdisposal depth contour plots of the Springhill Beach Site (Figures 3-4 and 3-5, respectively) indicated a natural shoaling within the survey area from 12.0 m offshore to 1.0 m near-shore. The postdisposal contour plot revealed several areas where disposal activities created shoals. In these areas the depth was reduced from 5.5 m to 3.5 m after disposal. Most of these shoal areas occurred along lanes 16 and 19 of the bathymetric survey grid, north of the buoy positions (Figure 3-6).

These discrete shoals appear clearly on the depth difference plot (Figure 3-7). The shallowest area resulting from disposal occurred approximately 600 meters from the western end of lane 16 (Figure 3-6) where the depth was 2.8 m (MLW). This represents a depth difference of 2.2 meters from the pre- to postdisposal survey. The other significant depth differences were 2.3, 2.1, and 2.2 m (Figure 3-7).

Comparison of the depth matrices from the pre- and postdisposal bathymetric surveys resulted in a volume calculation of 82,972 m^3 with 95% confidence limits of 67,736 and 98,208 m^3. This represents the sum of volumes calculated for lanes 12 through 27 of the bathymetric survey grid. Examination of disposal logs indicated that an estimated 87,628 m^3 of material were deposited in this area between pre- and postdisposal surveys.

3.2 REMOTS® Sediment-Profile Photography

Fifteen REMOTS® stations were located at 50 meter intervals to transect the historical CCDS mound. The mound center was located at 41° 49.189'N and 70° 24.947'W, based on the postdisposal bathymetric analysis (Figure 3-2). Records indicated that 228,735 and 4,590 m^3 were disposed at this site in 1980 and 1986, respectively.

A distinct, clearly-defined dredged material layer was not evident in any of the REMOTS® photographs. Ambient grain size at stations 350W and 300W consisted mainly of clay and silt (≥ 4 phi), with increasing grain size and sand content at stations located closer to the center of the mound (Table 3-1). The maximum grain size observed was at 50W (1-0 phi). The grain size gradient rapidly decreased (4-3 to ≥4 phi) at station 100E and eastward.

Sediments observed at stations 100W to 150E generally were sorted more poorly (Figure 3-8) than the more homogeneous sediment profiles observed at 350W and 300W (Figure 3-9). Much of the fine sand component at these stations (100W - 150E) appeared to have eroded, leaving behind a layer of shell lag (Figure 3-10). In addition, amphipods and other taxa had reworked the sediment surface extensively and produced a more porous surface layer. The sand appeared to be coarser-grained due to production of grain aggregates by meiofaunal and macrofaunal activities (Figure 3-11).

Camera prism penetration depths of 11.8 - 14.0 cm were recorded for stations at the western end of the transect (350W and 300W). Mean prism penetrations decreased gradually to 3.1 and 3.9 centimeters at stations located closer to the center of the disposal mound (100W - 150E), as a result of the increase in grain size, shell, and sand content (Table 3-1 and Figure 3-10). Stations farther to the east of the disposal mound showed a general increase in prism penetration with increased distance from the mound, coinciding with the observed decrease in sand content and grain size. Mean prism penetration depths at the transect's eastern end (9.9 and 8.4 cm at 300E and 350E, respectively) were approximately 2 - 3 centimeters shallower than penetrations at 300W and 350W.

The frequency distribution of small-scale boundary roughness was right-skewed with 61% of the photographs indicating values between 0.0 and 0.6 centimeters (Figure 3-12). This indicates that no significant disturbances had occurred recently.

The frequency distribution of the Redox Potential Discontinuity (RPD) values was also right-skewed with approximately 73% of all photographs indicating values less than 3.0 centimeters (Figure 3-13). Mean apparent RPD depths were greatest and most distinct at stations 350W and 300W (Table 3-1) with some patchiness in the distribution of grain size and RPD depth along the western half of the transect (e.g., Station 150W; Figure 3-14). Apparent RPD depths decreased, becoming less clearly defined toward the center of the mound where sediments were loosely consolidated and poorly sorted. RPD depth was indeterminate at 50W and CTR. Mean RPD depths gradually increased toward the eastern end of the transect to a maximum of 4.4 cm (300E). This was considerably less than RPD depths of 6.1 and 7.8 cm (stations 350W and 300W, respectively), which suggested that the distribution of dredged material extended beyond station 350E.

The predominant successional stage at stations 350W to 200W and 250E to 350E was a Stage I surface taxa over a Stage III taxa (Figure 3-15 and Table 3-1). At stations nearer the center of the mound, extensive reworking of the surface sediments indicated the presence of Stage II taxa. Decreased camera penetrations, resulting from increases in sediment grain size, prevented a conclusive determination of successional stage at some stations (100W - 100E). Dense assemblages of surface tubicolous taxa were observed in virtually all photographs taken at stations 200E and eastward, with Stage II amphipods dispersed among Stage I polychaete tubes (Figure 3-16).

The broad range of OSI values (Figure 3-17) exhibited a symmetrical distribution with OSI values increasing with distance from the mound center (Table 3-1). Median OSI values at stations 350W to 150W and 35OE to 150E ranged from +6 to +11, whereas OSI values at stations nearer to the center (100W, 50E, and 100E) ranged from +6 to +4. OSI values were indeterminate at stations CTR and 50W.

4.0 DISCUSSION

4.1 Cape Cod Canal Disposal Site

The Cape Cod Canal serves as a major thoroughfare for recreational and commercial vessels transiting Massachusetts waters. During the maintenance and improvement dredging conducted in the spring of 1990, sediments were disposed at CCDS and a near-shore site off Springhill Beach. The objective of the pre- and postdisposal bathymetric surveys was to delineate the areal extent of these disposed sediments.

The designated disposal point within CCDS was located approximately 600 m west of the CCDS center. Previous disposal records show that 228,735 and 4590 m^3 were disposed north of the CCDS center in 1980 and 1986, respectively. The objectives of the 1990 REMOTS® sediment-profile photographic survey were to assess the areal extent of dredged materials and the colonization status north of CCDS center at the historical CCDS mound.

The disposal logs indicated that 7,837 m^3 of sediments were deposited at CCDS during the two days prior to the predisposal bathymetric survey. There was no evidence of any obvious topographic anomalies due to this disposal activities (Figure 3-1). A conspicuous shoaling was observed in the postdisposal contour plot around the "CCD" buoy (Figure 3-2). The depth difference plot, reflecting changes in depth attributable to dredged materials released after the 22 March survey, revealed several individual mounds within this shoaled area with dredged material thicknesses up to 0.7 m.

The calculated volume of accumulated material for the CCDS was 21,823 m^3 with 95% confidence limits of 10,739 and 32,908 m^3. The volume calculation was based on changes in depth observed between lanes 16 and 35 of the bathymetric survey grid, where there was evidence of the newly-deposited material. The disposal log estimate of 15,296 m^3 fell within the calculated confidence limits; however, unlike previous DAMOS surveys (e.g., Western and Central Long Island Sound (WLIS, CLIS) and New London Disposal Sites (NLON); SAIC 1990c, 1990a, and 1990b, respectively), this estimate was less than the calculated volume. Tavolaro (1984) showed that "depth difference" volume estimates based on successive bathymetric surveys will be less than barge log estimates because of compaction of dredged material on the seafloor following disposal. Significant consolidation of the CCDS sediments may not have occurred prior to the 24 April survey because all 15,296 m^3 of sediment were deposited within one month of the survey. Volume difference calculations for CLIS, WLIS, and NLON were based on postdisposal surveys conducted up to six months after initial sediment disposal, allowing significantly more time during which compaction could occur. Until a comprehensive mass balance study can be performed and methods are developed to measure barge volumes easily and accurately, it will be difficult to eliminate discrepancies between bathymetric volume calculation and barge log volume estimates.

The predisposal bathymetry revealed the western portion of an historic mound in the northeast region of the survey grid (Figure 3-1). The postdisposal survey was extended an additional 300 m east in order to delineate the boundaries of this mound more clearly (Figure 3-2). The contour plot indicated that the postdisposal bathymetric survey was extended far enough to include the eastern boundary of this mound; however, REMOTS® sediment-profile analyses indicated that dredged material extended beyond the mound area detectable with bathymetry. It is important to note that the eastern-most REMOTS® station (350E) extended approximately 100 m beyond the postdisposal bathymetric survey area (Figure 2-2). Dredged material was therefore apparent up to at least 350 m east of the center of the mound.

Although mapping of dredged material was possible, clearly-defined layers of dredged material were not apparent in the REMOTS® photographs. This was not unexpected, because approximately 10 years had passed since the last significant volume of dredged material was disposed at this site, during which time the layers of dredged material could become incorporated into or made indistinct from each other or the ambient sediment. Despite the lack of clearly-defined layers, mapping of the dredged material was possible based on the changes in sand content and sediment grain size.

Ambient sediment characteristics were observed at the two western-most stations of the REMOTS® transect, 350W and 300W. Camera penetration was deepest here (11.8 and 14.0 cm, respectively). Sediment was well sorted, with a grain size typical of fine-clay and silt (≥ 4 phi). OSI values (+11) and mean apparent RPD depths (greater than 6 cm) showed a lack of disturbance. Stage III taxa were evident in all replicate photographs at these two stations.

At stations nearer the center of the mound, marked changes in all these parameters were noted, indicating the presence of dredged material. RPD depths decreased, ranging from 2.8 cm to 3.5 cm at stations 250W and 250E to < 1 cm and indeterminant at the center of the mound. RPD could not be measured at the center of the mound (stations 50W and CTR) where the sediment was loosely consolidated. Given the time since last disposal, 4 years, it would be expected that recolonization would have reached Stage III on the mound. Limited camera prism penetrations (>4 cm), resulting from the increase in sediment grain size and shell content, precluded an accurate determination of successional stage at six stations near the apex of the mound. Shallow RPDs and increased grain size at these apex stations, evidence of erosion or winnowing, may indicate a lack of Stage III taxa due to impact on the benthos by scour or erosion. However, these taxa may have been present below the depth of penetration. Several stations had shell lag (Figure 3-10). Presumably only one component of the dredged material, this shell lag, remained after the finer silt/sand components of the dredged material had been washed away. The height of the mound and the water depth, 19.8 m, may have caused the apex of the mound to be periodically within the wave base, serving as a source for the physical disturbance of these sediments. A dynamic equilibrium between deposition and erosion forces has been shown to exist in Long Island Sound at water depths of approximately 20 m (McCall, 1978). In this site with more exposure to wind and waves from the northeast, this equilibrium depth may be shallower.

For stations 200E and eastward, changes in OSI value, RPD depth, camera penetration, and grain size indicated conditions typical of the periphery of a disposal mound. Stage III taxa were present, and the OSI value increased to a value of +11 at station 300E and +9 at station 350E. Mean apparent RPD depths and camera penetration values did not return to the ambient conditions of the western end of the transect. These results imply a continued presence of coarse-grained dredged material at these REMOTS® stations with successful recolonization of this material.

4.2 Springhill Beach Site

Sediments from the Cape Cod Canal dredging operations also were disposed at the near-shore Springhill Beach Site. Pre-and postdisposal bathymetric surveys were conducted at the Springhill Beach Site to assess the distribution of these newly-deposited sediments. The postdisposal bathymetric survey at the Springhill Beach Site showed several individual mounds resulting from disposal activities. The majority of these mounds occurred on lanes 16 and 19 of the bathymetric survey. These lanes were located approximately 125 - 200 m north of the marker buoys deployed at this site. The depth profile plots for lanes 16 and 19 clearly reflected these subsequent changes in topography (Figure 3-6).

The depth difference plot did not provide substantial evidence of immediate beach replenishment resulting from the disposal operations. General shoaling and redistribution of sediments around the area of the individual disposal mounds were apparent. One would expect that, given a sufficient amount of time, natural processes (e.g., wave action and long shore currents) might serve to redistribute these sediments along the beach area. Additional bathymetric surveys after a period of time (e.g., six months) could help provide evidence as to whether or not the Springhill Beach Site is serving as a feeder berm for the beach area.

The volume of accumulated material calculated for the Springhill Beach Site was 82,972 m^3. Barge disposal logs estimated 87,628 m^3 of material were deposited at the Springhill Beach Site. This fell within the calculated 95% confidence limits (67,736 and 98,200 m^3) and was slightly more than the volume calculated from the successive bathymetric surveys. Typically, the volumes calculated for other disposal sites from successive bathymetric surveys have been significantly less than the barge disposal estimates (e.g., SAIC 1990a, 1990b, 1990c). However, at the Springhill Beach Site, no significant consolidation of sediments would be expected given that the postdisposal survey immediately followed disposal activities.

5.0 CONCLUSIONS

Dredged material deposited at CCDS occurred within a 300 m range of the "CCD" buoy. A broad region of shoaling 100 m north of the buoy represented an approximate dredged material thickness of 0.7 m. The maximum thickness of newly deposited material, 1.0 m, was located 150 m southwest of the buoy. Based on results of the pre- and postdisposal bathymetric analyses, an estimated 21,823 m^3 of dredged material have accumulated at this site.

Postdisposal bathymetry at the Springhill Beach Site revealed several mounds where depths decreased as much as 2.3 m due to the disposal operations. Most of these areas were located between four lanes (100 m) of the bathymetric survey grid. Shoaling around the mounds showed a redistribution of sediments, which, given sufficient time and exposure to the natural elements of waves and longshore currents, could replenish the beach. This indicated that the Springhill Beach Site indeed may serve as a feeder berm for the beach. Subsequent bathymetric surveys could confirm this dispersal of the sediments from the existing mounds to the beach area.

Volume calculations showed an estimated 82,972 m^3 of dredged material accumulated at the Springhill Beach Site. Unlike the monitoring results from other DAMOS sites, at both locations the barge log records were in agreement with the volume difference calculations, falling within the calculated 95% confidence limits.

A REMOTS® sediment-profile photographic survey was performed at the historic CCDS mound to delineate the areal extent of the deposit and to assess the benthic community recovery at this former disposal point. Records indicated that 228,735 and 4590 m^3 were deposited at this site in 1980 and 1986, respectively. A clearly-defined dredged material layer was no longer distinguishable as much of this sediment had been incorporated into the ambient sediments; however, the distribution of dredged material could be mapped based on changes in grain size along the transect. Ambient sediment conditions were apparent at the western end of the transect, whereas the continued, although diminished, influence of dredged material was apparent at the center and eastern portions of the transect. Definitive OSI values could not be calculated for several stations (100W to 100E) due to shallow REMOTS® camera penetrations.

The minimum depth of the historical mound was 19.3 m. Studies from more protected sites in Long Island Sound have shown that a dynamic equilibrium of erosional and depositional forces can exist at 20 m water depths, above which the effects of wind and waves can transport fine silts and sands (McCall, 1978). To minimize potential scouring at CCDS, future disposal should be directed to the flanks of the existing mound below 20 m water depth, or efforts should be made to reduce the height-to-width ratio of future disposal mounds. Management decisions at CCDS must consider whether such scouring and erosion are acceptable. If the disposed sediment is suitable for unconfined open water disposal, or if it is being eroded from the apex of the mound and redeposited on the flanks, scouring may be acceptable.

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Table 3-1. Summary of REMOTS® Survey Information for CCDS, April 1990.

	350W	300W	250W	200W	150W	100W	50W	CTR	50E	100E	150E	200E	250E	300E	350E
GRAIN SIZE MAJOR MODE (ø)	≥4	≥4	4-3	3-2	4-3	2-1	1-0	3-2	3-2	4-3	4-3	≥4	4-3	4-3	4-3
APPROX. STATION WATER DEPTH	23.5m	23.4m	23.6m	23.6m	23.3m	22.7m	21.7m	20.6m	19.8m	21.3m	23.2m	23.7m	UNK.	UNK.	UNK.
MEAN PRISM PENETRATION (cm)	11.8	14.0	8.3	6.8	8.6	3.5	3.1	3.2	3.8	3.9	3.1	6.6	7.7	9.9	8.4
MEAN APPARENT RPD (cm)	6.1	7.8	2.8	1.7	1.9	0.3	IND	IND	0.4	0.0	2.4	3.0	3.5	4.4	2.6
INFAUNAL SUCCESSIONAL STAGES[1]	▲	▲	▲	▲	△	○*	△*	○*	△*	△*	△*	△	▲	▲	▲
MEDIAN ORGANISM-SEDIMENT INDEX	11	11	9	8	6	4+	IND	IND	6+	4.5+	6+	10	10	11	9

* *Indicates those stations where low camera penetration precluded definitive determination of successional stage.*

\+ *Indicates stations where OSI values are approximate due to nondefinitive successional stage.*

[1] Key to Successional Stages

△ = Stage 1 on 3 in Combination with Stage 1 and/or Stage 2

▲ = Stage 3, Stage 2 on 3 and/or Stage 1 on 3

○ = Stage 1 and/or Stage 2

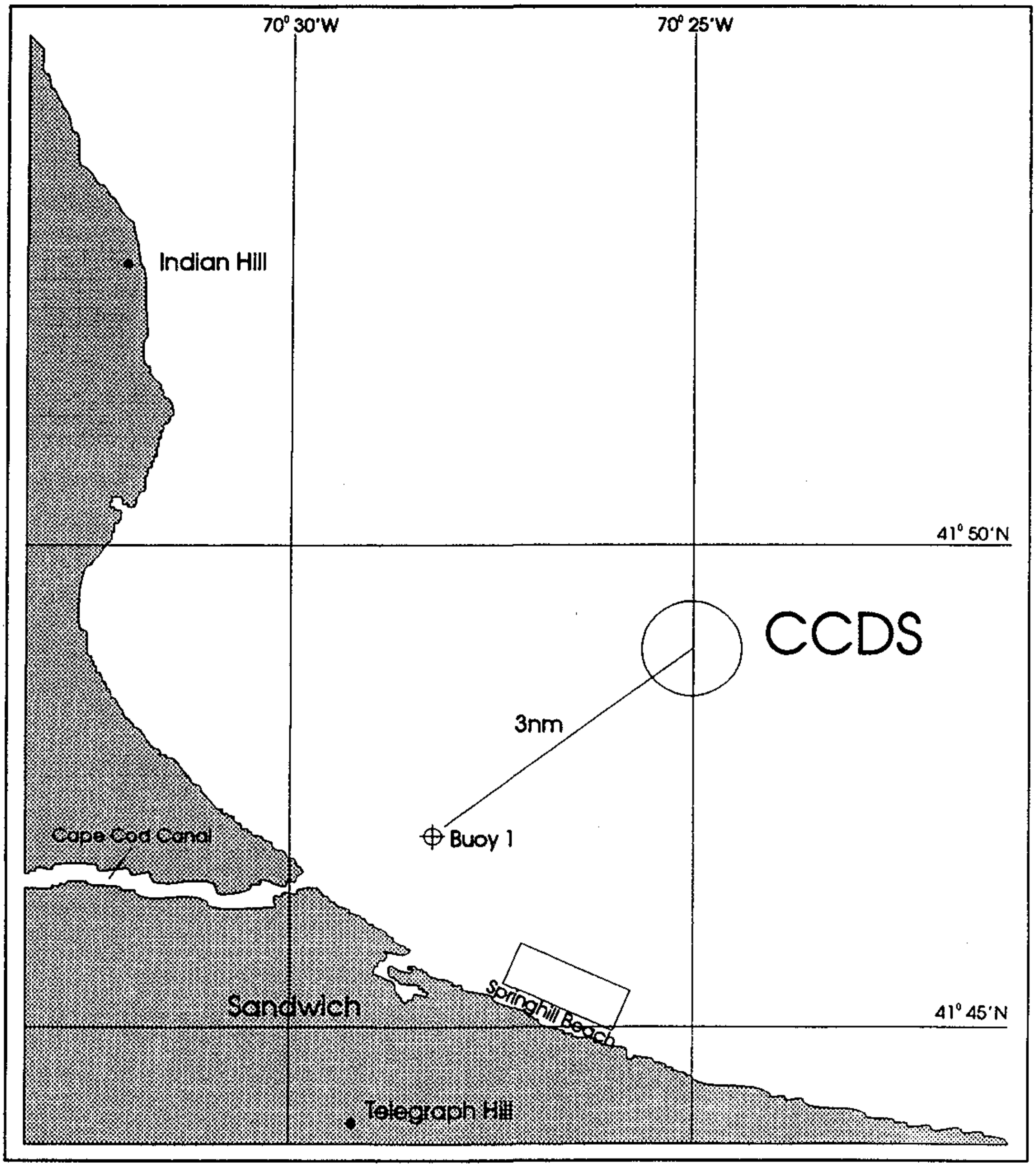


Figure 1-1. **Locations of Cape Cod Disposal Site and Springhill Beach Site in relation to the Cape Cod Canal Buoy #1 and Springhill Beach.**

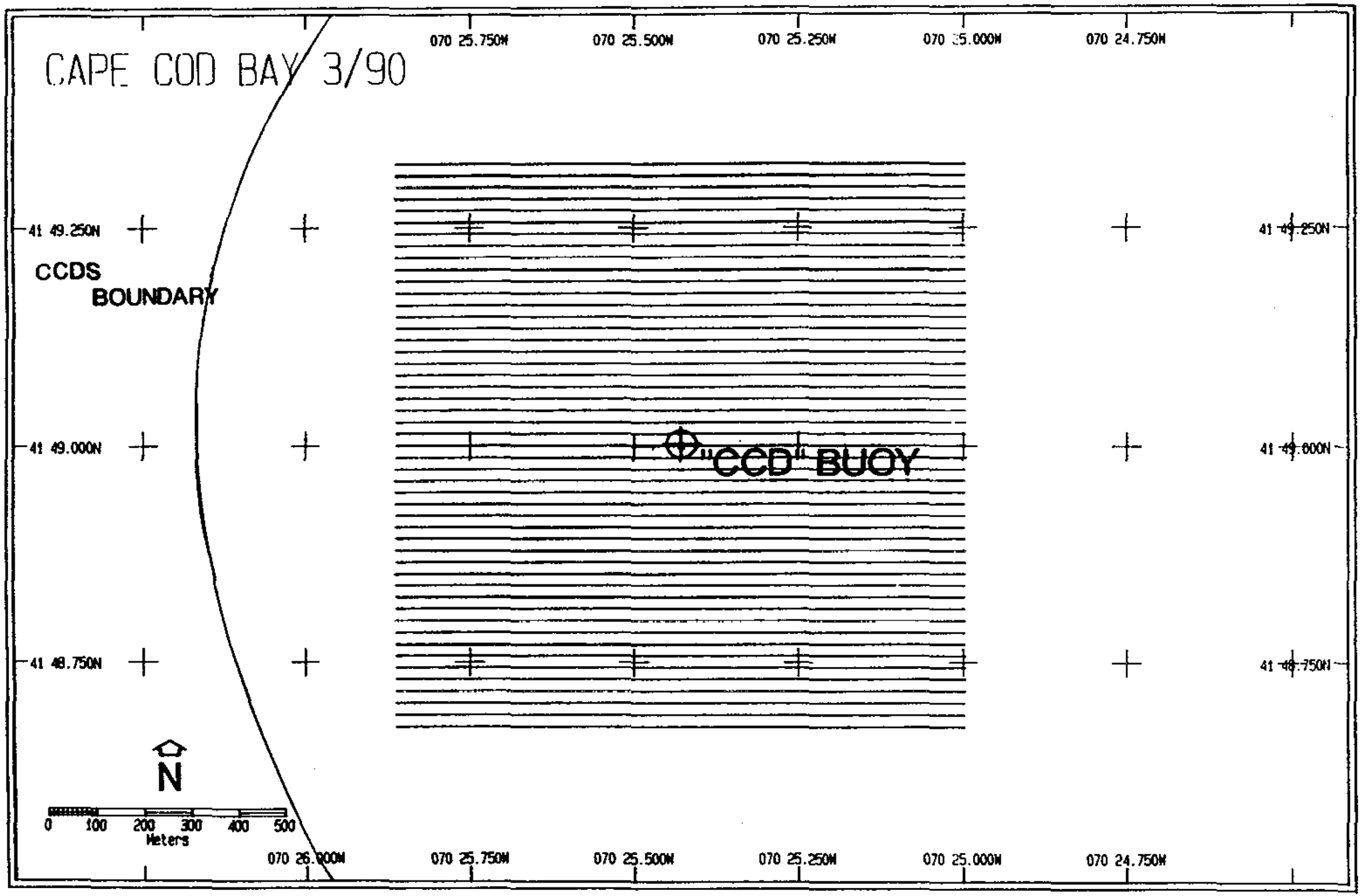


Figure 2- 1. **Predisposal bathymetric survey grid used at CCDS indicating the location of the "CCD" buoy and the boundary of the Cape Cod Canal Disposal Site.**

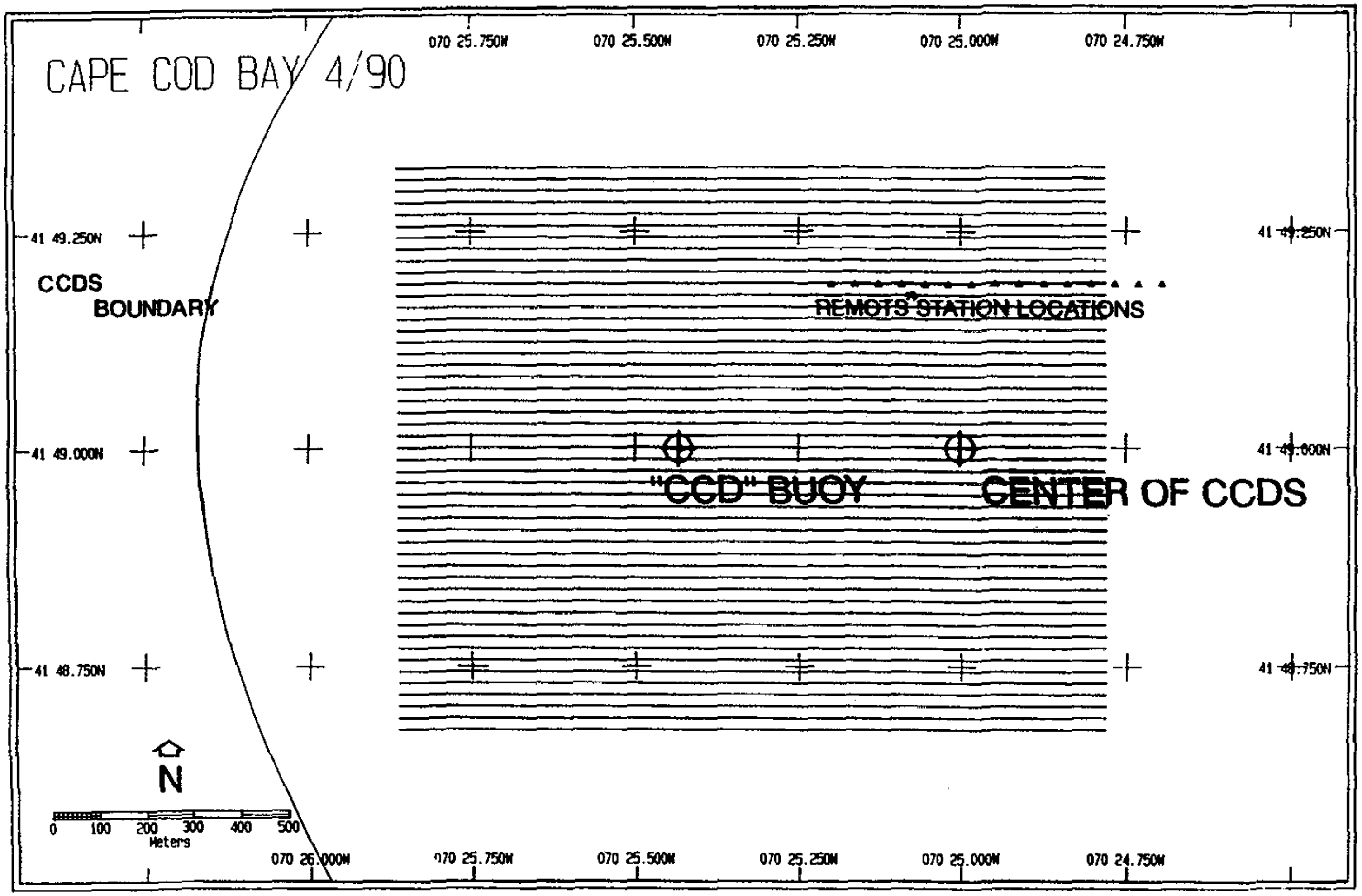


Figure 2-2. Postdisposal bathymetric survey grid used at CCDS indicating the location of the "CCD" buoy, the center of CCDS, and the REMOTS® station locations.

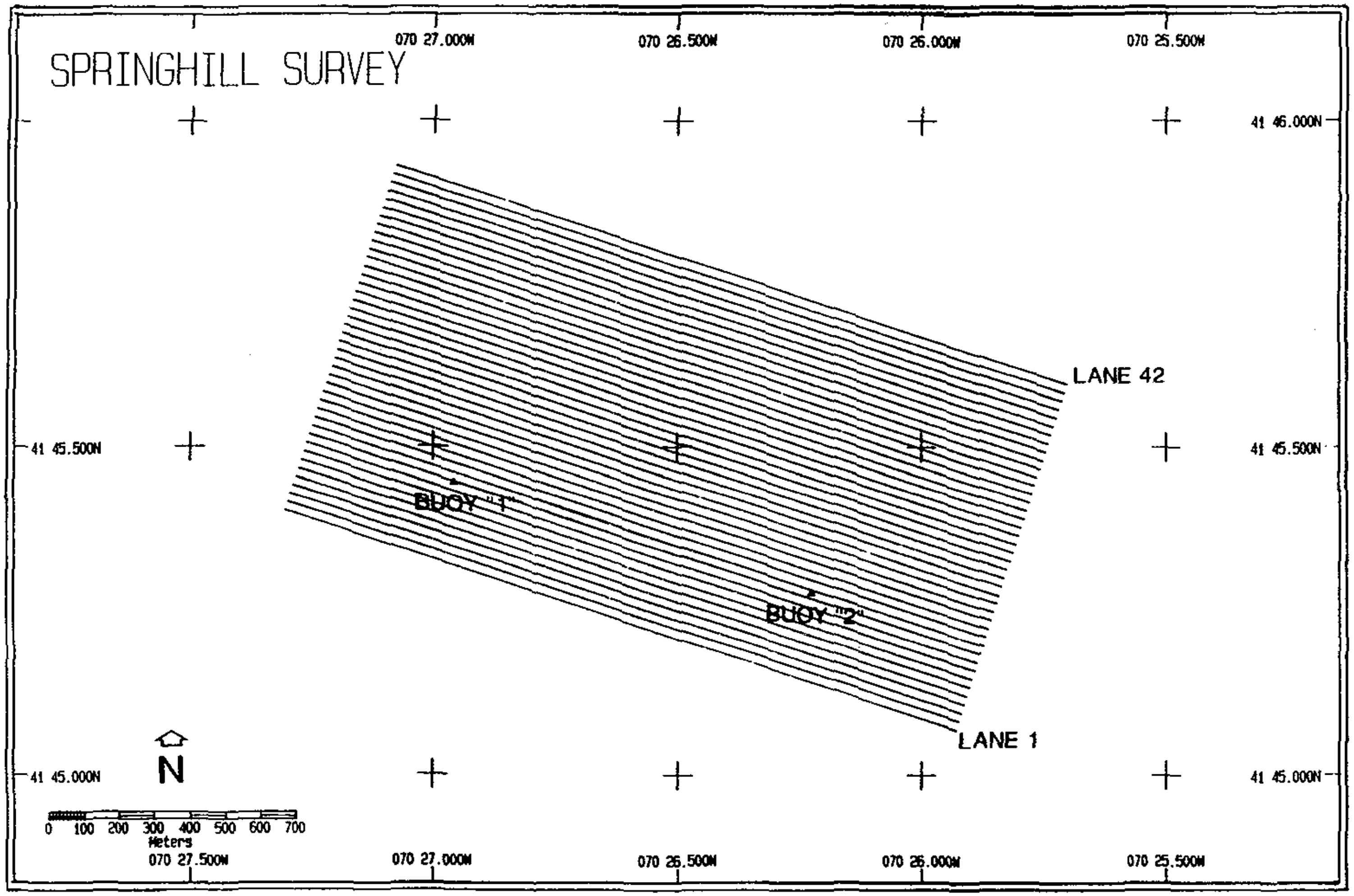


Figure 2-3. Pre- and postdisposal bathymetric survey grid used at the Springhill Beach Site, indicating lanes #1 and #42 and the location of marker buoys deployed at the site.

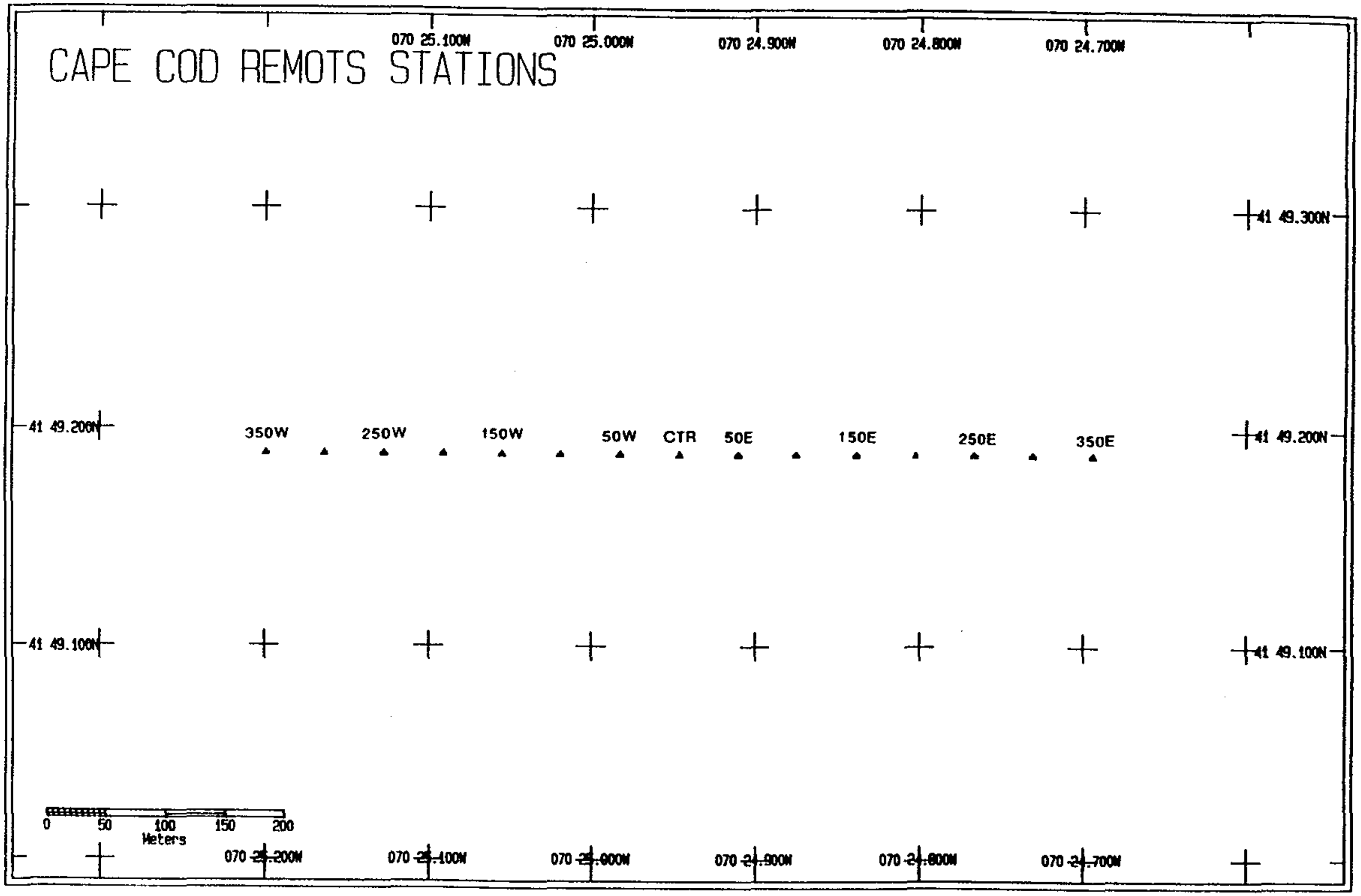


Figure 2-4. CCDS REMOTS® station locations.

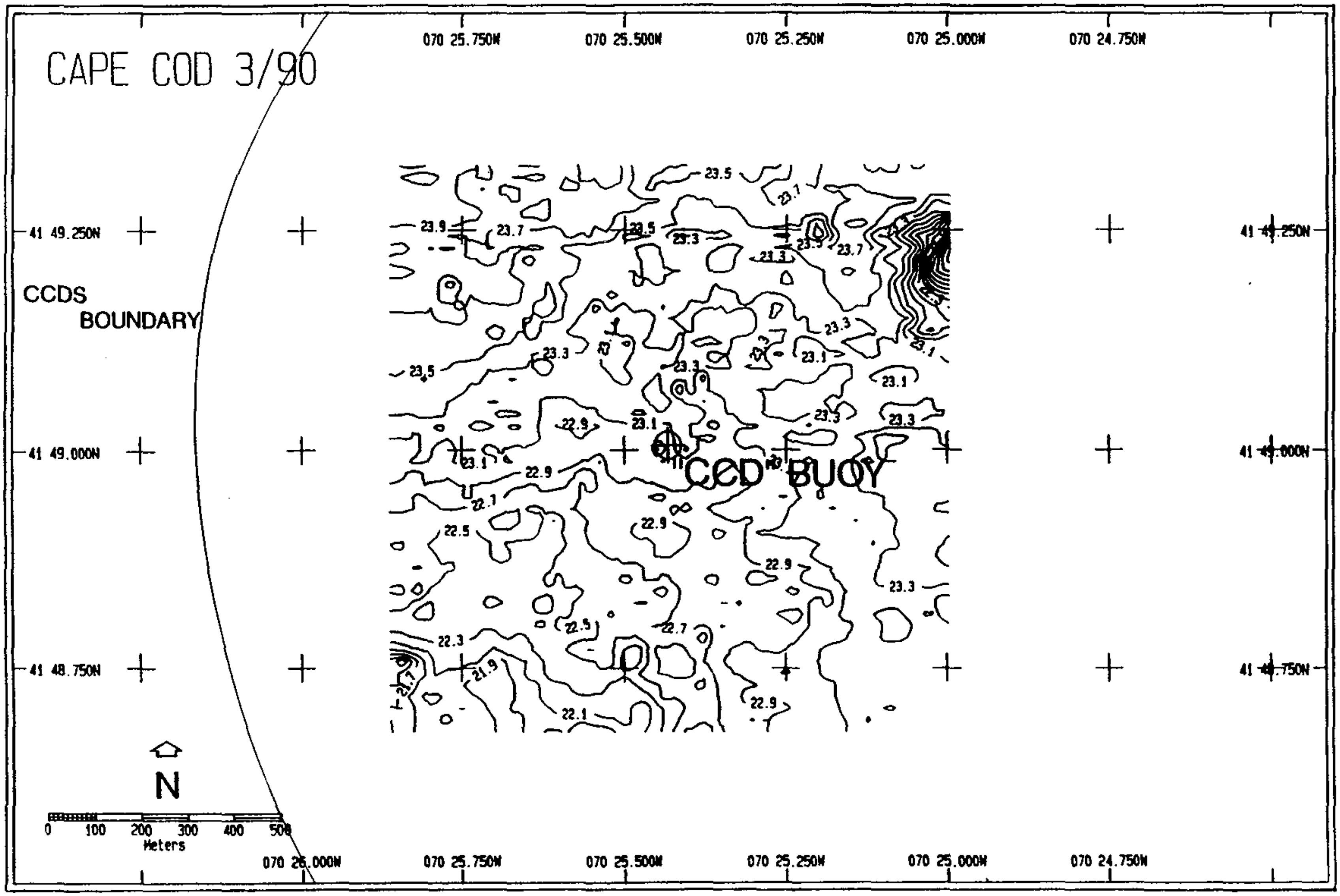


Figure 3-1. Predisposal bathymetric contour chart of area surrounding the "CCD" buoy, March 1990.

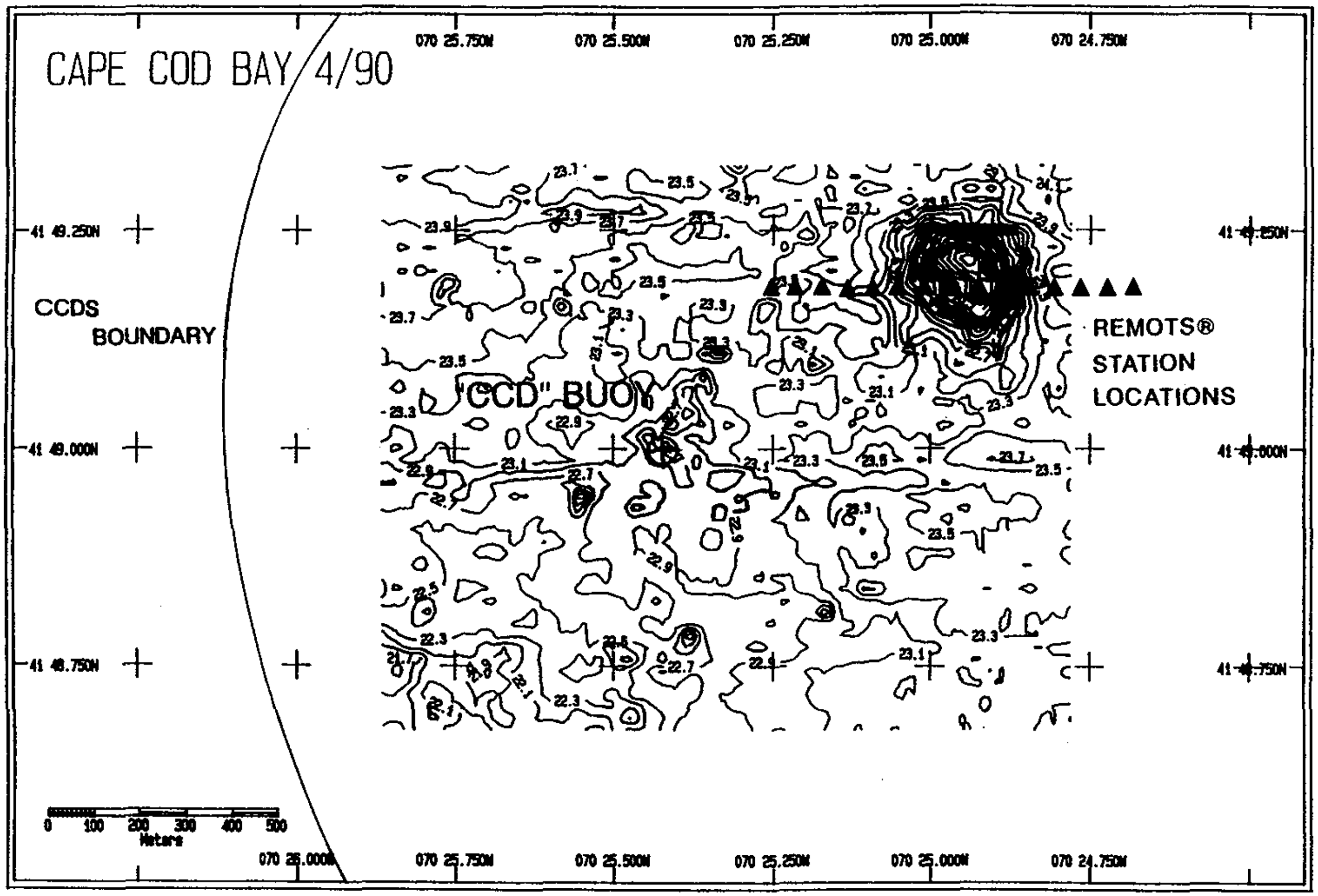


Figure 3-2. Postdisposal bathymetric contour chart of area surrounding the "CCD" buoy, indicating REMOTS® station locations transecting historic CCDS disposal mound, April 1990.

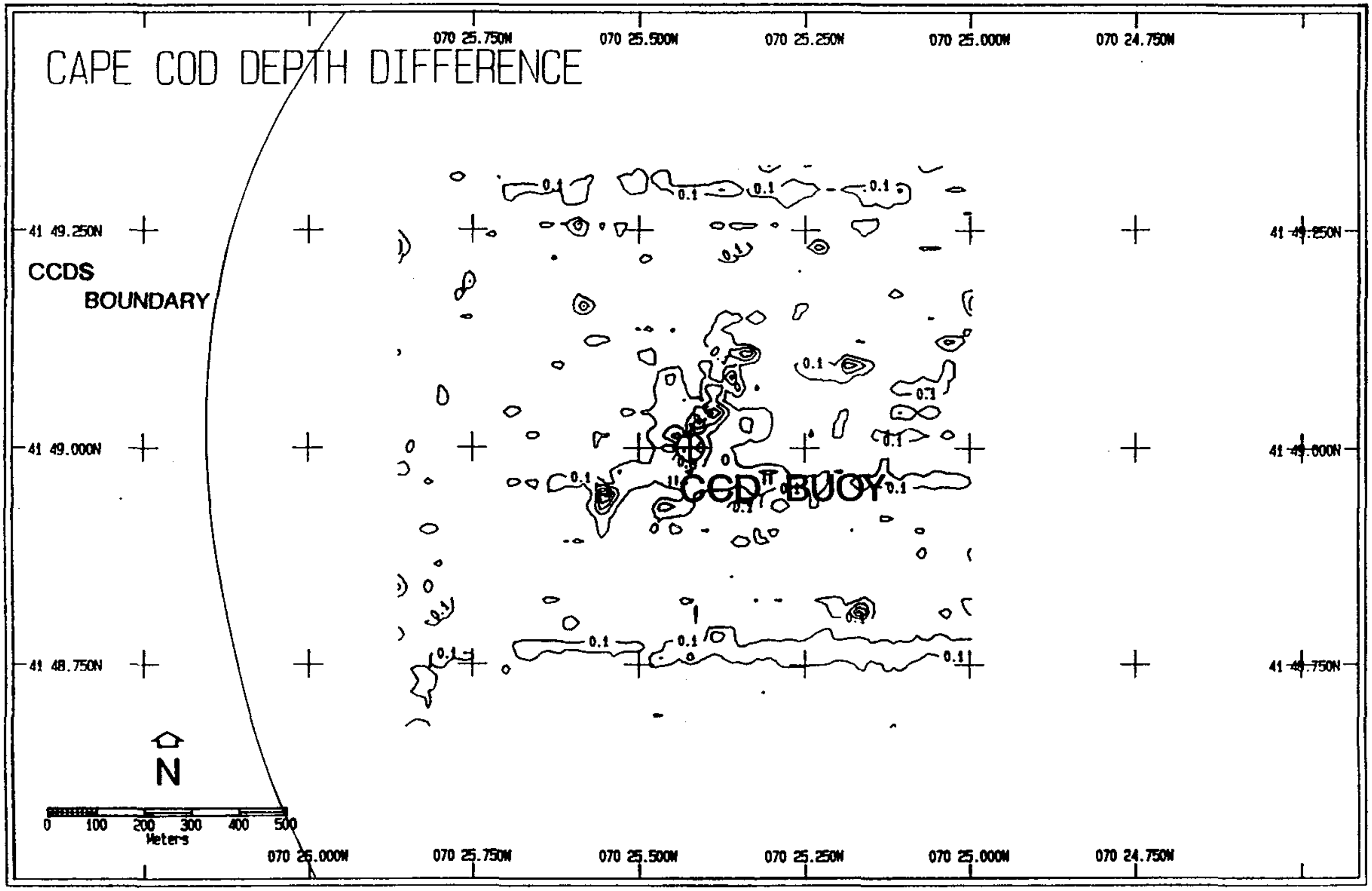


Figure 3-3. Depth Difference (in meters) contour map based on comparison of 21 March 1990 and 24 April 1990 precision bathymetric survey at the "CCD" buoy.

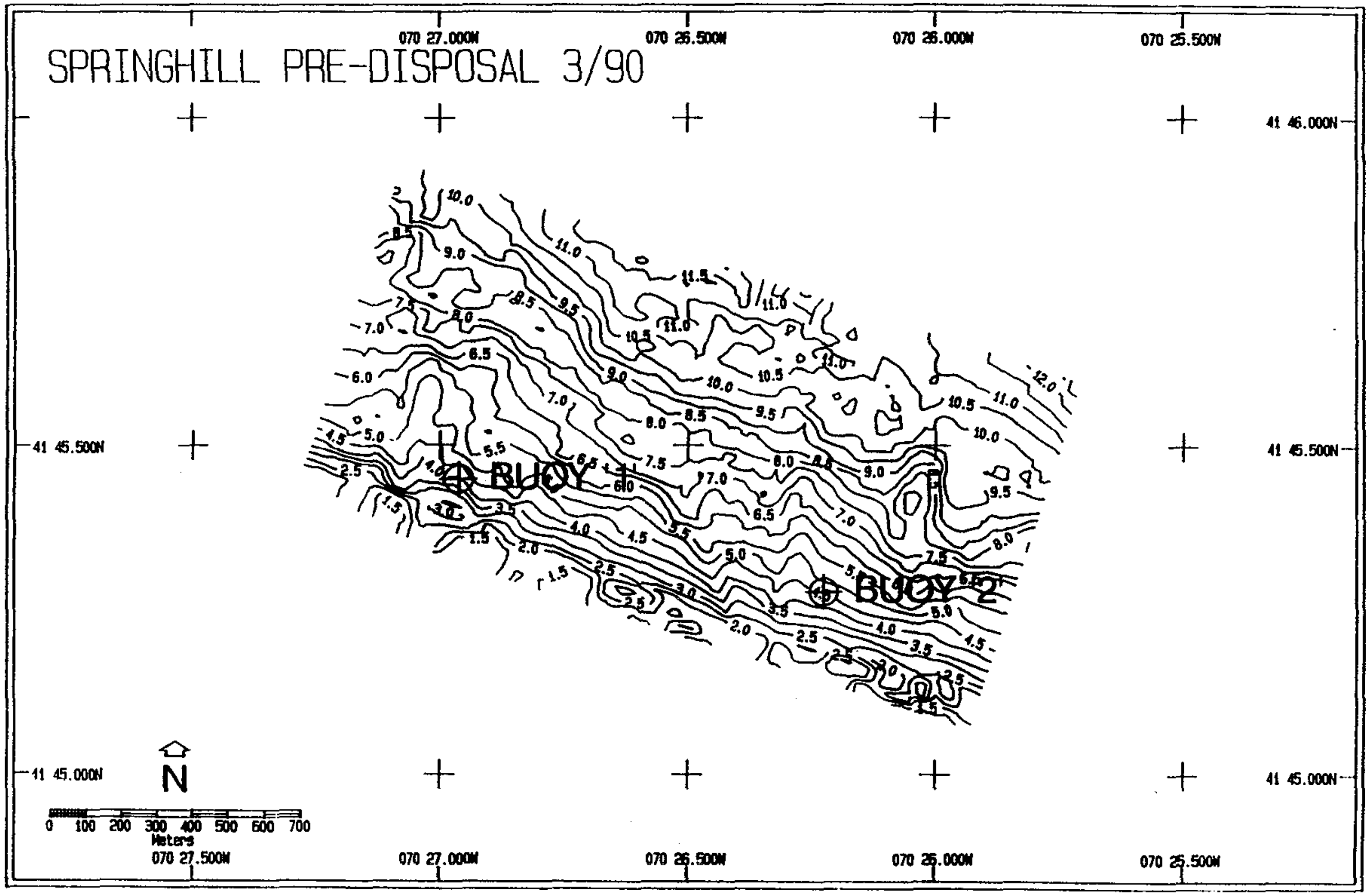


Figure 3-4. Predisposal bathymetric contour chart of Springhill Beach Site. indicating location of marker buoys deployed at the site , March 1990.

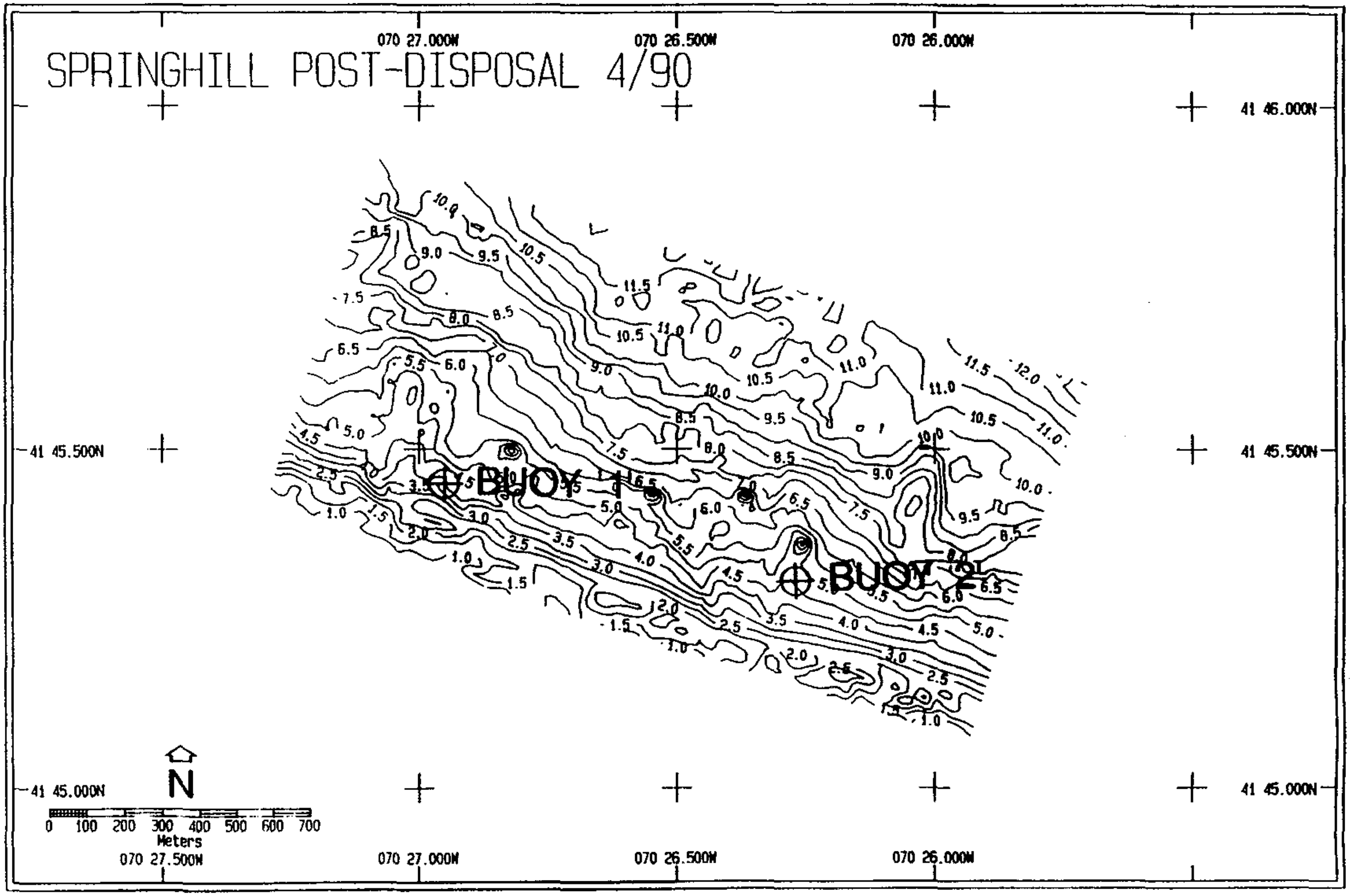


Figure 3-5. Postdisposal bathymetric contour chart of Springhill Beach Site, April 1990.

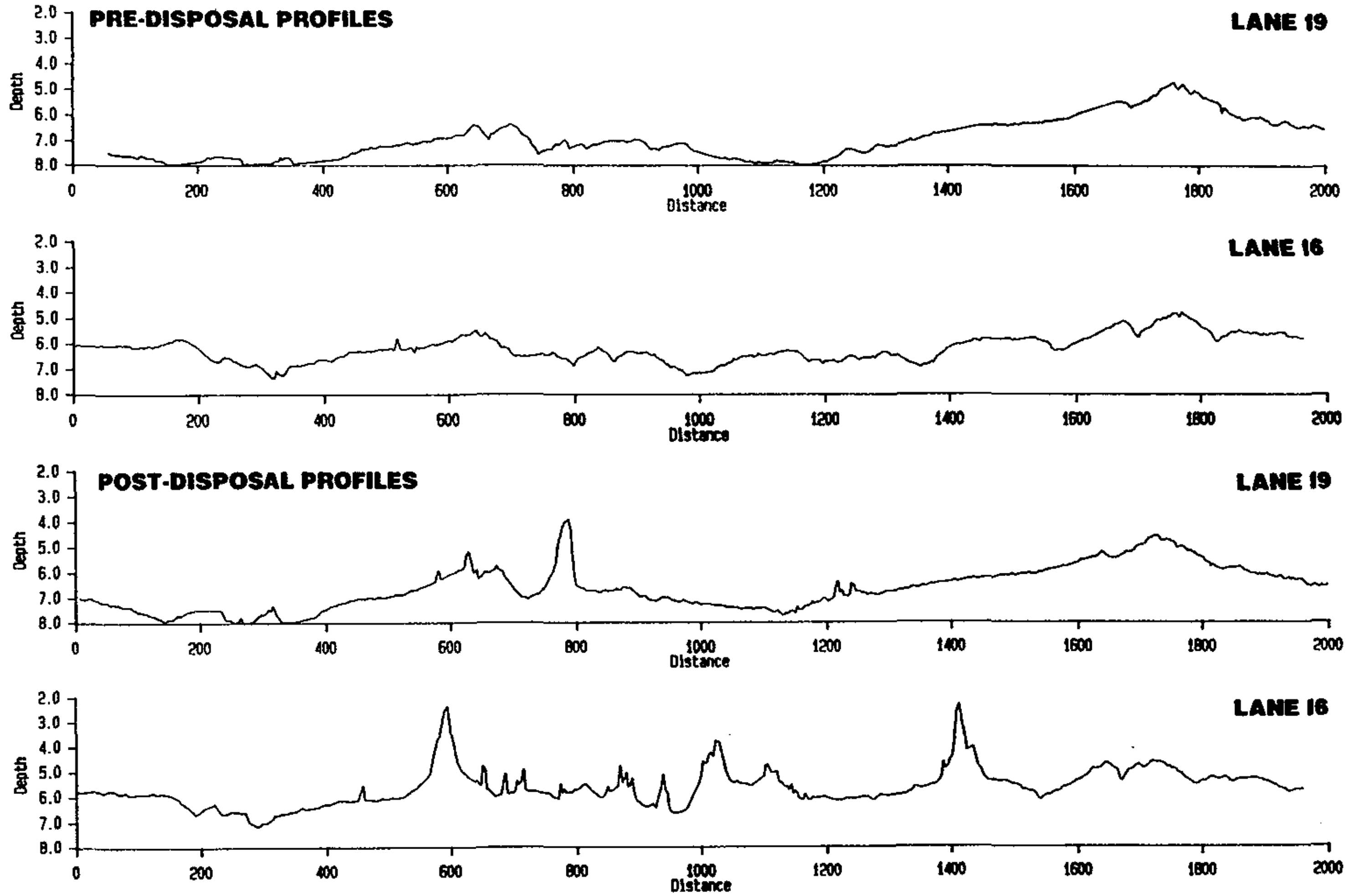


Figure 3-6. Pre- and postdisposal profile plot for lanes 16 and 19 of the Springhill Beach Site survey.

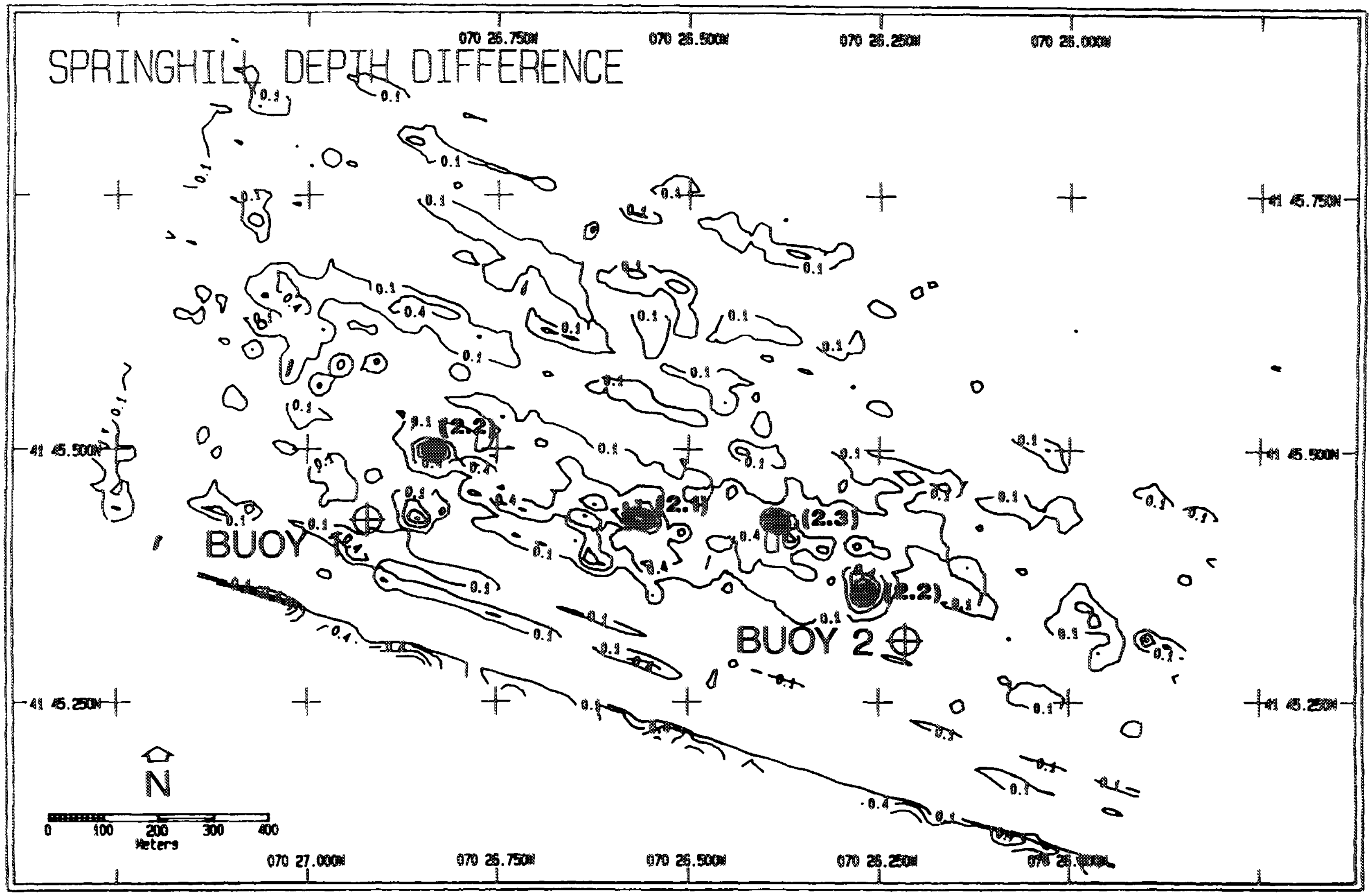


Figure 3-7. Depth Difference (in meters) contour map based on comparison of 22 March 1990 and 25 - 26 April 1990 precision bathymetric survey at the Springhill Beach Site.

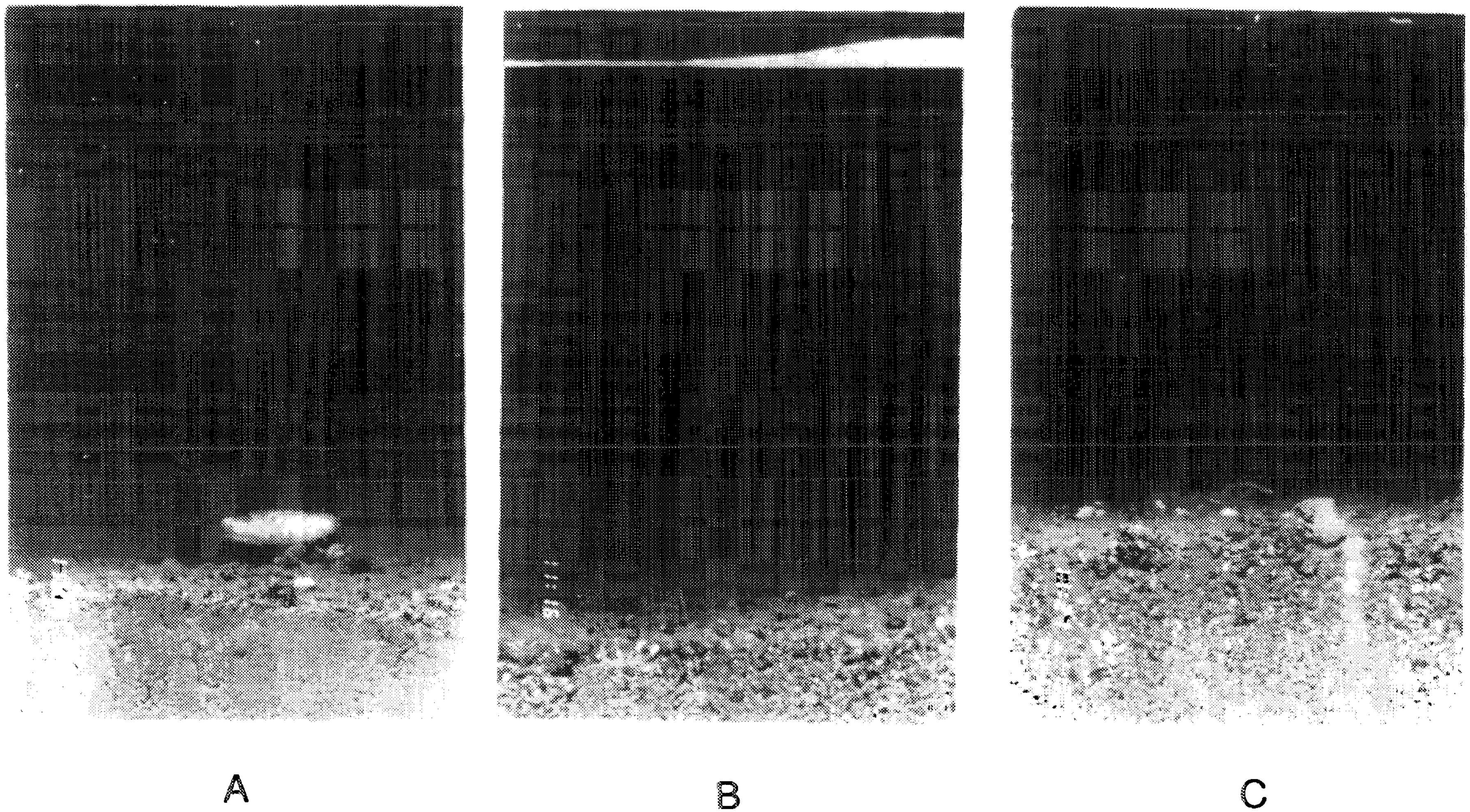


Figure 3-8. REMOTS® photographs from 100W (A), CTR (B), and 50E (C) showing poorly sorted sediments and decreased prism penetration depths.

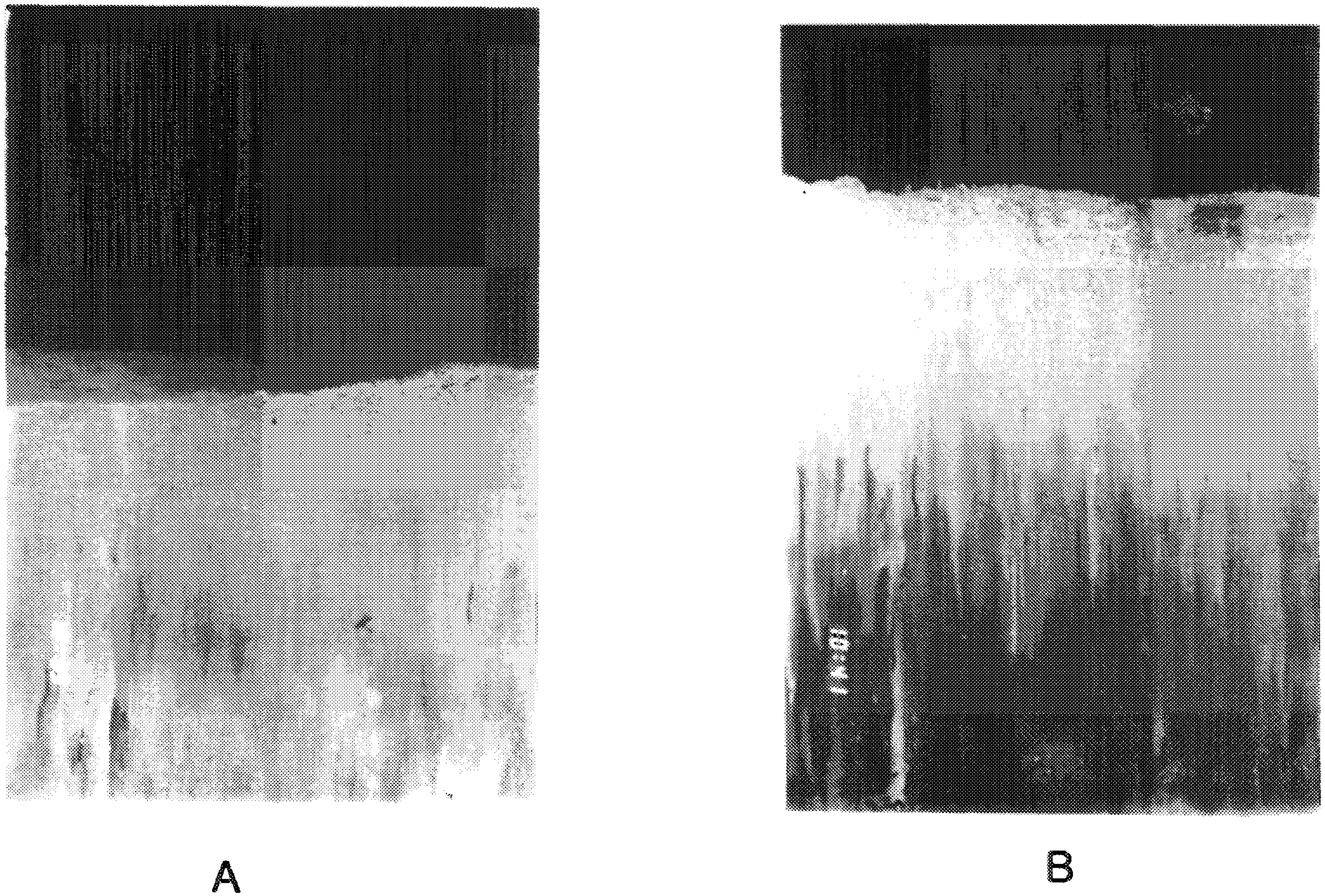


Figure 3-9. REMOTS® photographs from 350W (A) and 300W (B) showing homogeneous , well-sorted sediment with relatively well defined RPD and ambient camera penetrations.

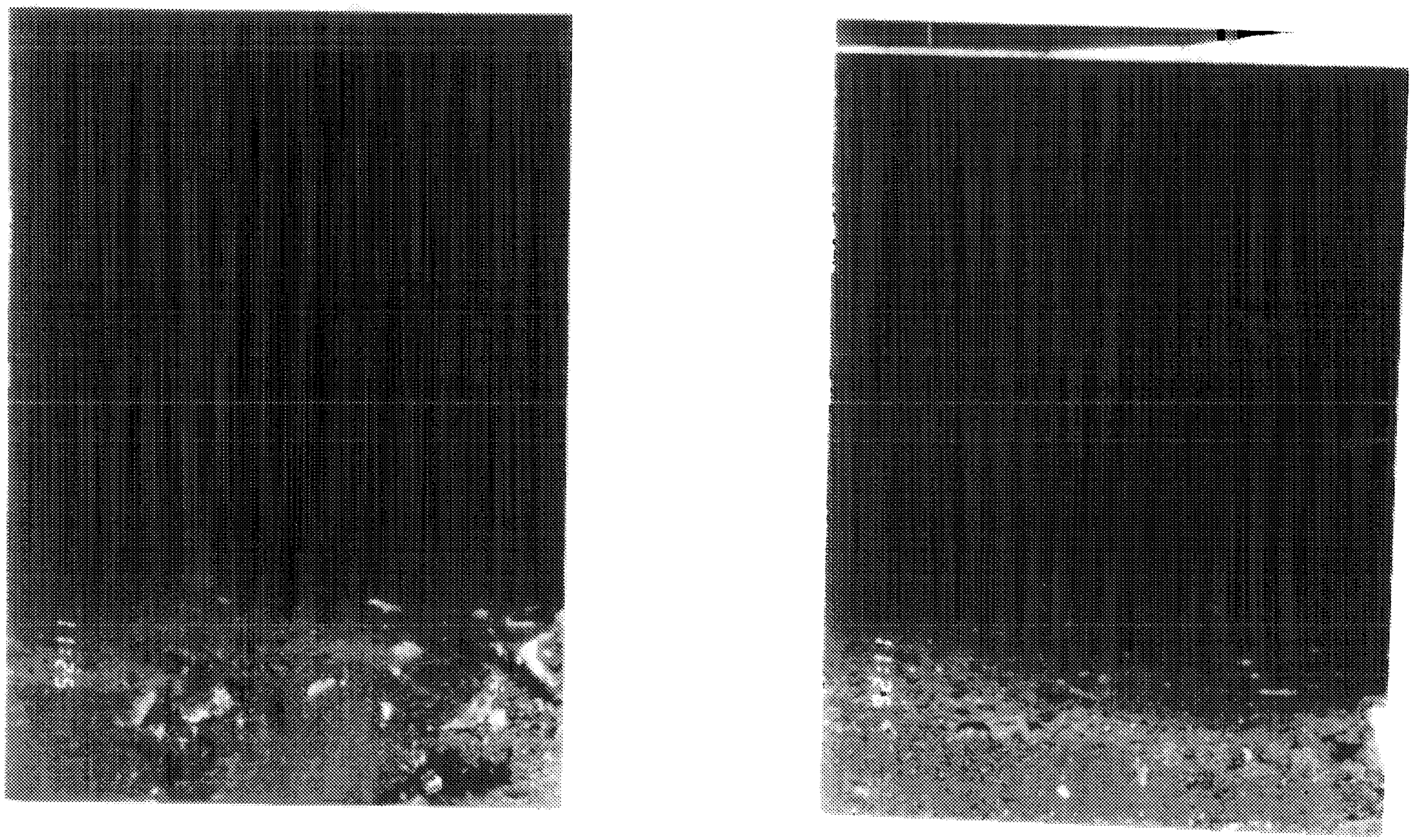


Figure 3- 10. REMOTS® photographs from 100E showing surface layer of shell lag.

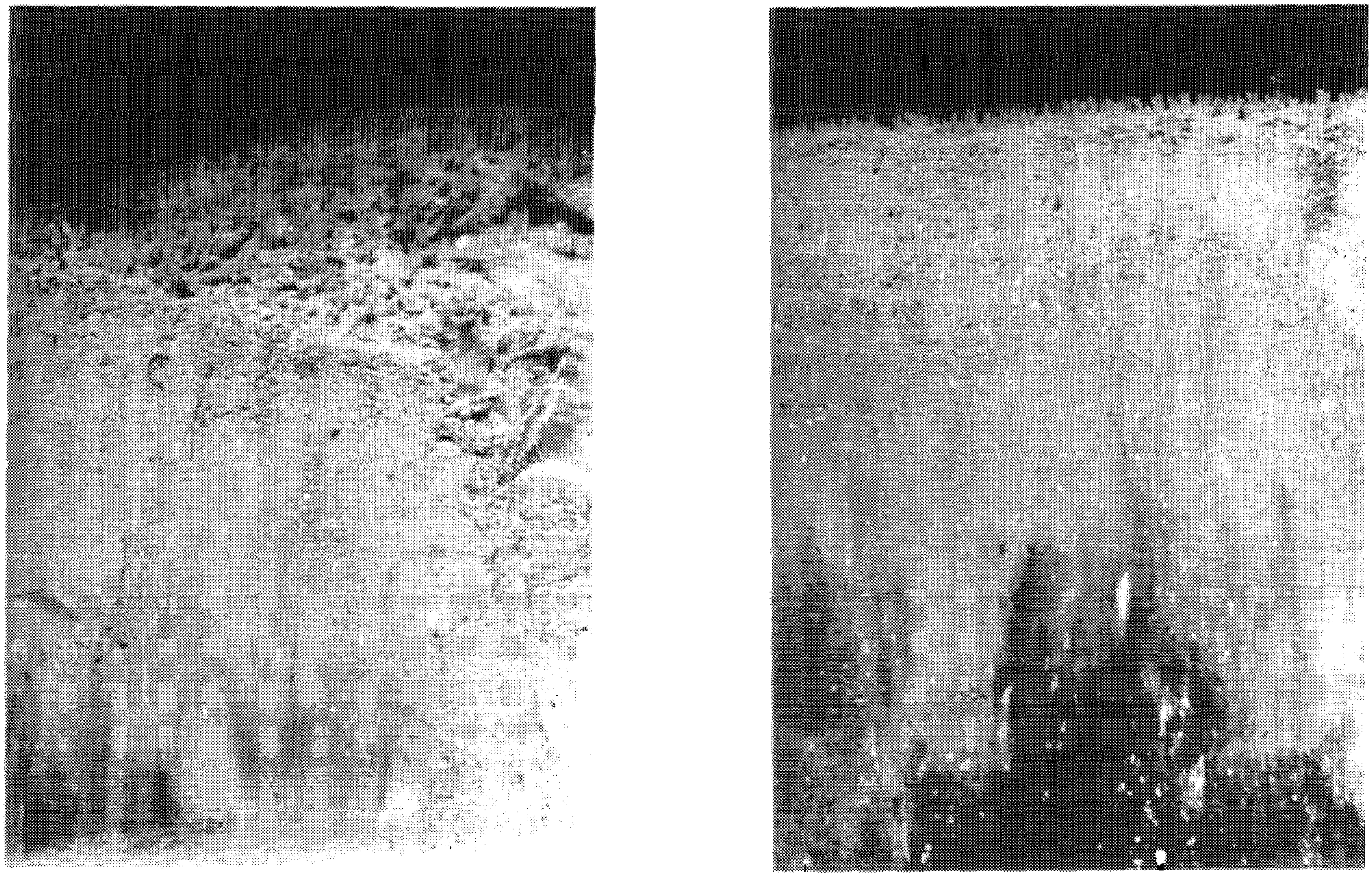


Figure 3-11. REMOTS® photographs from 300E (4 and 350E (B) showing dense surface tubes and extensive reworking of top centimeters of sediment.

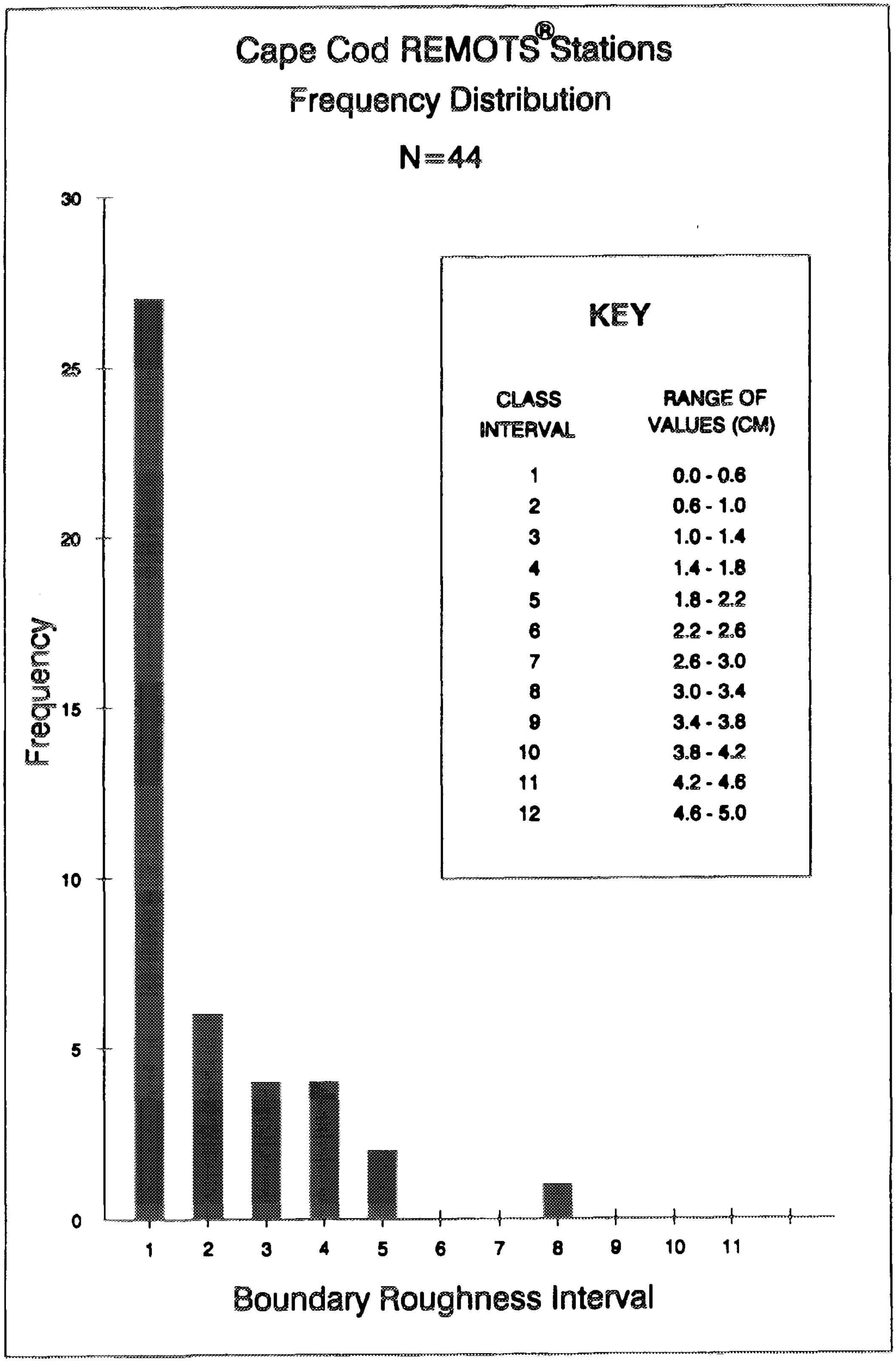


Figure 3-12. Frequency distributions of small-scale surface boundary roughness values for all photographs of the REMOTS® transect study of the historic CCDS mound.

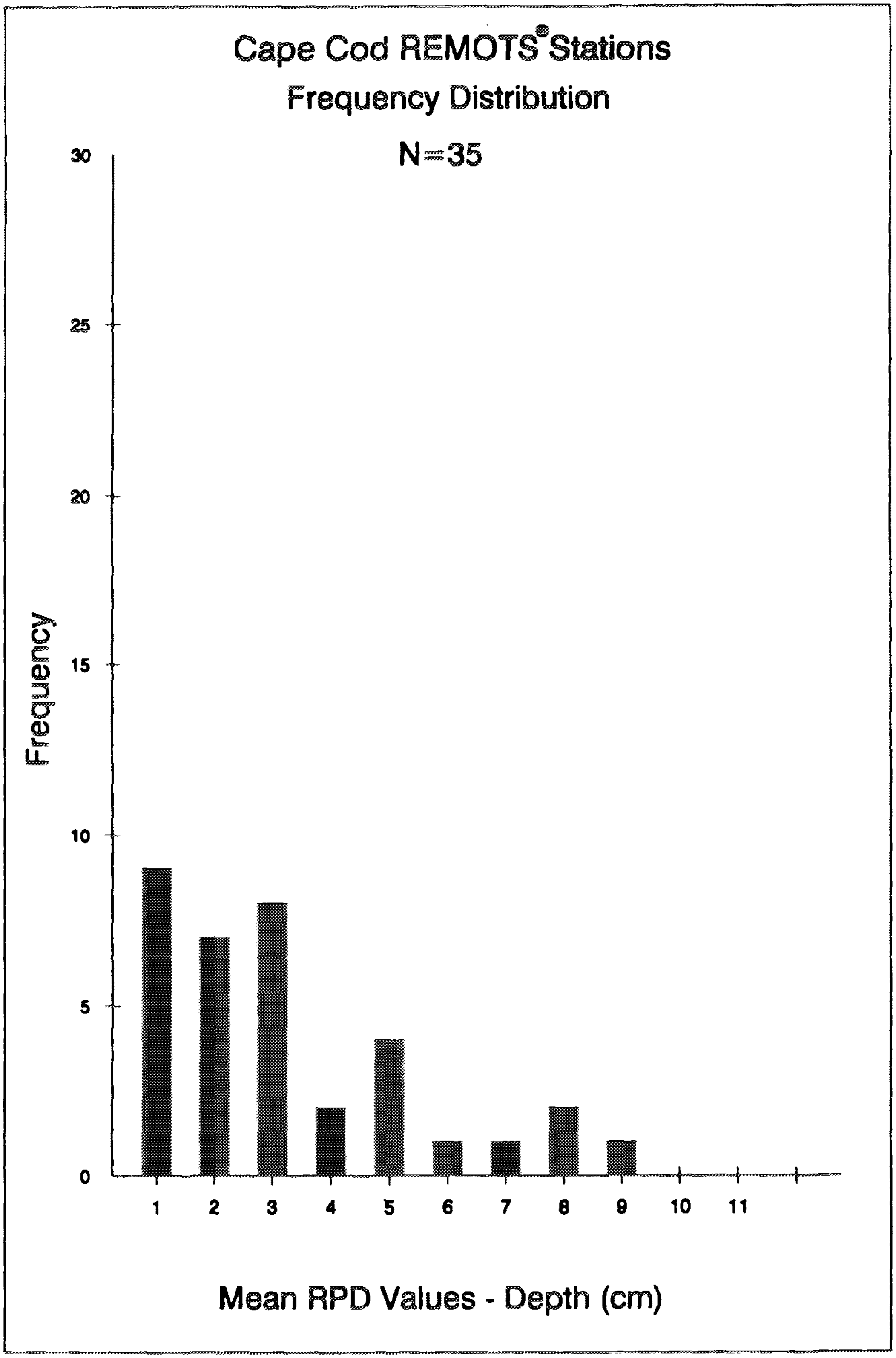
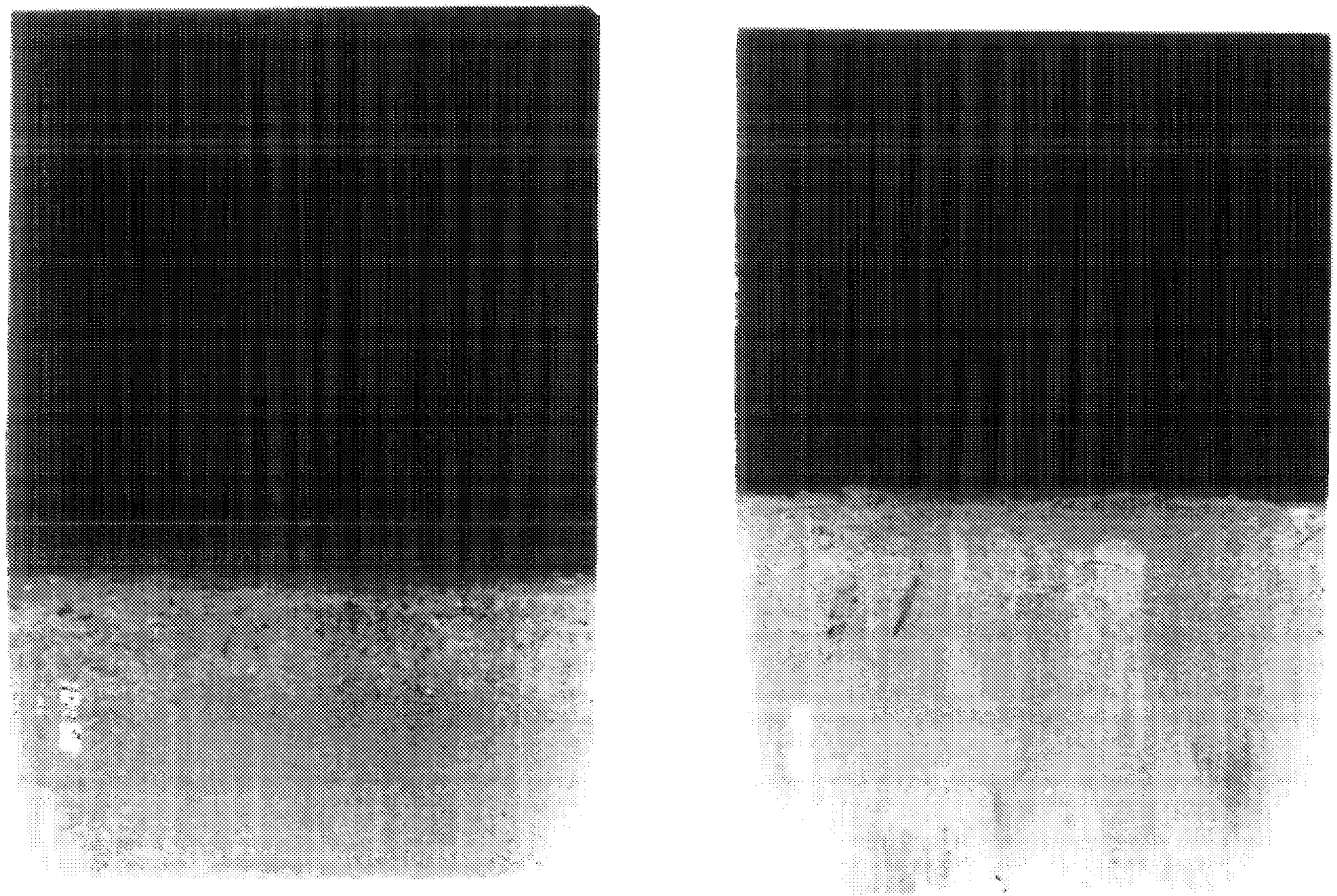
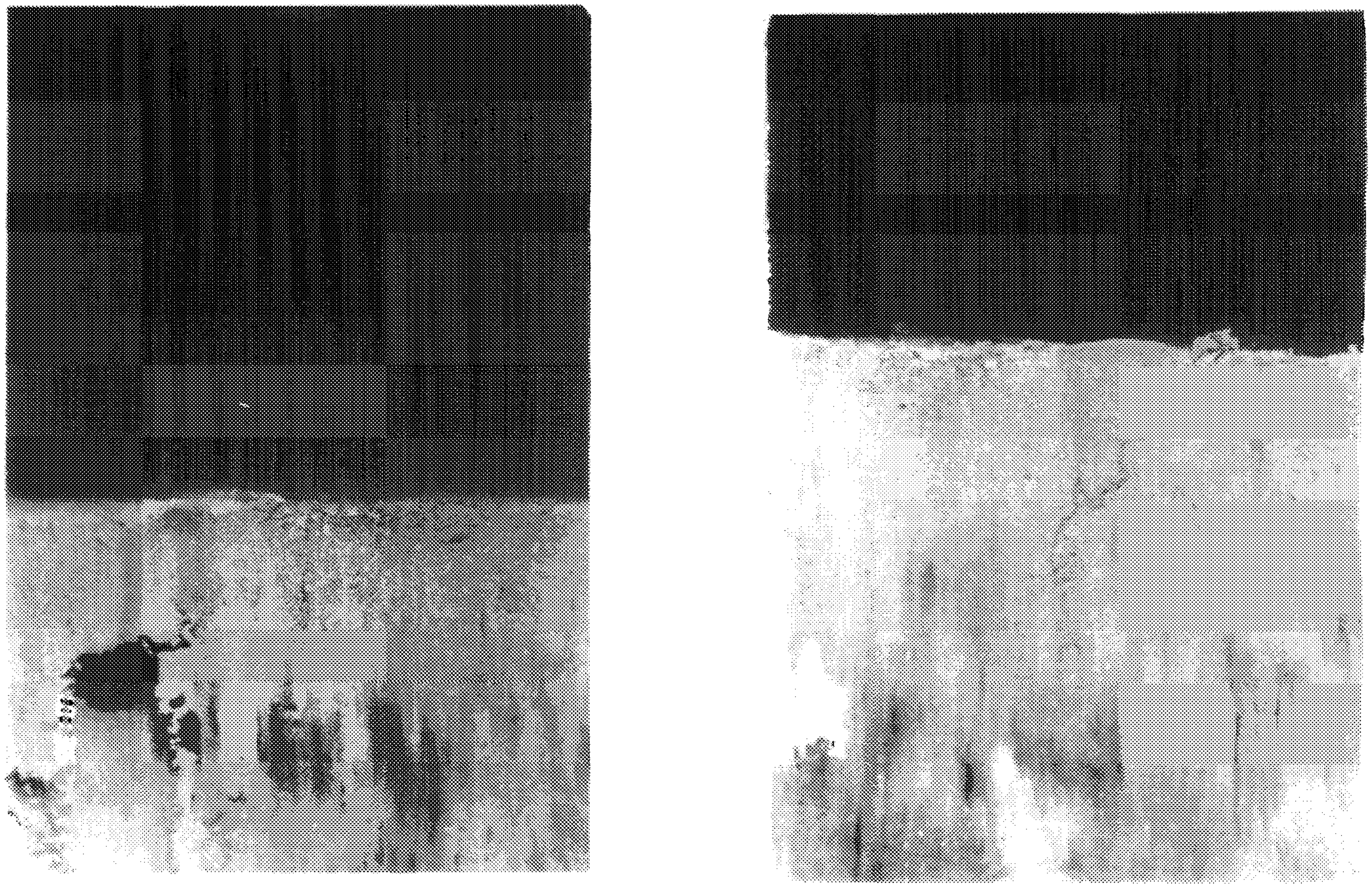


Figure 3-13. Frequency distributions of the apparent RPD depths for all photographs of the REMOTS® transect study of the historic CCDS mound.



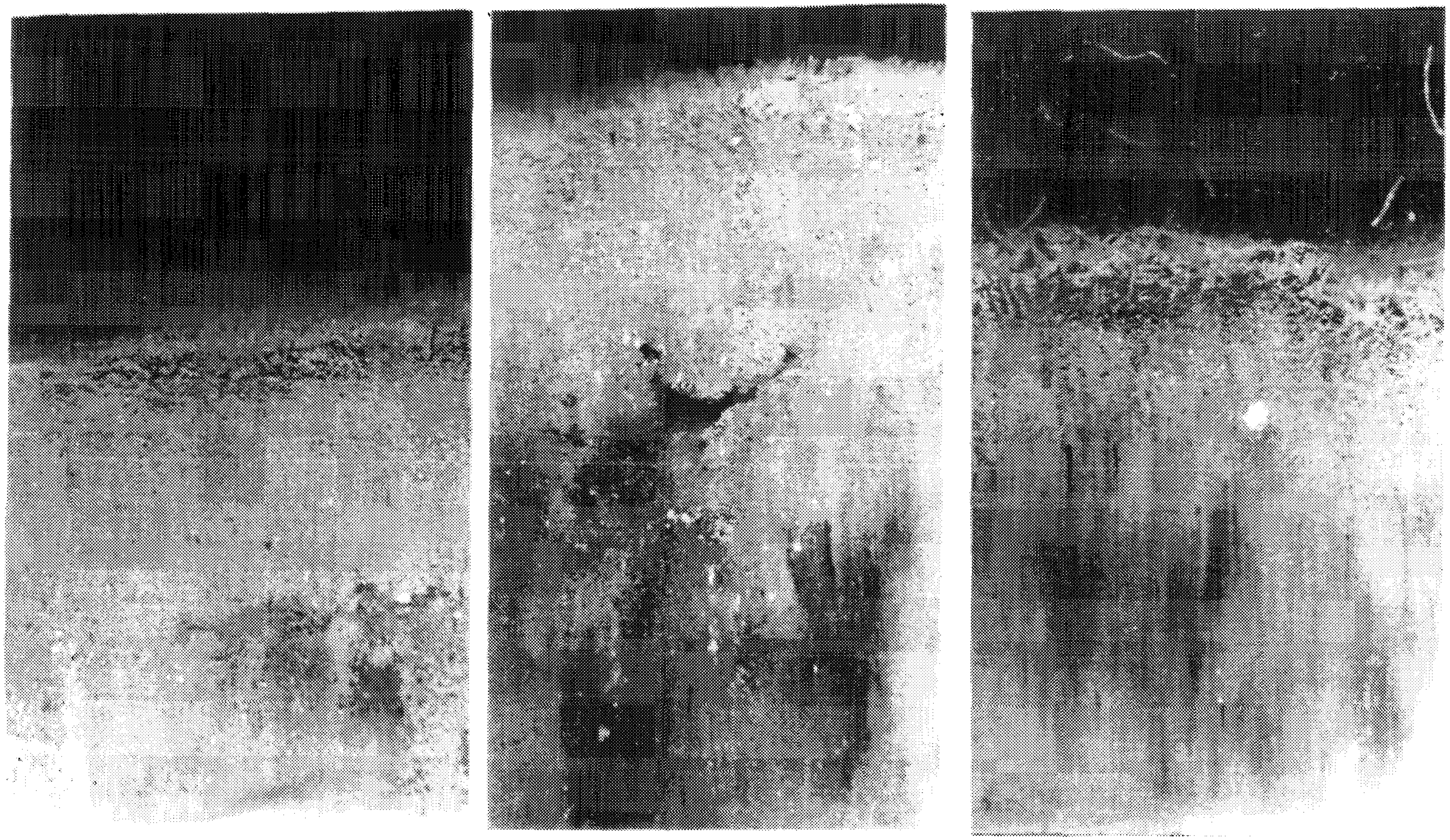
A B

Figure 3-14. REMOTS® photographs from 150W (A) and (B) showing moderate sorting of sediment, reworking of sediment surface, and moderate prism penetration depths.



A B

Figure 3- 15. REMOTS® photographs from station 350W (A) and (B) showing large burrow (A) and feeding void (B), indicative of Stage III taxa.



A B C

Figure 3-16. REMOTS® photographs from stations 200E (A), 300E (B), and 350E (C) showing dense tube population with thicker tube, indicative of Stage II amphipods.

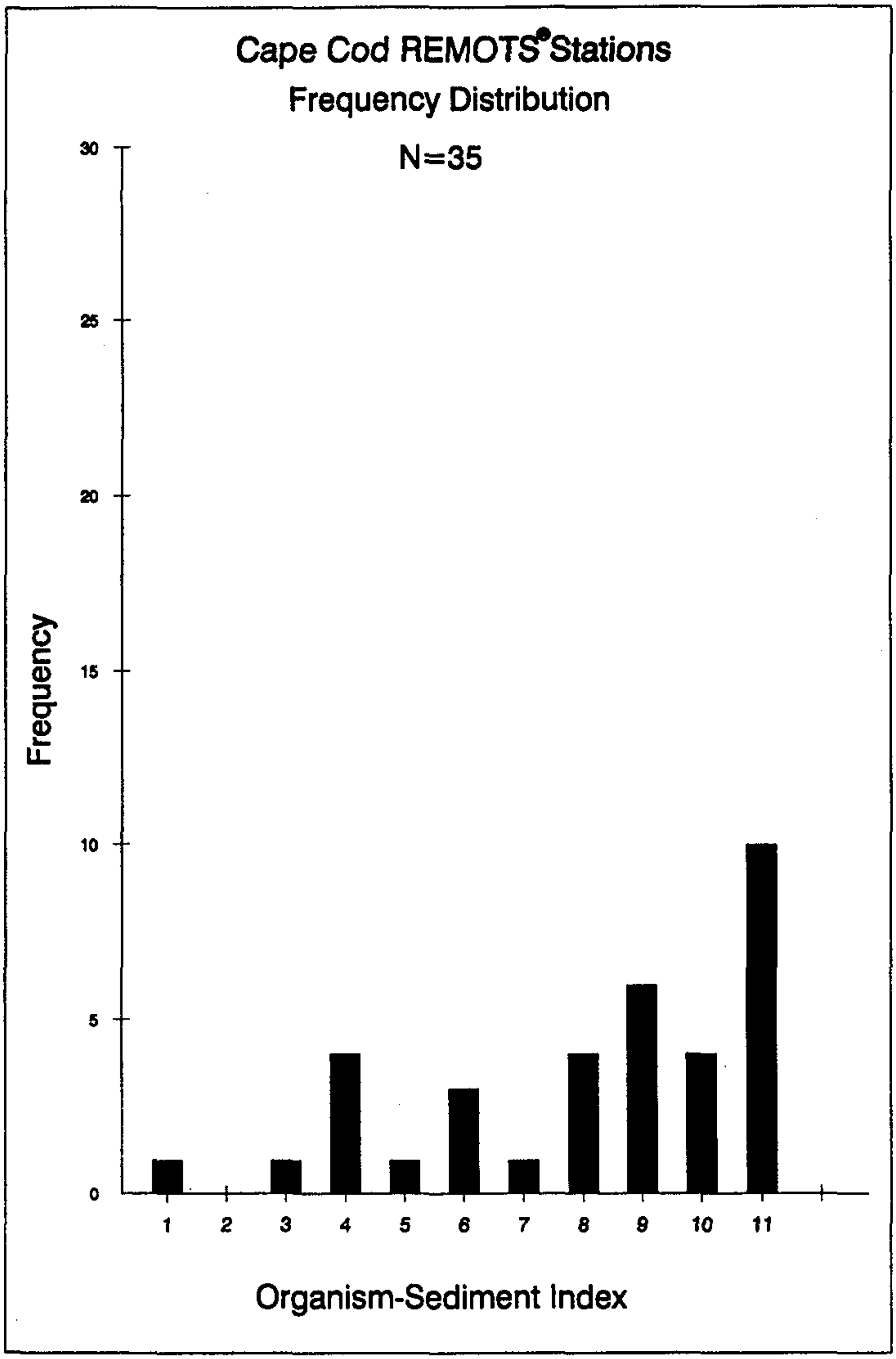


Figure 3- 17. Frequency distributions of Organism-Sediment Indices for all photographs of the REMOTS® transect study of the historic CCDS mound.