U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

The texture of surficial sediments in northeastern Long Island Sound

by

Poppe, L.J.[1], Lewis, R.S.[2], and Moffett, A.M.[1]

Open-File Report 92-550

[1] USGS
Quissett Laboratories
Woods Hole, MA 02543

[2] Connecticut Geological and Natural Survey
Long Island Sound Resource Center
University of Connecticut, Avery Point
Groton, CT 06340

ABSTRACT

Grain-size analyses were performed on 57 samples from northeastern Long Island Sound. The relative grain-size frequency distributions and related statistics are reported herein. Descriptions of the benthic character from video tapes of the bottom at these stations, and three others, are also presented.

The northeastern part of the study area is characterized by very poorly sorted surficial sediments that have bimodal distributions. Surficial sediments in the southwestern part of the study area are typically moderately sorted, have unimodal distributions, and contain much less silt and clay. These textural distributions are a product of the Holocene tidal current regime.

INTRODUCTION

There are four main reasons for performing particle-size analyses on sediments (Blatt et al., 1972): (1) the grain size is a basic measure of the sediment, (2) grain-size distributions are characteristic of sediments deposited in certain environments, (3) detailed study of the observed grain-size distributions often yield information about the physical mechanisms occurring during deposition and diagenesis, and (4) grain size can often be related to other properties, such as permeability or stability, and variations in these properties may be predicted from variations in grain size.

With this in mind, the fundamental objectives of this study were to accurately measure the grain size distribution of the surficial sediment samples from this part of northeastern Long Island Sound, to determine their frequency distributions, and to calculate statistical descriptions that adequately characterize these samples. These grain-size data will eventually be used to describe the sedimentary processes active in this portion of northeastern Long Island Sound, and to evaluate near-shore sand and gravel resources. Other potential uses for these textural data include benthic biologic studies that evaluate faunal distributions and relate them to habitats, and geochemical studies involving the transport and deposition of pollutants.

STUDY AREA

Long Island Sound, which is about 182 km long by a maximum of 32 km wide, is bordered on the north by the rocky shoreline of Connecticut and on the south by the eroding sandy bluffs of Long Island, New York. The study area (Figs. 1, 2) lies in northeastern Long Island Sound offshore from the Thames River estuary and covers about 5.4 km^2. Water depths in the study area average about 18 m; maximum depths of 31 m occur in the central and southwestern parts of the study area.

The bedrock beneath eastern Long Island Sound is believed to be composed of metamorphic and igneous rock of pre-Mesozoic age (Needell et al., 1987; Lewis and Needell, 1987). The bedrock is unconformably overlain by two sheets of glacial drift, one of pre-Wisconsinian age and one of late Wisconsinian age, and Holocene marine sediments (Lewis and Stone, 1991).

Strong tidal currents have extensively eroded and reworked the sediments and continue to control sedimentary processes and surficial sediment distributions in eastern Long Island Sound. The irregular bottom topography and extensive lag deposits of boulders reflect this scour, transport, and reworking of the glacial and early post-glacial deposits (Lewis and Stone, 1991).

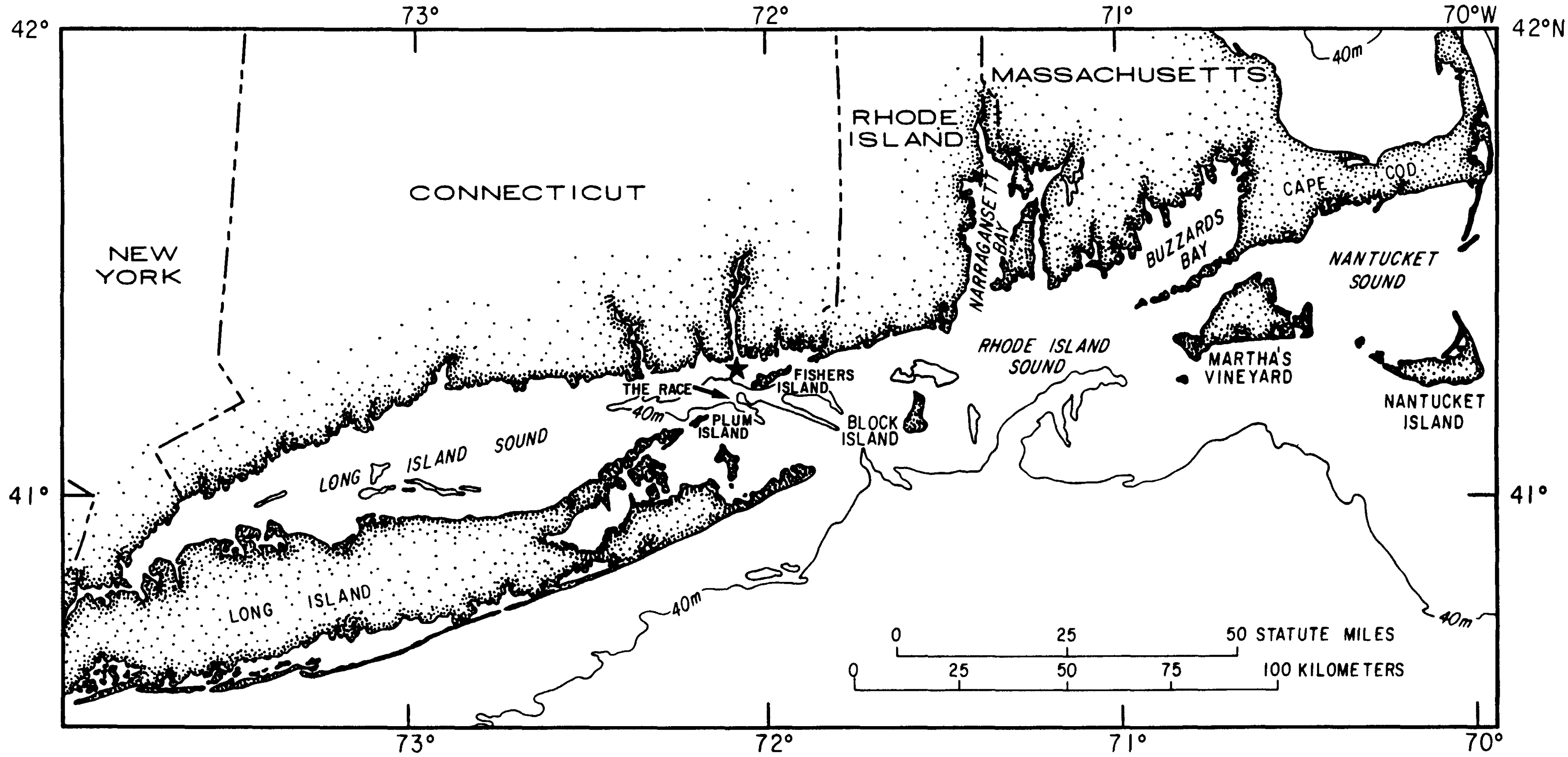
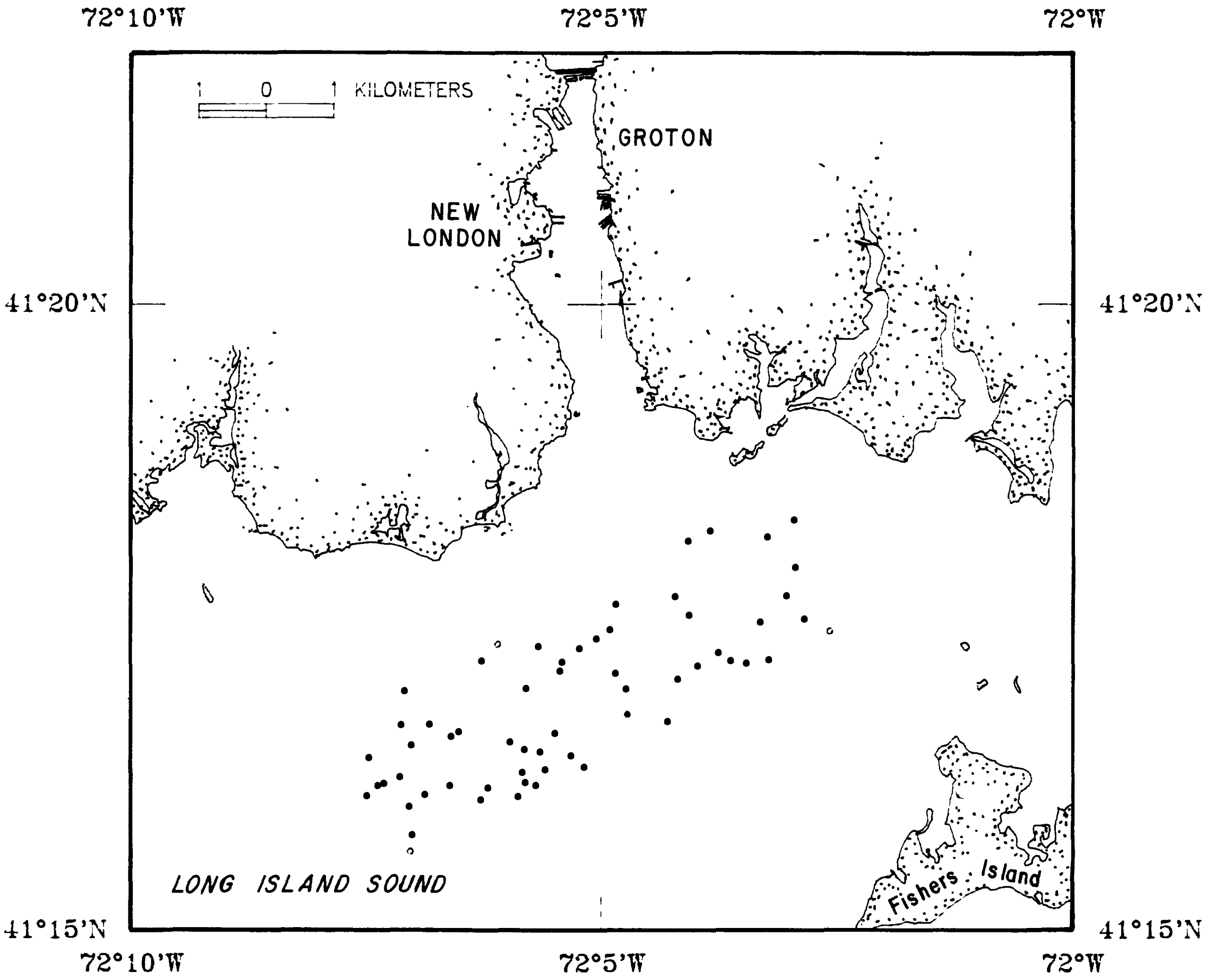


Figure 1. Index map showing the location of the study area (solid star). Map also shows the locations of Plum Island, Fishers Island, and the Race.

Figure 2. Map of eastern Long Island Sound showing the station locations. Stations where surficial sediment samples and bottom photographs were collected are shown as solid circles. Stations where only bottom photographs were taken due to the presence of boulders are shown as open circles.



METHODS

Surficial sediment samples and bottom photographs were attempted at 60 locations during June, 1992 aboard the RV Asterias using a Van Veen grab sampler (Fig. 1). This grab sampler was equipped with an Osprey Camera system attached to an 8 mm video cassette recorder. The video system was used to appraise intrastation bottom variability and observe boulder fields and bedrock outcrop areas where sediment samples could not be collected. The 0-2 cm interval in the surficial sediments was subsampled from the grab sampler; these samples were frozen and stored for later analysis. Navigation was performed using a differential Global Satellite Positioning system and LORAN-C.

A total of 57 samples were collected. The samples were thawed and visually inspected in the laboratory. If the sample contained gravel, the entire sample was analyzed. If the sample was composed of only sand, silt, and clay, an approximately 50 gram, representative split was analyzed. The sample to be analyzed was placed in preweighed 100 ml beaker, weighed, and dried in a convection oven set at 75 ^{o}C. When dried, the samples were placed in a desiccator to cool and then weighed. The decrease in weight due to water loss was used to correct for salt; salinity was assumed to be 30 ^{o}/oo. The weight of the sample and beaker less the weight of the beaker and the salt correction gave the sample weight.

The samples were disaggregated and then wet sieved through a number 230, 62 μm (4ϕ) sieve using distilled water to separate the coarse- and fine-fractions. The fine fraction was sealed in a Mason jar and reserved for analysis by Coulter Counter (Shideler, 1976). The coarse fraction was washed in tap water and reintroduced into the preweighed beaker. The coarse fraction was dried in the convection oven at 75 ^{o}C and weighed. The weight of the coarse (greater than 62 μm) fraction is equal to the weight sand plus gravel. The weight fines (silt and clay) can also be calculated by subtracting the coarse weight from the sample weight.

The coarse fraction was dry sieved through a number 10, 2.0 mm (-1ϕ) sieve to separate the sand and gravel. The size distribution within the gravel fraction was determined by sieving. Because biogenic carbonates commonly form in situ, they are not representative of the depositional environment from a textural standpoint. Therefore, bivalve shells and other biogenic debris greater than 0ϕ (1.0 mm) were manually removed from the samples and the weights corrected to mitigate this source of error.

If the sand fraction contained more than 16 grams of material (enough to run the analysis twice), a rapid sediment analyzer (Schlee, 1966) was used to determine the sand distribution. If less than 16 grams of sand were available, this fraction was dry sieved using a Ro-Tap.

The fine fraction was analyzed by Coulter Counter; storage in the Mason jars prior to analysis never exceeded five days. The gravel, sand, and fine fraction data were processed by computer to generate the distributions, statistics, and data base (Poppe et al., 1985). One limitation of using a Coulter Counter to perform fine fraction analyses is its ability to "see" only those particles for which it has been calibrated. Calibration for this study allowed us to determine the distribution down to 0.62 μm or about two-thirds of the 11ϕ fraction. Because clay particles finer than this diameter and all of the colloidal fraction were not determined, a slight decrease in the 11ϕ fraction is present in the size distributions (Appendix B).

RESULTS AND COMMENTS

The station locations, water depths, and brief comments on the bottom photography are presented in Appendix A. Station locations with low numerical designations (i.e. M-1 to M-29) tend to be located in the northeastern portion of the study area; station locations with higher numerical designations (i.e. M-30 to M-60) are located in the southwestern portion of the study area. The relative frequency distributions of the grain-size analyses are presented in Appendix B and the related statistics and verbal equivalents are presented in Appendix C. Size classifications are based on the method proposed by Wentworth (1929); the statistics were calculated using the method of moments (Folk, 1974). The verbal equivalents were calculated using the inclusive graphics statistical method (Folk, 1974) and are based on the nomenclature proposed by Shepard (1954).

The northeastern part of the study area is characterized by very poorly sorted sediments that have bimodal distributions. Three explanations are offered for these distributions. First, tills, which by definition are poorly sorted, underlie and are exposed in the study area (Lewis and Stone, 1991). Second, strong tidal currents, which flow in and out of Long Island Sound through the Race, erode the underlying glacial tills and winnow away the finer-grained surficial sediments. Under these conditions, thin lag deposits of gravel, which were penetrated by the grab sampler, often remain to armor the underlying silts and sands. Third, seaweed-encrusted coarse gravel was occasionally observed being "rafted" by currents across the study area during bottom photography. When the seaweed dies, the gravel is stranded in finer-grained, hydraulically-unequivalent sediments. The sediments from the northeastern portion of the study area range primarily from silty sand to gravelly sand. The siltier, organic-rich sediments typically contain scattered clam shells and are heavily burrowed by amphipods and polychaetes. Spider crabs are often observed in the bottom photographs.

The southwestern part of the study area is primarily characterized by moderately sorted sediments that have unimodal distributions and contain much less silt and clay. These coarser-grained sandy sediments are usually associated with current ripples and often contain rounded shell hash. Gravelly patches are commonly interspaced between the rippled sands. If these gravelly patches represent the exposed portions of a lag deposit that underlies this part of the study area, then the overlying sand sheets and waves are probably mobile. Starfish, seafans, sponges, gastropods, hermit crabs, and rock crabs inhabit these gravelly areas.

The greater maturity and better sorting reflected by the textural distributions of the surficial sediments in the southwestern part of the study area, relative to those in the northeastern part, is a product of the Holocene current regime. The southwestern part of the study area is more exposed to the strong tidal currents (up to 4.0 knots) that flow in and out of Long Island Sound through the Race, the strait between Fishers Island and Plum Island that is located to the southeast of the study area. Fishers Island deflects these strong currents away from the northeastern part of the study area, where bottom transport is probably controlled by the weaker tidal currents (<1.8 knots that flow in and out of Fishers Island Sound.

Between the northeastern and southwestern portions of the study area are station locations covered by lag deposits of mussel shells (i.e. M-26, M-32 to M-37). These shells, which were subtracted during the textural analyses, are commonly overgrown by hydrozoans and algae. The shells apparently serve to armor the bottom against current erosion and permit the accumulation of finer-grained sediment in the interstices. This matrix is usually heavily burrowed by polychaetes and amphipods; crabs scavenge and starfish browse across the surface.

Textural samples were not collected at stations M-8, M-43, and M-60, because bottom photography at these stations revealed the presence of numerous boulders. Scattered boulders were also observed at station M-40. The boulders, which would have prevented the collection of texturally representative sediment samples, are overgrown with kelp and other types of seaweed.

The cities of New London and Groton are situated on the Thames River estuary and have long been used as major seaports. Commercial shipping, chemical, shipbuilding, and petroleum facilities and naval installations are located along the shoreline of the estuary. These industries are directly or indirectly responsible for most of the loadings of anthropogenic contaminants that effect the texture of the sediments in eastern Long Island Sound. For example, dredge spoils, which are dumped off the mouth of the Thames River estuary, contribute muddy sediments to the environment of the study area (United States Naval Oceanographic Office, 1973; National Marine Fisheries Service, 1976; Reid and Frame, 1977; Bohlen and others, 1979; Brown, 1980). Also, gravel-sized coal, which was used as a fuel, and coal slag were observed at several of the sample sites.

Interested parties can obtain copies of the grain-size analysis data and an explanation of the variable headings in ASCII format and on 3.5" diskettes by contacting any of the authors. Videotapes showing the bottom character of the station locations can be viewed at the U.S. Geological Survey offices in Woods Hole, Massachusetts or at the Long Island Sound Resource Center in Groton, Connecticut.

ACKNOWLEDGMENTS

Collection and analysis of the samples was funded through a State of Connecticut/U.S. Geological Survey cooperative. We thank S. Quarrier (CGS), D. Tolderlund (CGA), A. Locklear (SCC), R. Zajac (UNH), J. Newman (UNH), and R. Wintsch (IU) for their assistance in the field, R. Oldale and R. Rendigs for reviewing this report, and D. Olmsted, who was captain of the R/V Asterias.

REFERENCES

Blatt, H., Middleton, G., and Murray, R., 1972, The origin of sedimentary rocks: Prentice-Hall Publishing Co., N.J., 634 p.

Bohlen, W.F., Cundy, D.F., and Tramontano, J.M., 1979, Suspended material distributions in the wake of estuarine channel dredging operations: Estuarine Coastal Shelf Science, v. 9, p. 699-711.

Brown, C.L., 1980, Final Report: Environmental monitoring program Phase II. - Dredging and dumping of spoils, Thames River, New London, Connecticut - March, 1977-March, 1979: Naval Underwater Systems Center, New London, Connecticut, 179 p.

Folk, R.L., 1974, The petrology of sedimentary rocks: Hemphill Publishing Co., Austin, 182 p.

Lewis, R.S., and Stone, J.R., 1991, Late Quaternary stratigraphy and depositional history of the Long Island Sound basin: Connecticut and New York: Journal Coastal Research, Special Issue 11, p. 1-23.

Lewis, R.S., and Needell, S.W., 1987, Maps showing the stratigraphic framework and quaternary geologic history of eastern Long Island Sound: U.S. Geological Survey Miscellaneous Field Studies Map MF-1939-A, 7 p., 3 sheets.

National Marine Fisheries Service, 1974, An environmental survey of the effects of dredging and spoil disposal, New London, Connecticut: 4th, 5th, and 6th Quarterly Report, NMFS Sandy Hook Laboratory, New Jersy.

Needell, S.W., Lewis, R.S., and Colman, S.M., 1987, Maps showing the Quaternary geology of east-central Long Island Sound: U.S. Geological Survey Miscellaneous Field Studies Map MF-1939-B, 3 sheets.

Poppe, L.J., Eliason, A.H., and Fredericks, J.J., 1985, APSAS - An automated particle size analysis system: U.S. Geological Survey Circular 963, 77 p

Reid, R.N., and Frame, A.B., 1977, Sediments and benthic macrofauna of river and disposal area: In Physical, Chemical, and Biological Effects of Dredging in the Thames River (CT), and Spoil Disposal at the New London (CT) Dumping Ground, NTIS Report No. AD10441064.

Schlee, J., 1966, A modified Woods Hole rapid sediment analyzer: Journal Sedimentary Petrology, v. 30, p. 403-413.

Shepard, F.P., 1954, Nomenclature based on sand-silt-clay ratios: Journal Sedimentary Petrology, v. 24, p. 151-158.

Shideler, G.L., 1976, A comparison of electronic particle counting and pipet techniques in routine mud analysis: Journal Sedimentary Petrology, v. 42, p. 122-134.

United States Naval Oceanographic Office, 1973, Preliminary report on the environmental investigation of a dredge spoil disposal site near New London, Connecticut: NAVOCEANO Technical Report No. 7300-73, 87 p.

Wentworth, C.K., 1929, Method of computing mechanical composition of sediments: Geological Society America Bulletin, v. 40, p. 771-790.

APPENDIX A

This table contains a list of the sample numbers, navigation (latitudes and longitudes) in decimal degrees, water depths in meters, and comments on the bottom character.

SAMPLE NUMBER	LATITUDE	LONGITUDE	WATER DEPTH	COMMENTS
M-1	41.301813	-72.067917	6	SCATTERED COBBLE, RED ALGAE, TILL?, NO BOTTOM VIDEO
M-2	41.303203	-72.064067	9	SCATTERED COBBLES, ALGAE, NO BOTTOM VIDEO
M-3	41.302377	-72.053928	10	BURROWED WITH AMPHIPOD AND WORM TUBES
M-4	41.304642	-72.049247	10	BURROWED WITH AMPHIPOD TUBES, A FEW SHELLS
M-5	41.298337	-72.049120	11	BURROWED WITH AMPHIPOD TUBES, SEAWEED
M-6	41.294578	-72.050587	12	BURROWED WITH AMPHIPOD TUBES, HERMIT CRABS
M-7	41.291522	-72.047507	12	BURROWED WITH AMPHIPOD TUBES, A FEW SHELLS
M-8	41.289887	-72.042970	11	BOULDERS, SEAWEED, NO TEXTURAL SAMPLE
M-9	41.285537	-72.057657	14	BURROWED WITH AMPHIPOD TUBES, SHELLS, FAINT RIPPLES
M-10	41.286062	-72.053680	13	BURROWED WITH AMPHIPOD TUBES, SOME CLAM AND WELK SHELLS
M-11	41.285907	-72.060353	14	AMPHIPOD BURROWS, SPIDER CRABS
M-12	41.283433	-72.069812	15	SPONGES, SHELL HASH, AMPHIPODS, SCATTERED BOULDERS
M-13	41.285257	-72.066315	14	AMPHIPOD BURROWS, SOME CLAM SHELLS
M-14	41.286972	-72.062580	14	AMPHIPOD BURROWS, SPIDER CRABS
M-15	41.291110	-72.055318	13	AMPHIPOD BURROWS, SOME SHELLS
M-16	41.292040	-72.067807	14	AMPHIPOD BURROWS, LOBSTERS
M-17	41.294475	-72.070253	13	AMPHIPOD BURROWS, SPIDER CRABS, SHELLS, SEAWEED
M-18	41.293420	-72.080773	12	AMPHIPOD BURROWS
M-19	41.287852	-72.094513	14	GRAVELLY PATCHES, FAINT RIPPLES, SPONGES, SOME SHELL HASH, CRABS
M-20	41.285767	-72.090345	16	ROCK CRABS, SOME SHELL HASH
M-21	41.287582	-72.087318	16	FAINT RIPPLES, SHELL HASH
M-22	41.288922	-72.084297	16	AMPHIPOD BURROWS, SOME SHELLS
M-23	41.290043	-72.081860	17	AMPHIPOD BURROWS, WORMS, SOME SHELLS
M-24	41.284583	-72.090775	16	SOME GRAVELLY PATCHES, SPONGES, SOME SHELLS
M-25	41.284308	-72.080597	15	AMPHIPOD BURROWS, WORMS
M-26	41.282167	-72.078978	14	MUSSEL SHELL HASH
M-27	41.273765	-72.094200	27	SPONGES, WORMS, NO BOTTOM VIDEO
M-28	41.278745	-72.078787	16	SCATTERED COBBLES, DENSELY BURROWED WITH AMPHIPOD TUBES, SPONGES
M-29	41.277785	-72.071607	17	GRAVEL PATCHES, AMPHIPODS, SPONGES, SEAFAN
M-30	41.271825	-72.086322	22	PATCHY TEXTURE, CRABS, SPONGES, AMPHIPODS
M-31	41.269347	-72.094977	21	SOME SHELL HASH, ROCK CRABS
M-32	41.267908	-72.098123	20	MUSSEL SHELL HASH, SOME AMPHIPOD BURROWS, STARFISH
M-33	41.269728	-72.096873	16	MUSSEL SHELL HASH, SOME HYDROZOANS GROW ON SHELLS
M-34	41.271073	-72.094728	24	MUSSEL SHELL HASH, NO BOTTOM VIDEO
M-35	41.271412	-72.093357	25	MUSSEL SHELL HASH, NO BOTTOM VIDEO
M-36	41.273268	-72.088760	24	MUSSEL SHELL HASH, NO BOTTOM VIDEO
M-37	41.269008	-72.103565	21	MUSSEL SHELL HASH, NO BOTTOM VIDEO
M-38	41.274062	-72.097043	24	SOME MUSSEL SHELL HASH, HERMIT CRABS, AMPHIPODS, STARFISH
M-39	41.276258	-72.091610	21	AMPHIPOD BURROWS AND SHELL HASH
M-40	41.275062	-72.099570	21	SCATTERED BOULDERS, MUSSEL SHELL HASH, SPONGES
M-41	41.282203	-72.096760	17	WORMS, AMPHIPOD BURROWS, SHELL HASH
M-42	41.285983	-72.104595	12	SPONGES, CLAM SHELLS, KELP, LOBSTER TRAP
M-43	41.288175	-72.101780	5	BOULDERS, KELP, NO TEXTURAL SAMPLE
M-44	41.281850	-72.118217	15	SHELL HASH, SOME RIPPLES, ROCK CRABS

SAMPLE NUMBER	LATITUDE	LONGITUDE	WATER DEPTH	COMMENTS
M-45	41.277325	-72.118820	21	SOME SHELLS, FAINT RIPPLES, SPARSE KELP
M-46	41.272968	-72.124520	20	SHELL HASH, KELP, STARFISH
M-47	41.274613	-72.117040	23	SCATTERED COBBLES, MUSSEL SHELL HASH
M-48	41.275768	-72.109968	23	CURRENT RIPPLES, SOME SHELLS, STARFISH
M-49	41.276478	-72.108703	23	CURRENT RIPPLES, SOME SHELLS, SKATE, SEAWEED, ROCK CRABS
M-50	41.277402	-72.113785	23	FAINT RIPPLES, SOME AMPHIPODS, SHELLS
M-51	41.267955	-72.124942	29	CURRENT RIPPLES, HERMIT CRABS, SOME SHELL HASH
M-52	41.269290	-72.122967	23	CURRENT RIPPLES, FINE-GRAINED SHELL HASH
M-53	41.269615	-72.121875	19	CURRENT RIPPLES, FINE-GRAINED SHELL HASH, SPONGES
M-54	41.270422	-72.119137	20	FAINT RIPPLES, SOME SHELL HASH, SPIDER CRABS
M-55	41.266505	-72.117452	25	RIPPLES, SHELL HASH
M-56	41.268097	-72.114720	23	RIPPLES, SHELL HASH, ROCK CRABS
M-57	41.269358	-72.110315	23	FAINT RIPPLES, WORM TUBES, MUSSEL SHELLS, SHELL HASH
M-58	41.267468	-72.104820	25	SOME SHELL HASH
M-59	41.262730	-72.116875	31	FAINT RIPPLES, ABUNDANT SHELL HASH, CRABS
M-60	41.260578	-72.117165	25	BOULDERS, SPONGES, ABUNDANT MUSSEL SHELLS, NO TEXTURAL SAMPLE

APPENDIX B

This table contains the relative grain-size frequency distributions by weight in whole phi units for each sample. The -5 ϕ fraction contains all sediment coarser than 32 mm; the 11 ϕ fraction contains sediment with diameters between .001 and .00063 mm.

	CLAY			SILT				SAND				GRAVEL				
SAMPLE NUMBER	11ϕ	10ϕ	9ϕ	8ϕ	7ϕ	6ϕ	5ϕ	4ϕ	3ϕ	2ϕ	1ϕ	0ϕ	-1ϕ	-2ϕ	-3ϕ	-4ϕ	-5ϕ
M-1	0.79	1.74	1.42	0.72	0.61	0.92	1.30	10.30	18.51	27.32	13.95	4.56	4.35	7.39	4.02	2.10	0.00
M-2	0.71	1.58	1.43	1.10	1.37	2.05	1.83	3.67	6.44	4.13	2.79	1.52	1.11	3.48	10.36	23.71	32.72
M-3	1.52	3.04	2.01	1.25	1.75	3.77	9.49	38.34	16.93	16.48	3.94	0.23	0.55	0.70	0.00	0.00	0.00
M-4	6.26	11.18	7.40	3.65	2.98	5.90	13.75	40.33	7.33	1.07	0.15	0.00	0.00	0.00	0.00	0.00	0.00
M-5	2.31	4.71	3.66	2.38	2.32	5.31	20.40	43.36	13.49	1.71	0.35	0.00	0.00	0.00	0.00	0.00	0.00
M-6	0.40	0.84	0.65	0.40	0.39	0.67	0.99	44.45	9.22	2.02	0.51	0.00	0.00	0.37	0.00	39.09	0.00
M-7	2.72	5.50	3.86	1.76	1.34	1.99	6.12	55.85	20.71	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M-9	3.42	7.08	5.34	2.80	2.46	4.31	6.54	44.44	20.07	3.40	0.14	0.00	0.00	0.00	0.00	0.00	0.00
M-10	2.80	5.66	4.26	2.69	2.38	4.67	15.63	48.17	13.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M-11	3.66	7.41	6.09	3.41	3.46	6.23	5.66	44.79	18.59	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M-12	0.34	0.78	0.70	0.43	0.44	0.86	0.88	2.37	2.19	5.16	9.13	7.22	4.42	10.25	21.25	33.58	0.00
M-13	1.78	4.16	3.74	2.35	1.94	3.93	11.59	21.44	28.20	19.74	1.13	0.00	0.00	0.00	0.00	0.00	0.00
M-14	1.49	2.50	2.15	1.49	1.54	5.88	19.46	40.21	20.76	4.13	0.39	0.00	0.00	0.00	0.00	0.00	0.00
M-15	4.85	7.20	3.43	1.96	1.80	4.89	14.98	47.25	10.29	2.98	0.37	0.00	0.00	0.00	0.00	0.00	0.00
M-16	5.60	7.76	3.57	2.45	4.34	9.39	12.78	33.17	14.77	5.36	0.81	0.00	0.00	0.00	0.00	0.00	0.00
M-17	1.64	2.99	1.68	1.09	2.20	8.82	22.07	40.23	17.32	1.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M-18	1.33	1.98	0.93	0.63	1.08	3.42	14.54	46.57	28.23	1.14	0.15	0.00	0.00	0.00	0.00	0.00	0.00
M-19	0.23	0.43	0.15	0.09	0.15	0.38	0.52	6.12	17.68	27.55	8.74	5.65	6.23	9.68	16.40	0.00	0.00
M-20	1.57	2.82	1.38	0.91	1.19	3.15	3.71	12.52	22.99	28.18	16.15	2.56	1.14	1.17	0.56	0.00	0.00
M-21	1.14	2.31	1.11	0.78	1.22	2.58	3.98	8.85	17.80	15.42	8.84	3.37	4.00	6.28	8.56	13.76	0.00
M-22	1.54	3.60	3.18	2.22	3.57	8.96	18.18	14.54	18.24	14.37	10.08	0.70	0.38	0.44	0.00	0.00	0.00
M-23	1.06	2.02	0.99	0.70	0.88	2.98	9.14	35.03	42.10	4.85	0.25	0.00	0.00	0.00	0.00	0.00	0.00
M-24	0.49	1.03	0.68	0.39	0.54	1.07	1.99	12.18	20.35	20.34	7.35	2.57	4.18	5.59	18.35	2.90	0.00
M-25	1.57	3.48	1.60	1.12	1.71	4.39	13.99	25.11	20.37	9.60	2.32	0.46	0.84	1.44	12.00	0.00	0.00
M-26	1.14	2.33	1.35	1.13	1.94	5.13	7.36	15.33	17.00	13.72	7.11	2.39	4.44	5.60	7.66	6.37	0.00
M-27	0.55	1.30	1.18	1.06	1.21	2.78	4.57	35.81	36.95	12.14	2.45	0.00	0.00	0.00	0.00	0.00	0.00
M-28	1.49	3.11	2.24	2.32	3.70	11.29	16.87	22.83	17.80	10.45	2.70	0.33	1.35	2.03	1.49	0.00	0.00
M-29	1.71	4.81	4.32	2.48	2.12	4.06	9.30	33.19	19.35	9.57	4.48	1.29	2.07	1.25	0.00	0.00	0.00

SAMPLE NUMBER	CLAY 11φ	10φ	9φ	8φ	SILT 7φ	6φ	5φ	4φ	SAND 3φ	2φ	1φ	0φ	-1φ	GRAVEL -2φ	-3φ	-4φ	-5φ
M-30	1.18	2.89	2.62	1.65	1.24	1.93	2.02	31.53	25.07	12.21	3.02	0.00	0.04	4.14	10.46	0.00	0.00
M-31	1.03	2.20	1.82	1.21	1.27	1.65	1.18	21.73	26.22	21.88	9.30	1.05	0.75	1.04	7.67	0.00	0.00
M-32	0.44	0.92	0.70	0.45	0.38	0.57	0.81	15.38	25.90	26.56	14.29	1.42	1.82	1.21	9.15	0.00	0.00
M-33	0.60	1.21	0.98	0.71	0.66	0.91	1.11	19.17	30.95	33.29	9.16	0.94	0.31	0.00	0.00	0.00	0.00
M-34	0.67	1.37	1.17	0.87	0.81	1.28	1.76	23.58	30.33	15.91	9.92	3.58	3.03	5.72	0.00	0.00	0.00
M-35	0.91	1.64	1.50	1.02	0.97	1.50	2.64	31.91	28.01	11.76	3.05	1.61	3.19	4.79	5.50	0.00	0.00
M-36	0.61	1.33	1.04	0.68	0.68	1.43	3.13	21.45	23.25	26.20	15.82	2.68	1.41	0.29	0.00	0.00	0.00
M-37	0.79	1.57	1.45	1.04	0.90	1.27	0.99	22.93	27.85	25.88	10.80	1.78	2.75	0.00	0.00	0.00	0.00
M-38	1.65	3.38	3.20	2.16	2.11	3.48	5.53	36.25	30.25	9.36	2.10	0.00	0.15	0.38	0.00	0.00	0.00
M-39	1.65	3.55	3.74	2.59	1.89	3.07	4.74	30.80	28.51	17.33	2.13	0.00	0.00	0.00	0.00	0.00	0.00
M-40	2.66	7.97	10.38	8.23	6.51	7.01	4.00	13.68	6.92	7.41	12.62	3.48	3.07	3.92	0.32	1.82	0.00
M-41	1.43	2.65	2.21	1.75	2.00	4.03	5.30	16.91	18.12	31.02	13.38	0.73	0.14	0.33	0.00	0.00	0.00
M-42	0.00	0.01	0.01	0.00	0.00	0.00	0.01	1.10	25.09	56.88	16.00	0.90	0.00	0.00	0.00	0.00	0.00
M-44	0.13	0.78	0.23	0.19	0.22	0.31	0.34	0.78	16.70	44.67	30.58	4.37	0.70	0.00	0.00	0.00	0.00
M-45	0.23	0.61	0.46	0.32	0.45	0.91	0.90	20.70	40.85	23.59	4.80	0.45	0.16	0.00	5.57	0.00	0.00
M-46	0.51	1.44	1.74	1.37	0.99	1.25	1.06	14.93	22.36	15.92	7.62	1.12	5.27	12.51	11.91	0.00	0.00
M-47	0.41	1.13	1.02	0.81	0.91	1.77	2.42	20.91	45.24	20.74	2.33	0.54	0.46	1.31	0.00	0.00	0.00
M-48	0.77	2.02	1.93	1.33	1.30	2.54	3.24	26.65	44.18	14.01	0.95	0.17	0.00	0.91	0.00	0.00	0.00
M-49	0.56	1.29	1.01	0.65	0.45	0.78	2.35	14.56	35.71	33.29	7.52	1.67	0.16	0.00	0.00	0.00	0.00
M-50	0.56	1.34	1.17	1.01	1.20	2.04	2.76	25.08	40.36	19.46	4.02	0.35	0.16	0.49	0.00	0.00	0.00
M-51	0.13	0.23	0.07	0.04	0.03	0.03	0.03	0.30	3.68	88.90	6.26	0.30	0.00	0.00	0.00	0.00	0.00
M-52	0.05	0.08	0.04	0.01	0.01	0.01	0.02	0.88	15.86	50.82	23.31	7.05	1.47	0.39	0.00	0.00	0.00
M-53	0.25	0.85	0.30	0.11	0.06	0.03	0.02	0.00	2.29	18.77	63.55	10.77	2.38	0.62	0.00	0.00	0.00
M-54	0.50	1.19	1.22	0.97	0.64	0.72	0.43	4.25	41.20	38.80	3.99	0.35	1.02	1.75	2.97	0.00	0.00
M-55	0.54	1.40	1.84	1.65	1.18	1.25	0.61	5.99	17.18	16.05	11.35	5.94	10.80	16.35	7.87	0.00	0.00
M-56	0.12	0.35	0.30	0.24	0.16	0.22	0.18	3.29	8.38	40.27	38.30	3.86	2.71	1.05	0.57	0.00	0.00
M-57	0.21	0.60	0.55	0.47	0.50	0.73	0.72	10.59	28.94	30.84	21.00	3.21	1.64	0.00	0.00	0.00	0.00
M-58	1.38	3.02	3.17	2.77	2.67	3.85	4.38	20.01	31.66	18.90	7.56	0.63	0.00	0.00	0.00	0.00	0.00
M-59	0.87	2.01	1.60	1.27	1.07	1.26	1.16	4.43	13.57	20.55	29.63	6.82	6.59	5.45	3.72	0.00	0.00

APPENDIX C

This table contains the sample weight analyzed, percent gravel (>2.0 mm), percent sand (2.0 mm>x>0.062 mm), percent silt (0.063 mm>x>0.004 mm), percent clay (<0.004 mm), the verbal-equivalent sediment classification (Shepard, 1954), and the related method of moments statistics for each sample. Modes are given in the middle of whole phi intervals.

SAMPLE NUMBER	WEIGHT (GRAMS)	PERCENT GRAVEL	PERCENT SAND	PERCENT SILT	PERCENT CLAY	SEDIMENT CLASS	MEDIAN (φ)	MEAN (φ)	STANDARD DEVIATION	SKEWNESS	KURTOSIS	MODE 1 (φ)	MODE 2 (φ)	MODE 3 (φ)
M-1	408.2600	17.86	74.64	3.54	3.95	GRAVELLY SAND	1.50	1.35	2.73	0.25	1.68	1.5	-3.5	0
M-2	764.6600	71.38	18.54	6.35	3.72	GRAVEL	-4.27	-2.26	4.17	0.66	0.61	-5.5	2.5	0
M-3	35.8587	1.25	75.92	16.26	6.57	SAND	3.29	3.47	2.11	0.61	2.61	3.5	0	0
M-4	30.1812	0.00	48.88	26.28	24.84	SAND-SILT-CLAY	4.08	5.37	2.59	0.39	-0.92	3.5	9.5	0
M-5	39.3628	0.00	58.91	30.41	10.68	SILTY SAND	3.79	4.42	2.01	0.79	1.74	3.5	0	0
M-6	46.1110	39.46	56.20	2.45	1.89	GRAVELLY SAND	2.87	0.36	4.03	-0.09	-1.45	3.5	-4.5	0
M-7	52.6727	0.00	76.71	11.21	12.08	SAND	3.52	4.21	2.11	0.93	2.10	3.5	9.5	0
M-8						GRAVEL								
M-9	56.2613	0.00	68.05	16.11	15.84	SILTY SAND	3.59	4.50	2.40	0.64	0.31	3.5	9.5	0
M-10	42.7473	0.00	61.91	25.36	12.72	SILTY SAND	3.75	4.54	2.11	0.79	1.23	3.5	9.5	0
M-11	47.3572	0.00	64.08	18.76	17.16	SILTY SAND	3.69	4.73	2.40	0.58	-0.08	3.5	9.5	5.5
M-12	397.9400	69.50	26.07	2.61	1.82	GRAVEL	3.23	-2.04	2.99	0.82	2.79	-4.5	0.5	0
M-13	49.5471	0.00	70.51	19.82	9.68	SILTY SAND	3.04	3.70	2.28	0.72	1.31	2.5	0	0
M-14	41.6177	0.00	65.49	28.37	6.14	SILTY SAND	3.61	3.98	1.75	0.93	3.79	3.5	0	0
M-15	39.2598	0.00	60.89	23.62	15.48	SILTY SAND	3.77	4.65	2.34	0.68	0.64	3.5	9.5	0
M-16	36.8060	0.00	54.11	28.97	16.93	SILTY SAND	3.88	4.80	2.53	0.49	-0.14	3.5	9.5	0
M-17	51.6873	0.00	59.51	34.18	6.31	SILTY SAND	3.76	4.17	1.72	0.94	3.78	3.5	0	0
M-18	56.0319	0.00	76.09	19.67	4.24	SAND	3.44	3.72	1.51	1.32	7.96	3.5	0	0
M-19	55.8246	32.31	65.74	1.14	0.81	GRAVELLY SAND	1.12	0.31	2.48	0.03	0.16	1.5	-3.5	0
M-20	252.0800	2.87	82.40	8.96	5.77	SAND	2.01	2.47	2.37	0.70	2.83	1.5	0	0
M-21	375.8900	32.60	54.28	8.56	4.56	GRAVELLY SAND	1.34	0.77	3.59	0.15	-0.18	2.5	-4.5	0
M-22	241.9200	0.82	57.93	32.93	8.32	SILTY SAND	3.40	3.69	2.44	0.37	0.41	2.5	4.5	0
M-23	53.1064	0.00	82.23	13.69	4.07	SAND	3.08	3.42	1.56	1.30	7.70	2.5	0	0
M-24	449.1000	31.02	62.79	4.00	2.20	GRAVELLY SAND	1.45	0.71	3.01	0.06	0.00	2.5	-3.5	0
M-25	39.6230	14.28	57.86	21.22	6.65	GRAVELLY SAND	3.12	2.77	3.15	-0.13	0.58	3.5	-3.5	0
M-26	321.5200	24.07	55.55	15.56	4.82	GRAVELLY SAND	2.16	1.71	3.43	0.01	-0.18	2.5	-3.5	0
M-27	51.0348	0.00	87.35	9.62	3.03	SAND	2.96	3.17	1.53	1.09	6.68	2.5	0	0
M-28	49.4311	4.87	54.11	34.18	6.84	SILTY SAND	3.61	3.73	2.51	0.02	1.31	3.5	0	0

SAMPLE NUMBER	WEIGHT (GRAMS)	PERCENT GRAVEL	PERCENT SAND	PERCENT SILT	PERCENT CLAY	SEDIMENT CLASS	MEDIAN (φ)	MEAN (φ)	STANDARD DEVIATION	SKEWNESS	KURTOSIS	MODE 1 (φ)	MODE 2 (φ)	MODE 3 (φ)
M-29	41.5081	3.32	67.87	17.97	10.84	SILTY SAND	3.36	3.71	2.55	0.35	0.81	3.5	0	0
M-30	49.9032	14.64	71.83	6.84	6.69	GRAVELLY SAND	2.80	2.48	3.04	-0.04	0.79	3.5	-3.5	0
M-31	52.5625	9.46	80.18	5.31	5.05	SAND	2.32	2.27	2.65	0.14	1.91	2.5	-3.5	0
M-32	47.2381	12.18	83.55	2.21	2.06	GRAVELLY SAND	1.83	1.59	2.31	-0.02	2.47	1.5	-3.5	0
M-33	50.3345	0.31	93.51	3.38	2.79	SAND	2.20	2.44	1.64	1.16	7.89	1.5	0	0
M-34	56.1791	8.75	83.32	4.72	3.21	SAND	2.39	2.23	2.22	0.27	2.54	2.5	-2.5	0
M-35	55.9490	13.48	76.33	6.13	4.05	GRAVELLY SAND	2.72	2.36	2.62	-0.04	1.52	3.5	-3.5	0
M-36	49.1520	1.70	89.41	5.92	2.98	SAND	2.15	2.36	1.87	0.77	4.56	1.5	0	0
M-37	44.8300	2.75	89.25	4.19	3.81	SAND	2.32	2.50	1.95	0.80	4.50	2.5	0	0
M-38	56.2137	0.53	77.97	13.28	8.23	SAND	3.21	3.67	2.12	0.75	2.37	3.5	0	0
M-39	55.1470	0.00	78.77	12.29	8.94	SAND	3.07	3.59	2.20	0.79	1.83	3.5	0	0
M-40	257.7400	9.13	44.11	25.75	21.01	SAND-SILT-CLAY	3.76	4.10	3.76	-0.07	-0.93	3.5	0.5	5.5
M-41	54.1726	0.47	80.16	13.08	6.29	SAND	2.24	2.87	2.30	0.74	2.06	1.5	0	0
M-42	53.6342	0.00	99.97	0.01	0.02	SAND	1.58	1.60	0.64	0.12	4.42	1.5	0	0
M-43						GRAVEL								
M-44	27.8677	0.70	97.10	1.06	1.14	SAND	1.32	1.40	1.25	1.67	19.09	1.5	0	0
M-45	48.4138	5.73	90.38	2.58	1.30	SAND	2.38	2.19	1.85	-0.33	5.56	2.5	-3.5	0
M-46	314.0000	29.69	61.95	4.67	3.69	GRAVELLY SAND	1.73	1.17	3.07	0.15	0.11	2.5	-2.5	0
M-47	50.1899	1.77	89.77	5.91	2.56	SAND	2.54	2.71	1.62	0.77	7.14	2.5	0	0
M-48	49.8225	0.91	85.96	8.41	4.72	SAND	2.77	3.14	1.81	0.90	5.25	2.5	0	0
M-49	53.6003	0.16	92.74	4.23	2.86	SAND	2.21	2.42	1.62	1.21	8.44	2.5	0	0
M-50	50.4414	0.65	89.28	7.01	3.07	SAND	2.63	2.86	1.66	0.95	6.35	2.5	0	0
M-51	55.2916	0.00	99.44	0.13	0.43	SAND	1.49	1.52	0.60	5.82	157.12	1.5	0	0
M-52	49.0090	1.86	97.93	0.05	0.17	SAND	1.35	1.26	0.94	0.27	11.40	1.5	0	0
M-53	57.4768	3.00	95.28	0.22	1.50	SAND	0.57	0.71	1.31	2.32	29.92	0.5	0	0
M-54	229.2300	5.74	88.59	2.76	2.91	SAND	2.03	2.06	1.95	0.43	6.18	2.5	0	0
M-55	289.9200	35.02	56.51	4.69	3.78	GRAVELLY SAND	0.80	0.70	3.00	0.42	0.76	2.5	-2.5	0
M-56	275.1400	4.33	94.10	0.80	0.77	SAND	1.09	1.13	1.32	0.92	12.97	1.5	0	0
M-57	59.0418	1.64	94.59	2.42	1.36	SAND	1.78	1.89	1.50	0.91	7.59	1.5	0	0
M-58	57.8030	0.00	78.76	13.67	7.57	SAND	2.72	3.30	2.27	0.72	1.59	2.5	0	0
M-59	43.2433	15.76	75.00	4.77	4.48	GRAVELLY SAND	0.93	1.26	2.63	0.61	2.51	0.5	0	0
M-60						GRAVEL								