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The texture of surficial sediments in eastern Long Island Sound near Niantic Bay, Connecticut

by

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ABSTRACT

Grain-size analyses were performed on 61 samples from the Niantic Bay vicinity in eastern Long Island Sound. The relative grain-size frequency distributions and related statistics are reported herein. Descriptions of the benthic character from video tapes and still camera photographs of the bottom at these stations, and 8 others, are also presented.

Gravelly sands, gravels, and boulders dominate the surficial sediments across the southern part of the study area and in the channel between Twotree Island and White Point. These coarse-grained sediments tend to be replaced by progressively finer-grained sediments toward areas that are more protected from the strong tidal currents and toward the central part of Niantic Bay where sandy silts are common. These textural distributions are a result of the late Pleistocene glaciation, the Holocene eustatic rise in sea level, and the present day tidal regime.

INTRODUCTION

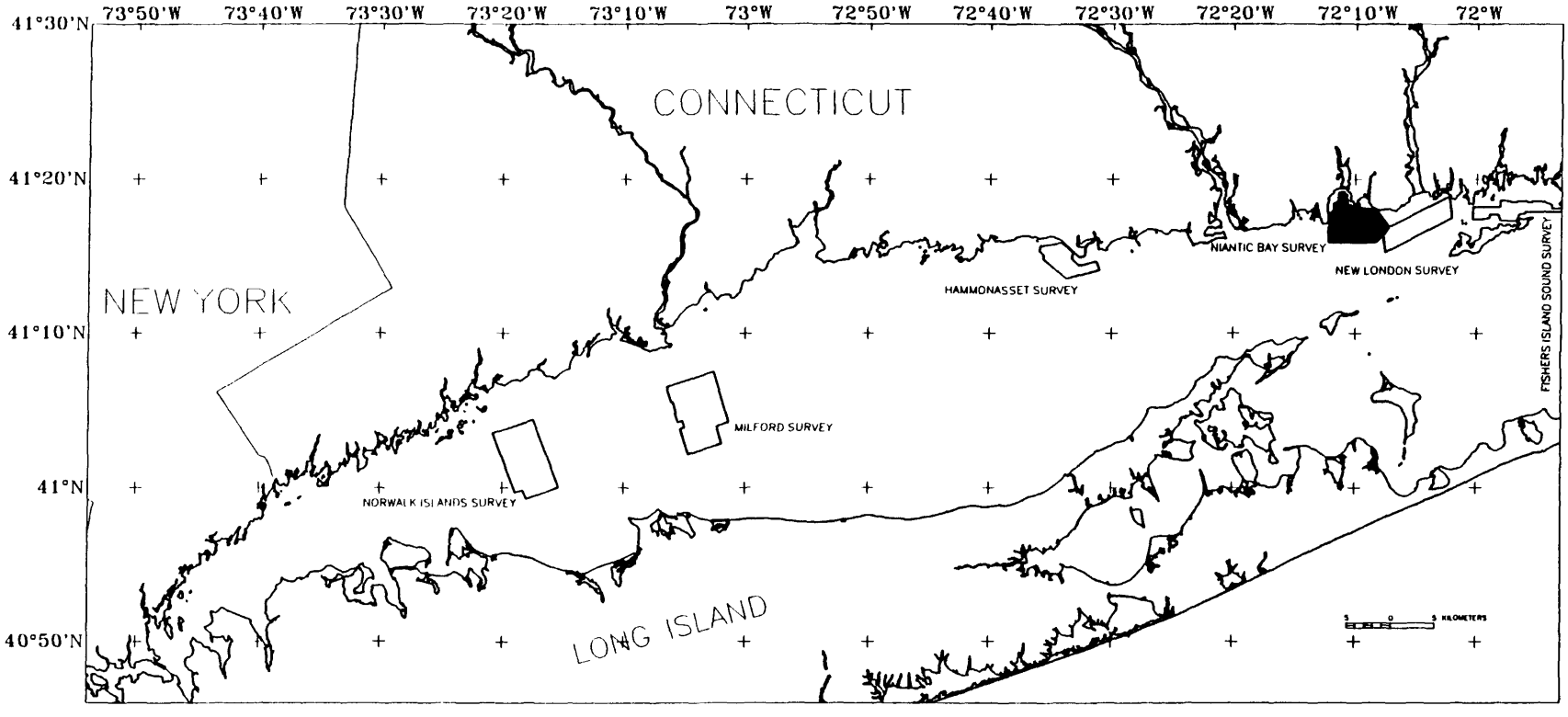
The purpose of this study was: 1) to measure the grain size distributions of the surficial sediment samples from eastern Long Island Sound near Niantic Bay, 2) to determine the frequency distributions, and 3) to calculate statistical descriptions that adequately characterize these samples. These grain-size data will eventually be used to help describe the sedimentary processes active in this portion of eastern 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 is about 182 km long by a maximum of 32 km wide. It 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), which covers about 28.7 km^2, lies in northeastern Long Island Sound offshore from Niantic Connecticut. The Millstone Nuclear Power Station and the marine recreational facilities of the Niantic River are also adjacent to the study area.

The bedrock beneath the study area is believed to be primarily composed of gray to dark gray gneissic and schistose metamorphic rocks of pre-Silurian age (Goldsmith, 1980; Rodgers, 1985). Most of Black Point and the substrates of Twotree Island and Bartlett Reef are composed of the Tatnic Hill Formation. The Rope Ferry Gneiss and, to a much lesser extent, dikes of the Westerly Granite are exposed on Millstone and White Points along the northeast shore of Niantic Bay, and on Waterford Island.

Figure 1. Index map showing the location of the study area (solid polygon). Map also shows the locations of other sidescan sonar and sampling surveys (open polygons) being completed as part of this series (Poppe and others, 1992; Poppe and others, 1994; Moffett and others, 1994; Twichell and others, 1995; Poppe and others, 1995a; Poppe and others, 1995b; Poppe and others 1996a; Poppe and others 1996b; Poppe and others, 1996c; Twichell and others, in press; Poppe and others, in press).



The bedrock across much of southeastern Connecticut is unconformably overlain by two tills, one of pre-Wisconsinan age and one of late Wisconsinan age (Lewis and Needell, 1987; Needell and others, 1987; Stone and Schafer, 1994). The tills surrounding Niantic Bay typically have a smooth surface, are loose to compact, sandy and stony with many large subrounded boulders, and contain thin lenses of stratified material (Goldsmith, 1980). Glacial stream deposits blanket the tills and bedrock in the Niantic River valley and along Jordan Cove. Deltaic and varved lake deposits of glacial Lake Connecticut variously overlie the bedrock and glacial drift under much of Niantic Bay (Lewis and Stone, 1991; Stone and others, 1992). A marine mud facies, which occurs in quiet-water areas throughout the Long Island Sound basin, overlies these earlier deposits and records deposition during the postglacial Holocene eustatic rise of sea level. Although the northward retreat of the late Wisconsinan ice sheet is marked in southeastern Connecticut by a northward succession of minor recessional moraines (i.e. the Hammonasset-Ledyard, Old Saybrook, and Mystic Moraines) no end moraines have been identified along the shores of Niantic Bay (Goldsmith, 1980).

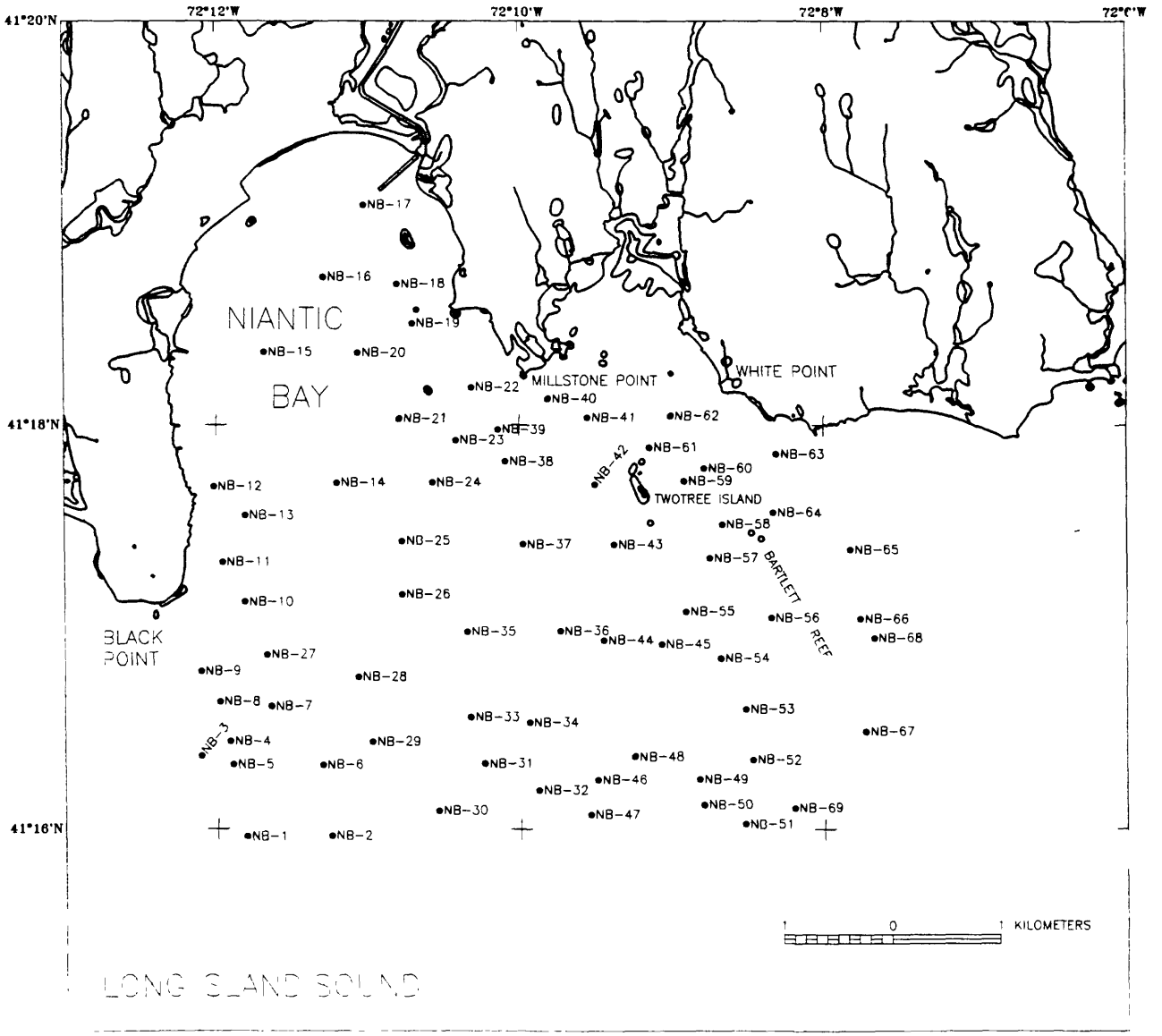
Strong tidal currents have extensively eroded and reworked both the glacial and post-glacial deposits and continue to influence sedimentary processes and surficial sediment distributions in eastern Long Island Sound. The irregular bottom topography and extensive lag deposits of the eastern Sound reflect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

METHODS

Surficial sediment samples and bottom photographs were attempted at 69 locations during March, 1996 aboard the State of Connecticut Department of Environmental Protection vessel the RV John Dempsey using a Van Veen grab sampler (Figs. 1 and 2). This grab sampler was equipped with Osprey video and still camera systems; the video system was attached to an 8 mm video cassette recorder. These photographic systems were used to appraise intra-station bottom variability and to observe boulder fields and bedrock outcrops where sediment samples could not be collected (Appendix A). 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.

A total of 61 sediment samples were collected for grain size analysis. 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 °C. When dried, the samples were placed in a desiccator to cool and then weighed.

Figure 2. Map of the Niantic Bay vicinity in eastern Long Island Sound showing the sampling and bottom photography station locations. Stations where surficial sediment samples and/or bottom photographs were collected are shown as solid circles.



The decrease in weight due to water loss was used to correct for salt; salinity was assumed to be 30 °/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 °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, the sand fraction was dry sieved using a Ro-Tap shaker.

The fine fraction was analyzed by Coulter Counter. To mitigate biologic or chemicalchanges, 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 and others, 1985). One limitation of using a Coulter Counter to perform fine fraction analyses is that it has only the ability to "see" those particles for which it has been calibrated. Calibration for this study allowed us to determine the distribution down to 0.7 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 (and finer) fraction is present in the size distributions (Appendix B).

RESULTS AND COMMENTS

Sample locations, water depths, and brief comments on the bottom photography are presented in Appendix A. Sample locations with low numerical designations (i.e. NB-1) tend to be located in the western portion of the study area; sample locations with higher numerical designations (NB-61) tend to be located in the eastern portion of the study area (Fig. 2). 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).

Gravelly sands dominate the surficial sediment distributions across the southern part of the study area (e.g. NB-30, NB-47) and in the channel between Twotree Island and White Point (e.g. NB-61, NB-62), areas that are exposed to strong tidal currents. These gravelly sediments, which are usually very poorly sorted and coarsely skewed, are typically characterized by abundant mussel shell detritus, sponges, and hydrozoans. Patches of boulders and gravel (e.g. NB-50, NB-69) are common in the gravelly sands and around the bathymetric highs associated with Black Point, Twotree Island, and Bartlett Reef. The boulders are usually covered by mussel beds; starfish, crabs (cancer), anemonies, and hydrozoans are common. Barnacles grow on the boulders and, especially east of Bartlett Reef, kelp grows amoung them in the shallower areas. Bedrock outcrops were observed in the bottom video off both Black and White Points.

The gravelly sands in the southern part of the study area progressively grade northward into sands (e.g. NB-33, NB-48, NB-66) and finer-grained sediments. The sands are moderately to poorly sorted, finely skewed to nearly symmetrical, and leptokurtic. The ubiquitous presence of bedforms (ripples and, in places, sand wave fields) indicate that tidal currents are strong enough to rework the sands. Shell debris, gravel, and hydrozoans occur in the troughs of the bedforms within the higher energy areas; amphipods communities occur in the troughs of the bedforms in the lower energy areas.

Silty sands occur at the mouth of Niantic Bay and between Twotree Island and Bartlett Reef (e.g. NB-13, NB-25, NB-58). These silty sands are primarily moderately sorted, finely skewed, and leptokurtic. They are also are characterized by faint ripples and scattered, patchy concentrations of amphipod and worm tubes. The sediments fine from silty sands to sandy silts within the more protected area of Niantic Bay. The sandy silts, which are poorly to moderately well sorted and leptokurtic, are characterized by undulating, bioturbated bottoms, extensive worm and amphipod communities, and shrimp burrows. Many of the faint current-modified bedforms observed on the bottom video within the areas of sandy silts appeared to originate from biological activity. For example, crabs feeding or burrowing mollusks mound the sediments. These mounds are then modified by the tidal currents.

Interested parties can obtain copies of the grain-size analysis data, the associated statistics, and an explanation of the variable headings in ASCII format and on 3.5" diskettes for this and other bottom sampling and photographic studies completed as part of this series (Poppe and others, 1992; Poppe and others, 1995b; Poppe and others, 1996a, Poppe and others, 1996b) by contacting the manager of the Sedimentation Laboratory at the offices of the Marine and Coastal Geology Program of the U.S. Geological Survey in Woods Hole, Massachusetts or any of the

authors. Videotapes showing the bottom character of the station locations can be viewed at the offices of the U.S. Geological Survey in Woods Hole, Massachusetts or at the Long Island Sound Resource Center at Avery Point in Groton, Connecticut.

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APPENDIX A

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

SAMPLE	LATITUDE	LONGITUDE	DEPTH (M)	COMMENTS
NB-1	41d15.9638'	-72d11.8413'	30.5	RIPPLES, SOME GRAVEL, ABUNDANT SHELLS AND DEBRIS, SNAILS, FLOUNDER, HYDROZOANS
NB-2	41d15.9669'	-72d11.2519'	31.2	RIPPLES, SOME GRAVEL, ABUNDANT SHELLS AND DEBRIS, HYDROZOANS
NB-3	41d16.3632'	-72d12.1104'	14.0	BEDROCK, SPONGES
NB-4	41d16.4350'	-72d11.9165'	35.7	SOME GRAVEL, SCATTERED SHELLS AND DEBRIS, AMPHIPOD TUBES, STARFISH, SPONGES, HYDROZOANS
NB-5	41d16.3208'	-72d11.8967'	29.8	SOME GRAVEL, SHELL DEBRIS, AMPHIPOD TUBES, SNAILS, HYDROZOANS, SKATE
NB-6	41d16.3194'	-72d11.3085'	26.1	RIPPLES, ABUNDANT MUSSEL SHELLS AND DEBRIS, SNAILS, HYDROZOANS
NB-7	41d16.6082'	-72d11.6455'	26.0	FAINT RIPPLES, ABUNDANT SHELLS AND DEBRIS, AMPHIPOD TUBES, SKATE
NB-8	41d16.6307'	-72d11.9861'	28.0	SOME GRAVEL, SCATTERED SHELLS AND DEBRIS, HYDROZOANS
NB-9	41d16.7811'	-72d12.1115'	19.5	GRAVEL, SHELLS AND DEBRIS, STARFISH, HYDROZOANS
NB-10	41d17.1267'	-72d11.8187'	13.5	RIPPLES, SCATTERED SHELLS AND DEBRIS, SPARSE AMPHIPOD TUBES, CRABS (SPIDER), SEAWEED
NB-11	41d17.3239'	-72d11.9636'	9.5	PATCHY GRAVEL, FAINT RIPPLES, PATCHY SHELL DEBRIS, AMPHIPOD TUBES, HYDROZOANS ON SHELLS
NB-12	41d17.6984'	-72d12.0204'	5.9	PATCHY GRAVEL, FAINT RIPPLES, SCATTERED SHELL DEBRIS, AMPHIPOD AND WORM TUBES, SEAWEED
NB-13	41d17.5561'	-72d11.8116'	6.9	RIPPLES, AMPHIPOD TUBES, TRACES OF SHELL DEBRIS
NB-14	41d17.7168'	-72d11.2084'	8.0	UNDULATING BIOTURBATED BOTTOM, FAINTLY RIPPLED, SPONGES, PATCHY AMPHIPOD TUBES
NB-15	41d18.3577'	-72d11.6842'	5.7	TURBID, SCATTERED SHELL DEBRIS, WORM AND AMPHIPOD TUBES
NB-16	41d18.7328'	-72d11.2920'	5.7	UNDULATING BIOTURBATED BOTTOM, TRACES OF SHELL DEBRIS, TRACKS
NB-17	41d19.0911'	-72d11.0219'	4.2	SEAWEED RAFTED GRAVEL
NB-18	41d18.6776'	-72d10.8026'	6.1	BIOTURBATED, FAINTLY RIPPLED, TRACE OF SHELL DEBRIS, AMPHIPOD AND WORM TUBES
NB-19	41d18.5029'	-72d10.7210'	6.6	UNDULATING BIOTURBATED BOTTOM, SCATTERED SHELL DEBRIS, LOBSTER AND SHRIMP BURROWS, AMPHIPOD AND WORM TUBES
NB-20	41d18.3551'	-72d11.0668'	6.1	TURBID, DENSE NEPHALOID LAYER, RIPPLES, AMPHIPOD AND WORM TUBES
NB-21	41d18.0313'	-72d10.7921'		UNDULATING BIOTURBATED BOTTOM, SHRIMP BURROWS, WORM AND AMPHIPOD TUBES, TRACE OF SHELL DEBRIS
NB-22	41d18.1844'	-72d10.3177'	9.0	TURBID, RIPPLED, SCATTERED SHELLS AND DEBRIS (RAZOR CLAM)
NB-23	41d17.9261'	-72d10.4177'	11.6	RIPPLES, SOME GRAVEL, SHELLS AND DEBRIS (RAZOR CLAM), SPONGES, SEAWEED, HYDROZOANS, CRABS (SPIDER), WELK
NB-24	41d17.7190'	-72d10.5758'	9.2	RIPPLES, SHELLS AND DEBRIS, AMPHIPOD TUBES
NB-25	41d17.4282'	-72d10.7779'	9.4	TRACE OF SHELL DEBRIS, PATCHES OF DENSE AMPHIPOD AND WORM TUBES
NB-26	41d17.1625'	-72d10.7816'	12.8	FAINT RIPPLES, SCATTERED SHELL DEBRIS, AMPHIPOD TUBES, CRABS (SPIDER)
NB-27	41d16.8632'	-72d11.6722'	26.6	GRAVEL, SHELLS AND DEBRIS (RAZOR CLAM), HYDROZOANS
NB-28	41d16.7524'	-72d11.0720'	18.5	ABUNDANT SHELLS AND DEBRIS, SPARSE AMPHIPOD TUBES, HYDROZOANS, CRABS (SPIDER)
NB-29	41d16.4335'	-72d10.9798'	17.7	BOULDERS WITH GRAVEL, ELEVATED MUSSEL BEDS, STARFISH, SNAILS, WELKS
NB-30	41d16.0905'	-72d10.5432'	23.2	GRAVEL, SCATTERED SHELLS AND DEBRIS, MUSSEL BEDS, STARFISH, SNAILS
NB-31	41d16.3256'	-72d10.2375'	22.0	RIPPLES, GRAVEL, ABUNDANT SHELLS AND DEBRIS, ELEVATED MUSSEL BEDS

SAMPLE	LATITUDE	LONGITUDE	DEPTH (M)	COMMENTS
NB-33	41d16.5546'	-72d10.3278'	17.0	RIPPLES WITH COARSER DETRITUS (SHELL DEBRIS) AND SOME AMPHIPOD TUBES IN TROUGHS, HYDROZOANS
NB-34	41d16.5306'	-72d09.9394	16.9	SAND WAVES WITH SHELLS AND DEBRIS IN TROUGHS, SOME AMPHIPOD TUBES, HYDROZOANS
NB-32	41d16.1930'	-72D09.8793'	25.7	GRAVEL, ABUNDANT SHELLS AND DEBRIS, ELEVATED MUSSEL BEDS, CRABS (CANCER)
NB-35	41d16.9767'	-72d10.3510'	15.7	FAINT RIPPLES, SCATTERED SHELL DEBRIS, AMPHIPOD AND WORM TUBES, SNAILS
NB-36	41d16.9804'	-72d09.7369'	14.5	RIPPLES, SCATTERED SHELL DEBRIS, AMPHIPOD TUBES
NB-37	41d17.4126'	-72d09.9783'	9.8	RIPPLES, SCATTERED SHELL DEBRIS, PATCHES OF AMPHIPOD AND WORM TUBES
NB-38	41d17.8217'	-72d10.0939'	8.8	TURBID, RIPPLES, SCATTERED SHELL DEBRIS, AMPHIPOD TUBES
NB-39	41d17.9986'	-72d10.1407'	13.0	FAINTLY RIPPLED, SOME GRAVEL, SCATTERED ANDPATCHY SHELL DEBRIS
NB-40	41d18.1294'	-72d09.8100'	15.9	RIPPLES, SHELL DEBRIS IN THE TROUGHS, SEAWEED RAFTED LIMPETS, HYDROZOANS
NB-41	41d18.0377'	-72d09.5525'	13.5	RIPPLES, SPONGES, TRACES OF SHELL DEBRIS, HYDROZOANS
NB-42	41d17.7092'	-72d09.5045'	7.1	BOULDERS WITH SAND IN BETWEEN, TRACES OF SHELL DEBRIS, AMPHIPOD TUBES
NB-43	41d17.4099'	-72d09.3824'	9.4	BIOTURBATED, FAINT RIPPLES, SCATTERED SHELL DEBRIS, ABUNDANT AMPHIPOD AND WORM TUBES
NB-44	41d16.9339'	-72d09.4500'	14.5	FAINT RIPPLES, SCATTERED SHELL DEBRIS, WORM AND AMPHIPOD TUBES
NB-45	41d16.9126'	-72d09.0746'	10.2	BOULDERS WITH GRAVEL IN BETWEEN, SPONGES, SEAWEED, HYDROZOANS
NB-46	41d16.2454'	-72d09.4932'	26.1	RIPPLES, SCATTERED SHELL DEBRIS, SCATTERTED CLUMPS OF MUSSELS
NB-47	41d16.0710'	-72d09.5418'	36.6	GRAVEL, SCATTERED SHELL DEBRIS, STARFISH, HYDROZOANS
NB-48	41d16.3601'	-72d09.2509'	17.3	RIPPLED SAND WAVES, ECHINODERMS (SAND DOLLARS), SOME SHELL DEBRIS
NB-49	41d16.2478'	-72d08.8295'	20.4	RIPPLED SAND WAVES WITH SHELL DEBRIS IN TROUGHS, TRACKS, ECHINODERMS (SAND DOLLARS)
NB-50	41d16.1211'	-72d08.7990'	27.1	SOME GRAVEL, MUSSEL BEDS AND SCATTERED SHELL DEBRIS, CRABS (CANCER)
NB-51	41d16.0235'	-72d08.5269'	24.0	BOULDERS WITH GRAVEL, SHELL DEBRIS, HYDROZOANS
NB-52	41d16.3444'	-72d08.4741'	13.4	BOULDERS WITH SAND IN BETWEEN, MUSSEL BEDS, SPONGES
NB-53	41d16.5944'	-72d08.5223'	13.9	FAINTLY RIPPLED, TRACE OF SHELL DEBRIS, WORM AND AMPHIPOD TUBES, HERMIT CRABS
NB-54	41d16.8448'	-72d08.6858'	13.5	SOME GRAVEL, SCATTERED MUSSEL BEDS, ABUNDANT SHELL DEBRIS, KELP
NB-55	41d17.0773'	-72d08.9136'	11.8	BOULDERS WITH COBBLES AND GRAVEL IN BETWEEN, MUSSEL BEDS AND ABUNDANT SHELLS AND DEBRIS, SPONGES
NB-56	41d17.0461'	-72d08.3518'	10.7	SCATTERED COBBLES, FAINTLY RIPPLED, SCATTERED QUAHOG AND MUSSEL SHELLS AND DEBRIS
NB-57	41d17.3430'	-72d08.7561'	9.0	MUSSEL BEDS AND ABUNDANT SHELLS AND DEBRIS, CRABS
NB-58	41d17.5122'	-72d08.6751'	8.5	UNDULATING BIOTURBATED BOTTOM, FAINT RIPPLES, AMPHIPOD AND WORM TUBES
NB-59	41d17.7264'	-72d08.9220'	4.7	RIPPLES, TRACES OF SHELL DEBRIS, SEAWEED, SPARSE HYDROZOANS
NB-60	41d17.7877'	-72d08.7903'	5.2	RIPPLES, SCATTERED CLUSTERS OF MUSSELS AND SHELL DEBRIS, KELP
NB-61	41d17.8907'	-72d09.1482'	7.6	MUSSEL BEDS WITH SHELLS AND DEBRIS, STARFISH, REDUCED BELOW 1 CM
NB-62	41d18.0459'	-72d09.0092'	20.0	GRAVEL ARMORING SAND, TRACES OF SHELL DEBRIS, BARNACLES, HYDROZOANS
NB-63	41d17.8576'	-72d08.3136'	20.1	BEDROCK, STARFISH, MUSSELS, CRABS (CANCER), SPONGES, KELP, HYDROZOANS

SAMPLE	LATITUDE	LONGITUDE	DEPTH (M)	COMMENTS
NB-64	41d17.8546'	-72d08.3090'	4.7	BOULDERS WITH GRAVEL, MUSSELS, KELP, STARFISH
NB-65	41d17.3839'	-72d07.8255'	8.7	FAINT RIPPLES, SOME VERY FINE GRAVEL, MUSSELS, SNAILS
NB-66	41d17.0404'	-72d07.7614'	12.0	MUSSEL SHELLS AND DEBRIS, HERMIT CRABS
NB-67	41d16.4851'	-72d07.7264'	15.0	RIPPLES, PATCHY GRAVEL, SOME SHELL DEBRIS AND AMPHIPOD TUBES, HYDROZOANS
NB-68	41d16.9436'	-72d07.6730'	11.7	GRAVEL, SCATTERED SHELLS AND SHELL DEBRIS
NB-69	41d16.1061'	-72d08.2061'	15.9	BOULDERS WITH GRAVEL, ELEVATED MUSSEL BEDS, STARFISH, ANEMONIES, CRABS, (CANCER)

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 .00072 mm.

	CLAY				SILT					SAND				GRAVEL			
SAMPLE NUMBER	11ϕ	10ϕ	9ϕ	8ϕ	7ϕ	6ϕ	5ϕ	4ϕ	3ϕ	2ϕ	1ϕ	0ϕ	-1ϕ	-2ϕ	-3ϕ	-4ϕ	-5ϕ
NB-1	0.06	0.18	0.24	0.24	0.28	0.37	0.50	2.26	5.49	29.30	30.43	13.24	14.18	3.23	0.0	0.0	0.0
NB-2	0.62	1.89	2.52	2.43	2.49	2.76	1.90	9.44	22.27	35.85	12.33	2.90	2.17	0.43	0.0	0.0	0.0
NB-4	0.22	0.72	1.03	1.34	1.50	1.66	1.53	7.20	8.22	8.12	1.85	0.31	0.58	2.51	29.77	33.44	0.0
NB-5	0.28	0.87	1.17	1.27	1.62	2.07	2.30	10.38	20.83	29.02	13.50	4.29	2.60	1.72	8.08	0.0	0.0
NB-6	0.43	1.43	2.11	2.20	2.39	1.47	7.21	35.38	29.78	8.06	4.41	1.92	1.00	0.0	0.0	0.0	0.0
NB-7	0.44	1.28	1.58	1.78	2.15	3.22	6.46	14.89	22.83	30.44	12.24	2.32	0.38	0.0	0.0	0.0	0.0
NB-8	0.07	0.21	0.29	0.33	0.44	1.32	5.89	6.66	6.02	20.29	21.24	9.19	8.84	12.95	6.26	0.0	0.0
NB-9	0.37	1.01	1.23	1.38	1.77	3.06	3.65	7.17	12.21	29.73	13.59	6.28	6.68	2.66	6.40	2.84	0.0
NB-10	0.16	0.46	0.57	0.64	0.93	1.78	4.05	28.24	46.07	16.73	0.0	0.37	0.0	0.0	0.0	0.0	0.0
NB-11	0.21	0.61	0.82	0.96	1.52	5.02	26.01	41.84	12.64	6.12	2.71	1.16	0.0	0.38	0.0	0.0	0.0
NB-12	0.02	0.06	0.08	0.09	0.15	0.33	0.41	0.69	2.16	12.29	53.38	18.00	5.44	1.81	5.09	0.0	0.0
NB-13	0.19	0.49	0.55	0.60	1.07	2.88	17.24	59.51	17.48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-14	0.50	1.47	1.97	2.26	3.34	8.68	31.00	38.59	8.68	3.05	0.46	0.0	0.0	0.0	0.0	0.0	0.0
NB-15	0.30	0.78	0.91	1.07	2.29	9.52	33.22	47.39	4.10	0.42	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-16	0.12	0.32	0.39	0.49	1.15	9.70	60.04	23.81	3.81	0.19	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-17	0.24	0.62	0.78	0.99	1.67	4.42	6.54	26.19	55.59	2.28	0.42	0.0	0.25	0.0	0.0	0.0	0.0
NB-18	0.28	0.84	1.10	1.35	2.80	10.73	51.65	29.50	1.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-19	0.50	1.56	2.18	2.57	4.42	13.42	40.34	31.20	3.54	0.28	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-20	0.38	0.99	1.11	1.18	2.09	7.59	26.22	55.07	5.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-21	1.16	2.84	3.51	3.94	6.17	13.12	23.74	36.14	9.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-22	0.43	1.13	1.52	1.68	2.52	6.79	7.98	11.24	28.38	28.92	7.52	1.47	0.42	0.0	0.0	0.0	0.0
NB-23	0.08	0.20	0.23	0.26	0.48	2.13	10.35	7.60	13.41	27.16	15.81	4.45	1.72	3.17	8.84	4.11	0.0
NB-24	0.24	0.70	0.93	1.07	1.36	2.46	5.77	15.37	17.47	33.89	18.87	1.75	0.12	0.0	0.0	0.0	0.0
NB-25	0.26	0.71	0.91	1.08	1.59	5.48	29.76	44.74	11.80	3.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-26	0.45	1.48	2.08	2.35	3.11	5.03	7.34	34.39	42.83	0.94	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-27	0.28	0.93	1.38	1.73	2.37	3.58	4.44	9.69	12.58	21.46	23.98	6.29	2.33	2.17	6.78	0.0	0.0
NB-28	0.25	0.75	0.98	1.07	1.23	2.54	4.77	19.86	26.62	26.10	11.86	3.43	0.53	0.0	0.0	0.0	0.0
NB-30	0.23	0.77	1.05	1.04	0.82	0.55	0.44	2.19	7.71	23.02	19.01	8.81	13.43	12.72	8.21	0.0	0.0

SAMPLE NUMBER	CLAY 11φ	10φ	9φ	8φ	SILT 7φ	6φ	5φ	4φ	SAND 3φ	2φ	1φ	0φ	-1φ	GRAVEL -2φ	-3φ	-4φ	-5φ
NB-31	0.29	0.99	1.40	1.44	1.12	0.70	0.63	3.79	17.54	30.32	12.35	6.18	13.02	5.24	5.00	0.0	0.0
NB-32	0.72	2.29	3.43	3.68	3.52	2.34	1.03	9.35	22.85	26.21	5.60	1.84	5.38	6.47	5.28	0.0	0.0
NB-33	0.13	0.39	0.48	0.53	0.71	1.14	1.54	6.41	17.92	31.19	20.21	12.12	6.10	1.12	0.0	0.0	0.0
NB-34	0.37	1.23	1.67	1.70	1.88	2.51	2.86	9.94	62.00	8.39	3.80	2.33	1.32	0.0	0.0	0.0	0.0
NB-35	0.71	2.26	2.60	2.63	3.14	4.47	7.56	34.64	32.26	9.73	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-36	0.45	1.37	1.87	2.04	2.60	4.39	10.35	48.16	27.54	0.62	0.62	0.0	0.0	0.0	0.0	0.0	0.0
NB-37	0.35	1.09	1.50	1.67	2.27	5.12	24.31	46.44	17.26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-38	0.03	0.07	0.08	0.08	0.11	0.18	0.45	1.19	25.23	59.95	9.00	3.56	0.07	0.0	0.0	0.0	0.0
NB-39	0.40	1.14	1.42	1.48	2.02	4.22	5.32	5.53	26.50	39.30	8.50	2.72	1.42	0.0	0.0	0.0	0.0
NB-40	0.10	0.26	0.32	0.36	0.57	1.64	2.20	3.76	6.76	43.84	33.99	5.54	0.67	0.0	0.0	0.0	0.0
NB-41	0.02	0.04	0.05	0.05	0.06	0.10	0.15	0.49	2.47	31.09	51.82	12.83	0.81	0.0	0.0	0.0	0.0
NB-42	0.28	0.68	0.68	0.62	0.74	1.14	2.62	66.39	26.85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-43	0.46	1.35	1.78	1.93	2.29	4.73	9.52	55.26	21.98	0.70	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-44	0.33	1.03	1.32	1.40	1.82	3.54	14.13	42.35	32.94	1.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-46	0.25	0.79	1.00	0.96	1.02	1.16	0.85	4.02	15.61	63.10	7.03	1.55	2.65	0.0	0.0	0.0	0.0
NB-47	0.24	0.86	1.39	1.81	1.94	1.63	1.15	3.44	15.19	27.19	11.26	4.43	6.71	6.37	9.84	6.54	0.0
NB-48	0.02	0.05	0.05	0.05	0.06	0.08	0.07	1.49	25.90	49.00	21.71	1.49	0.0	0.0	0.0	0.0	0.0
NB-49	0.02	0.04	0.05	0.05	0.06	0.09	0.13	1.69	30.60	63.88	2.58	0.60	0.22	0.0	0.0	0.0	0.0
NB-50	0.21	0.72	1.01	1.13	1.08	1.02	0.48	4.22	10.50	16.34	6.65	2.84	3.58	6.33	24.62	19.28	0.0
NB-53	0.26	0.78	0.93	1.10	1.70	2.89	7.92	42.21	40.10	2.11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MN-54	0.64	2.26	3.46	3.96	3.97	4.85	1.79	21.36	16.63	22.40	9.46	4.07	1.63	0.34	0.0	3.18	0.0
NB-55	0.23	0.77	1.07	1.19	1.53	5.42	17.32	23.35	13.56	11.99	9.79	4.08	1.55	4.21	3.94	0.0	0.0
NB-56	0.23	0.70	0.91	0.98	1.22	2.22	7.90	34.62	29.03	19.30	1.02	0.68	0.00	1.20	0.0	0.0	0.0
NB-57	0.28	0.95	1.41	1.57	2.25	6.50	27.42	30.52	15.11	8.34	2.39	1.98	1.28	0.0	0.0	0.0	0.0
NB-58	0.30	0.90	1.18	1.33	1.86	5.37	24.47	54.38	9.36	0.84	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NB-59	0.03	0.09	0.10	0.12	0.15	0.24	0.69	3.74	35.91	50.08	5.61	3.05	0.19	0.0	0.0	0.0	0.0
NB-60	0.02	0.05	0.06	0.07	0.07	0.09	0.11	0.10	16.54	54.71	18.24	5.01	4.73	0.30	0.0	0.0	0.0
NB-61	0.13	0.31	0.38	0.41	0.44	0.66	1.06	5.37	26.39	49.33	10.84	4.03	0.63	0.0	0.0	0.0	0.0
NB-62	0.42	1.08	1.28	1.42	1.72	2.70	3.83	7.44	15.28	19.91	10.04	3.72	2.09	6.16	18.99	3.91	0.0
NB-65	0.06	0.18	0.24	0.27	0.29	0.34	0.31	1.24	14.59	38.55	22.47	6.05	13.00	2.42	0.0	0.0	0.0
NB-66	0.49	1.48	1.86	1.89	2.29	3.23	3.39	22.32	17.90	32.92	9.16	2.55	0.53	0.0	0.0	0.0	0.0
NB-67	0.41	1.13	1.69	1.69	1.77	1.95	2.20	14.66	23.53	26.82	3.50	3.00	5.35	5.30	5.42	1.58	0.0
NB-68	0.10	0.29	0.43	0.46	0.47	0.79	3.02	8.38	14.78	12.12	2.51	0.30	0.65	1.33	6.76	19.45	28.14

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)
NB-1	40.4134	17.41	80.72	1.39	0.48	GRAVELLY SEDIMENT	0.64	0.57	1.54	0.55	5.24	0.5	-1.5	
NB-2	30.4997	2.60	82.78	9.59	5.03	SAND	1.90	2.47	2.27	0.74	2.30	1.5		
NB-4	614.2400	66.30	25.70	6.03	1.97	GRAVEL	-3.44	-1.49	3.70	0.54	-0.02	-4.5	2.5	
NB-5	38.7001	12.40	78.01	7.27	2.32	GRAVELLY SEDIMENT	1.68	1.63	2.47	0.11	1.55	1.5	-3.5	
NB-6	32.8705	2.92	84.83	8.28	3.97	SAND	2.14	2.41	2.11	0.70	2.97	2.5		
NB-7	34.6253	0.38	82.71	13.61	3.30	SAND	2.20	2.64	1.98	0.73	2.59	1.5		
NB-8	398.5300	28.04	63.41	7.98	0.57	GRAVEL	0.60	0.52	2.36	0.19	0.23	0.5	-2.5	3.5
NB-9	432.0300	18.58	68.97	9.85	2.60	GRAVELLY SEDIMENT	1.39	1.31	2.76	0.17	0.89	1.5	-1.5	-3.5
NB-10	36.4567	0.00	91.41	7.40	1.19	SAND	2.71	2.89	1.19	1.21	9.95	2.5		
NB-11	32.5928	0.38	64.47	33.52	1.64	SILTY SAND	3.65	3.64	1.45	0.15	4.19	3.5		
NB-12	41.7635	12.34	86.52	0.98	0.17	GRAVELLY SEDIMENT	0.37	0.20	1.36	0.06	6.34	0.5	-3.5	
NB-13	37.8649	0.00	76.99	21.79	1.22	SAND	3.55	3.68	0.97	1.49	13.65	3.5		
NB-14	30.3730	0.00	50.78	45.28	3.94	SILTY SAND	3.98	4.23	1.49	0.73	3.44	3.5		
NB-15	35.3960	0.00	51.91	46.10	1.99	SILTY SAND	3.96	4.20	1.11	1.13	7.70	3.5		
NB-16	32.6189	0.00	27.81	71.37	0.83	SANDY SILT	4.37	4.35	0.82	0.87	10.90	4.5		
NB-17	36.4144	0.25	84.48	13.62	1.64	SAND	2.85	3.21	1.29	1.17	7.89	2.5		
NB-18	32.9176	0.00	31.25	66.53	2.22	SANDY SILT	4.36	4.48	1.05	1.16	8.08	4.5		
NB-19	30.0661	0.00	35.02	60.75	4.23	SANDY SILT	4.37	4.60	1.36	0.86	3.75	4.5		
NB-20	35.9500	0.00	60.45	37.07	2.48	SILTY SAND	3.81	4.11	1.17	1.29	8.41	3.5		
NB-21	32.4712	0.00	45.52	46.97	7.50	SANDY SILT	4.19	4.68	1.74	0.68	1.40	3.5		
NB-22	36.7628	0.42	77.54	18.96	3.08	SAND	2.41	2.86	1.95	0.66	2.00	1.5		
NB-23	439.9300	17.84	68.42	13.22	0.52	GRAVELLY SEDIMENT	1.44	1.15	2.59	-0.21	0.13	1.5	4.5	-3.5
NB-24	39.3527	0.12	87.34	10.66	1.87	SAND	1.86	2.30	1.75	0.40	1.07	1.5		
NB-25	31.1211	0.00	60.21	37.91	1.89	SILTY SAND	3.77	3.91	1.21	0.87	6.33	3.5		
NB-26	35.8268	0.00	78.16	17.83	4.01	SAND	3.18	3.64	1.60	1.04	4.08	2.5		
NB-27	397.5200	11.28	74.01	12.12	2.59	GRAVELLY SEDIMENT	1.39	1.65	2.61	0.23	0.91	0.5	-3.5	
NB-28	38.0164	0.53	87.86	9.62	1.99	SAND	2.30	2.48	1.74	0.68	3.54	2.5		
NB-30	344.9500	34.36	60.74	2.84	2.06	GRAVELLY SEDIMENT	0.36	0.23	2.49	0.53	2.35	1.5	-1.5	

SAMPLE NUMBER	WEIGHT (GRAMS)	PERCENT GRAVEL	PERCENT SAND	PRECENT SILT	PRECENT CLAY	SEDIMENT CLASS	MEDIAN (ϕ)	MEAN (ϕ)	STANDARD DEVIATION	SKEWNESS	KURTOSIS	MODE 1 (ϕ)	MODE 2 (ϕ)	MODE 3 (ϕ)
NB-31	257.2400	23.25	70.18	3.89	2.69	GRAVELLY SEDIMENT	1.27	1.05	2.49	0.41	1.96	1.5	-1.5	
NB-32	372.2600	17.14	65.86	10.57	6.44	GRAVELLY SEDIMENT	1.97	2.15	3.08	0.22	0.28	1.5	-2.5	
NB-33	40.7965	7.22	87.86	3.92	1.00	SAND	1.33	1.37	1.74	0.58	3.98	1.5		
NB-34	35.3548	1.32	86.47	8.95	3.26	SAND	2.55	2.82	1.75	0.84	4.93	2.5		
NB-35	33.7045	0.00	76.63	17.80	5.57	SAND	3.23	3.66	1.84	0.87	2.75	3.5		
NB-36	35.1146	0.00	76.93	19.38	3.69	SAND	3.44	3.75	1.49	1.06	5.08	3.5		
NB-37	34.9220	0.00	63.70	33.36	2.94	SILTY SAND	3.71	3.97	1.31	1.09	5.96	3.5		
NB-38	39.4711	0.07	98.93	0.82	0.17	SAND	1.62	1.66	0.81	0.91	18.03	1.5		
NB-39	35.7274	1.42	82.57	13.04	2.96	SAND	1.95	2.44	1.95	0.80	3.24	1.5		
NB-40	40.3241	0.67	93.89	4.77	0.67	SAND	1.22	1.41	1.37	1.21	9.04	1.5		
NB-41	39.6061	0.81	98.71	0.37	0.11	SAND	0.70	0.76	0.80	1.09	18.93	0.5		
NB-42	38.0312	0.00	93.24	5.11	1.64	SAND	3.35	3.42	0.98	2.08	21.66	3.5		
NB-43	35.9308	0.00	77.94	18.47	3.59	SAND	3.49	3.80	1.42	1.18	6.04	3.5		
NB-44	35.2419	0.00	76.44	20.89	2.68	SAND	3.38	3.62	1.34	1.17	6.75	3.5		
NB-46	38.3469	2.65	91.31	3.99	2.04	SAND	1.61	1.89	1.59	1.27	9.52	1.5		
NB-47	499.1600	29.46	61.51	6.54	2.50	GRAVELLY SEDIMENT	1.18	0.67	3.03	0.18	0.37	1.5	-3.5	-1.5
NB-48	39.0716	0.00	99.60	0.27	0.13	SAND	1.55	1.56	0.80	0.77	13.34	1.5		
NB-49	39.1449	0.22	99.35	0.33	0.10	SAND	1.73	1.82	0.62	1.29	30.71	1.5		
NB-50	472.3500	53.81	40.54	3.71	1.94	GRAVEL	-2.04	-0.86	3.35	0.39	-0.02	-3.5	1.5	
NB-53	36.8456	0.00	84.43	13.61	1.97	SAND	3.18	3.40	1.25	1.32	8.89	3.5		
NB-54	310.8900	5.15	73.92	14.57	6.36	SAND	2.54	2.83	2.79	0.12	0.89	1.5	3.5	
NB-55	355.0600	9.70	62.76	25.46	2.07	GRAVELLY SEDIMENT	3.04	2.55	2.53	-0.19	0.56	3.5		
NB-56	37.7881	1.20	84.65	12.32	1.84	SAND	2.96	3.00	1.54	0.46	5.34	3.5		
NB-57	33.9593	1.28	58.36	37.73	2.63	SILTY SAND	3.68	3.65	1.75	0.13	2.23	3.5		
NB-58	34.1553	0.00	64.58	33.04	2.38	SILTY SAND	3.73	3.98	1.19	1.19	7.88	3.5		
NB-59	39.0080	0.19	98.39	1.20	0.22	SAND	1.82	1.87	0.89	0.77	13.95	1.5		
NB-60	40.6440	5.03	94.49	0.34	0.13	SAND	1.40	1.25	1.01	-0.05	7.75	1.5		
NB-61	37.6657	0.63	95.97	2.57	0.83	SAND	1.70	1.83	1.25	1.13	11.67	1.5		
NB-62	394.5600	31.16	56.39	9.66	2.79	GRAVELLY SEDIMENT	1.26	0.74	3.28	0.14	-0.26	1.5	-3.5	
NB-65	39.8009	15.41	82.91	1.20	0.48	GRAVELLY SEDIMENT	1.16	0.93	1.53	0.31	4.43	1.5	-1.5	
NB-66	32.7168	0.53	84.85	10.79	3.83	SAND	2.27	2.72	2.02	0.73	2.56	1.5	3.5	
NB-67	401.9200	17.64	71.52	7.60	3.23	GRAVELLY SEDIMENT	1.96	1.77	2.74	0.05	0.89	1.5	-3.5	-1.5
NB-68	681.5200	56.34	38.10	4.74	0.82	GRAVEL	-3.64	-1.53	3.90	0.22	-1.27	-5.5	2.5	