BEAUFORT SEA BASELINE MONITORING PROGRAM FOR AMAULIGAK DRILLING AND PRODUCTION ACTIVITIES

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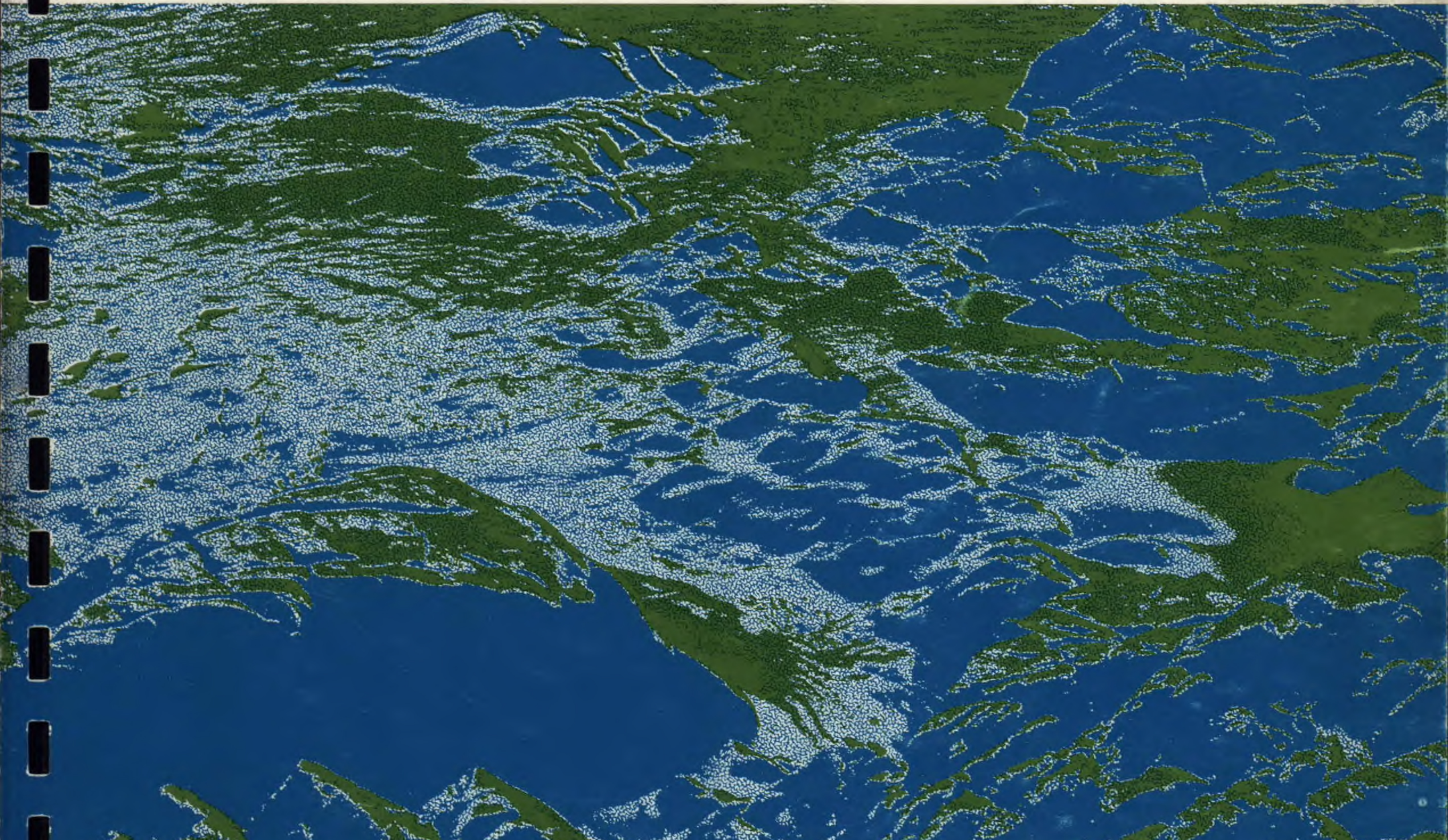

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November 4, 1988

Mr. Russell Shearer
Department of Indian
and Norther Affairs
10 Wellington Street
Ottawa
Canada

Dear Mr. Shearer:

Please find enclosed the following:

1. Standard Methods and Procedures for Monitoring Sediment Quality in the Canadian Beaufort Sea

2. A Technical Guide to Standard Methods and Procedures for Monitoring Sediment Quality in the Canadian Beaufort Sea

3. Beaufort Sea Baseline Monitoring Program for Amauligak Drilling and Production Activities

Sincerely,
SEAKEM OCEANOGRAPHY LTD.

(for)

David J. Thomas
Director

BEAUFORT SEA BASELINE MONITORING PROGRAM FOR AMAULIGAK DRILLING AND PRODUCTION ACTIVITIES

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Conservation and Protection
Environment Canada
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March 1988

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ABSTRACT

A sediment sampling survey was conducted September 30 - October 01 at the Amauligak F-24 drillsite prior to the initiation of drilling there in October 1987 to define the pre-development levels of Ba, Cd, Hg, Pb, Cr and hydrocarbons. In addition, samples of benthic invertebrates were collected and stored for possible analysis of community composition, abundance and contaminant concentrations at a later date. Overall concentration ranges for Pb, Cd, Hg, Cr and Ba were 2.5 - 27 $\mu g \cdot g^{-1}$, <0.10 - 0.32 $\mu g \cdot g^{-1}$, 3 - 68 $ng \cdot g^{-1}$, 17 - 173 $\mu g \cdot g^{-1}$ and 300 - 1730 $\mu g \cdot g^{-1}$, respectively. Total alkane concentrations ranged between 930 - 14160 $ng \cdot g^{-1}$, whereas total PAH concentrations were in the range <5.3 - 1051 $ng \cdot {}^{-1}$. The observed contaminant concentrations generally correlated with sediment grain size. The lowest concentrations occurred in sediments having the highest sand content (sediments nearest the Amauligak sub-sea berm) whereas highest concentrations occurred in the finer sediments characteristic of the local sediments. A notable exception was the alkane content of sand-rich sediments. This anomaly is probably related to the use of coarse borrow material contaminated with VISTA ODC base oil (from the abandoned Minuk artificial island) to construct the Amauligak sub-sea berm.

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ACKNOWLEDGEMENTS

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Ms. Gerrie Hosick (word processing)
Ms. Brenda Fraser (drafting)
Mr. David Hope (hydrocarbon analyses)
Mr. Brad Pearce (hydrocarbon analyses)

The field sampling team consisted of D.J. Thomas, A. Ethier and R. Kashino (Seakem); W. Cross (LGL) and R. Shearer (EP/Yellowknife).

Sincere thanks are also extended to the master and crew of the MV Terry Fox and MV Kalvik and the operations staff of Gulf Canada Resources Limited for logistic support in the field and without whose co-operation the study could not have been completed.

1. BACKGROUND AND STATEMENT OF OBJECTIVES

Gulf Canada and its partners have made application to carry out extended production testing on the Amauligak oil field discovered in 1984 (Figure 1). Gulf plans to drill up to three deviated wells from the Amauligak F-24 wellsite. There will be an estimated combined discharge of 15,000 m^3 of dilute drilling muds and cuttings from the three wells during the period 1987 - 1988. (There are no plans to use oil based drilling muds.) In addition, as much as 5,600 m^3 per day of ballast water may be discharged with a maximum concentration of 40 mg L^{-1} hydrocarbons. Gulf has made a prediction (as yet unproven), based on data available from other offshore production areas (e.g., North Sea), that the effect of waste discharges will be local and short-term in the water column and localized (within 1 km) in the sediment due to the shallow depth and limited number of wells.

Further monitoring of effects or residual contaminant concentrations in the sediment surrounding the Amauligak F-24 wellsite requires that baseline or pre-development data be available. The objective of this study was to collect and analyse sufficient sediment samples from the assumed zone of waste disposal influence to define pre-development levels of selected trace metals and hydrocarbons. Accordingly, a sediment sampling survey was conducted September 30 - October 1, 1987, at the Amauligak F-24 drillsite prior to the initiation of drilling there in October 1987. In addition, samples of benthic invertebrates were collected and stored for possible analysis of community composition, abundance and contaminant concentrations at a later date.

2. SAMPLING STRATEGY

2.1 Definition of Study Area

It is anticipated that because the wastes from delineation drilling will be discharged primarily in the winter and because of the limited water depth (approximately 30 m), the zone of influence will be restricted to 1 km or less with most of the wastes accumulating within 500 m of the drillsite discharge. The potential zone of influence could increase, however, should a significant number of additional wells be drilled from the same site in the future. In the North Sea, effects have been detected as far as 8 km from offshore structures in use for many years in water depths of 60 m or more. Effects should be far more restricted at Amauligak than those observed in the North Sea even with extended drilling operations at this site, because of the shallower depth, presence of a berm and 7 - 9 months of ice cover at Amauligak.

Consequently, in this study, the outer boundary of the study area was taken to be three kilometres. A radial sampling design around the wellsite was chosen because the exact drilling location, depth of discharge (surface, subsurface) and strength and direction of water currents around Amauligak were not known at the time this study was undertaken.

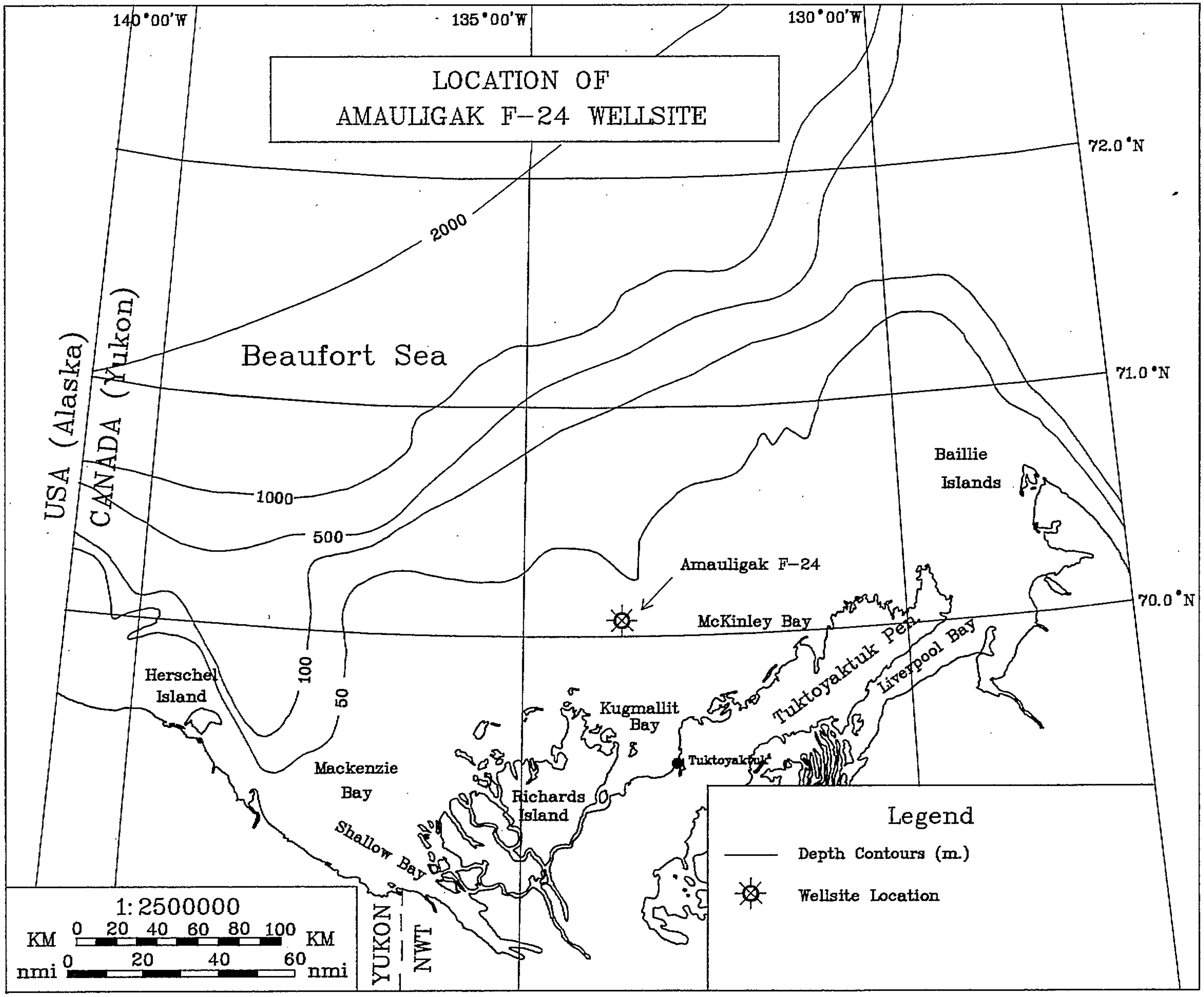

Figure 1. Location of the Amauligak F-24 drillsite in the southern Beaufort Sea.

The objective of the infaunal and epibenthic community component of the study was to provide baseline benthic samples which could be used for future environmental effects monitoring programs.

2.2 Sample Site Selection - Geochemistry

The study area was divided into three strata (as shown in Figure 2):

Stratum A	The outer boundary of stratum A was defined by a circle of radius 300 metres centred on the well site.
Stratum B	The area bounded by circles of radius 300 metres and 1500 metres.
Stratum C	The area bounded by circles of radius 1500 metres and 3000 metres.

Samples for metals, hydrocarbons and particle size were obtained in the following manner. (Locations of sample collection are also shown in Figure 2.)

Stratum A	Within Stratum A, 12 samples were taken in a systematic manner at locations 200 metres from the wellsite at 30° intervals. A systematic sampling approach was used because the area immediately adjacent to the berm is most likely to be affected by drilling activity and because the area adjacent to the berm will probably have the most variable sediment texture due to the presence of sand material (berm) in an area where clay/silt sediment texture is typical.
Strata B and C	These strata were divided into 100 quadrats of equal area, 25 in Stratum B and 75 in Stratum C (e.g., concentric circles of 3, 5, 7, 10, 11, 13, 15, 17 and 19 quadrants). Stations were defined as the geometric centres of the quadrats. A total of 12 samples were taken at random from Stratum B and 24 from Stratum C.Random sampling was chosen because there was no basis to expect a non-uniform distribution of metals or hydrocarbons in the area beyond the location where the berm was constructed.

In addition, two reference stations were sampled, one 5000 m NW of the Molikpaq and the other 5000 m SE of the Molikpaq.

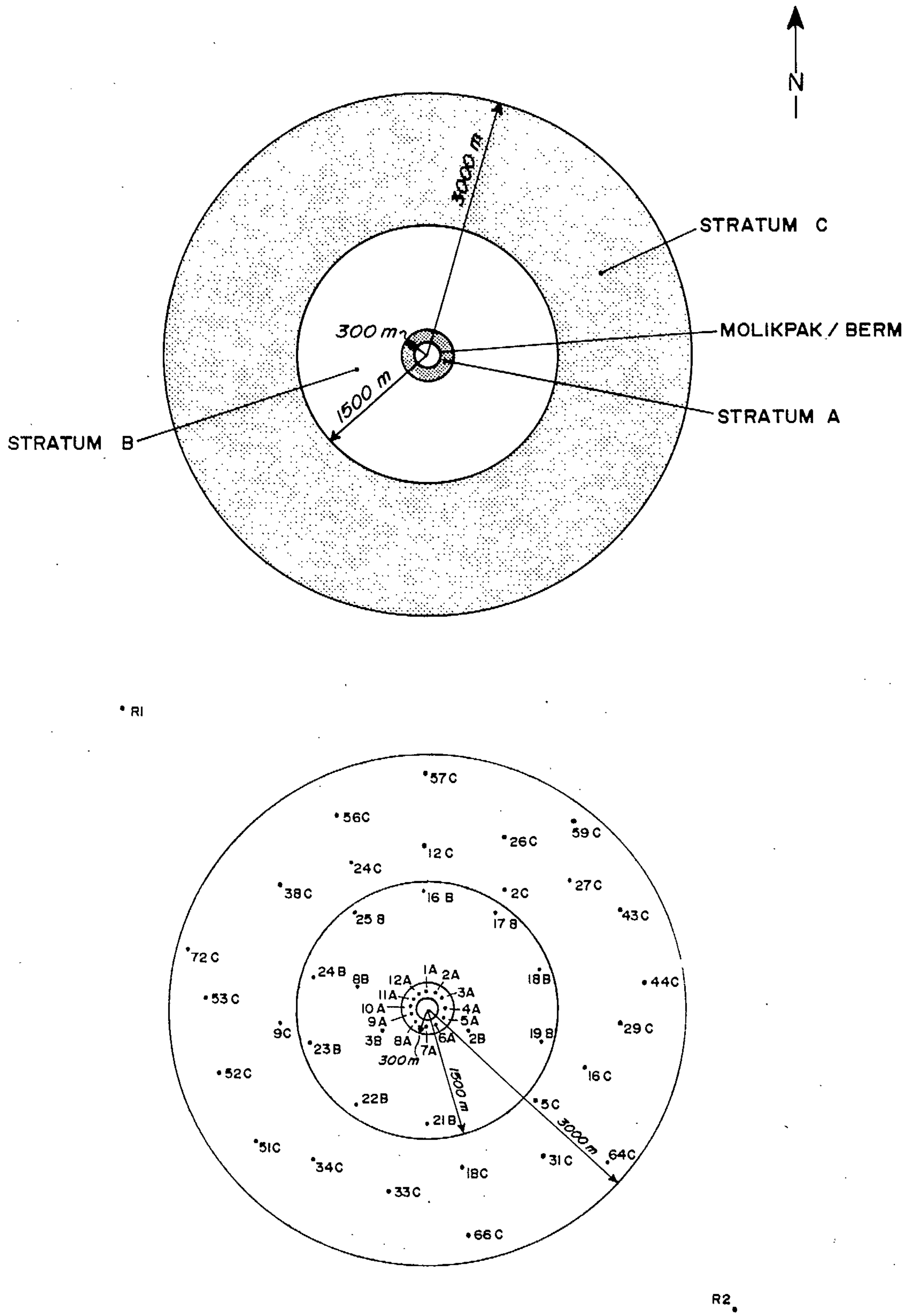

Figure 2. Division of study area into strata (A, B and C) and location of sampling sites within the strata.

2.3 Estimation of Required Number of Samples - Metals and Hydrocarbons

In a report by Hoff and Thomas (1986), predictions were made for the number of sample analyses required within a study area to give a detectability of $\delta = \sigma$ at $\alpha = \beta = 0.05$ using population values for the whole Beaufort Sea and based on double sampling. (δ = magnitude of the effect; σ = the std. dev. of the population; α = the significance of the test; and β = the power of the (one-tailed) test.) Because the variance in the localized area around Amauligak should be less than that for the Beaufort Sea, the number of analyses referred to above were considered to be maxima. In a recent study, the characterization of two potential Beaufort Sea ocean dumpsites (Arctic Laboratories and LGL 1987) confirmed that for a 3 km radius circular area with homogeneous sediment/texture, the number of samples required was far less than that predicted in the above report (Maximum of $N_i = 5$). Nonetheless, it was considered prudent to collect as many samples as possible in the 24 - 36 hour period of dedicated ship time. The number of samples predicted using the calculations outlined by Hoff and Thomas (1986) for Cd was 20. This was used as a guideline and fifty samples were collected allowing for approximately 100% oversampling.

2.4 Depth of Sediment Samples

The upper 1 - 2 cm of sediment was collected as this was the thinnest practical sample that could be taken in a reproducible manner. It was essential to collect only the most recent sediment deposition to improve the ability of future monitoring to detect change in sediment parameters.

2.5 Sampling Design - Benthic Community Component

The object of the benthic community component of the sampling programme was to provide pre-impact information around the Amauligak F-24 wellsite and a reference site.

Given that such pre-impact information on the benthic community was obtained, then identical post-impact sampling could be used to compare the wellsite with the reference site. For statistical analysis, a 2 x 2 (before-after times and control-impact areas) factorial analysis of variance (ANOVA) would be used to test the null hypothesis (H_0) of no impact. If the area x time interaction term in ANOVA is significant, the H_0 is rejected. In other words, evidence for impact would be temporal change in the impact area that does not occur in the "control" (reference) area.

The following calculations of necessary sample size are based on those of Green(1979: 42-43), with the sampling programme to be able to detect a decrease of 50% in benthic faunal density at the wellsite in contrast to no change in the control, while accepting a 0.05 risk of making a Type 1 error. In the absence of previous benthic data from the Amauligak wellsite, the following data set extracted from Table 5 of Wacasey *et al.* (1977) was used for the calculations. This data set consists of numbers of individuals in 0.1 m areas at a group of stations near the Amauligak F-24 wellsite (Stations 547 - 552, 559, and 571 of Wacassey *et al.* (1977), in water depths from 24 - 58 m.

174	201	105	137	105	126	130	49

1. The mean (Z_i) and variance (S_z) of the above data set after log-transformation (ln (X + 1)) are 4.7948 and 0.1773, respectively. A Z_1 = 4.7948 value corresponds to $X_1 = e^Z - 2 =$ 119.9, and a decrease of 50% will reduce that to X_2 = 59.94, which corresponds to Z_2 = 4.1099. The programme is, therefore, designed to detect a change of Z = -0.6849 in the impact area.

2. In a 2 x 2 factorial ANOVA with r replicates per area-by-time combination, the interaction is

$$F(1,4(r-1)df) = ((0.6849r)^2 / 4y) \ 0.1773 = 0.6614r$$

3. For values of

r	=	2	4	6	7
$F_{.95}$ (1,4(r-1)df)	=	7.71	4.75	4.35	4.26
0.66614r	=	1.32	2.65	3.97	4.63

Therefore, r = 7 replicate grab samples should be randomly allocated per area-by-time combination. A 100% oversampling, i.e., 14 replicate samples from each of the two sites (Amauligak F-24 and reference site) at each time (i.e., before and after impact) would allow for a degree of unforeseen error, e.g., higher among-replicate variability than that in the data set used for the calculations above.

In summary, the above calculations required that 14 grab samples be collected from the wellsite and from a reference site at a similar depth in the study area. Sampling locations should be randomly chosen within each site. This level of replication represents 100% oversampling, relative to the number of replicates calculated above. Based on a data set for a group of stations near the Amauligak wellsite, the calculated number of replicates (7) should characterize the sites to the extent that a 50% decrease in densities of benthos could be detected (with 0.05 risk of committing a Type 1 error), following identical post-impact sampling.

3. FIELD SAMPLING: SUMMARY AND PROCEDURES

During the sampling survey 50 samples were taken from within the vicinity of the wellsite location. Due to ship time constraints and the difficulty encountered with processing the samples, only one sample was obtained at each of the two reference sites.

3.1 Field Sampling Summary

All field samples were collected using a Smith-McIntyre grab sampler during the period September 30 to October 1, 1987. A summary of the locations sampled, the samples obtained and the observations made on those samples in the field is given in Table 1. A total of 50 samples for metals, hydrocarbons and particle size, and 22 samples for benthic community analysis, were obtained.

3.2 Field Sampling Procedures

3.2.1 Sediment Metals, Hydrocarbons and Particle Size

Sediment samples for trace metals, hydrocarbons and particle size were taken from a single grab sample. Immediately after retrieval of the grab, surface water was carefully removed (leaving fines undisturbed). The appearance of the grab was noted (general characteristics, presence of any large objects, benthos, etc.). Subsamples were skimmed from the upper 1 cm (approximately) of the sediment through the top of the grab. Samples were taken in the following order: trace metals, hydrocarbons, particle size. A plastic scoop was used for metals; a solvent-cleaned stainless steel scoop was used for hydrocarbons and particle size. Sediment samples for metal and particle size analysis were stored in plastic "Whirl Pak" bags. Samples for hydrocarbon analysis were stored in solvent-cleaned baked glass jars. Both metal and hydrocarbon samples were frozen immediately after collection and kept frozen until analysed. Particle size samples were kept cool. Clean sea water was used to clean sub-sampling utensils between samples or when accidentally dropped or exposed to contamination.

3.2.2 Benthic Community Component

Infauna and epibenthos were also sampled using a Smith-McIntyre grab. Upon retrieval, the depth of sediment contained in each grab was recorded in order to estimate sediment volume. The contents of each grab were then emptied either into a bucket or tray for immediate sieving/processing or a large plastic bag if interim storage was necessary before processing could take place.

Each sample was gently sieved through a 0.5 mm mesh screen. Large rocks (if any) were removed and discarded, and the screen contents were emptied into a plastic

TABLE 1. Summary of Samples/Observations Obtained During the Amauligak F-24 Sampling Survey, September 30 - October 01, 1987

Station Sample No.[a]	Date	Time (MDT)	Sounding Depth (m)	Sediment Characteristics			Flora/ Fauna	Samples Taken
				Type[b]	Colour	Odour		
1A	30/09/87	1630	32	silt/sand	brown	oxic	none visible	M,HC,PS,B(11)
2A	30/09/87	1715	32	silt/sand	brown	oxic	none visible	M,HC,PS
3A	30/09/87	1730	32	mud/sand	brown	oxic	amphipods	M,HC,PS,B
4A	30/09/87	1905	32	mud/sand	brown	oxic	amphipods	M,HC,PS
5A	30/09/87	1920	32	mud/sand	brown	oxic	polychaetes	M,HC,PS,B(11)
6A	30/09/87	1935	32	silt/fine sand (occasional pebbles)	brown	oxic	none visible	M,HC
12A	30/09/87	1950	32	sand/silt	brown	oxic	polychaetes	M,HC,PS
11A	30/09/87	2000	32	clay/sand	brown	oxic	none visible	M,HC,PS,B(10)
10A	30/09/87	2010	32	clay/sand	brown	oxic	none visible	M,HC,
9A	30/09/87	2025	32	sand/silt	brown	oxic	amphipod	M,HC,PS,B(10)
8A	30/09/87	2048	32	sand/silt	brown	oxic	none visible	M,HC,PS
7A	30/09/87	2100	32	sand/clay	brown	oxic	none visible	M,HC,PS,B(10)
3B	30/09/87	2120	31	clay	black streaks otherwise brown	anoxic portions	brittle star	M,HC,PS,B(15)
8B	30/09/87	2130	33	clay	grey/brown	oxic	none visible	M,HC,PS
16B	30/09/87	2200	34	clay	brown;black streaks	mottled anoxic	polychaetes	M,HC,PS
2B	01/10/87	0650	32	mud/sand	brown	oxic	none visible	M,HC,PS,B(9)
19B	01/10/87	0715	33	mud	brown;black streaks	oxic	none visible	M,HC,PS,B(13)
18B	01/10/87	0730	34	mud	brown	oxic	none visible	M,HC,PS
17B	01/10/87	0820	32	mud	brown	oxic	none visible	M,HC,PS,B(17)
25B	01/10/87	0900	33	clay	brown/black	anoxic (H_2S)	none visible	M,HC,PS,B(15)
24B	01/10/87	0910	33	mud	brown(top 3mm) black(below 3mm)	oxic anoxic (H_2S)	none visible	M,HC,PS
23B	01/10/87	0930	31	clay	brown;black streaks	oxic	none visible	M,HC,PS
22B	01/10/87	0945	31	clay	brown	oxic	none visible	M,HC,PS,B(14)
21B	01/10/87	1005	31	mud/silt	brown	oxic	none visible	M,HC,PS
5C	01/10/87	1022	31	clay	sfc-brown subsfc-black	oxic anoxic (H_2S)	none visible	M,HC,PS
16C	01/10/87	1045	32	silt/clay	sfc-brown subsfc-black	oxic anoxic (H_2S)	none visible	M,HC,PS,B(17)
29C	01/10/87	1058	32	clay/silt	brown	oxic	none visible	M,HC,PS
44C	01/10/87	1120	33	clay/silt	brown;black streaks	oxic	none visible	M,HC,PS,B(14)
43C	01/10/87	1140	33	clay	brown (upper 5mm) black (below 5mm)	oxic anoxic	none visible	M,HC,PS,B(16)
27C	01/10/87	1148	33	clay	brown	oxic	none visible	M,HC,PS
2C	01/10/87	1208	35	clay	brown	oxic	none visible	M,HC,PS
12C	01/10/87	1224	32	clay	brown black streaks	anoxic (H_2S)	brittle star	M,HC,PS
24C	01/10/87	1245	33	clay	brown	oxic	brittle stars	M,HC,PS
38C	01/10/87	1255	33	clay	brown	oxic (top 3mm) anoxic (below 3mm)	none visible	M,HC,PS,B(15)
72C	01/10/87	1310	33	mud	brown	oxic	none visible	M,HC,PS
53C	01/10/87	1320	31	clay/mud	sfc-brown black below 5mm	oxic anoxic	brittle stars	M,HC,PS,B(16)
9C	01/10/87	1340	31	clay	sfc-brown subsfc-black streaks	oxic anoxic (H_2S)	brittle star	M,HC,PS
52C	01/10/87	1355	32	clay	brown	oxic	none visible	M,HC,PS
51C	01/10/87	1410	30	clay	brown with black streaks	anoxic beneath a thin oxic layer	brittle star	M,HC,PS,B(14)
34C	01/10/87	1426	32	clay	brown	oxic	none visible	M,HC,PS
33C	01/10/87	1442	30	clay	brown	oxic	none visible	M,HC,PS
18C	01/10/87	1453	31	clay	brown	oxic	brittle star	M,HC,PS
66C	01/10/87	1505	31	clay	brown	oxic	none visible	M,HC,PS
31C	01/10/87	1523	30	clay	brown	oxic	brittle stars	M,HC,PS,B(12)
64C	01/10/87	1540	31	clay	brown	oxic	none visible	M,HC,PS
59C	01/10/87	1558	34	clay	brown	oxic	none visible	M,HC,PS
26C	01/10/87	1610	32	clay	brown	oxic	none visible	M,HC,PS
56C	01/10/87	1633	33	clay	brown	oxic	none visible	M,HC,PS,B(16)
R1	01/10/87	1655	35	clay	brown	oxic	none visible	M,HC,PS,B(16)
R2	01/10/87	1744	36	clay	brown	oxic	none visible	M,HC,PS,B(14)

a) for station locations see Figure 2.
b) silt/sand means a layer of silt overlying sand.
c) M = metals; HC = hydrocarbons; PS = particle size; B( ) = benthos (penetration of Smith-McIntyre grab in cm).

container, labelled, and preserved in 10% formalin (90% sea water buffered with sodium borate). The grab, tray, bucket, and screen were carefully rinsed and picked clean of visible organisms during the above process. Sample numbers were written in indelible ink on the sample container and lid, the container was placed into a sealed plastic bag, and the sample then placed into its shipping container.

No benthic biological samples were analysed in this study. All samples have been transferred to alcohol-based solutions for long-term storage in the LGL laboratory in King City, Ontario.

3.3 Positioning

Positioning was achieved by radar range and bearing to the Molikpaq. Estimated positioning accuracy was ±100 metres.

4. LABORATORY ANALYSES

Not all samples collected were analysed. Those analysed were selected at random.

4.1 Determination of the Concentration of Pb, Cd, Hg, Ba and Cr in Sediment

4.1.1 Pretreatment

Each frozen sediment sample was homogenised by kneading the contents of each "Whirl-Pak" bag. A subsample (~10 g) was withdrawn, dried and pulverised before analysis.

4.1.2 Lead and Cadmium

Lead and cadmium concentrations were determined by ICP/MS following reverse aqua regia digestion by Quanta Trace Labortories Ltd. in Vancouver.

4.1.3 Barium and Chromium

Barium, in some mineral forms, is incompletely dissolved by wet acid (oxidative) digestion in Teflon bombs. Consequently, the elements were digested by a fusion method using lithium metaborate (Owens and Gladney 1976). Chromium was also determined from this digest. Approximately 0.5 g dried sediment was fused with $Li_2B_4O_7$ in $LiNO_3$ with dissolution of the melt in nitric acid. Elemental detection was by ICAP at Quanta Trace Laboratories Ltd. Vancouver.

4.1.4 Mercury

Mercury in sample digests was determined by cold vapour atomic absorption spectrophotometry (CVAAS). The diluted sample was divided into 2 equal portions. Just before analysis, 10 mL of a 10% (w/v) stannous chloride solution were added to the 250 mL samples (a solution containing 10% (w/v) stannous chloride and 20% (v/v) sulphuric acid was prepared in tap water and purged with nitrogen for 4-6 hours to remove traces of mercury). The diffuser was immediately inserted, the sample shaken for 30 seconds, let stand for 30 seconds and purged with N_2 gas at a flow rate of 0.4 L min^{-1} for approximately one minute through a 30 cm path length cell of a Laboratory Data Control U.V. monitor. The peak absorbance of mercury at 253.7 nm is proportional to its concentration. Peak heights from two 250-mL aliquots were averaged for each sample.

The instrument settings were:

U.V. Monitor (Laboratory Data Control, Riviera Beach, Florida -
30 cm path length cell)

Range - 0.02 Absorbance

Recorder (Fisher Recordall - Series 5000)
Range - 1 mV Full Scale (25 cm)
Chart Speed - 5 cm/minute

Nitrogen Gas (Grade G) Flow Rate - 0.4 L/minute

The system was purged between samples using tap water. The 6 cm (length) x 2 cm (diameter) polyethylene drying tube was re-packed with fresh ACS grade magnesium perchlorate after analysis of approximately 30 aliquots. Glass wool was used at each end of the drying tube to prevent $Mg(ClO_4)_2$ from entering the U.V. gas cell.

The recorder span factor (ng Hg/mm peak height) was determined by spiking each 3-5 aliquots of 250 mL of tap water, containing 5 mL nitric acid/dichromate solution, with 5 ng Hg. Three to five aliquots were analysed and a mean factor derived. Standard spiked samples were analysed before every run (approximately 9 samples).

4.2 Determination of the Concentration of Hydrocarbons in Sediment

4.2.1 Rationale for GC/FID and GC/MS Analytical Methods

A cost-effective strategy in many monitoring studies is to screen samples with a low cost method for compounds of interest before committing to more expensive analyses. For hydrocarbons, two screening methods have been used; a total hydrocarbon analysis by infra-red spectrophotometry (IR) and an aromatic hydrocarbon analysis by UV/fluorescence. These methods could represent a considerable savings over a GC method if equivalent data are obtained. It was believed, however, that neither method was suitable for this study due to the nature and background levels of hydrocarbons in Beaufort Sea sediments.

Reported sediment concentrations of total saturated hydrocarbons range from 18.4 to 163.6 $\mu g \cdot g^{-1}$ (Wong *et al.* 1976) and 1.3 to 80.3 $\mu g \cdot g^{-1}$ (Thomas *et al.* 1982). The concentration range for polycyclic aromatic hydrocarbons (PAHs) is also large (e.g., 68 to 1856 $\mu g \cdot g^{-1}$)(Erickson *et al.* 1983). For a sensitive characterization of the impact area, the analytical method must accurately quantify background hydrocarbons over these entire concentration ranges. The general screening techniques are unable to do this and also lack standard material for calibration, thereby introducing serious uncertainty into the results.

Consequently, alkane determinations were carried out by GC/FID. This is a sensitive and relatively rapid instrumental method which, with the aid of internal standard quantification methods, provides accurate and sensitive total alkane analyses. Individual PAHs listed in Table 2 were analysed by GC/MS with selected ion monitoring (SIM) and isotope dilution internal standard quantification.

The base digestion/partition extraction method used is based upon our standard method and this type of extraction has been found to give high accuracy and reproducibility (Wong and Williams, 1980). Kuderna-Danish tube evaporators were used throughout to avoid losses of the more volatile components, as this method has been found to recover alkanes down to n-octane quantitatively.

4.2.2 Moisture/Dry Weight Determination

A subsample (approximately 5 g)of homogenized sediment was weighed into a tared glass Petri dish and air-dried at 80°C to constant weight. The percent moisture determined was used to convert hydrocarbon analysis results from a wet weight to a dry weight basis.

4.2.3 Analyses

a) Materials

Solvents were pesticide grade, distilled in glass (hexane, pentane, acetone, methanol, isopropanol and dichloromethane, supplied by BDH Omnisolv).

Distilled water and potassium hydroxide solutions were extracted with hexane before use. Anhydrous sodium sulphate (BDH Chemicals) was cleaned by heating at 350°C overnight. Silica gel (BDH, 60-120 mesh) was heated for 10 hours at 350°C, cooled, deactivated with 5% (by weight) glass-distilled water and allowed to stand at least 24 hours before use. The silica gel was slurry packed in pentane into a 13 cm x 10 cm column, covered with a 1-cm layer of anhydrous sodium sulphate and flushed with ≈25 mL of pentane.

Glassware and metal items were washed with laboratory detergent, rinsed with distilled water and heated at 350°C overnight. Non-heatable and plastic items were solvent rinsed (acetone and dichloromethane) before use.

Internal standards (hexadecylbenzene, Aldrich; perdeuterated n-decane, hexatriacontane, m-xylene, naphthalene, fluorene, phenanthrene, pyrene, chrysene, perylene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene and indeno(1,2,3-c,d)pyrene; Merck, Sharp and Dohme) were used as received. Polycyclic

Table 2

List of PAHs Analysed

Naphthalene
Fluorene
Phenanthrene
Anthracene
Fluoranthene
Pyrene
Benz(a)anthracene
Chrysene
Benzo(e)pyrene
Perylene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Dibenz(ah)anthracene
Benzo(ghi)perylene
Indeno(1,2,3cd)pyrene

aromatic hydrocarbons (naphthalene, fluorene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, perylene, benzo(e)pyrene, benzo(a)pyrene, phenanthrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, indeno(1,2,4-c,d)pyrene) were obtained from Sigma Chemical, Aldrich and Eastman Chemicals.

b) Sample Containers and Storage

Sediment samples were stored in pre-cleaned 250-mL glass jars with Teflon-lined screw-on lids. The glass jars were cleaned by washing with laboratory detergent, rinsing with distilled water and heating at 350°C before use. The Teflon liners were rinsed in chromic acid and then in solvent (acetone and dichloromethane) before use.

c) Hydrocarbon Extraction Procedures

The procedure used in the determination of hydrocarbons in sediments is an adaptation of the method of Cretney *et al.* (1980). It is shown schematically in Figure 3. A sample of sediment (20 - 30 g) was placed in a 500-mL round bottom flask to which was added 100 mL of MeOH, 8 mL of KOH (50% by weight), boiling stones and 1.0 mL of internal standards. The flask was refluxed for 1 h, then 100 mL of distilled water was added and fluxed for a further 30 min. The flask was cooled and the solution carefully decanted into a 1 L separatory funnel. The reflux flask was rinsed with pentane (4 x 25 mL) and the pentane rinses were added to the funnel. After each rinse, the flask was placed in an ultrasound to release pentane trapped in sediment, which also was added to the funnel. The MeOH/pentane solution was shaken and separated. The aqueous phase was extracted with two additional portions of pentane (2 x 100 mL). The combined pentane extracts were washed with distilled water (3 x 100 mL) and then dried over anhydrous sodium sulphate. The dried extract was decanted into a Kuderna-Danish flask to which 1 mL of iso-octane was added, and then the extract was concentrated to -1 mL in a 50°C water bath. The concentrated extract was then transferred to centrifuge tubes for fractionation by silica gel liquid chromatography. The alkane fraction was eluted with 25 mL of pentane and the PAH fraction with 40 mL of dichloromethane. Each fraction was then reduced in volume to ~1 mL in a Kuderna-Danish concentrator and transferred to centrifuge tubes for GC/FID and GC/MS analysis. The alkane fractions were analysed by capillary GC/FID for total alkanes and the aromatic fractions were analysed by GC/MS for individual PAHs.

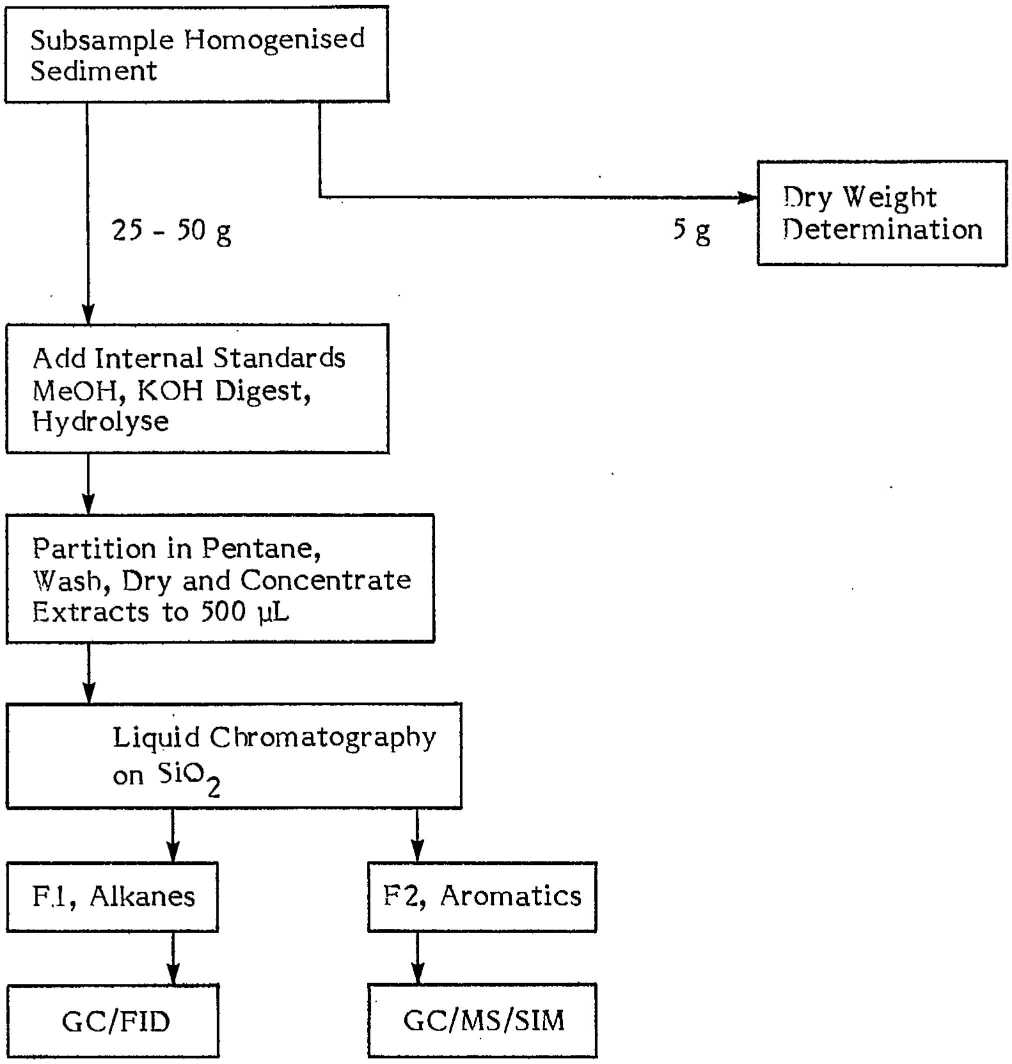

Figure 3. Analytical scheme for hydrocarbons.

d) Instrumental Analysis

Alkane Fraction

Alkane fractions were analysed using a Hewlett-Packard 5830/40A gas chromatograph with flame ionization detection (FID) operated with the following instrumental conditions.

Column:	30 m x 0.25 mm, BP-5 bonded phase silica column (S.G.E.) giving 90,000 effective theoretical plates (for nC-13)
Carrier:	Hydrogen at 16 p.s.i., column flow 1 mL min^{-1}
Injector Temperature:	250°C
Detector Temperature:	300°C
Detector Flows:	H_2 30 mL min^{-1}, air 240 mL min^{-1}, and N_2 (make-up) 30 mL min^{-1}

All injections made in the splitless mode for 1.0 min.

Temperature Program:	Sample injected at 50°C, held for 1.0 min column oven heated at 10° min^{-1} to 300 °C and held for 5 min.

Calibration of the GC/FID system to alkanes and internal standards was by daily injection of a response calibration standard containing fourteen even carbon number n-alkanes (nC_{10} to nC_{36}, 20 ng each) and the internal standards.

Compound identities were assigned on the basis of the relative retention time of the GC peak maximum.

A procedural blank was carried through the analysis for each batch of 6 to 10 samples.

Quantification was by automated integration of resolved peak areas in the boiling range of n-dodecane to n-octatriacontane. Sediment concentrations of total alkanes are provided on a $\mu g \cdot g^{-1}$ dry weight basis.

Aromatic Fraction

Aromatic fractions were analysed on a Finnigan 9500/3200 gas chromatograph/mass spectrometer (GC/MS), with a Finnigan 6100 data system using the following conditions:

Column:	30 m x 0.25 mm BP-1 bonded phase fused silica column (S.G.E.)
Carrier Gas:	helium
Injector Flow Rate:	60 mL min^{-1}
Injector Pressure:	17 p.s.i.
Column Flow:	40 cm s^{-1}
Split Ratio:	40:1 (approximately)
Injector Temeprature:	260 °C
Injection Sequence:	splitless injection at room temperature, splitting resumed at 1 minute, 100 °C at 2 minutes and 10 ° min PT-1PT at 4.5 minutes to 280°C and hold for 10 minutes. 0.5 μL injections.
Mass Spectrometer:	electron impact source
Source Emission:	0.5 mA
Electron Energy:	40 eV
Operating Pressure:	1 x 10^{-5} torr
Multiplier Voltage:	2400 V (gain > 10^6)
Data Acquisition:	data acquired in the "selected ion monitor" mode with one scan/sec; four ions per scan in five clusters of four ions per run. Data archived on magnetic tap.

The GC provides separation power of 50,000 effective theoretical plates (for nC-16) and the following compounds were resolved (10% of baseline or better, with peak maxima separated by a minimum of three MS scans) as determined by analysis of authentic standards:

phenanthrene/anthracene;
benz(a)anthracene/chrysene;
benzo(e)pyrene/benzo(a)pyrene/perylene;

The mass spectrometer was tuned daily for optimal mass resolution and sensitivity to selected ions from perfluorobutylamine (FC43) with baseline resolution at 219, 264 and 502. The data system was mass calibrated daily and the calibration confirmed by comparison to an acquired spectrum of FC43. The centres of the 219 and 264 fragment peaks were required to be within 0.2 amu, otherwise the spectrometer was retuned and the data system recalibrated. The mass spectrometer resolution and ion transmission was periodically evaluated by injection of 100 ng of decafluorotriphenylphosphine. Using the ion abundance criteria of the US EPA (Eichelberger *et al.* 1975) for acceptable performance, it is required that the 442^+ ion be 40% or more of the base peak (198).

Calibration of the GC/MS system to PAH and internal standards was by twice-daily injection of a response calibration standard containing approximately 10 ng of each PAH and the perdeuterated internal standards. The relative response of each PAH with respect to the appropriate internal standard must be constant within 10% over each working day for acceptance of data acquired on that day.

Compound identities were assigned on the basis of the relative retention time of the GC peak maximum in the characteristic ion mass chromatogram, with the relative retention time required to be within 0.004 ± 0.002 RRT units of the expected relative retention time as determined on that day using the calibration standard.

A procedural blank was carried through the analysis for each batch of 6 to 10 samples.

Quantification was by manually-controlled area integration of the mass chromatogram.

A linearity check of the GC/MS response using three standards with concentrations ranging from ten times to one thousand times the detection limit indicated that the response was essentially linear within experimental error under the conditions used.

The method was verified by analysis of standard reference materials and intercalibration samples.

4.3 Determination of the Particle Size Distribution in Sediments

Particle size analyses were done by wet-sieving to separate the sand/gravel fractions from clay/silt (63 μm, 4 phi, 230 mesh). The clay/silt content (at 1.0 phi intervals) was determined by standard sedimentation procedures using hydrometer tests (ASTM D422). Sample preparation was as per the procedures outlined in Walton (1978). Sieving and hydrometer tests were done under subcontract to Thurber Consultants in Victoria.

4.4 Quality Control/Quality Assurance

4.4.1 Metals

Accuracy of the methods was estimated by analysing marine reference materials whose metal compositoin has been certified. Two reference materials, produced by the National Research Council of Canada, were used (MESS-1 and BCSS-1). The reference materials were digested with each set of sediments analysed. The results (Appendix A) were within the quoted 95% tolerance limits of the certified means for each metal.

Precision was estimated in two ways:

(1) by repetitive analysis of the certified reference materials (see Appendix A); and

(2) by including blind replicates in the analysis programme (blind replicates are those whose identity is unknown to the analyst).

The results of the blind replicate analysis programme (Table 3) indicate that the variability of replicates from the mean was generally higher than that obtained using reference materials (non-blind analysis).

4.4.2 Hydrocarbons

Procedural blank determinations are given in Tables 4 and 5 for alkanes and PAH, respectively. These data were used to determine limits of detection and limits of quantification for the alkanes and PAHs reported in this study.

Accuracy of hydrocarbon analyses could not be measured in the same manner as was done for the metal analyses because no suitable certified reference material is available for the hydrocarbon content of marine sediment. The results were tied to absolute concentrations by including internal standards in the analyses and adjusting for recoveries. In addition, an intercalibration for PAH was conducted with the Ocean Chemistry Division, Institute of Ocean Sciences wherein a bulk Beaufort Sea sediment sample was analysed repeatedly. The results of this intercalibration are given in Table 6.

Table 3.
Blind Replicate Results for Metals

Sample		Ba	Cr	Cd	Pb	Hg
11A		640	49	0.12	6.7	7
		870	74	0.13	9.6	9
	x	755	61.5	0.125	8.2	8
	σ	163	17.7	0.007	2.1	1.4
	%RSD	22	29	6	25	18
24B		1000	156	0.16	22	51
		1270	135	0.35	24	63
		1230	129	0.39	23	62
	X	1167	140	0.30	23	59
	σ	145	14	0.12	1	7
	%RSD	12	10	41	4	11
44C		940	105	0.24	20	49
		940	109	0.24	24	50
	x	940	107	0.24	22	49.5
	σ	0	2.9	0	2.8	7.7
	%RSD	0	3	0	13	1
R1		1010	132	0.17	24	57
		1050	120	0.10	24	60
	x	1030	126	0.135	0	58.5
	σ	28	85	0.049	0	2.1
	%RSD	3	7	37	0	4
BCSS-1	%RSD	7	14	14	9	10
MESS-1	%RSD	5	14	9	27	6

Table 4.
Alkanes in Sediments: Procedural Blanks and Method Detection Limits

Compound	Blank Runs (ng)									Mean Blank	Std Dev.	Det. Limit*	Quant. Limit**	Det. Limit* (based on a dry sample weight of 20 g)	Quant. Limit**
nC-12	<30	<16	<21	<31	<33	<24	<16	<49	<22	<27	10.3	<34	<93	<1.6	<4.7
nC-13	<31	<16	<21	<31	<32	<23	<15	<50	<21	<27	10.8	<33	<97	<1.6	<4.9
Farnesane	<30	<16	<20	<30	<31	<22	<15	<51	<20	<26	11.2	<34	<101	<1.7	<5.1
nC-14	<30	<16	<20	<30	<31	<22	<15	<51	<20	<25	12.6	<38	<113	<1.9	<5.7
Trimethyl nC-13	<31	<16	<20	<30	<31	<22	<15	<51	<20	<26	11.2	<34	<101	<1.7	<5.1
nC-15	<32	<16	<20	<31	<31	<22	<15	<51	<20	<26	11.3	<34	<101	<1.7	<5.1
nC-16	<36	<17	<19	<32	<31	<22	<16	<50	<20	<23	14.8	<44	<133	<2.2	<6.7
Norpristane	<35	<17	<19	<32	<31	<22	<16	<50	<20	<27	11.1	<33	<100	<1.7	<5.0
Nc-17	<34	<17	<20	<34	<34	<24	<17	<53	<21	<28	11.7	<35	<106	<1.8	<5.3
Pristane	<35	<16	<20	<34	<34	<24	<17	<53	<21	<28	11.9	<36	<107	<1.8	<5.4
nC-18	<37	<16	<21	<36	<36	<26	<19	<57	<22	<30	12.9	<39	<116	<2.0	<5.8
Phytane	<38	<16	<21	<36	<36	<26	<19	<57	<22	<29	14.4	<43	<129	<2.2	<6.4
nC-19	<39	<19	<22	<38	<38	<27	<20	<64	<24	<32	14.3	<43	<129	<2.2	<6.4
nC-20	<40	<19	<23	<40	<40	<28	<21	<74	<26	<35	17.0	<51	<153	<2.6	<7.7
nC-21	<40	<20	<25	<41	<42	<30	<21	<75	<27	<36	17.0	<51	<153	<2.6	<7.7
nC-22	<42	<21	<26	<43	<44	<31	<22	<77	<28	<37	17.4	<52	<157	<2.6	<7.9
nC-23	<46	<21	<28	<45	<46	<33	<23	<80	<29	<39	18.2	<55	<164	<2.8	<8.3
nC-24	<47	<23	<29	<47	<48	<35	<25	<82	<31	<41	18.2	<55	<164	<2.8	<8.3
nC-25	<48	<24	<30	<48	<49	<36	<25	<82	<31	<41	18.1	<54	<163	<2.7	<8.2
nC-26	<50	<25	<31	<49	<51	<37	<26	<81	<31	<42	17.8	<53	<160	<2.7	<8.0
nC-27	<54	<25	<32	<51	<53	<39	<28	<80	<32	<44	17.5	<53	<158	<2.7	<7.9
nC-28	<56	<26	<34	<52	<56	<41	<29	<79	<32	<45	17.2	<52	<155	<2.6	<7.8
nC-29	<60	<30	<36	<53	<58	<43	<30	<77	<32	<47	16.4	<49	<148	<2.5	<7.4
nC-30	<61	<31	<36	<54	<59	<45	<31	<75	<32	<47	15.9	<48	<144	<2.4	<7.2
nC-31	<63	<31	<38	<56	<61	<46	<32	<72	<32	<48	15.6	<47	<140	<2.4	<7.0
nC-32	<68	<32	<39	<57	<63	<48	<33	<67	<32	<49	15.3	<46	<138	<2.3	<6.9
nC-33	<70	<32	<41	<60	<66	<50	<34	<64	<32	<50	15.5	<47	<140	<2.4	<7.0
nC-34	<74	<35	<43	<62	<69	<52	<36	<60	<33	<52	15.5	<47	<140	<2.4	<7.0
nC-35	<79	<37	<46	<65	<74	<56	<38	<57	<34	<54	16.5	<49	<148	<2.5	<7.4
nC-36	<83	<38	<49	<70	<79	<60	<40	<53	<34	<56	18.0	<54	<162	<2.7	<8.1
Sum	<1400	<720	<780	<1200	<900	<630	<1700	<700	<900						

*Limit of Detection defined as 3 times the Standard Deviation of the mean blank.
**Limit of Quantification defined as 9 times the Standard Deviation of the mean blank.

Table 5.
PAH in Sediments: Procedural Blanks and Method Detection Limits

Hydrocarbon Analyses

Compound	Blank Runs (ng)									Mean Blank	Std Dev.	Det. Limit*	Quant. Limit**	Det. Limit* (based on a dry sample weight of 20 g)	Quant. Limit** (based on a dry sample weight of 20 g)
Naphthalene	<2.4	<12	4.4	<3.4	8.1	<4.0	8.0	13	<13	<7.6	4.3	<13	<38	<.65	<1.9
Flourene	<1.0	1.4	1.2	3.3	2.9	1.6	4.5	4.1	<1.4	<2.4	1.3	<4.0	<12	<20	<0.6
Phenanthrene	<1.0	1.3	1.0	2.2	2.7	1.8	2.4	11	9.1	<3.6	3.7	<11	<34	<.55	<1.7
Anthracene	<0.44	.59	.39	1.0	1.7	<1.0	<2.1	1.8	<2.5	<1.3	0.8	<2.3	<6.9	<0.12	<.35
Fluoranthene	0.80	.49	<.46	1.4	1.6	1.1	<.34	3.7	<2.1	<1.3	1.1	<3.2	<9.6	<0.16	<0.48
Pyrene	<0.30	1.5	1.4	1.9	2.4	<0.88	<.34	6.1	<1.9	<1.9	1.7	<5.2	<16	<.26	<0.80
Benz(a)anthracene	<0.65	<.53	1.6	<1.1	8.3	1.3	5.6	5.2	16	<4.5	5.1	<15	<46	<.75	<2.3
Chrysene	<1.0	2.2	2.1	<1.0	<2.1	1.9	<4.9	2.3	7.4	<2.8	2.1	<6.2	<19	<.31	<0.93
Benzofluoranthenes	2.1	3.0	5.0	5.3	7.0	4.8	<5.5	4.9	14	<5.7	3.4	<10	<31	<0.50	<1.5
Benzo(e)pyrene	<0.78	<.56	2.9	2.4	<2.1	<2.0	<5.8	<2.5	<4.4	<2.4	1.8	<5.4	<16	<0.27	<0.81
Benzo(a)pyrene	1.1	<.60	2.6	1.7	<2.5	2.6	<7.1	<3.1	<5.3	<3.0	2.1	<6.2	<19	<0.31	<0.92
Perylene	3.2	3.8	4.4	4.8	5.7	<2.2	<6.9	<3.1	<4.7	<4.3	1.4	<4.3	<13	<0.22	<0.64
Benzo(g,h,i)perylene	<1.1	3.6	<1.5	<2.4	3.6	<1.6	<6.3	<4.3	<4.9	<2.3	1.7	<5.1	<15	<0.26	<0.77
Dibenz(a,h)anthracene	<1.2	7.2	<1.5	<2.4	5.4	6.6	<6.7	<4.9	<5.8	<4.4	2.6	<7.9	<24	<0.40	<1.2
Indeno(1,2,3cd)pyrene	<0.45	0	<.7	<.8	<.1	<1.0	<2.2	<2.0	<4.9	<1.8	2.2	<6.6	<20	<0.33	<0.98
Sum	<18	<39	<31	<35	<56	<34	<69	<72	<83	<50					

* Limit of Detection defined as 3 times the Standard Deviation of the mean blank.

** Limit of Quantification defined as 9 times the Standard Deviation of the mean blank.

Table 6.
PAH Intercalibration Exercise Results: Seakem and IOS

Compound	Seakem 1	Seakem 2	Seakem 3	x̄	σ	Ocean Chemistry Division 1	2	3	4	x	σ
Naphthalene	58.01	59.87	60.65	59.51	1.1	97.5	102.9	97.3	89.1	96.7	5.7
Flourene	37.43	41.39	44.61	41.15	2.94	30.5	32.9	32.2	65.5	40.3	16.8
Phenanthrene	249.72	259.70	269.81	259.74	8.20	191.1	218.5	186.8	207.3	200.9	14.7
Anthracene	4.00	2.00	3.00	3.00	0.82	1.7	5.1	21.6	5.7	8.5	8.9
Fluoranthene	31.91	29.90	31.94	31.25	0.95	27.6	30.0	35.5	26.2	29.8	4.1
Pyrene	43.81	40.80	39.87	41.49	1.68	49.8	55.4	66.3	60.1	57.9	7.0
Benz(a)anthracene	10.00	9.00	10.00	9.67	0.47	27.2	29.6	34.4	26.0	29.3	3.7
Chrysene	90.62	96.59	94.74	93.99	2.50	119.8	105.9	188.2	134.9	137.2	36.0
Benzofluoranthenes	70.62	67.59	68.74	68.99	1.25	73.4	73.8	109.6	94.9	87.9	17.6
Benzo(e)pyrene	100.00	130.00	94.00	108.00	15.75	202.8	318.0	487.7	205.5	303.5	134
Benzo(a)pyrene	15.00	11.00	14.00	13.33	1.70	21.8	29.2	78.7	17.8	36.9	28.3
Perylene	290.00	310.00	260.00	286.67	20.55	157.4	10.3	219.5	134.3	130.4	87.8
Dibenz(a,h)anthracene	18.00	21.00	12.00	17.00	3.74	35.3	18.1	0.0	82.0	33.9	35.2
Indeno(1,2,3-c,d)pyrene	19.00	21.00	12.00	17.33	3.86	15.0	33.7	0.0	109.8	39.6	48.4
Benzo(g,h,i)perylene	140.00	160.00	110.00	136.67	20.55	240.9	0.0	680.6	235.2	289.2	284.1

The analytical precision for hydrocarbon analysis was estimated through the use of blind replicates. The results of the blind replicate programme (Tables 7, 8) indicate that the variability in estimating total alkanes and total PAH is approximately 4-15% RSD and 1-22% RSD respectively, the precision obtained for individual compounds can be much poorer (in some cases >100% RSD).

Table 7.
Blind Replicate Analyses of Alkanes in Sediments
(All concentrations in ng·g-1 dry weight)

	11A			24B			9C			44C			53C		
	Run 1	Run2	% RSD	Run1	Run2	% RSD	Run 1	Run 2	% RSD	Run 1	Run 2	% RSD	Run 1	Run 2	% RSD
nC_{10}	20	<3	105	140	140	0	150	160	5	54	110	48	130	150	40
nC_{11}	40	65	28	360	270	20	500	380	19	94	340	80	220	290	19
nC_{12}	19	3	103	280	310	7	440	430	2	130	260	47	230	330	25
nC_{13}	27	35	18	410	450	7	510	550	5	210	310	27	320	460	25
Farnesane	29	32	7	140	160	9	260	250	3	73	100	22	100	180	40
nC_{14}	36	32	8	470	530	8	420	460	6	270	370	22	420	590	24
TrimethylnC_{13}	49	48	1	270	300	7	400	430	5	200	220	7	200	320	33
nC_{15}	49	54	7	540	570	4	510	520	1	370	490	20	480	590	52
nC_{16}	40	51	17	470	500	4	470	450	3	370	420	9	450	500	7
Norpristane	39	52	20	220	220	0	300	290	2	140	210	28	210	230	6
nC_{17}	45	52	10	640	650	1	600	620	2	510	510	0	650	700	5
Pristane	58	67	10	640	630	1	740	760	2	510	490	3	570	620	6
nC_{18}	37	41	7	520	110	117	480	500	3	420	400	3	530	550	3
Phytane	41	39	4	370	350	4	400	370	6	310	300	2	400	400	0
nC_{19}	38	55	26	580	520	8	480	520	6	440	420	3	590	580	1
nC_{20}	58	65	8	490	490	0	510	500	1	420	390	5	610	530	10
nC_{21}	38	39	2	520	630	14	490	590	13	450	450	0	810	640	17
nC_{22}	28	36	18	400	460	10	380	410	5	3700	390	4	540	450	13
nC_{23}	39	45	10	490	560	9	460	510	7	430	450	3	530	530	0
nC_{24}	33	57	38	360	440	14	340	410	13	330	330	0	410	410	0
nC_{25}	51	88	38	450	550	14	420	490	11	410	420	2	500	490	1
nC_{26}	39	77	46	250	320	17	220	270	14	220	260	12	280	280	0
nC_{27}	65	100	30	520	670	18	460	600	19	550	670	14	600	600	0
nC_{28}	30	57	44	220	260	12	180	250	23	190	300	32	290	290	0
nC_{29}	50	59	12	480	650	21	420	550	19	430	520	13	620	650	3
nC_{30}	26	6	88	220	350	32	150	200	20	150	190	17	340	320	4
nC_{31}	34	<7	93	400	660	35	330	430	19	320	410	17	530	580	6
nC_{32}	15	<8	43	120	300	61	96	96	0	120	<24	94	160	170	4
nC_{33}	<0.9	<8	113	180	390	52	140	170	14	<2	<26	121	200	260	18
nC_{34}	<1	<10	116	73	210	68	53	70	20	<3	<30	116	120	120	0
nC_{35}	<1	<11	118	<7	<7	0	<6	<12	47	<3	<33	118	<7	<6	11
nC_{36}	<1	<12	120	29	120	86	<7	<13	42	<3	<38	121	40	53	20
nC_{37}	<1	<12	120	<8	<7	9	<7	<13	42	<3	<38	121	<7	<7	0
nC_{38}	<1	<12	120	<8	<7	9	<7	<13	42	<3	<38	121	<7	<7	0
Total	1080	1340	15	11280	12790	9	11340	12340	6	8510	9970	11	12100	12880	4

Table 8.
Blind Replicate Analyses of PAH in Sediments
(All concentrations in $ng{\cdot}g^{-1}$ dry weight)

	11A			24B			9C			44C			53C		
	Run 1	Run2	% RSD	Run1	Run2	% RSD	Run 1	Run 2	% RSD	Run 1	Run 2	% RSD	Run 1	Run 2	% RSD
Naphthalene	0.9	2	54	57	47	14	60	83	23	29	18	33	66	56	12
Fluorene	<0.3	<0.4	20	9	21	57	29	4	107	2	0.7	68	0.6	15	131
Phenanthrene	<0.4	<1	61	170	180	4	150	140	5	210	140	28	170	210	15
Anthracene	<0.4	1	61	<0.04	<0.08	47	2	<0.02	139	<0.4	<0.4	0	<0.4	<0.08	94
Fluoranthene	<0.1	<0.3	71	18	16	8	27	5	97	2	1	47	0.4	19	136
Pyrene	<0.1	<0.2	47	38	4	114	44	18	59	9	4	54	6	34	99
Benz(a)anthracene	<0.2	<0.5	61	12	12	0	14	0.2	139	0.3	<0.5	35	<0.5	<0.1	94
Chrysene	<0.2	<0.5	61	68	74	6	73	55	20	16	12	20	27	77	68
Benzofluoranthenes	<0.2	<0.6	71	33	39	12	54	11	94	2	1	47	1	26	131
Benzo(e)pyrene	<0.2	<0.7	79	95	85	8	87	60	26	20	9	54	36	75	50
Benzo(a)Pyrene	<0.2	<0.8	85	10	23	56	17	<0.3	137	<0.5	<0.7	24	<0.9	2	54
Perylene	<0.2	<0.8	85	360	350	2	280	420	28	170	150	9	460	400	10
Dibenz(a,h)anthracene	<0.5	<2	85	10	13	18	22	13	36	0.9	<2	54	2	12	101
Indeno(1,2,3cd)pyrene	<0.5	<2	85	<0.2	17	138	7	<0.5	123	<0.8	<1	16	<2	5	61
Benzo(g,h,i)perylene	<0.9	<3	76	97	170	39	110	37	70	<2	<3	28	9	140	124
Total	<5.3	<15.8	-	977	1051	5	835	847	1	465	342	22	782	1011	18

5. RESULTS AND DISCUSSION

5.1 Particle Size

A summary of the surficial particle size data (% sand + gravel, % silt and % clay) is given in Appendix C. The sediments in stratum B and stratum C are a mixture of clay and silt-sized particles in a ratio of approximately 60%/40%, essentially the same as the background (reference) stations. The sediments in stratum A are dominated by sand-sized particles, typical of the material which was imported to the area to build the foundation berm for the Molikpaq. A triangular plot of sediment grain size is presented in Figure 4. This plot clearly indicates the linear mixing of the two end members of sediment type (sand near berm, clay/silt background). The addition of sand-sized particles associated with the berm to background sediments gives rise to the variable sand content observed at the sites which occur between the berm and background locations.

5.2 Metals - Ba, Cr, Cd, Pb and Hg

Overall concentration ranges for Pb, Cd, Hg, Cr and Ba were 2.5 - 27 $\mu g \cdot g^{-1}$, <0.10 - 0.32 $\mu g \cdot g^{-1}$, 3 - 68 $ng \cdot g^{-1}$, 17 - 173 $\mu g \cdot g^{-1}$, and 300 - 1730 $\mu g \cdot g^{-1}$, respectively. A summary of the Ba, Cr, Cd, Pb and Hg concentrations in sediment samples taken in the vicinity of the Amauligak F-24 drillsite is given in Table 3 and in Appendix A. For all metals, average concentrations were lower in stratum A than in samples obtained outside stratum A. This is generally related to the particle size of the sediments. Metals are lower in samples dominated by sand sized particles than they are in samples dominated by clay/silt particles. Scatter plots of the concentration of each metal vs % clay (Figure 5) indicated this relationship is strongest for Hg, Pb and Cr. An interesting aspect of the scatter plots is the apparent enrichment of Ba, Pb and Cr in several sand samples. Possible sources of these metals include (1) waste discharge streams associated with activities at Amauligak F-24; and (2) import of these metals with the sand from the borrow area (i.e., some of the sand from the borrow area appears to be contaminated with Ba, Pb and Cr).

5.3 Hydrocarbons

A summary of the concentrations of aliphatic and aromatic hydrocarbons found in surficial sediment samples collected near the Amauligak F-24 drillsite is given in Table 3 and in Appendix B. Concentration ranges of total alkanes and total PAH were 930 - 14160 $ng \cdot g^{-1}$ and <5.3 - 1051 $ng \cdot g^{-1}$, respectively. As with the metals, concentrations were generally lower in samples collected within stratum A than in

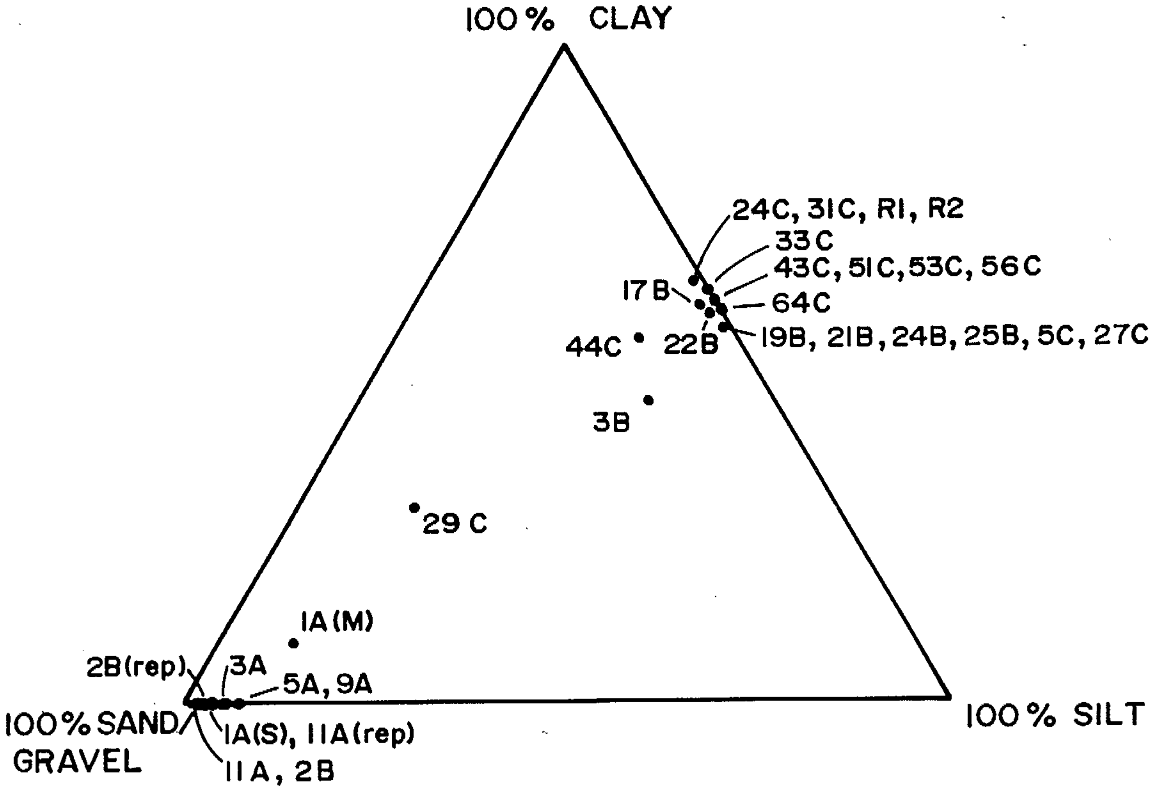

Figure 4. Triangular plot of sediment grain size for samples collected in the vicinity of the Amauligak F-24 drillsite.

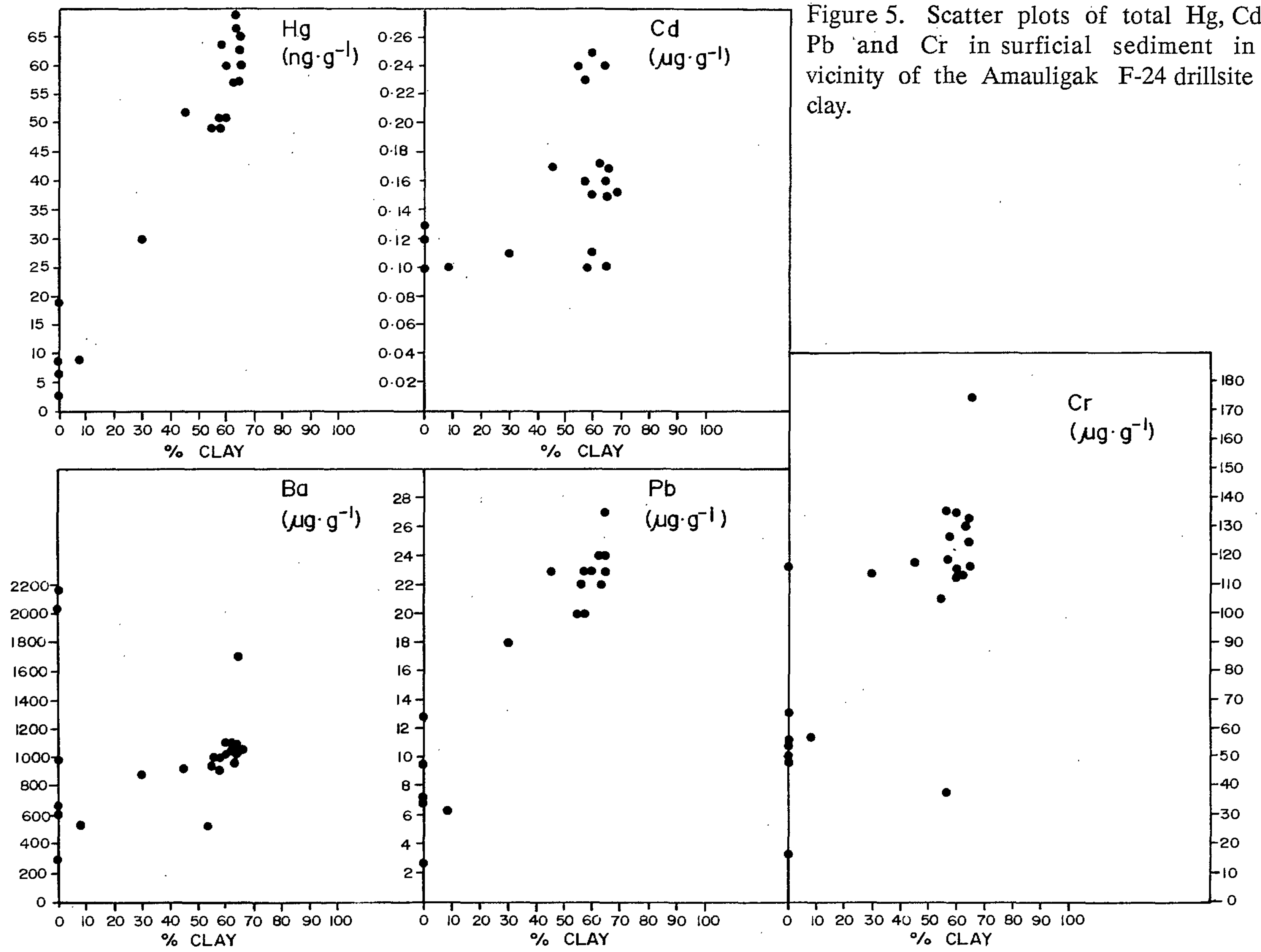

Figure 5. Scatter plots of total Hg, Cd, Ba, Pb and Cr in surficial sediment in the vicinity of the Amauligak F-24 drillsite vs % clay.

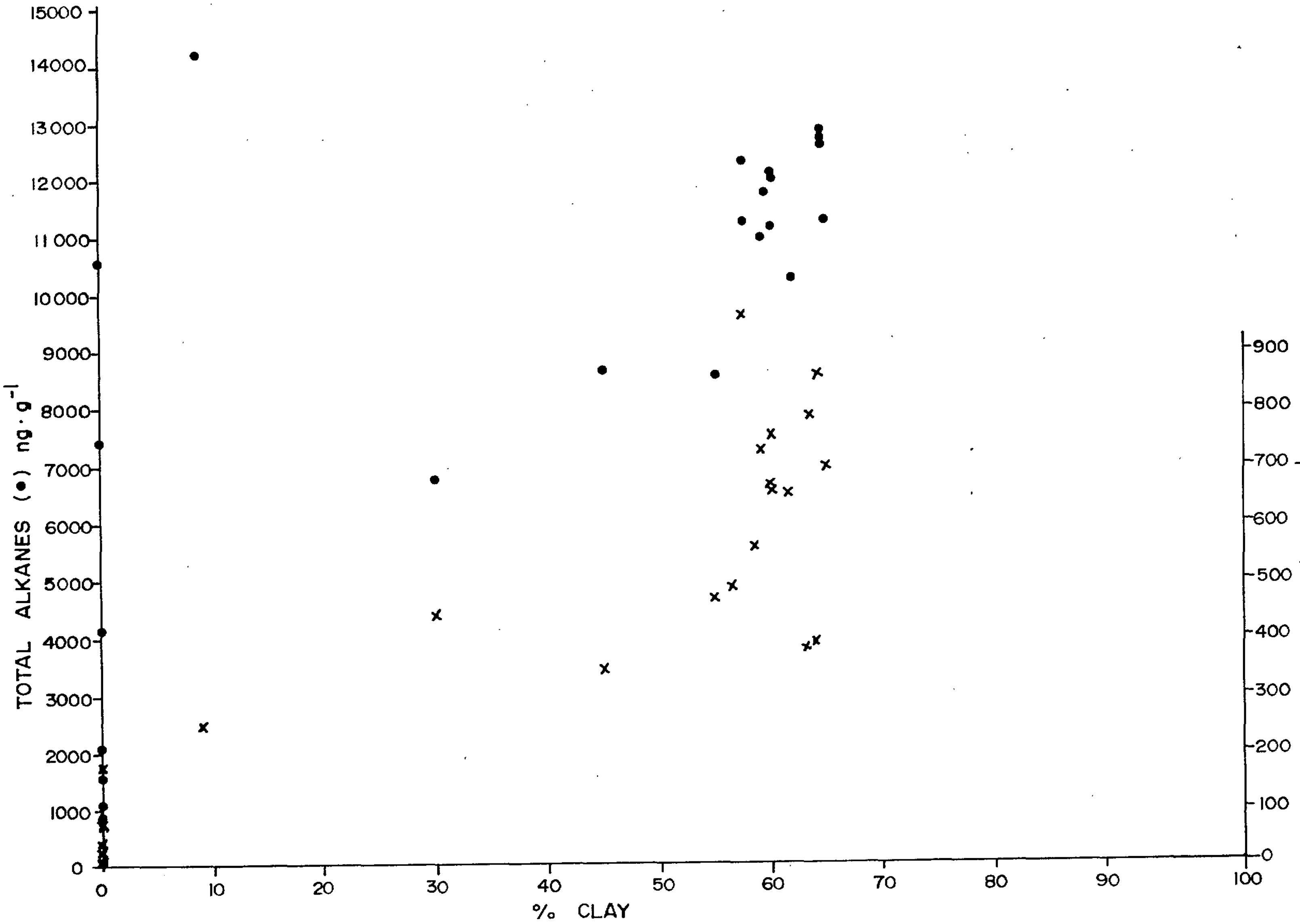

Figure 6. Scatter plot of total alkanes in surficial sediment in the vicinity of the Amauligak F-24 drillsite vs % clay.

samples collected outside stratum A. Furthermore, some of the sand samples were clearly enriched with hydrocarbons, particularly the isoprenoids (see Appendix B and Figure 6). As in the case of metals, probable sources of these hydrocarbons include (1) waste discharge streams associated with activities at Amauligak F-24; and (2) the import of hydrocarbons with sand from the borrow area. The dominance of the isoprenoid hydrocarbons and the qualitative characteristics of the gas chromatograms leads to a strong suspicion that a paraffinic refined product such as Vista ODC base oil is present in these samples. The ratio of n-alkanes (B) to total alkanes (A) can be used as an index of the presence of isoprenoid-rich hydrocarbons like Vista ODC. The value of this ratio (B/A) is compared in Table 3 for Stratum A and Strata (B + C). The B/A ratio is relatively consistent throughout Strata (B + C) having values of 0.86 $\pm$ 0.03. By contrast the ratio is lower and more variable (0.64 $\pm$ 0.12) in stratum A; the lower ratio and increased variability are caused by the disproportionate presence of isoprenoids in these sediments. Vista ODC is known to contain significant quantities of isoprenoid hydrocarbons.

An explanation for the presence of VISTA ODC type base oil has come forth following its identification in this study. In September 1987, Gulf Canada Resources Limited carried out a dredging operation at the abandoned Minuk I-53 artificial island in the Beaufort Sea to provide coarse material for construction of the subsea berm at Amauligak F-24. A total quantity of 64,000 m^3 of borrow material (gravel) was removed from Minuk and placed at the Amauligak F-24 berm site. Vista ODC base oil had been used at Minuk during the 1985/1986 drilling season and base oil-contaminated drill cuttings had subsequently been discharged near the Minuk site. The recent dredging at Minuk disturbed the drill cuttings contaminated with base oil causing numerous surface oil slicks to appear at the dredging area.

5.4 Spatial Variability of Contaminants in the Sediments in the Vicinity of Amauligak F-24

A summary of the concentrations of contaminants in the sediments in the vicinity of Amauligak F-24 is shown in Table 3. Generally contaminant concentrations in Strata B and C were similar and representative of background Beaufort Sea conditions. By contrast, contaminant concentrations in Stratum A were clearly lower. As indicated above, most of the differences in the concentrations of metals and hydrocarbons between Stratum A and Strata (B + C) can be explained by sediment grain size relationships.

The sediments in Stratum A were coarser than those in Strata (B + C) because coarse material was imported from other areas to build the F-24 subsea berm. As contaminant concentrations generally decrease with increasing grain size, the concentrations of metals and hydrocarbons in Stratum A were predictably lower than those in the finer indigenous sediments in Strata (B + C).

Table 9. Summary of Sediment Data for Amauligak F-24[a].

Amauligak F-24

	Stratum A[b]		Stratum (B+C)[b]		Ref 1	Ref 2	Overall	
	Range	($\bar{x} \pm \sigma$)	Range	($\bar{x} \pm \sigma$)			Range	($\bar{x} \pm \sigma$)
Constituent[c]								
Pb ($ug \cdot g^{-1}$)	6.3 - 13	8.2 ± 2.6 (n=6)	2.5 - 27	21.8 ± 4.8 (n=21)	24 (n=1)	22 (n=1)	2.5 - 27	19.1 ± 7.1 (n=29)
Cd ($ug \cdot g^{-1}$)	<0.10 - 0.13	0.11 ± 0.01 (n=6)	<0.10 - 0.32	0.16 ± 0.06 (n=21)	0.17 (n=1)	0.24 (n=1)	<0.10 - 0.32	0.15 ± 0.06 (n=29)
Hg ($ng \cdot g^{-1}$)	7-19	10 ± 4 (n=6)	3 - 68	53 ± 15 (n=21)	57 (n=1)	57 (n=1)	3 - 68	45+ 21 (n=29)
Cr ($ug \cdot g^{-1}$)	49 - 117	49 ± 17 (n=6)	17 - 173	118 ± 35 (n = 21)	132 (n=1)	132 (n=1)	17 - 173	108 ± 39 (n=29)
Ba ($ug \cdot g^{-1}$)	570 - 2190	1002 ± 884 (n=6)	300 - 1730	987 ± 253 (n=21)	1010 (n=1)	960 (n=1)	300 - 1730	959 ± 462 (n=29)
Alkanes ($ng \cdot g^{-1}$)								
Total[d] (A)	1080 - 14160	5880 ± 5030 (n=7)	930 - 12840	11310 ± 3660 (n=21)	-	12880 (n=1)	930 - 12840	9250 ± 4250 (n=29)
n-alkanes (B) (C_{10} - C_{38})	863 - 8580	3400 ± 2840 (n=7)	820 - 12210	9400 ± 2430 (n=21)	-	11000 (n=1)	820 - 12210	7560 ± 3490 (n=29)
n-alkanes (C_{12} - C_{38})	-	3050 ± 2540 (n=7)	-	9000 ± 2330 (n=21)	-	10410 (n=1)	-	6580 ± 4190 (n=29)
B/A	0.49 - 0.82	0.64 ± 0.12 (n=7)	0.81 - 0.95	0.86 ± 0.03 (n=21)	-	0.85 (n=1)	0.49 - 0.95	0.81 ± 0.12 (n=29)
Aromatics[e] ($ng \cdot g^{-1}$)	5.3 - 242	106 ± 88 (n=7)	16 - 1051	603 ± 225 (n=21)	-	866 (n=1)	5.3 - 1051	492 ± 299 n=29)
Particle Size[f]								
% Clay	-	1.3+3.4 (n=7)	-	56.3 ± 14.8 (n=20)	6	64	-	43.0 ± 27.2 (n=29)
% Silt	-	5.6 ± 2.4 (n=7)	-	34.0 ± 9.1 (n=26)	34	35	-	27.2 ± 14.7 (n=29)
% Sand	-	93.1 ± 5.6 (n=7)	-	9.7 ± 23.3 (n=20)	1	1	-	29.9 ± 41.6 (n=29)

a See Appendices A, B and C for a complete data listing.
b See Figure 2.
c Concentrations are expressed on a dry weight basis.
d Total alkanes includes n-alkanes from nC_{10} to nC_{38} plus 5 isoprenoids (farnesane, trimethyl-nC13, norpristane, pristane and phytane).
e The sum of napthalene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(a)pyrene, perylene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, dibenz(a,h anthracene, benzo(g,h,i)perylene and indeno(1,2,3,c,d)pyrene.
f Clay is defined as particles <0.002 mm in diameter; silt is defined as particles <0.063 mm and >0.002 mm; sand is defined as particles >0.063 mm in diameter.

Table 10. Comparison of Hydrocarbons and Metals at Amauligak and Other Beaufort Sea Locations

	Amauligak F-24	Dumpsite A (Note 1)	Dumpsite B (Note 1)	Various Offshore Beaufort Sea Drilling Locations (Note 2)	Coastal Beaufort Sea (Note 3)
Constituent					
Pb ($ug \cdot g^{-1}$)	19.1 ± 7.1 (n=29)	23.4 ± 2.7 (n=20)	21.2 ± 2.2 (n=20)		14 ± 7 (n=66)
Cd ($ug \cdot g^{-1}$)	0.15 ± 0.06 (n=29)	0.10 ± 0.02 (n=20)	0.11 ± 0.02 (n=20)	0.20 - 0.41 (n>100)	0.23 ± 0.21 (n=66)
Hg ($ng \cdot g^{-1}$)	45 ± 21 (n=29)	72 ± 14 (n=20)	66 ± 10 (n=20)	3 - 151 (n>100)	90 ± 60 (n=66)
Cr ($ug \cdot g^{-1}$)	108 ± 39 (n=29)	131 ± 10 (n=20)	121 ± 11 (n=20)		
Ba ($ug \cdot g^{-1}$)	959 ± 462 (n=29)	864 ± 35 (n=20)	856 ± 31 (n=20)		
Alkanes ($ng \cdot g^{-1}$)					
Total Alkanes	9250 ± 4250 (n=29)	-	-		9690 ± 7410 (n=43)
n-alkanes (C_{10} - C_{38})	7560 ± 3490 (n=29)	-	-		
n-alkanes (C_{12} - C_{38})	6580 ± 4190 (n=29)	6400 ± 1800 (n=19)	5000 ± 300 (n=20)		
Aromatics ($ng \cdot g^{-1}$)	492 ± 299 (n=29)	660 ± 78 (n=18)	540 ± 56 (n=14)		632 ± 752 (n=43)
Reference	This Study	Arctic Labs (1987)	Arctic Labs (1987)	Thomas et al. (1982)	Thomas et al. (1983)

Note 1. Dumpsite A at 70°39', 135°50' W; Dumpsite B at 69°40'N, 138°30' N.

Note 2. Includes data from Tarsiut A-25, Tarsiut N-44, Uviluk, Ukalerk, Tingmiark, Kenalooak, Natsek, Kopanoar, Koakoak, Miterk, Silukoak, Nerlerk, Sissuak, Issungnak and Kadluk.

Note 3. Includes data from McKinley Bay, Tuft Point, Hutchison Bay, Tuktoyaktuk Harbour and adjoining coastal locations.

5.5 Comparison of Contaminant Concentrations in the Vicinity of the Amauligak F-24 Drillsite with those at other Beaufort Sea Locations

A comparison of the data obtained in this study at Amauligak F-24 with data reported for other Beaufort Sea locations is presented in Table 4. The most likely explanation for the hydrocarbon anomalies found near the Amauligak berm in this study is that some base-oil-contaminated dredge spoils originating at Minuk I-53 were incorporated into the Amauligak F-24 subsea berm.

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APPENDICES

Sediment Analytical Data

A. Ba, Cr, Cd, Pb and Hg

B. Hydrocarbons

C. Particle Size

APPENDIX A

Ba, Cr, Cd, Pb and Hg in the sediments in the vicinity of the Amauligak F-24 Drillsite.

Metals in Sediment Samples Collected in the Vicinity of the Amauligak F-24 Drillsite

Station/Sample No.	Ba (ppm)	Cr (ppm)	Cd (ppm)	Pb (ppm)	Hg (ppb)
1A	570	56	<0.10	6.3	9
3A	2010	66	0.12	9.5	19
5A	2190	50	<0.10	13	19
7A	990	117	0.12	6.8	9
9A	600	55	0.10	6.9	9
9A Replicate	620	58	0.10	6.8	-
11A	640	49	0.12	6.7	7
11A Blind Replicate	870	74	0.13	9.6	9
2B	300	17	<0.10	2.5	3
3B	920	118	0.17	23	52
17B	1030	113	0.17	24	67
19B	550	38	0.23	23	51
22B	1010	114	0.15	23	51
22B Replicate	1000	120	0.12	23	49
24B	1000	156	0.16	22	51
24B Blind Replicate	1270	135	0.35	24	63
24B Blind Replicate	1230	129	0.39	23	62
25B	1020	112	0.25	23	60
2C	1040	115	0.15	23	65
5C	1000	119	<0.10	20	49
9C	1080	111	0.32	23	52
18C	1000	165	0.10	23	58
26C	1060	145	0.14	24	42
27C	1100	135	0.11	23	60
29C	890	114	0.11	18	30
33C	1020	173	0.10	23	60
44C	940	105	0.24	20	49
44C Blind Replicate	940	109	0.24	24	50
51C	1030	124	0.10	24	68
53C	1730	115	0.15	27	65
56C	1100	130	0.16	24	63
64C	950	127	0.15	23	64
72C	960	130	0.16	23	61
R1	1010	132	0.17	24	57
R1 Blind Replicate	1050	120	0.10	24	60
R2	960	132	0.24	22	57
R2 Replicate	960	135	0.27	24	57
REFERENCE MATERIALS					
BCSS (Certified)	330[a]	123 ± 14	0.25 ± 0.4	22.7 ± 3.4	129 ± 12
BCSS (Measured)	320 ± 22	126 ± 18	0.29 ± 0.04	21.0 ± 1.9	136 ± 13
RSD (%)[b]	7	14	14	9	10
MESS (Certified)	270[a]	71 ± 11	0.59 ± 0.10	34.0 ± 6.1	178 ± 10
MESS (Measured)	280 ± 14	73 ± 10	0.68 ± 0.06	28.0 ± 7.6	178 ± 10
RSD (%)	5	14	9	27	6

a = not certified

b %RSD = Relative Standard Deviation = $(x/\sigma) \times 100\%$

APPENDIX B

Hydrocarbons in the sediments in the vicinity of the Amauligak F-24 Drillsite.

Hydrocarbons in Sediment Samples Collected in the Vicinity of the Amauligak F-24 Drillsite

Station/ Sample No.	1A (Mud)	1A (Sand)	3A	5A	7A	9A	11A	11A (Blind Rep.)	2B	3B	17B	19B	22B	24B	24B (Blind Rep.)	25B	2C
COMPOUND																	
A. Alkanes																	
nC_{10}	290	210	32	200	21	32	20	<3	6	69	130	99	170	140	140	140	130
nC_{11}	520	470	120	350	66	93	40	65	70	170	170	250	280	360	270	280	190
nC_{12}	1400	1200	120	980	75	130	19	<3	17	160	300	270	290	280	310	260	280
nC_{13}	1200	960	310	820	82	110	27	35	22	240	380	420	420	410	450	420	400
Farnesane	1300	1100	290	900	58	140	29	32	13	83	130	170	110	140	160	140	120
nC_{14}	550	460	150	370	72	140	36	32	18	300	390	450	460	470	530	490	400
Trimethyln-C_{13}	1700	1400	380	1200	90	160	49	48	23	220	290	320	280	270	300	280	270
nC_{15}	630	520	140	450	73	130	49	54	24	400	490	580	570	540	570	620	520
nC_{16}	410	400	140	270	58	90	40	51	25	380	500	520	500	470	500	530	500
Norpristane	790	740	220	550	58	79	39	52	19	130	230	190	230	220	220	180	280
nC_{17}	280	210	110	160	70	78	45	52	30	570	610	660	690	640	650	670	650
Pristane	1200	1100	350	790	100	120	58	67	34	390	610	710	680	640	630	710	660
nC_{18}	180	120	120	68	58	56	37	41	27	410	510	530	550	520	110	550	460
Phytane	590	530	210	370	62	70	41	39	22	300	370	410	390	370	350	380	350
nC_{19}	150	70	75	60	51	53	38	55	22	420	530	530	610	580	520	540	520
nC_{20}	1400	330	420	150	60	78	58	65	320	400	460	490	530	490	490	500	400
nC_{21}	180	71	13	75	95	84	38	39	27	440	490	870	570	520	630	50	490
nC_{22}	98	46	65	40	39	44	28	36	17	350	400	470	430	400	460	460	460
nC_{23}	140	64	100	49	47	54	39	45	22	440	500	580	550	490	560	540	520
nC_{24}	98	44	70	34	35	40	33	57	15	290	340	410	410	360	440	360	420
nC_{25}	140	69	130	45	44	51	51	88	21	450	430	590	520	450	550	520	400
nC_{26}	65	34	74	24	25	26	39	77	11	230	230	360	290	250	320	290	260
nC_{27}	170	95	130	44	55	62	65	100	22	560	460	790	620	520	670	690	500
nC_{28}	68	29	63	18	21	21	30	57	10	180	160	290	220	220	260	230	200
nC_{29}	160	100	110	39	45	48	50	59	34	450	440	620	540	480	650	580	540
nC_{30}	59	29	75	18	18	20	26	<6	<3	140	150	230	220	220	350	200	130
nC_{31}	190	95	90	47	41	42	34	<7	20	350	290	440	470	400	660	440	260
nC_{32}	38	<7	93	<4	<4	21	15	<8	<4	120	82	170	170	120	300	160	60
nC_{33}	80	43	<1	16	16	17	<0.9	<8	<4	<1	130	<0.6	210	180	390	<0.7	110
nC_{34}	52	<7	<1	<4	<4	<4	<1	<10	<4	<2	73	<0.7	93	73	210	<0.8	70
nC_{35}	<7	<8	<1	<4	<4	<4	<1	<11	<5	<2	<6	<0.8	<12	<7	<7	<0.9	<6
nC_{36}	<8	<9	<2	<5	<5	<5	<1	<12	<5	<2	<7	<0.9	<13	29	120	<1	<6
nC_{37}	<8	<9	<2	<5	<5	<5	<1	<12	<5	<2	<7	<0.9	<13	<8	<7	<1	<7
nC_{38}	<8	<9	<2	<5	<5	<5	<1	<12	<5	<2	<7	<0.9	<13	<8	<7	<1	<7
Total Alkanes (A) ($ng.g^{-1}$)	14160	10590	4210	7450	1560	2110	1080	1340	930	8650	10300	12420	12120	11280	12790	11220	10580
Total n-Alkanes (B) ($ng.g^{-1}$)	8580	5720	2260	3640	1190	1540	863	1100	820	7530	8670	10620	10430	9640	11130	9530	8900
B/A	0.61	0.54	0.54	0.49	0.76	0.73	0.80	0.82	0.88	0.87	0.84	0.86	0.86	0.85	0.87	0.85	0.84

Station/ Sample No.	5C	9C	9C (Blind Rep.)	18C	26C	27C	29C	33C	44C	44C (Blind Rep.)	51C	53C	53C Rep.	56C	64C	72C	R2
COMPOUND																	
A. Alkanes																	
nC_{10}	150	150	160	130	180	140	75	160	54	110	130	130	150	130	170	160	140
nC_{11}	420	500	380	270	360	210	220	260	94	340	230	220	290	360	290	390	450
nC_{12}	310	440	430	280	360	240	170	280	130	260	280	230	330	290	340	320	300
nC_{13}	400	510	550	370	490	330	250	380	210	310	450	320	460	370	420	400	400
Farnesane	130	260	250	120	170	130	82	130	73	100	130	100	180	120	150	130	110
nC_{14}	480	420	460	490	550	460	270	490	270	370	490	420	590	470	490	510	470
Trimethyln-C_{13}	330	400	430	270	300	210	170	280	200	220	320	200	320	310	280	300	330
nC_{15}	540	510	520	560	570	500	330	570	370	490	630	480	590	540	540	520	540
nC_{16}	520	470	450	500	490	430	300	510	370	420	570	450	500	540	500	520	530
Norpristane	280	300	290	220	230	220	150	240	140	210	190	210	230	270	220	280	270
nC_{17}	680	600	620	670	680	660	390	710	510	510	720	650	700	680	660	660	680
Pristane	680	740	760	610	640	600	390	640	510	490	690	570	620	620	610	650	770
nC_{18}	550	480	500	520	540	530	320	560	420	400	560	530	550	570	520	500	560
Phytane	390	400	370	390	390	390	240	410	310	300	400	400	400	390	370	390	400
nC_{19}	550	480	520	560	570	560	330	590	440	420	580	590	580	570	550	550	570
nC_{20}	520	510	500	480	510	540	300	540	420	390	520	610	530	520	450	500	520
nC_{21}	610	490	590	710	680	650	310	600	450	450	600	810	640	610	590	570	600
nC_{22}	510	380	410	430	430	450	240	430	370	390	500	540	450	490	400	490	500
nC_{23}	650	460	510	510	550	580	290	500	430	450	600	530	530	590	510	530	590
nC_{24}	490	340	410	370	440	410	210	360	330	330	410	410	410	440	370	410	440
nC_{25}	730	420	490	420	500	560	280	440	410	420	600	500	490	640	470	550	610
nC_{26}	500	220	270	230	270	330	150	230	220	260	360	280	280	420	260	270	340
nC_{27}	1100	460	600	450	590	640	300	480	550	670	790	600	600	910	560	620	880
nC_{28}	480	180	250	180	260	280	120	200	190	300	360	290	290	320	240	300	330
nC_{29}	860	420	550	380	550	600	300	430	430	530	630	620	650	750	540	560	630
nC_{30}	310	150	200	130	200	210	120	210	150	190	320	340	320	210	260	200	210
nC_{31}	610	330	430	290	440	410	220	330	320	410	500	530	580	480	480	470	450
nC_{32}	<24	96	96	60	160	130	62	96	120	<24	180	160	170	<22	140	110	<25
nC_{33}	<27	140	170	93	170	60	110	140	<2	<26	<0.6	200	260	<25	280	150	<29
nC_{34}	<31	53	70	60	110	70	32	60	<3	<30	<0.7	120	120	<29	65	90	<33
nC_{35}	<35	<6	<12	<10	<14	<8	<5	<8	<3	<33	<0.8	<7	<6	<33	<13	<10	<38
nC_{36}	<41	<7	<13	<12	<16	<9	<6	<9	<3	<38	<0.9	40	53	<39	<14	<12	<44
nC_{37}	<41	<7	<13	<12	<16	<9	<6	<9	<3	<38	<0.9	<7	<7	<39	<14	<12	<44
nC_{38}	<41	<7	<13	<12	<16	<9	<6	<9	<3	<38	<0.9	<7	<7	<39	<14	<12	<44
Total Alkanes (A) ($ng.g^{-1}$)	14020	11340	12340	10780	12540	11610	6750	11290	8510	9970	12740	12100	12880	12840	11780	12150	12880
Total n-Alkanes (B) ($ng.g^{-1}$)	12210	9240	10190	9190	11110	5720	10060	9590	7280	8650	11010	10620	11130	11130	10150	10400	11000
B/A	0.87	0.81	0.83	0.95	0.89	0.87	0.85	0.85	0.86	0.87	0.86	0.88	0.86	0.87	0.95	0.86	0.85

Hydrocarbons in Sediment Samples Collected in the Vicinity of the Amauligak F-24 Drillsite, cont'd.

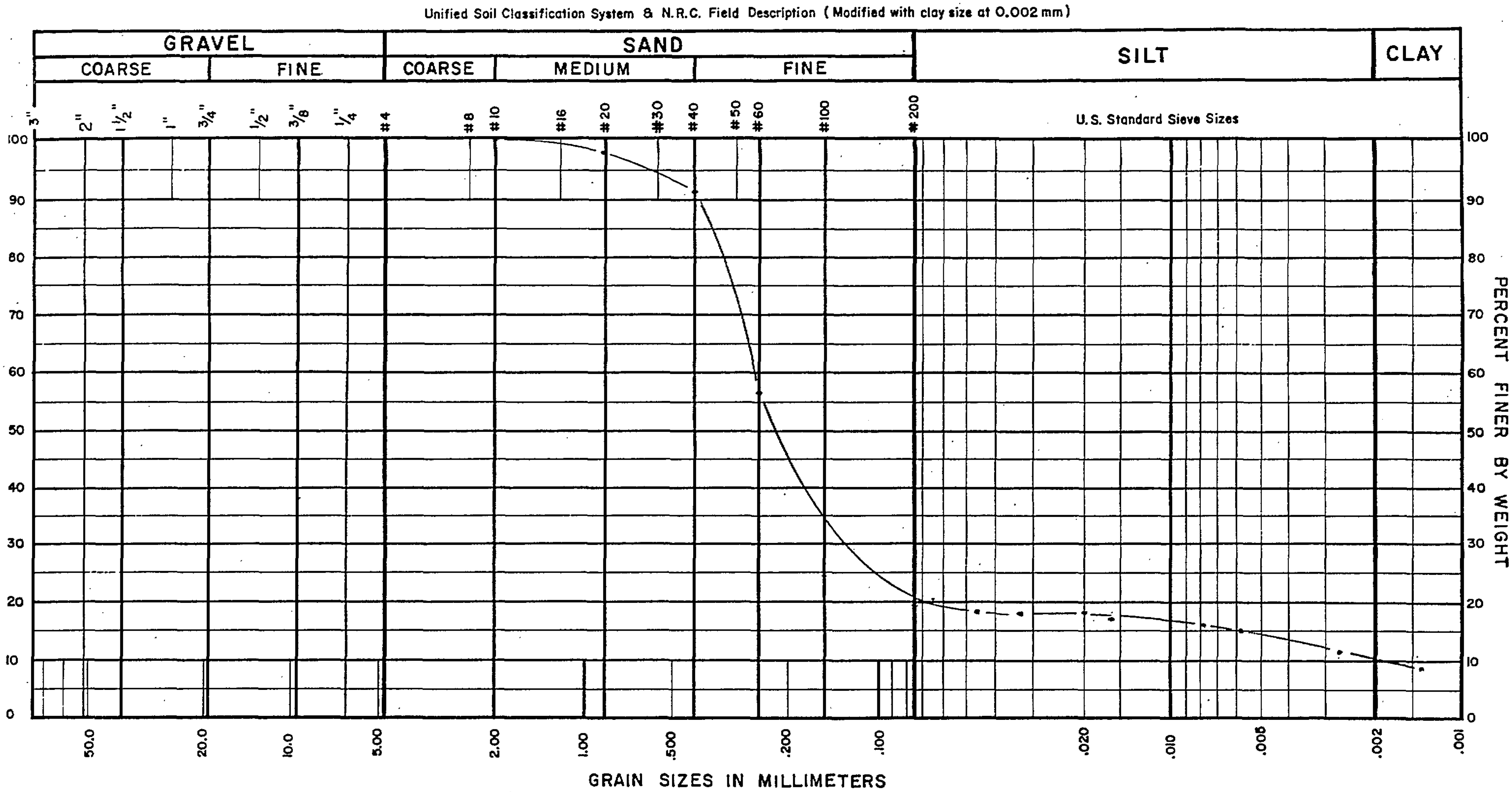
Station/ Sample No.	1A (Mud)	1A (Sand)	3A	5A	7A	9A	11A	11A (Blind Rep.)	2B	3B	17B	19B	22B	24B	24B (Blind Rep.)	25B	2C	5C	9C	9C (Blind Rep.)	18C	26C	27C	29C	33C	44C	44C (Blind Rep.)	51C	53C	53C Rep.	56C	64C	72C	R2
COMPOUND																																		
B. Aromatics																																		
Naphthalene	19	8	23	8	8	3	0.9	2	3	37	54	41	0	57	47	42	25	40	60	83	53	19	21	36	54	29	18	33	66	56	33	56	30	33
Fluorene	8	17	<0.2	19	0.2	0.6	<0.3	<0.4	0.5	6	21	2	7	9	21	12	6	2	29	4	1	30	29	17	5	2	0.7	1	0.6	15	1	13	4	2
Phenanthrene	86	38	38	92	9	15	<0.4	<1	6	81	140	220	140	170	180	210	280	350	150	140	150	150	130	98	150	210	140	260	170	210	240	140	550	730
Anthracene	<0.04	0.5	<0.5	<0.03	<0.02	<0.02	<0.4	1	0.08	<0.02	2	<0.6	<0.06	<0.04	<0.08	<0.2	<0.8	<0.9	2	<0.02	0.07	<0.2	<0.8	0.6	<0.1	<0.4	<0.4	<0.6	<0.4	<0.08	<0.8	<0.04	<0.8	<1
Fluoranthene	3	10	<0.2	1	0.1	2	<0.1	<0.3	0.4	11	26	1	11	18	16	9	1	0.2	27	5	2	8	10	15	6	2	1	2	0.4	19	2	15	8	3
Pyrene	5	10	0.07	3	0.5	3	<0.1	<0.2	1	19	45	6	26	38	4	23	8	5	44	18	12	22	25	27	18	9	4	11	6	34	6	30	20	8
Benz(a)anthracene	<0.7	6	<0.4	0.02	<0.04	0.05	<0.2	<0.5	<0.06	<0.7	26	<1	9	12	12	<0.2	<1	<1	14	0.2	0.2	<0.3	6	9	<0.2	<0.3	<0.5	<0.4	<0.5	<0.1	<0.5	2	1	<0.6
Chrysene	7	10	<0.5	4	0.4	3	<0.2	<0.5	0.6	14	68	8	52	68	74	43	15	11	73	55	41	47	40	46	44	16	12	35	27	77	34	58	26	18
Benzofluoranthenes	1	9	<0.4	0.5	0.06	0.3	<0.2	<0.6	<0.1	<2	63	1	13	33	39	17	1	1	54	11	4	16	21	34	7	2	1	5	1	26	5	18	11	1
Benzo(e)pyrene	4	11	<0.5	0.9	0.2	1	<0.2	<0.7	<0.1	10	13	11	56	95	85	51	11	12	87	60	33	74	59	55	52	20	9	35	36	75	27	59	29	9
Benzo(a)pyrene	0.09	7	<0.5	0.06	0.05	0.04	<0.2	<0.8	<0.1	<2	12	<1	0.04	10	23	<0.2	<1	<1	17	<0.3	0.1	0.8	3	8	<0.3	<0.5	<0.7	<0.6	<0.9	2	<0.8	0.7	<0.8	<0.8
Perylene	99	33	21	32	7	12	<0.2	<0.8	3	150	38	190	290	360	350	240	100	120	280	420	350	430	310	15	330	170	150	<0.6	460	400	260	280	50	53
Dibenz(a,h) anthracene	0.6	2	<1	0.7	2	0.4	<0.5	<2	<0.2	<4	17	<3	5	10	13	0.1	<2	<2	22	13	7	12	10	8	4	<0.9	<2	<1	2	12	<2	9	<2	<2
Indeno(1,2,3c,d) pyrene	0.2	2	<1	0.9	<0.1	0.08	<0.5	<2	<0.2	<6	10	<2	<0.3	<0.2	17	9	<2	<2	7	<0.5	0.2	0.4	<2	4	<0.6	<0.8	<1	<1	<2	5	<2	<0.2	<2	<2
Benzo(g,h,i) perylene	9	8	<2	3	0.4	3	<0.9	<3	<0.2	<5	120	<5	61	97	170	<0.8	<3	<4	110	37	10	140	90	73	29	<2	<3	<2	9	140	<3	54	<3	<3
Total Aromatics ($ng.g^{-1}$)	242	172	89	165	28	43	<5.3	<15.8	16	348	655	493	670	977	1051	657	457	552	835	847	664	949	757	446	700	465	342	388	782	1011	383	735	738	866

APPENDIX C

Particle Size of sediment samples in the vicinity of the Amauligak F-24 Drillsite.

SEDIMENT PARTICLE SIZE AROUND AMAULIGAK F-24

Sample	% Clay	% Silt	% Sand/Gravel
1A (Mud)	9	10	81
1A (Sand)	0	4	96
3A	0	5	95
3A (rep)	0	6	94
5A	0	6	94
7A	0	6	94
9A	0	6	94
9A	0	2	98
11A (rep)	0	4	96
11A (rep)	0	2	98
11A (rep)	0	2	98
2B	0	2	98
2B (rep)	0	3	97
3B	45	36	19
17B	62	36	2
19B	57	40	3
21B	58	40	2
22B	60	38	2
24B	57	35	4
25B	60	38	2
5C	58	40	2
24C	64	35	2
27C	60	39	1
29C	30	14	56
31C	65	34	1
33C	65	35	0
43C	63	37	0
44C	55	28	17
51C	64	36	0
53C	64	36	0
56C	63	36	1
64C	59	41	0
R1	65	34	1
R2	64	35	1



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

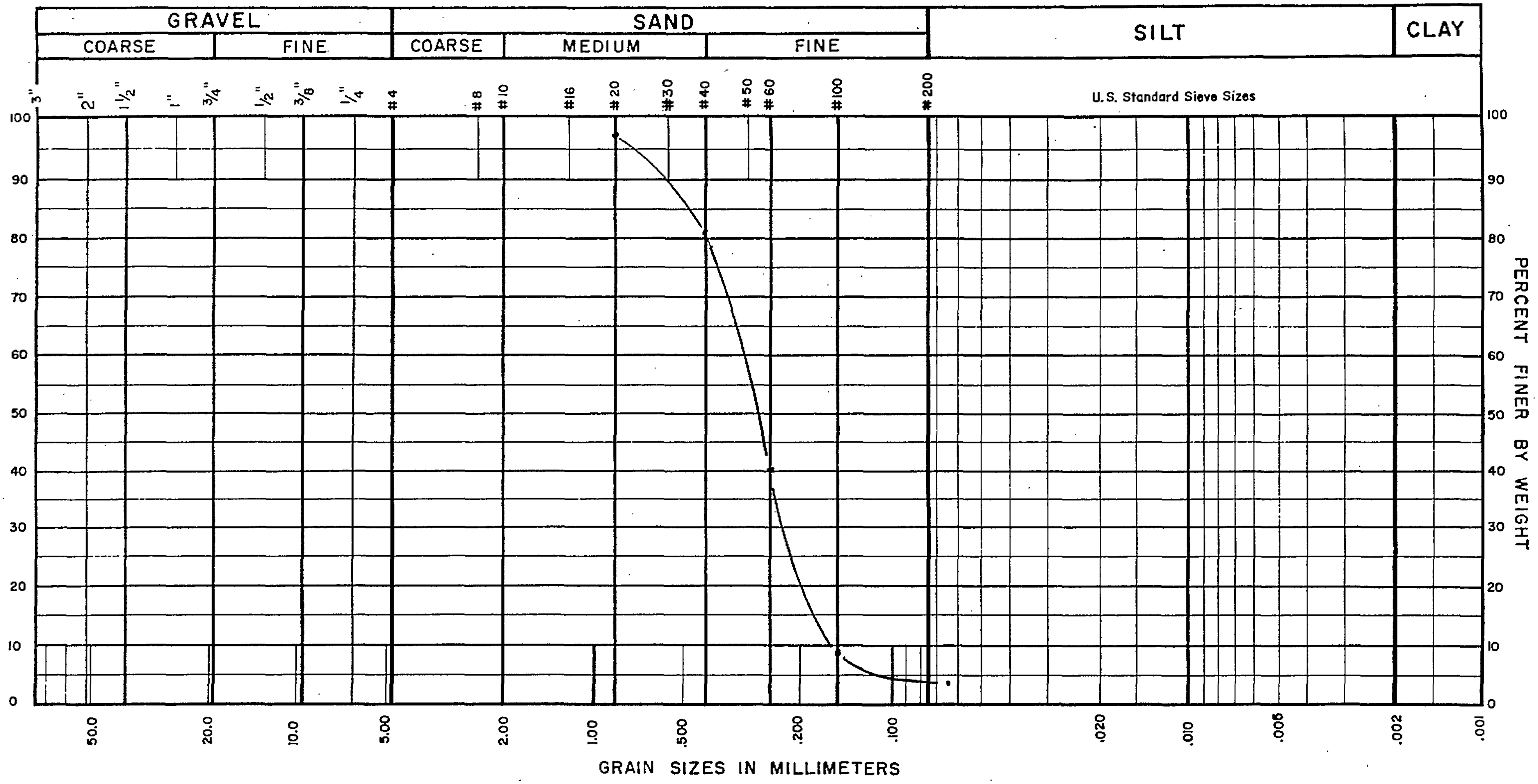
Clay			%
Silt			
Sand			
Gravel			

Classification

CLIENT SEAKEM
PROJECT
LOCATION 87 AK
SAMPLE 1A - MUD
TEST DATE MAR 22/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



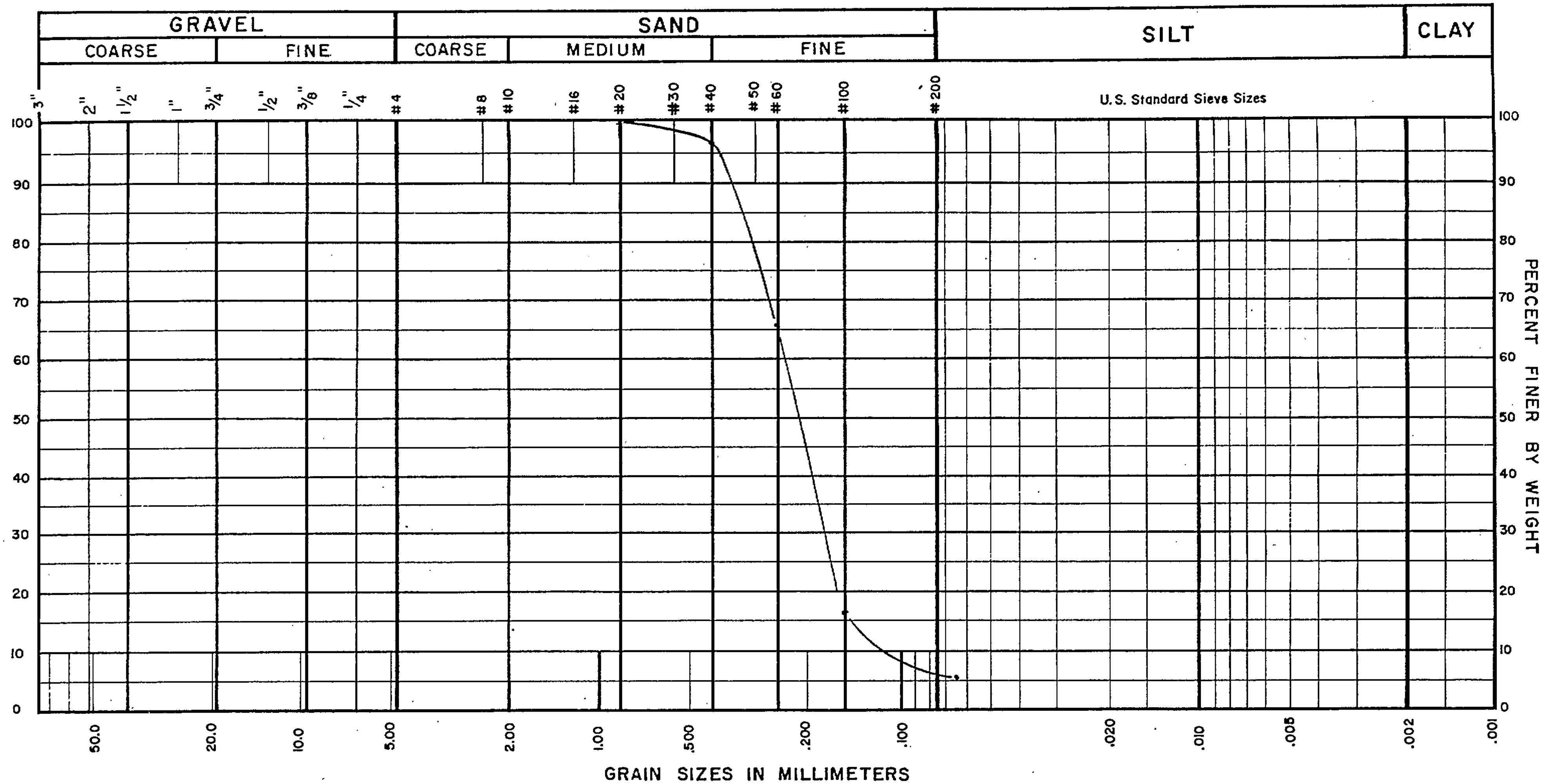
Nat. Water Content	%		Clay	%
Liquid Limit			Silt	
Plastic Limit			Sand	
Plastic Index			Gravel	

Classification

CLIENT SEAKEM
PROJECT
LOCATION
SAMPLE 1A SAND
TEST DATE MAR 29/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

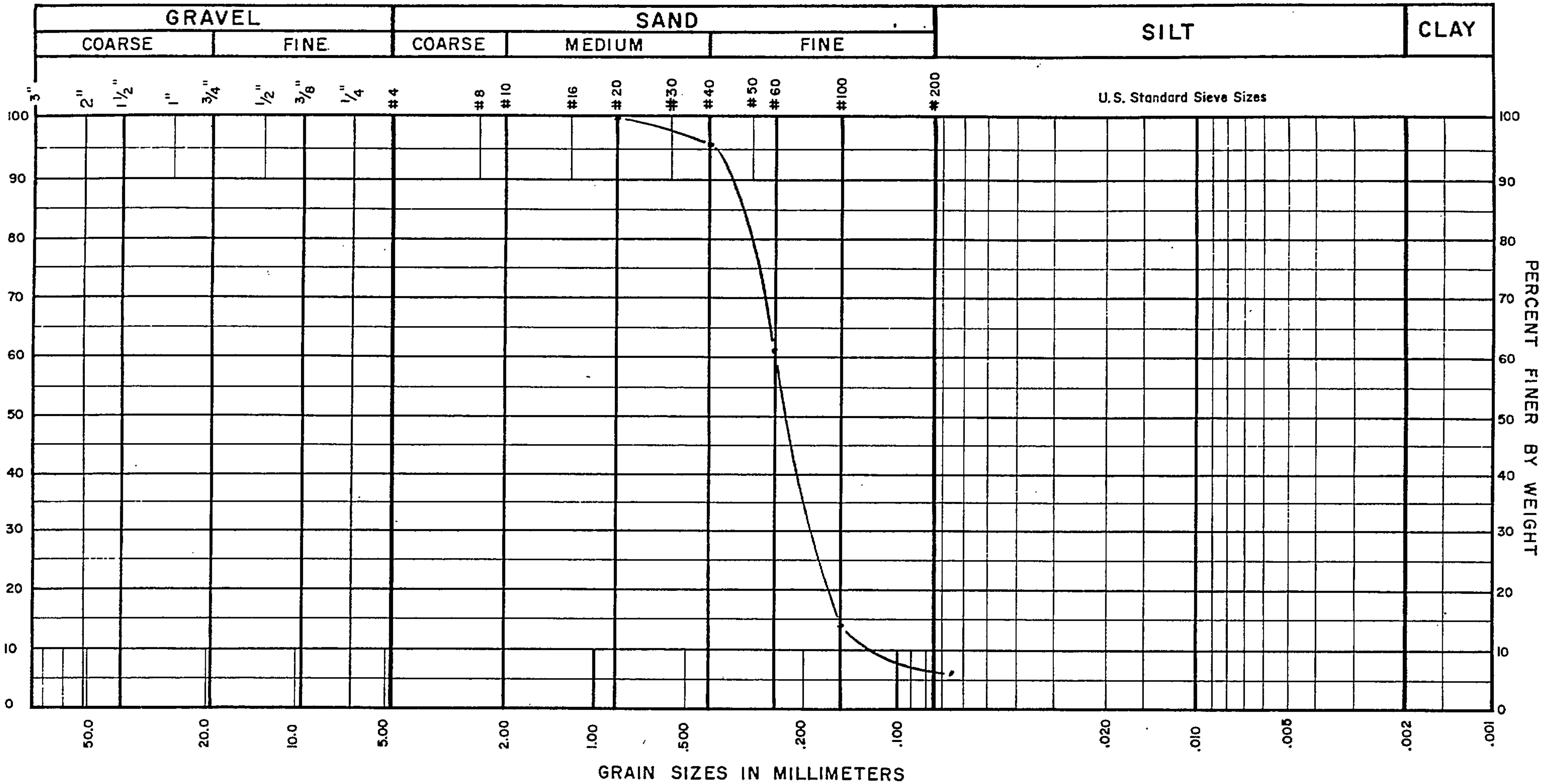
Clay			%
Silt			
Sand			
Gravel			

Classification

CLIENT SEAKEM
PROJECT
LOCATION
SAMPLE 3A
TEST DATE MAR 29/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

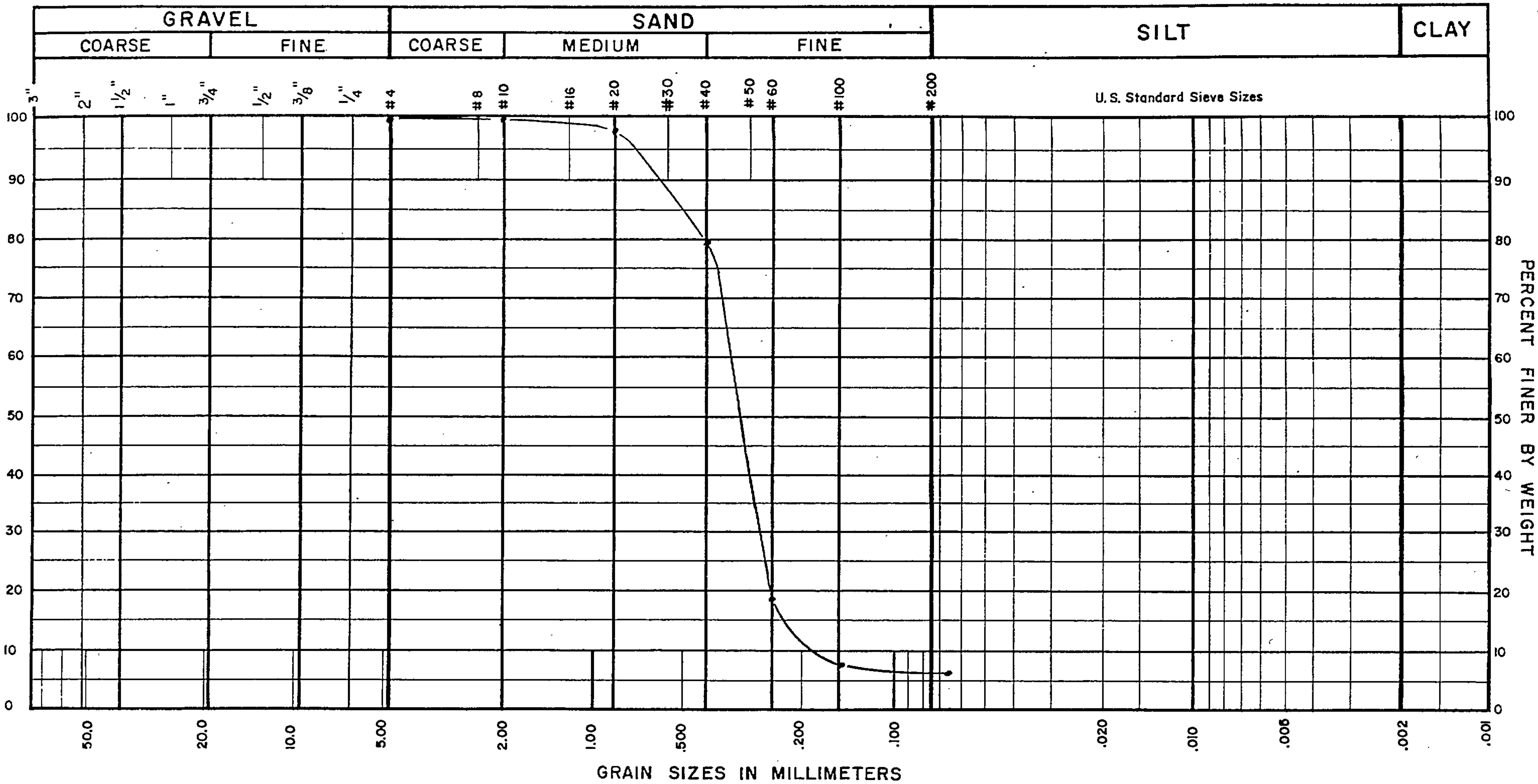
Clay			%
Silt			
Sand			
Gravel			

Classification

CLIENT	SEAKEM
PROJECT	
LOCATION	
SAMPLE	5A
TEST DATE	MAR 29/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



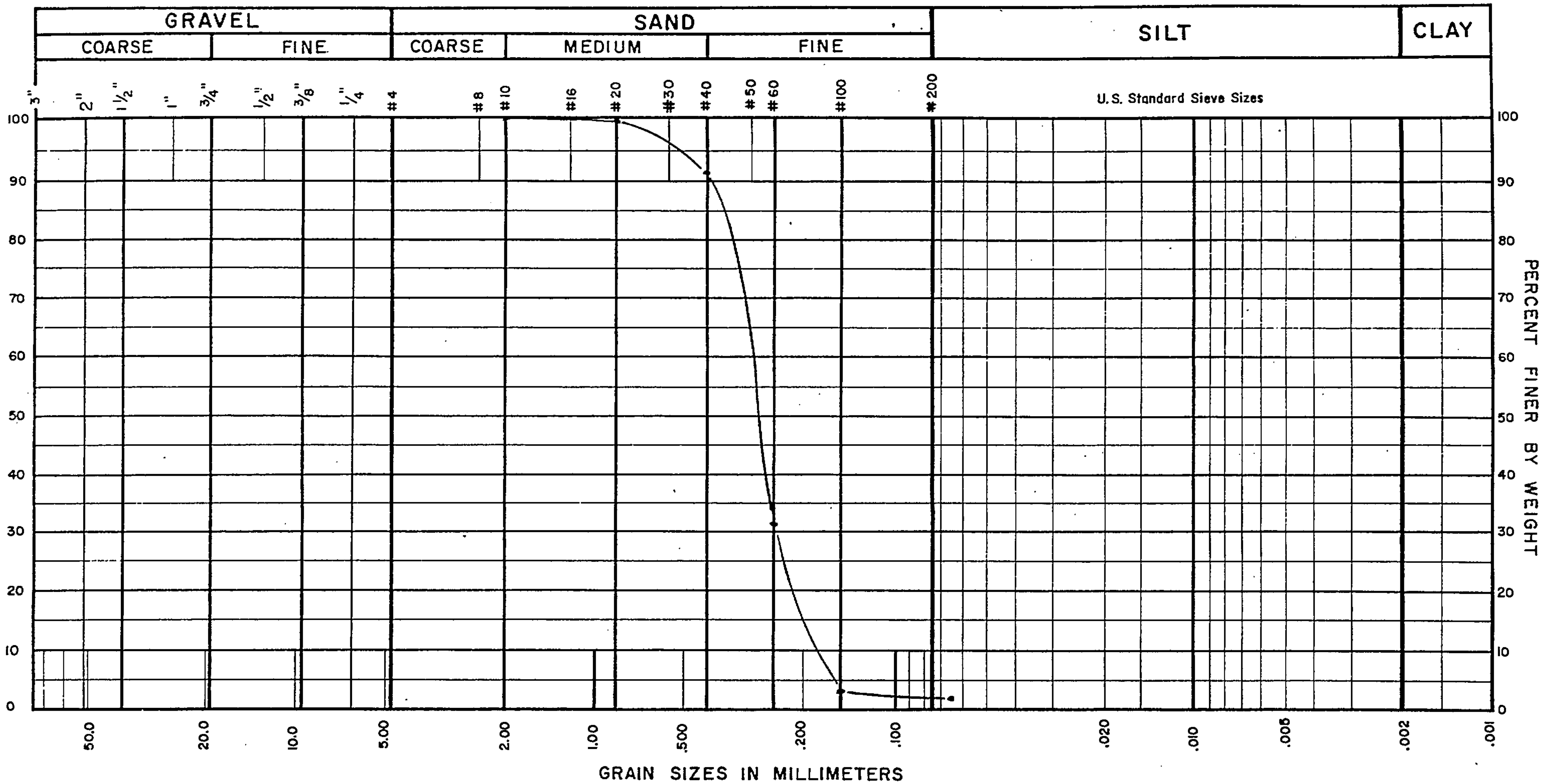
Nat. Water Content			%	Clay			%
Liquid Limit				Silt			
Plastic Limit				Sand			
Plastic Index				Gravel			

Classification ______________________

CLIENT	SEAKEM
PROJECT	
LOCATION	
SAMPLE	9A
TEST DATE	MAR 29/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



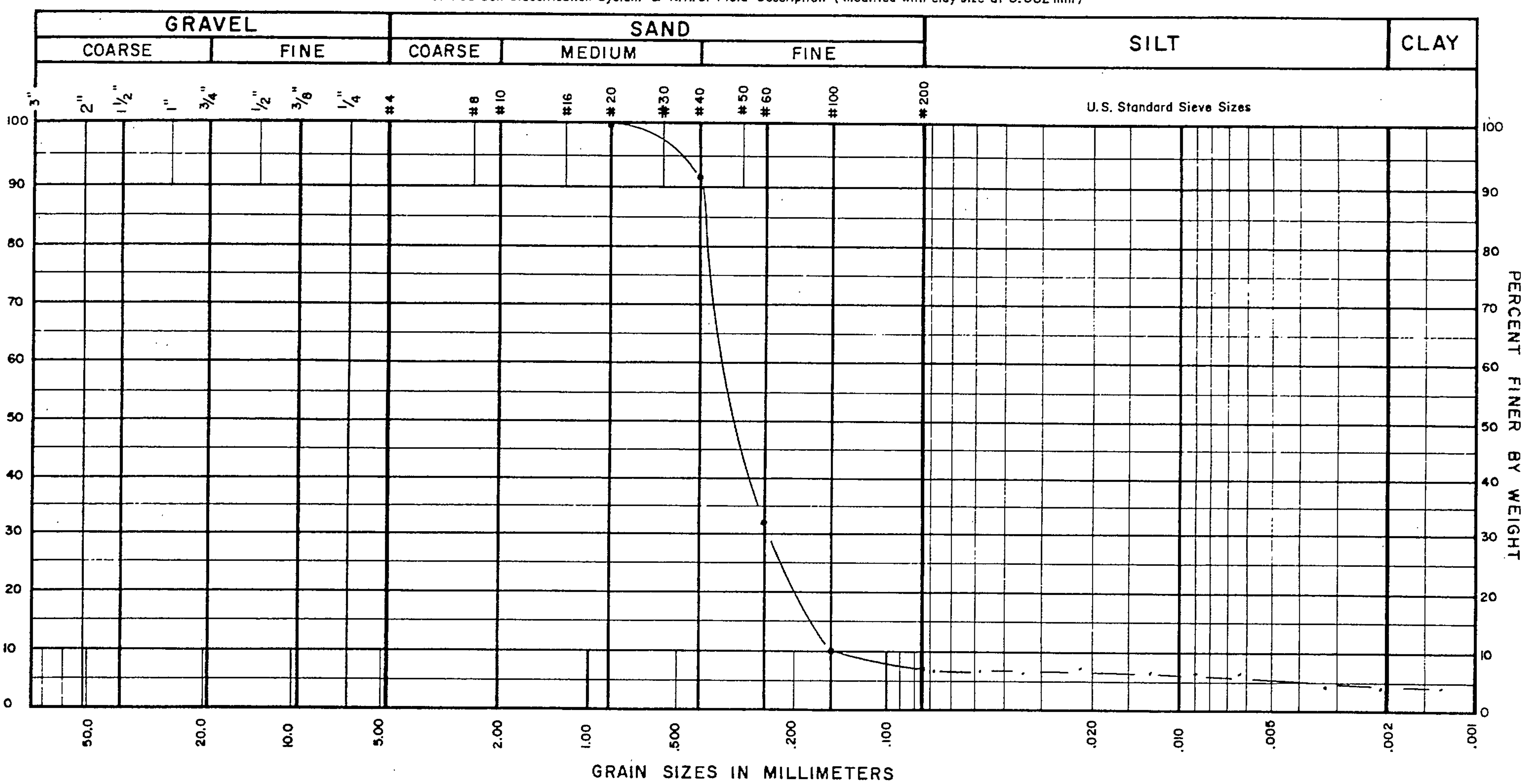
Nat. Water Content			%	Clay			%
Liquid Limit				Silt			
Plastic Limit				Sand			
Plastic Index				Gravel			

Classification

CLIENT	SEAKEM
PROJECT	
LOCATION	
SAMPLE	11A
TEST DATE	MAR 29/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

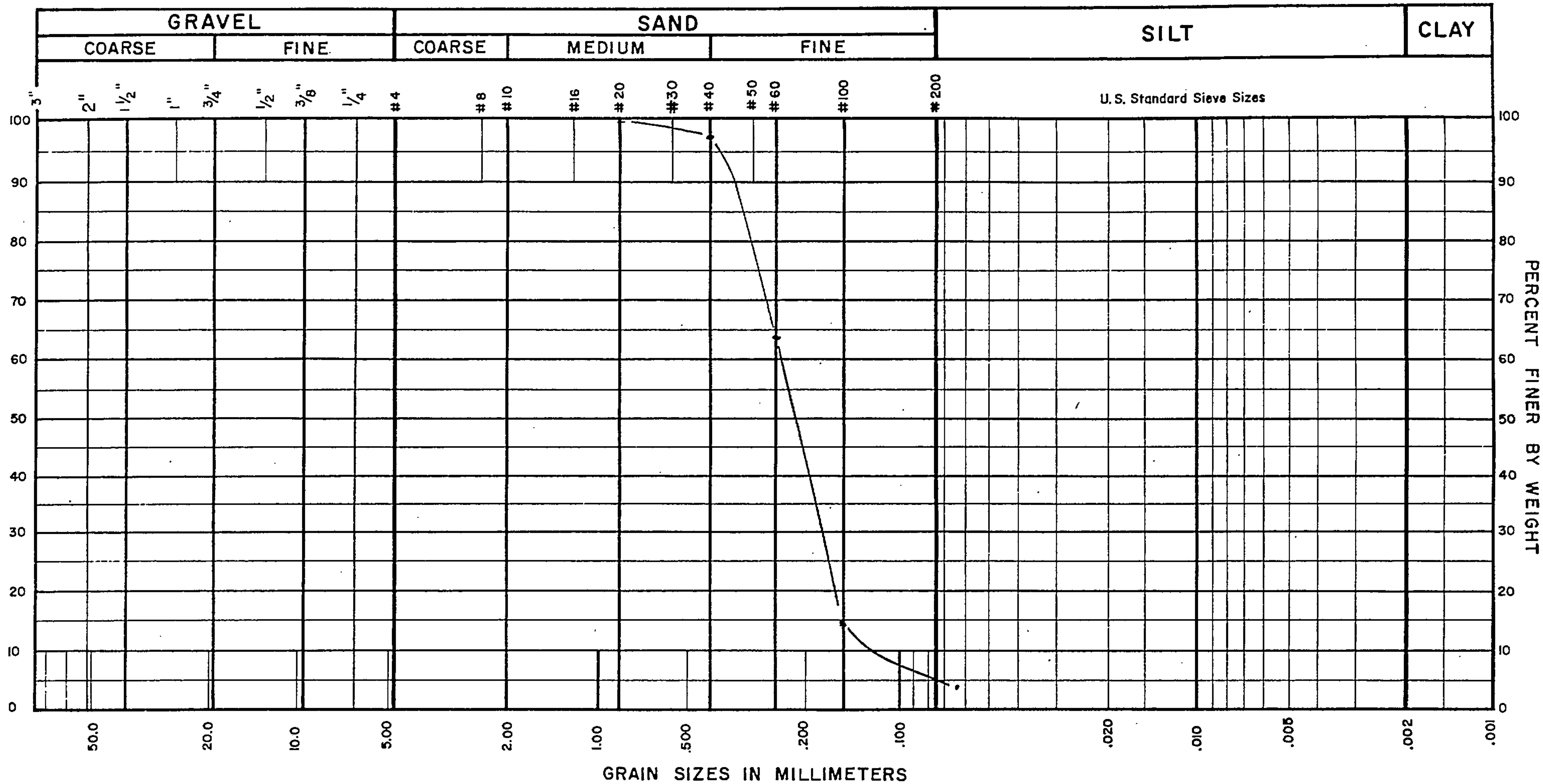
Clay	4.5		%
Silt	2.4		
Sand	93.1		
Gravel			

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	11A
TEST DATE	FILE Nº 19-395-2

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay			%
Silt			
Sand			
Gravel			

Classification

CLIENT SEAKEM.

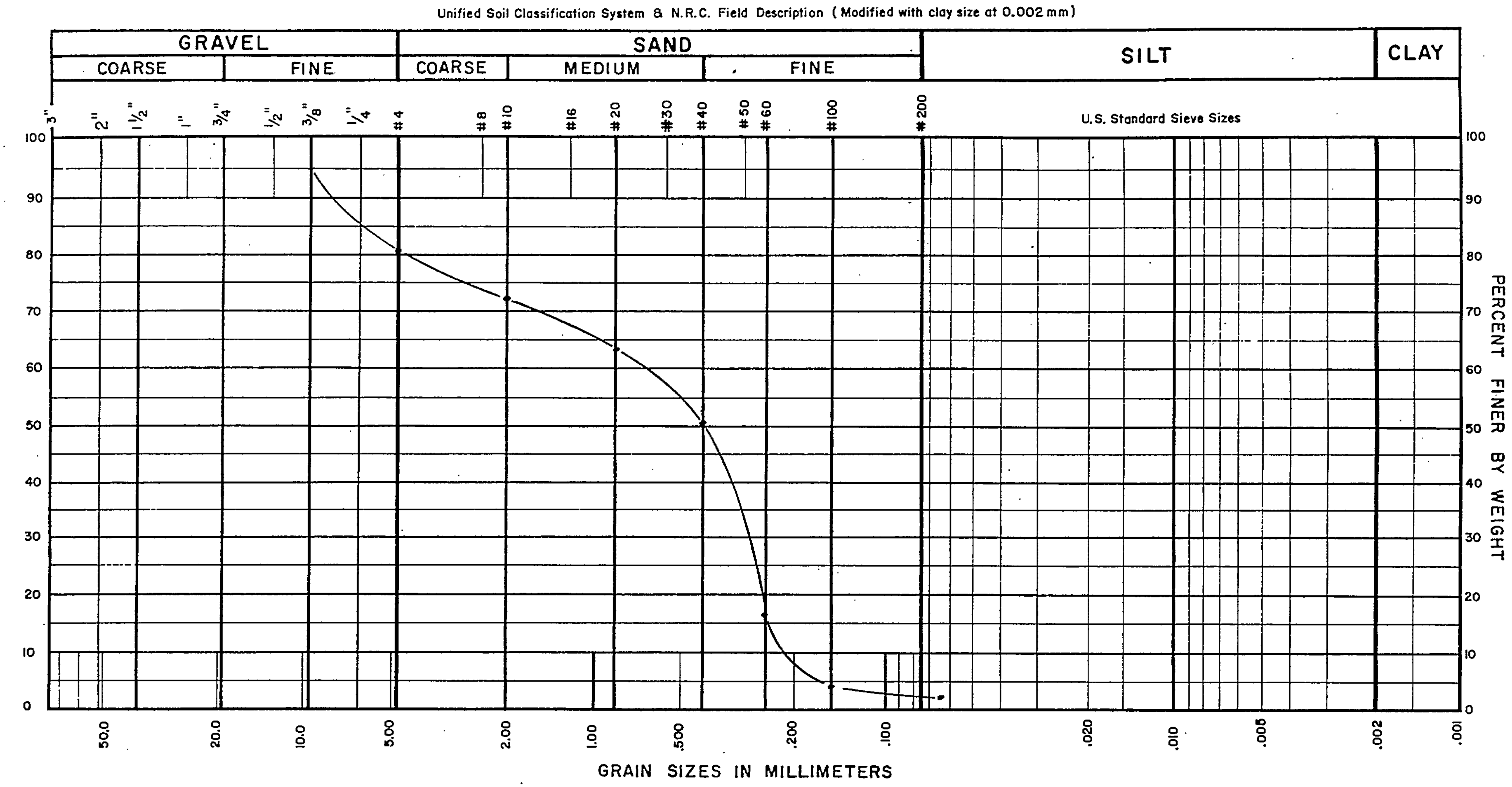
PROJECT

LOCATION

SAMPLE 88A ([illegible])

TEST DATE MAR 29/83 FILE No 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			%	Clay			%
Liquid Limit				Silt			
Plastic Limit				Sand			
Plastic Index				Gravel			

Classification

CLIENT SEAKEM

PROJECT

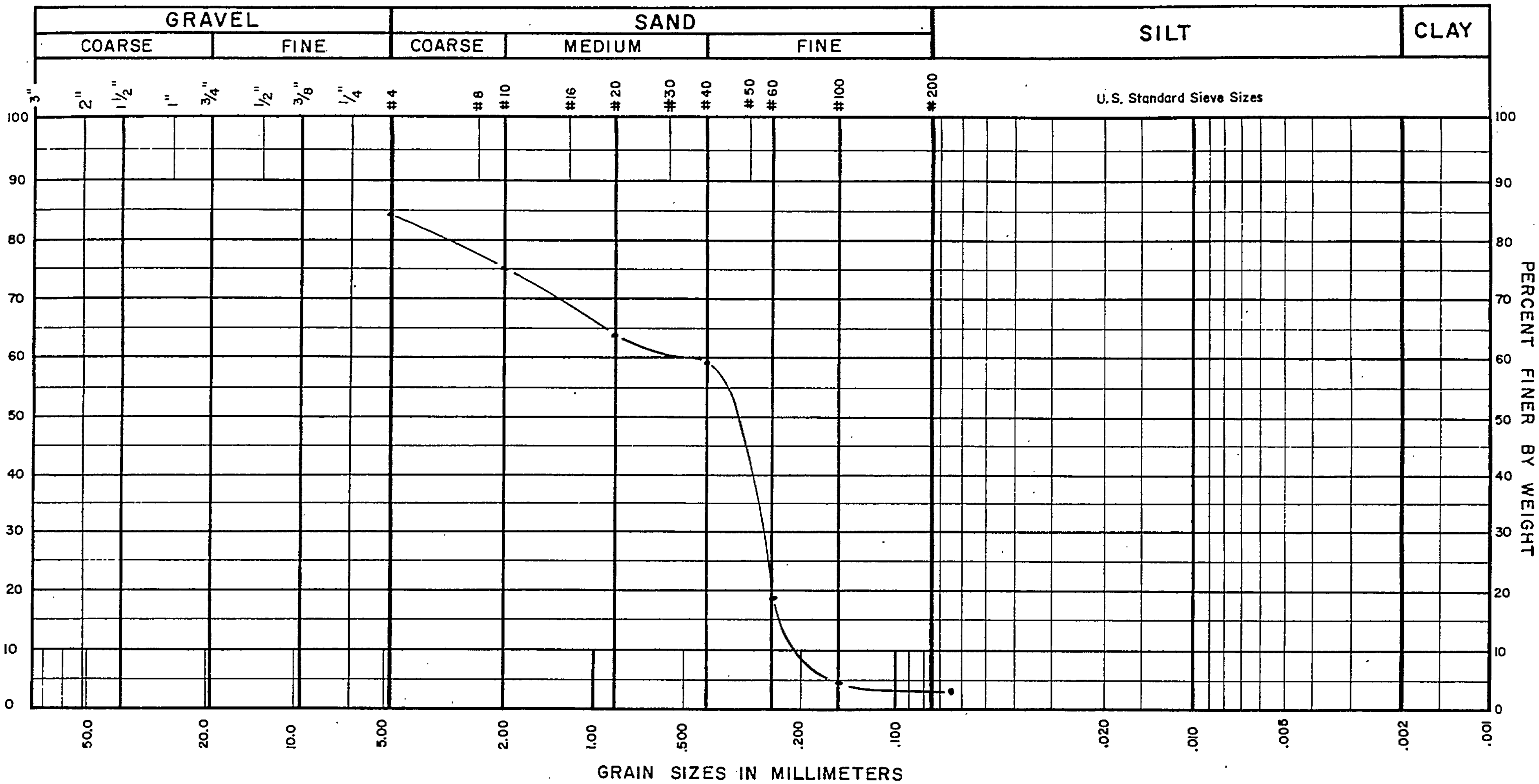
LOCATION

SAMPLE 2B

TEST DATE MAR 29/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%	Clay	6		%
Liquid Limit				Silt	3		
Plastic Limit				Sand	47		
Plastic Index				Gravel			

Classification

CLIENT SEA KEM

PROJECT

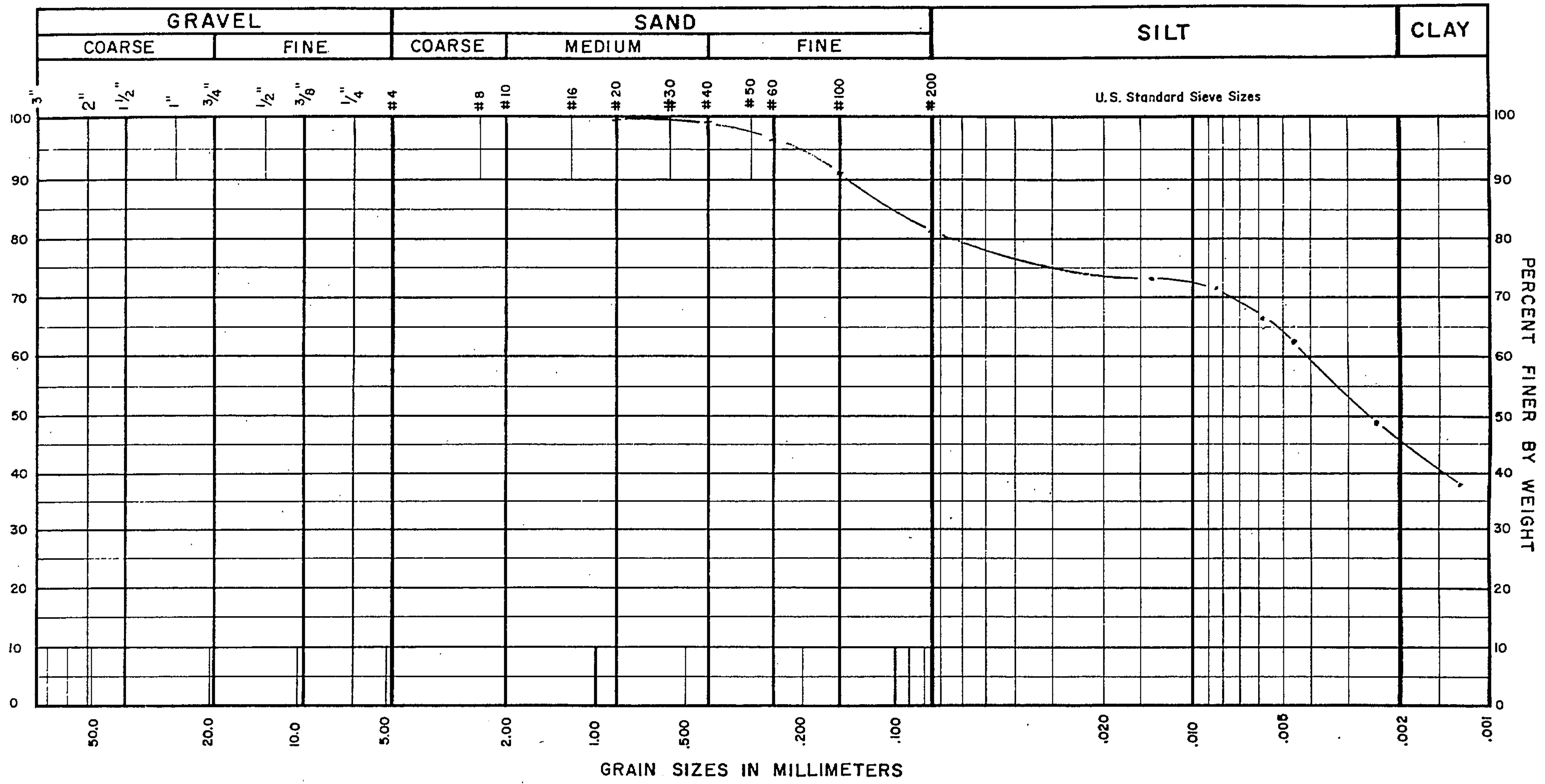
LOCATION

SAMPLE 90A (2B)

TEST DATE MAR 29/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

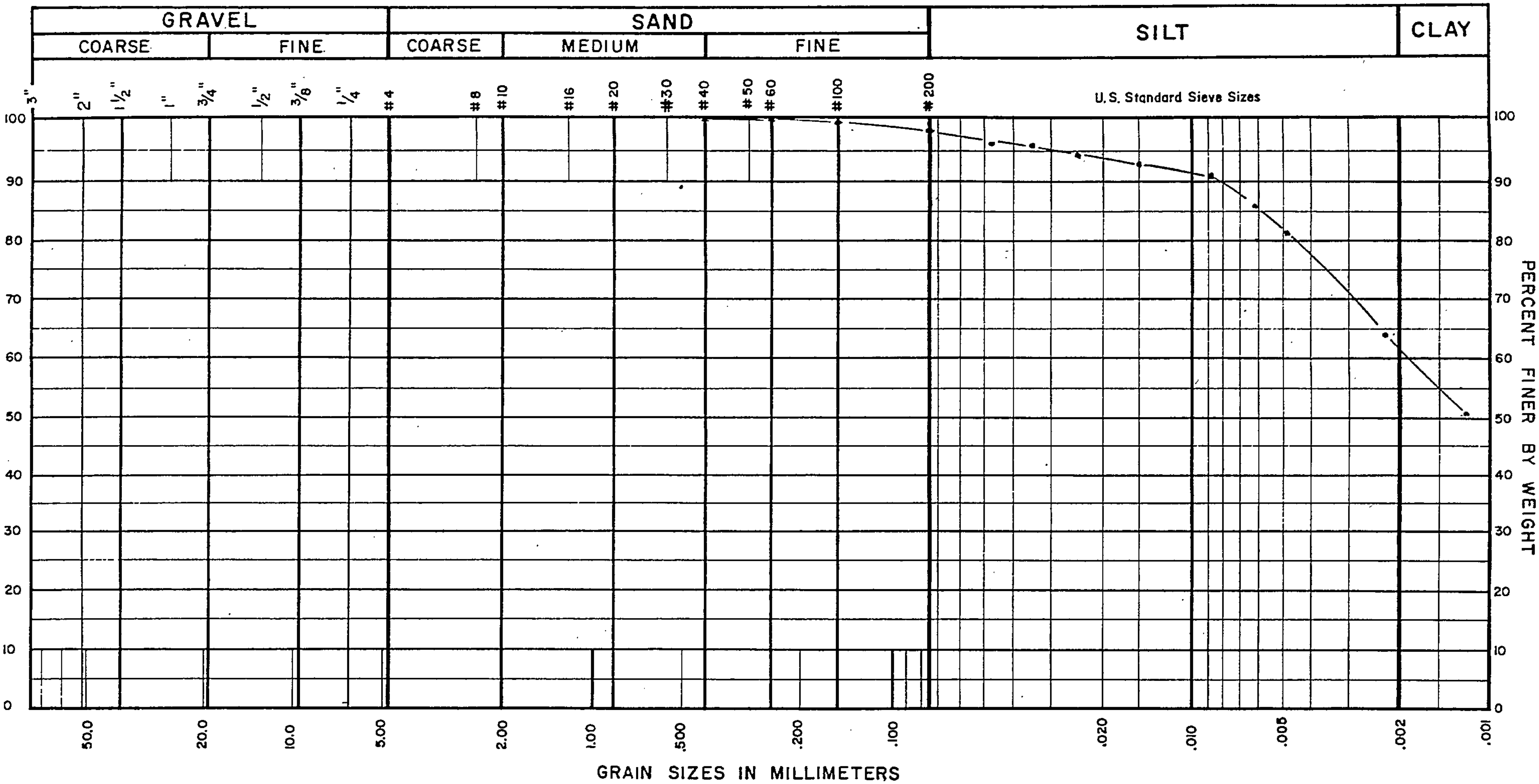
Clay			%
Silt			
Sand			
Gravel			

Classification ______

CLIENT	SEAKEM
PROJECT	
LOCATION	87AK
SAMPLE	3B
TEST DATE	MAR 22/88 — FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay			%
Silt			
Sand			
Gravel			

Classification

CLIENT SEAKEM

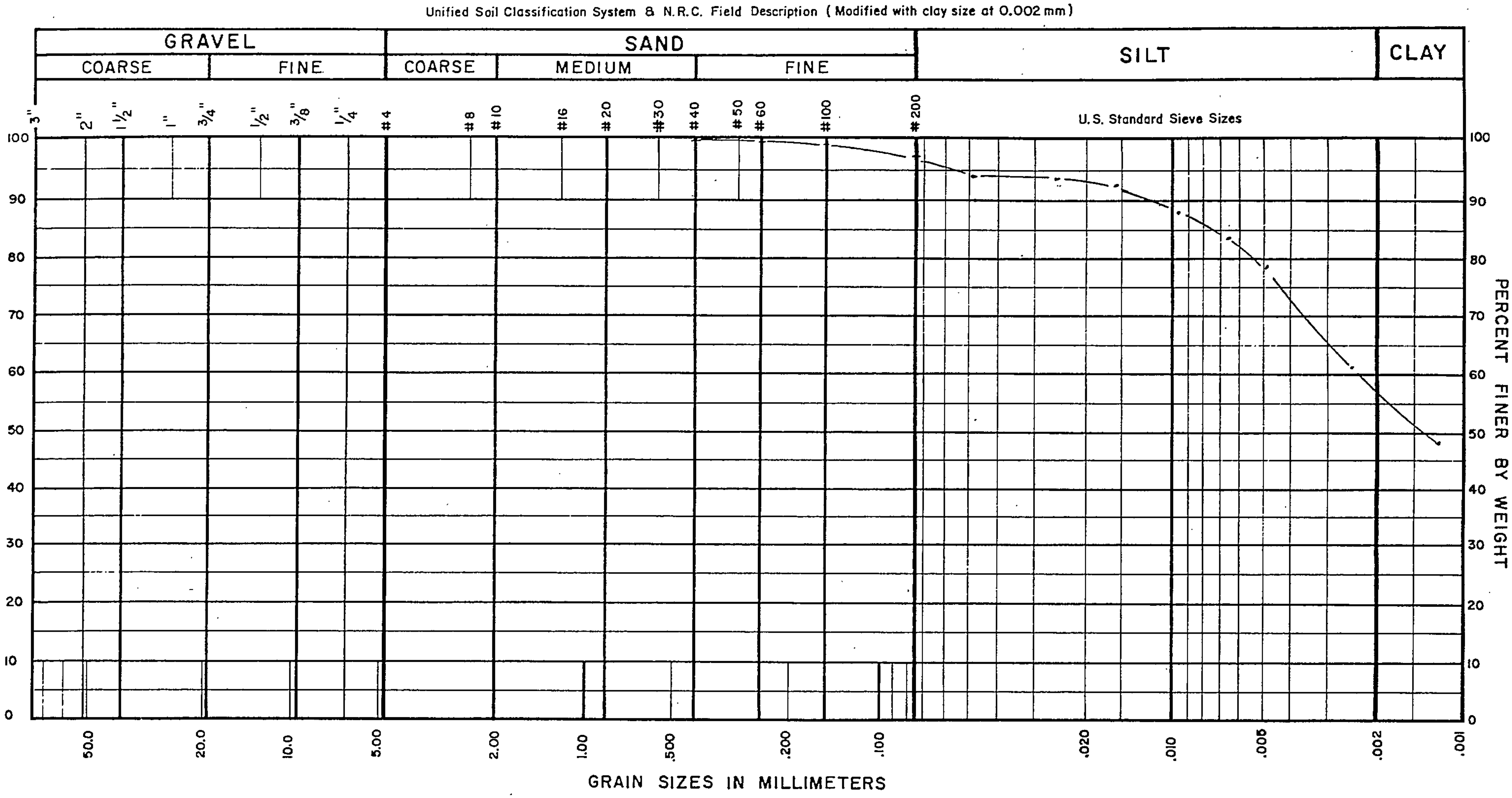
PROJECT

LOCATION 87 AK

SAMPLE 17 B

TEST DATE MAR 22/85 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

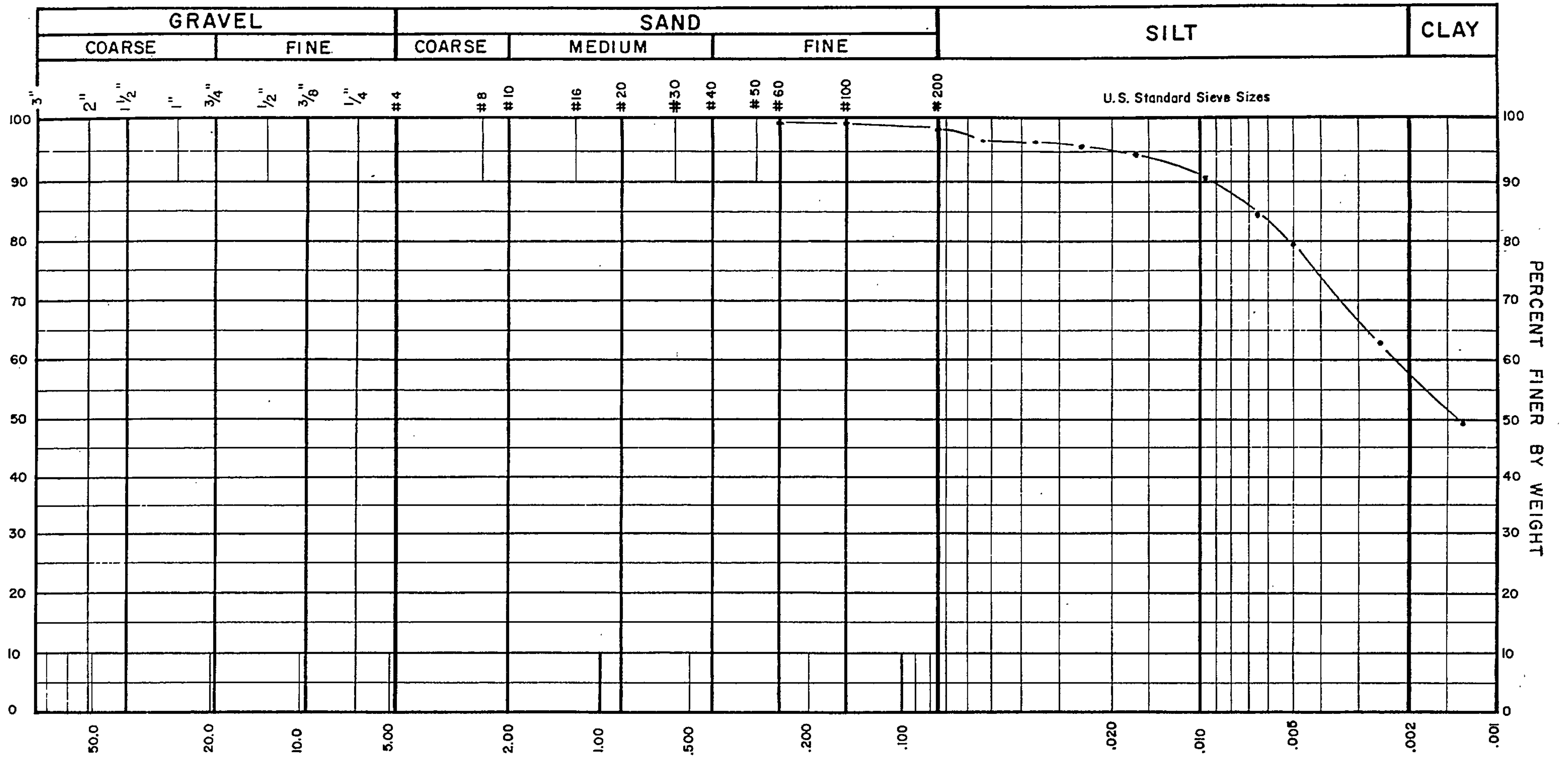
Clay			%
Silt			
Sand			
Gravel			

Classification ______________________

CLIENT	SEAKEM
PROJECT	
LOCATION	87 AK
SAMPLE	19 B
TEST DATE	MAR 22/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

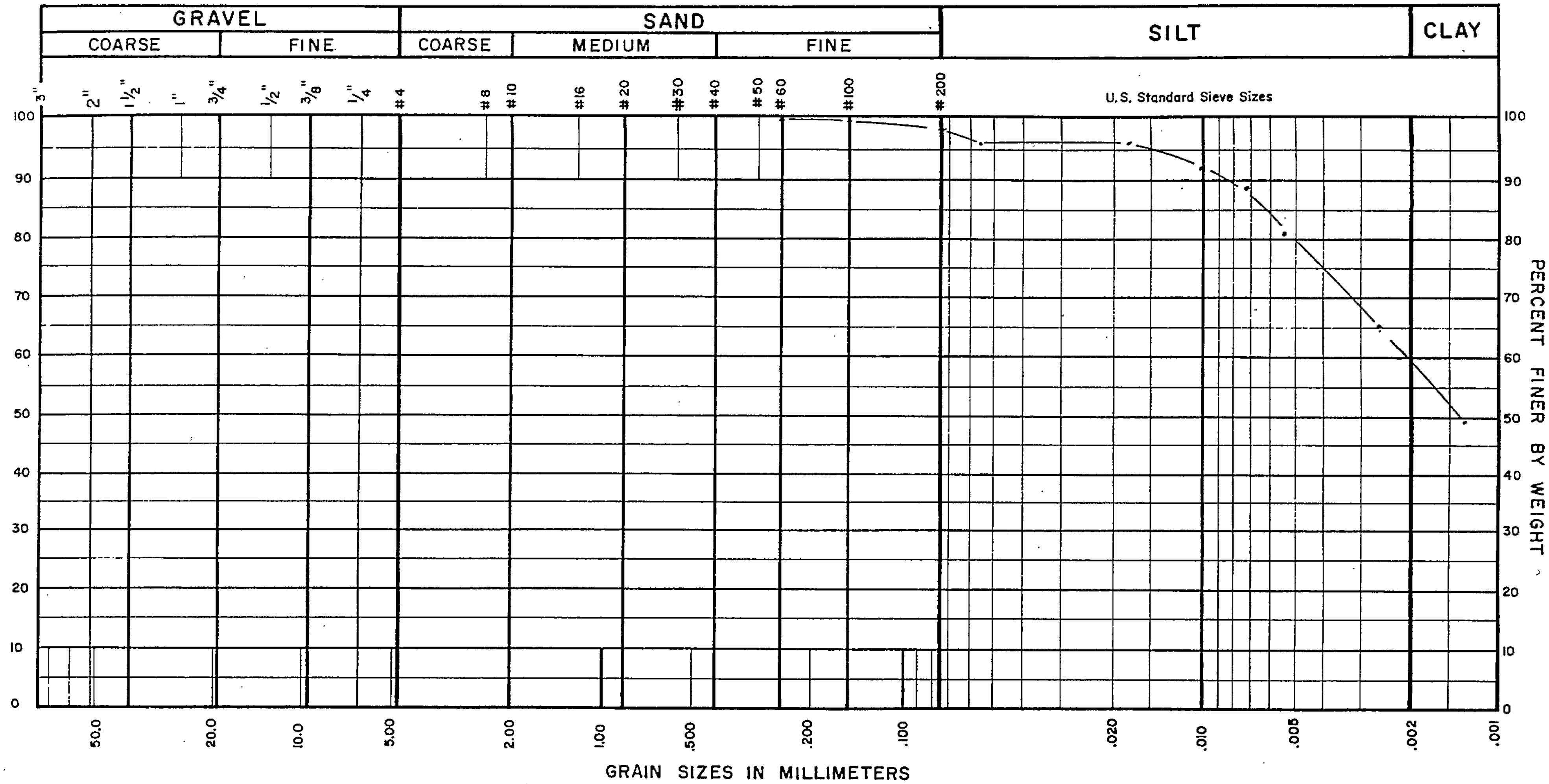
Clay			%
Silt			
Sand			
Gravel			

Classification

CLIENT	SEAKEM
PROJECT	
LOCATION	87AK
SAMPLE	21B
TEST DATE	MAR 22/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

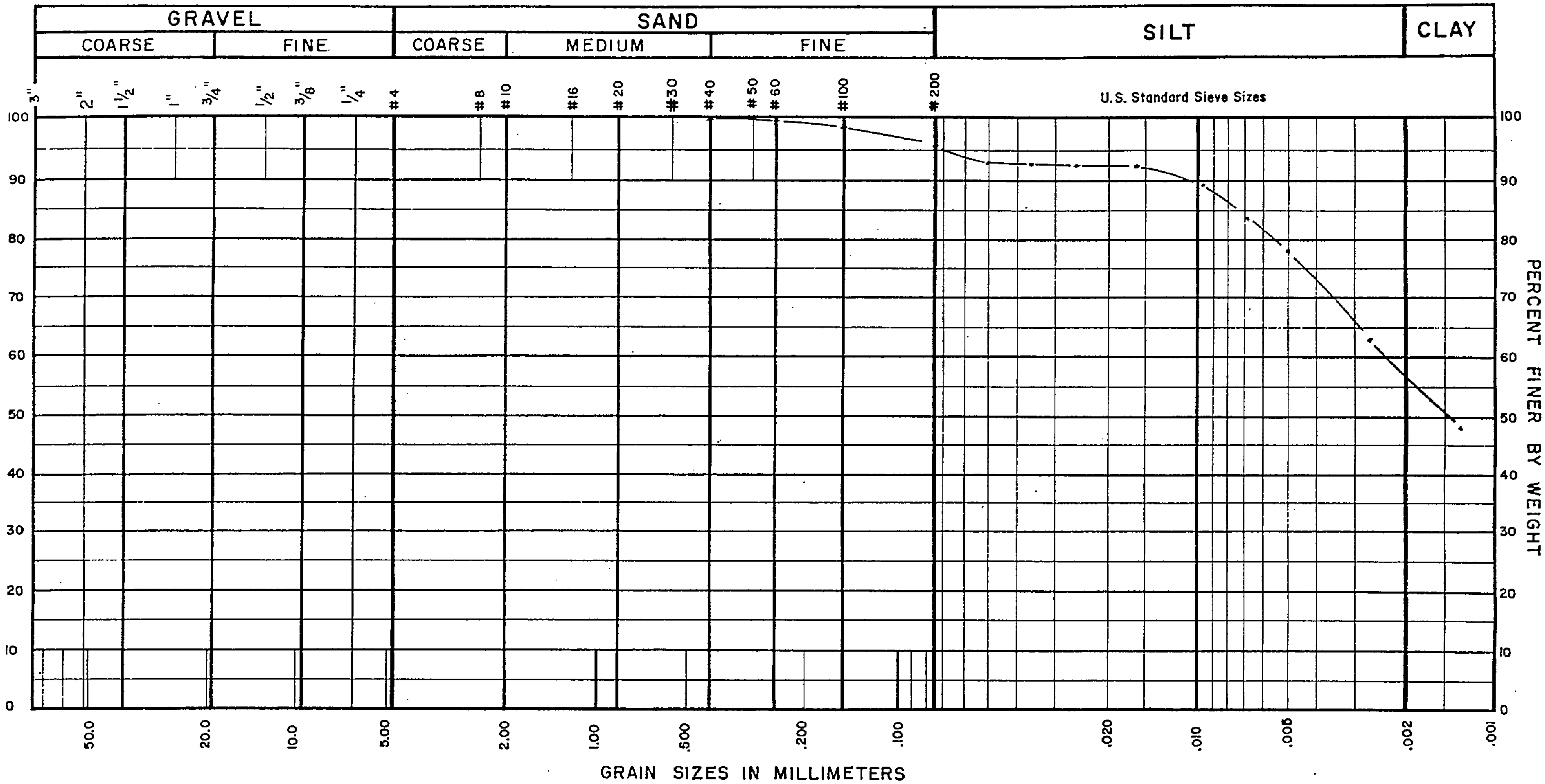
Clay			%
Silt			
Sand			
Gravel			

Classification ____________________

CLIENT SEAKEM
PROJECT
LOCATION 87 AK
SAMPLE 22B
TEST DATE MAR 22/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

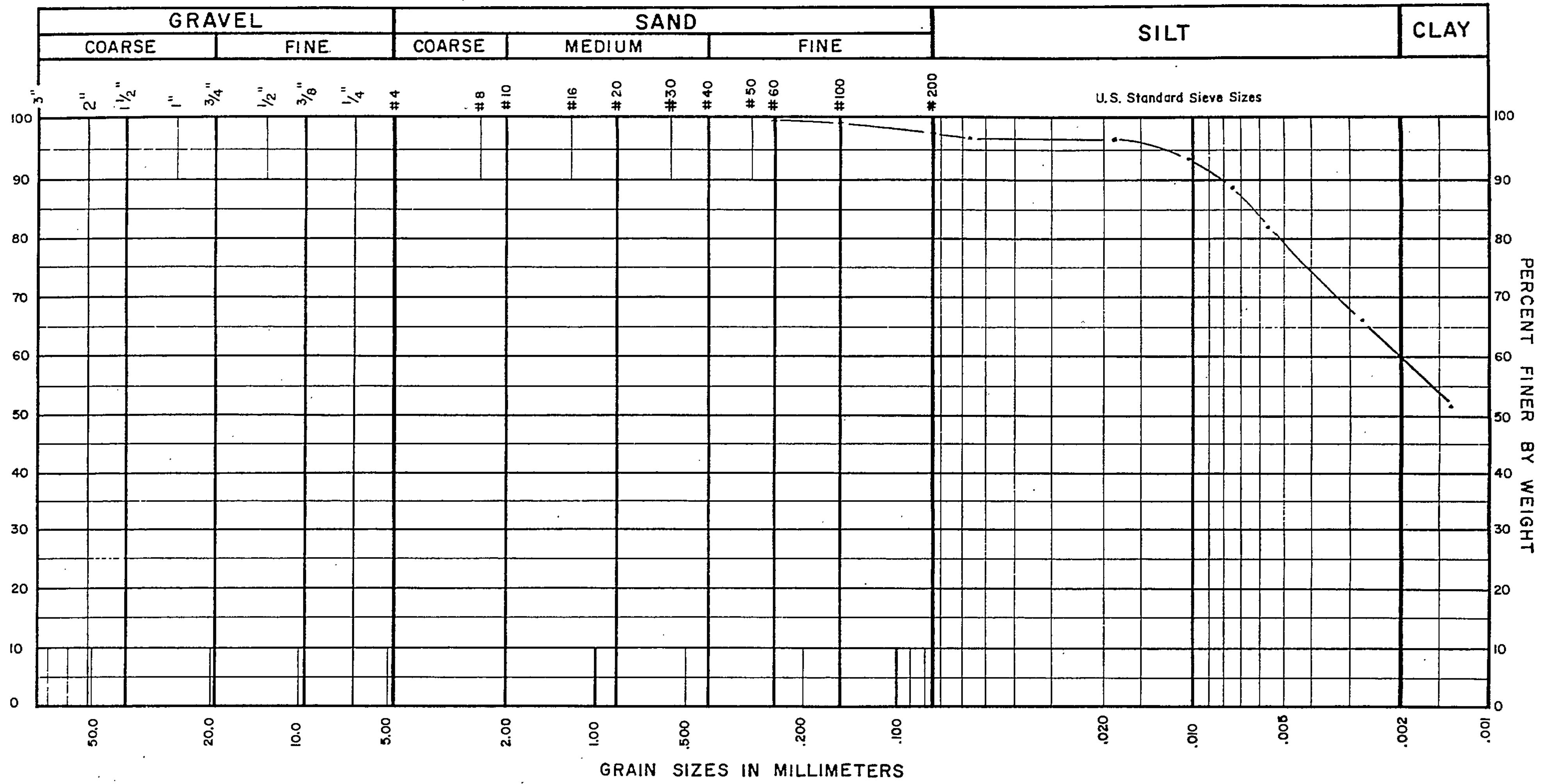
Clay			%
Silt			
Sand			
Gravel			

Classification

CLIENT	SEAKEM
PROJECT	
LOCATION	87AK
SAMPLE	24-B
TEST DATE	MAR 22/88 — FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

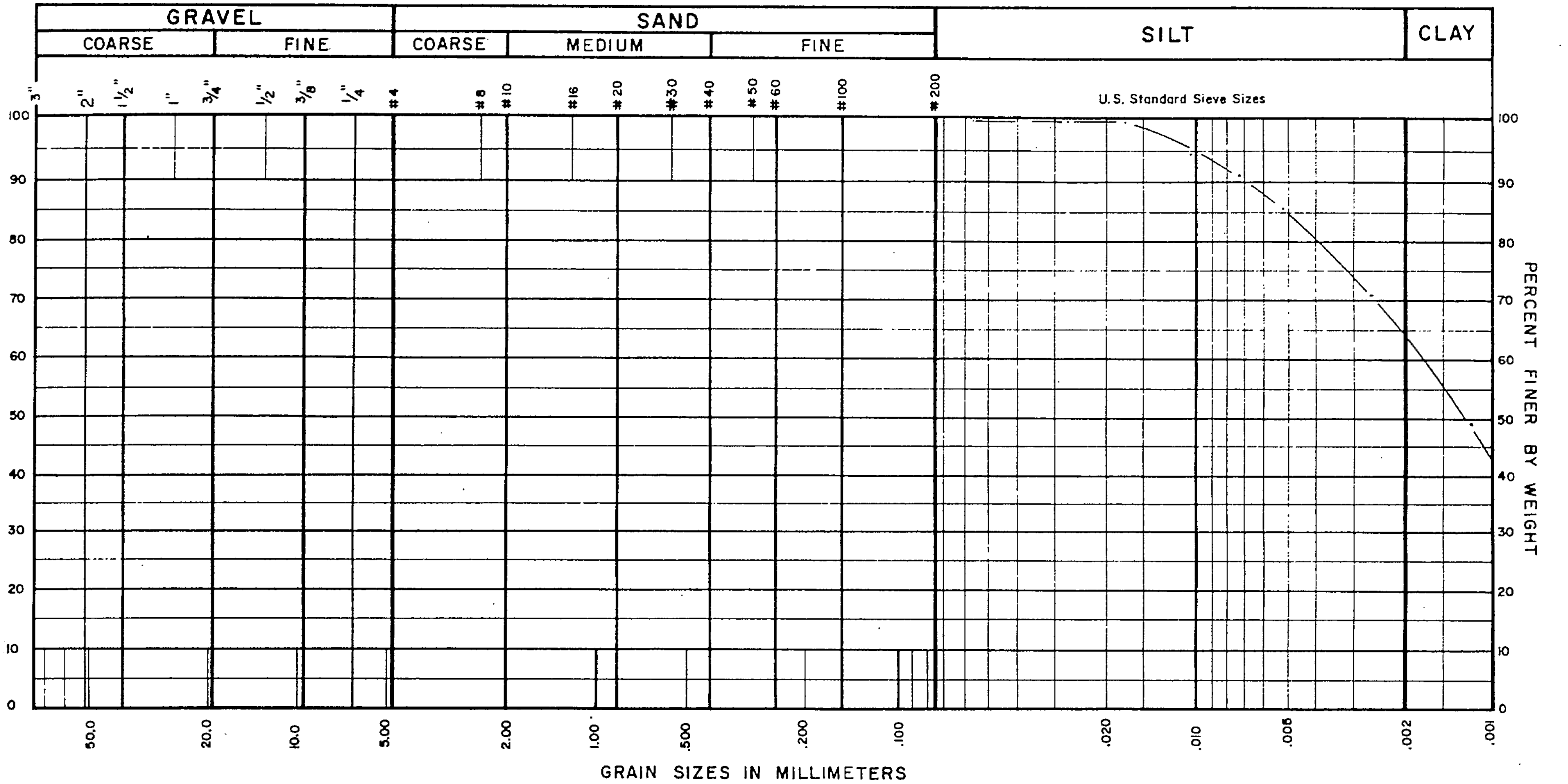
Clay			%
Silt			
Sand			
Gravel			

Classification ______________________

CLIENT	SEA KEM
PROJECT	
LOCATION	87 AK
SAMPLE	25 B
TEST DATE	MAR 22/88 — FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%	Clay	64.0		%
Liquid Limit				Silt	36.0		
Plastic Limit				Sand			
Plastic Index				Gravel			

Classification

CLIENT SEAKEM OCEANOGRAPHIC

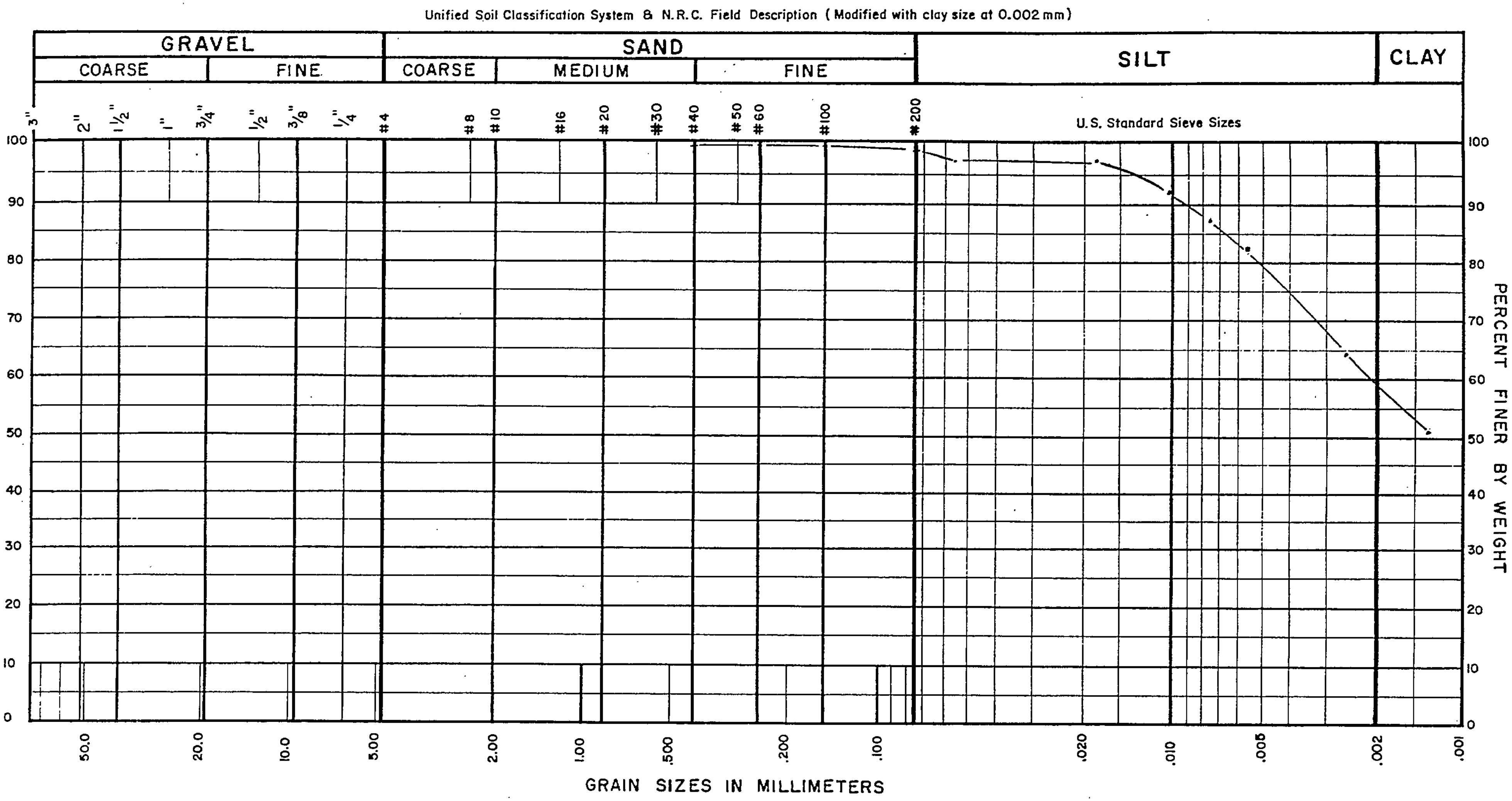
PROJECT

LOCATION

SAMPLE 2C

TEST DATE FILE Nº 19-395-2

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

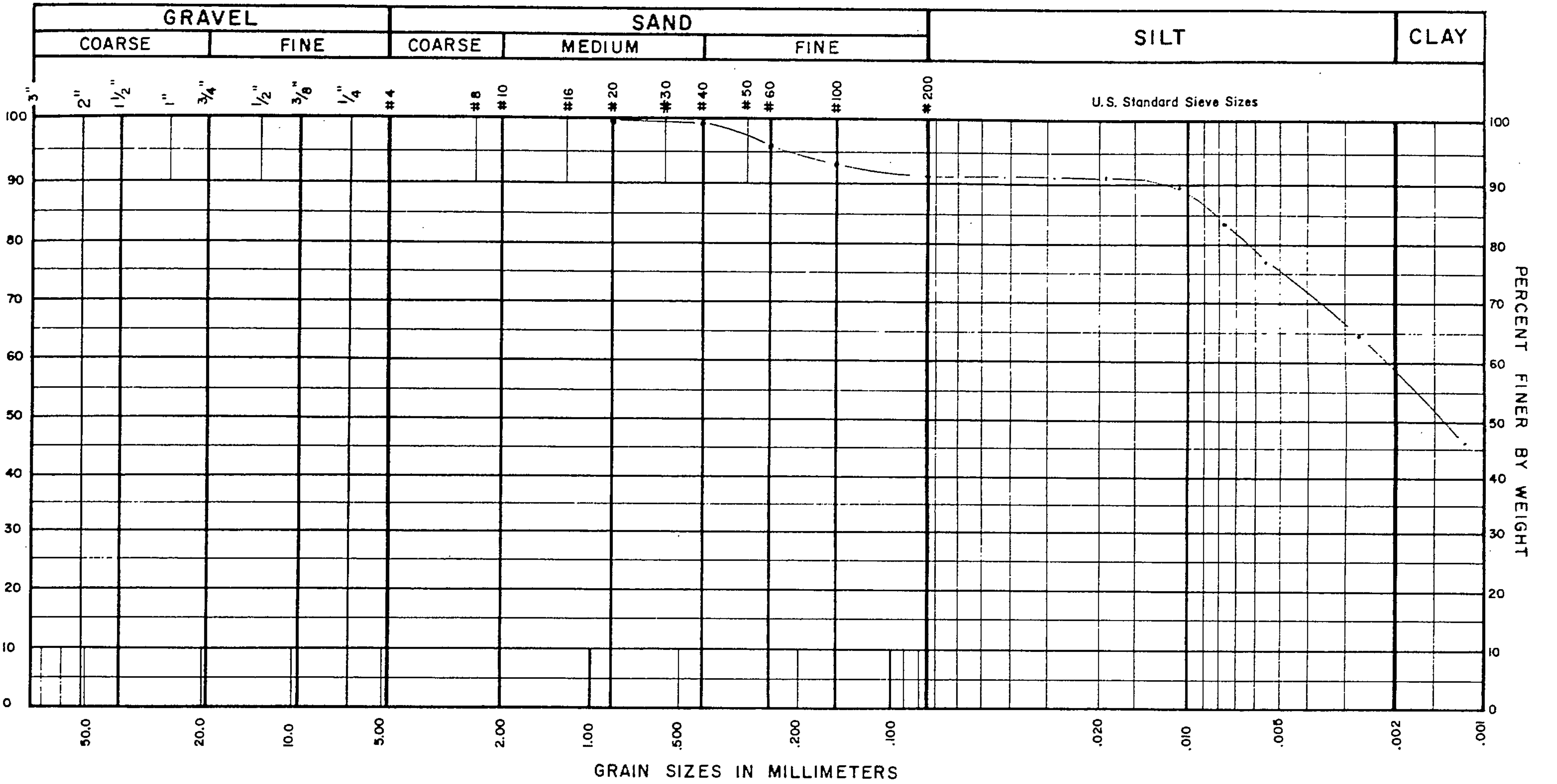
Clay			%
Silt			
Sand			
Gravel			

Classification

CLIENT	SEAKEM
PROJECT	
LOCATION	87AK
SAMPLE	5C
TEST DATE	MAR 22/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



			%
Nat. Water Content			
Liquid Limit			
Plastic Limit			
Plastic Index			

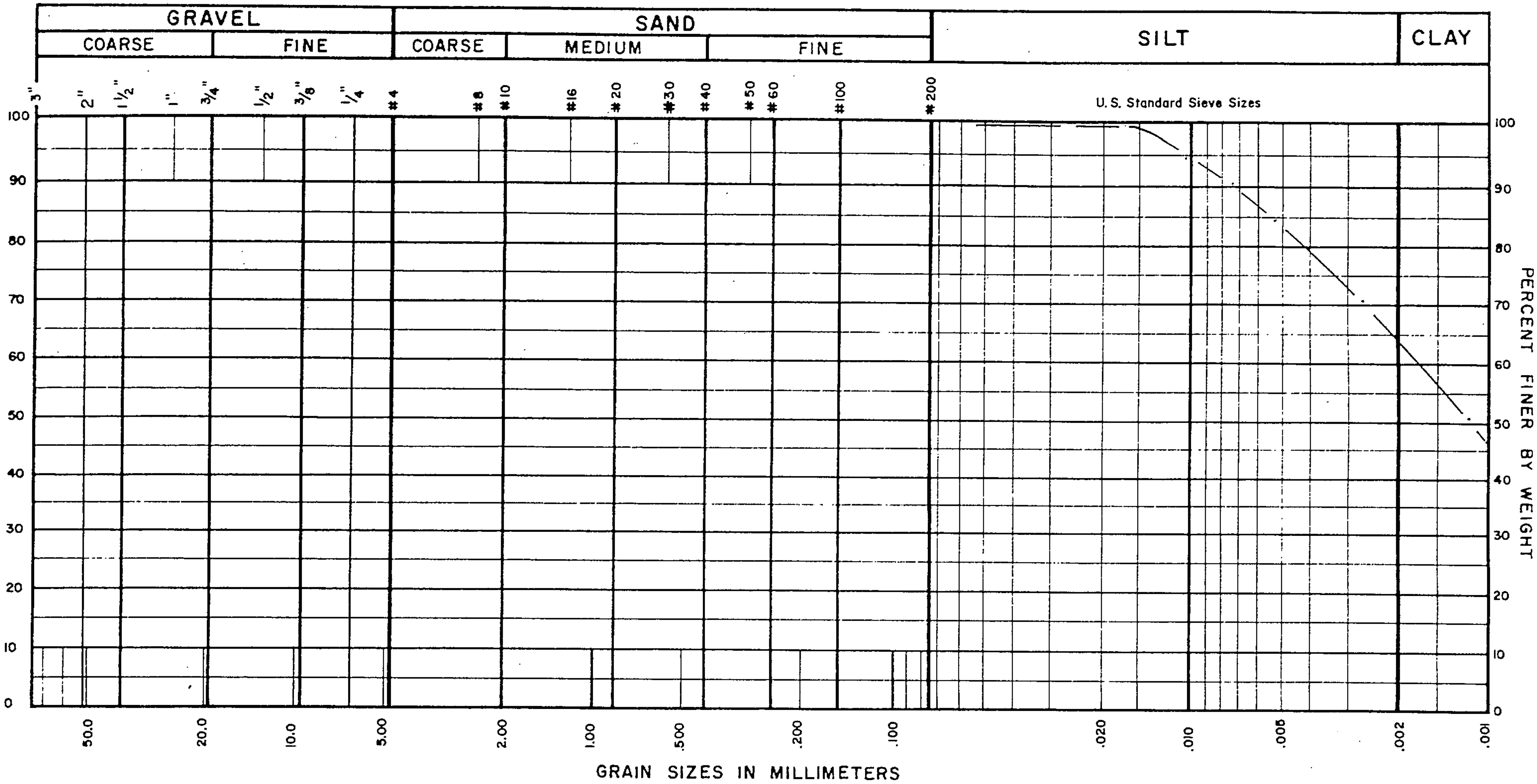
			%
Clay	59.0		
Silt	32.3		
Sand	8.7		
Gravel			

Classification ______

CLIENT SEAKEM OCEANOGRAPHIC
PROJECT
LOCATION
SAMPLE 9C
TEST DATE FILE NO 19-395-7

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



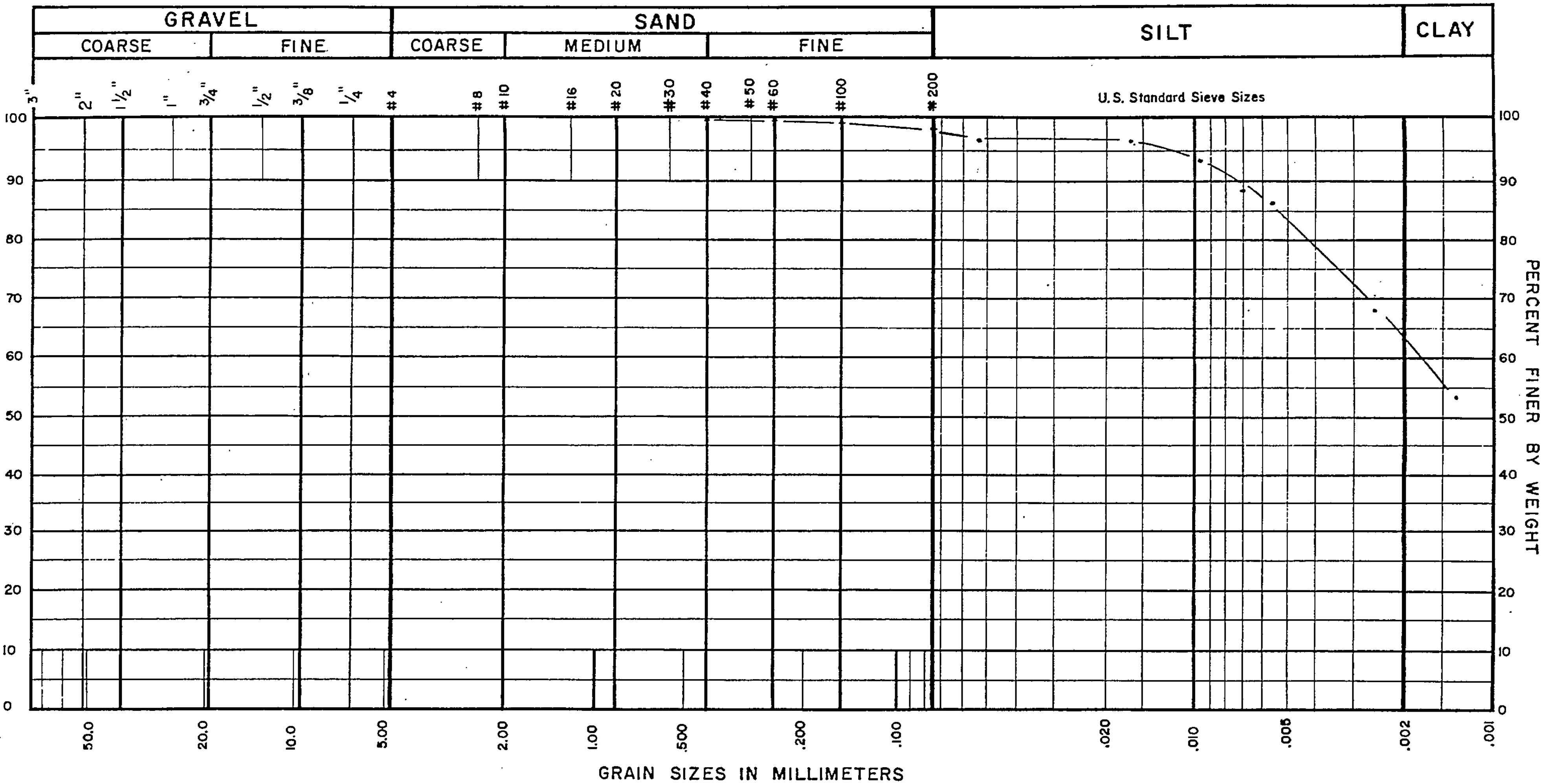
Nat. Water Content	%		Clay	64.0 %
Liquid Limit			Silt	36.0
Plastic Limit			Sand	
Plastic Index			Gravel	

Classification ______

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	18C
TEST DATE	FILE Nº 19-375-2

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



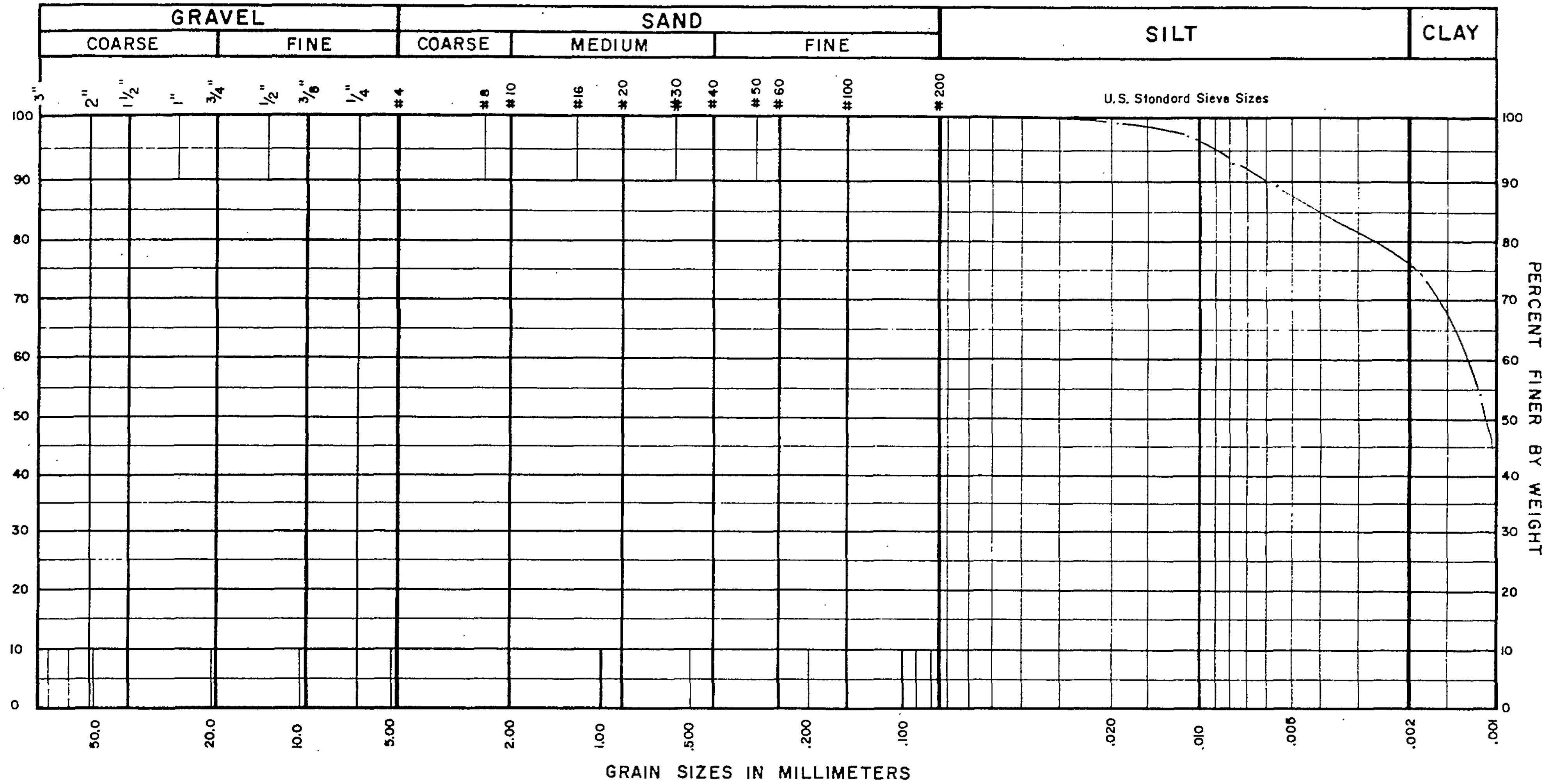
Nat. Water Content			%	Clay			%
Liquid Limit				Silt			
Plastic Limit				Sand			
Plastic Index				Gravel			

Classification

CLIENT	SEAKEM
PROJECT	
LOCATION	87 AK
SAMPLE	24 C
TEST DATE	MAR 22/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content				%
Liquid Limit				
Plastic Limit				
Plastic Index				

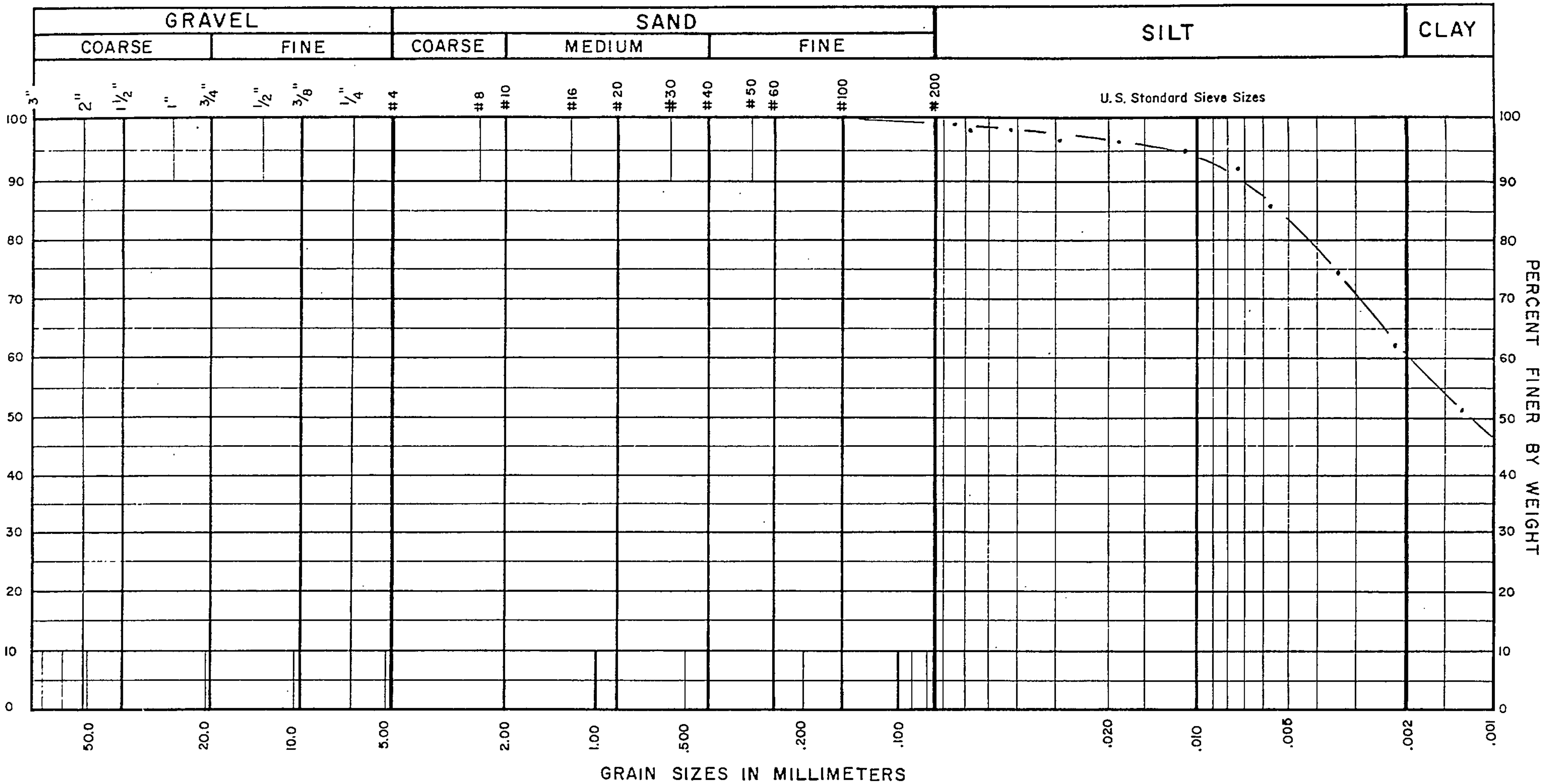
Clay	76.0			%
Silt	24.0			
Sand				
Gravel				

Classification

CLIENT	SEAKEN OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	26C
TEST DATE	FILE Nº 19-395-2

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

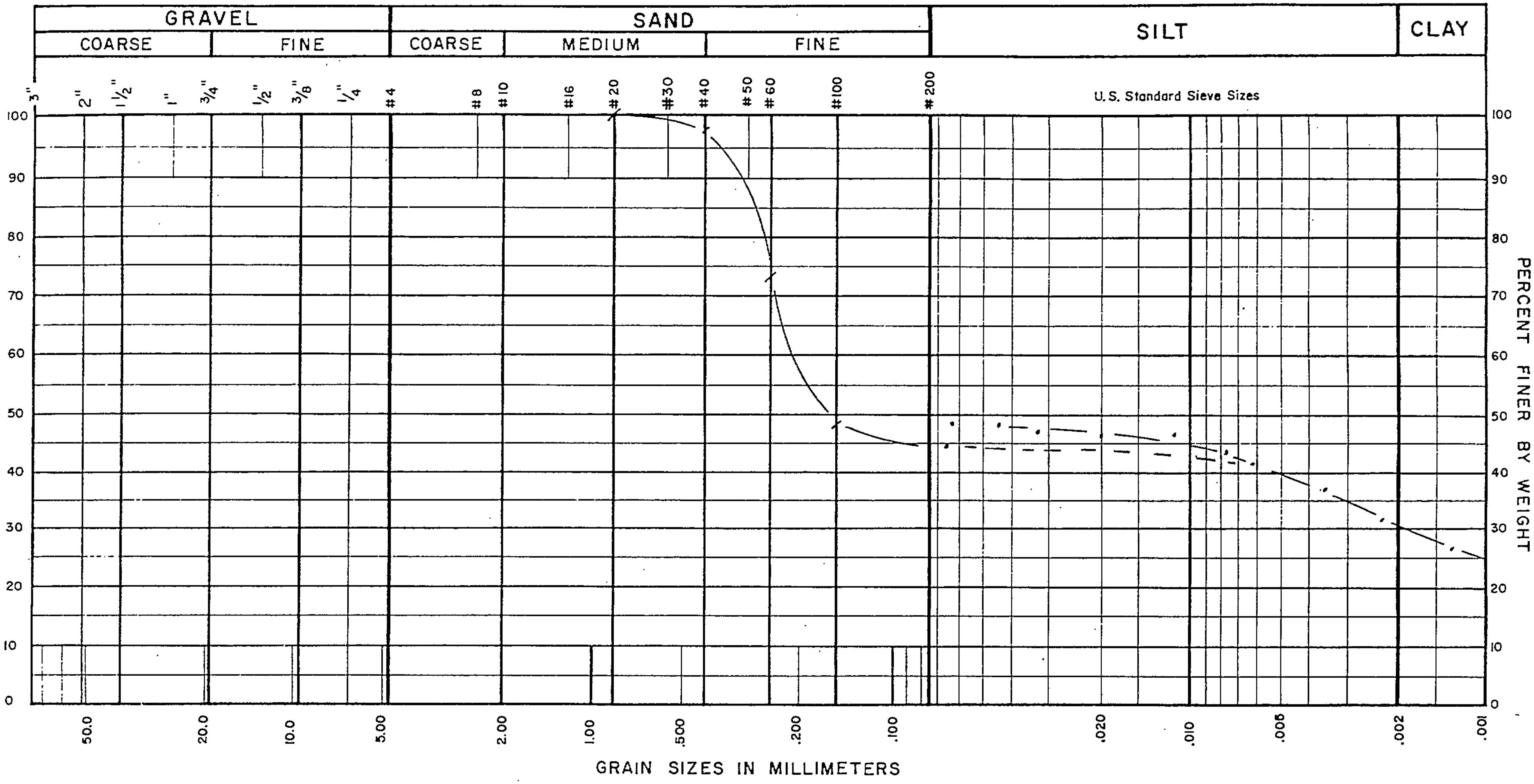
Clay	60.0		%
Silt	38.7		
Sand	1.3		
Gravel	–		

Classification

CLIENT	SEAKEM
PROJECT	
LOCATION	87 AK
SAMPLE	27 c
TEST DATE	Mar 28/83 — FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



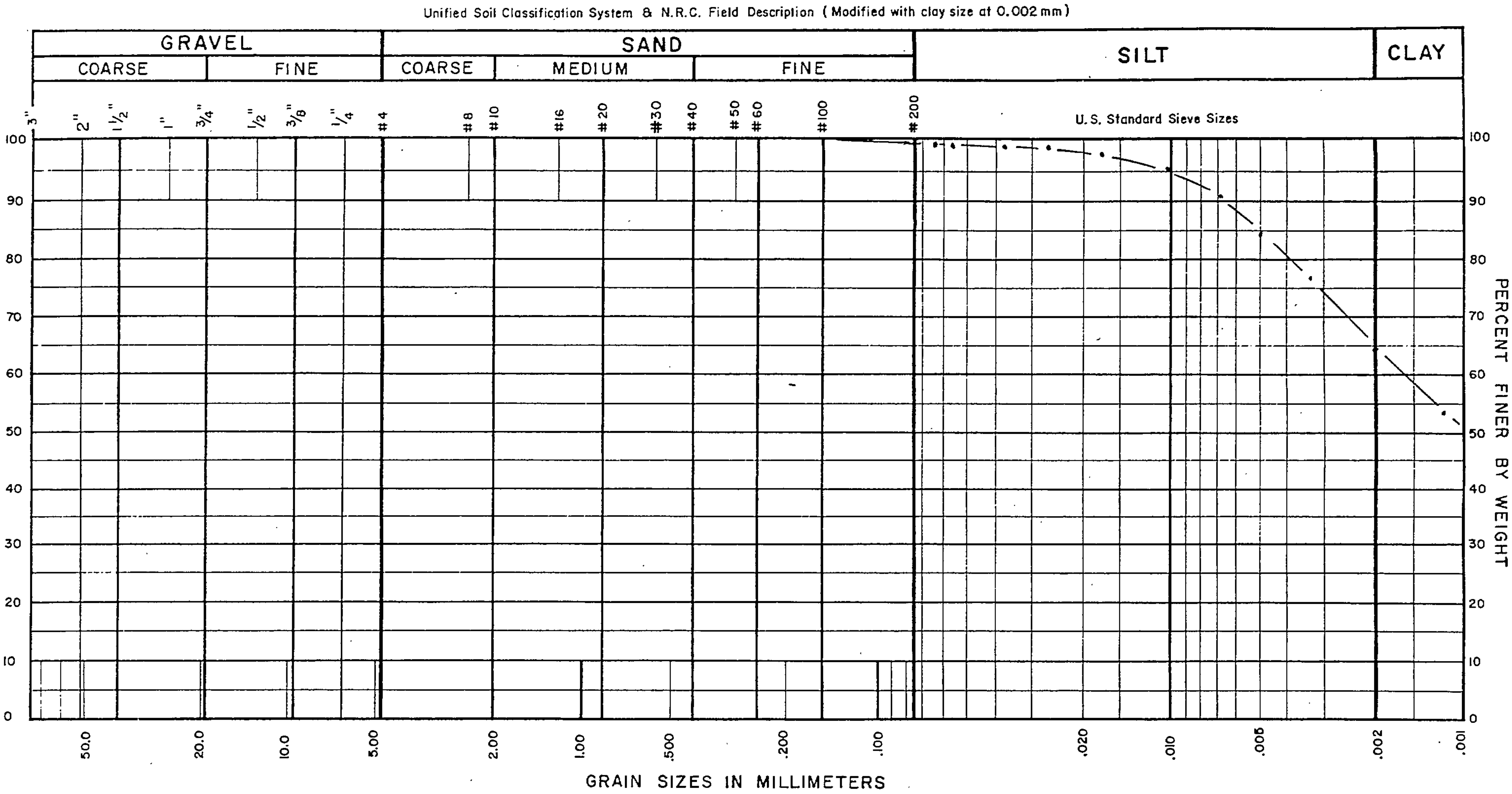
Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	30.0		%
Silt	14.4		
Sand	55.6		
Gravel			

Classification

CLIENT	SEAKEM
PROJECT	
LOCATION	87 AK
SAMPLE	29C
TEST DATE	MAR 23/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers



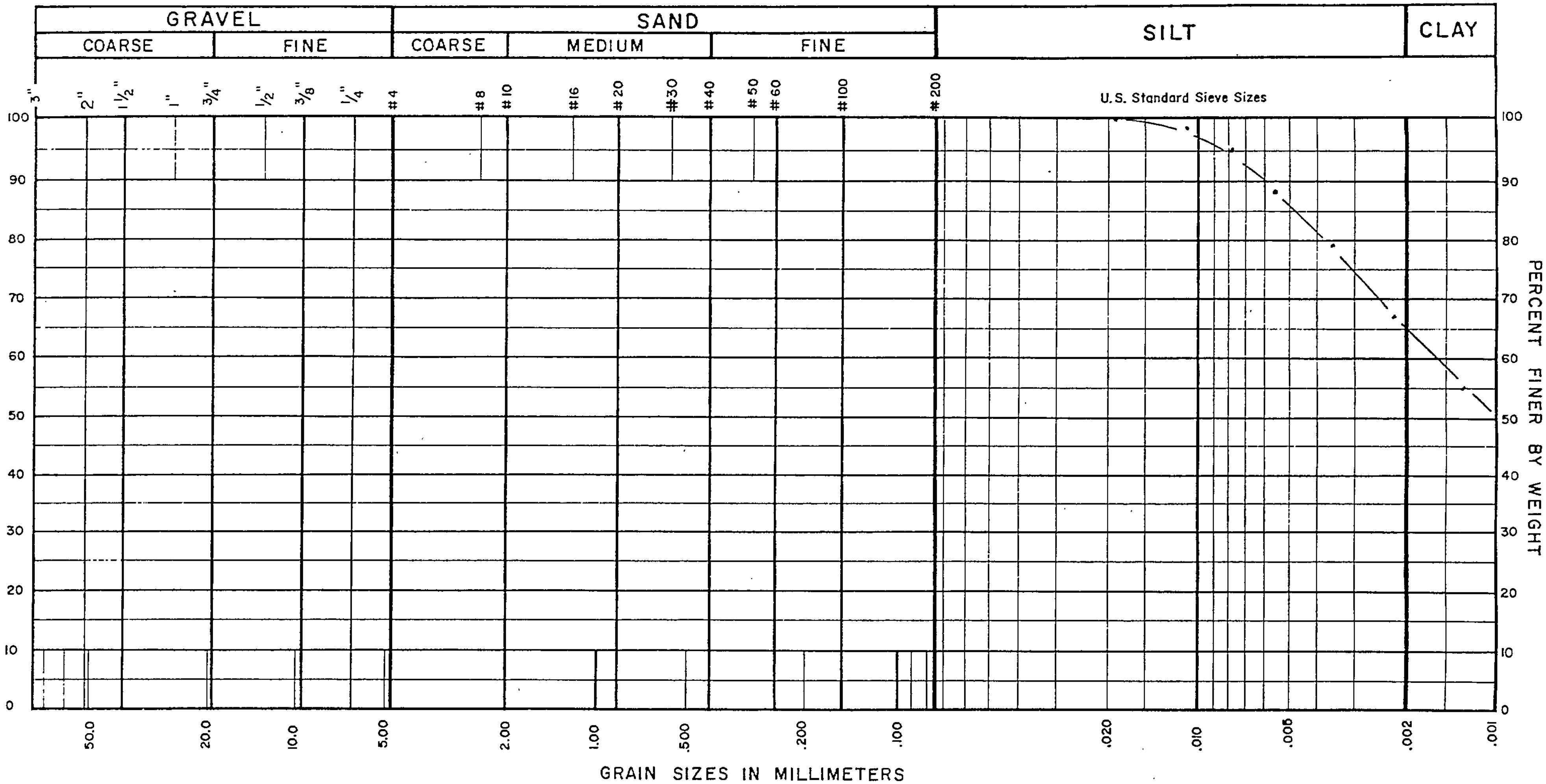
Nat. Water Content	%		Clay	64.6 %
Liquid Limit			Silt	34.7
Plastic Limit			Sand	0.7
Plastic Index			Gravel	

Classification ______________________

CLIENT	Seakem
PROJECT	
LOCATION	87 AK
SAMPLE	31c
TEST DATE	Mar 28/83 — FILE No 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



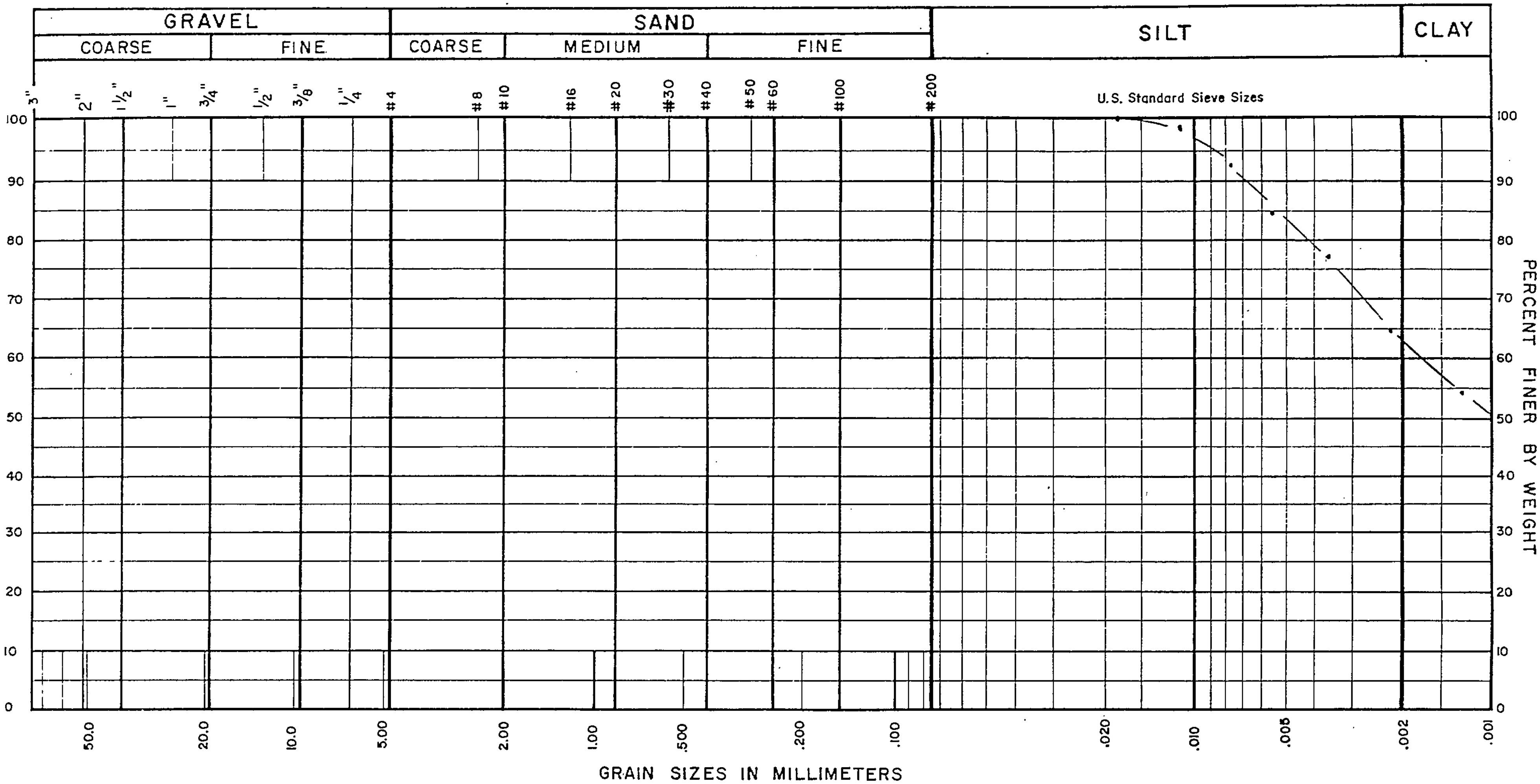
Nat. Water Content			%	Clay	65.0		%
Liquid Limit				Silt	35.0		
Plastic Limit				Sand	—		
Plastic Index				Gravel	—		

Classification ______

CLIENT	SEAKEM		
PROJECT			
LOCATION	87 AK		
SAMPLE	33 C		
TEST DATE	MAR 28/88	FILE Nº	19-775.0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



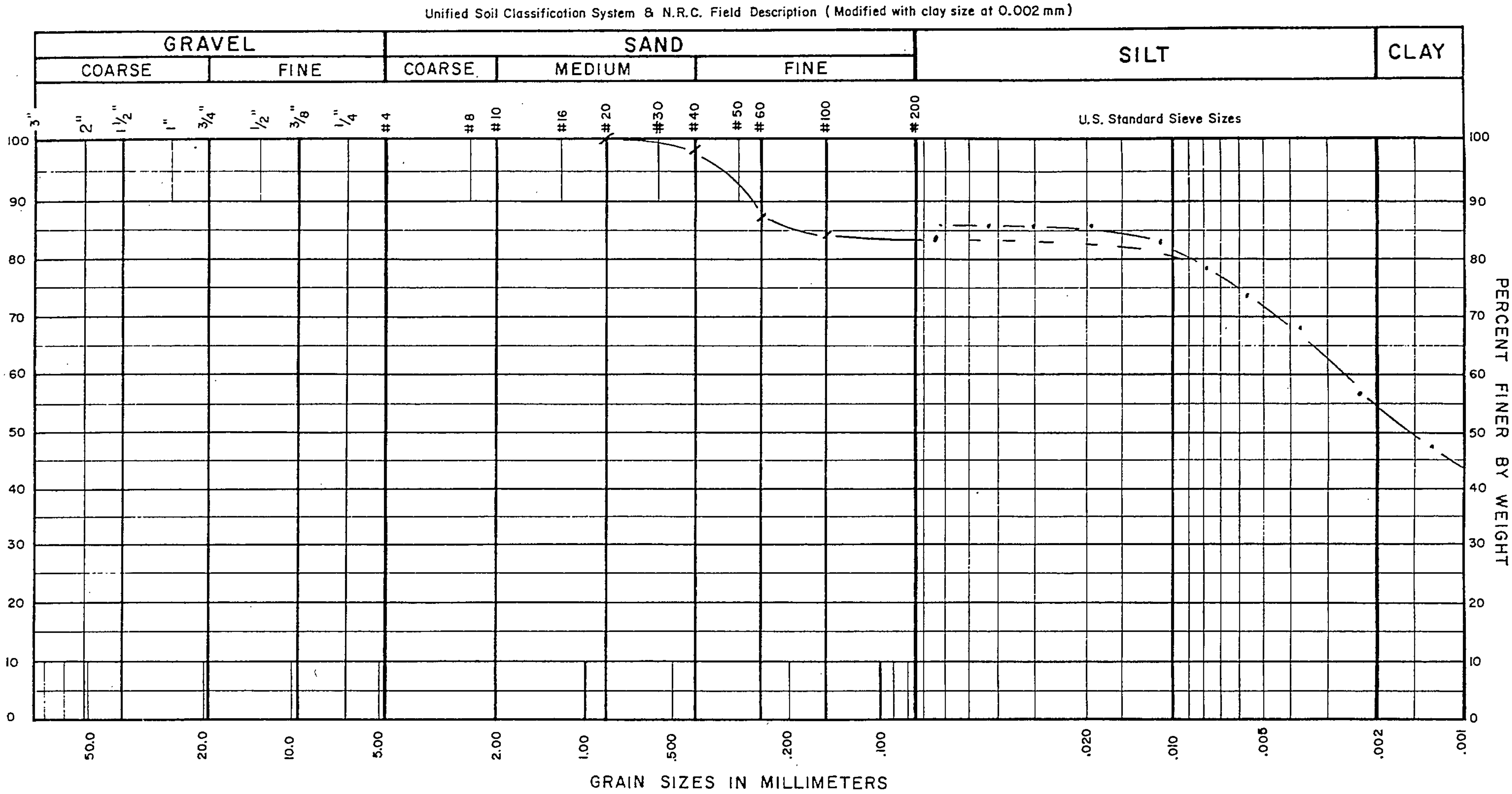
			%
Nat. Water Content			
Liquid Limit			
Plastic Limit			
Plastic Index			

			%
Clay	63.0		
Silt	37.0		
Sand	—		
Gravel			

Classification

CLIENT	Seakem
PROJECT	
LOCATION	87AK
SAMPLE	43 c
TEST DATE	Mar 28/88 FILE No 19-345-0

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

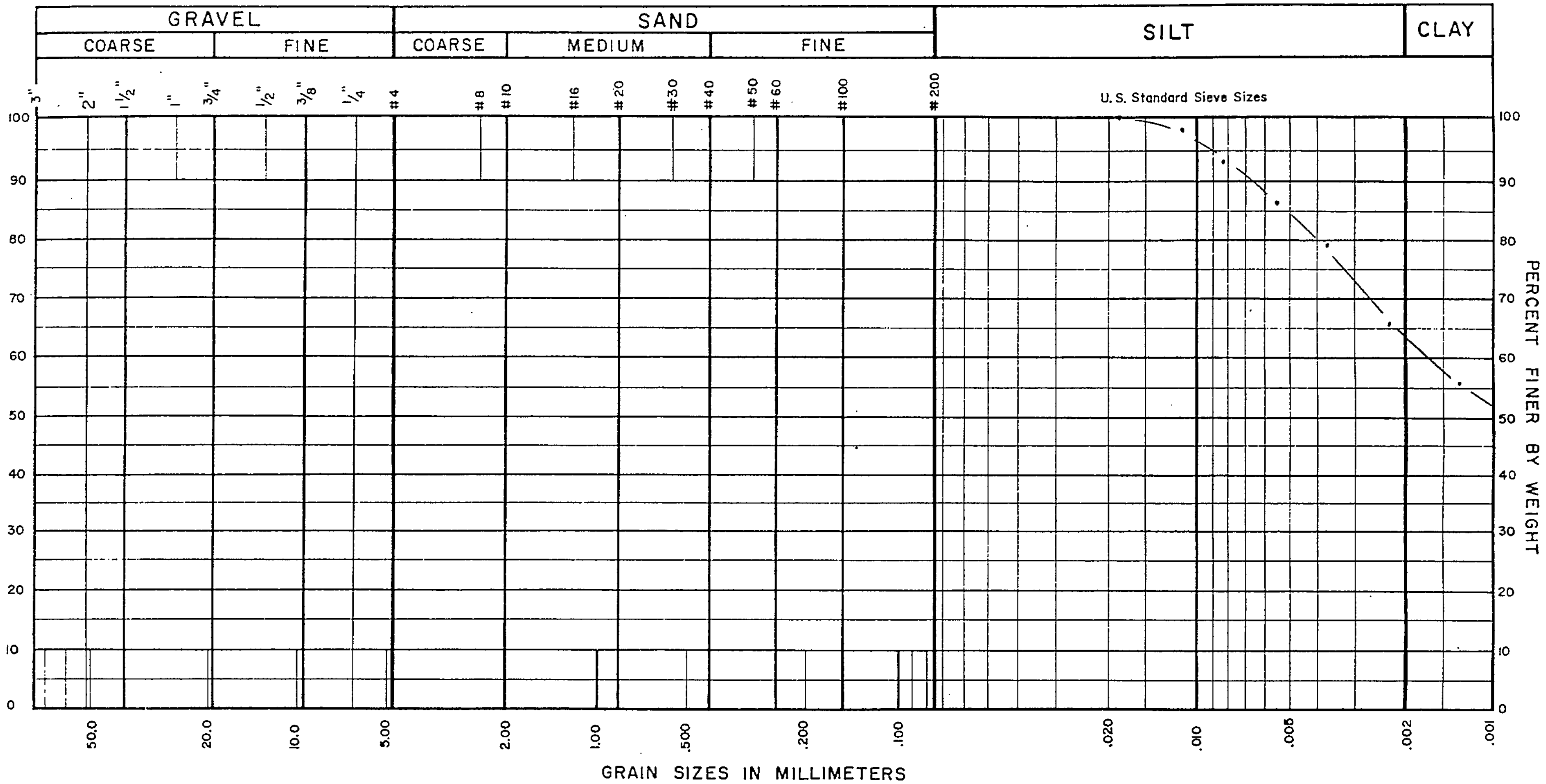
Clay	55.0		%
Silt	28.3		
Sand	16.7		
Gravel			

Classification ______________________

CLIENT	SEAKEM
PROJECT	
LOCATION	87AK
SAMPLE	44C
TEST DATE	MAR 29/88 FILE Nº 19-395.0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

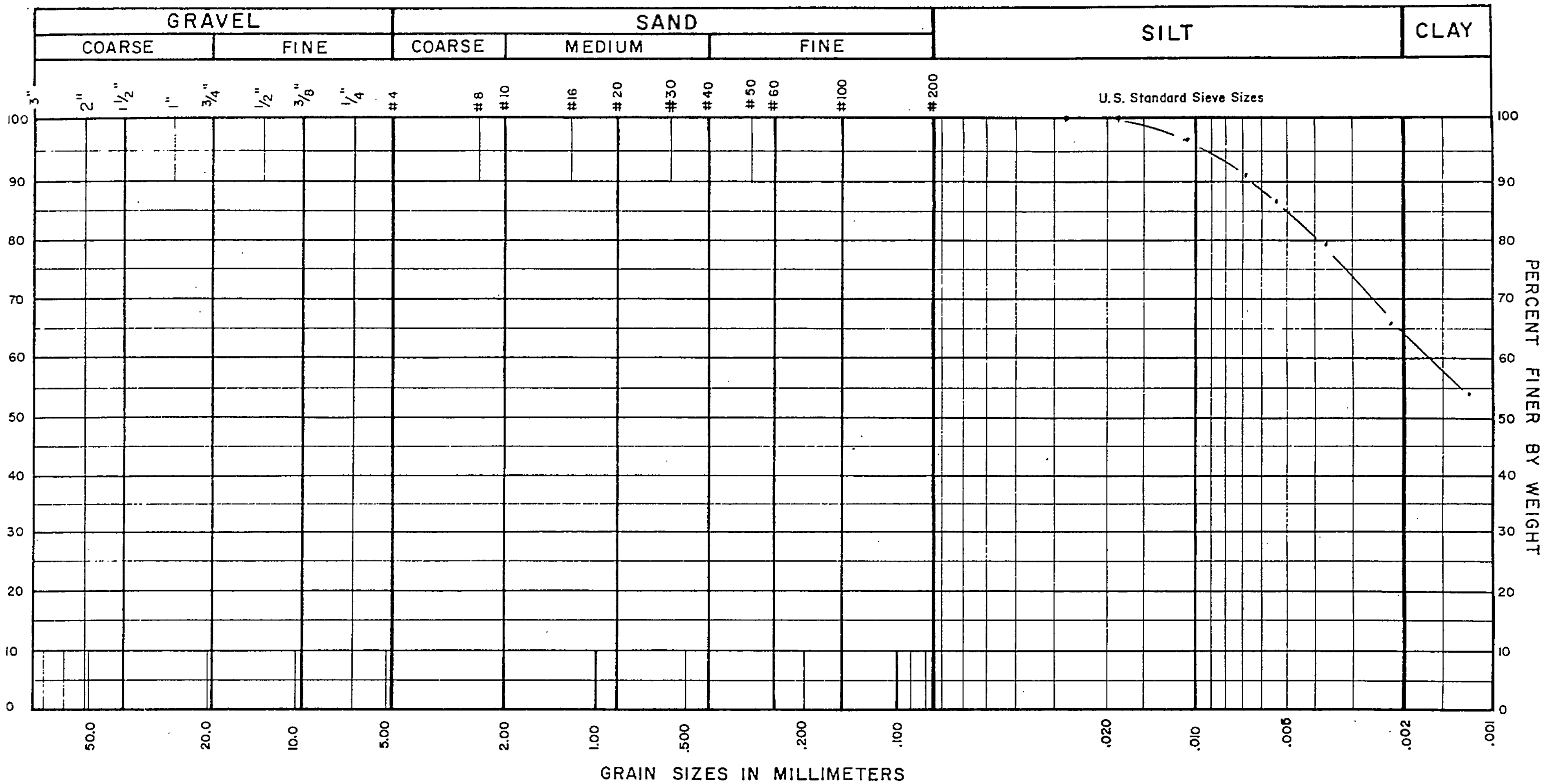
Clay	64.0		%
Silt	36.0		
Sand	—		
Gravel			

Classification

CLIENT	SEAKEM
PROJECT	
LOCATION	87 AK
SAMPLE	5'1 C
TEST DATE	MAR 23/83 — FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



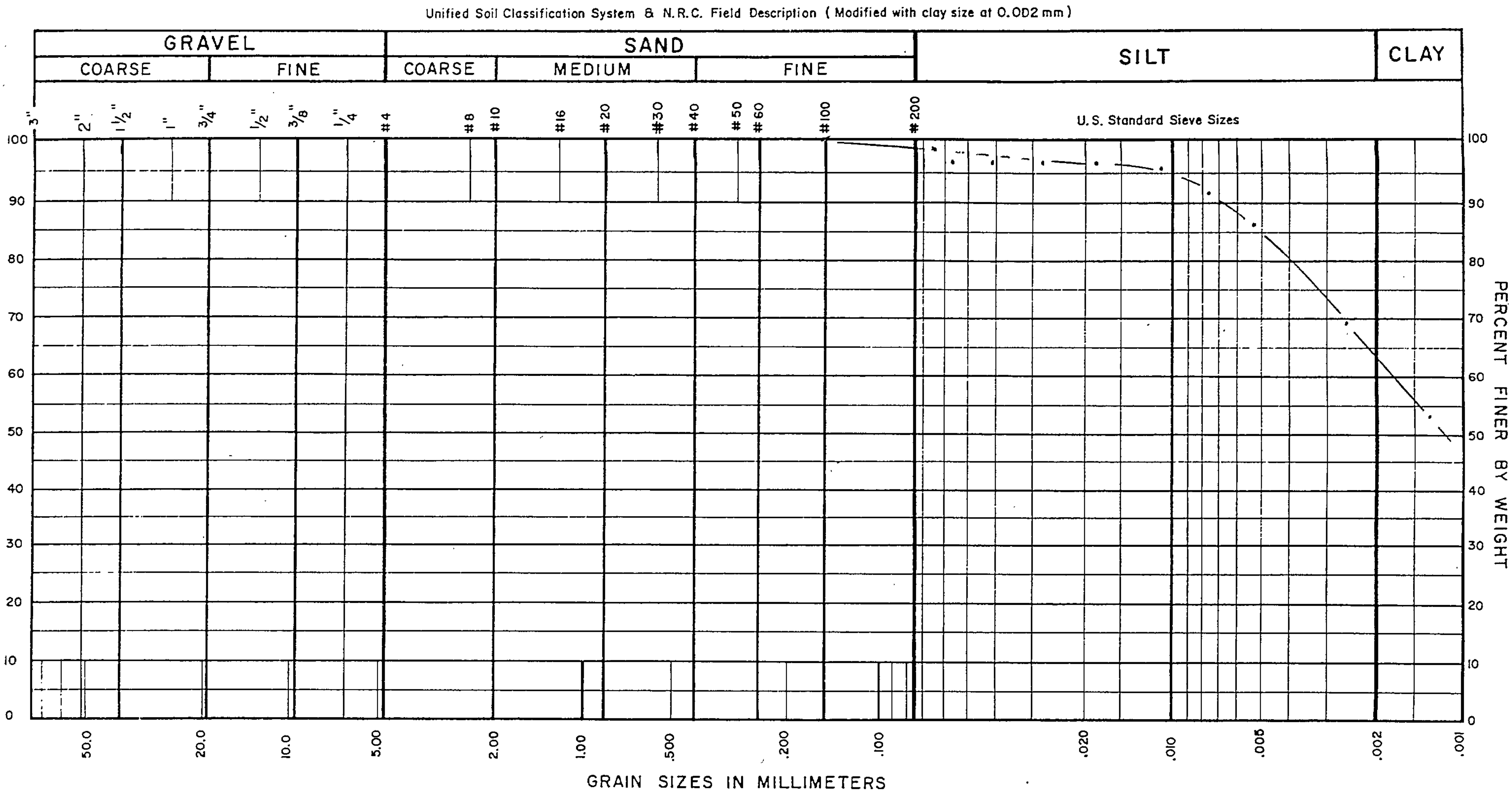
Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	64.0		%
Silt	36.0		
Sand			
Gravel			

Classification

CLIENT	SEAKEM
PROJECT	
LOCATION	57 AK
SAMPLE	53 C
TEST DATE	MAR 28/88 — FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	63.0		%
Silt	35.7		
Sand	1.3		
Gravel			

Classification

CLIENT SEAKEM

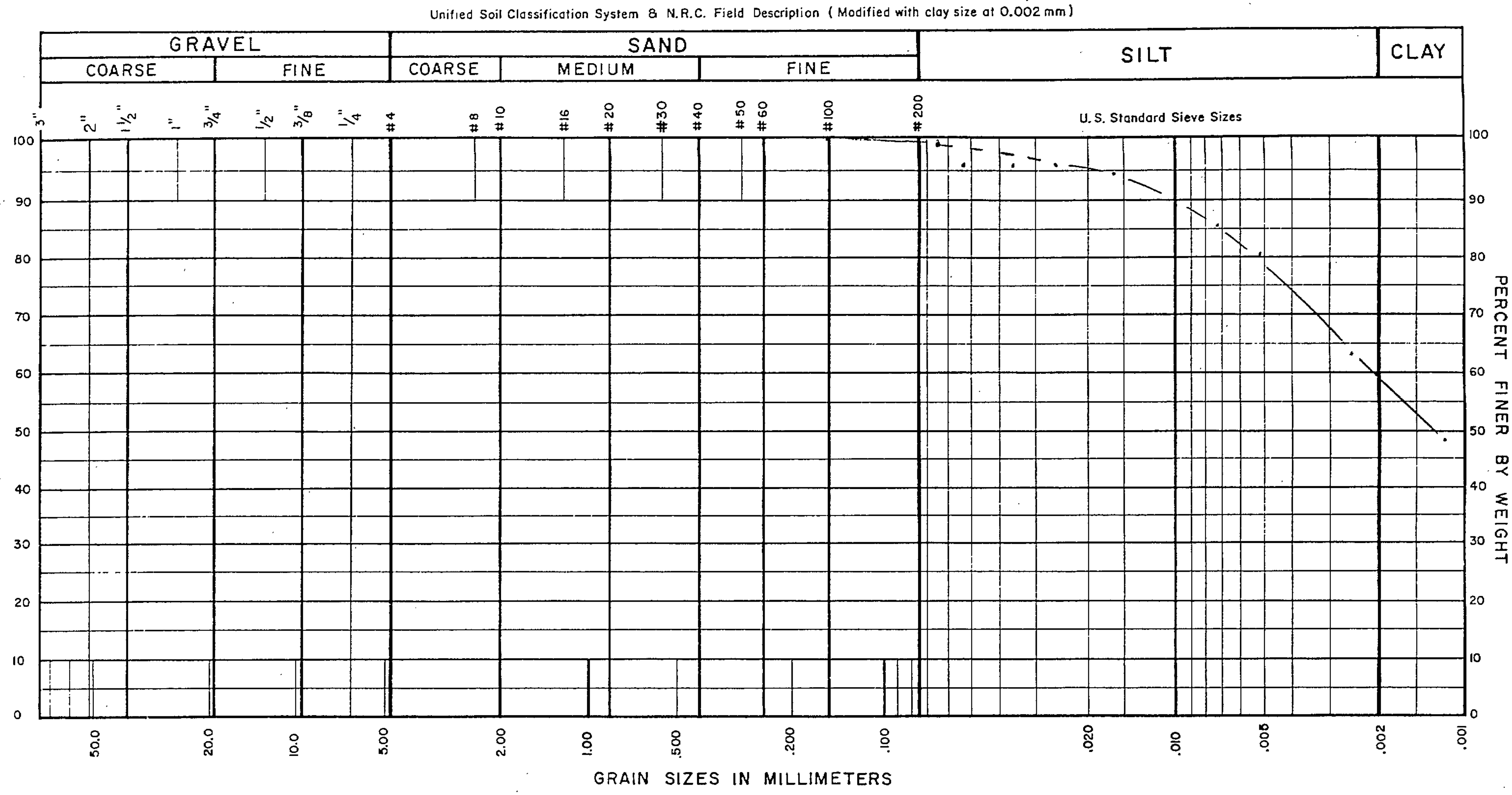
PROJECT

LOCATION 87AK

SAMPLE 56C

TEST DATE MAR 29/88 FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

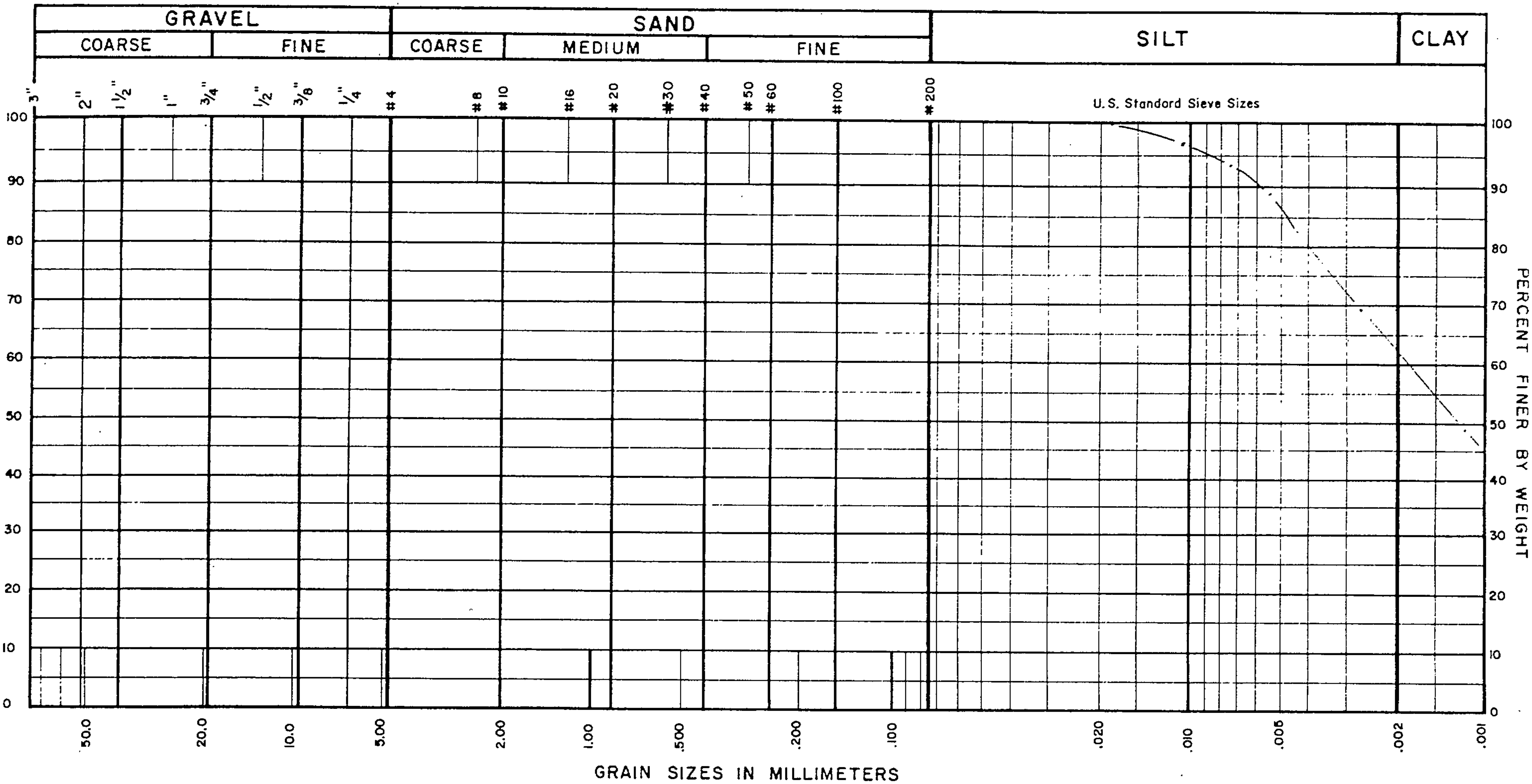
Clay	59.0		%
Silt	40.6		
Sand	0.4		
Gravel			

Classification ______________________

CLIENT	SEAKEM
PROJECT	
LOCATION	87AK
SAMPLE	64C
TEST DATE	MAR 29/83 FILE Nº 19-395

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%	
Liquid Limit				
Plastic Limit				
Plastic Index				

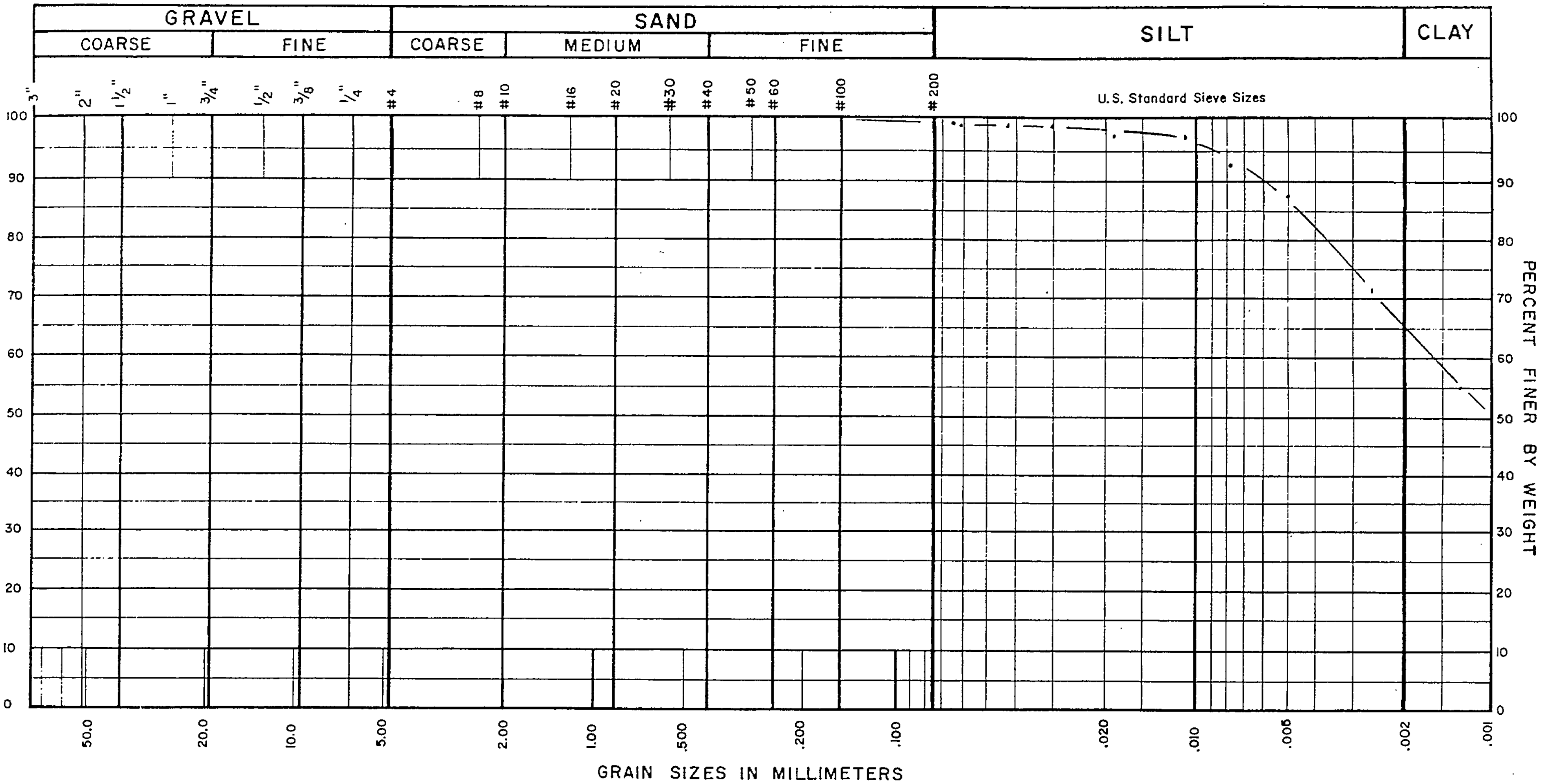
Clay	62.5		%
Silt	37.5		
Sand			
Gravel			

Classification

CLIENT	SEAKEM OCEANOGRAPHIC
PROJECT	
LOCATION	
SAMPLE	72 C
TEST DATE	FILE Nº 19-395-2

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

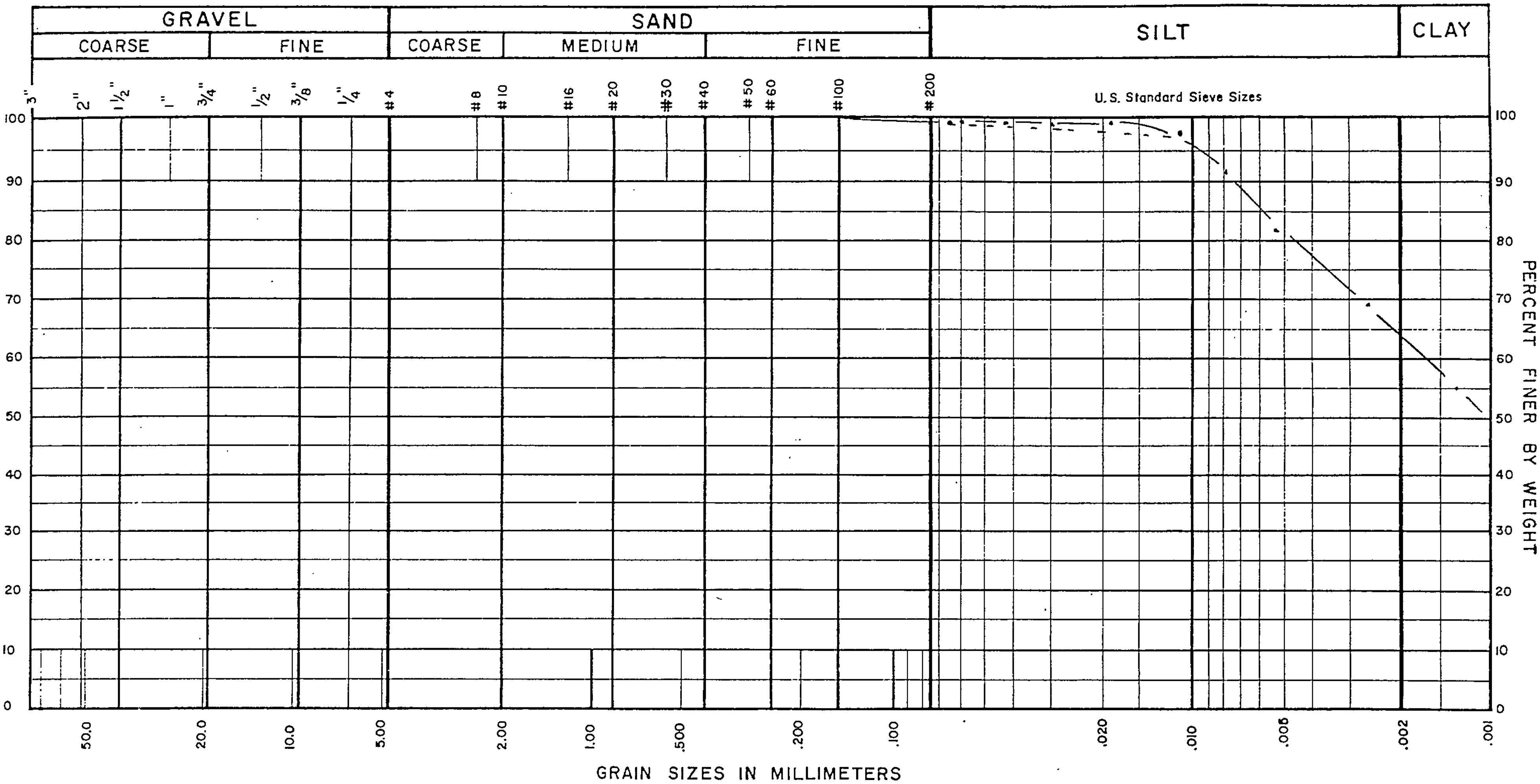
Clay	65.0		%
Silt	34.4		
Sand	0.6		
Gravel			

Classification

CLIENT	SEAKEM
PROJECT	
LOCATION	87AK
SAMPLE	R1
TEST DATE	MAR 29/83 — FILE Nº 19-395..

THURBER CONSULTANTS LTD., Geotechnical Engineers

Unified Soil Classification System & N.R.C. Field Description (Modified with clay size at 0.002 mm)



			%
Nat. Water Content			%
Liquid Limit			
Plastic Limit			
Plastic Index			

Clay	64.0		%
Silt	34.8		
Sand	1.2		
Gravel			

Classification

CLIENT	SEAKEM
PROJECT	
LOCATION	87 AK
SAMPLE	R2
TEST DATE	MAR 29/83 — FILE Nº 19-395-0

THURBER CONSULTANTS LTD., Geotechnical Engineers

SEAKEM OCEANOGRAPHY LTD

OFFERING SERVICES IN CHEMICAL, PHYSICAL
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