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A report prepared for

BP Exploration (Alaska), Inc.
900 E. Benson Blvd.
Anchorage, AK 99519-6612

GEOTECHNICAL EXPLORATION
Liberty Development
North Slope, Alaska

by

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Professional Geologist AA 0062

DM&A Job No. 4119.23

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SUMMARY

During March 1998, Duane Miller & Associates (DM&A) drilled and sampled 27 geotechnical borings in the Foggy Island Bay area of the North Slope of Alaska for the proposed Liberty Development Project. Borings were drilled at the island site, along the preferred pipeline route connecting the island to shore and at the proposed material site. The location of each drill hole is shown on Plates 2 through 5.

Laboratory testing of samples included primary testing and secondary testing. Primary testing included moisture contents, salinity tests, moisture/density determinations on undisturbed samples, visual classification of samples, and classification tests (sieve analysis and/or Atterberg Limits) and specific gravity tests. Secondary testing included triaxial shear strength and consolidation tests. Non standardized testing included consolidation tests of remolded samples, sedimentation tests and moisture retention tests.

The soils at the island can be divided into three primary layers: 1) the upper Holocene non-plastic silt, a soft, compressible layer that is five to six feet thick, 2) the intermediate Pleistocene clayey silt, a stiff, over-consolidated material that extends to depths of 18 to 22 feet, and 3) the underlying granular sand and gravel that extends to the depths explored. The only frost bonded materials observed in the borings at the island site were thin layers of bonded sand just below the Pleistocene clayey silt.

Soils along the pipeline vary from the conditions described above at the island to sand and gravel near the shoreline and include intermediate deposits of silty sand and organic material. The conditions are summarized on the cross sections presented on Plates 3 and 4. The only permafrost found along the route is at the shoreline crossing, below the pipe invert, and is confined to sand and gravel deposits with a small potential for thaw settlement.

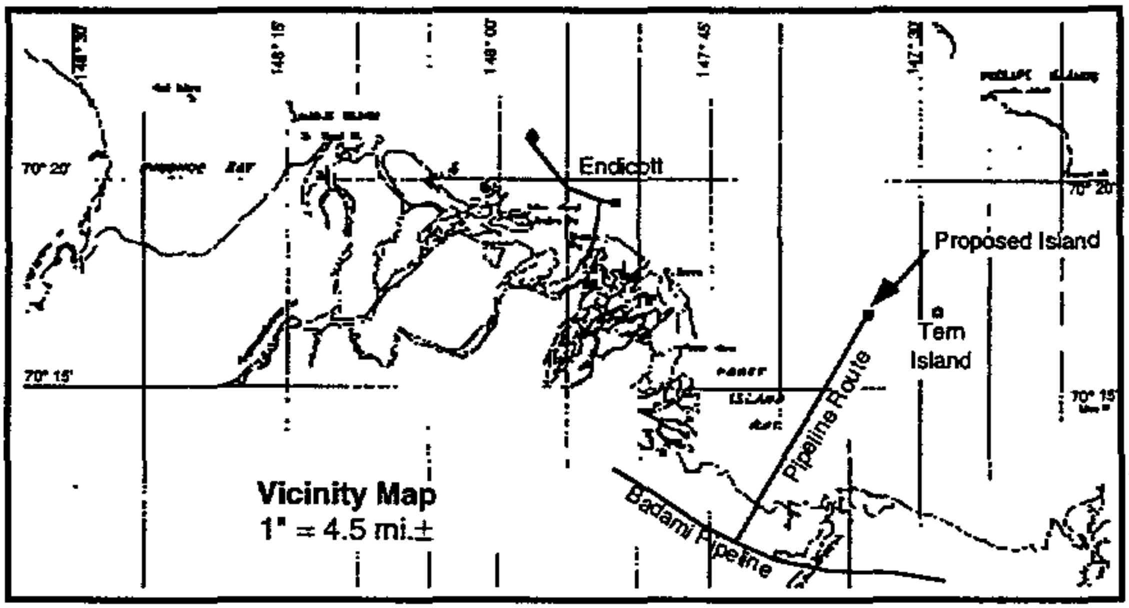
The proposed onshore material site is in the floodplain of the Kadleroshilik River and consists of sand and gravel with varying amounts of fines content. The material is similar to sand and gravel used on previous projects in this area.

During island construction, the stability of the steep winter slopes will have a factor of safety greater than 1.5 if the slopes are flatter than 0.75 H to 1 V. The island can be constructed with the steep slopes up to sea level, but the portion of the fill placed above sea level should be constructed behind a bench at least 30 feet wide between the toe of the higher fill and the top of the steeper below water slope.

Settlement of the island will result from four main causes: 1) consolidation of the fine grained soil under the weight of the island, 2) elastic compression of the deeper granular soils, 3) thaw settlement of frozen fill, and 4) creep settlement of frozen fill. Settlement due to consolidation under the weight of the island will be about 12 inches from the Holocene layer and an additional 6 inches from the Pleistocene clayey silt. The elastic settlements will occur as the fill is placed and should not have a significant long term effect. Thaw settlement will be 10% or more of each foot of material that thaws. The summer active layer (5 to 6 feet thick) where traffic loads will occur and further densify the gravel will result in about one foot of settlement. In the area affected by the production wells, the total thaw settlement will be on the order of four to six feet. Creep settlement in the unfrozen icy gravel fill will add about one inch per year to the island's settlement.

INTRODUCTION

This report presents the results of the geotechnical investigation conducted for the proposed Liberty Development Project, an offshore petroleum project in Foggy Island Bay. The proposed project is located southeast of the Endicott Field and about 18 miles east of Deadhorse in Federal waters of the OCS. The general location of the work is shown in the map below and details of the area are shown on Plate 1.



BP Exploration (Alaska), Inc., (BPXA) is evaluating the feasibility of developing the Liberty field. The potential petroleum field was explored in early 1997 by drilling a slant well from a spray ice island constructed at the remnant of Tern Island. Based on the findings from that exploration well and concurrent geophysical surveys, the proposed production island was located about 1-1/2 miles west of Tern Island. Water depths at the location are 22 to 23 feet.

The production island will have a rectangular shape with rounded corners (see Plate 2). The island will be constructed of gravel, mined onshore and hauled by trucks to the site over an ice road during the winter. The surface of the island will be at elevation +15 feet, mean sea level, and the top dimensions will be 345 by 680 feet. A sheetpile retained dock will extend out from south end of the island to the toe of the slope and add 135 feet to the overall length of the top of the island. With side slopes at 3 horizontal to 1 vertical (3:1) and an intermediate

30-foot wide bench just above sea level, the base dimension of the island will be 615 feet by 950 feet.

The oil will be transported from the production island to shore in a steel pipeline. Offshore, the pipeline will be buried between depths of 7 and 10 feet below the ocean floor; onshore, the pipeline is expected to be supported above grade on piling. The transition from the buried offshore section to the above ground onshore pipe will be about 180 feet inshore of the water's edge. The pipeline will be constructed using winter ice roads. Production equipment will be in modules and will be brought to the island on barges during the ice free summer season. Emergency support and crew changes will be via helicopter.

The 1998 geotechnical exploration was started during the fall of 1996 when DM&A collected existing data to allow for an assessment of expected geotechnical conditions. Also to provide data for the design of the spray ice island, DM&A drilled one boring through the remnant of Tern Island, an abandoned gravel island. Using the existing data a field program was developed for exploring the offshore conditions for a tentative island location and alternative pipeline routes for the Liberty project. The originally proposed island site and three alternative offshore pipeline routes were explored in the spring of 1997 by drilling and sampling 30 borings and performing laboratory testing. The alternatives, Routes A, B and C, are shown on Plate 1. The results of the 1997 exploration were presented in the DM&A report to BPXA dated September 10, 1997.

Watson Company of Anchorage performed a marine geophysical survey of the island location and pipeline route during the summer of 1997. Using that data, a geotechnical program was designed to complement the data collected last year and to explore the conditions at the selected island location and the preferred pipeline route. The proposed onshore material site was also explored.

The geotechnical work was performed in accordance with our contract with BPXA dated January 15, 1997. We coordinated our work with the Liberty Project Management Team through Mr. James C. Lewis of BPXA. Ms. Karen Wuestenfeld and Ms. Debby Oylear of BPXA provided permitting and environmental coordination. The Endicott Operating Unit provided field support for housing and meals.

The object of the 1998 geotechnical investigation was to explore the soil and permafrost conditions at the proposed production island site and along the pipeline route and at the material site. The geotechnical work was divided into the following tasks:

- Drilling and sampling borings,
- Measuring ground temperatures,
- Primary and secondary laboratory testing of soil samples, and
- Data analysis and report preparation.

An independent, water column and shallow sea floor evaluation of environmental conditions was performed by Montgomery Watson in conjunction with the startup of the field program.

EXPLORATION

Existing data

The geotechnical evaluation of the project area started with the collection and review of existing data. The surficial geology in Foggy Island Bay has been studied for many years by numerous agencies and at least one subsurface study was conducted by Shell Oil as part of their wildcat oil drilling program in the late 1970s and early 1980s.

The United States Geological Survey (USGS) has been involved in regional studies in the area since Schraeder first descended the Colville River right after the turn of the century. Leffingwell, who spent at least nine summers on the arctic coastal plain, produced the first definitive geologic study of the region and was the first to identify the geologic and ecological significance of the Flaxman boulder deposits. Surficial studies in the area have been conducted off and on since that time including detailed studies resulting from the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of the 1970s. A complete narrative summary of government work in the area is presented in Public Data File 90-27 by the Alaska Division of Geological and Geophysical Surveys (Rawlinson, 1990).

In 1979 the USGS contracted with Harding Lawson Associates (HLA) to explore the geotechnical conditions in the proposed offshore lease sale area from the Kuparuk River to Flaxman Island. As shown on Plate 1, two of the borings drilled during the spring of 1979 were located near the Liberty area (HLA/USGS 13 and HLA/USGS 14).

Prior to building Tern Island, Shell Oil commissioned HLA to evaluate subsea soil conditions in the vicinity of the present island remnant. The results of the geotechnical investigation for the Tract 42 Well Site are in the HLA report dated February 1981 (HLA Job No. 9644,004.08). The island was instrumented by HLA after its construction and that data is presented in their report dated September 2, 1982 (HLA Job No. 9644,009.08).

Shell Oil also had HLA explore for onshore material sources for the construction of offshore facilities. After an initial reconnaissance study, HLA drilled two sites in detail (Site 2 and Site 9). Shell Site 2, which was not developed, is located just to the east of the material source proposed for Liberty (see Borings S 2-1, S 2-2, etc. on Plate 5). The exploration included many gradation tests, maximum and minimum density tests and triaxial shear strength tests of remolded samples of the sandy gravel material.

Extensive sea floor studies also have been conducted to determine the extent of the "boulder patch" areas immediately northwest and northeast of the project site. These seafloor boulders are unique in the arctic and support an unusual abundance of sea life. In addition to the ecological significance of the boulder patch material, the boulders are an indicator of subsurface geology.

DM&A drilled many holes and tested samples for the design of the Badami pipeline which crosses the Kadleroshilik River just south of the material site.

Selected references are cited in the bibliography at the end of this report and copies of boring logs from the HLA/USGS and Tern Island explorations are presented in Appendix F.

Data from the 1997 holes drilled closest to the selected pipeline alignment are shown on the cross sections on Plates 3 and 4.

Subsurface exploration

Between March 17 and March 26, 1998, 27 holes were drilled and sampled for the Liberty Development Project. Five holes were drilled at the island location, seventeen holes were drilled along the pipeline route and five holes were drilled at the proposed material site. All work was conducted in accordance with the following permits:

North Slope Borough - Development Permit No. 98-074,

U.S. Army Corps of Engineers - Nationwide Permit D-980994,

Alaska Department of Fish and Game - Fish Habitat Permit No. FG98-III-0015,

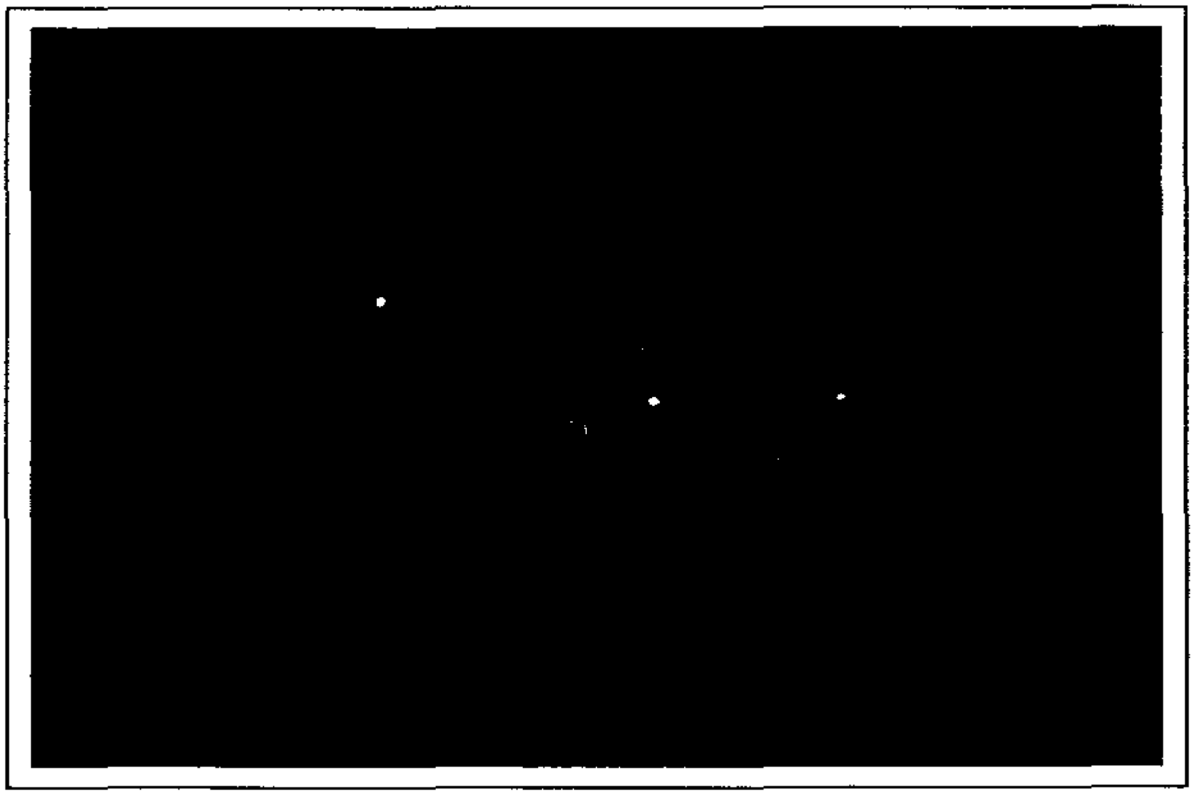
Alaska Department of Natural Resources, Division of Land - Tundra Travel Permit No. LAS 19505,

Minerals Management Service - Notice of Preliminary Activity No. OCS-Y1650, and

Polar Bear Interaction Plan - NSB 98-0258.

The coordinates of the proposed borings were calculated before the field work began and hole locations were established in the field using a Differential Global Positioning System (GPS). The GPS system employed by Bell Associates for field staking gave a precision for the initial hole locations at about +/- one foot. The drilled locations were generally within 8 to 12 ft of the staked location and the as-drilled locations shown on the Summary of Borings, Plates 6 and 7, show coordinates corrected for the offset from the staked location. Boring B-27 was added after the staking and was referenced to the adjacent hole locations by taping.

Photograph of the Drill and Support Sled
(photograph by Thomas Culkin)



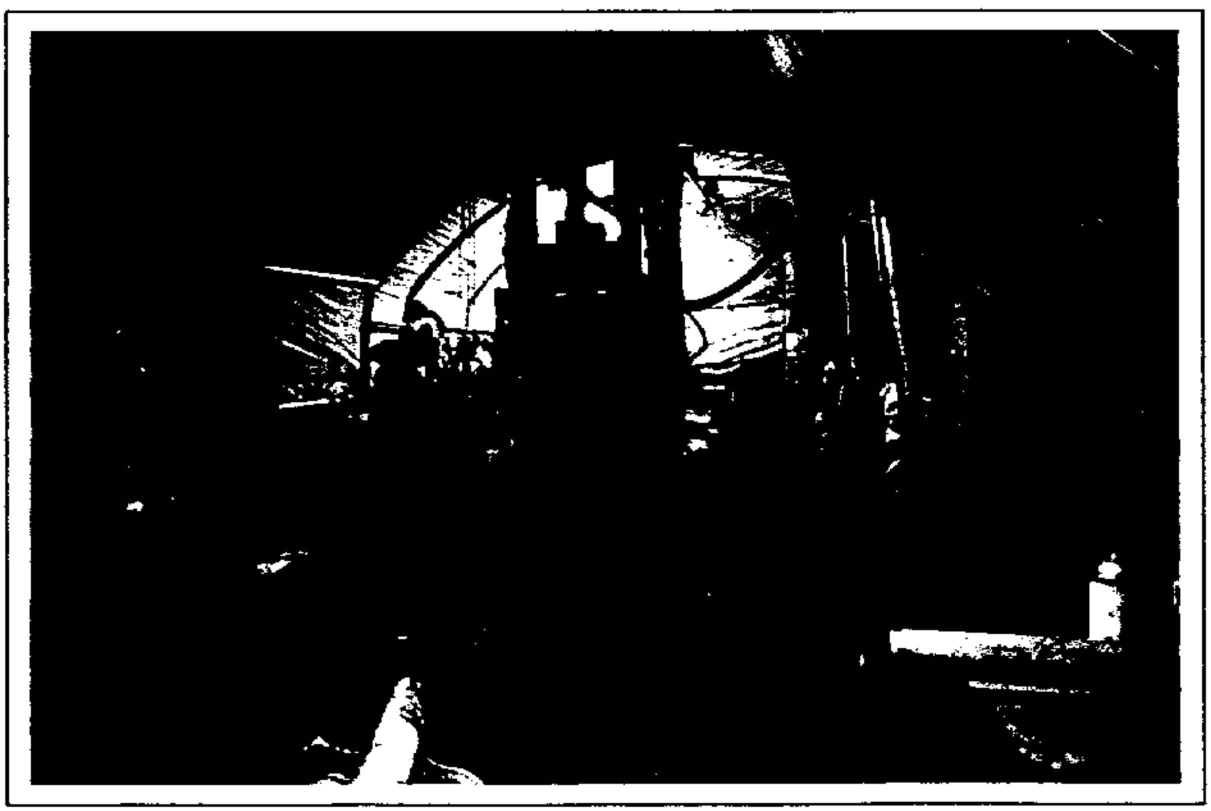
The drill, a CME-75, was mounted on a sled, and the drill and work area were protected from the weather by a canvas (Weatherport) enclosure. A canvas shroud enclosed the tower above the Weatherport enclosure. A second sled carried a survival shed and a generator. The drill equipment was supplied and operated by Discovery Drilling of Anchorage. Logistical support was provided by CATCO from their base of operations at Prudhoe Bay. One roller-driven

Rolligon (CATCO RD-85) with 8 supporting air bags was used for transport. The drill rig and emergency shelter sleds were moved from site to site by the Rolligon. A 3000-gallon fuel tank was mounted on the Rolligon. The RD-85 also served as a crew carrier between the drill sites and the ice road. A second RD-85 with a 3000-gallon water tank was used to provide drilling water when necessary in bottom-fast ice areas.

The crews were housed at BP's Endicott Facility and commuted to the project area by pick-up truck along the ice road serving the Badami project. Meals and office support were obtained at Endicott Operations Center. No on-site camp facilities were utilized except for the small sled-mounted emergency shelter that was kept with the drill rig at all times.

The work was performed on a double shift basis with crews working 12 hours at the drill rig. Each shift had a 4 person crew consisting of a DM&A geologist or engineer, a Discovery Drilling driller and a drill helper, and a CATCO operator. A DM&A technician provided expediting support as needed and was responsible for sample packaging and shipping.

Photograph of the Drill Sled Interior
(photograph by Thomas Culkin)



The borings were drilled to depths of 15 to 74 feet using a CME-75 soils drill rig equipped with hollow stem augers. Offshore depths are below the mudline. The soils were logged as the borings were drilled by Mr. Walt Phillips, PG, and Mr. Thomas Culkin. The locations of the borings for the island are shown on Plate 2. The locations of the holes along the pipeline along with nearby borings from the 1997 exploration and a cross section of the data are shown on Plates 3 and 4. The locations of the holes at the material site are shown on Plate 5. The drilled borings are summarized on Plates 6 and 7.

Subsurface sampling

Samples of the soil were obtained by pushing thin wall samplers, by driving split barrel samplers and by grab sampling off the augers. Sampling was generally attempted at five-foot intervals.

In fine grained soils (silts and clays), thin-walled (Shelby) tubes were used where practical (this method is designated as Tw on the boring logs). The Shelby tubes are 3-inch OD (2.87-inch ID) and were pushed into the soil using the hydraulic down pressure of the drill rig. The sample was generally left in the tube, and the ends of the tube were sealed. The Shelby tubes of unfrozen soil were protected from freezing and were transported in cushioned boxes.

For sand and gravel or for fine grained soils that were too stiff for a Shelby tube, the sampling methods consisted of split-barrel samplers advanced into the soil below the tip of the auger by driving with an above ground hammer. The CME-75 was equipped with an automatic hammer system. The hammer weighs 340 pounds and has a drop of 30 inches. The drive samples were obtained in a 3-inch OD by 2.5-inch ID split barrel (samples designated as Sha on the boring logs). Blow counts for each 6-inch increment of the drive were recorded. Six-inch long brass tubes were commonly used in the 3-inch OD sampler, and the tubes were logged and capped for subsequent examination and testing. Occasionally the split barrel sampler was used when soft soil was present, and the sampler was pushed into the soil by the weight of the hammer (these samples are designated Sp on the logs).

On shore, larger bulk samples of the soils were sometimes obtained by retrieving cuttings with the auger flights (designated on the boring logs as Ag for auger grab). The ice content and soil type were logged and the samples were sealed in 5-gallon plastic buckets.

A graphic log of each boring is presented in Appendix A on Plates A-1 through A-37. The soils and ice have been classified in accordance with the Unified Soil Classification System presented on Plate A-38. The boring logs show the type of sampler used and the blow counts required to drive the sampler. Blow counts have not been corrected to Standard Penetration Test values.

All samples were maintained at their field thermal state during storage in the field and shipment to the laboratories in Anchorage. Frozen samples were kept frozen and unfrozen soils were kept from freezing. As discussed above, samples sensitive to mechanical shock were stored and shipped in foam padded boxes. Cooler boxes were used to ship other samples.

Laboratory testing

Laboratory testing in Anchorage included primary testing and secondary testing. The samples were inventoried upon receipt at the laboratory and the inventory was compared with the field shipping list. A testing program was developed based on the condition and type of sample and the field boring logs. Laboratory testing was performed by two different laboratories: R&M Consultants, Inc., (R&M) performed the testing of samples from the material site, and Alaska Testlab (ATL) performed the testing of samples from the pipeline and island locations.

Primary testing included moisture contents on most samples, salinity tests, moisture/density determinations on undisturbed samples, visual classification of samples, and classification tests (sieve analysis and/or Atterberg Limits) and specific gravity tests.

Salinities were determined using two different methods. R&M determines salinity by measuring the electrical conductivity of diluted pore fluid and correlates the conductivity to salinity using published values for sea water. ATL measures salinity using a titration paper that shows the amount of chloride in a diluted sample and then adjusts the chloride to a sea water salinity on a molar basis and corrects for dilution.

The results of the salinity and moisture contents are graphically shown on the boring logs and are tabulated on the Summary of Samples on Plates B-1 through B-13. The Summary of Samples also shows measured dry densities, strength tests, organic contents, specific gravity and classification test results. Results of the Atterberg Limit tests are shown on Plate B-14, and the results of the particle size analysis are shown on Plates B-15 through B-27. The results of the compaction curve and the maximum and minimum dry densities of the bulk samples from the material site are shown on Plate B-28 along with the particle size distribution for the tested samples.

Secondary testing was performed by ATL and included triaxial shear strength and consolidation tests of unfrozen samples. Thaw consolidation tests had been performed on frozen samples during last year's exploration, but no suitable samples were obtained this year. Both unconsolidated, undrained triaxial tests (TXUU) and consolidated, drained triaxial tests (TXCD) were performed. The results of the strength testing are summarized in the Summary of Samples in Appendix B. Laboratory data for the triaxial strength testing are presented in Appendix C. One dimensional consolidation tests were performed on unfrozen fine grain soils; the laboratory data sheets are presented in Appendix D.

Non standardized testing included three procedures. To provide a lower bound estimate of the backfill material's weight above the pipeline, remolded consolidation tests were performed by ATL. Seven individual samples from the top ten feet of the offshore borings were tested (3 samples from the 1997 borings and 4 from this year's samples). Also four additional tests were performed on composite samples that were mixes of materials averaging the soil types through the depth of the trench. Each of the samples was mixed to a consistency wet of the liquid limit and placed into a 2.87-inch inside diameter by 4-inch high mold. The consistency of the samples was on the order of thick batter.

After letting the sample sit for at least two days with it's top covered to prevent moisture loss, the bottom two-inch high portion of the sample was cut and placed in a consolidometer. The sample was then loaded in steps to about 70 psf, 170 psf and 380 psf and then unloaded to 70 psf and then disassembled. Time rates of deflections were measured for each load increment.

All of the data were interpreted using the following steps. The initial height of sample less the final measured deflection gives the final height of sample. The total weight of solids at the end of the test and diameter and final height of sample result in a final dry unit weight. Intermediate dry weights are calculated for each height of sample. The final moisture content is taken as a given. The specific gravity is adjusted so that the final saturation is near 100%. This seems appropriate because of the wide range of organic content in the shallow offshore materials. Then all of the intervening moisture contents and total and buoyant weights are calculated assuming saturation. The buoyant weights are calculated by subtracting the unit weight of seawater (64 pcf) from the calculated total weights. The results of these tests are presented in Appendix E.

R&M Consultants performed two other specialized tests. Samples from the material site were tested for moisture retention. This test estimates the moisture content that a gravel fill will retain after it is saturated and then allowed to drain from its base. This value is useful for the thermal analysis of gravel fills above the water table. A sample of the sandy gravel is compacted at a moisture content near optimum in a 1/10th cubic foot mold to a density of about 95% of the maximum value. The sample is soaked overnight and then is allowed to drain but not to dry on its surface. The sample is weighed at regular intervals over several days until the weight becomes constant and then the moisture content is measured. The moisture retention tests are summarized below.

Moisture Retention Test Results

Boring	Depth	Drained Moisture Content
D-22	12 ft.	4.5%
D-23	12 ft.	4.4%
D-24	27 ft.	4.3%

The third non-standard test is a sedimentation test. Samples of the material from the material site were mixed with sea water in a 500 cc graduated cylinder and then the time for the sand and silt fractions to settle out was measured and photographically documented. Test results are presented in Appendix E.

Ground temperatures

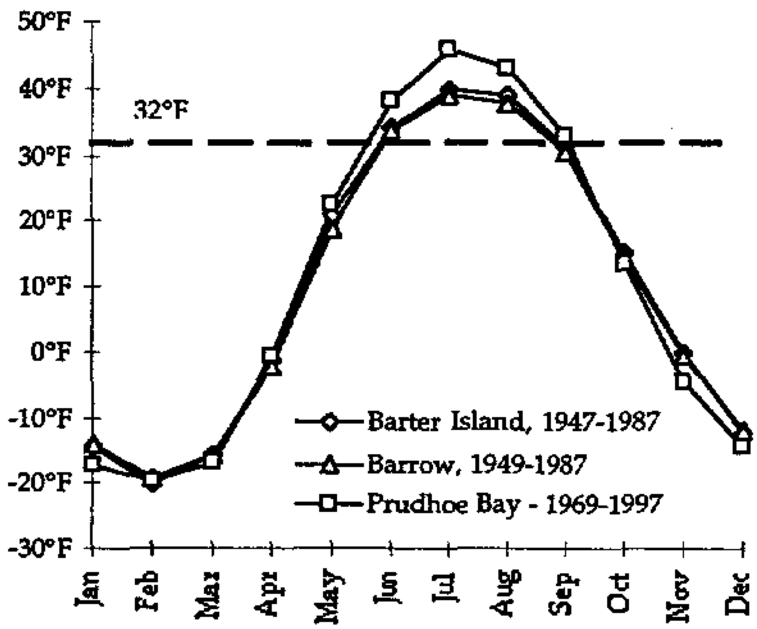
A 3/4-inch diameter pipe was installed in eight borings to allow for the later measurement of ground temperatures: two pipes at the island site and six pipes along the shoreline crossing. Mike Hendee of DM&A returned to the sites on April 24, about one month after the drilling was completed and obtained ground temperature readings in six of the pipes. The pipe in Boring D-3 was blocked by ice. He also was able to obtain a set of readings in the pipe in Boring B-1 drilled last year on the tundra above the beachline.

Multiconductor cables with thermistor beads mounted at various intervals were used to obtain ground temperature readings. For each set of readings the thermistor cable was inserted in the pipe and left to stabilize for at least 45 minutes before the readings were obtained. A 4-1/2 digit multimeter was used to obtain the resistance of each thermistor. The measured temperatures are tabulated and graphically presented in Appendix F.

SITE and SUBSURFACE CONDITIONS

Climate

The project area has an arctic coastal climate. The mean annual temperature is 9 °F. Precipitation is light with most occurring during the short summer season and the fall. Wind is generally from the northeast (N 70° E is the average dominant direction), but strong westerly and southwesterly winds can occur during storms. The adjacent plot of mean monthly temperatures for Barrow (1947 through 1987) and Barter Island (1949 through 1987) show that the temperatures along the coastline do not vary much over the 300 miles that separate the two villages. Inland locations tend to have more sunshine, less fog and higher summer temperatures. The temperatures shown for Prudhoe Bay are warmer in the summer than either of the two coastal villages, but the difference could also be due to the difference in the period of record.



Geologic setting

Foggy Island Bay is located on the northern edge of the physiographic province known as the Arctic Coastal Plain (Wharhaftig, 1965). The Arctic Coastal Plain is typified by gentle topography, ice bonded permafrost soils, wet tundra, wind-oriented thaw lakes, and braided and beaded stream channels. The coastal plain slopes gently northward to elevations of only a few feet above sea level at the shore of the Beaufort Sea.

The Foggy Island Bay shoreline is formed by a series of river deltas separated by an eroding coastline. The active delta of the east fork of the

Sagavanirktok River forms the western edge of Foggy Island Bay. The Kadleroshilik and Shaviovik Rivers cross the coastal plain and discharge into the bay from the south. Tigvariak Island, an erosional remnant of onshore tundra, forms the eastern limits of Foggy Island Bay.

The ice-rich sediments beneath the onshore coastal plain subside significantly if they thaw (thermokarst collapse). Thermal erosion of the coastline occurs as wave action undercuts the ice-rich organic and silt deposits and blocks of tundra topped peat and icy silt collapse onto the beach (thermo-erosional niching). Thermal erosion is reported to be about three meters per year between Heald Point of the Sagavanirktok River delta and Tigvariak Island (Hopkins and Hartz, 1978). In the surf zone, the peat blocks are subject to further destruction by wave and ice processes. Therefore, it is believed that offshore archaeological remains would be totally or partially destroyed and difficult or impossible to recognize.

The offshore Holocene soils in Foggy Island Bay include beach, delta, lagoon, marine and shoal deposits, along with the Flaxman Lag, the "boulder patch". Pleistocene soils include the Flaxman formation and marine, beach and alluvial deposits. In the borings drilled for this exploration, the offshore Holocene sediments generally consisted of lagoonal and deltaic deposits (silt and organic silts) with some sandier beach and shoal deposits. In the deeper water, a Holocene marine sediment is present. The Holocene sediments are generally thin and are sometimes missing. The Flaxman Lag (the material that forms the "boulder patch" environment) was not found in any of the 1997 or 1998 borings.

The uppermost layer of the Pleistocene deposits, the stiff plastic silt and clay is present under much of the deeper offshore area and is part of the Flaxman formation, a marine unit probably deposited about 70,000 years ago. A beach deposit of sand and gravelly sand is found at the base of the marine unit and is in turn underlain by alluvial sand and gravel deposited as glacial outwash.

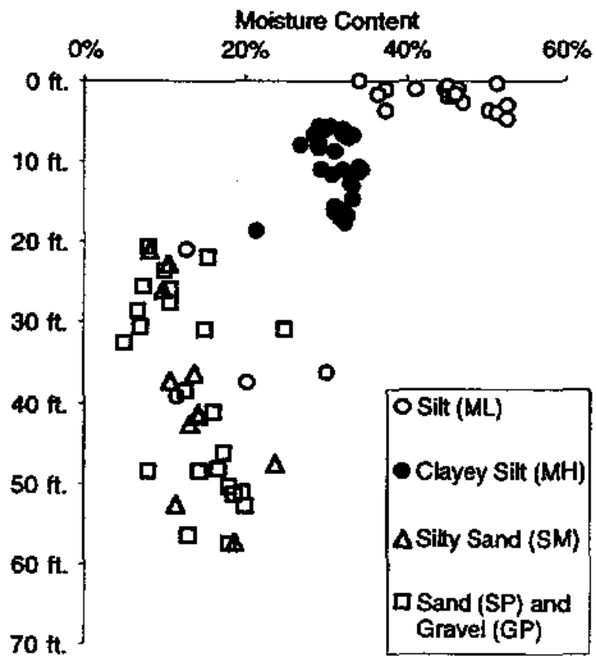
Where the Pleistocene marine deposits outcrop on the sea floor, they are often composed of overconsolidated, stiff to very stiff silt or clay. At Tigvariak Island and along other parts of the coast, scattered gravel, cobbles and boulders are incorporated within the marine deposits. The boulders, commonly called Flaxman boulders, are characterized by mineral constituents foreign to the geology of Alaska. Some of the rock has been traced to bedrock in the Canadian shield. It is believed that the Flaxman boulders represent glacial dropstones which were ice rafted to their present locations during an interglacial period of elevated sea level. As the grounded ice bergs rotted in place, the cobbles and boulders dropped to the seafloor and were then buried in fine grained marine deposits. When the fine-grained marine sediments are eroded away, the coarse material of the Flaxman formation remains as a lag deposit of cobbles and boulders and forms the "boulder patch" environments. However, unless the location is an erosional setting, the surface boulders and cobbles associated with the Flaxman Lag should not be present. At all of the borings drilled at the island and along the pipeline, the Flaxman formation was blanketed by soft Holocene soils.

Subsurface conditions at the island

The soils at the island can be divided into three primary layers: the upper Holocene non-plastic silt, the intermediate Pleistocene clayey silt and the underlying granular sand and gravel. As shown in the following table that summarizes the conditions found at the island, additional layers of silty and organic material are interbedded at some locations in the deeper sand and gravel.

Summary of the holes drilled at the Island

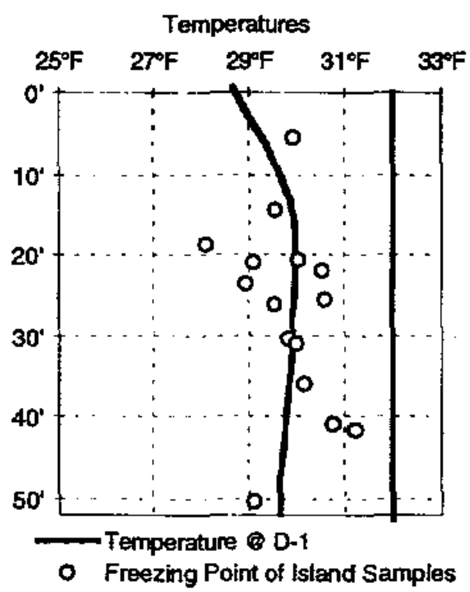
Boring	Soil Conditions (depths are in feet below seafloor)
D-1	0-4 soft SILT (ML) 4-18 stiff Clayey SILT (MH), 18-52 loose to medium dense Sandy GRAVEL (GP)
D-2	0-4.5 soft SILT (ML), 4.5-20 stiff Clayey SILT (MH), 20-23.5 Silty SAND (SM) w/ stiff Organic SILT (OL), 23.5-57.5 medium dense Silty Gravelly SAND (SM)
D-3	0-6 soft SILT (ML), 5-19 stiff Clayey SILT (MH), 19-53 medium dense SAND (SP) w/ some Gravel
D-4	0-5 soft SILT (ML), 5-21.5 stiff Clayey SILT (MH), 21.5-23 stiff Organic SILT (OL), 23-50 medium dense SAND (SP) and Sandy GRAVEL (GP)
D-5	0-5.5 soft SILT (ML), 5.5-20 stiff Clayey SILT (MH), 20-25.5 medium dense Silty SAND (SM), 25.5-37 medium dense Sandy GRAVEL (GP), 37-42 very stiff Sandy SILT (ML), 42-74 medium dense Gravelly SAND (SP) AND SANDY GRAVEL (GP)



The moisture content of the various materials at the island are shown in the adjacent plot by depth and soil type. The near surface silt is the only material with a relatively high moisture content.

Ground temperatures show that the soils are below 32° F., however, because of pore water salinity, the presence of ice bonded soils is not prevalent. The Pleistocene silty clay and underlying sand and gravel are believed to have been hard frozen during a low sea level stand when the materials were exposed to subaerial conditions. As the sea level rose during the end of the last ice age, the materials were warmed by the sea water to a temperature near the freezing point of sea water. Salt diffused into the soil and depressed the freezing point allowing much of the ice in the soil to degrade.

Frozen ground was found in three of the borings (D-2, D-4 and D-5) at the island at depths of about 21 to 25 feet. The frozen material consisted of ice bonded sand immediately below the stiff clayey silt layer. No visible ice was observed, but the consistency of the material notably changed when the samples were allowed to warm in the drill enclosure. The marginally frozen layers were only a couple of feet thick.



The adjacent plot, compares the freezing point of the soils beneath the island location with the temperatures measured in Boring D-1. The freezing point is assumed to be linearly related to the measured salinity of the pore fluid (0.1° F freezing point depression per 1 ppt salinity). The slightly lower salinities with depth suggest that the ground is cold enough to be partially frozen in the sand and gravel deposit. However, sampling blow counts in the sand and gravel were generally low to moderate and indicate that little if any frost bonding is actually present.

Subsurface conditions along the pipeline

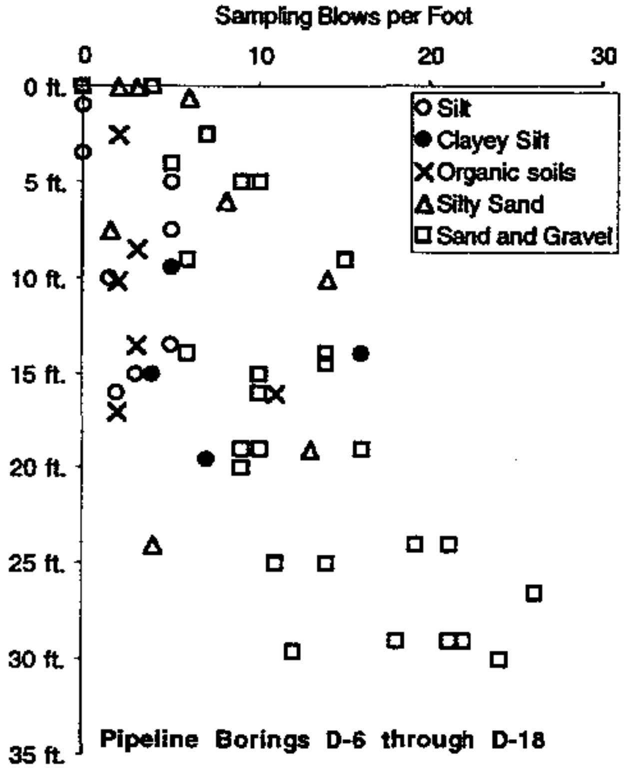
Soils along the pipeline vary from the conditions described above at the island to sand and gravel near the shoreline. The conditions are shown on the cross sections presented on Plates 3 and 4.

From the island (Station 0+00) to just south of Boring D-6 (Station 26+00), the seafloor is relatively flat and appears to be underlain by conditions similar to the island. The geophysical record suggests that the soft layer might pinch out to the south. But at Boring D-6 we still found six feet of soft silt although the layer contained more sand lenses than at the island and a 3-foot thick layer of silty sand was between the base of the silt and deeper stiff clayey silt.

From Station 26+00 to Station 158+00 the seafloor rises gently from -22 feet to -15 feet. Soil along this section consists of sand, silty sand, with some soft silt and many pockets and layers of peaty soil. An offshore shoal is at Station 73+00 and consists of a uniform fine-grained, clean sand. The shoal is 4.5 feet thick at Boring D-8 and, from the geophysical record, appears to extend along the alignment for about 1400 feet.

From Station 158+00 to Station 186+00 the seafloor rises from -15 feet to -7 feet, only a gradient of 0.3% but still a rather abrupt slope for the offshore setting. This break in slope might represent an intermediate coastline when the last major sea level rise occurred. The shoal at Station 73+00 could be a remnant from wave action occurring when the sea level was at this lower position. Boring D-12 on the slope shows silty sand interbedded with medium stiff silt to the pipe burial depth of 10 feet. Stiff silt is found below that depth and then sandy gravel at a depth of 16 feet.

From Station 186+00 to the shore transition, about Station 316+00, the sea floor rises only 3 feet. Throughout this section the dominant material is silty sand

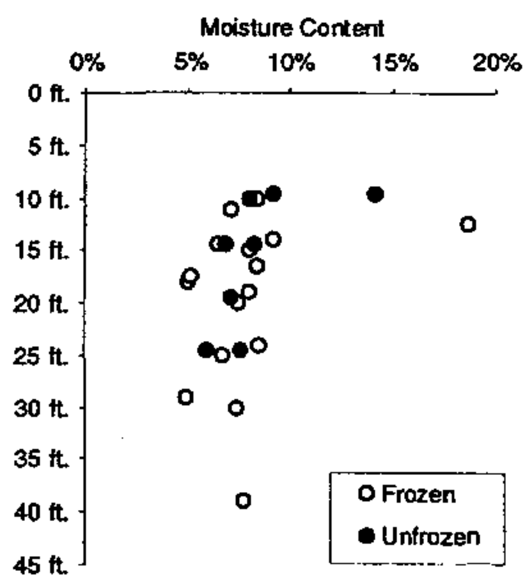


with thin interbeds of silt and thin organic rich layers. At Borings D-16 and D-17, the underlying gravelly sand is shallower than the pipe burial depth.

No frozen soils were encountered at any location along the offshore pipeline route. The deeper borings drilled in 1997 and 1998 to depths of 30 feet all showed medium dense conditions and no high blow counts that would suggest that the material beneath the alignment was ice bonded.

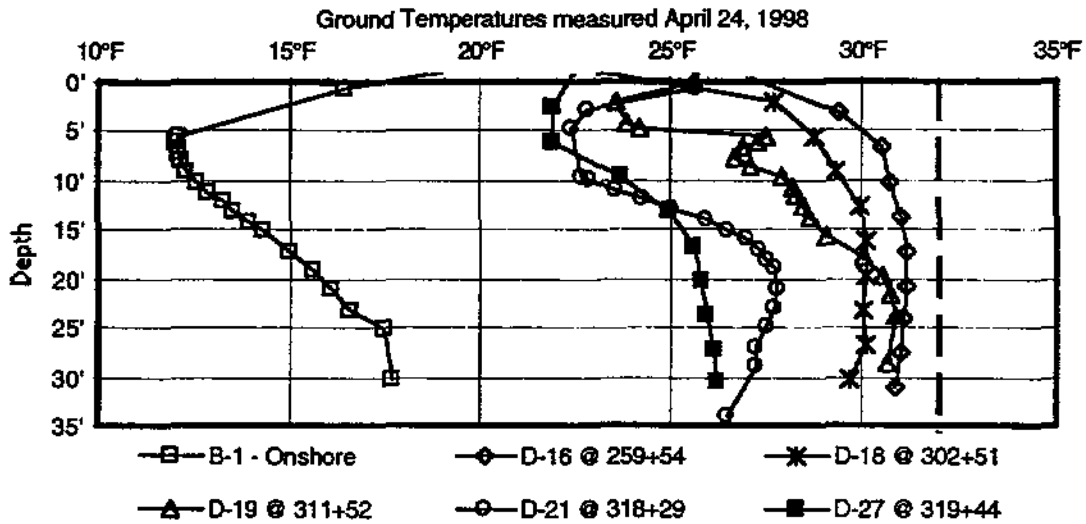
Subsurface conditions at the shoreline

Soils at the shoreline transition consist of thin surface layers of sand and soft silt with the underlying sand and gravel at shallow depths of 5 to 6 feet. Boring B-2 was drilled in 1997 on the beach and found frozen material to the full depth of the hole (31 feet). In 1998 we drilled intermediate holes starting halfway between Boring B-2 and Boring D-18 (4.4 feet of water). Relatively uniform water depths of 4.5 to 4.0 feet were found up through Boring D-21 drilled only 230 feet from the beach. The soils in Boring D-21 were frozen but only marginally so; considerable heave occurred up into the auger when sampling at several



locations. At Boring D-27 drilled where 2.7 feet of sea-ice was hard frozen to the bottom, the soil was well frozen. The chart on the preceding page compares the moisture contents for the unfrozen soil and frozen soil samples from below a depth of six feet. Except for the silty sand sample from Boring D-27 at 12.5 feet with a moisture content of 18.7%, the frozen samples have moisture contents essentially the same as the unfrozen materials. This suggests that the frozen granular materials have little if any thaw strain potential.

The ground temperatures through the transition are shown in the following plot.



Subsurface conditions onshore

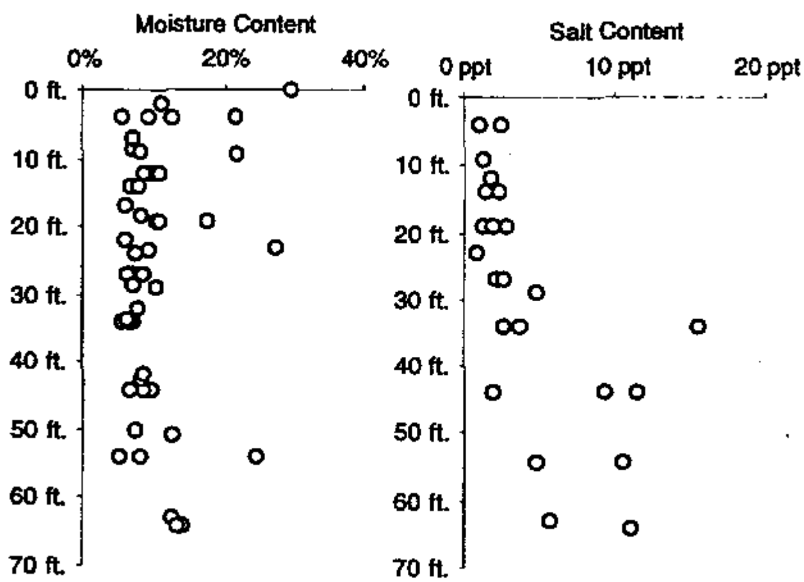
The subsurface conditions onshore are known from the 1997 drilling at Boring B-1 and B-1a and the drilling for the Badami pipeline about 1.5 miles to the south of the shoreline. Upland areas between the major river channels are underlain by fine-grained surface deposits over granular alluvial material. A typical soil profile consists of an organic surface layer over silt that in turn overlies sand and gravel/sand mixtures.

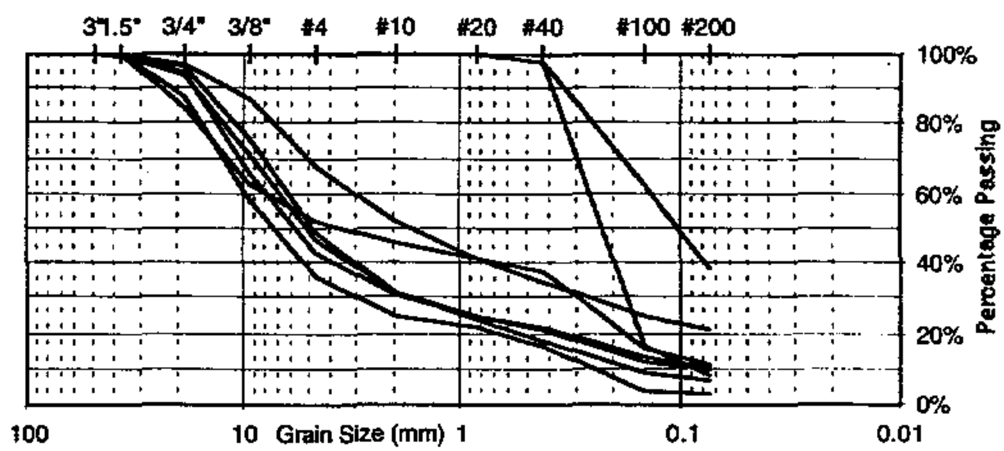
The organic surface layer varies from a few inches thick to many feet thick and is made up of the tundra mat and lake sediments that have mixed to varying degrees by frost action (cryoturbation) with the underlying mineral soil. A non-plastic silt is commonly found beneath the organic layer. The silt is underlain by sand and silty sand and mixtures of sand and gravel. The gravel content tends to increase with depth.

The upland soils are well frozen with ground temperatures considerably colder than the permafrost at the shoreline or under the river drainages. The near surface organic and silty soil is frequently ice rich. Thick (>1 ft.) layers of ground ice are sometimes present. Polygonal ground is common throughout the area so ice wedges are expected to be encountered along much of the onshore pipeline route.

Proposed material source

The material site is in the floodplain of the Kadleroshilik River. The surface cover is thin to nonexistent at the site. The underlying material consists of sand and gravel with varying amounts of fines content. The adjacent charts show the moisture contents and pore water salinity in the sand and gravel materials at the material site. The higher moisture contents are generally associated with siltier materials. As shown in the summary of all the gradations of samples from the material site, some lenses of fine-grained sand and silty sand are present.





GEOTECHNICAL PROPERTIES

The island site

The three primary layers at the island have distinctly different compressibilties and strengths. The upper Holocene non-plastic silt is soft and compressible and normally consolidated (it has only experienced the weight of the overlying sediments). The intermediate Pleistocene clayey silt is stiff to very stiff and is overconsolidated. The underlying granular sand and gravel is loose to medium dense, and the material will compress elastically, and most of the resulting settlements will occur as the load of the island is applied.

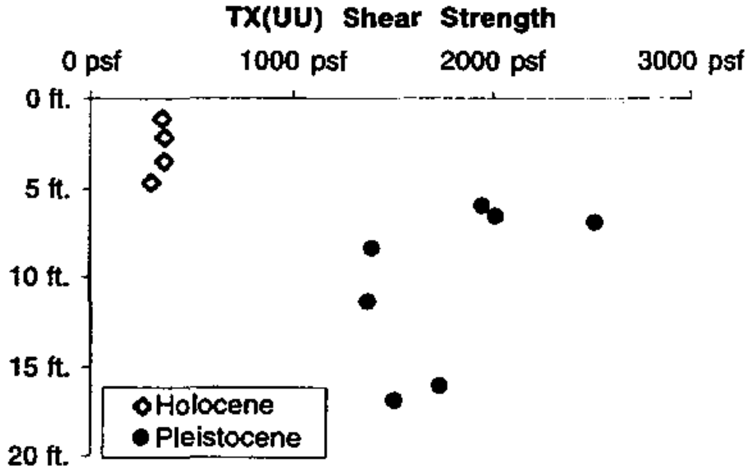
The following table summarizes the consolidation tests performed on the offshore fine grained materials and includes last year's data. "Cc" is the modified compression index, and "Cr" is the modified recompression index.

Summary of Consolidation Tests

Boring	Depth	Soil Type	Geology	Moisture	Density	"Cc"	"Cr"
D-1	1.0'	ML	Holocene	44.8%	76 pcf	0.11	0.02
D-1	5.5'	MH	Pleistocene	30.6%	93 pcf	0.11	0.03
D-1	10.8'	MH	Pleistocene	31.2%	90 pcf	0.14	0.03
D-1	15.5'	CH	Pleistocene	31.1%	90 pcf	0.14	0.03
D-2	1.6'	ML	Holocene	46.1%	74 pcf	0.12	0.01
D-2	6.5'	MH	Pleistocene	28.6%	94 pcf	0.12	0.03
D-3	11.7'	MH	Pleistocene	30.9%	91 pcf	0.12	0.02
D-3	16.5'	MH	Pleistocene	32.8%	88 pcf	0.13	0.04
D-4	4.0'	ML	Holocene	51.3%	70 pcf	0.17	0.02
D-5	3.0'	ML	Holocene	52.8%	69 pcf	0.15	0.02
D-5	8.1'	MH	Pleistocene	26.9%	96 pcf	0.09	0.03
I-1	3.0'	ML+OL	Holocene	50.9%	65 pcf	0.27	0.08
I-1	5.5'	ML	Pleistocene	29.6%	93 pcf	0.12	0.04
I-1	15.5'	MH	Pleistocene	35.0%	85 pcf	0.17	0.04
I-2	9.7'	ML	Pleistocene	28.6%	99 pcf	0.18	0.06
I-3	2.5'	ML	Holocene	28.3%	97 pcf	0.08	0.02
I-3	7.5'	MH	Pleistocene	32.4%	91 pcf	0.12	0.03
I-3	12.5'	ML	Pleistocene	36.2%	86 pcf	0.20	0.04
I-3	20.0'	ML	Pleistocene	28.2%	94 pcf	0.11	0.02
I-4	2.0'	SM	Holocene	32.0%	95 pcf	0.04	0.01
I-4	22.0'	MH	Pleistocene	28.7%	90 pcf	0.13	0.02

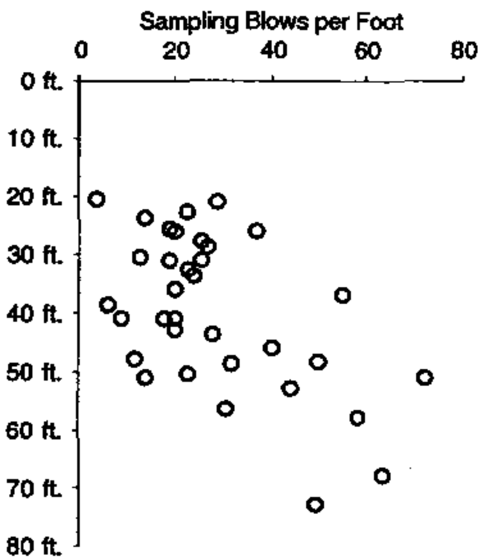
Uniaxial consolidation tests were performed on 11 "undisturbed" samples from the island site. The tested samples of Holocene material show a modified compression index, "Cc", of 0.11 to 0.17 with an average of 0.14. The overconsolidated materials associated with the Pleistocene formation show a modified recompression index, "Cr", of 0.02 to 0.04 and average 0.03.

The strength tests also show a large variation between the Holocene and Pleistocene materials. As the chart below indicates, the shallow silt is soft with an



average shear strength of only 350 psf. The TXUU tests of the Pleistocene clayey silt show shear strengths as low of 1370 psf and an average 1780 psf.

The TXCD data show similar strength envelopes for both materials. The two tests of each material each indicated an angle of internal friction of 29° to 31° and each had a cohesive intercept of 400 psf. TXCU tests reported by HLA in 1981 for the soils at nearby Tern Island show that the soft to very soft silt and organic silts have undrained shear strengths of more than 1000 psf after being consolidated with pressures of 2000 to 3000 psf.



The sampling blow counts shown in the adjacent plot are for the Sha method in the deeper sand and gravel (and silty sand) below the Pleistocene clayey silt. Based on the difference in sampler annulus and hammer weight, the blow counts probably have to be increased by 180% to be equivalent to SPT N-values. However, the increased efficiency of the automatic hammer compared with a hammer operated with rope and cathead also requires another adjustment; our experience suggests the blow counts from the automatic hammer are about 2/3s the SPT cathead value. Therefore the N-values would be 2.5 to 3 times the values shown on the logs or the adjacent plot. With this correction, most of the sand and gravel is medium dense to dense. Based on the materials similarity to the sand

and gravel found onshore, we estimate the unfrozen granular gravelly material has an insitu dry density of 125 to 135 pcf and an angle of internal friction of at least 37°.

The pipeline route

The critical soil properties along the pipeline route are the stability of the material to the depth of the trench and the density of the material when it is used as backfill over the pipe. The stability of the soils has a direct bearing on the quantity of soil that has to be excavated to construct the trench. The worst condition is the fine-grained, uniform, clean sand found at the shoal at Station 73+00. These sands are expected to flow into the trench as the material is excavated and result in very flat side slopes. However, most of the route crosses siltier mixtures of sand, and the trench walls will stand at steeper slopes.

The material from the trench will be used to backfill the pipeline. When the pipeline is operational, the heat of the product will cause the pipe to expand, and the weight of the backfill will be the primary restraint to keep the pipe from buckling upward in the trench. To evaluate the buoyant weight restraint, we tested remolded soils from discrete samples in the top ten feet of soil.

Summary of Remolded Buoyant Weight Tests

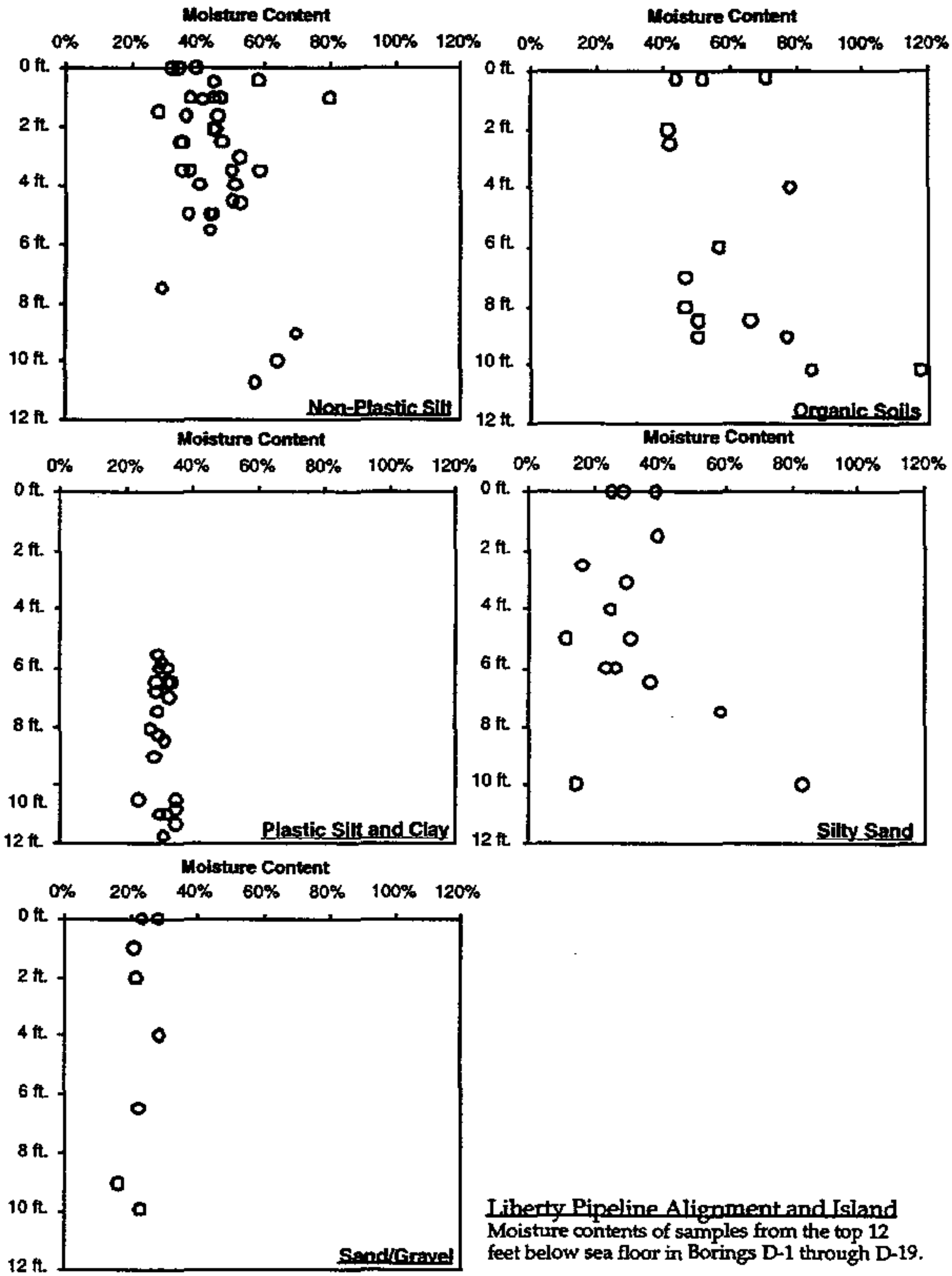
Sample	Field Moisture	Lab Buoyant wt. @ 170 psf	@ 380 psf	comments
Boring I-3 @ 7.5' - slurry	32.4%	42 pcf @ 52.0%	43 pcf	
Boring I-3 @ 7.5' - chunks	32.4%	42 pcf @ 51.6%	43 pcf	
Boring B-8 @ 2.5'	83.8%	25 pcf @ 88.6%	26 pcf	4.3% organic content
Boring D-9 @ 6'	56.6%	35 pcf @ 62.1 %	39 pcf	13 to 14% organic content
Boring D-10 @ <10'		39 pcf @ 46.3%	39 pcf	5.1% organic content
Boring D-13 @ 2.5'	41.6%	45 pcf @ 42.6%	46 pcf	4.2% organic content
Boring D-15 @ 5'	43.8%	43 pcf @ 47.5%	45 pcf	6.0% organic content
Boring D-7 @ 0' to 10'	combined	53 pcf @ 33.4 %	55 pcf	3.6% organic content
Boring D-9 @ 0' to 10'	combined	44 pcf @ 48.1%	46 pcf	7.3% organic content
Borings D-10 & D-14 @ 6' to 10'	combined	34 pcf @ 72.5%	35 pcf	10.3% organic content
Boring D-18 @ 0 to 5.5'	combined	41 pcf @ 50.0%	42 pcf	5.4 % organic content

The values from the tests are summarized in the preceding table for the intermediate consolidation load of 170 psf ± 10 psf, and for the highest load, 380 psf ± 20 psf. The samples from I-3 and B-8 (last year's borings) were used to start the testing before this year's fieldwork was completed. All of the values reflect the buoyancy of seawater (64 pcf).

The last four tests were on composite samples of the material from the top ten feet of the trench section. The combined sample from D-7 consisted of 70% silty sand from the upper portion of the hole and 30% plastic silt from the lower 3'. The combined sample from D-9 consisted of 30% silt, 10% organic silt and 60% nonplastic silt w/ peat from the lower 6'. Samples from Borings D-10 and D-14 were combined to simulate the expected proportions from a 10' trench. The combined sample consisted of 60% silty sand, 20% organic silt and peat and 20% black silt (high moisture content). The combined sample from D-18 consisted of 10% fine sand, 10% nonplastic silt and 80% mix of organic silt and silt w/ some wood fragments.

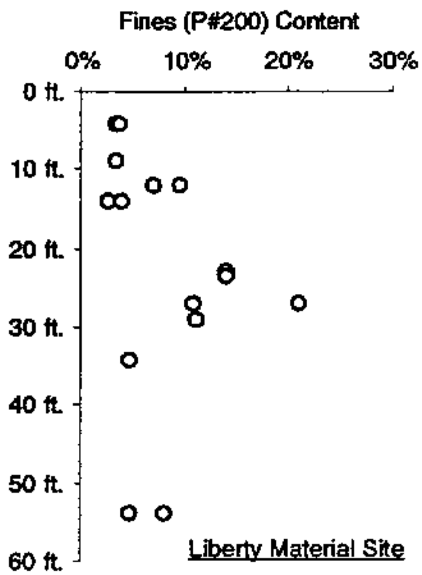
The sample from B-8 @ 2.5' represents the lowest density of the non-plastic silt. These silts from deeper water contain a diffused, amorphous organic matter that is different than the organic samples that contain fibrous material. This type of soil is related to the soft, surface layer which is less than 6 feet thick. Based on last year's data from the A and B alignments, only 5 of the 126 tested samples from the top 12 feet had moisture contents above 60% and only 2 of those samples were silts (found @ depths of 2.5 and 4.5 feet).

The moisture contents of this year's samples from the island and pipeline borings are plotted by soil type on the following page. Only one of the non-plastic silt samples has a moisture content in the 80% range (Boring D-6 @ 1') and the sample only 1.5 feet deeper had a moisture content of 35%. A high moisture content silt material (69% at a depth of 9 feet in Boring D-10) was included as part of the composite sample from Borings D-10 and D-14. That sample also included peat material. The organic samples (peats and organic silts) have high moisture contents, but as seen from the tested samples, they do not have as low a buoyant weight after consolidation as the high moisture content ooze. The weight of 25 pcf appears to be an extreme condition and not one that would occur throughout the depth of the trench at any given location.



Liberty Pipeline Alignment and Island
Moisture contents of samples from the top 12 feet below sea floor in Borings D-1 through D-19.

The material source



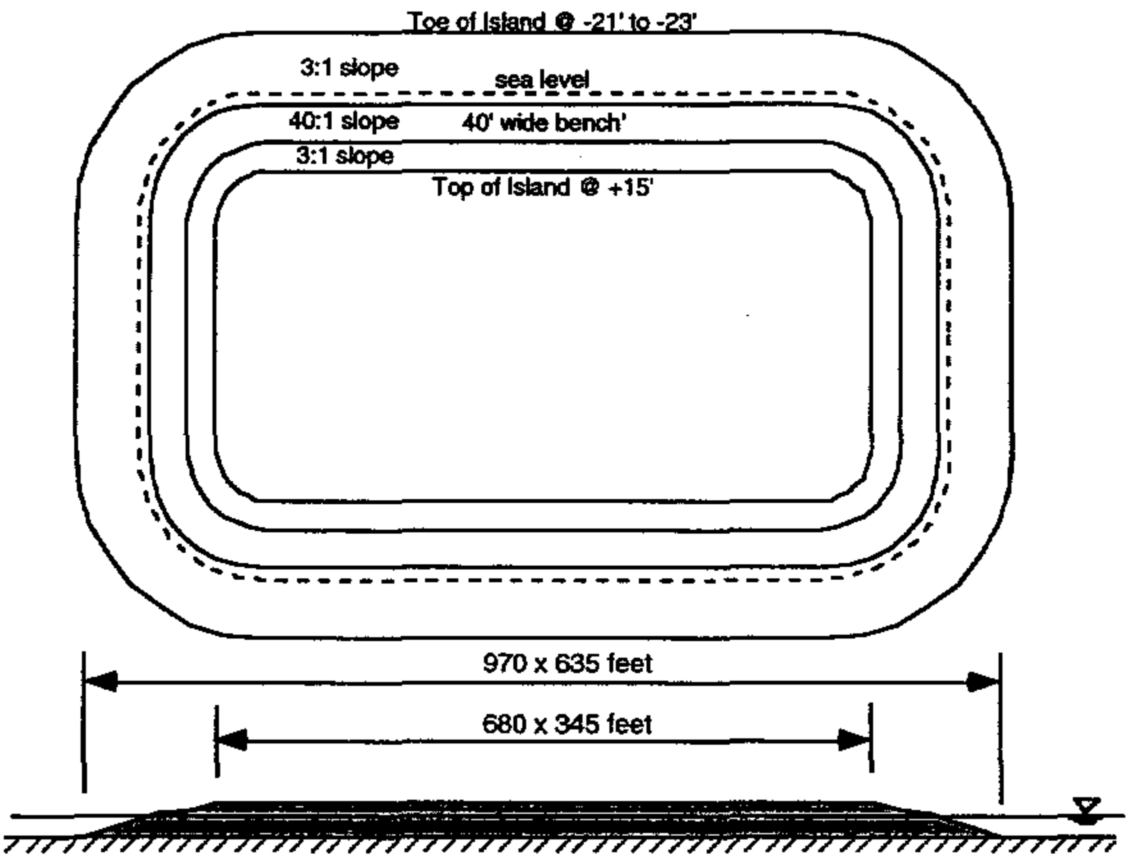
The sand and gravel from the material site has moderate amounts of silt fines (material passing the #200 sieve), but as shown in the accompanying plot, some zones are silty (>12% fines). The material has a thawed density similar to other projects completed on the North Slope. The measured maximum dry densities for the Liberty material site (see Plate B-28) vary from 140 to 143 pcf. The minimum unfrozen dry density varies from 118 to 120 pcf. For comparison the material from the Duck Island pit used to construct the Endicott project had an average maximum density of 138 pcf and a minimum dry density of 118 pcf. The material from the Kuparuk River pit used to construct Seal Island had a maximum dry density of 137 pcf and a minimum dry density of 116 pcf.

In 1981 HLA did a series of triaxial shear strength tests on remolded samples of material from the proposed pit at Shell's Site 2. The plus #4 material was removed and replaced with coarse sand and the samples were remolded at a range of relative densities from 0% to 70%, very loose to dense. The five consolidated-drained shear strength tests showed an angle of internal friction, Ø, varying from a low of 39° to a high of 42°.

ISLAND DESIGN AND PERFORMANCE

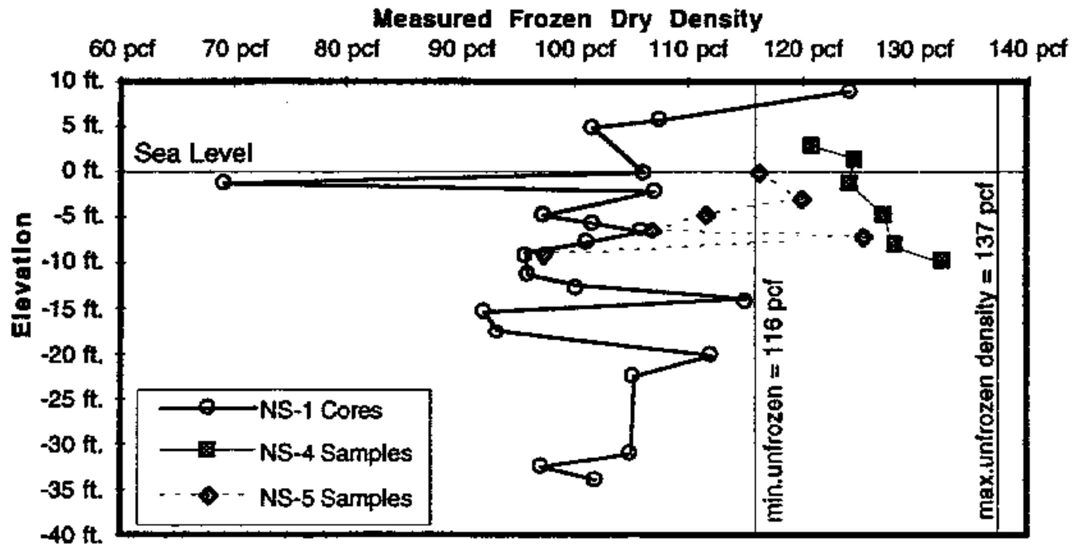
Construction of the island

The island will be constructed in the winter. Frozen gravel will be mined at the onshore material source, hauled to the island site and then dozed through holes cut in the sea ice.



When the sand and gravel fill is placed during cold winter conditions, much of the material flash freezes when it is pushed into the water. This results in dry densities lower than the minimum dry density of the unfrozen material and less infusion of sea water than if the material were unfrozen. Because of the flash freezing, the fill slopes can become quite steep during the winter construction.

During the first summer, the side slopes and the surface of the fill will thaw from warmer air and seawater temperatures. As the side slopes thaw, they will slump to an angle of repose which is strongly effected by wave action. Material will also be reworked by the contractor so that the geometry of the island is created by flattening the winter slopes to the desired 3:1 inclination with the intervening bench. Much of the reworked sand and gravel fill will also be thawed during the reshaping of the island.



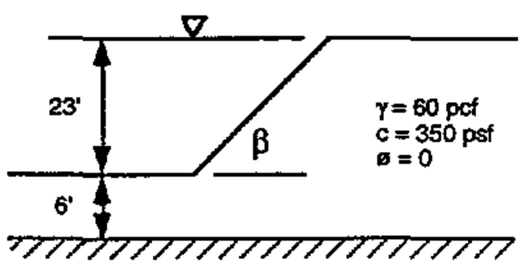
The preceding plot shows the measured densities of samples recovered from Seal Island during March and April 1997. The data provides a basis for estimating constructed densities in the island. The cores from Boring NS-1 were obtained with a CME "Continuous Core" system. The samples from NS-4 and NS-5 were larger chunk samples obtained in test pits. The densities were determined in the field by weighing the sample in air and then after sealing the surface with ice, weighing the sample when submerged in chilled diesel and using the Archmides principle to determine the volume.

Boring NS-1 was located in a location that had not been disturbed or thawed since the island was originally constructed. The lower portion of NS-5 is also in an undisturbed condition. NS-4 was dug in fill that had been reworked during the decommissioning work when the erosion control gravel bags were removed from the island during the summer.

Slope stability of the island

The steep slopes resulting from the winter construction of the island will be the most critical slope stability condition. If the slopes were to fail, the result would be a displacement of the five to six-foot thick soft silt and would result in a local area of thicker fill. Such a failure would not impair the function or performance of the island but would require more fill material for construction of the island. The failure would occur during construction so the need for additional material would be obvious when material could still be hauled over the ice road.

For an initial evaluation of the slope stability of the steep winter slopes we have used the Janbu chart solution. This method is conservative since it assumes the strength of the soil in the slope is the same as the material under the slope.



With an average shear strength of 350 psf in the 5 to 6 feet of material immediately beneath the fill and with the fill placed to the level of the ocean, a slope of 0.75 H to 1 V ($\beta < 53°$) will have a factor of safety of greater than 1.5.

If the fill was placed to the full height of the island at this same steep slope the underlying soft layer would probably fail. Therefore, the island can be constructed with the steep slopes up to sea level, but the portion of the fill placed above sea level should be constructed behind a bench at least 30 feet wide between the toe of the higher fill and the top of the steeper, below water slope.

After the fill has been in place and consolidated the underlying soft layer, the base will gain strength and the factor of safety will increase. As shown by the HLA TXCU testing at Tern in 1981, the consolidated silt and organic silt will have an undrained shear strength of at least 1000 psf. Flattening the slopes during the summer after winter construction will also increase the factor of safety.

<u>Settlement of the island</u>

Settlement of the island will result from four main causes: 1) consolidation of the fine grained soil under the weight of the island, 2) elastic compression of the deeper granular soils, 3) thaw settlement of frozen fill, and 4) creep settlement of frozen fill.

Both the Holocene and Pleistocene silts beneath the island will contribute to the settlement from consolidation. For the Holocene sediments we have used a compression ratio, "Cr", of 0.14. For the overconsolidated Pleistocene clayey silt a recompression ratio of 0.03 was used for the analysis. With the full weight of the island, the settlement due to consolidation will be about 12 inches from the Holocene layer and an additional 6 inches from the Pleistocene clayey silt.

Elastic compression of the underlying sand and gravel will add a few inches to the settlement of the fill but it will not be noticed since it will occur essentially as the fill load is applied.

Thaw settlement of frozen fill will be the most obvious of the settlements. When the fill is placed in the winter it will have a dry density similar to the material at Seal Island, about 105 pcf when frozen. Based on tests performed for the design of the Endicott project, we estimate that when the material thaws it will collapse about 10%. This would result in 6 inches of thaw settlement per 5 feet of thaw. For the surface materials that thaw during the summer, much of it will also be subjected to wheel loads or to water pulses from wave action, both of which will cause further compaction. Consequently, we conclude that a foot of thaw settlement should be assumed for the first year of summer thaw.

Thaw settlement in the area effected by the line of production wells will extend through the full thickness of the island, a total thickness of almost 40 feet (23 feet of water + 15 feet of freeboard + 1.5 feet of consolidation). Thaw settlement in the area of the producing wells will be on the order of 4 feet. With vibratory loads, the total could increase to 6 feet or more.

Creep settlement of frozen fill will occur at a small rate but probably on a continuing basis for the life of the island. At Tern Island, creep settlements of up to 3 inches were measured in the first year after construction. Long term creep rates are expected to be fractions of an inch per year. An evaluation of creep settlement is currently being made for the project by Sandwell, Inc.

<u>Geotechnical monitoring of the island</u>

The geotechnical performance of the island should be monitored. The monitoring program should include periodic level surveys of surface marks and footings so that the total amount and rate of settlement can be determined. The distribution of settlement within and under the island should be determined using a Sondex® system or multi-position borehole extensometers (MPBX).

Ground temperatures through the island and into the seafloor should also be measured at representative locations to determine the extent and rate of warming and thaw caused by the production wells.

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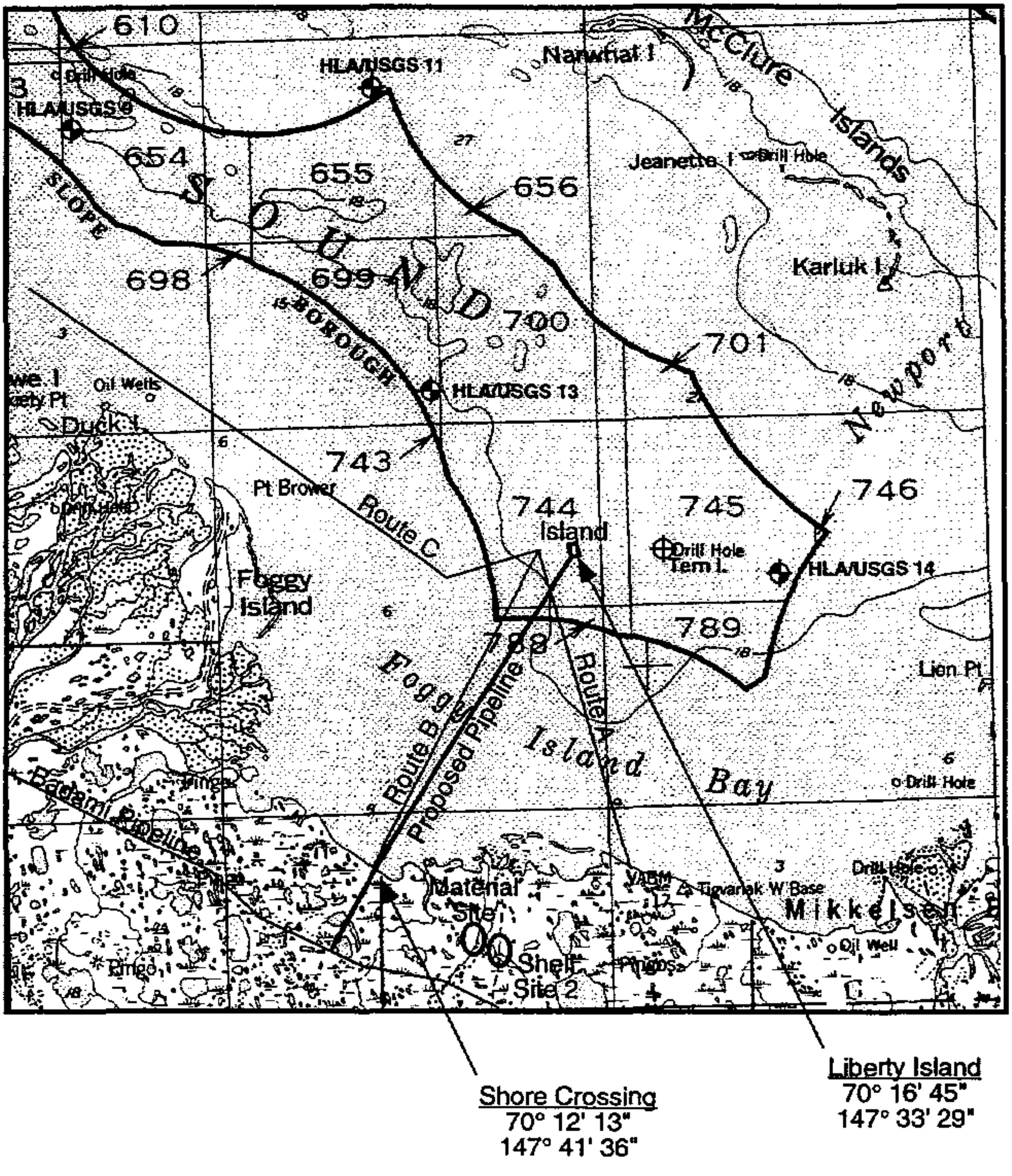
ILLUSTRATIONS

Plate 1	Vicinity Map
Plate 2	Boring Locations at the Island
Plates 3 and 4	Pipeline Boring Locations and Cross Section
Plate 5	Boring Locations at Material Site
Plates 6 and 7	Summary of Borings

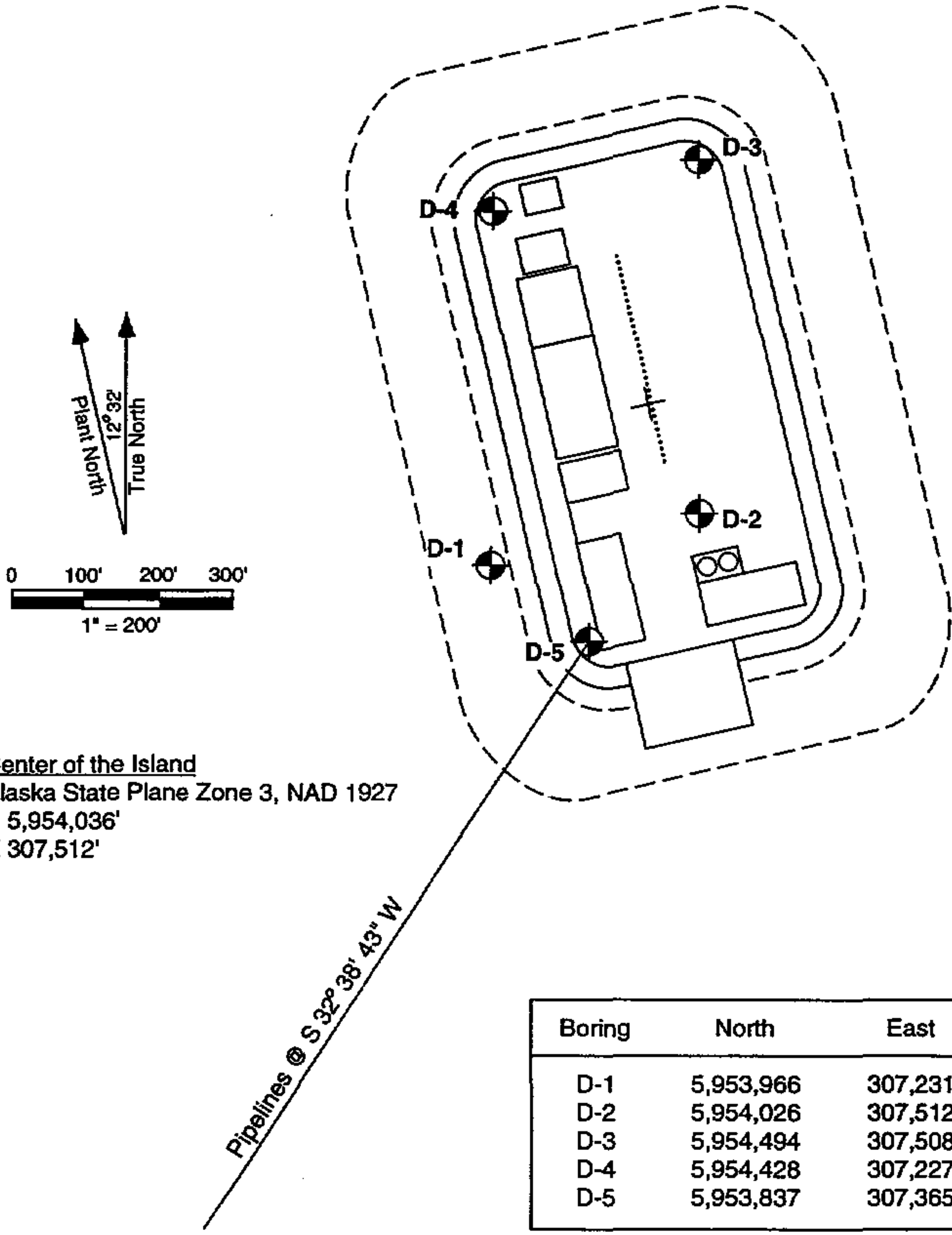


Scale : 1" = 2.5 miles

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date: July 1998

LOCATION MAP
Liberty Development
Foggy Island Bay, Alaska

Plate
1



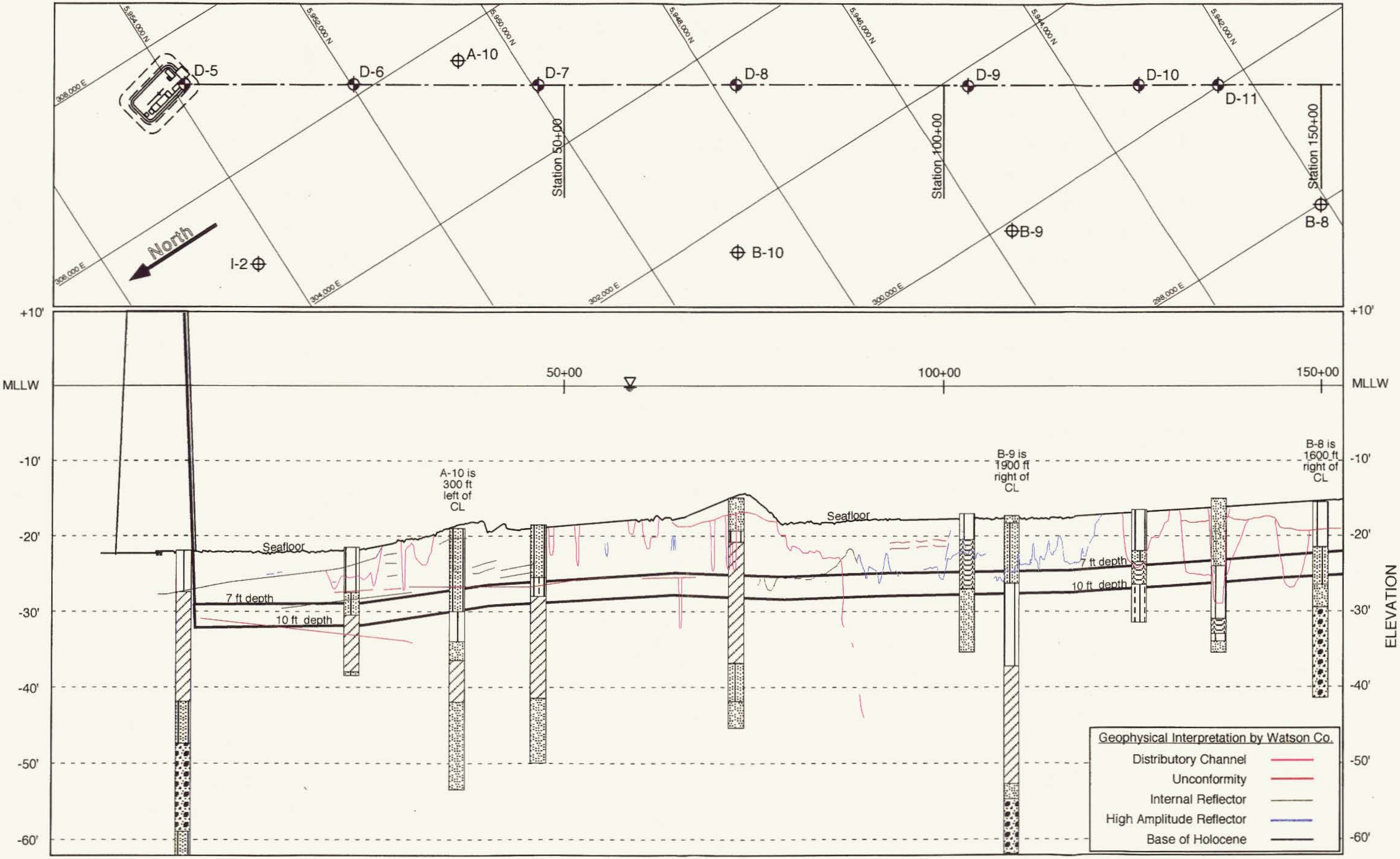
Center of the Island
Alaska State Plane Zone 3, NAD 1927
N 5,954,036'
E 307,512'

Boring	North	East
D-1	5,953,966	307,231
D-2	5,954,026	307,512
D-3	5,954,494	307,508
D-4	5,954,428	307,227
D-5	5,953,837	307,365

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date : July 1998

BORING LOCATIONS
Liberty Island
Foggy Island Bay, Alaska

Plate
2



Symbols

Stiff Clayey Silt | Sand | Sandy Gravel | Organic Silt
Soft Silt | Silty Sand/ Sandy Silt | Silty Gravel | Peat

Horizontal Scale 1" = 1200'

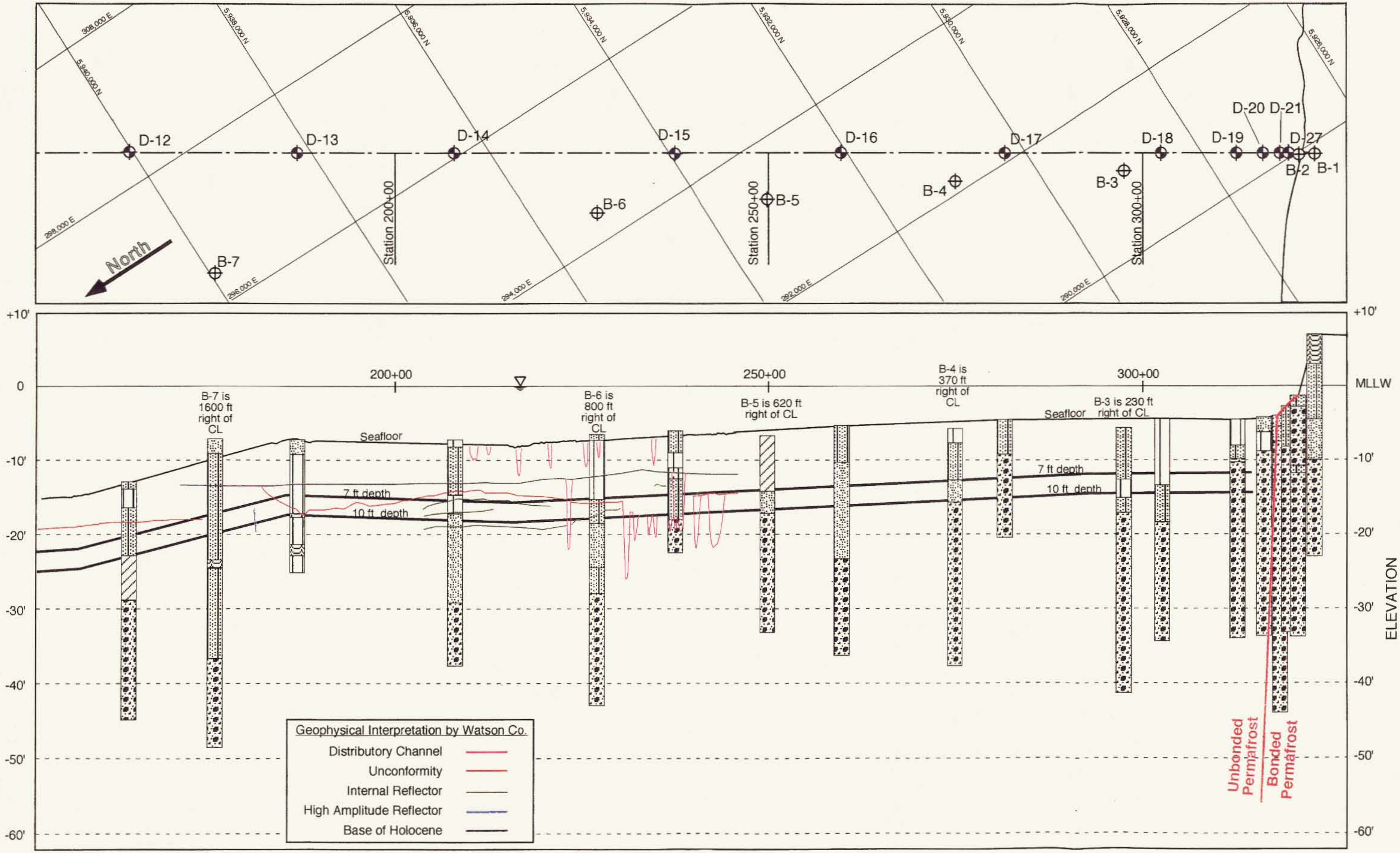
0 600' 1200' 1800' 2400'

Vertical to Horizontal is 1:100

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date : May 1998

Boring Locations and Cross Section (1 of 2)
Liberty Development
Foggy Island Bay, Alaska

Plate
3



Symbols

Stiff Clayey Silt | Sand | Sandy Gravel | Organic Silt
Soft Silt | Silty Sand/ Sandy Silt | Silty Gravel | Peat

Horizontal Scale 1" = 1200'

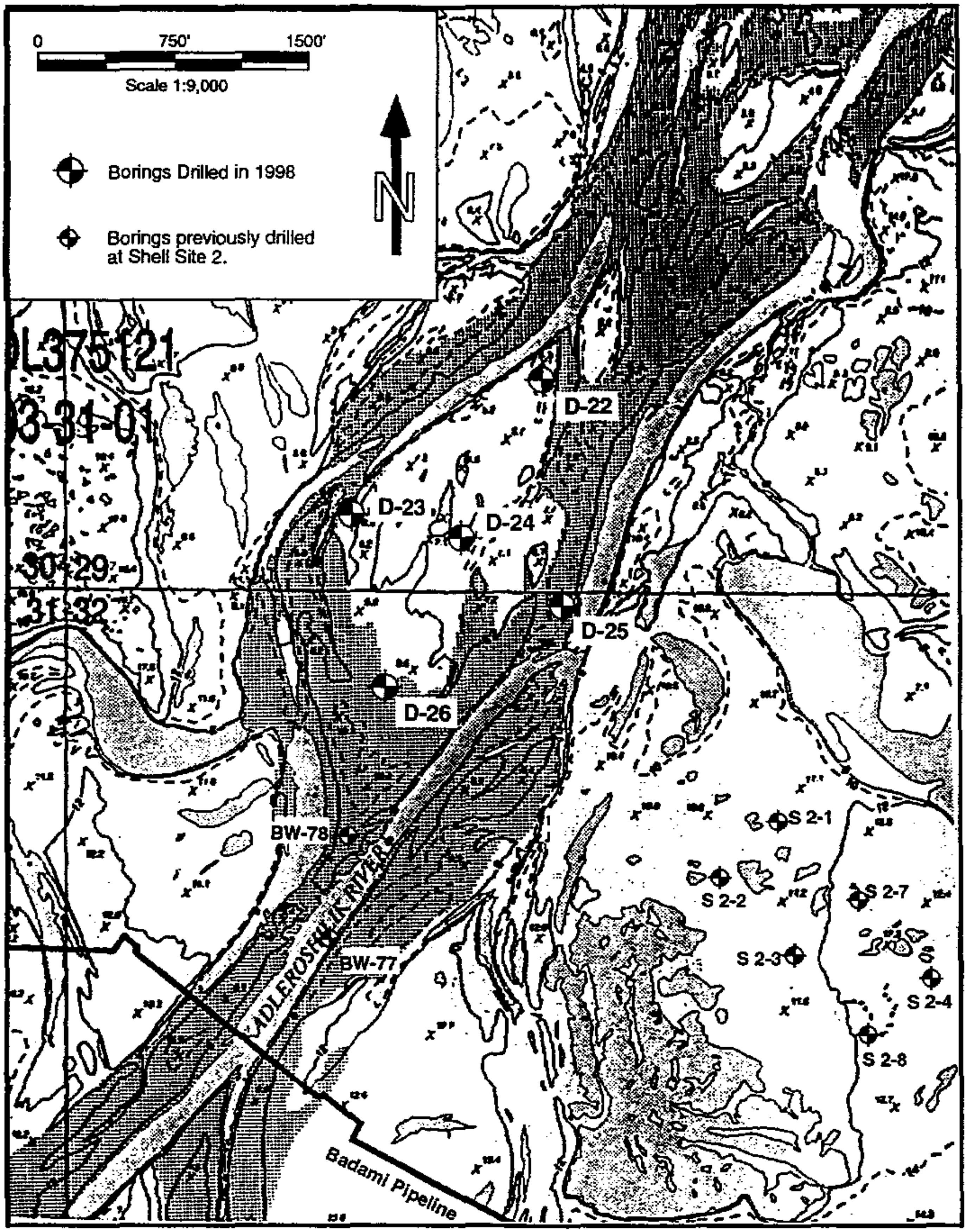
0 600' 1200' 1800' 2400'

Vertical to Horizontal is 1:100

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date : May 1998

Boring Locations and Cross Section (2 of 2)
Liberty Development
Foggy Island Bay, Alaska

Plate
4



Reference : Liberty Planning Map by BPXA, dated January 1997

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Arctic & Geotechnical Engineering
Job No.: 4119.23
Date: July 1998

MATERIAL SITE BORING LOCATIONS
Liberty Development
Foggy Island Bay, Alaska

Plate
5

Bor. No.	Location of hole	Pipe Station	Date of Drilling	As-drilled ASP Zone 3 Easting	As-drilled ASP Zone 3 Northing	Water Depth	Total Depth*	Pipe	Total Pipe	Bonded Perma-frost	Depth to Frozen
D-1	Island		3/19/98	307,231'	5,953,966'	22.7'	52.0'	Y	75'	ne	ne
D-2	Island		3/19/98	307,370'	5,954,036'	23.0'	57.5'	N		marginal	21'-22'
D-3	Island		3/19/98	307,508'	5,954,494'	21.6'	53.0'	Y	75'	ne	ne
D-4	Island		3/20/98	307,227'	5,954,428'	22.3'	50.0'	N		marginal	21.5'-23'
D-5	Island and Pipeline Riser	0+00	3/20/98	307,364'	5,953,838'	22.0'	74.0'	N		marginal	22'-25'
D-6	Pipeline	22+21	3/20/98	306,137'	5,951,973'	21.5'	17.0'	N		ne	ne
D-7	Pipeline	46+51	3/21/98	304,822'	5,949,930'	18.5'	31.5'	N		ne	ne
D-8	Pipeline	72+70	3/21/98	303,399'	5,947,719'	14.9'	30.5'	N		ne	ne
D-9	Pipeline	103+18	3/21/98	301,760'	5,945,160'	17.0'	17.0'	N		ne	ne
D-10	Pipeline	125+88	3/21/98	300,524'	5,943,265'	16.5'	15.0'	N		ne	ne
D-11	Pipeline	136+39	3/21/98	299,951'	5,942,376'	15.0'	20.5'	N		ne	ne
D-12	Pipeline	165+32	3/21/98	298,389'	5,939,929'	12.9'	32.0'	N		ne	ne
D-13	Pipeline	187+76	3/22/98	297,180'	5,938,050'	7.2'	18.0'	N		ne	ne

Bor. No.	Location of hole	Pipe Station	Date of Drilling	As-drilled ASP Zone 3 Easting	As-drilled ASP Zone 3 Northing	Water Depth	Total Depth*	Pipe	Total Pipe	Bonded Perma-frost	Depth to Frozen
D-14	Pipeline	207+87	3/22/98	296,078'	5,936,367'	7.2'	30.5'	N		ne	ne
D-15	Pipeline	237+27	3/22/98	294,480'	5,933,900'	6.0'	16.5'	N		ne	ne
D-16	Pipeline	259+54	3/24/98	293,273'	5,932,037'	5.3'	31.0'	Y	37'	ne	ne
D-17	Pipeline	281+32	3/26/98	292,093'	5,930,207'	4.5'	16.8'	N		ne	ne
D-18	Pipeline	302+51	3/26/98	290,954'	5,928,424'	4.4'	30.0'	Y	33'	ne	ne
D-19	Shore Crossing	311+52	3/26/98	290,451'	5,927,664'	4.5'	29.5'	Y	32'	ne	ne
D-20	Shore Crossing	316+03	3/26/98	290,204'	5,927,286'	4.2'	29.5'	Y	34'	ne	ne
D-21	Shore Crossing	318+29	3/26/98	290,083'	5,927,097'	4.0'	39.7'	Y	44'	yes	9.5'
D-22	Material Site		3/22/98	298,554'	5,921,056'	onshore	64.7'	N		yes	0.0'
D-23	Material Site		3/22/98	297,510'	5,920,350'	onshore	50.4'	N		yes	0.0'
D-24	Material Site		3/23/98	298,100'	5,920,226'	onshore	64.5'	N		yes	0.0'
D-25	Material Site		3/23/98	298,680'	5,919,850'	onshore	51.5'	N		yes	0.0'
D-26	Material Site		3/23/98	297,671'	5,919,409'	onshore	63.0'	N		yes	0.0'
D-27	Shore Crossing	319+44	3/26/98	290,029'	5,927,000'	2.7'	30.5'	Y	33'	yes	0.0'

* Total depth is below the seafloor, ne = not encountered

APPENDIX A

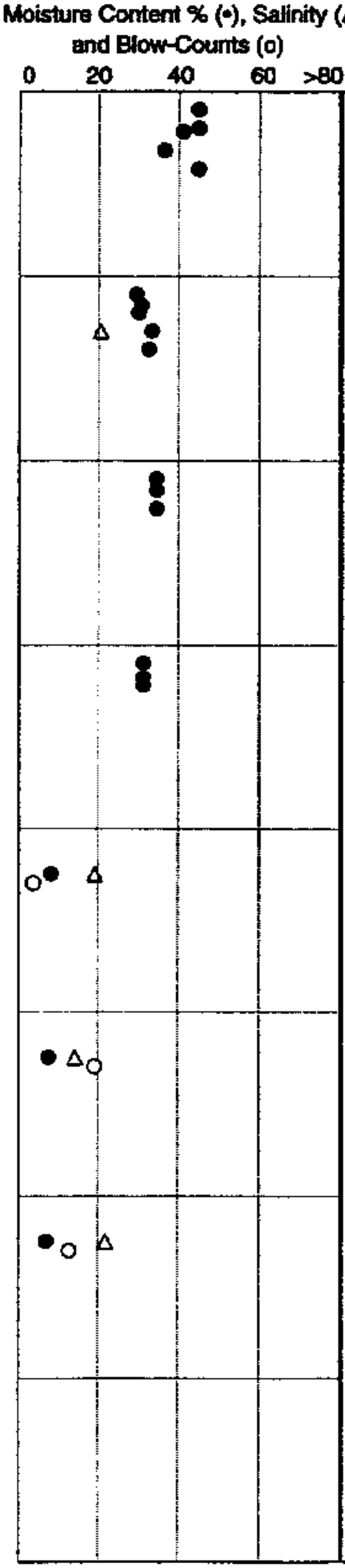
APPENDIX A - Logs of Borings

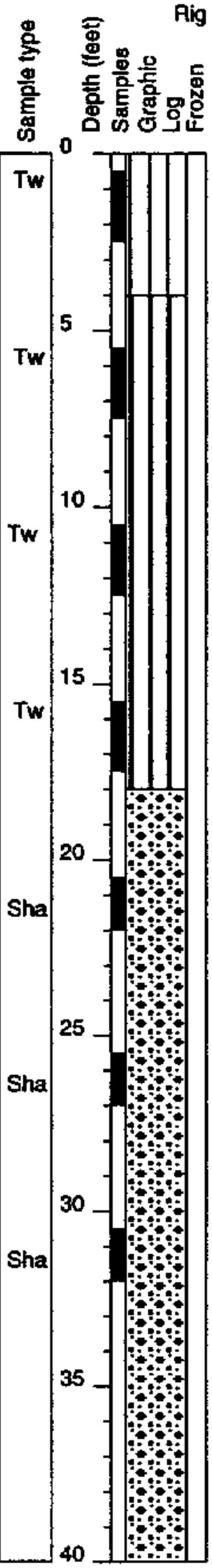
DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No. : 4119.23
Logged By: W. Phillips, P.G.

Log of HOLE : D-1

Date Drilled: March 19, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 22.7' Ice Thickness: 4.2'
Elevation: --
307,231'E 5,953,966'N (ASP)





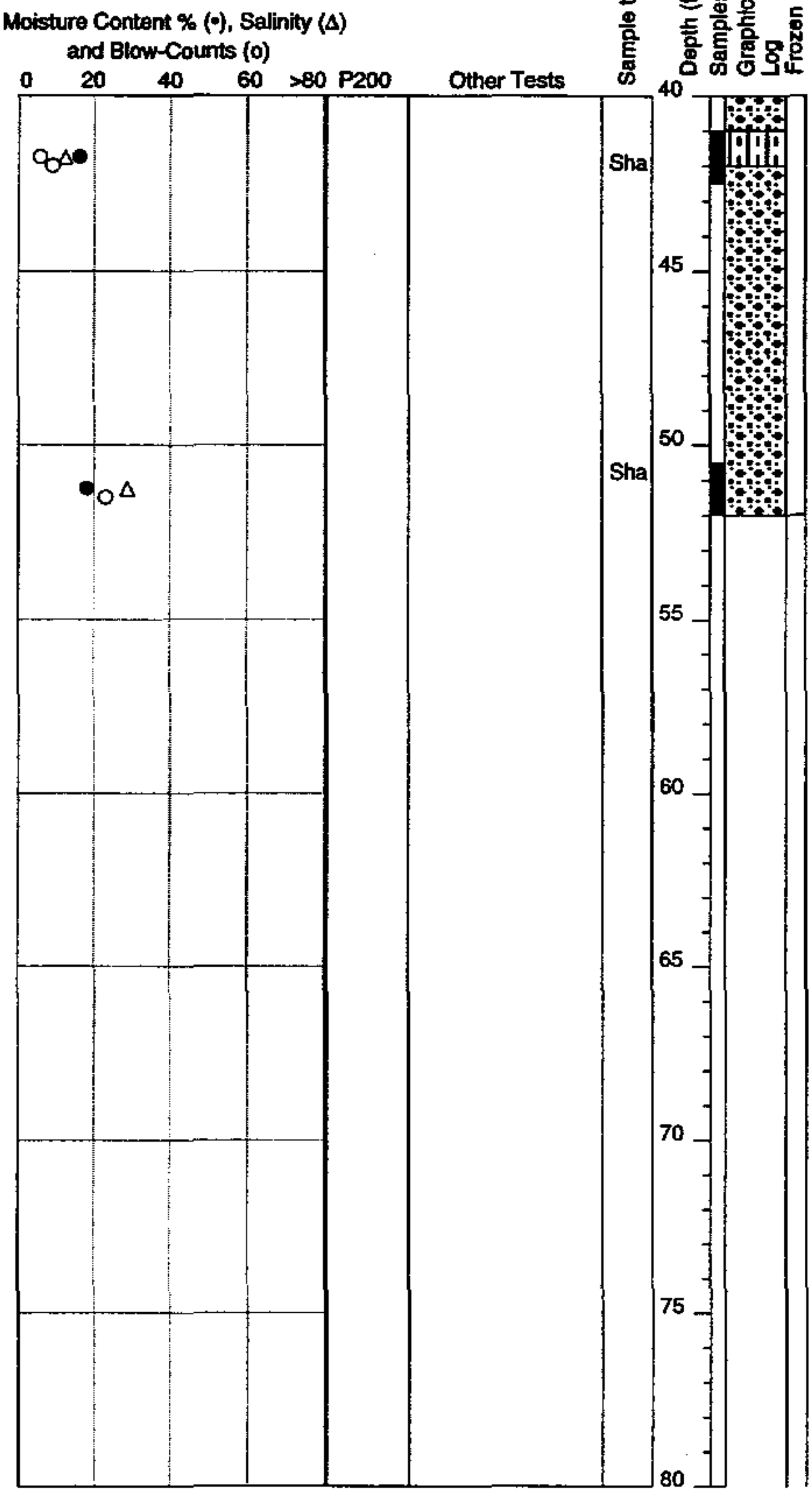
Depth (feet)	P200	Other Tests	Sample type	Description
0–5		Dd=76 pcf, PI=NP TXUU 340(1000) TXCD 1910(1000) TXCD 2920(2000) Con	Tw	SILT: (ML) Dark gray to black, soft
5–10		Dd=93 pcf, LL=50, PI=20, TXUU 1940(1000) TXCD 1800(1000) TXCD 2590(2000) Con	Tw	CLAYEY SILT: (MH) Dark gray, stiff, plastic, w/ lenses of plastic Clay (CH)
10–15		Dd=87 pcf TXUU 1370(1000) Con	Tw	
15–20		Dd=90 pcf, LL=51, PI=25, TXUU 1730(1000) Con	Tw	SANDY GRAVEL: (GP) Gray, loose, gravel is subround to round to <1.5" size, sand is medium
20–25	0.7%	SA	Sha	
25–30			Sha	
30–35			Sha	Interbedded w/ 6"-12" layers of Sand (SP)
35–40				Boring D-1 is continued on Plate A-2

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No. : 4119.23
Logged By: W. Phillips, P.G.

Log of HOLE : D-1 cont.

Date Drilled: March 19, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 22.7' Ice Thickness: 4.2'
Elevation: —
307,231'E 5,953,966'N (ASP)



Description

SANDY GRAVEL: (GP) Gray, loose, gravel is subround to round to <1.5" size, sand is medium

ORGANIC SILT: (OL) Dark brown, stiff, interbedded w/ fine sand (SP)

SANDY GRAVEL: (GP) Gray, medium dense

Fine grained Sand (SP) at 51'

Installed 1" diameter closed black iron pipe to 52'

DUANE MILLER & ASSOCIATES

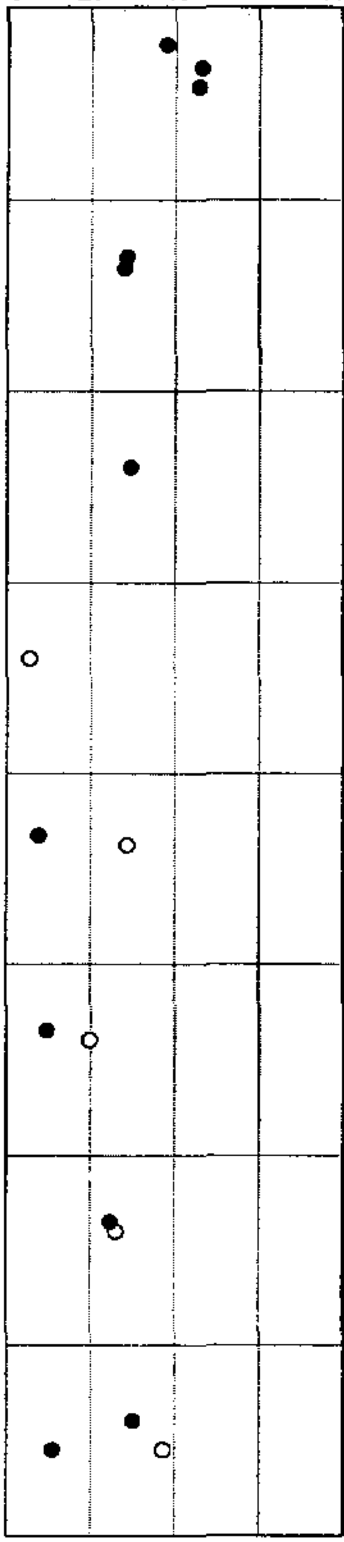
Project: **Liberty**
DM&A Job No. : 4119.23
Logged By: W. Phillips, P.G./T. Culkin, Geologist

Log of HOLE : D-2

Date Drilled: March 19, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 23.0' Ice Thickness: 4.8'
Elevation: --
307,370'E 5,954,036'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)

0 20 40 60 >80



P200	Other Tests	Sample type	Depth (feet)	Description
	PI=NP, Dd=76 pcf, TXUU360(1000) Con	Tw	0	SILT: (ML) Dark gray, soft
	Dd=94 pcf, TXUU2520(1000) Con	Tw	5	CLAYEY SILT: (MH) Black, stiff, plastic
	LL=51, PI=22, Dd=93 pcf	Tw	10	
		Sha	15	
44.0%	MA	Sha	20	SILTY SAND: (SM) Brown, stiff, w/ trace gravel, interbedded w/ Organic Silt (OL), sand beds are marinally frozen
15.0%	MA	Sha	25	SILTY SAND: (SM) Gray, Gravelly, medium dense, Gravel is subround to round to <1.0" size
11.0%	MA	Sha	30	Black, interbedded w/ Sand (SP-SM) w/ trace organics @ 32'
22.0%	MA	Sha	35	Interbedded w/ layers of Silt (ML) below 36'
			40	Boring D-2 is continued on Plate A-4

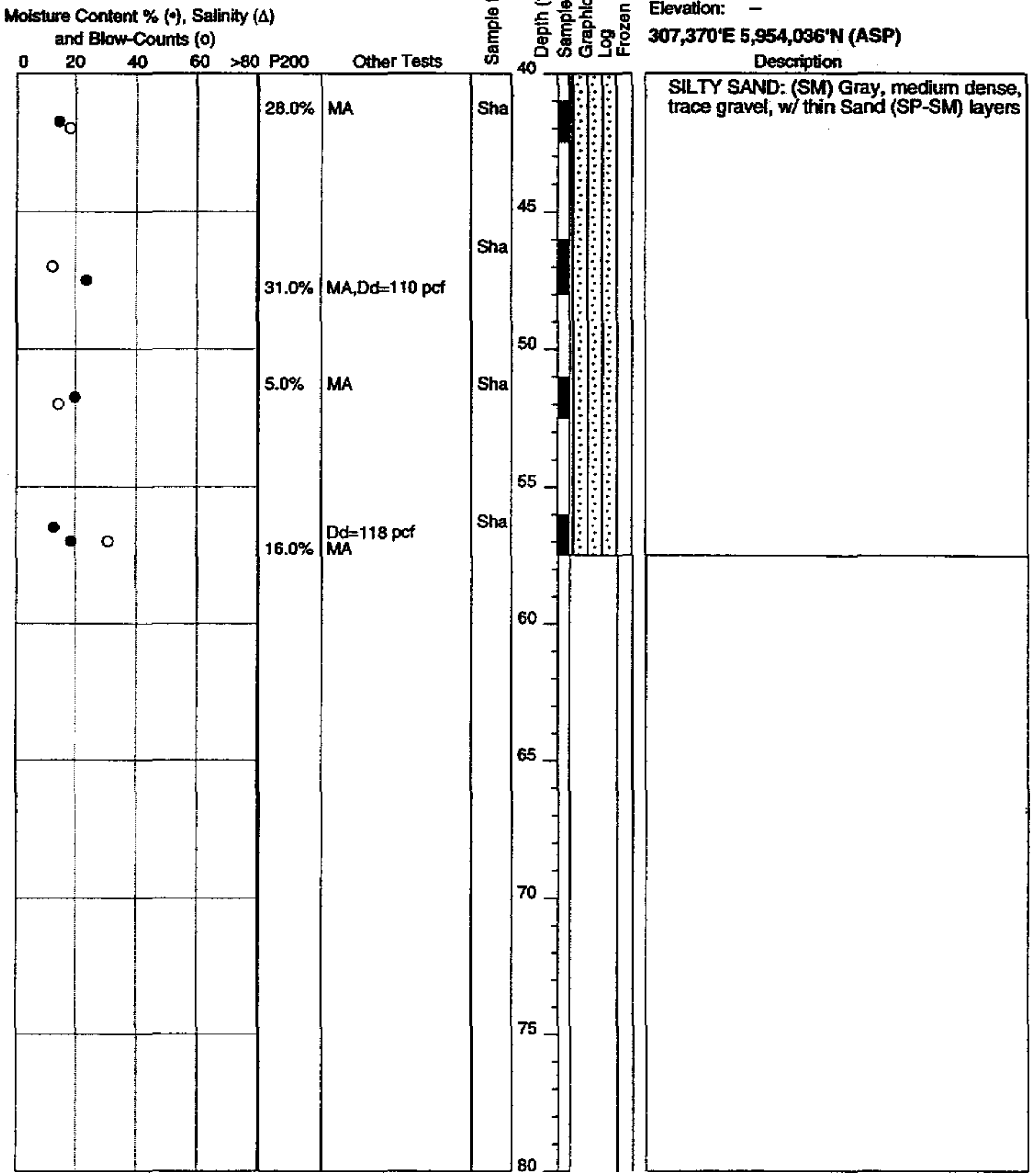
Samples / Graphic Log / Frozen

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: W. Phillips, P.G./T. Culkin, Geologist

Log of HOLE: D-2 cont.

Date Drilled: March 19, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 23.0' Ice Thickness: 4.8'
Elevation: –
307,370'E 5,954,036'N (ASP)



DUANE MILLER & ASSOCIATES

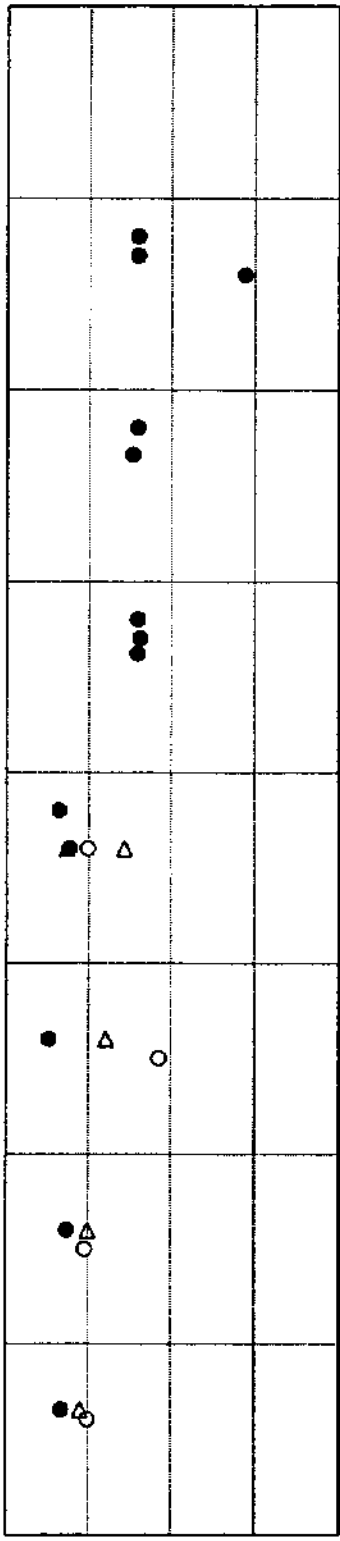
Project: **Liberty**
DM&A Job No. : 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE : D-3

Date Drilled: March 19 & 20, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 21.6' Ice Thickness: 4.3'
Elevation: --
307,508'E 5,954,494'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)

0 20 40 60 >80



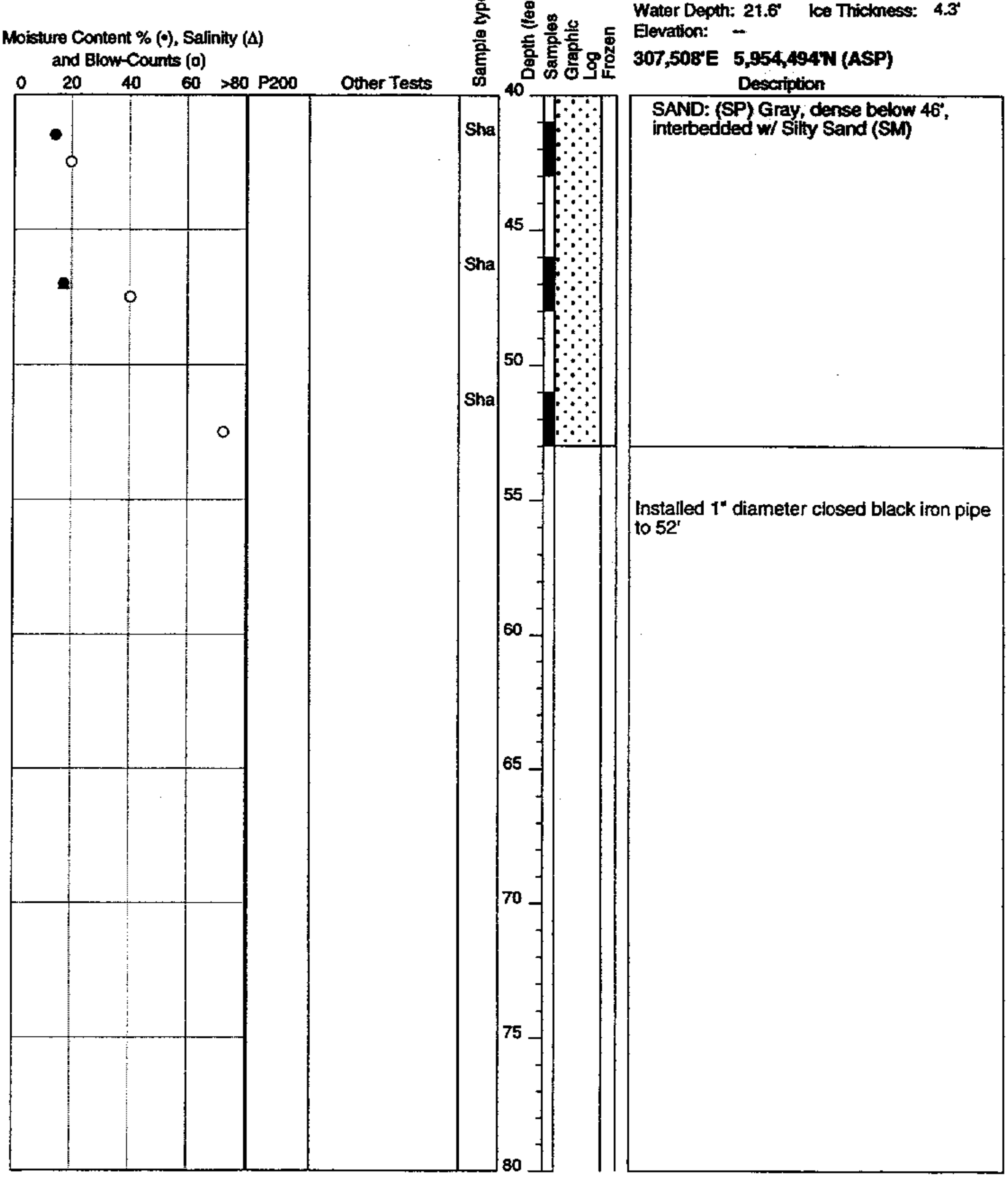
P200	Other Tests	Sample type	Depth (feet)	Description
		Tw	0	SILT: (ML) Gray, w/ trace fine Sand (SP), soft
	LL=53, PI=23, Dd=90 pcf, TXUU 2010(1000)	Tw	5	CLAYEY SILT: (MH) Gray, stiff, plastic
	Dd=91 pcf, Con	Tw	10	
	Dd=91 pcf, TXUU 1510 (1000) Con	Tw	15	
		Sha	20	SAND: (SP) Gray, w/ trace organics material and shell fragments, some fine subround to round Gravel, medium dense, 12" layer of gray Silt (ML) at 21'
4.2%	SA	Sha	25	
		Sha	30	
		Sha	35	Interbedded Silty Sand (SM), 35' to 46'
			40	Boring D-3 is continued on Plate A-6

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE: D-3 cont.

Date Drilled: March 19 & 20, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 21.6' Ice Thickness: 4.3'
Elevation: --
307,508'E 5,954,494'N (ASP)



DUANE MILLER & ASSOCIATES

Project: **Liberty**
DM&A Job No. : 4119.23
Logged By: W. Phillips, P.G.

Log of HOLE : D-4 cont.

Date Drilled: March 20, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 22.3' Ice Thickness: 5.0'
Elevation: --
307,227'E 5,954,428'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o) 0 20 40 60 >80	P200	Other Tests	Sample type	Depth (feet)	Samples	Graphic Log	Frozen	Description
				40				SANDY GRAVEL: (GP) Gray, dense, Gravel subround to round gravel to <1.5" size, occassional 4" to 6" layers of light gray fine Gravelly Silt (ML)
o (blow count ~28)			Sha	45				
• (moisture ~32)			Sha	50				
				55				
				60				
				65				
				70				
				75				
				80				

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Date: July 1998

LOG OF BORING D-4
Liberty Development
Beaufort Sea, Alaska

Plate
A-7

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: W. Philips, P.G.

Log of HOLE: D-4 cont.

Date Drilled: March 20, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 22.3' Ice Thickness: 5.0'
Elevation: --
307,227'E 5,954,428'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o): 0, 20, 40, 60, >80 | P200 | Other Tests | Sample type | Depth (feet) | Samples | Graphic Log | Frozen | Description

Depth (feet)	Sample type	Description
40		SANDY GRAVEL: (GP) Gray, dense, Gravel subround to round gravel to <1.5" size, occassional 4" to 6" layers of light gray fine Gravelly Silt (ML)
45	Sha	
50	Sha	
55		
60		
65		
70		
75		
80		

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: W. Phillips, P.G./T. Culkin, Geologist

Log of HOLE : D-5

Date Drilled: March 20, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 22.0' Ice Thickness: 4.7'
Elevation: --
307,364'E 5,953,838'N (ASP)

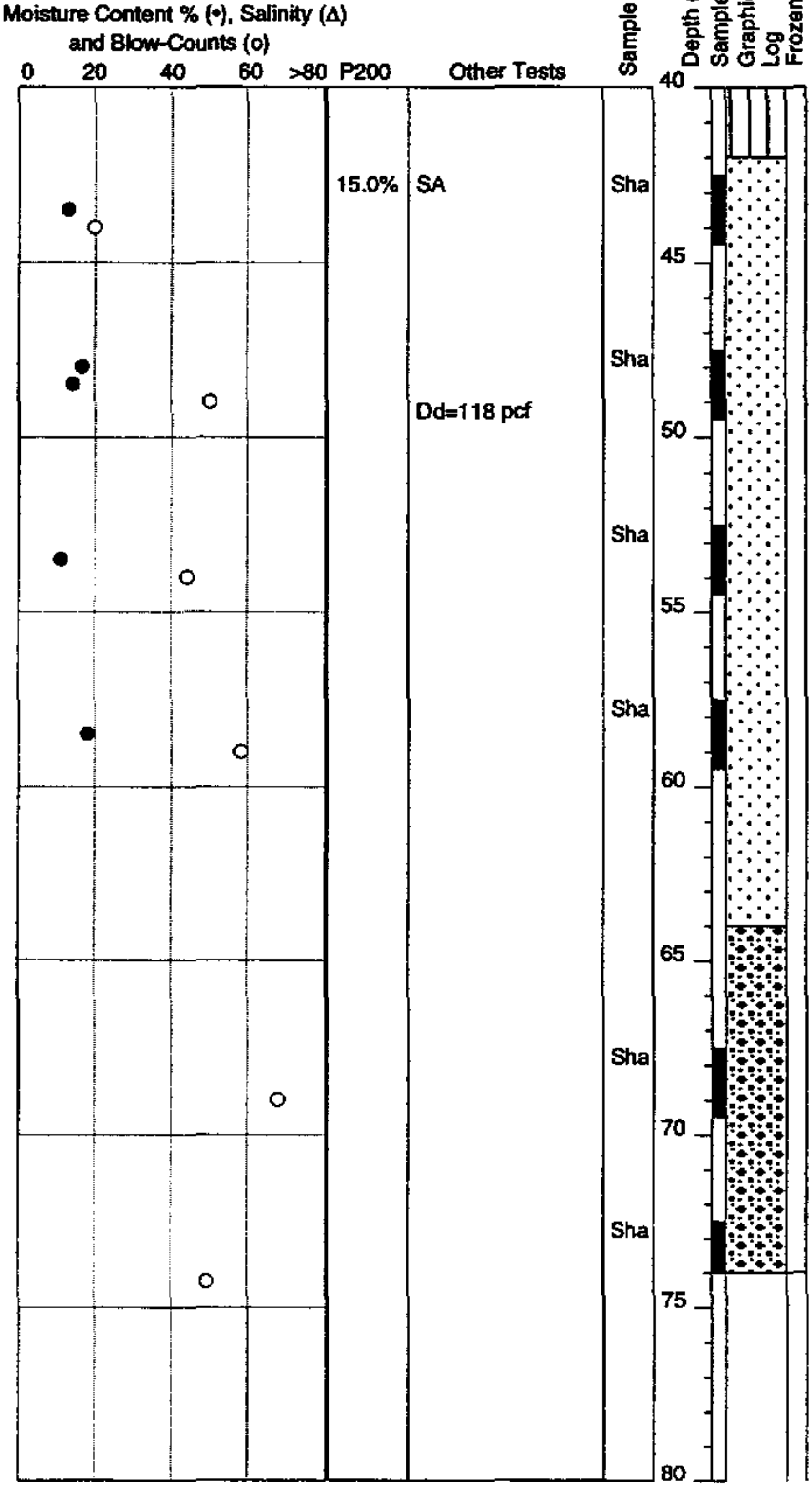
Moisture Content % (•), Salinity (Δ) and Blow-Counts (o): 0, 20, 40, 60, >80

P200	Other Tests	Sample type	Depth (feet)	Description
	OLI=5%	Sp	0	SILT: (ML) Black, w/ layers of Organic Silt (OL), v. soft
	PI=NP, Dd=73 pcf, TXUU 360(1000) Con	Tw	5	
	Dd=93 pcf, TXUU 1400(1000) Con	Tw		CLAYEY SILT: (MH) Dark gray, w/ some layers of fine Silty Sand (SM), stiff, plastic
	Dd=89 pcf LL=51, PI=22	Sha	10	
		Sha	15	
24.0%	SA	Sha	20	SILTY SAND: (SM) Dark gray, w/ some Gravel and organics material, medium dense
1.2%	SA	Sha	25	SANDY GRAVEL: (GW) Gray, medium dense, gravel is subround to round to < 1.5" size
		Sha	30, 35	
		Sha	40	SANDY SILT: (ML) Black, trace organics and fine sand layers, v. stiff

Boring D-5 is continued on Plate A-10

Project:	Liberty	Log of HOLE :	D-5 cont.
DM&A Job No. :	4119.23	Date Drilled:	March 20, 1998
Logged By:	W. Phillips, P.G./T. Culkin, Geologist	Contractor:	Discovery Drilling/CATCO
		Rig Type:	CME-75 on sled w/ hollow stem

Water Depth: 22.0' Ice Thickness: 4.7'
Elevation: --
307,364'E 5,953,838'N (ASP)



Description

SANDY SILT: (ML) Black, v. stiff, w/ trace organic material, some fine sand layers

SAND: (SP-SM) Gray, medium dense, w/ fine Gravel and organic material, interbedded w/ layers of Silty Sand (SM)

Dense below 48'

SANDY GRAVEL: (GP) Gray, v. dense, gravel is subround to round to <1.0 size

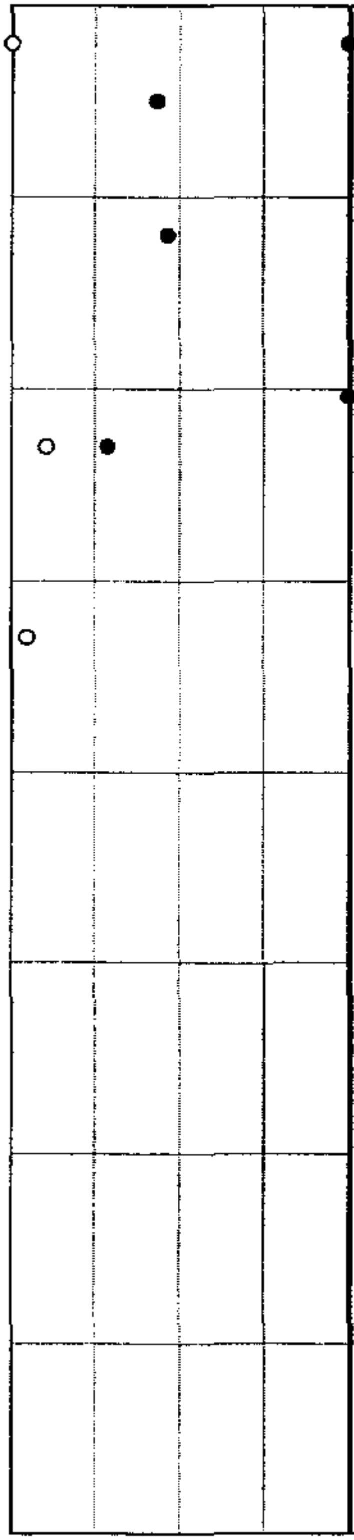
DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE: D-6

Date Drilled: March 20, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 21.5' Ice Thickness: 5.0'
Elevation: --
306,137'E 5,951,973'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)



Depth (feet)	P200	Other Tests	Sample type	Description
0			Sha	SILT: (ML) Gray, soft, w/ trace organic material and fine Silty Sand (SM)
		Dd=82 pcf, TXUU 1150 (1000)	Tw	
5	66.0%	SA, Dd=84 pcf	Tw	
				SILTY SAND: (SM) Gray, medium dense
10			Sha	CLAYEY SILT: (MH) Gray, stiff, w/ thin Peat (Pt) layer at 10', plastic
15			Sha	
				SILTY SAND: (SM) Gray, loose
20				
25				
30				
35				
40				

Columns: Samples, Graphic Log, Frozen

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Arctic & Geotechnical Engineering
Job No.: 4119.23
Date: July 1998

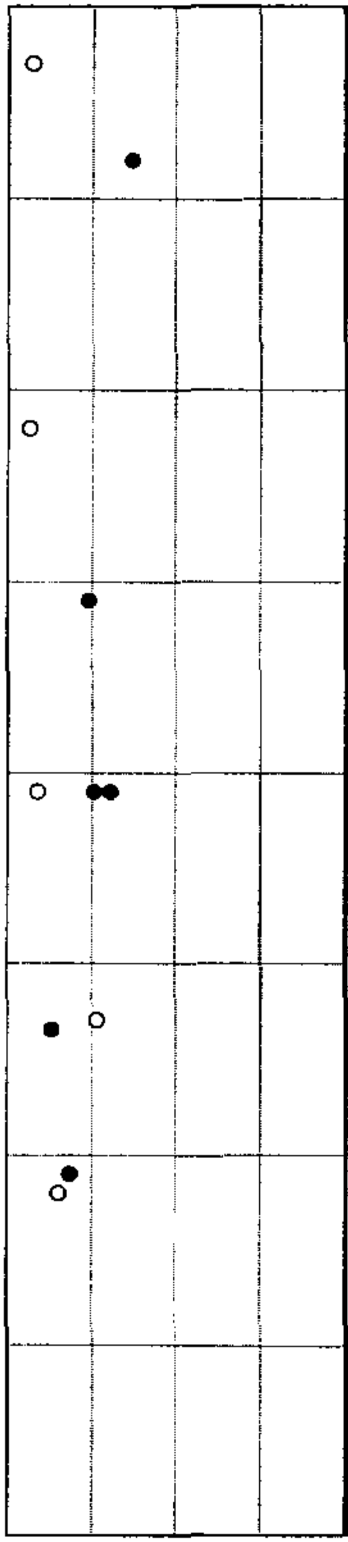
LOG OF BORING D-6
Liberty Development
Beaufort Sea, Alaska

Plate
A-11

DUANE MILLER & ASSOCIATES

Project:	Liberty	**Log of HOLE :**	**D-7**
DM&A Job No. :	4119.23	Date Drilled:	March 21, 1998
Logged By:	T. Culkin, Geologist	Contractor:	Discovery Drilling/CATCO
		Rig Type:	CME-75 on sled w/ hollow stem
		Water Depth: 18.5'	Ice Thickness: 4.1'
		Elevation:	--
		304,822'E 5,949,930'N (ASP)	

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)



Depth (feet)	P200	Other Tests	Sample type	Description
0			Sha	SILTY SAND: (SM) Gray, loose, interbedded w/ soft Sandy Silt (ML), w/ some shell fragments
		Dd=96 pcf	Tw	
5				
		LL=62, PI=26, Dd=74 pcf, TXUU 450(1000)	Tw	ORGANIC SILT: (OH) Soft
10			Sha	CLAYEY SILT: (MH) Gray, stiff, trace organic material, plastic
15		Dd=110 pcf	Tw	
20			Sha	Interbedded Sandy Silt (ML) below 20'
				SAND: (SP) Gray, medium dense, w/ Gravel which is subround to round to < 0.7" size, sand is fine to medium
25			Sha	
	3.6%		Sha	
30			Sha	
35				
40				

Columns: Depth (feet), Samples, Graphic Log, Frozen

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date: July 1998

LOG OF BORING D-7
Liberty Development
Beaufort Sea, Alaska

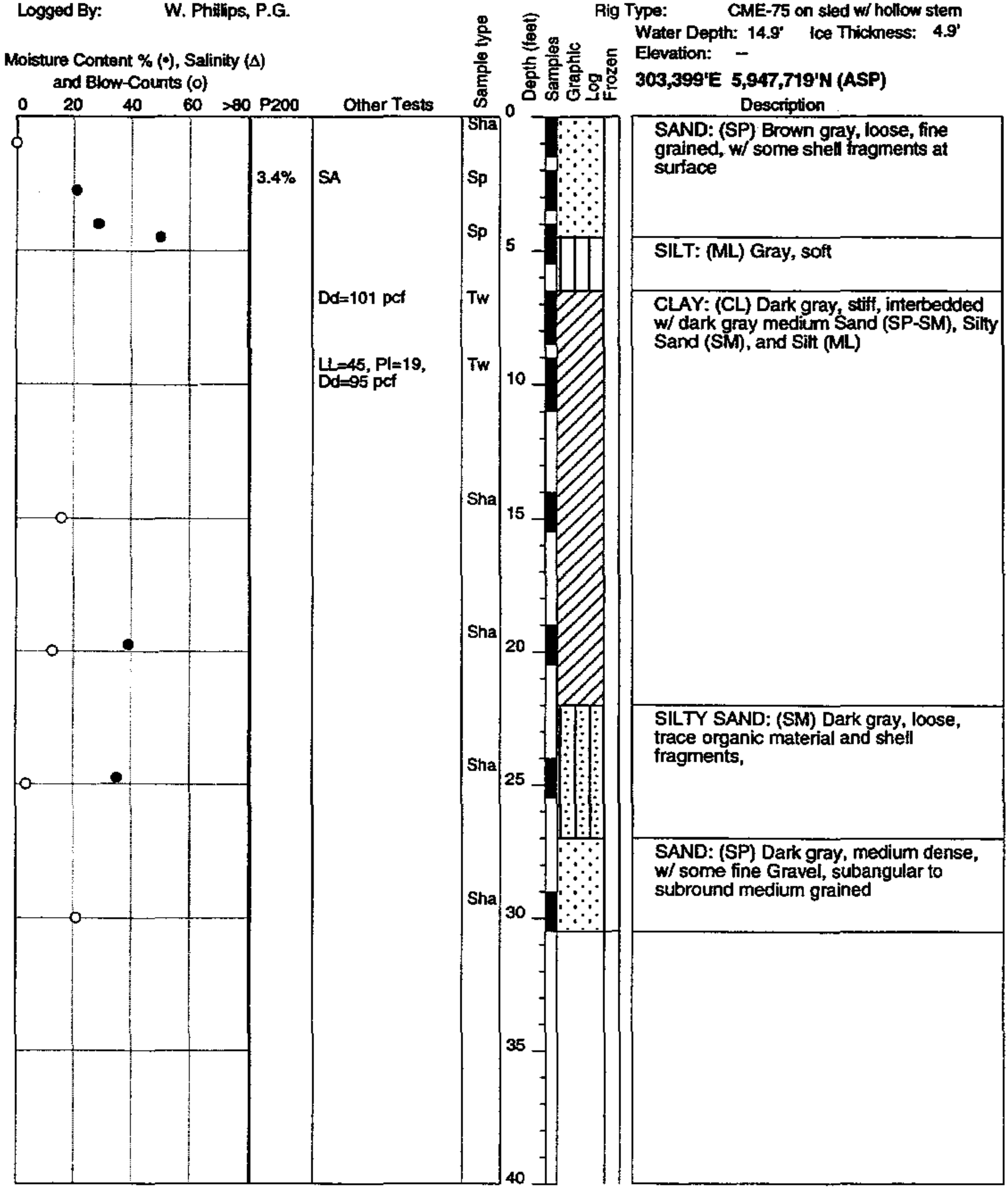
Plate
A-12

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No. : 4119.23
Logged By: W. Phillips, P.G.

Log of HOLE : D-8

Date Drilled: March 21, 1996
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 14.9' Ice Thickness: 4.9'
Elevation: --
303,399'E 5,947,719'N (ASP)



Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date: July 1998

LOG OF BORING D-8
Liberty Development
Beaufort Sea, Alaska

Plate
A-13

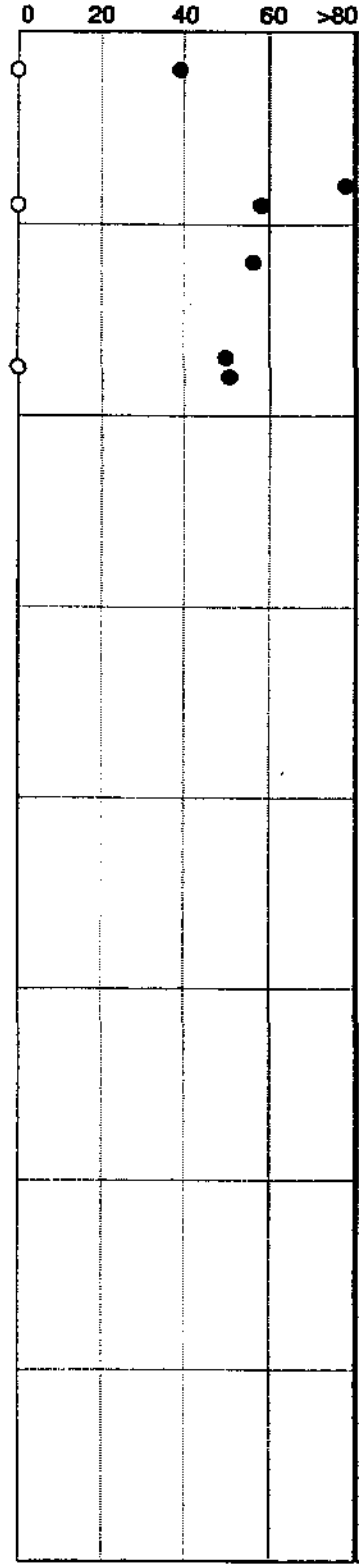
DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: W. Phillips, P.G.

Log of HOLE: D-9

Date Drilled: March 21, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 17.0' Ice Thickness: 5.0'
Elevation: –
301,760'E 5,945,160'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)



P200	Other Tests	Sample type	Depth (feet)	Description
	PI=NP	Sha	0	SILT: (ML) Black, soft
45.0%	SA, OLI=14%	Sha		PEAT: (Pt) Brown, soft, w/ lenses of Silty Sand (SM) and Silt (ML), fibrous
	Dd=65 pcf	Sp	5	
	Dd=69 pcf OLI=13%	Sp		
		Sp	10	SAND: (SP) Light gray, medium dense
			15	
			20	
			25	
			30	
			35	
			40	

DUANE MILLER & ASSOCIATES

Log of HOLE : D-10

Project:	Liberty
DM&A Job No. :	4119.23
Logged By:	W. Phillips, P.G.
Date Drilled:	March 21, 1998
Contractor:	Discovery Drilling/CATCO
Rig Type:	CME-75 on sled w/ hollow stem
Water Depth:	11.2'
Ice Thickness:	5.0'
Elevation:	--

300,524'E 5,943,265'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)

0 20 40 60 >80

P200	Other Tests	Sample type
		Sp
	Dd=90 pcf	Sp
73.0%	MA, OLI=4%, PI= NP, Dd=85 pcf	
	Dd=79 pcf	Sp
18.0%	SA	Sp
	OLI=26%	Sha
		Sha

Depth (feet) 0 5 10 15 20 25 30 35 40

Samples Graphic Log Frozen

Description
SILT: (ML) Dark gray, soft, 2" layer of Silty Sand (SM) at surface, lenses of Sand (SP-SM) and Organic Silt (OL)
SILTY SAND: (SM) Gray, loose, fine grained
PEAT: (Pt) Brown, soft, trace light gray silt, fibrous
ORGANIC SILT: (OL) Black, soft, w/ wood fragments and occasional Sand (SP-SM) lenses

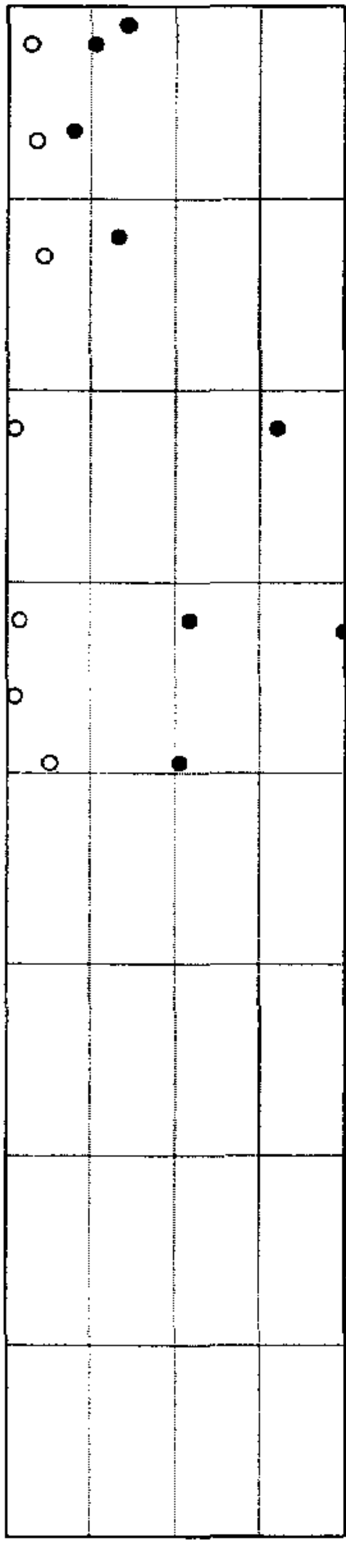
DUANE MILLER & ASSOCIATES

Project: **Liberty**
DM&A Job No. : 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE : D-11

Date Drilled: March 21, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 15.0' Ice Thickness: 5.2'
Elevation: --
299,951'E 5,942,376'N (ASP)

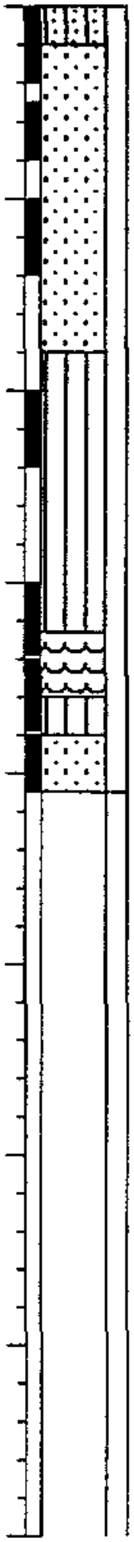
Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)



P200	Other Tests	Sample type
		Sha
5.7%	SA	Sha
		Sha
20.0%	SA	
		Sha
		Sha
		Sha
		Sha

Depth (feet): 0, 5, 10, 15, 20, 25, 30, 35, 40

Samples / Graphic Log / Frozen



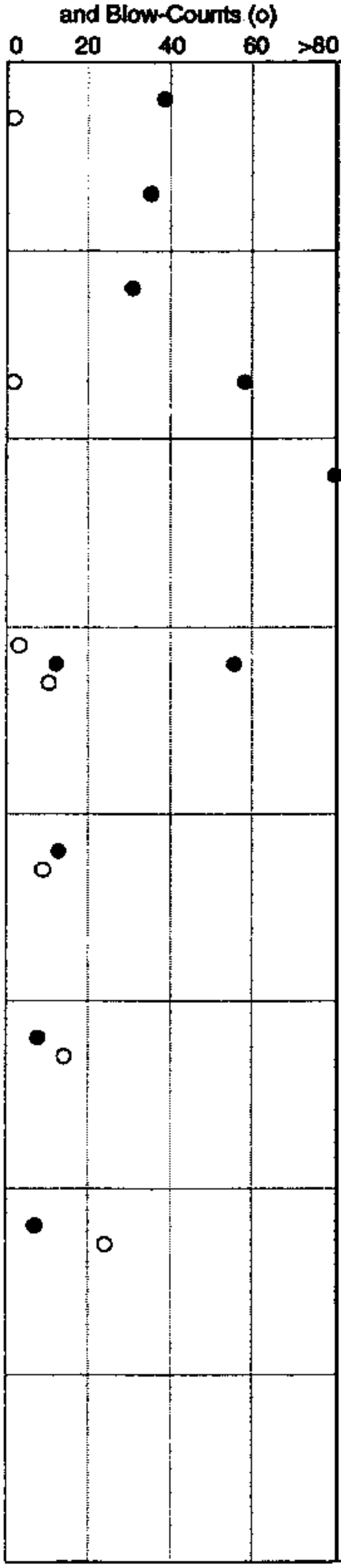
Description
SILTY SAND: (SM) Gray, loose, scattered shell fragments
SAND: (SP-SM) Gray, medium dense, interbedded w/ 1" layers of Silt (ML), trace shell fragments
SILT: (ML) Gray, soft, w/ pockets of organic material
PEAT: (Pt) Brown, soft, trace gray Silt (ML), fibrous
SILT: (ML) Gray, soft, w/ trace organic material
SAND: (SP) Gray, loose, w/ some fibrous organic material and fine subround Gravel

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: T. Cufkin, Geologist

Log of HOLE: D-12

Date Drilled: March 21 and 22, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 12.9' Ice Thickness: 4.1'
Elevation: –
298,389'E 5,939,929'N (ASP)



Depth (feet)	P200	Other Tests	Sample type	Description
0			Sha	SILTY SAND: (SM) Gray, loose, trace gravel, organcis, shell fragments
		Dd=85 pcf	Tw	SILT: (ML) Gray, medium stiff
				SILTY SAND: (SM) Gray, loose, interbedded w/ Sand (SP), trace organic material
5	27.0%	SA, Dd=86 pcf	Tw	
			Sha	
10		Dd=53 pcf	Tw	SILT: (ML) Gray, stiff, w/ trace organic material and thin layers of Sand (SP)
15			Sha	SANDY GRAVEL: (GW) & (GP) Gray, medium dense, subangular to subround to <2.0" size
20	2.8%	SA	Sha	
25			Sha	
30			Sha	
35				
40				

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date: July 1998

LOG OF BORING D-12
Liberty Development
Beaufort Sea, Alaska

Plate
A-17

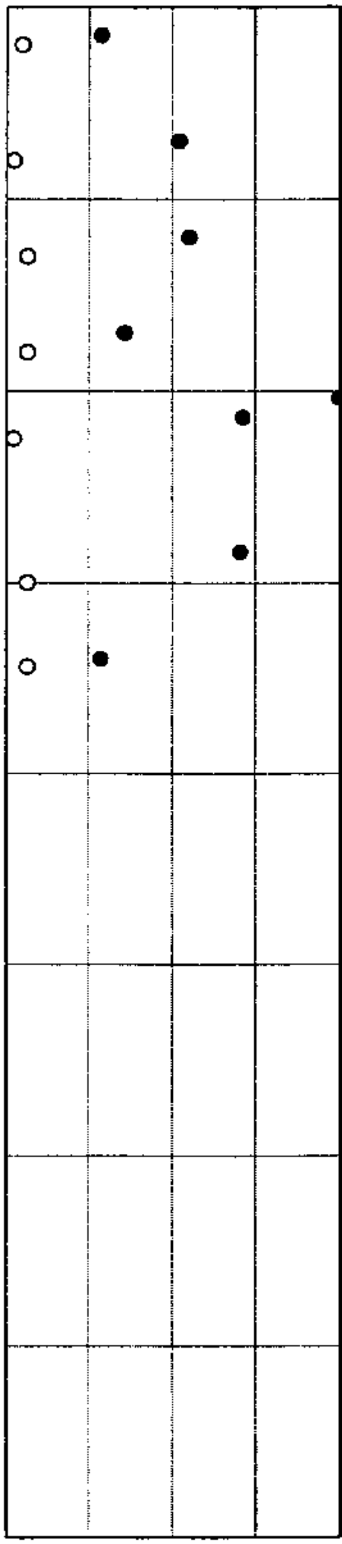
DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No. : 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE : D-13

Date Drilled: March 22, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 7.2' Ice Thickness: 4.7"
Elevation: --
297,180'E 5,938,050'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)



P200	Other Tests	Sample type	Depth (feet)
3.3%	SA	Sha	0
	OLi=4%	Sha	
84.0%	MA	Sha	5
		Sha	
		Sha	10
		Sha	
		Sha	15

Depth (feet): 0, 5, 10, 15, 20, 25, 30, 35, 40

Samples | Graphic Log | Frozen

Description

SAND: (SP) Brown gray, loose, w/shell fragments

SILT: (ML) Gray, soft to stiff, w/ some fine Sand (SP) and thin organic layers

5" thick Peat (Pt) layer at 10'

PEAT: (Pt) Brown, w/ some Organic Silt (OL) and Sand (SP)

SILT: (ML) Gray, medium stiff, w/ trace organic material

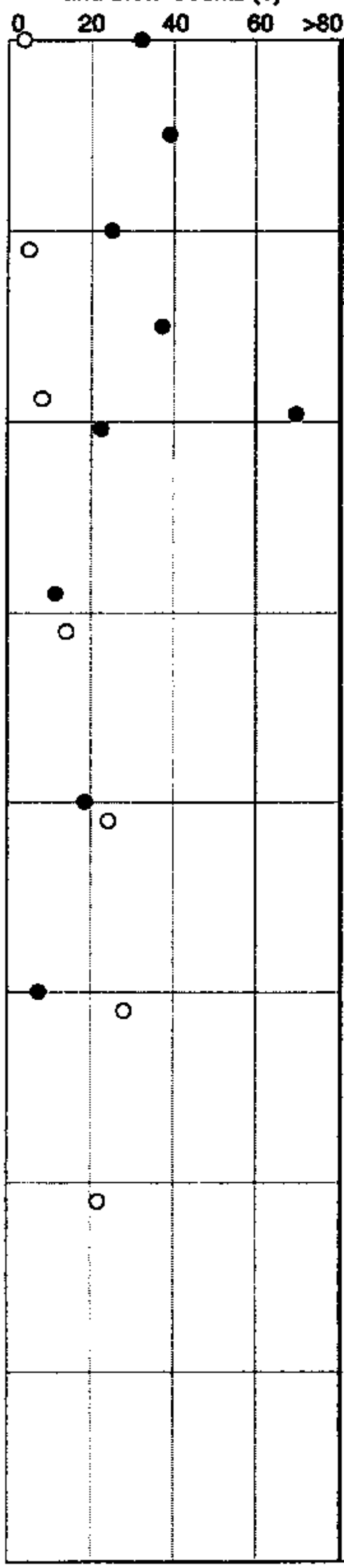
DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: T. Culkin, Geologist/W. Phillips, P.G.

Log of HOLE: Boring D-14

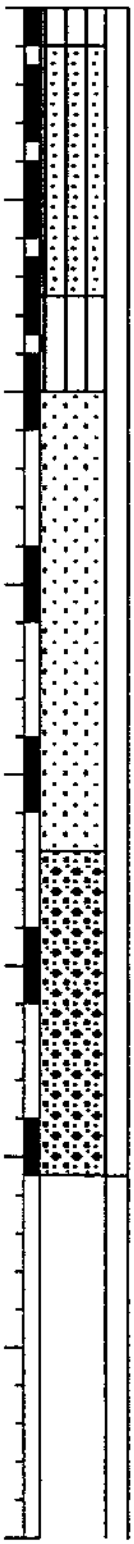
Date Drilled: March 22, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 7.2' Ice Thickness: 4.2'
Elevation: --
296,078'E 5,936,367'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)



P200	Other Tests	Sample type	Depth (feet)
		Sha	0
	Dd=85 pcf	Tw	
12.0%	SA	Sha	5
	Dd=76 pcf	Tw	
		Sha	10
	Dd=127 pcf	Sha	15
		Sha	20
4.5%	SA	Sha	25
		Sha	30
			35
			40

Samples / Graphic Log / Frozen



Description

SILT: (ML) Gray, soft, some Sand (SP) and trace organic material

SILTY SAND: (SM) Gray, loose, w/ lenses of Silt (ML)

SILT: (ML) Gray to black, medium stiff, trace organic material in scattered layers

SAND: (SP) Gray, wet, medium dense, fine to medium grained

SANDY GRAVEL: (GP) Gray, medium dense, gravel to <1.5" size

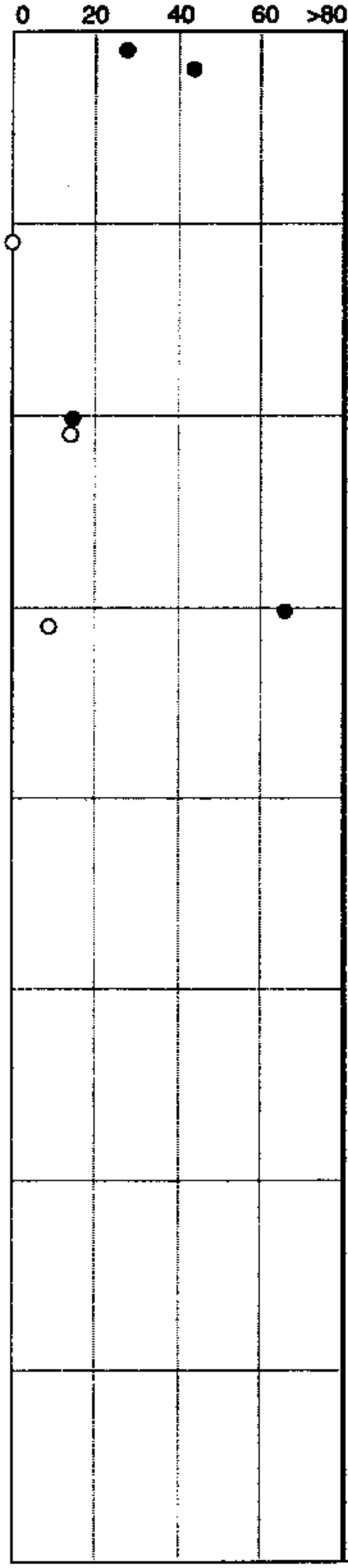
DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No. : 4119.23
Logged By: W. Phillips, P.G.

Log of HOLE : D-15

Date Drilled: March 22, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 6.0' Ice Thickness: 5.0'
Elevation: –
294,480'E 5,933,900'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)



P200	Other Tests	Sample type	Depth (feet)	Description
28%	SA, OLI=3.8%	Sp	0	SILTY SAND: (SM) Brown, loose, interbedded w/ soft black Organic Silt (OL)
		Sp		SILT: (ML) Dark gray, medium stiff, trace organic material
		Sp	5	ORGANIC SILT: (OL) Black, soft
				SILTY SAND: (SM) Grey, some scattered fine gravel, medium dense
13%	SA	Sha	10	
				GRAVELLY SAND: (SP) Brown, some gravel, medium dense
		Sha	15	thin layer of brown Silt (ML) & Organic Silt (OL) at 16'
			20	
			25	
			30	
			35	
			40	

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date: July 1998

LOG OF BORING D-15
Liberty Development
Beaufort Sea, Alaska

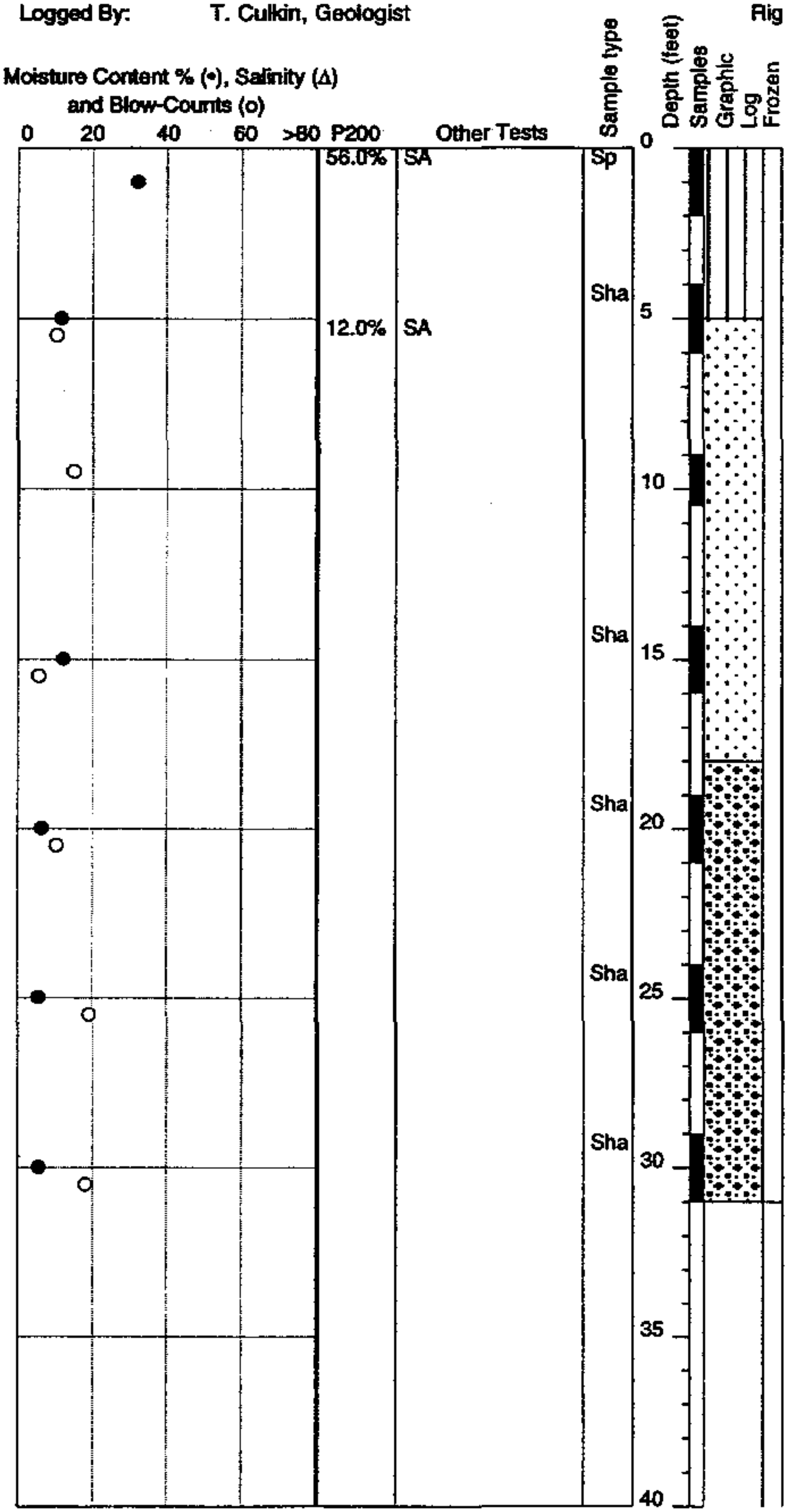
Plate
A-20

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE: D-16

Date Drilled: March 24 & 26, 1996
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 5.3' Ice Thickness: 4.4'
Elevation: --
293,273'E 5,932,037'N (ASP)



Description

SANDY SILT: (ML) Gray, loose, sand is fine grained

SAND: (SP-SM) Gray, medium dense, w/ thin interbeds of Gravelly Sand (SP) and Sandy Silt (ML)

SANDY GRAVEL: (GW) Gray, medium dense, sand is medium to coarse, gravel is subangular to subround to <2.5" size

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date: July 1998

LOG OF BORING D-16
Liberty Development
Beaufort Sea, Alaska

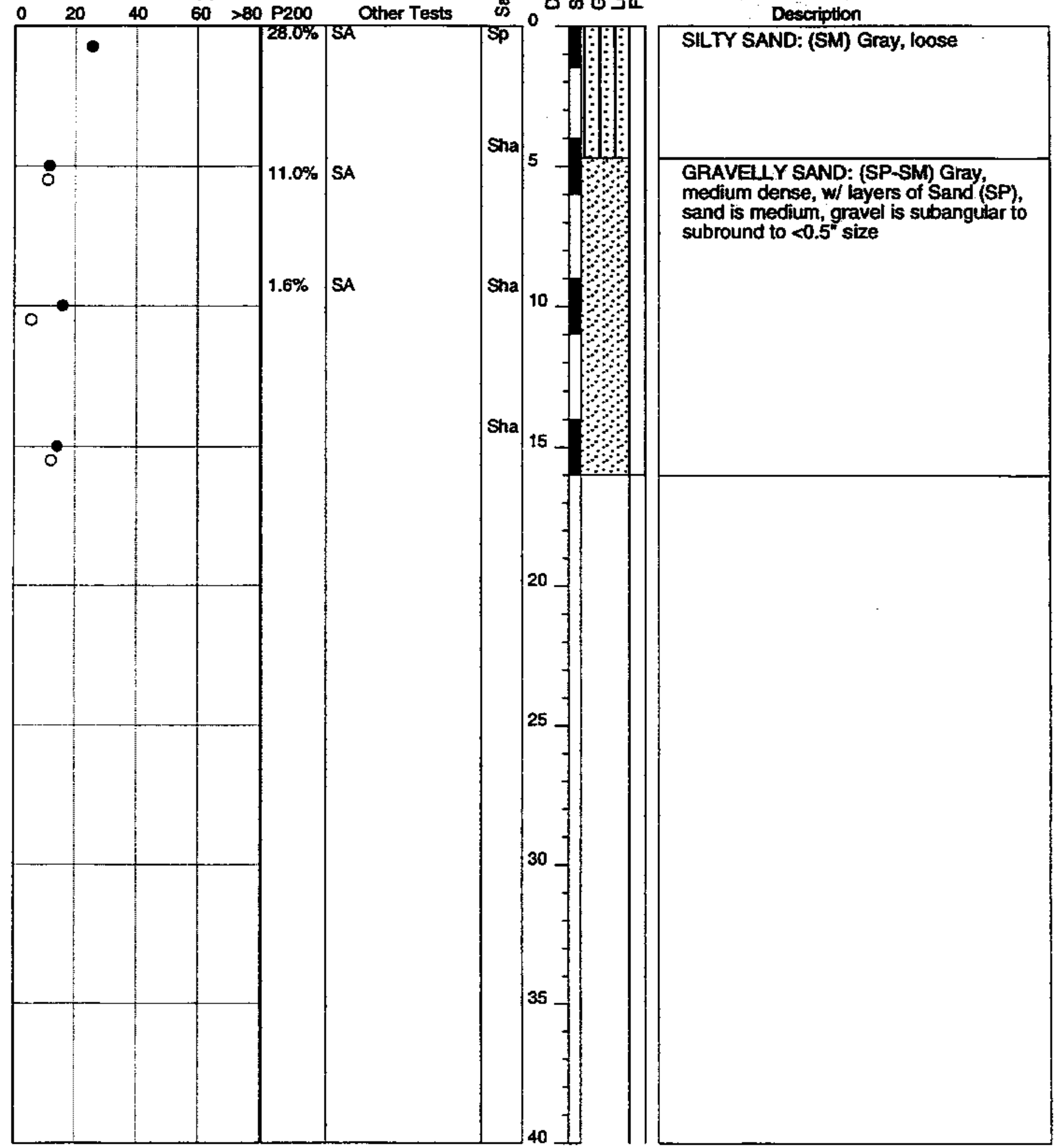
Plate
A-21

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE: D-17

Date Drilled: March 26, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 4.5' Ice Thickness: 4.2'
Elevation: —
292,093'E 5,930,207'N (ASP)



DUANE MILLER & ASSOCIATES

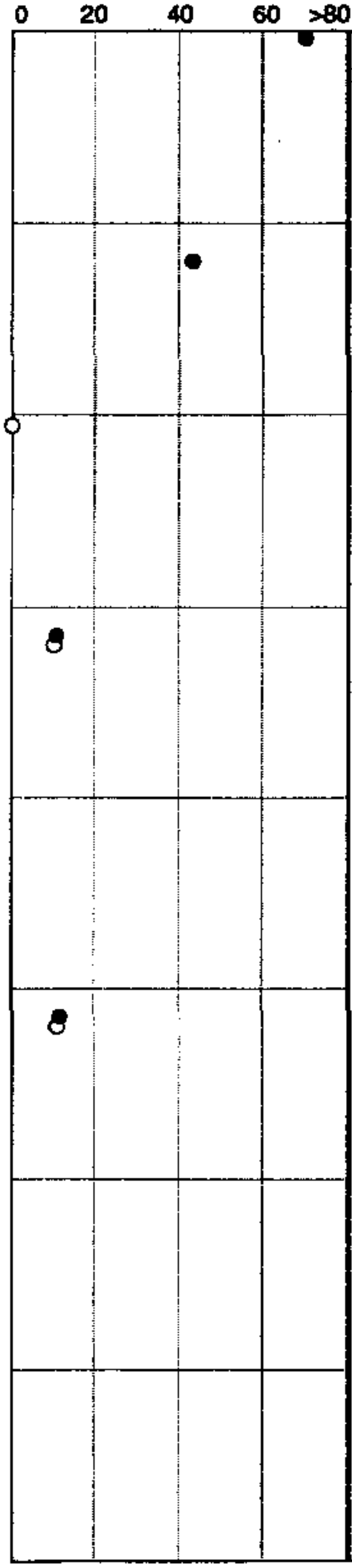
Project: Liberty
DM&A Job No. : 4119.23
Logged By: W. Phillips, P.G.

Log of HOLE : D-18

Date Drilled: March 26, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 4.4' Ice Thickness: 4.2'
Elevation: --
290,954'E 5,928,424'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)

0 20 40 60 >80



Depth (feet)	P200	Other Tests	Sample type	Description
0			Sp	SILT: (ML) Dark gray, soft, w/ layers of Organic Silt (OL)
5		Dd=78 pcf, TXUU 780(1000)	Tw	
9				w/ interbeds of Silty Sand (SM) below 9'
10			Sp	
14				SANDY GRAVEL: (GP) Gray, medium dense, sand is medium, gravel subround to <1.0" size
15			Sha	
20				
25			Sha	
30				Installed 0.75" diameter closed PVC pipe to 29'
35				
40				

Samples Graphic Log Frozen

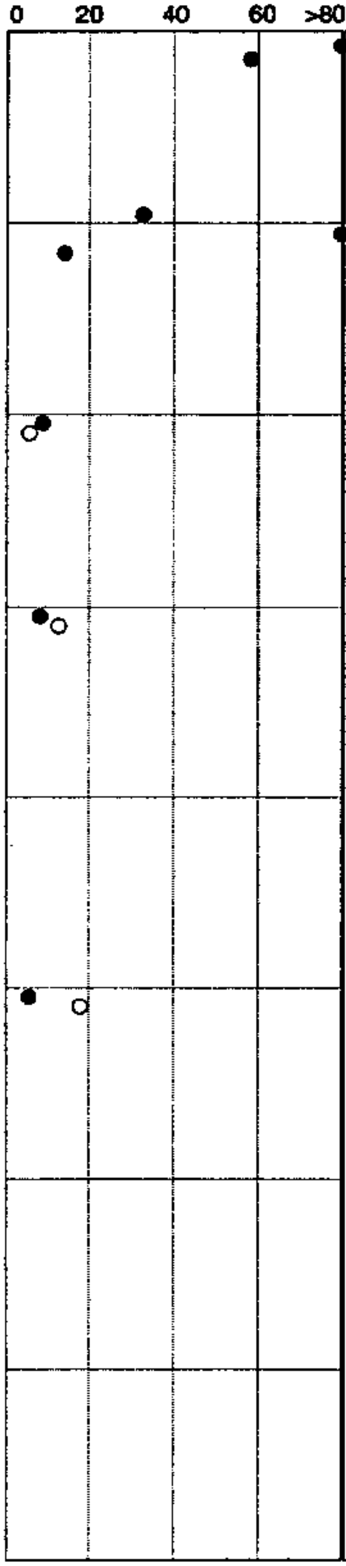
DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: W. Phillips, P.G.

Log of HOLE: D-19

Date Drilled: March 26, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 4.5' Ice Thickness: 3.8'
Elevation: –
290,451'E 5,927,664'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)



P200	Other Tests	Sample type	Depth (feet)	Description
	PI=NP	Sp	0	SILT: (ML) Dark gray, soft, trace organic material
				SILTY SAND: (SM) Light gray, medium dense
16.0%	SA	Sp	5	
6.4%	SA			PEAT: (Pt) Brown, fibrous
				SANDY GRAVEL: (GP) Gray, loose, w/ interbeds of Gravelly Sand (SP-SM)
		Sha	10	
		Sha	15	thin layers of medium dense Silt (ML) below 15'
			20	
		Sha	25	scattered small Cobbles below 24'
			30	Installed 0.75" diameter closed PVC pipe to 27.5'
			35	
			40	

Columns: Samples, Graphic Log, Frozen

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date: July 1998

LOG OF BORING D-19
Liberty Development
Beaufort Sea, Alaska

Plate
A-24

DUANE MILLER & ASSOCIATES

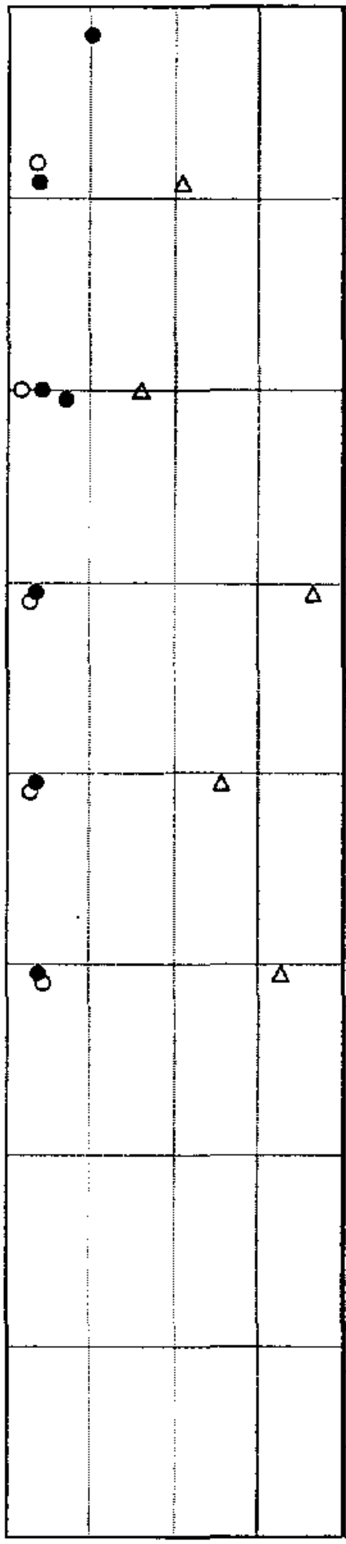
Project: Liberty
DM&A Job No.: 4119.23
Logged By: W. Phillips, P.G.

Log of HOLE: D-20

Date Drilled: March 26, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 4.2' Ice Thickness: 3.6'
Elevation: --
290,204'E 5,927,286'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)

0 20 40 60 >80



P200	Other Tests	Sample type	Depth (feet)	Description
		Sp	0	SAND: (SP-SM) Gray, loose
				SILT: (ML) Dark gray, soft, w/ organic material and scattered pebbles
7.8%	SA	Sha	5	SANDY GRAVEL: (GW-GM) Gray brown, loose, w/ layers of Gravelly Sand (SP-SM)
7.1%	SA	Sha	10	SANDY GRAVEL: (GP)+(GW) Gray, loose
2.4%	SA	Sha	15	
		Sha	20	
		Sha	25	Scattered cobbles below 24'
			30	
			35	
			40	

Samples / Graphic Log / Frozen

DUANE MILLER & ASSOCIATES

Project: **Liberty**
DM&A Job No.: 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE : D-21

Date Drilled: March 26, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 4.0' Ice Thickness: 4.0'
Elevation: --
290,083'E 5,927,097'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)
0 20 40 60 >80

P200	Other Tests	Sample type
		Sha
15.0%	SA	Sha
		Sh
6.4%	SA	Sha
8.9%	SA, Dd=139 pcf	Sha
9.9%	SA, Dd=136 pcf	Sha
		Sha
8.8%	SA	Sha
		Sha
		Sha

Depth (feet): 0 5 10 15 20 25 30 35 40

Samples / Graphic Log / Frozen

Description

SAND: (SP) Gray, marginally frozen, Nbn

SILTY SAND: (SM) Gray, Gravelly, gravel to <1" size, Nbe, unfrozen below 2.5'

SANDY GRAVEL: (GW-GM) Gray, w/ layers of Gravelly Sand (SP), marginally frozen at 10', Nbn & Nf

Trace scattered Cobbles below 24'

5% visible ice (Vx+Vc) below 28

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: W. Phillips, P.G./T. Culkin, Geologist

Log of HOLE: D-22

Date Drilled: March 22, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: -- Ice Thickness: --
Elevation: --
298,554'E 5,921,056'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)

0 20 40 60 >80

P200	Other Tests	Sample type
3.3%	SA	Sha
		Sha
9.6%	SA, RD	Ag
		Sha
		Sha
21.0%	SA	Ag
		Sha
4.7%		Sha

Depth (feet): 0, 5, 10, 15, 20, 25, 30, 35, 40

Samples | Graphic Log | Frozen

Description

GRAVELLY SAND: (SP) Gray brown, Nbn

SANDY GRAVEL: (GP) Gray, Gravel to < 1.0" size , 5-10% visible ice (Vx)

SAND: (SP-SM) Gray, with interlayered Sandy Gravel (GP), 5-10% visible ice (Vx)

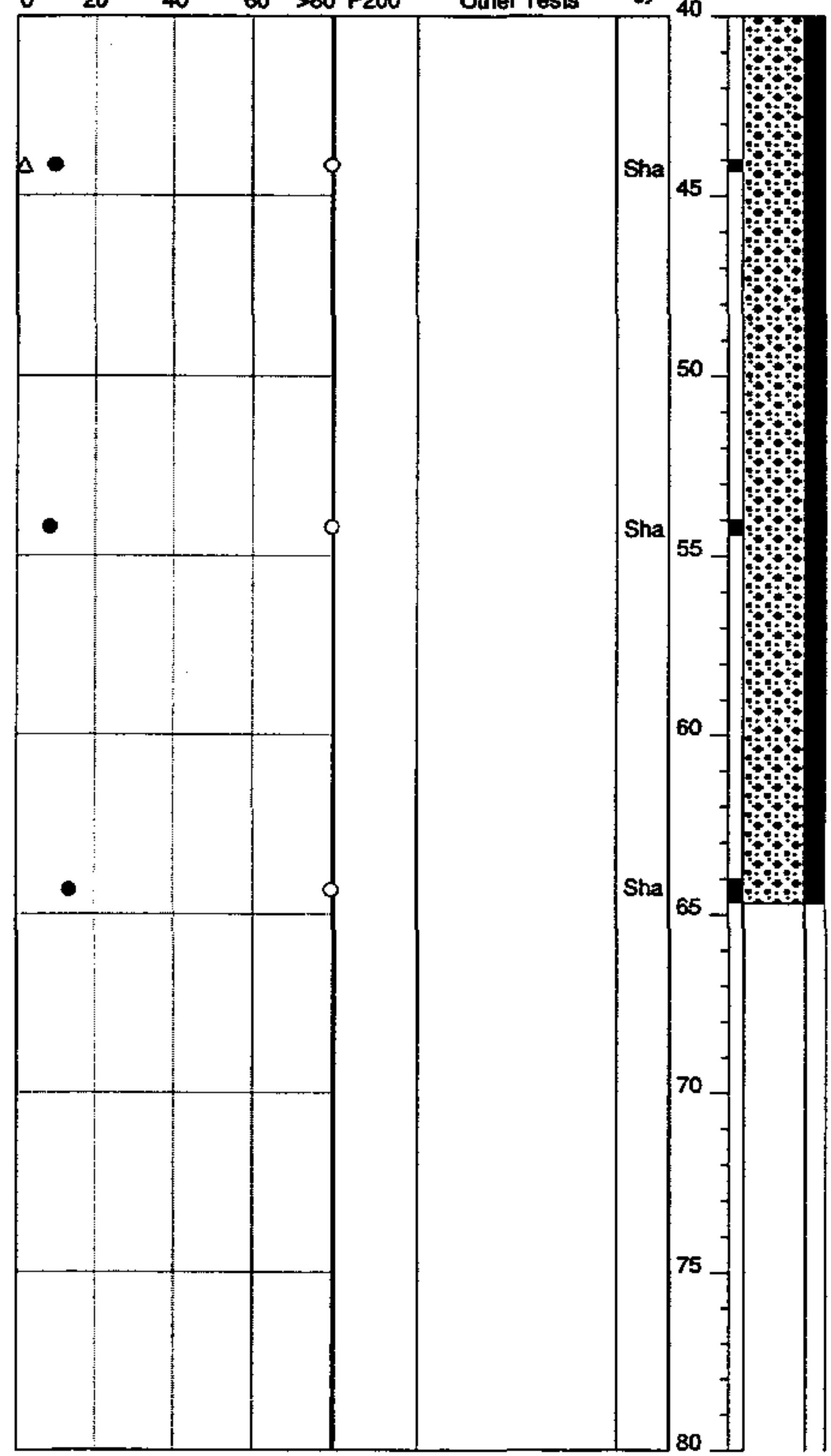
SANDY GRAVEL: (GP-GM) Gray, occasional Cobbles, 10-15% visible ice (Vx+Vc) w/ occasional icier lenses to 40%

Coarser gravel below 22' w/ occasional lenses of Silty Sand (SM)

Boring D-22 is continued on Plate A-28

DUANE MILLER & ASSOCIATES

Project:	Liberty	Log of HOLE :	D-22 cont.
DM&A Job No. :	4119.23	Date Drilled:	March 22, 1998
Logged By:	W. Phillips, P.G./T. Culkin, Geologist	Contractor:	Discovery Drilling/CATCO
		Rig Type:	CME-75 on sled w/ hollow stem
		Water Depth: --	Ice Thickness: --
		Elevation:	--
		298,554'E 5,921,056'N (ASP)	



Description

SANDY GRAVEL: (GP-GM) Gray, occasional Cobbles and lenses of Silty Sand (SM), 10-15% visible ice (Vx+Vc) w/ occasional icier lenses to 40%

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No. : 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE : D-23

Date Drilled: March 22 to 23, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: -- Ice Thickness: --
Elevation: --
297,510'E 5,920,350'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o): 0 20 40 60 >80

P200	Other Tests	Sample type	Depth (feet)	Description
			0	SANDY GRAVEL: (GP-GM) Gray, gravel to <3.0" size, 3-10% visible ice (Vx+Vc), w/ scattered <6" thick layers of gray Sand (SP) and Gravel (GP)
		Sha	5	
3.3%		Sha	10	
7.1%	SA, SpG=2.65, RD	Ag		
			15	Occasional Cobbles below 15'
		Sha	20	
14.0%		Sha	25	Silty Gravel (GM) at 23'
		Sha	30	
		Sha	35	
			40	Boring D-23 is continued on Plate A-30

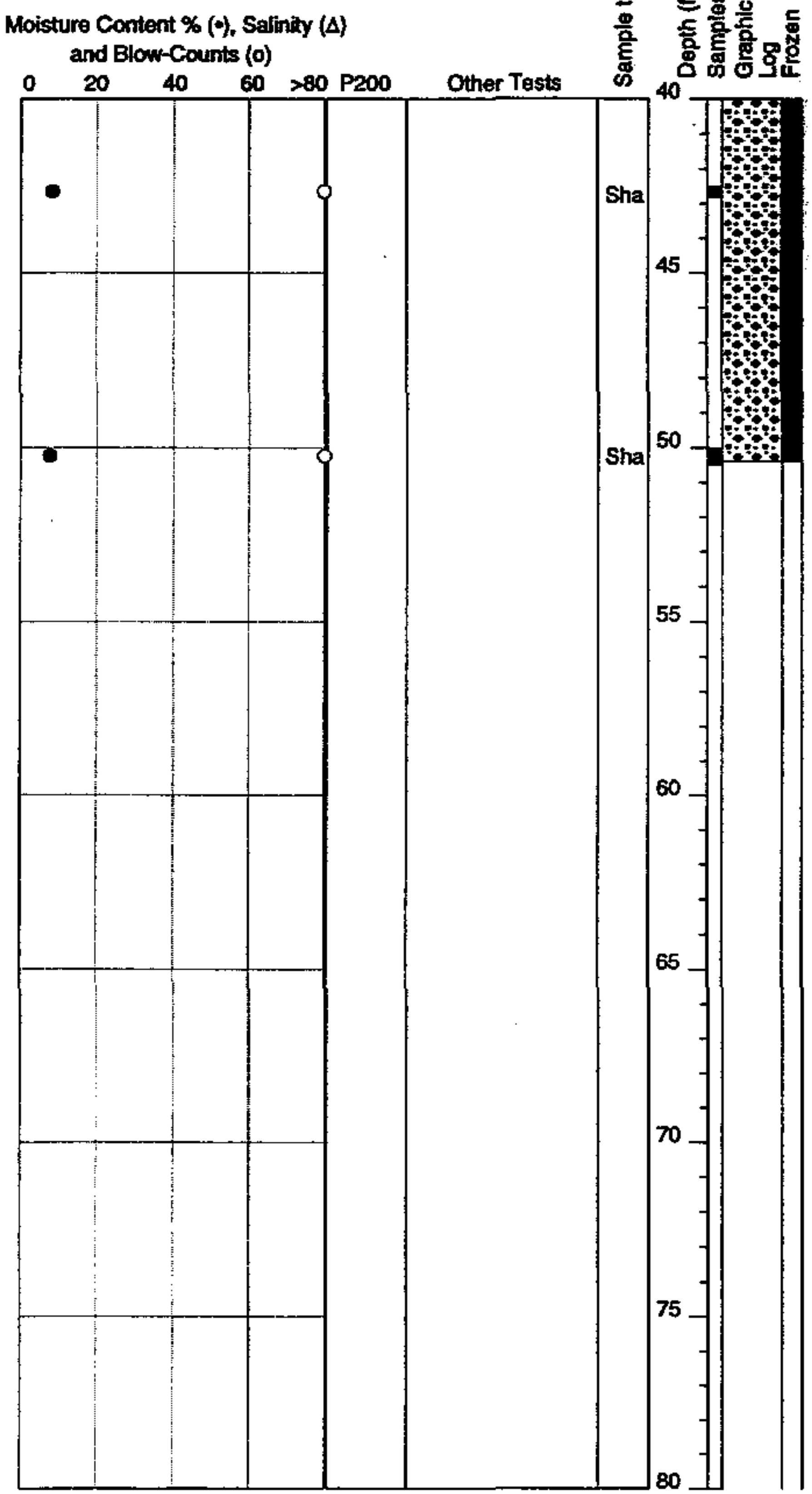
Depth (feet) | Samples | Graphic Log | Frozen

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No.: 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE: D-23 cont.

Date Drilled: March 22 to 23, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: -- Ice Thickness: --
Elevation: --
297,510'E 5,920,350'N (ASP)



Description

SANDY GRAVEL: (GP-GM) Gray, gravel to <3.0" size, 3-10% visible ice (Vx+Vc), scattered <6" thick layers of gray Sand (SP), Gravel (GW), occasional Cobbles

DUANE MILLER & ASSOCIATES

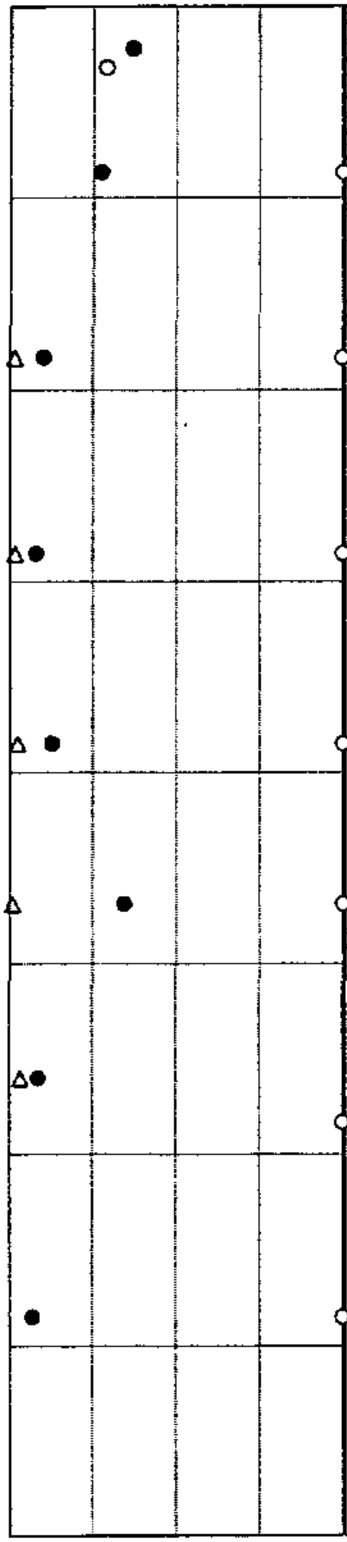
Project: Liberty
DM&A Job No. : 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE : D-24

Date Drilled: March 23, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: -- Ice Thickness: --
Elevation: --
298,100'E 5,920,226'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)

0 20 40 60 >80



P200	Other Tests	Sample type
39.0%	SA	Sha
		Sha
		Sha
2.7%		Sha
		Sha
14.0%		Sha
10.8%	SA, SpG=2.65, D1557, RD	Ag
		Sha
		Sha

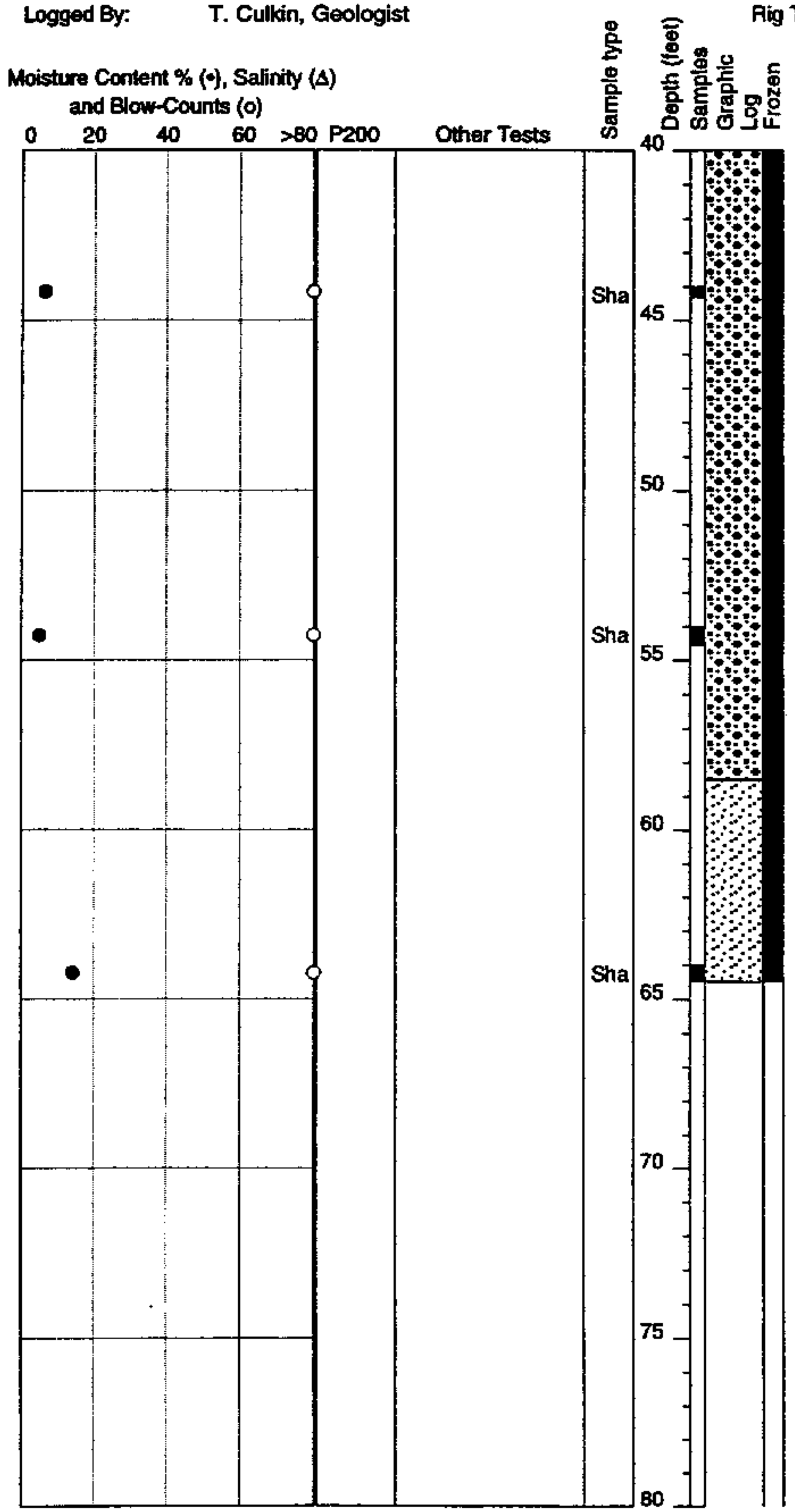
Depth (feet): 0, 5, 10, 15, 20, 25, 30, 35, 40

Samples / Graphic Log / Frozen

Description
SILTY SAND: (SM) Gray, trace Silt and Gravel, fine to medium, Nbn, thin Organic layer at surface
SANDY GRAVEL: (GP) Gray, gravel is subangular to subround to <1.5" size, occasional obbles, 5-20% visible ice (Vx+ Vc)
SILTY SAND: (SM) Gray, fine to medium, Nbe
SANDY GRAVEL: (GP-GM) Gray, gravel to <1.5" size, 5-25% visible ice (Vx+Vc) Scattered <6" thick layers of gray Sand (SP-SM) below 32' Boring D-24 is continued on Plate A-32

DUANE MILLER & ASSOCIATES

Project:	Liberty	**Log of HOLE :**	**D-24 cont.**
DM&A Job No. :	4119.23	Date Drilled:	March 23, 1998
Logged By:	T. Culkin, Geologist	Contractor:	Discovery Drilling/CATCO
		Rig Type:	CME-75 on sled w/ hollow stem
		Water Depth: --	Ice Thickness: --
		Elevation:	--
		298,100'E	5,920,226'N (ASP)



SANDY GRAVEL: (GP-GM) Gray, scattered <6" thick layers of gray Sand (SP), gravel to <1.5" size, 5-25% visible ice (Vx+Vc)

GRAVELLY SAND: (SP) Gray, 5% visible ice (Vx)

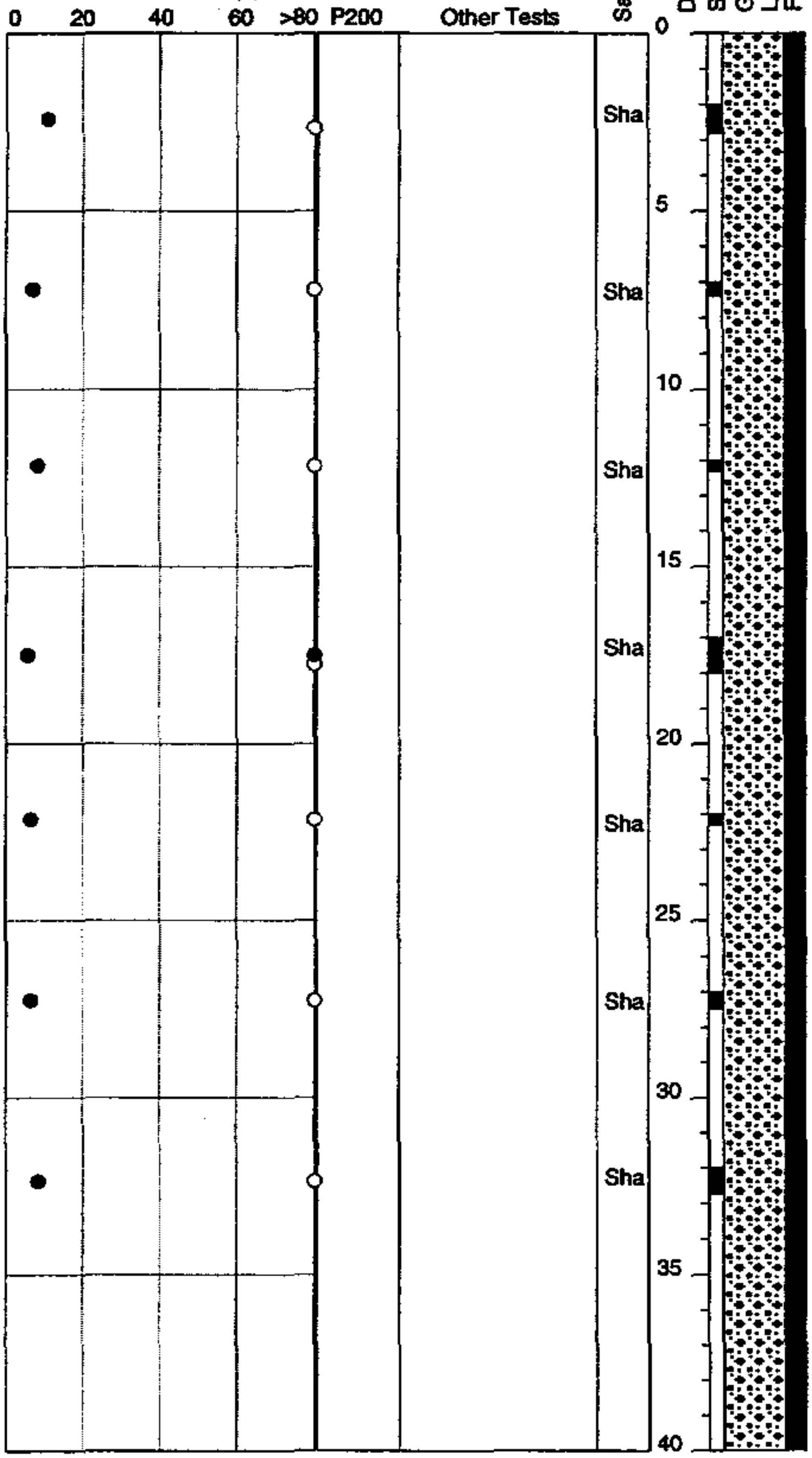
DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No. : 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE : D-25

Date Drilled: March 23 and 24, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: -- Ice Thickness: --
Elevation: --
298,680'E 5,919,850'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)



Description

SANDY GRAVEL: (GP) Gray, gravel to < 1.5" size, occasional Cobbles, 5-15% visible ice (Vx+Vc) w/ layers of Gravelly Sand and Sand (SP)

thin Peat (Pt) layers at 17.5'

Boring D-25 is continued on Plate A-34

DUANE MILLER & ASSOCIATES

Project: Liberty
DM&A Job No. : 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE : D-25 cont.

Date Drilled: March 23 and 24, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: – Ice Thickness: –
Elevation: –
298,680'E 5,919,850'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)

0 20 40 60 >80 P200 Other Tests | Sample type | Depth (feet) | Samples | Graphic Log | Frozen | Description

Sample type	Depth (feet)	Description
	40	SANDY GRAVEL: (GP) Gray, gravel to < 1.5" size, occasional Cobbles, 5-15% visible ice (Vx+Vc) w/ layers of Gravelly Sand and Sand (SP)
Sha		
	45	
	50	
Sha		
	55	
	60	
	65	
	70	
	75	
	80	

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date : May 1998

LOG OF BORING D-25 cont.
Liberty Development
Beaufort Sea, Alaska

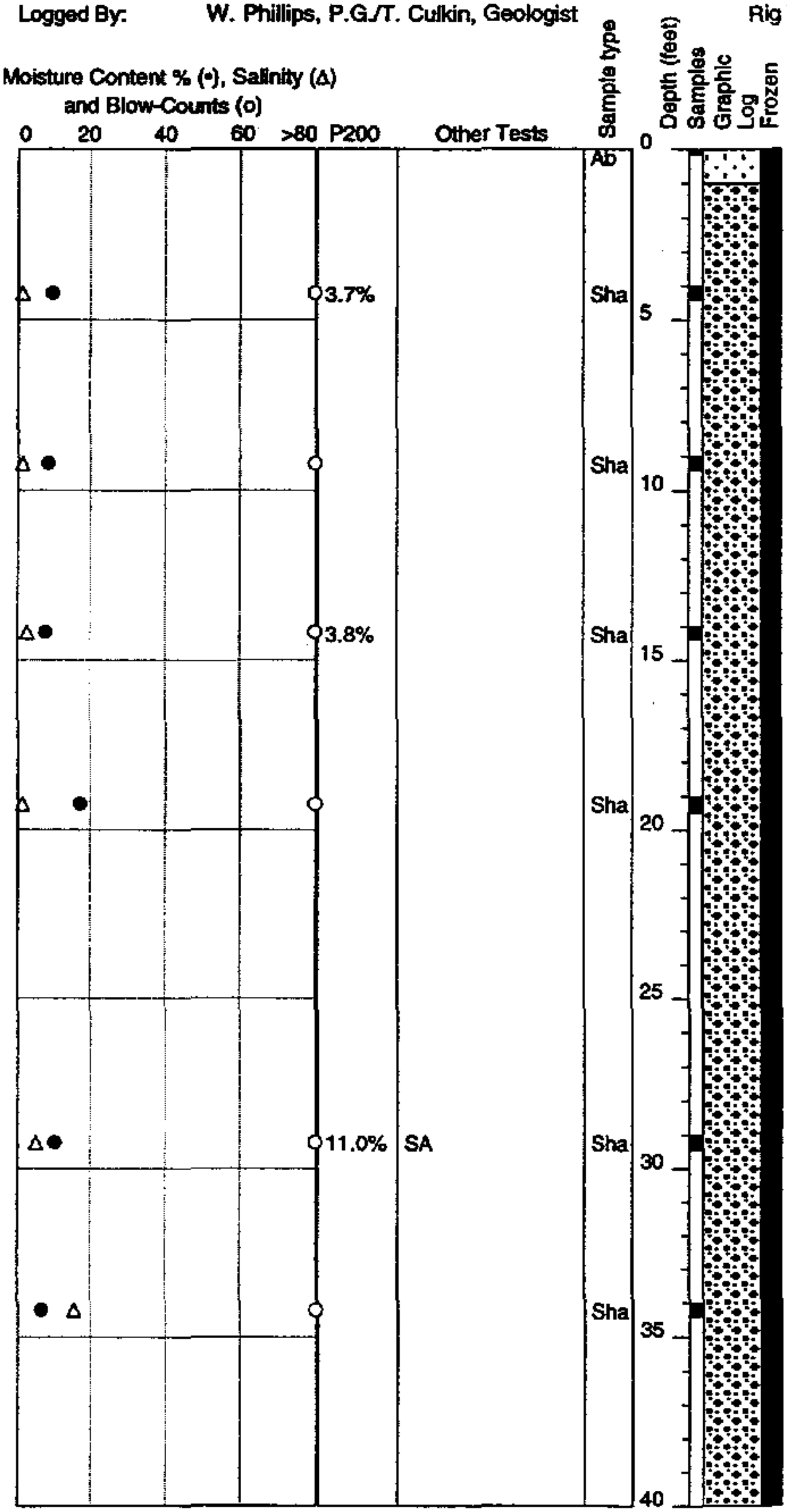
Plate
A-34

DUANE MILLER & ASSOCIATES

Project: **Liberty**
DM&A Job No.: 4119.23
Logged By: W. Phillips, P.G./T. Culkin, Geologist

Log of HOLE: D-26

Date Drilled: March 24, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: -- Ice Thickness: --
Elevation: --
297,671'E 5,919,409'N (ASP)



Description

SAND: (SP) Brown, thin Silt (ML) layer at surface, Nbn

SANDY GRAVEL: (GP) Gray, interbedded with Sand (SP) and Gravel (GP-GM), occasional Cobbles, gravel is subround to <2" size, 5-10% visible ice (Vx+Vc) w/ occasional zones w/ up to 20% visible ice

Boring D-26 is continued on Plate A-36

DUANE MILLER & ASSOCIATES

Project:	Liberty	**Log of HOLE :**	**D-26 cont.**
DM&A Job No. :	4119.23	Date Drilled:	March 24, 1998
Logged By:	W. Phillips, P.G./T. Culkin, Geologist	Contractor:	Discovery Drilling/CATCO
		Rig Type:	CME-75 on sled w/ hollow stem
		Water Depth: --	Ice Thickness: --
		Elevation: --	
		297,671'E	5,919,409'N (ASP)

Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)

0 20 40 60 >80 P200 Other Tests Sample type Depth (feet) Samples Graphic Log Frozen Description

Depth (feet)	P200	Sample type	Description
40			SANDY GRAVEL: (GP) Gray, interbedded w/ Sand (SP) and Gravel (GP-GM), occasional Cobbles , gravel is subround to <2" size, 5-10% visible ice (Vx+Vc) w/ occasional zones w/ up to 20% visible ice
45		Sha	
50			
55	8.0%	Sha	SAND: (SP-SM) Gray, medium grained, Nbn
60			SANDY GRAVEL: (GP) Gray, 5% visible ice (Vx)
65		Sha	
70			
75			
80			

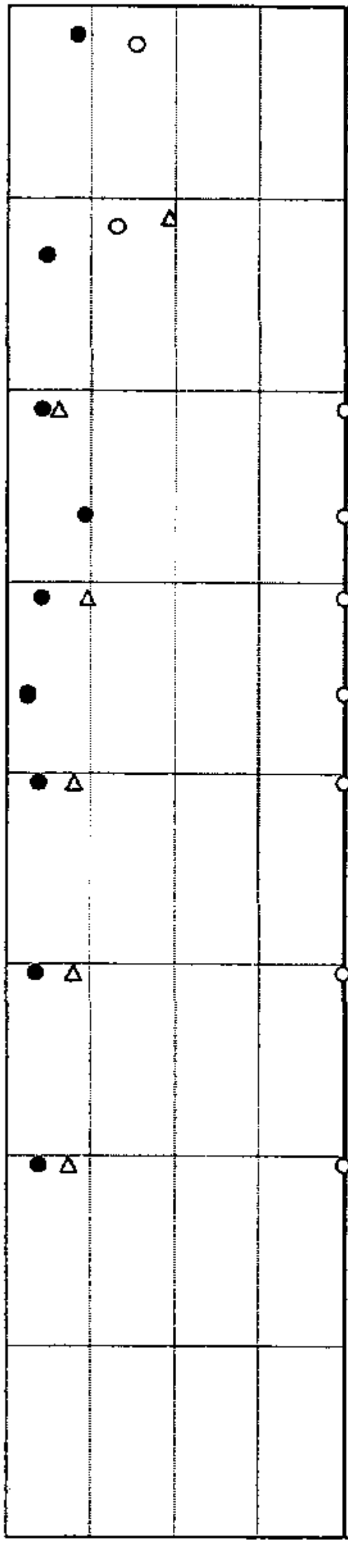
DUANE MILLER & ASSOCIATES

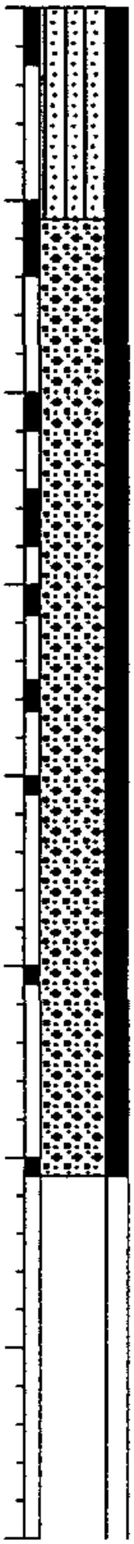
Project: **Liberty**
DM&A Job No.: 4119.23
Logged By: T. Culkin, Geologist

Log of HOLE : D-27
Date Drilled: March 26 & 27, 1998
Contractor: Discovery Drilling/CATCO
Rig Type: CME-75 on sled w/ hollow stem
Water Depth: 2.7' Ice Thickness: --
Elevation: --
290,029'E 5,927,000'N (ASP)

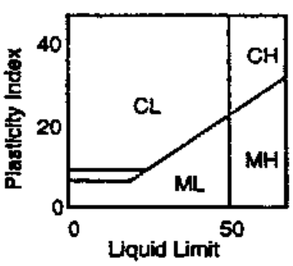
Moisture Content % (•), Salinity (Δ) and Blow-Counts (o)

0 20 40 60 >80





Depth (feet)	P200	Other Tests	Sample type	Description
0	16.0%	SA	Sha	SILTY SAND: (SM) Brown, Nb, fine grained
5			Sha	SANDY GRAVEL: (GW-GM) Gray, w/ 5% visible ice (Vx+Vc) w/ occasional layers of Silty Sand (SM) and Gravel (GW)
10	9.7%	SA	Sha	
	15.0%	SA, Dd=108 pcf	Sha	
15	7.0%	SA	Sha	
	4.1%	SA, Dd=124 pcf	Sha	
20	5.6%	SA	Sha	
25			Sha	Grading to Sandy Gravel (GP) below 25'
30	4.8%	SA	Sha	
				Installed 0.75" diameter closed PVC pipe to 30.5'
35				
40				

MAJOR DIVISIONS			SYMBOL	TYPICAL NAMES
COARSE GRAINED SOILS More than 50% larger than #200 sieve, 0.07 mm	**GRAVELS** More than half of the coarse fraction is larger than #4 sieve size, > 4.75 mm.	Clean gravels with little or no fines	GW	Well graded gravels, sandy gravel
			GP	Poorly graded gravels, sandy gravel
		Gravels with more than 12% fines	GM	Silty gravels, silt sand gravel mixtures
			GC	Clayey gravels, clay sand gravel mixtures
	SANDS More than half of the coarse fraction is smaller than #4 sieve size	Clean sands with little or no fines	SW	Well graded sand, gravelly sand
			SP	Poorly graded sands, gravelly sand
		Sands with more than 12% fines	SM	Silty sand, silt gravel sand mixtures
			SC	Clayey sand, clay gravel sand mixtures
FINE GRAINED SOILS >50%finer than #200 sieve, 0.07 mm	Plasticity Chart 	**SILTS and CLAYS** Liquid limit less than 50	ML	Inorganic silt and very fine sand, rock flour
			CL	Inorganic clay, gravelly and sandy clay, silty clay
			OL	Organic silts and clay of low plasticity
		SILTS and CLAYS Liquid limit greater than 50	MH	Inorganic silt
			CH	Inorganic clay, fat clay
			OH	Organic silt and clay of high plasticity
HIGHLY ORGANIC SOILS			Pt	Peat and other highly organic soil

UNIFIED SOIL CLASSIFICATION SYSTEM

KEY TO TEST DATA

Dd = Dry Density (pcf)
LL = Liquid Limit
PL = Plastic Limit
PI = Plastic Index
NP = non Plastic
SpG = Specific Gravity
SA = Sieve Analysis
MA = Sieve and Hydrometer Analysis
OLI = Organic Loss
RD = Relative Density
D1557 = modified Proctor
TC = Thaw Consolidation
Con = Consolidation
TXUU = Unconsolidated Undrained Triaxial
TXCU = Consolidated Undrained Triaxial
TXCD = Consolidated Drained Triaxial

Strength Data
XXX(YYY), where
XXX = $(\sigma_1 - \sigma_3)/2$
YYY = σ_3

KEY TO SAMPLE TYPE

Ag = Auger grab
Ab = Auger bulk
Ac = Air chip
Sh = 2.5" ID split barrel w/340 lb. manual hammer
Sha= 2.5" ID split barrel w/340 lb. automatic hammer
Sp = 2.5" ID split barrel pushed
Tw = Shelby tube
Ss = 1.4" ID split barrel w/ 140 lb. manual hammer

GROUP	ICE VISIBILITY	DESCRIPTION		SYMBOL	
N	Segregated ice not visible by eye	Poorly bonded or friable		Nf	
		Well bonded	No excess ice	Nb	Nbn
			Excess microscopic ice		Nbe
V	Segregated ice is visible by eye and is one inch or less in thickness	Individual ice crystals or inclusions		Vx	
		Ice coatings on particles		Vc	
		Random or irregularly oriented ice		Vr	
		Stratified or distinctly oriented ice		Vs	
ICE	Ice greater than one inch in thickness	Ice with soil inclusions		ICE + soil type	
		Ice without soil inclusions		ICE	

ICE CLASSIFICATION SYSTEM

Duane Miller & Associates
Arctic & Geotechnical Engineering
Job No.: 4119.23
Date: May 1998

SOIL and ICE CLASSIFICATION and KEY TO DATA
Liberty Development
Beaufort Sea, Alaska

Plate
A-38

APPENDIX B

APPENDIX B - Primary Laboratory Data

Summary of Samples

Plasticity Charts

Particle Size Data

Fill Material Data

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test	1/2 deviator	Sigma 3	Passing #4	Passing #200	Other Tests
D-01	0.5 ft.	ML	No	Shelby	45.1%	76 pcf										
D-01	1.0 ft.	ML	No		44.8%	76 pcf			NP							Consol
D-01	1.1 ft.	ML	No		41.0%	81 pcf					TX(UU)	340 psf	1000 psf			
D-01	1.6 ft.	ML	No		36.6%	84 pcf					TX(CD)	1910 psf	1000 psf			
D-01	2.1 ft.	ML	No		45.1%	77 pcf					TX(CD)	2920 psf	2000 psf			
D-01	5.5 ft.	MH	No	Shelby	29.2%	93 pcf				21 ppt						
D-01	5.8 ft.	MH	No		30.6%	93 pcf		50	20							Consol
D-01	6.0 ft.	MH	No		29.9%	93 pcf					TX(UU)	1940 psf	1000 psf			
D-01	6.5 ft.	MH	No		33.6%	88 pcf					TX(CD)	1800 psf	1000 psf			
D-01	7.0 ft.	MH	No		32.8%	86 pcf					TX(CD)	2590 psf	2000 psf			
D-01	10.5 ft.	MH	No	Shelby	34.3%	87 pcf										
D-01	10.8 ft.	MH	No		34.6%	87 pcf										Consol
D-01	11.3 ft.	MH	No		34.3%	87 pcf					TX(UU)	1370 psf	1000 psf			
D-01	15.5 ft.	CH	No	Shelby	31.1%	91 pcf										
D-01	15.9 ft.	CH	No		31.2%	90 pcf		51	25							Consol
D-01	16.1 ft.	CH	No		31.1%	90 pcf					TX(UU)	1730 psf	1000 psf			
D-01	20.5 ft.	GP	No	4 a	8.1%					19 ppt				30%	0.7%	SA
D-01	25.5 ft.	GP	No	19 a	7.4%					14 ppt						
D-01	30.5 ft.	GP	No	13 a	6.8%					22 ppt						
D-01	40.5 ft.	GP	No													
D-01	41.0 ft.	OL+SP	No	9 a	15.9%					12 ppt						
D-01	50.5 ft.	SP	No	23 a	18.0%					29 ppt						
D-02	1.0 ft.	ML	No	Shelby	37.5%	76 pcf										
D-02	1.6 ft.	ML	No		46.1%	74 pcf			NP							Consol

Duane Miller & Associates
Job No. 4119.23
July 1998

SAMPLE SUMMARY
Liberty Development
Beaufort Sea, Alaska

Plate
B-1

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test - 1/2 deviator - Sigma 3	Passing #4	Passing #200	Other Tests
D-02	2.1 ft.	ML	No		45.6%	71 pcf					TX(UU) 360 psf 1000 psf			
D-02	6.0 ft.	MH	No	Shelby										
D-02	6.5 ft.	MH	No		28.6%	94 pcf								Consol
D-02	6.8 ft.	MH	No		28.4%	95 pcf					TX(UU) 2520 psf 1000 psf			
D-02	11.0 ft.	MH	No	Shelby	29.4%	93 pcf		51	22					
D-02	16.0 ft.	MH	No	6 a										
D-02	21.0 ft.	SM	No	29 a	7.9%							91%	44.0%	MA
D-02	26.0 ft.	SM	No	20 a	9.6%							69%	15.0%	MA
D-02	31.0 ft.	SP-SM	No	26 a	24.9%							96%	11.0%	MA
D-02	36.0 ft.	ML	No	24 a	30.1%									
D-02	37.0 ft.	SM	No	55 a	10.7%							87%	22.0%	MA
D-02	41.0 ft.	SM	No	18 a	14.0%							97%	28.0%	MA
D-02	46.0 ft.	ML	No											MA
D-02	47.5 ft.	SM	No	12 a	23.4%	110 pcf						99%	31.0%	MA
D-02	51.0 ft.	SP-SM	No	14 a	19.6%							96%	5.0%	MA
D-02	56.5 ft.	SP	No	31 a	13.0%	118 pcf								
D-02	57.0 ft.	SM	No		18.6%							100%	16.0%	MA
D-03	1.0 ft.	ML	No	Shelby										
D-03	6.0 ft.	MH	No	Shelby	32.0%	90 pcf		53	23					
D-03	6.5 ft.	MH	No		32.0%	89 pcf					TX(UU) 2010 psf 1000 psf			
D-03	11.0 ft.	MH	No	Shelby	32.0%	91 pcf								
D-03	11.7 ft.	MH	No		30.9%	91 pcf								Consol
D-03	16.0 ft.	MH	No	Shelby	31.7%	91 pcf								
D-03	16.5 ft.	MH	No		32.8%	88 pcf								Consol

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test - 1/2 deviator - Sigma 3	Passing #4	Passing #200	Other Tests
D-03	16.9 ft.	MH	No		31.7%	90 pcf					TX(UU) 1510 psf 1000 psf			
D-03	21.0 ft.	ML	No	13 a	12.6%					29 ppt				
D-03	22.0 ft.	SP	No		15.4%					15 ppt				
D-03	26.0 ft.	SP	No	37 a	10.5%					24 ppt		79%	4.2%	SA
D-03	31.0 ft.	SP	No	19 a	15.0%					20 ppt				
D-03	36.0 ft.	SM	No	20 a	13.6%					18 ppt				
D-03	41.0 ft.	SM	No	20 a										
D-03	41.5 ft.	SM	No		13.9%					8 ppt				
D-03	46.0 ft.	SP	No	40 a	17.3%									
D-03	46.5 ft.	SP	No											SA
D-03	51.0 ft.	SP	No	72 a										
D-03	51.5 ft.	SP	No		18.6%									
D-03	52.7 ft.	SP	No		19.8%					17 ppt				
D-04	1.0 ft.	ML	No	Shelby	46.4%	78 pcf			NP					
D-04	3.5 ft.	ML	No	Shelby	50.4%	71 pcf								
D-04	4.0 ft.	ML	No		51.3%	70 pcf								Consol
D-04	4.6 ft.	ML	No		52.8%	68 pcf					TX(UU) 290 psf 1000 psf			
D-04	8.5 ft.	MH	No	Shelby	31.2%	92 pcf								
D-04	13.5 ft.	MH	No	8 a										
D-04	14.0 ft.	MH	No											
D-04	14.5 ft.	MH	No		33.4%	88 pcf				25 ppt				
D-04	18.5 ft.	MH	No	4 a	21.1%					39 ppt				
D-04	23.5 ft.	SP	No	14 a	10.1%					31 ppt				
D-04	28.5 ft.	GP	No	27 a	6.6%									

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test - 1/2 deviator - Sigma 3	Passing #4	Passing #200	Other Tests
D-04	33.5 ft.	GP	No	24 a										
D-04	38.5 ft.	GP	No	6 a	12.6%									
D-04	39.2 ft.	ML	No		11.6%									
D-04	43.5 ft.	GP	No	28 a										
D-04	48.5 ft.	GP	No	32 a	8.1%									
D-05	0.0 ft.	ML	No	Push	34.0%									
D-05	0.3 ft.	OL	No	Push	51.5%		4.9%							
D-05	2.5 ft.	ML	No	Shelby	47.1%	73 pcf								
D-05	3.0 ft.	ML	No		52.8%	69 pcf			NP					Consol
D-05	3.5 ft.	ML	No		37.6%	80 pcf					TX(UU) 360 psf 1000 psf			
D-05	7.5 ft.	MH	No	Shelby	29.3%	93 pcf								
D-05	8.1 ft.	MH	No		26.9%	96 pcf								Consol
D-05	8.3 ft.	MH	No		29.3%	94 pcf					TX(UU) 1400 psf 1000 psf			
D-05	12.5 ft.	MH	No	9 a	33.1%	89 pcf								
D-05	13.0 ft.	MH	No		33.6%			51	22					
D-05	17.5 ft.	MH	No	7 a	32.4%									
D-05	22.5 ft.	SM	No	23 a	10.4%							86%	24.0%	SA
D-05	27.5 ft.	GW	No	26 a	10.6%							44%	1.2%	SA
D-05	32.5 ft.	GP	No	23 a	4.9%									
D-05	37.5 ft.	ML	No	14 a	20.1%									
D-05	42.5 ft.	SM	No	20 a	13.0%							94%	15.0%	SA
D-05	48.0 ft.	SP-SM	No	50 a	16.7%									
D-05	48.5 ft.	SP-SM	No		14.4%	118 pcf								
D-05	52.5 ft.	SM	No	44 a	11.2%									

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test - 1/2 deviator - Sigma 3	Passing #4	Passing #200	Other Tests
D-05	57.5 ft.	SP-SM	No	58 a	17.9%									
D-05	67.5 ft.	GP	No	63 a										
D-05	72.5 ft.	GP	No	49 a										
D-06	1.0 ft.	ML	No	0 a	80.2%									
D-06	2.5 ft.	ML	No	Shelby	34.6%	82 pcf								
D-06	3.5 ft.	ML	No		35.0%	86 pcf					TX(UU) 1150 psf 1000 psf			
D-06	5.0 ft.	ML	No	Shelby	37.1%	84 pcf						100%	66.0%	SA
D-06	10.2 ft.	Pt	No	2 a	117.5%									
D-06	10.5 ft.	MH	No		23.3%									
D-06	15.0 ft.	MH	No	4 a										
D-06	16.5 ft.	SM	No		15.7%									
D-07	0.5 ft.	SM	No	6 a										
D-07	3.0 ft.	SM	No	Shelby	29.5%	96 pcf								
D-07	7.0 ft.	OH	No	Shelby	46.6%	74 pcf		62	26					
D-07	8.0 ft.	OH	No		46.8%	73 pcf					TX(UU) 450 psf 1000 psf			
D-07	9.5 ft.	MH	No	5 a										
D-07	14.5 ft.	MH	No	Shelby	19.3%	110 pcf								
D-07	19.5 ft.	MH	No	7 a	24.5%									
D-07	20.5 ft.	ML	No		20.6%									
D-07	26.5 ft.	SP	No	26 a	10.3%							100%	3.6%	SA
D-07	29.5 ft.	SP	No	12 a	15.0%									
D-08	0.0 ft.	SP	No	0 a										
D-08	0.5 ft.	SP	No											
D-08	2.0 ft.	SP	No	Push	21.1%							100%	3.4%	SA

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test - 1/2 deviator - Sigma 3	Passing #4	Passing #200	Other Tests
D-08	4.0 ft.	SP	No	Push	28.5%									
D-08	4.5 ft.	ML	No	Push	50.2%									
D-08	6.5 ft.	SP-SM	No	Shelby	21.6%	101 pcf								
D-08	9.0 ft.	CL	No	Shelby	28.1%	95 pcf		45	19					
D-08	14.0 ft.	CL	No	16 a										
D-08	19.0 ft.	SM	No	13 a	39.0%									
D-08	24.0 ft.	SM	No	4 a	35.1%									
D-08	29.0 ft.	SP	No	21 a										
D-09	0.0 ft.	ML	No	0 a	39.1%				NP					
D-09	3.5 ft.	ML	No	0 a	58.5%									
D-09	4.0 ft.	Pt	No		77.8%		14.0%					100%	45.0%	SA
D-09	6.0 ft.	Pt	No	Push	56.6%	65 pcf								
D-09	8.5 ft.	Pt	No	Push	50.2%	69 pcf								
D-09	9.0 ft.	Pt	No		50.3%		13.4%							
D-09	10.5 ft.	SP	No	Push										
D-10	0.1 ft.	SM	No	Push										
D-10	1.5 ft.	ML	No	Push	27.7%	90 pcf								
D-10	2.0 ft.	OL	No		41.1%	85 pcf	4.3%		NP			100%	73.0%	MA
D-10	4.0 ft.	ML	No	Push	40.8%	79 pcf								
D-10	6.0 ft.	SM	No	Push	23.9%							100%	18.0%	SA
D-10	8.5 ft.	Pt	No	3 a	66.1%									
D-10	9.0 ft.	Pt	No		77.0%		26.0%							
D-10	13.5 ft.	OL	No	3 a	39.9%									
D-11	0.0 ft.	SM	No	3 a	29.1%									

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test - 1/2 deviator - Sigma 3	Passing #4	Passing #200	Other Tests
D-11	1.0 ft.	SP-SM	No		20.9%									
D-11	2.5 ft.	SP-SM	No	7 a	16.2%							100%	5.7%	SA
D-11	6.0 ft.	SM	No	8 a	26.8%							100%	20.0%	SA
D-11	10.0 ft.	ML	No	2 a	64.3%									
D-11	15.0 ft.	ML	No	3 a	43.6%									
D-11	16.3 ft.	Pt	No		115.2%									
D-11	17.0 ft.	Pt	No	2 a										
D-11	18.0 ft.	ML	No											
D-11	19.0 ft.	SP+Pt	No	10 a	40.8%									
D-12	0.0 ft.	SM	No	2 a	38.7%									
D-12	2.5 ft.	ML	No	Shelby	35.4%	85 pcf								
D-12	5.0 ft.	SM	No	Shelby	31.0%	86 pcf						100%	27.0%	MA
D-12	7.5 ft.	SM	No	2 a	58.2%									
D-12	10.0 ft.	SM	No	Shelby	82.7%	53 pcf								
D-12	15.0 ft.	ML	No	3 a	55.7%									
D-12	16.0 ft.	GP	No	10	12.2%									
D-12	20.0 ft.	GW	No	9 a	12.7%							45%	2.8%	SA
D-12	25.0 ft.	GP	No	14 a	7.9%									
D-12	30.0 ft.	GP	No	24 a	7.2%									
D-13	0.0 ft.	SP	No	4 a	23.1%							100%	3.3%	SA
D-13	2.5 ft.	OL+Pt	No	2 a	41.6%		4.2%							
D-13	5.0 ft.	ML	No	5 a	44.1%							100%	84.0%	MA
D-13	7.5 ft.	ML	No	5 a	28.8%									
D-13	10.2 ft.	Pt	No	2 a	84.0%									

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test - 1/2 deviator - Sigma 3	Passing #4	Passing #200	Other Tests
D-13	10.7 ft.	ML	No		56.7%									
D-13	13.5 ft.	ML	No	5 a										
D-13	14.2 ft.	Pt	No		56.1%									
D-13	16.0 ft.	ML	No	2 a	23.3%									
D-14	0.0 ft.	ML	No	4 a	32.1%									
D-14	1.5 ft.	SM	No	Shelby	39.1%	85 pcf								
D-14	4.0 ft.	SP-SM	No	5 a	24.9%							100%	12.0%	SA
D-14	6.5 ft.	SM	No	Shelby	37.1%	76 pcf								
D-14	9.0 ft.	ML+OL	No	a	69.9%									
D-14	9.9 ft.	SP	No		22.6%									
D-14	14.5 ft.	SP	No	14 a	11.6%	127 pcf								
D-14	19.0 ft.	SP	No	16 a	18.8%									
D-14	24.0 ft.	GP	No	21 a	7.8%							50%	4.5%	SA
D-14	29.0 ft.	GP	No	22 a										
D-15	0.0 ft.	SP-SM	No	Push	27.7%									
D-15	0.3 ft.	OL/SM	No	Push	43.8%		3.8%					100%	28.0%	SA
D-15	2.5 ft.	OL	No	Push										
D-15	3.0 ft.	ML	No	Push										
D-15	5.0 ft.	OL	No	Push			6.0%							
D-15	6.0 ft.	OL	No	Push										
D-15	10.0 ft.	SM	No	14 a	14.7%							94%	13.0%	SA
D-15	16.0 ft.	OL	No	11 a	66.2%									
D-16	0.0 ft.	ML	No	Push	32.2%							100%	56.0%	SA
D-16	5.0 ft.	SP-SM	No	10 a	11.8%							100%	12.0%	SA

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test - 1/2 deviator - Sigma 3	Passing #4	Passing #200	Other Tests
D-16	9.0 ft.	SP-SM	No	15 a										
D-16	14.0 ft.	SP	No	6 a	12.0%									
D-16	19.0 ft.	GP	No	9 a	6.7%									
D-16	24.0 ft.	GW	No	19 a	5.7%									
D-16	29.0 ft.	GW	No	18 a	6.0%									
D-17	0.0 ft.	SM	No	Push	25.7%							100%	28.0%	SA
D-17	5.0 ft.	SP-SM	No	9 a	11.4%							68%	11.0%	SA
D-17	9.0 ft.	SP	No	6 a	15.9%							87%	1.6%	SA
D-17	14.0 ft.	SP-SM	No	14 a	14.0%									
D-18	0.0 ft.	ML	No	Push										
D-18	0.2 ft.	OL	No		70.5%									
D-18	5.0 ft.	ML	No	Shelby	43.7%	78 pcf								
D-18	5.5 ft.	ML	No		43.7%	74 pcf					TX(UU) 780 psf 1000 psf			
D-18	10.5 ft.	ML	No	Push										
D-18	15.0 ft.	GP	No	10 a	11.2%									
D-18	25.0 ft.	GP	No	11 a	11.5%									
D-19	0.0 ft.	ML	No	Push										
D-19	0.4 ft.	ML	No		58.3%				NP					
D-19	4.5 ft.	SM	No	Push	32.6%							100%	16.0%	SA
D-19	5.3 ft.	Pt	No		104.8%									
D-19	5.8 ft.	SP-SM	No		14.3%							72%	6.4%	SA
D-19	9.5 ft.	GP	No	6 a	9.2%									
D-19	14.5 ft.	GP	No	13 a	8.3%									
D-19	24.5 ft.	GP	No	18 a	6.0%									

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test - 1/2 deviator - Sigma 3	Passing #4	Passing #200	Other Tests
D-20	0.0 ft.	SP-SM	No	Push	20.4%									
D-20	4.6 ft.	GW-GM	No	7 a	7.7%					42 ppt		45%	7.8%	SA
D-20	9.5 ft.	SP-SM	No		14.2%							90%	7.1%	SA
D-20	10.0 ft.	GP	No	3 a	8.0%					32 ppt				
D-20	14.5 ft.	GW	No	6 a	6.9%					73 ppt		39%	2.4%	SA
D-20	19.5 ft.	GP	No	6 a	7.1%					51 ppt				
D-20	24.5 ft.	GP	No	9 a	7.7%					66 ppt				
D-21	0.5 ft.	SP	Yes	50 a	16.9%									
D-21	1.5 ft.	SP	Yes		12.5%									
D-21	4.0 ft.	SM	No	17 a	9.8%					36 ppt		62%	15.0%	SA
D-21	10.0 ft.	GW-GM	Yes	74 m	8.3%									
D-21	11.0 ft.	GW-GM	Yes	260 a	7.2%					23 ppt		45%	6.4%	SA
D-21	14.0 ft.	GP-GM	Yes		9.2%									
D-21	14.5 ft.	GP-GM	Yes	173 a	6.5%	139 pcf				12 ppt		44%	8.9%	SA
D-21	16.5 ft.	GP-GM	Yes	126 a	8.4%	136 pcf				8 ppt		43%	9.9%	SA
D-21	19.0 ft.	GP-GM	Yes	240 a	8.0%					10 ppt				
D-21	24.0 ft.	GW-GM	Yes	170 a	8.6%					9 ppt		52%	8.8%	SA
D-21	29.0 ft.	GP-GM	Yes	230 a	4.9%					9 ppt				
D-21	39.0 ft.	GP-GM	Yes	248 a	7.8%					17 ppt				
D-22	4.0 ft.	GP	Yes	240 a	12.6%					3 ppt		36%	3.3%	SA
D-22	9.2 ft.	SP-SM	Yes	130 a	21.6%									
D-22	12.0 ft.	GP-GM	Yes	Grab	10.9%					2 ppt		49%	9.6%	SA, RD
D-22	19.0 ft.	GP-GM	Yes	110 a	11.0%					3 ppt				
D-22	24.0 ft.	GP-GM	Yes	252 a	7.3%									

Duane Miller & Associates
Job No. 4119.23
July 1998

SAMPLE SUMMARY
Liberty Development
Beaufort Sea, Alaska

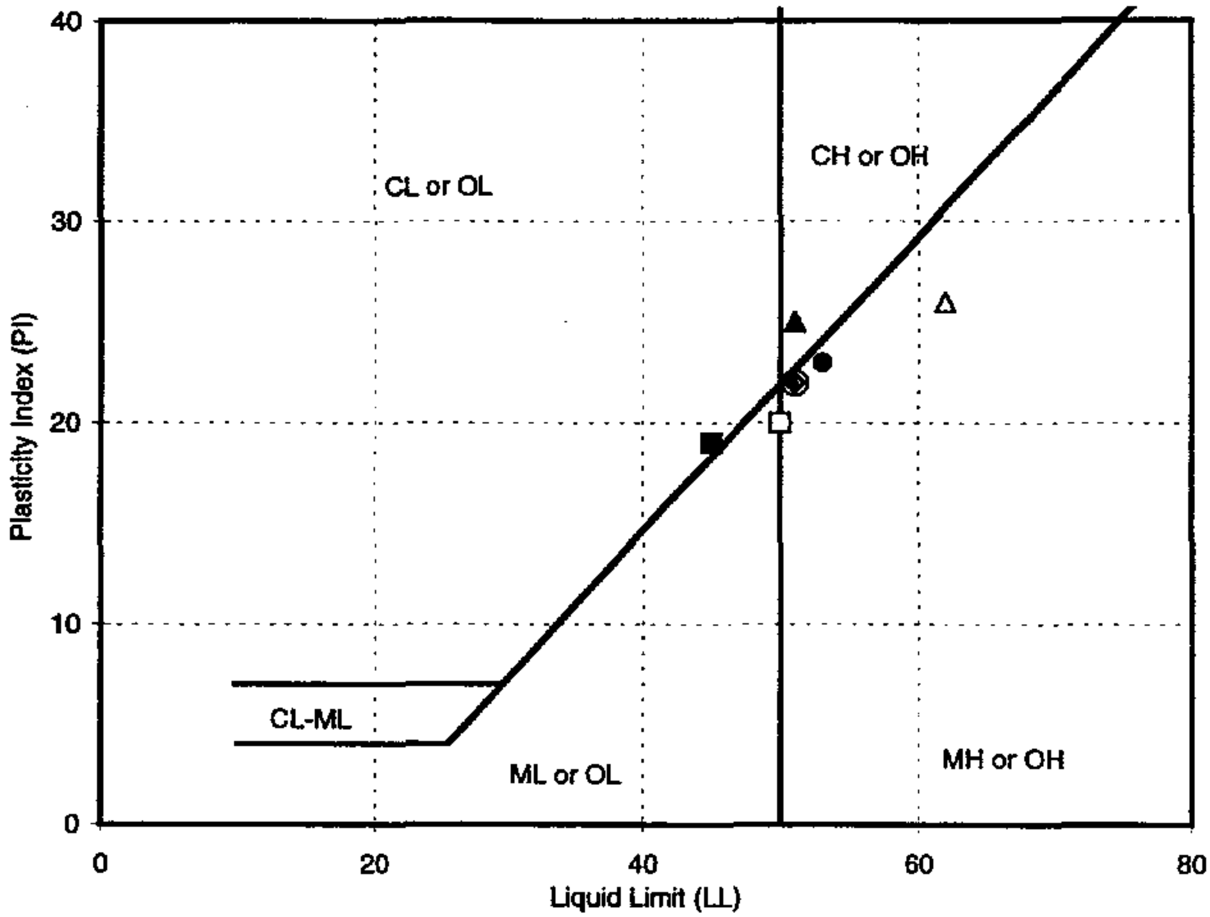
Plate
B-10

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test - 1/2 deviator - Sigma 3	Passing #4	Passing #200	Other Tests
D-22	27.0 ft.	SM	Yes	Grab	8.6%					2 ppt		68%	21.0%	SA
D-22	29.0 ft.	GP	Yes	165 a	10.6%									
D-22	34.0 ft.	GP	Yes	222 a	7.2%					3 ppt			4.7%	
D-22	44.0 ft.	GP	Yes	300 a	9.8%					2 ppt				
D-22	54.0 ft.	GP	Yes	240 a	8.2%									
D-22	64.0 ft.	SP-SM	Yes	285 a	13.5%									
D-23	4.0 ft.	GW	Yes	240 a	5.5%									
D-23	8.7 ft.	GW	Yes	159 a	7.1%								3.3%	
D-23	12.0 ft.	GW-GM	Yes	Grab	9.7%							47%	7.1%	SA, SpG=2.65, RD
D-23	18.5 ft.	GW	Yes	200 a	8.1%									
D-23	23.5 ft.	GM	Yes	218 a	9.2%								14.0%	
D-23	28.5 ft.	GW	Yes	192 a	7.2%									
D-23	33.5 ft.	GW	Yes	300 a	6.3%									
D-23	42.5 ft.	GP	Yes	300 a	8.2%									
D-23	50.0 ft.	GP	Yes	200 a	7.6%									
D-24	0.1 ft.	SM	Yes	23 a	29.4%							100%	39.0%	SA
D-24	4.0 ft.	SP-SM	Yes	88 a	21.5%									
D-24	9.0 ft.	GP	Yes	300 a	8.3%					1 ppt				
D-24	14.0 ft.	GP	Yes	171 a	6.6%					1 ppt			2.7%	
D-24	19.0 ft.	GP	Yes	200 a	10.3%					2 ppt				
D-24	23.0 ft.	SM	Yes	144 a	27.4%					1 ppt			14.0%	
D-24	27.0 ft.	GP-GM	Yes	Grab	7.0%					3 ppt		43%	10.8%	SA, SpG=2.65, D1557, RD
D-24	29.0 ft.	GP-GM	Yes	300 a										

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test - 1/2 deviator - Sigma 3	Passing #4	Passing #200	Other Tests
D-24	34.0 ft.	GP-GM	Yes	200 a	5.5%					4 ppt				
D-24	44.0 ft.	GP-GM	Yes	300 a	6.7%					11 ppt				
D-24	54.0 ft.	GP	Yes	216 a	5.1%					11 ppt			4.6%	
D-24	64.0 ft.	SP-SM	Yes	156 a	14.1%					11 ppt				
D-25	2.0 ft.	GP	Yes	300 a	11.1%									
D-25	7.0 ft.	GP	Yes	240 a	7.1%									
D-25	12.0 ft.	GP	Yes	300 a	8.6%									
D-25	17.0 ft.	GP	Yes	200 a	6.0%									
D-25	17.5 ft.	Pt	Yes		151.1%									
D-25	22.0 ft.	GW	Yes	300 a	6.1%									
D-25	27.0 ft.	GW	Yes	200 a	6.5%									
D-25	32.0 ft.	GP	Yes	187 a	8.0%									
D-25	42.0 ft.	GP	Yes	136 a	8.5%									
D-25	51.0 ft.	GP	Yes	240 a	12.8%									
D-26	0.0 ft.	ML	Yes	Bulk										
D-26	4.0 ft.	GP	Yes	180 a	9.5%					1 ppt			3.7%	
D-26	9.0 ft.	GP	Yes	144 a	8.3%					1 ppt				
D-26	14.0 ft.	GP	Yes	200 a	7.8%					2 ppt			3.8%	
D-26	19.0 ft.	SP	Yes	124 a	17.5%					1 ppt				
D-26	29.0 ft.	GP-GM	Yes	164 a	10.5%					5 ppt		52%	11.0%	SA
D-26	34.0 ft.	GP	Yes	180 a	6.7%					16 ppt				
D-26	44.0 ft.	GP-GM	Yes	192 a	8.6%					9 ppt				
D-26	54.0 ft.	SP-SM	Yes	88 a	24.5%					5 ppt		100%	8.0%	SA
D-26	63.0 ft.	GP-GM	Yes	300 a	12.8%					6 ppt				

Boring	Depth	Type (USCS)	Frz?	Sampling Blows/ft	Moisture Content	Dry Density	Organic Loss	LL	PI	Salinity	Shear Strength Tests Test - 1/2 deviator - Sigma 3	Passing #4	Passing #200	Other Tests
D-27	0.0 ft.	SM	Yes	31 a	16.8%							96%	16.0%	SA
D-27	5.5 ft.	GP-GM	Yes	26 a	9.4%					39 ppt				
D-27	10.0 ft.	GW-GM	Yes	126 a	8.5%					12 ppt		46%	9.7%	SA
D-27	12.5 ft.	SM	Yes	135 a	18.7%	108 pcf						99%	15.0%	SA
D-27	15.0 ft.	GW-GM	Yes	214 a	8.0%					19 ppt		45%	7.0%	SA
D-27	17.5 ft.	GW	Yes	222 a	5.2%	124 pcf						41%	4.1%	SA
D-27	18.0 ft.	GW	Yes		5.1%									
D-27	20.0 ft.	GW-GM	Yes	260 a	7.5%					16 ppt		44%	5.6%	SA
D-27	25.0 ft.	GP	Yes	260 a	6.8%					16 ppt				
D-27	30.0 ft.	GP	Yes	150 a	7.4%					15 ppt		36%	4.8%	SA

a = automatic hammer, m = manual hammer, SA = sieve analysis, MA = hydrometer and sieve analysis, SpG = specific gravity,
Consol = consolidation test, D1557 = modified Proctor compaction density, RD = maximum and minimum densities from shaking table

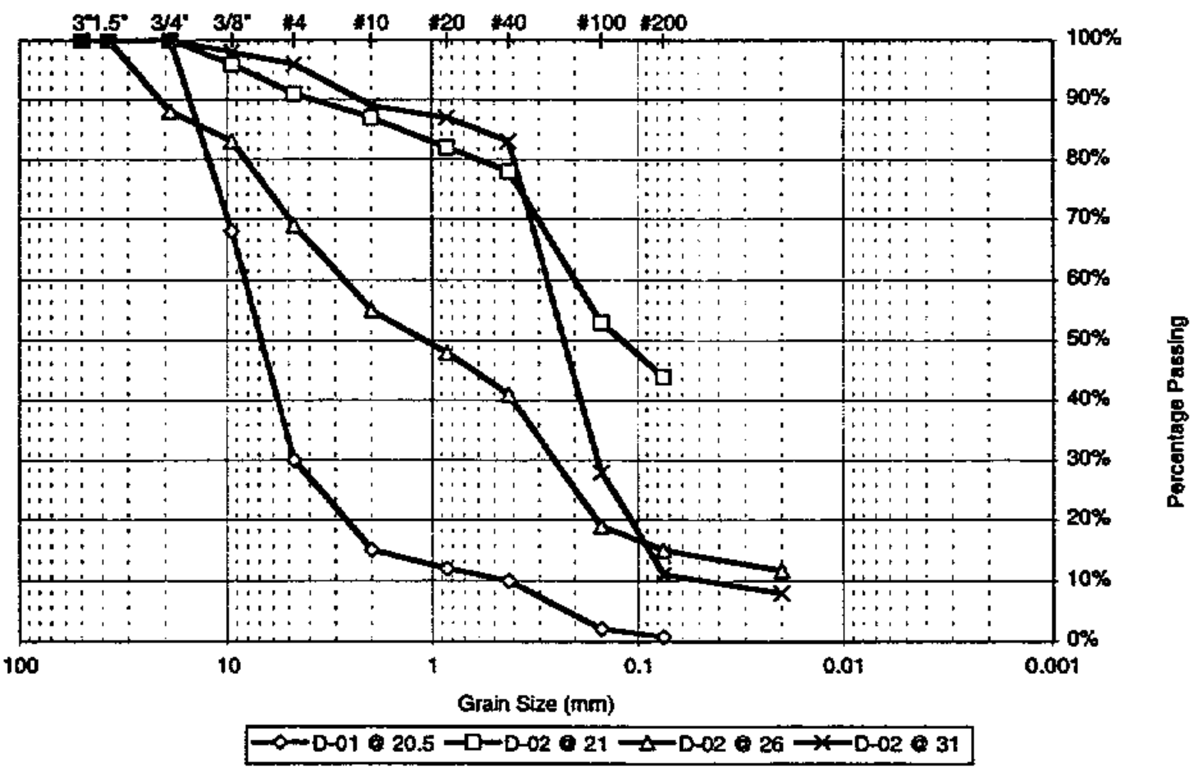


	Sample Location	Plastic Limit	Liquid Limit	Index	Moisture	USCS
	D-01 @ 0.5 ft.			NP	44.8%	ML
□	D-01 @ 5.5 ft.	30	50	20	30.6%	MH
▲	D-01 @ 15.0 ft.	26	51	25	31.2%	CH
	D-02 @ 1.0 ft.			NP	46.1%	ML
◆	D-02 @ 11.0 ft.	29	51	22	29.4%	MH
●	D-03 @ 6.0 ft.	30	53	23	32.0%	MH
	D-04 @ 1.0 ft.			NP	46.4%	ML
	D-05 @ 2.5 ft.			NP	47.1%	ML
○	D-05 @ 13.0 ft.	29	51	22	33.6%	MH
△	D-07 @ 7.0 ft.	36	62	26	46.6%	OH
■	D-08 @ 9.0 ft.	26	45	19	28.1%	CL
	D-09 @ 0.0 ft.			NP	39.1%	ML
	D-10 @ 2.0 ft.			NP	41.1%	OL
	D-19 @ 0.4 ft.			NP	58.3%	ML

Duane Miller & Assoc.
Job No 4119.23
July 1998

PLASTICITY CHART
Liberty Development
Beaufort Sea, Alaska

Boring =>	D-01	D-02	D-02	D-02
Depth =>	20.5 ft.	21.0 ft.	26.0 ft.	31.0 ft.
Location =>	Island	Island	Island	Island
3" =>	100.0%	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	100.0%	100.0%	100.0%
3/4" =>	100.0%	100.0%	88.0%	100.0%
3/8" =>	68.0%	96.0%	83.0%	98.0%
#4 =>	30.0%	91.0%	69.0%	96.0%
#10 =>	15.0%	87.0%	55.0%	89.0%
#20 =>	12.0%	82.0%	48.0%	87.0%
#40 =>	10.0%	78.0%	41.0%	83.0%
#100 =>	2.0%	53.0%	19.0%	28.0%
#200 =>	0.7%	44.0%	15.0%	11.0%
0.02 mm		30%	12%	8%
0.005 mm				
0.002 mm				
Analysis of Data				
D10 size =>	0.425 mm	N/A	N/A	N/A
D30 size =>	4.750 mm	N/A	0.252 mm	0.156 mm
D50 size =>	6.841 mm	0.119 mm	1.085 mm	0.228 mm
D60 size =>	8.210 mm	0.201 mm	2.724 mm	0.275 mm
Coeff. of Uniformity, Cu =	19.32	N/A	N/A	N/A
Coeff. of Curvature, Cc =	6.47	N/A	N/A	N/A
Gravel (+#4) percentage =	70.0%	9.0%	31.0%	4.0%
Sand percentage =	29.3%	47.0%	54.0%	85.0%
Fines percentage =	0.7%	44.0%	15.0%	11.0%
Unified Soil Class Symbol =	GP	SM	SM	SP-SM



Duane Miller & Associates
Job No. 4119.23
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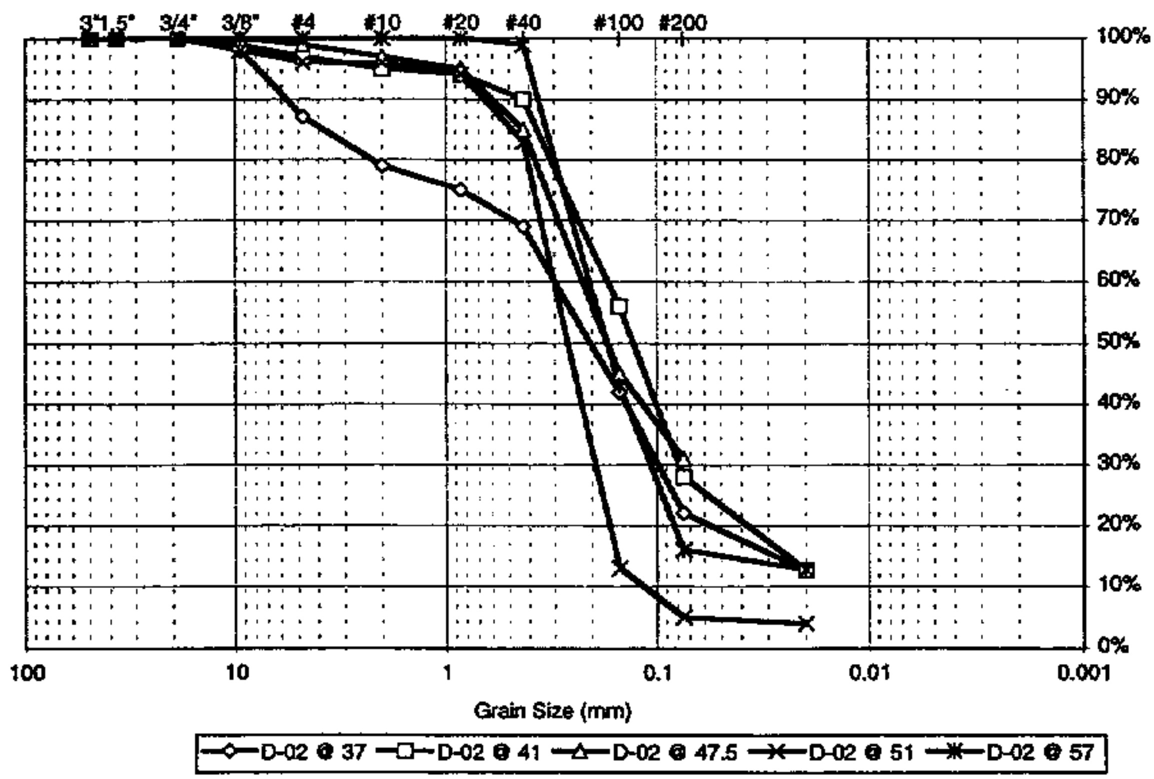
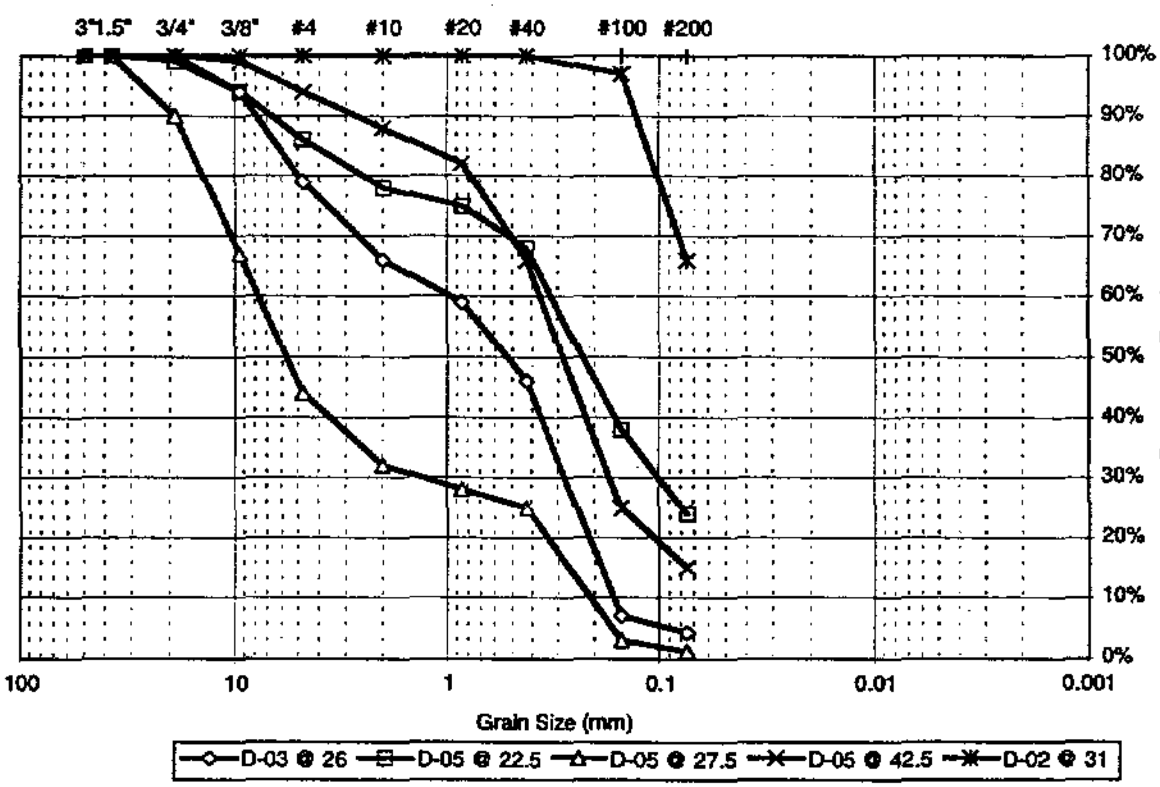
PARTICLE DATA
Liberty Development
Beaufort Sea, Alaska

Plate
B-15

Boring =>	D-02	D-02	D-02	D-02	D-02
Depth =>	37.0 ft.	41.0 ft.	47.5 ft.	51.0 ft.	57.0 ft.
Location =>	Island	Island	Island	Island	Island
3" =>	100.0%	100.0%	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	100.0%	100.0%	100.0%	100.0%
3/4" =>	100.0%	100.0%	100.0%	100.0%	100.0%
3/8" =>	98.0%	99.0%	100.0%	98.0%	100.0%
#4 =>	87.0%	97.0%	99.0%	96.0%	100.0%
#10 =>	79.0%	95.0%	97.0%	96.0%	100.0%
#20 =>	75.0%	94.0%	95.0%	94.0%	100.0%
#40 =>	69.0%	90.0%	85.0%	83.0%	99.0%
#100 =>	42.0%	56.0%	45.0%	13.0%	43.0%
#200 =>	22.0%	28.0%	31.0%	5.0%	16.0%
0.02 mm	12.5%	12.6%	18.1%	4.0%	12.8%
0.005 mm					
0.002 mm					
Analysis of Data					
D10 size =>	N/A	N/A	N/A	0.116 mm	N/A
D30 size =>	0.099 mm	0.079 mm	N/A	0.193 mm	0.107 mm
D50 size =>	0.204 mm	0.129 mm	0.171 mm	0.260 mm	0.171 mm
D60 size =>	0.300 mm	0.170 mm	0.222 mm	0.302 mm	0.206 mm
Coeff. of Uniformity, Cu =	N/A	N/A	N/A	2.61	N/A
Coeff. of Curvature, Cc =	N/A	N/A	N/A	1.07	N/A
Gravel (+#4) percentage =	13.0%	3.0%	1.0%	4.0%	0.0%
Sand percentage =	65.0%	69.0%	68.0%	91.0%	84.0%
Fines percentage =	22.0%	28.0%	31.0%	5.0%	16.0%
Unified Soil Class Symbol =	**SM**	**SM**	**SM**	**SP-SM**	**SM**



Boring =>	D-03	D-05	D-05	D-05	D-06
Depth =>	26.0 ft.	22.5 ft.	27.5 ft.	42.5 ft.	5.0 ft.
Location = >	Island	Sta 0+00	Sta 0+00	Sta 0+00	Sta 22+21
3" =>	100.0%	100.0%	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	100.0%	100.0%	100.0%	100.0%
3/4" =>	100.0%	99.0%	90.0%	100.0%	100.0%
3/8" =>	94.0%	94.0%	67.0%	99.0%	100.0%
#4 =>	79.0%	86.0%	44.0%	94.0%	100.0%
#10 =>	66.0%	78.0%	32.0%	88.0%	100.0%
#20 =>	59.0%	75.0%	28.0%	82.0%	100.0%
#40 =>	46.0%	68.0%	25.0%	66.0%	100.0%
#100 =>	7.0%	38.0%	3.0%	25.0%	97.0%
#200 =>	4.2%	24.0%	1.2%	15.0%	66.0%
0.02 mm					
0.005 mm					
0.002 mm					
Analysis of Data					
D10 size =>	0.163 mm	N/A	0.209 mm	N/A	N/A
D30 size =>	0.277 mm	0.101 mm	1.304 mm	0.170 mm	N/A
D50 size =>	0.526 mm	0.228 mm	5.691 mm	0.283 mm	N/A
D60 size =>	0.961 mm	0.322 mm	7.693 mm	0.365 mm	N/A
Coeff. of Uniformity, Cu =	5.91	N/A	36.82	N/A	N/A
Coeff. of Curvature, Cc =	0.49	N/A	1.06	N/A	N/A
Gravel (+#4) percentage =	21.0%	14.0%	56.0%	6.0%	0.0%
Sand percentage =	74.8%	62.0%	42.8%	79.0%	34.0%
Fines percentage =	4.2%	24.0%	1.2%	15.0%	66.0%
Unified Soil Class Symbol =	SP	SM	GW	SM	ML

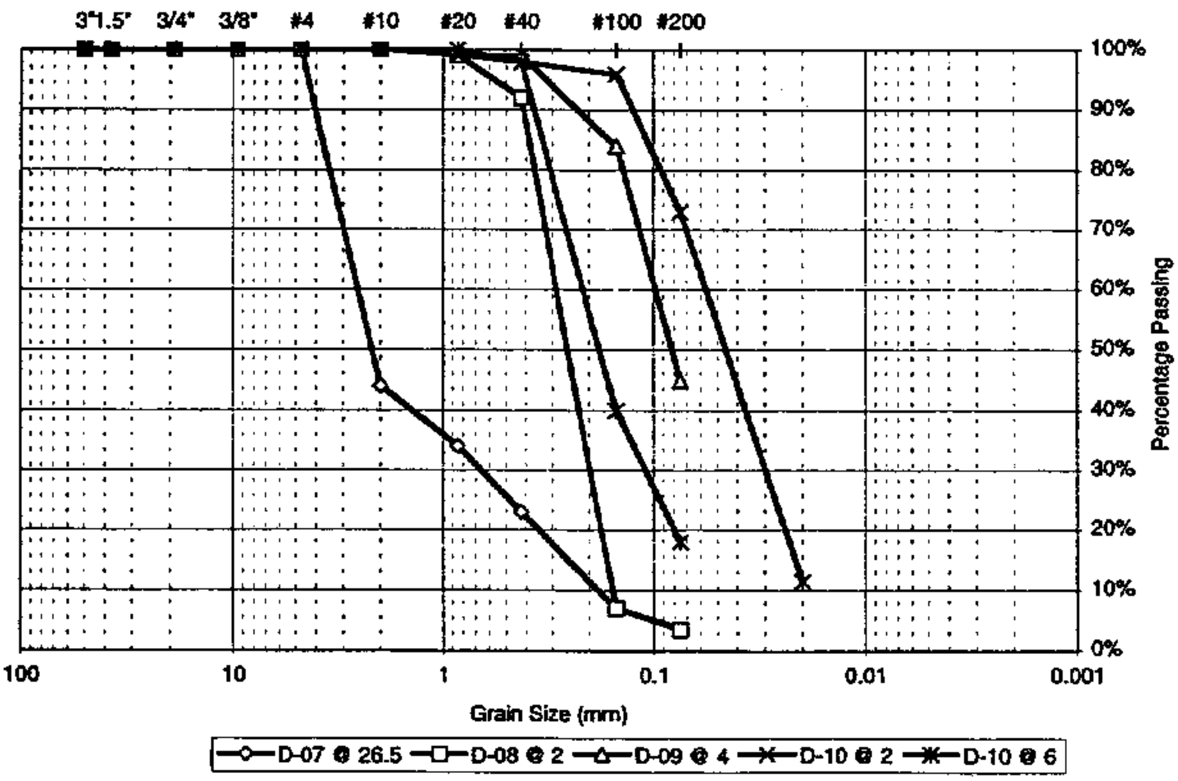


Duane Miller & Associates
Job No. 4119.23
July 1998

PARTICLE DATA
Liberty Development
Beaufort Sea, Alaska

Plate
B-17

		[redacted]		[redacted]	[redacted]
Boring =>	D-07	D-08	D-09	D-10	D-10
Depth =>	26.5 ft.	2.0 ft.	4.0 ft.	2.0 ft.	6.0 ft.
Location =>	Sta 46+51	Sta 72+70	Sta 103+18	Sta 125+88	Sta 125+88
3" =>	100.0%	100.0%	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	100.0%	100.0%	100.0%	100.0%
3/4" =>	100.0%	100.0%	100.0%	100.0%	100.0%
3/8" =>	100.0%	100.0%	100.0%	100.0%	100.0%
#4 =>	100.0%	100.0%	100.0%	100.0%	100.0%
#10 =>	44.0%	100.0%	100.0%	100.0%	100.0%
#20 =>	34.0%	99.0%	99.0%	99.0%	100.0%
#40 =>	23.0%	92.0%	99.0%	98.0%	98.0%
#100 =>	7.0%	7.0%	84.0%	96.0%	40.0%
#200 =>	3.6%	3.4%	45.0%	73.0%	18.0%
0.02 mm				11.5%	
0.005 mm					
0.002 mm					
Analysis of Data					
D10 size =>	0.182 mm	0.156 mm	N/A	N/A	N/A
D30 size =>	0.661 mm	0.199 mm	N/A	N/A	0.109 mm
D50 size =>	2.194 mm	0.254 mm	0.082 mm	N/A	0.180 mm
D60 size =>	2.561 mm	0.287 mm	0.098 mm	N/A	0.215 mm
Coeff. of Uniformity, Cu =	14.04	1.85	N/A	N/A	N/A
Coeff. of Curvature, Cc =	0.93	0.88	N/A	N/A	N/A
Gravel (+#4) percentage =	0.0%	0.0%	0.0%	0.0%	0.0%
Sand percentage =	96.4%	96.6%	55.0%	27.0%	82.0%
Fines percentage =	3.6%	3.4%	45.0%	73.0%	18.0%
Unified Soil Class Symbol =	SP	SP	SM	OL	SM



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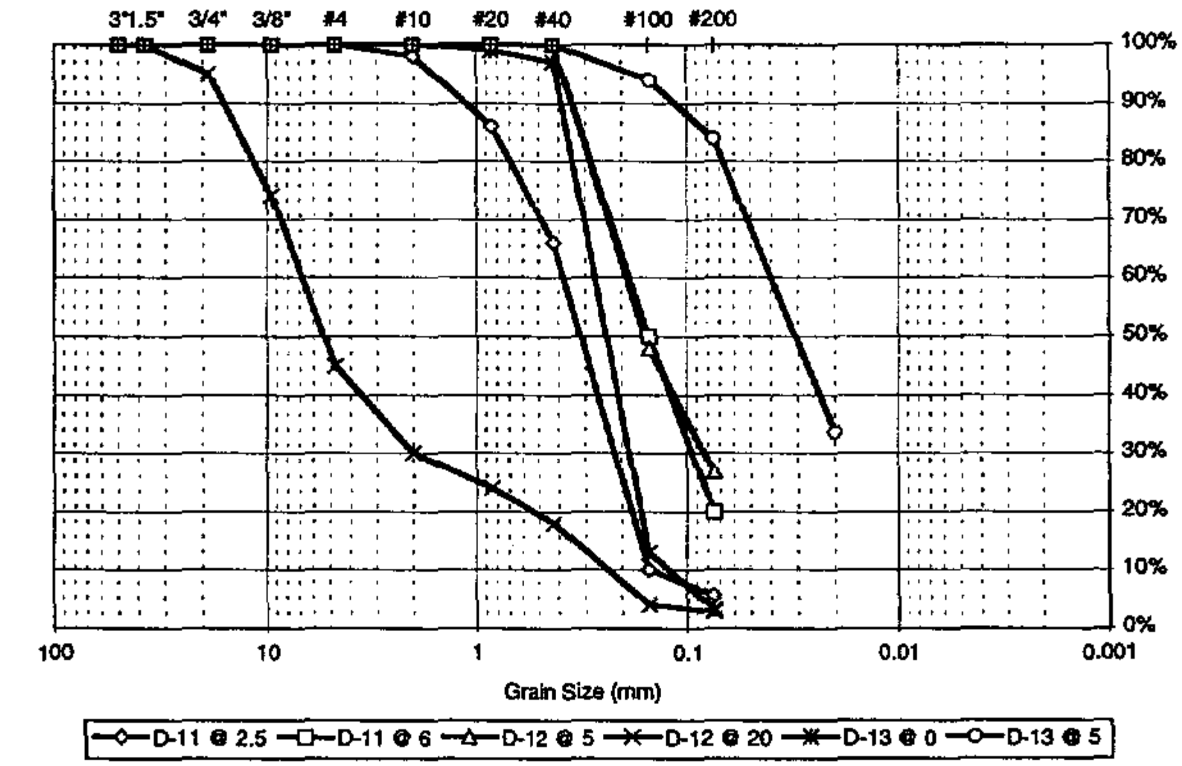
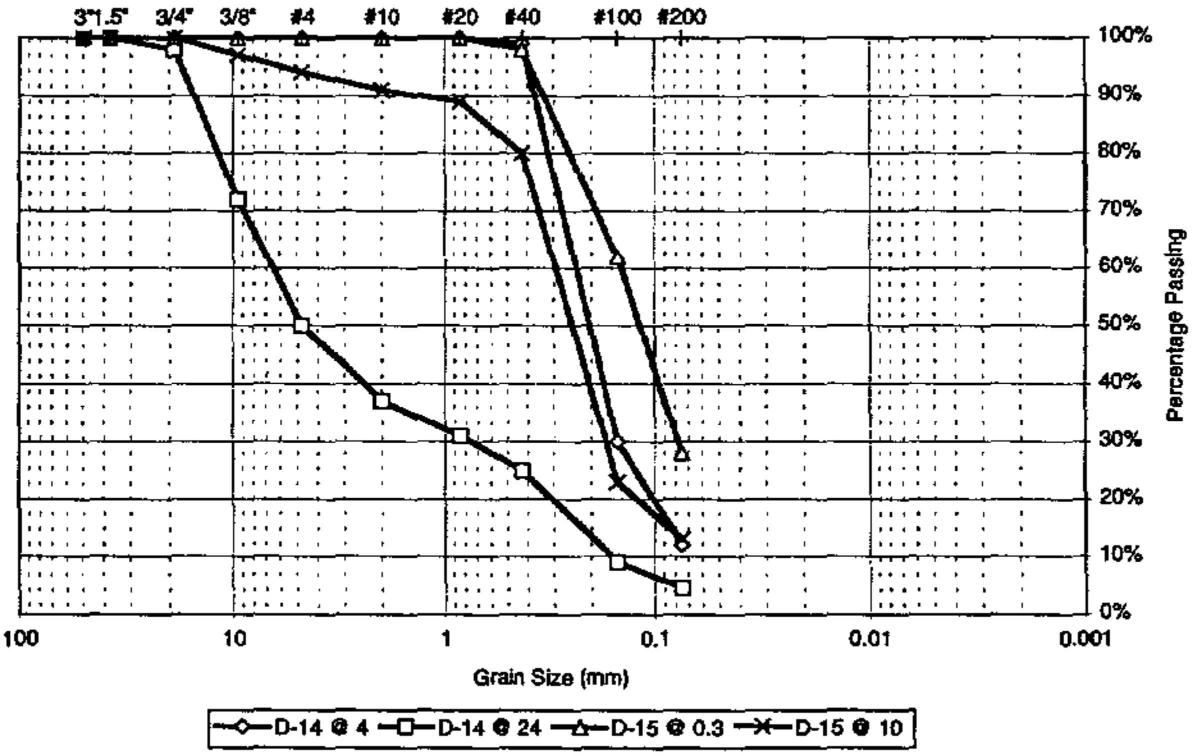
Boring =>	D-11	D-11	D-12	D-12	D-13	D-13
Depth =>	2.5 ft.	6.0 ft.	5.0 ft.	20.0 ft.	0.0 ft.	5.0 ft.
Location =>	Sta 136+39	Sta 136+39	Sta 165+32	Sta 165+32	Sta 187+76	Sta 187+76
3" =>	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
3/4" =>	100.0%	100.0%	100.0%	95.0%	100.0%	100.0%
3/8" =>	100.0%	100.0%	100.0%	74.0%	100.0%	100.0%
#4 =>	100.0%	100.0%	100.0%	45.0%	100.0%	100.0%
#10 =>	98.0%	100.0%	100.0%	30.0%	100.0%	100.0%
#20 =>	86.0%	100.0%	100.0%	24.0%	99.0%	100.0%
#40 =>	66.0%	100.0%	100.0%	18.0%	97.0%	100.0%
#100 =>	10.0%	50.0%	48.0%	4.0%	13.0%	94.0%
#200 =>	5.7%	20.0%	27.0%	2.8%	3.3%	84.0%
0.02 mm						33.6%
0.005 mm						
0.002 mm						
Analysis of Data						
D10 size =>	0.150 mm	N/A	N/A	0.234 mm	0.121 mm	N/A
D30 size =>	0.218 mm	0.094 mm	0.083 mm	2.000 mm	0.185 mm	N/A
D50 size =>	0.316 mm	0.150 mm	0.156 mm	5.353 mm	0.237 mm	N/A
D60 size =>	0.380 mm	0.185 mm	0.191 mm	6.798 mm	0.269 mm	N/A
Coeff. of Uniformity, Cu =	2.53	N/A	N/A	29.00	2.22	N/A
Coeff. of Curvature, Cc =	0.83	N/A	N/A	2.51	1.05	N/A
Gravel (+#4) percentage =	0.0%	0.0%	0.0%	55.0%	0.0%	0.0%
Sand percentage =	94.3%	80.0%	73.0%	42.2%	96.7%	16.0%
Fines percentage =	5.7%	20.0%	27.0%	2.8%	3.3%	84.0%
Unified Soil Class Symbol =	SP-SM	SM	SM	GW	SP	ML



	[redacted]		[redacted]	[redacted]
Boring =>	D-14	D-14	D-15	D-15
Depth =>	4.0 ft.	24.0 ft.	0.3 ft.	10.0 ft.
Location =>	Sta 207+87	Sta 207+87	Sta 237+27	Sta 237+27
3" =>	100.0%	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	100.0%	100.0%	100.0%
3/4" =>	100.0%	98.0%	100.0%	100.0%
3/8" =>	100.0%	72.0%	100.0%	97.0%
#4 =>	100.0%	50.0%	100.0%	94.0%
#10 =>	100.0%	37.0%	100.0%	91.0%
#20 =>	100.0%	31.0%	100.0%	89.0%
#40 =>	99.0%	25.0%	98.0%	80.0%
#100 =>	30.0%	9.0%	62.0%	23.0%
#200 =>	12.0%	4.5%	28.0%	13.0%
0.02 mm				
0.005 mm				
0.002 mm				
Analysis of Data				
D10 size =>	0.065 mm	0.160 mm	N/A	N/A
D30 size =>	0.150 mm	0.757 mm	0.078 mm	0.170 mm
D50 size =>	0.203 mm	4.750 mm	0.117 mm	0.246 mm
D60 size =>	0.236 mm	6.509 mm	0.144 mm	0.295 mm
Coeff. of Uniformity, Cu =	3.63	40.66	N/A	N/A
Coeff. of Curvature, Cc =	1.47	0.55	N/A	N/A
Gravel (+#4) percentage =	0.0%	50.0%	0.0%	6.0%
Sand percentage =	88.0%	45.5%	72.0%	81.0%
Fines percentage =	12.0%	4.5%	28.0%	13.0%
Unified Soil Class Symbol =	SP-SM	GP	SM	SM



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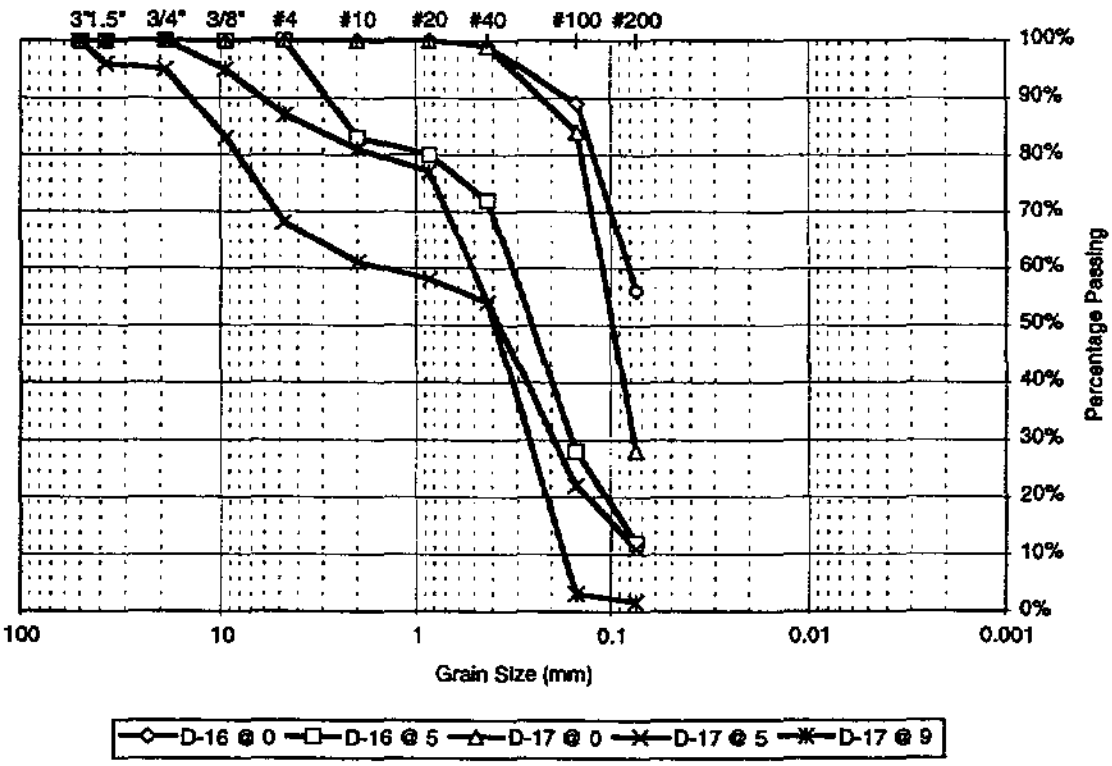
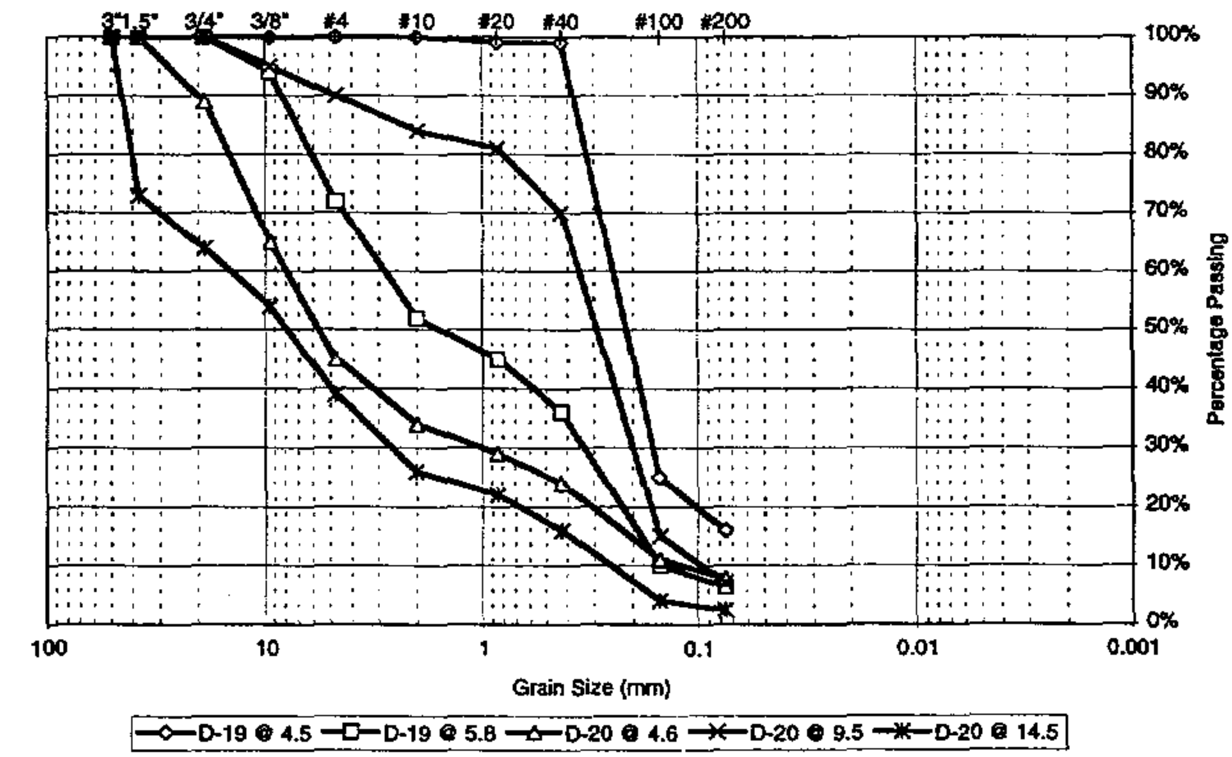
Boring =>	D-16	D-16	D-17	D-17	D-17
Depth =>	0.0 ft.	5.0 ft.	0.0 ft.	5.0 ft.	9.0 ft.
Location =>	Sta 259+54	Sta 259+54	Sta 281+32	Sta 281+32	Sta 281+32
3" =>	100.0%	100.0%	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	100.0%	100.0%	96.0%	100.0%
3/4" =>	100.0%	100.0%	100.0%	95.0%	100.0%
3/8" =>	100.0%	100.0%	100.0%	83.0%	95.0%
#4 =>	100.0%	100.0%	100.0%	68.0%	87.0%
#10 =>	100.0%	83.0%	100.0%	61.0%	81.0%
#20 =>	100.0%	80.0%	100.0%	58.0%	77.0%
#40 =>	99.0%	72.0%	99.0%	54.0%	54.0%
#100 =>	89.0%	28.0%	84.0%	22.0%	3.0%
#200 =>	56.0%	12.0%	28.0%	11.0%	1.6%
0.02 mm					
0.005 mm					
0.002 mm					
Analysis of Data					
D10 size =>	N/A	0.060 mm	N/A	0.060 mm	0.173 mm
D30 size =>	N/A	0.157 mm	0.077 mm	0.195 mm	0.260 mm
D50 size =>	N/A	0.252 mm	0.098 mm	0.373 mm	0.392 mm
D60 size =>	0.082 mm	0.320 mm	0.111 mm	1.504 mm	0.509 mm
Coeff. of Uniformity, Cu =	N/A	5.33	N/A	25.06	2.94
Coeff. of Curvature, Cc =	N/A	1.29	N/A	0.42	0.77
Gravel (+#4) percentage =	0.0%	0.0%	0.0%	32.0%	13.0%
Sand percentage =	44.0%	88.0%	72.0%	57.0%	85.4%
Fines percentage =	56.0%	12.0%	28.0%	11.0%	1.6%
Unified Soil Class Symbol =	ML	SP-SM	SM	SP-SM	SP



[redacted] [redacted]

Boring =>	D-19	D-19	D-20	D-20	D-20
Depth =>	4.5 ft.	5.8 ft.	4.6 ft.	9.5 ft.	14.5 ft.
Location =>	Sta 311+52	Sta 311+52	Sta 316+03	Sta 316+03	Sta 316+03
3" =>	100.0%	100.0%	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	100.0%	100.0%	100.0%	73.0%
3/4" =>	100.0%	100.0%	89.0%	100.0%	64.0%
3/8" =>	100.0%	94.0%	65.0%	95.0%	54.0%
#4 =>	100.0%	72.0%	45.0%	90.0%	39.0%
#10 =>	100.0%	52.0%	34.0%	84.0%	26.0%
#20 =>	99.0%	45.0%	29.0%	81.0%	22.0%
#40 =>	99.0%	36.0%	24.0%	70.0%	16.0%
#100 =>	25.0%	10.0%	11.0%	15.0%	4.0%
#200 =>	16.0%	6.4%	7.8%	7.1%	2.4%
0.02 mm					
0.005 mm					
0.002 mm					
Analysis of Data					
D10 size =>	N/A	0.150 mm	0.121 mm	0.097 mm	0.252 mm
D30 size =>	0.161 mm	0.334 mm	1.009 mm	0.199 mm	2.610 mm
D50 size =>	0.213 mm	1.566 mm	5.649 mm	0.291 mm	7.897 mm
D60 size =>	0.245 mm	2.827 mm	7.989 mm	0.352 mm	14.399 mm
Coeff. of Uniformity, Cu =	N/A	18.85	66.14	3.64	57.03
Coeff. of Curvature, Cc =	N/A	0.26	1.05	1.17	1.87
Gravel (+#4) percentage =	0.0%	28.0%	55.0%	10.0%	61.0%
Sand percentage =	84.0%	65.6%	37.2%	82.9%	36.6%
Fines percentage =	16.0%	6.4%	7.8%	7.1%	2.4%
Unified Soil Class Symbol =	SM	SP-SM	GW-GM	SP-SM	GW



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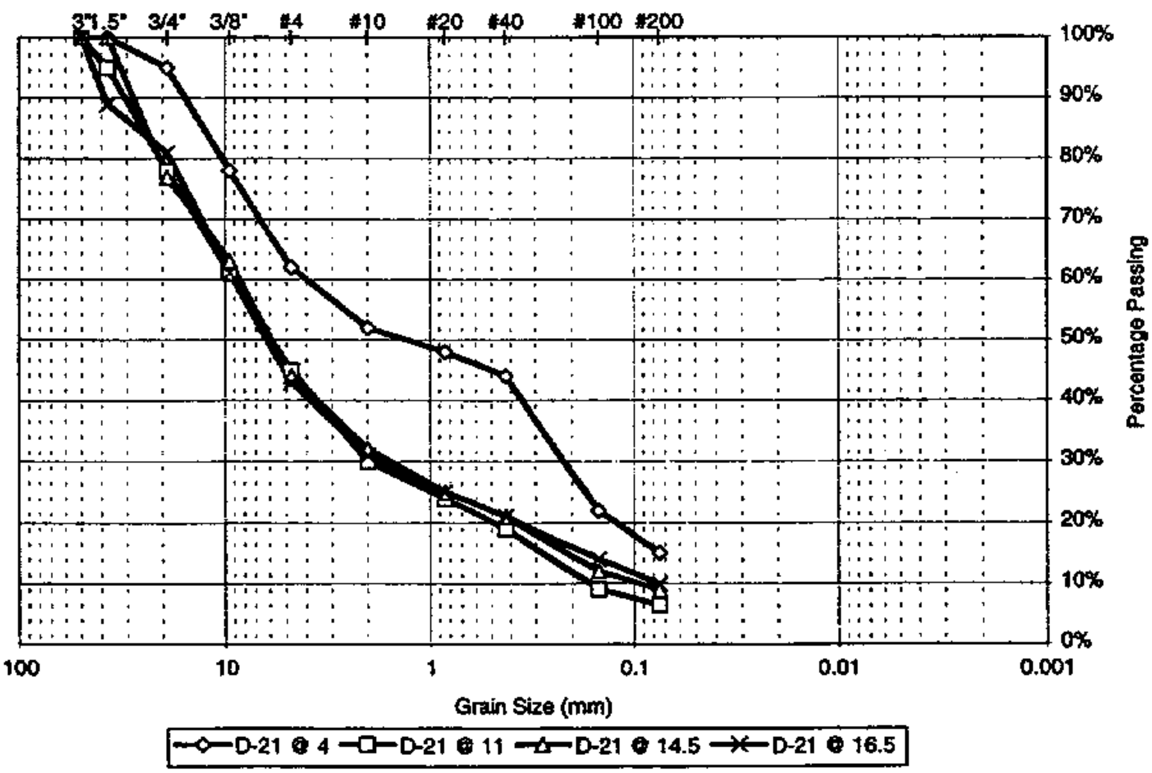
Boring =>	D-21	D-21	D-21	D-21	D-21
Depth =>	4.0 ft.	11.0 ft.	14.5 ft.	16.5 ft.	24.0 ft.
Location =>	Sta 318+29	Sta 318+29	Sta 318+29	Sta 318+29	Sta 318+29
3" =>	100.0%	100.0%	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	95.0%	100.0%	89.0%	100.0%
3/4" =>	95.0%	78.0%	77.0%	81.0%	90.0%
3/8" =>	78.0%	61.0%	63.0%	61.0%	73.0%
#4 =>	62.0%	45.0%	44.0%	43.0%	52.0%
#10 =>	52.0%	30.0%	32.0%	31.0%	36.0%
#20 =>	48.0%	24.0%	25.0%	25.0%	26.0%
#40 =>	44.0%	19.0%	21.0%	21.0%	20.0%
#100 =>	22.0%	9.0%	12.0%	14.0%	12.0%
#200 =>	15.0%	6.4%	8.9%	9.9%	8.8%
0.02 mm					
0.005 mm					
0.002 mm					
Analysis of Data					
D10 size =>	N/A	0.166 mm	0.096 mm	0.076 mm	0.097 mm
D30 size =>	0.219 mm	2.000 mm	1.566 mm	1.734 mm	1.197 mm
D50 size =>	1.304 mm	5.899 mm	5.912 mm	6.220 mm	4.263 mm
D60 size =>	3.995 mm	9.097 mm	8.515 mm	9.141 mm	6.165 mm
Coeff. of Uniformity, Cu =	N/A	54.65	88.78	119.84	63.60
Coeff. of Curvature, Cc =	N/A	2.64	3.00	4.31	2.38
Gravel (+#4) percentage =	38.0%	55.0%	56.0%	57.0%	48.0%
Sand percentage =	47.0%	38.6%	35.1%	33.1%	43.2%
Fines percentage =	15.0%	6.4%	8.9%	9.9%	8.8%
Unified Soil Class Symbol =	SM	GW-GM	GP-GM	GP-GM	GW-GM

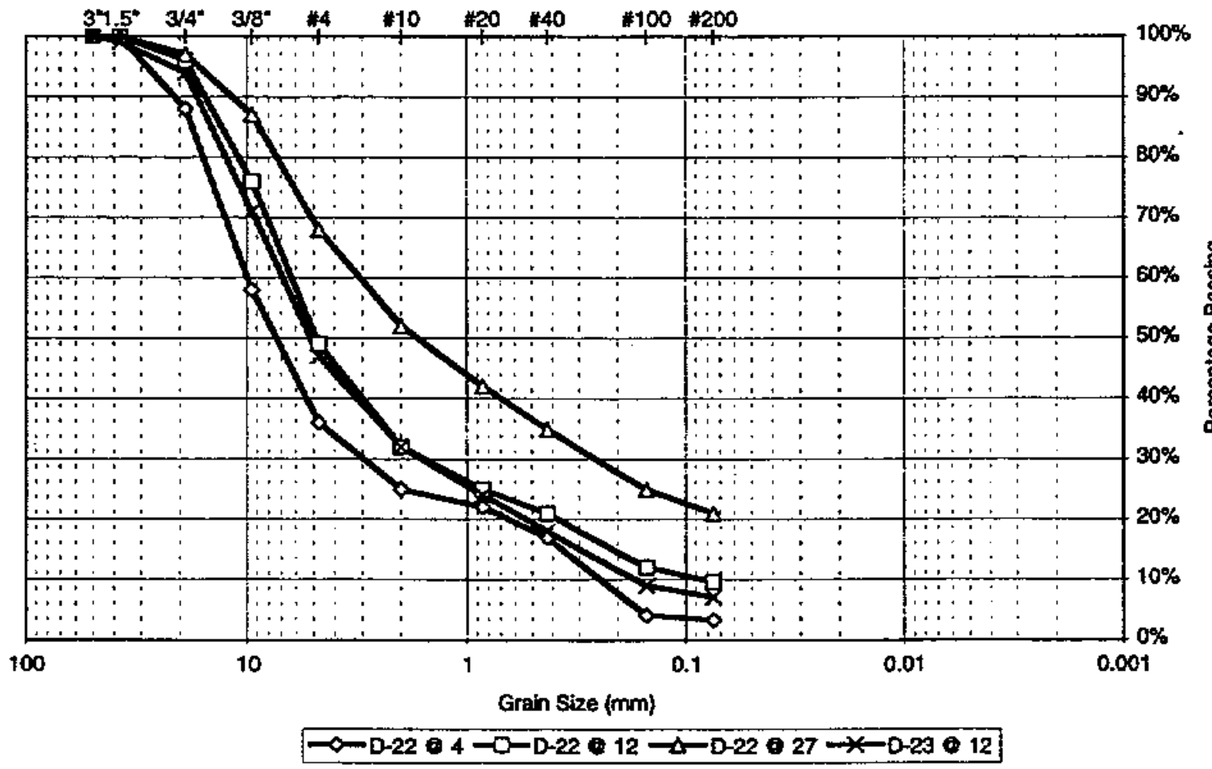


Duane Miller & Associates
Job No. 4119.23
July 1998

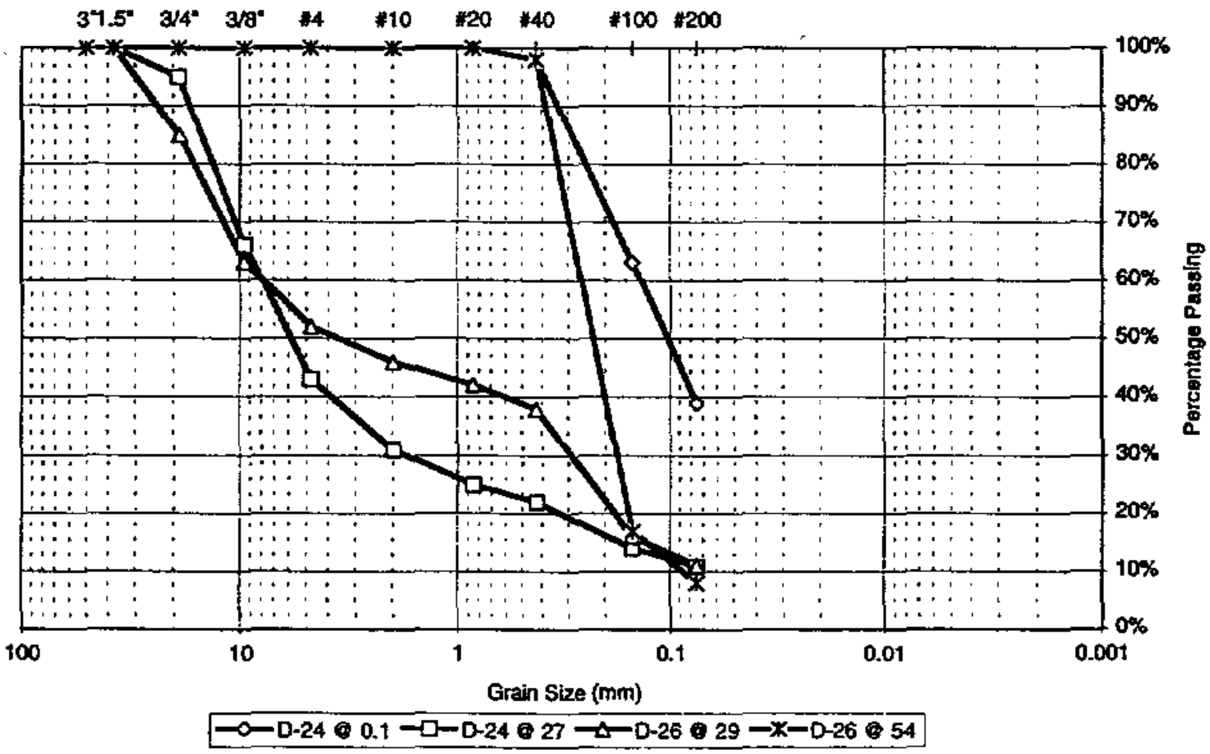
PARTICLE DATA
Liberty Development
Beaufort Sea, Alaska

Plate
B-23

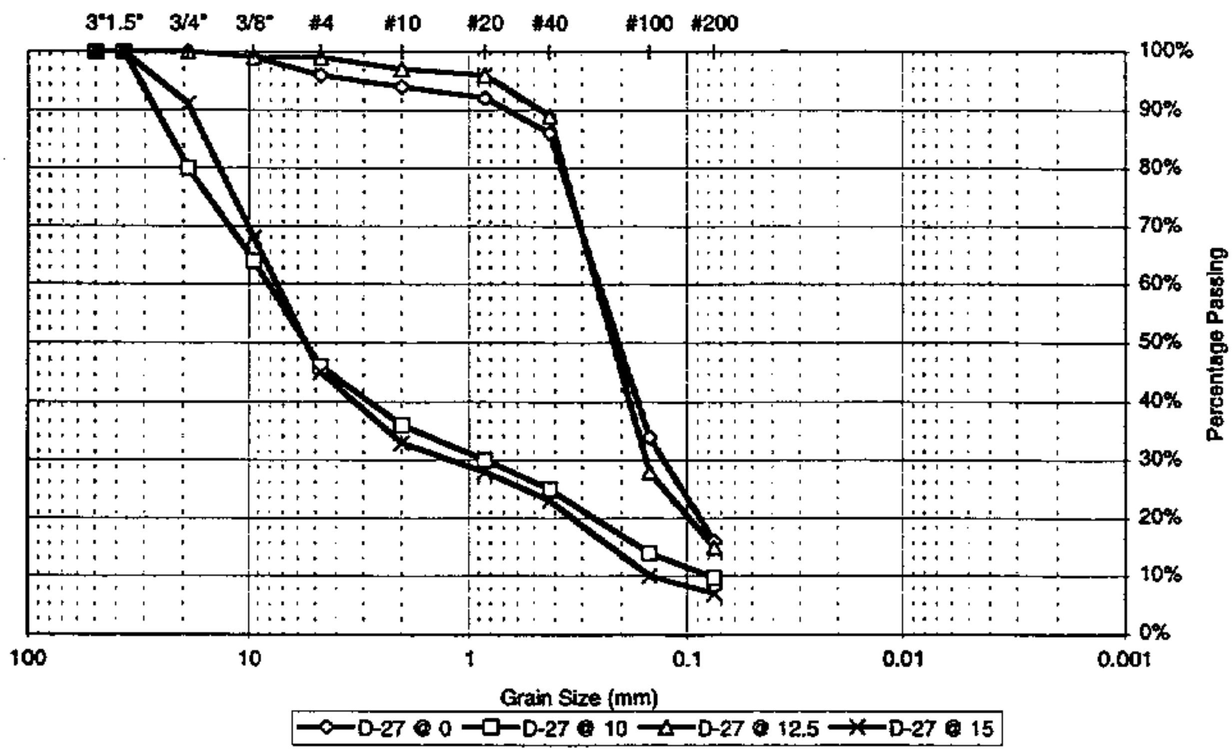
Boring =>	D-22	D-22	D-22	D-23
Depth =>	4.0 ft.	12.0 ft.	27.0 ft.	12.0 ft.
Location =>	Material Site	Material Site	Material Site	Material Site
	D-22 @ 4	D-22 @ 12	D-22 @ 27	D-23 @ 12
3" =>	100.0%	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	100.0%	100.0%	99.0%
3/4" =>	88.0%	96.0%	97.0%	94.0%
3/8" =>	58.0%	76.0%	87.0%	71.0%
#4 =>	36.0%	49.0%	68.0%	47.0%
#10 =>	25.0%	32.0%	52.0%	32.0%
#20 =>	22.0%	25.0%	42.0%	24.0%
#40 =>	17.0%	21.0%	35.0%	18.0%
#100 =>	4.0%	12.0%	25.0%	9.0%
#200 =>	3.3%	9.6%	21.0%	7.1%
0.02 mm				
0.005 mm				
0.002 mm				
Analysis of Data				
D10 size =>	0.243 mm	0.084 mm	N/A	0.168 mm
D30 size =>	2.963 mm	1.566 mm	0.252 mm	1.615 mm
D50 size =>	7.383 mm	4.874 mm	1.685 mm	5.180 mm
D60 size =>	9.949 mm	6.300 mm	3.082 mm	6.914 mm
Coeff. of Uniformity, Cu =	41.02	74.83	N/A	41.06
Coeff. of Curvature, Cc =	3.64	4.63	N/A	2.24
Gravel (+#4) percentage =	64.0%	51.0%	32.0%	53.0%
Sand percentage =	32.7%	39.4%	47.0%	39.9%
Fines percentage =	3.3%	9.6%	21.0%	7.1%
Unified Soil Class Symbol =	GP	GP-GM	SM	GW-GM



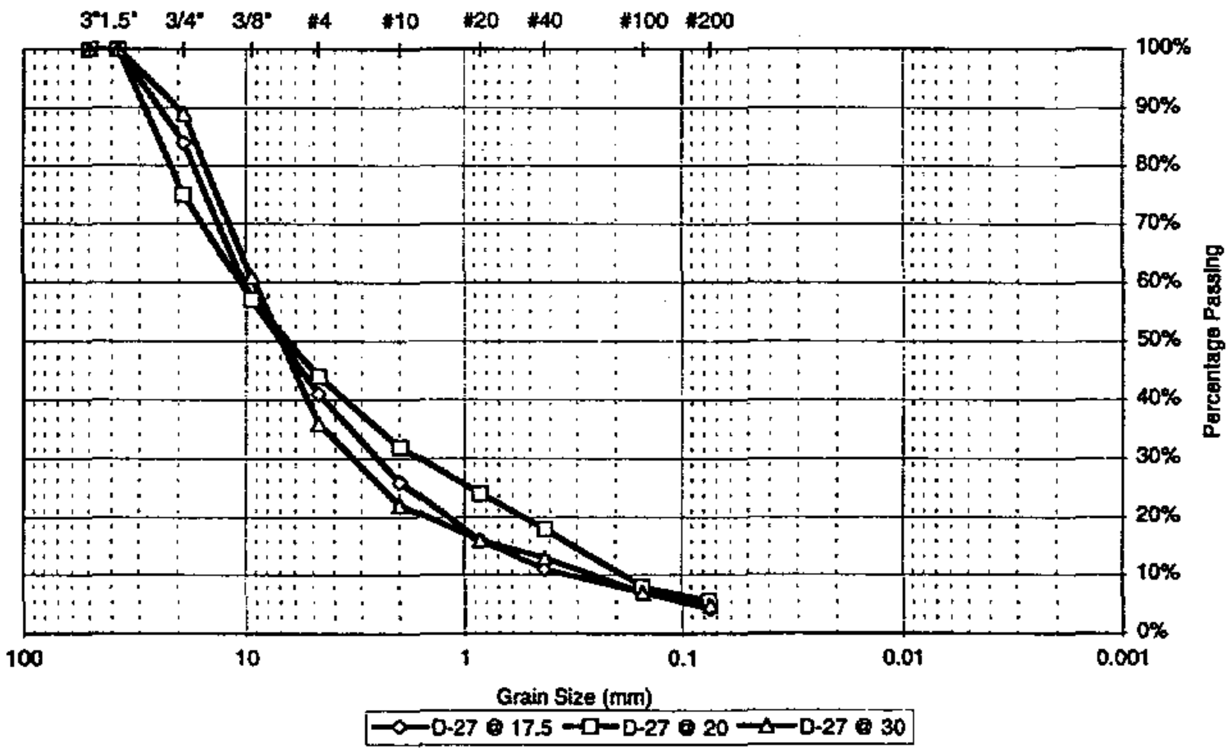
Boring =>	D-24	D-24	D-26	D-26
Depth =>	0.1 ft.	27.0 ft.	29.0 ft.	54.0 ft.
Location =>	Material Site	Material Site	Material Site	Material Site
	D-24 @ 0.1	D-24 @ 27	D-26 @ 29	D-26 @ 54
3" =>	100.0%	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	100.0%	100.0%	100.0%
3/4" =>	100.0%	95.0%	85.0%	100.0%
3/8" =>	100.0%	66.0%	63.0%	100.0%
#4 =>	100.0%	43.0%	52.0%	100.0%
#10 =>	100.0%	31.0%	46.0%	100.0%
#20 =>	100.0%	25.0%	42.0%	100.0%
#40 =>	98.0%	22.0%	38.0%	98.0%
#100 =>	63.0%	14.0%	16.0%	17.0%
#200 =>	39.0%	10.8%	11.0%	8.0%
0.02 mm				
0.005 mm				
0.002 mm				
Analysis of Data				
D10 size =>	N/A	N/A	N/A	0.087 mm
D30 size =>	N/A	1.734 mm	0.291 mm	0.177 mm
D50 size =>	0.103 mm	5.866 mm	3.560 mm	0.229 mm
D60 size =>	0.138 mm	7.929 mm	7.864 mm	0.261 mm
Coeff. of Uniformity, Cu =	N/A	N/A	N/A	2.98
Coeff. of Curvature, Cc =	N/A	N/A	N/A	1.38
Gravel (+#4) percentage =	0.0%	57.0%	48.0%	0.0%
Sand percentage =	61.0%	32.2%	41.0%	92.0%
Fines percentage =	39.0%	10.8%	11.0%	8.0%
Unified Soil Class Symbol =	SM	GP-GM	GP-GM	SP-SM



Boring =>	D-27	D-27	D-27	D-27
Depth =>	0.0 ft.	10.0 ft.	12.5 ft.	15.0 ft.
Location =>	Sta 319+44	Sta 319+44	Sta 319+44	Sta 319+44
	D-27 @ 0	D-27 @ 10	D-27 @ 12.5	D-27 @ 15
3" =>	100.0%	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	100.0%	100.0%	100.0%
3/4" =>	100.0%	80.0%	100.0%	91.0%
3/8" =>	99.0%	64.0%	99.0%	68.0%
#4 =>	96.0%	46.0%	99.0%	45.0%
#10 =>	94.0%	36.0%	97.0%	33.0%
#20 =>	92.0%	30.0%	96.0%	28.0%
#40 =>	86.0%	25.0%	89.0%	23.0%
#100 =>	34.0%	14.0%	28.0%	10.0%
#200 =>	16.0%	9.7%	15.0%	7.0%
0.02 mm				
0.005 mm				
0.002 mm				
Analysis of Data				
D10 size =>	N/A	0.079 mm	N/A	0.150 mm
D30 size =>	0.129 mm	0.850 mm	0.155 mm	1.197 mm
D50 size =>	0.207 mm	5.541 mm	0.218 mm	5.522 mm
D60 size =>	0.252 mm	8.144 mm	0.259 mm	7.465 mm
Coeff. of Uniformity, Cu =	N/A	103.46	N/A	49.77
Coeff. of Curvature, Cc =	N/A	1.13	N/A	1.28
Gravel (+#4) percentage =	4.0%	54.0%	1.0%	55.0%
Sand percentage =	80.0%	36.3%	84.0%	38.0%
Fines percentage =	16.0%	9.7%	15.0%	7.0%
Unified Soil Class Symbol =	SM	GW-GM	SM	GW-GM



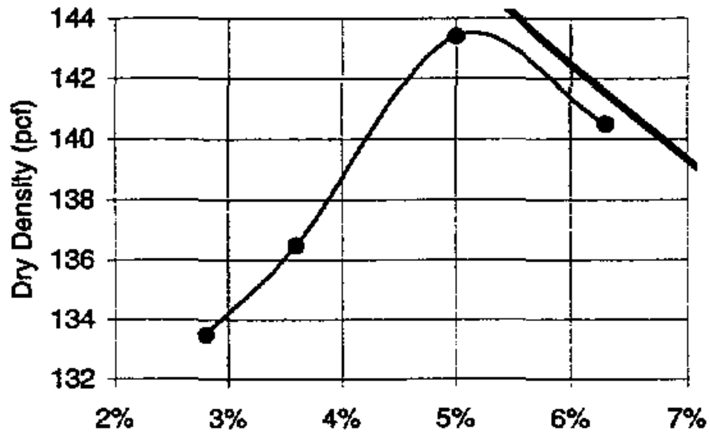
Boring =>	D-27	D-27	D-27
Depth =>	17.5 ft.	20.0 ft.	30.0 ft.
Location =>	Sta 319+44	Sta 319+44	Sta 319+44
	D-27 @ 17.5	D-27 @ 20	D-27 @ 30
3" =>	100.0%	100.0%	100.0%
1 1/2" =>	100.0%	100.0%	100.0%
3/4" =>	84.0%	75.0%	89.0%
3/8" =>	57.0%	57.0%	61.0%
#4 =>	41.0%	44.0%	36.0%
#10 =>	26.0%	32.0%	22.0%
#20 =>	16.0%	24.0%	16.0%
#40 =>	11.0%	18.0%	13.0%
#100 =>	7.0%	8.0%	7.0%
#200 =>	4.1%	5.6%	4.8%
0.02 mm			
0.005 mm			
0.002 mm			
Analysis of Data			
D10 size =>	0.328 mm	0.185 mm	0.252 mm
D30 size =>	2.519 mm	1.615 mm	3.279 mm
D50 size =>	7.015 mm	6.541 mm	7.003 mm
D60 size =>	10.261 mm	10.663 mm	9.240 mm
Coeff. of Uniformity, Cu =	31.32	57.72	36.60
Coeff. of Curvature, Cc =	1.89	1.32	4.61
Gravel (+#4) percentage =	59.0%	56.0%	64.0%
Sand percentage =	36.9%	38.4%	31.2%
Fines percentage =	4.1%	5.6%	4.8%
Unified Soil Class Symbol =	GW	GW-GM	GP

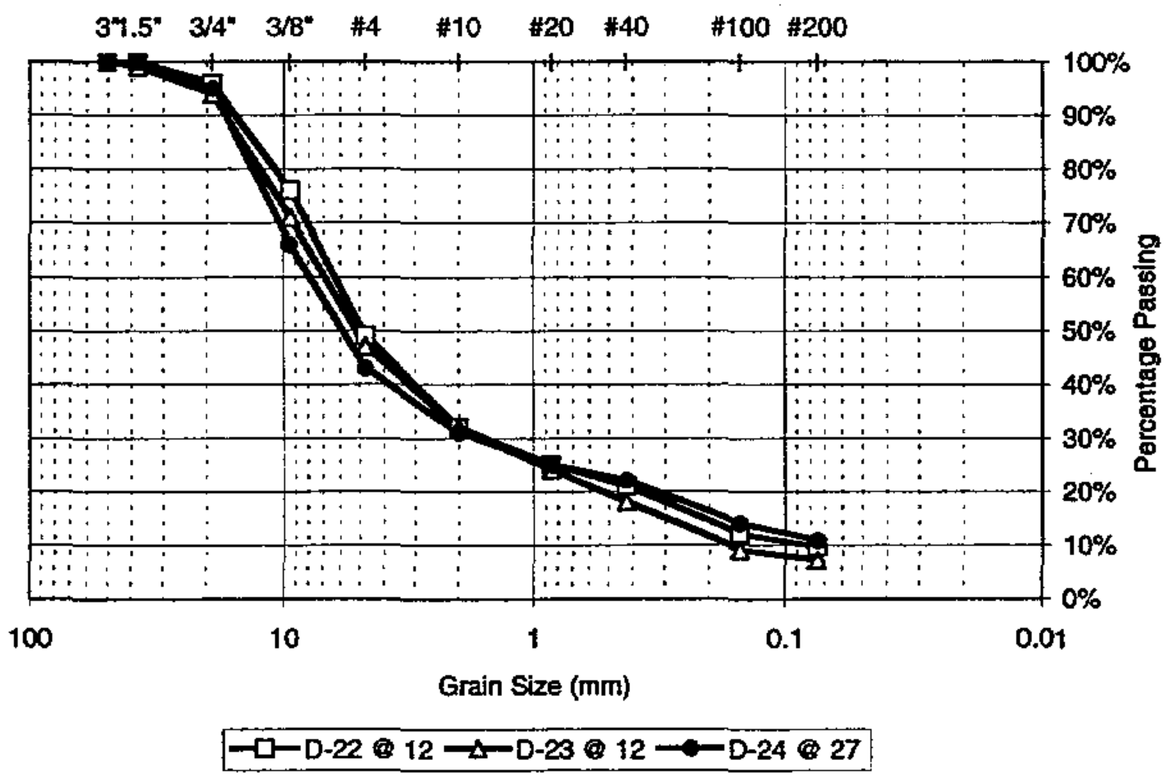


Boring	USCS	Passing #200	Compaction Test: Optimum Moisture	Compaction Test: Dry Density (D1557c)	Relative Density (D-4253): Min	Relative Density (D-4253): Max	Apparent Specific Gravity
D-22 @ 12.0 ft.	GP-GM	9.6%	---	---	120	140.3	---
D-23 @12.0 ft	GW-GM	7.1%	---	---	119.7	141.1	2.65
D-24 @ 27.0 ft.	GW-GM	10.8%	5.00%	143.4	118.2	140.4	2.65

Laboratory testing performed by R&M Consultants

D-24 @ 27.0 ft.





Duane Miller & Associates
Job No. 4119.23
July 1998

FILL MATERIAL DATA
Liberty Development
North Slope, Alaska

Plate
B-28