Geotechnical Feasibility Appendix

Robe Lake Ecosystem Restoration

Valdez, Alaska

Alaska District, Pacific Ocean Division

30 August 2023
Status: DRAFT

US Army Corps of Engineers
Alaska District

DEPARTMENT OF THE ARMY
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CEPOA-ECG-M 30 August 2023

MEMORANDUM FOR

Civil Works Project Management (CEPOA-PM-C), Leif Hammes

SUBJECT: Draft Geotechnical Feasibility Appendix for the Robe Lake Aquatic Ecosystem Restoration Feasibility Study, Valdez, Alaska.

1. Enclosed is the Draft Geotechnical Feasibility Appendix for the Robe Lake Aquatic Ecosystem Restoration feasibility study located in Valdez, Alaska. Included with this appendix are discussions of the anticipated subsurface conditions, preliminary geotechnical evaluation, and historical geotechnical site investigation located near the proposed project site.

2. Questions should be addressed to Twain Cacek at 907-753-2784 or Amy Steiner at 907-753-2800.

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1 Introduction

This report summarizes the data gathered from research of geotechnical information available for Robe Lake area to support an aquatic ecosystem restoration study for Robe Lake. Geotechnical information and analyses of soils in the vicinity were inferred from a report authored by Alaska Petroleum Company (AlPetCo) in 1979. Information and assumptions were developed through site assessment intended for use by design engineers and planners to evaluate the feasibility of the alternatives for an aquatic ecosystem restoration project. This report is not intended for use in construction contract documents.

2 Location and Project Description

Robe Lake is located approximately eight (8) miles southeast of Valdez and approximately 300 miles east of Anchorage. The project site can be accessed from the Richardson highway as shown in Figure 2-1.

The goal of the Robe Lake Ecosystem Restoration project is to return tributary flows to the lake, reconfigure dikes and embankments to reintroduce glacial water to the lake in hopes that it will restore the old aquatic ecosystem by limiting and/or eliminating the current growth of vegetation. Valdez Fisheries Development Association (VFDA) have enhanced the salmonid habitat by removing Robe Lake vegetation on an annual basis. Robe Lake vegetation growth was caused by the loss of turbid, cold, glacial flow from the diversion of Corbin Creek. During construction of the Richardson Highway and associated diversion dike along Corbin Creek channel, now known as Old Corbin Creek, reduced flow into Robe Lake.

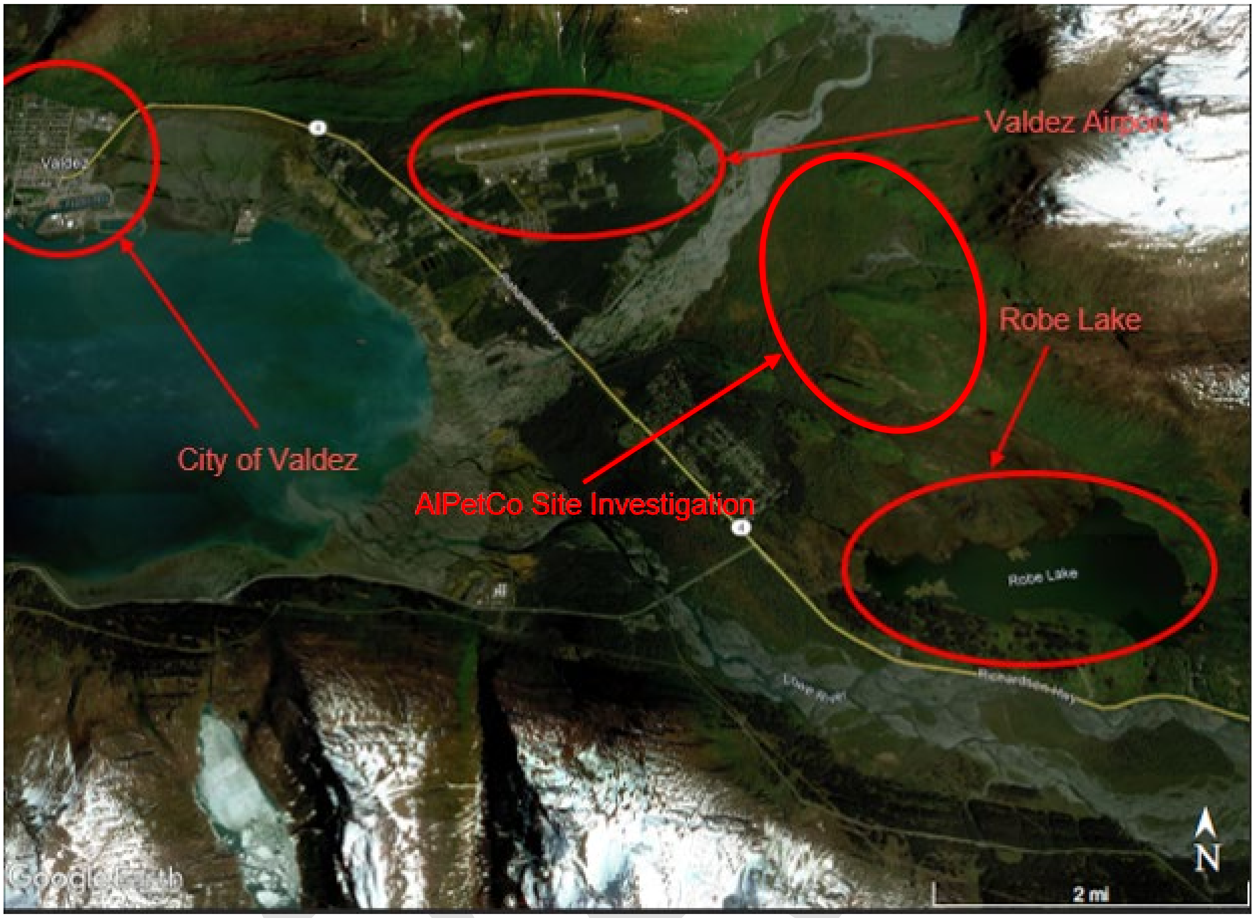

Figure 2-1. Project Location and Vicinity Map

3 Previous Geotechnical Investigations

The only geotechnical information identified within the Robe Lake is from a proposed refining and petrochemical facility located approximately 2.5 miles northwest of Robe Lake. Conditions encountered at this site may not be representative of conditions in the project area.

Alaska Petroleum Company (AlPetCo) conducted a geotechnical and geophysical investigation 15 June to 11 July 1979 to gain knowledge and understanding of the underlying soils. Sixteen test borings were drilled to depths ranging from 50 to 501 feet below ground surface (bgs). The geophysical survey used seismic refraction and theorized that the depth to bedrock was 700-900ft bgs. This was determined using the seismic refraction study and reported depths to bedrock in Port Valdez. Soils generally consisted of coarse granular soils consisting of silt, sand, gravel and occasional cobbles. The soil classifications were generally GW, GP, and GM with instances of SW, SP, and SM. Silt lenses up to 3 feet thick were encountered, with organics noted in some silt lenses. No frozen soil was encountered during the historic geotechnical investigation, although seasonal frost can penetrate up to 10 feet bgs in areas without snow cover during a cold winter season. Relative density of the soils ranged from medium dense to dense with instances of loose and very dense soils. Consistency of the fine-grained soil unit ranged from soft to hard. The groundwater table varied in depth from 3 feet bgs in the south and east to 60 feet bgs in the northern portion of the exploration area. The soil boring logs are included as Annex A.

AlPetCo also performed a seismic refraction geophysical survey in their project area, indicating 700 to 900 feet of glacial outwash overlying sedimentary graywacke bedrock.

4 Regional Geology

Robe Lake is located on the eastern part of Prince William Sound region, approximately 8 miles southeast of the city of Valdez. Bedrock in the area consists of thickly inter-bedded slate and greywacke of the late-Cretaceous Valdez Group. The topography shows the area has been glaciated. Subsurface conditions of the area surrounding Robe Lake and vicinity have been geologically influenced by the Valdez Glacier Stream and Lowe River, creating an outwash delta composed of a thick section of silty sands and gravels. Bedrock was estimated to be between 700 and 900 feet deep below ground surface. The 1979 geotechnical investigation encountered bedrock at depths ranging from 60 feet, 105 feet, and 327 feet bgs and may be evidence of a series of resistant bedrock ridges remain in the general area of Valdez.

5 Geotechnical Design Considerations

The alternatives described in Section 6 are considered constructible with the assumed geotechnical conditions. It’s important that consideration be given to subsurface conditions and construction aspects, including but not limited to deleterious foundation soils, stability, seismic concerns, and settlement. The preliminary engineering analysis in this report are based on historical geotechnical information and a geophysical survey performed by AlPetCo at a site 2.5 miles away from the project area.

The following sections are based on anticipated conditions and must be reevaluated following a formal subsurface site investigation.

5.1 Anticipated Soil Profile

The soil profile in the project area is assumed to consist of medium dense to dense Well to Poorly-Graded Gravels and Silty Gravels overlying sedimentary graywacke bedrock. Bedrock was encountered between 50 and 327 feet bgs according to the AlPetCo geotechnical and geophysical report.

5.2 Anticipated In-Situ Soil Properties

Soil properties used to design the revetment profile are summarized in Table 5-1. Typical unit weights from Table 5-2 (Coduto, 2001) and effective internal friction angles were estimated in accordance with Table 3-1 of EM 1110-1-1905, *Bearing Capacity of Soils* (1992). Table 5-1 soil properties are assumed and will require re-evaluation following a geotechnical site investigation. Due to its depth, the bedrock mechanical properties were not considered. The range of typical values are provided, with the recommended design value shown in parenthesis.

Table 5-1. Anticipated Design Foundation Soil Properties

Interpreted Geology	[1]Physical Properties	Unified Soil Classification Symbol	[2]Dry Unit Weight (pcf)	[2]Internal Friction Angle (degrees)
Glacial Outwash	Medium Dense to Dense	GW, GP, GM	100 – 130 (120)	30 - 40 (36)
[1] Physical properties are assumed and should be considered approximate. [2] Range of applicable values, recommended value is shown in parentheses				

5.3 Design Factors of Safety

Appropriate factors of safety must be determined to ensure adequate performance of the project throughout its design life. Three important considerations in determining appropriate factors of safety include: uncertainties in the conditions being analyzed, the consequences of failure, and the acceptable performance. Table 5-2 provides applicable factors of safety and source documents, which include procedures for performing analyses.

Table 5-2. Applicable Factors of Safety

Reference	Analysis Condition	Minimum Factor of Safety
EM 1110-1-1905	Bearing Capacity	2.5
EM-1110-2-1902	Slope Stability, End of Construction	1.3
EM-1110-2-1902	Slope Stability, Long Term	1.5
EM-1110-2-1902	Slope Stability, Earthquake Loading	>1.0

5.4 Training Dike Engineering Properties

It is anticipated that the proposed training dikes will be constructed using three different rock materials: armor rock (A Rock), intermediate rock (B Rock), and core rock. Assumed engineering properties of the training dike materials are shown in Table 5-3. The range of typical values are provided, with the recommended design value shown in parenthesis.

Table 5-3. Assumed Training Dike Fill Properties

Breakwater Unit	[1]Dry Unit Weight (pcf)	[1]Internal Friction Angle (degrees)	Median Rock Size (lbs)
A-Rock	95 – 115 (107)	40 - 55 (45)	1200
B-Rock	95 – 115 (107)	40 – 55 (45)	120
Core Rock	95 – 115 (107)	40 - 55 (45)	< 120
[1] Range of applicable values, recommended design value is shown in parentheses			

5.5 Earthquake Ground Motions

Robe Lake falls within a region of high seismicity. Governing documents for seismic site classifications are the Unified Facilities Criteria (UFC) 3-220-01 Geotechnical Engineering Section 2-2.1 Section 1613 Earthquake Loads and the American Society of Civil Engineers (ASCE) 7 Hazard Tool. The Robe Lake project area categorized as Site Class D due to underlying stiff soils and Risk Category I due to the low hazard to human life in the event of a failure, per the UFC. Table 5-4 provides site-adjusted seismic parameters per ASCE 7 Hazard Tool for a seismic event with 2% probability of exceedance within a 50-year period.

Table 5-4. Probabilistic Ground Motions (g) for Robe Lake

Parameter	Value
Probability of Exceedance	2% in 50 years
PGA_M	0.53
S_{MS}	1.64
S_{M1}	1.99

6 Alternatives

The study team evaluated four ecosystem improvement alternatives (Alternatives A through D) and a "no action" alternative in the process of recommending a tentatively selected plan (TSP). The five alternatives considered are shown in the list below and described is the following sections. Alternatives A and B have sub-alternatives that capture different culvert configurations. Figure 6-1 shows the proposed alternative locations for the project.

- Alternative A: Training Dike with Richardson Culverts/AlPetCo Trail Bridge
- Alternative B: Training Dike with Trail Bridge and Extended Channel Excavation
- Alternative C: Sheet Pile Broad Crested Weir with Trail Bridge
- Alternative D: Training Dike with Excavated Channel to Brownie Creek
- Alternative E: No Action

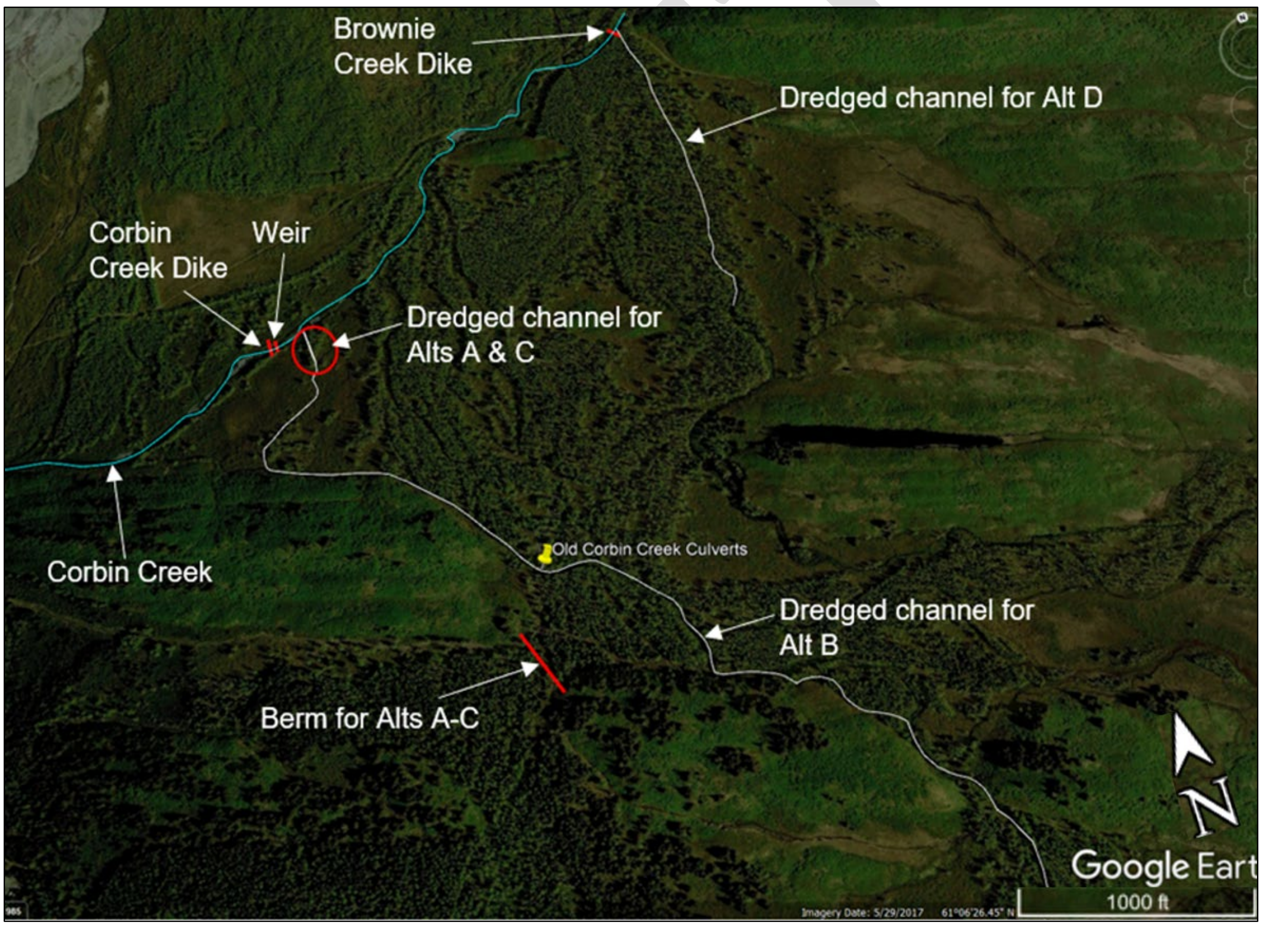

Figure 6-1. Layout of Alternatives

6.1 Alternative A

Alternative A consists of rerouting Corbin Creek into the relic channel of Old Corbin Creek by constructing an approximately 250-foot-long training dike across Corbin Creek. The dike would have an approximate crest elevation of 84 feet NAVD88 with 3H:1V side slopes, an armored toe, and 10-foot-wide crest as shown in Figure 6-3. The armor rock (A rock) will have median rock size of 1200 pounds, B rock has a median rock size of 120 pounds, and the C rock (core rock) will have rock less than 120 lbs (Table 5-3). All three sub-alternatives for Alternative A include construction an approximately 275-foot long channel to connect Corbin Creek and Old Corbin Creek and an approximately 450-foot-long berm (Figure 6-4) in the low-lying area between the two bluffs near the Old Corbin Creek culverts (shown in Figure 6-2). The proposed dredge extents are shown in Figure 6-1.

6.1.1 Alternative A-1

Alternative A-1 consists of rerouting the flow of Corbin Creek into Old Corbin and excavating a channel to connect Old Corbin Creek and Corbin Creek. The culverts under the existing AlPetCo trail on Old Corbin Creek would be replaced with a 20-foot-wide trail bridge. An approximately 450-foot-long would be constructed in the low-lying area between the two bluffs near the Old Corbin Creek culverts.

6.1.2 Alternative A-2

Alternative A-2 consists of rerouting the flow of Corbin Creek into Old Corbin and excavating a channel to connect Old Corbin Creek and Corbin Creek. The two existing 12.75-foot diameter culverts would be replaced with three 12.75-foot diameter culverts.

6.1.3 Alternative A-3

Alternative A-3 consists of rerouting the flow of Corbin Creek into Old Corbin and excavating a channel to connect Old Corbin Creek and Corbin Creek. The culvers under the AlPetCo trail system on Old Corbin Creek would be replaced with a 20-foot-wide trail bridge. The two existing 12.75-foot diameter culverts would be replaced with three 12.75-foot diameter culverts.

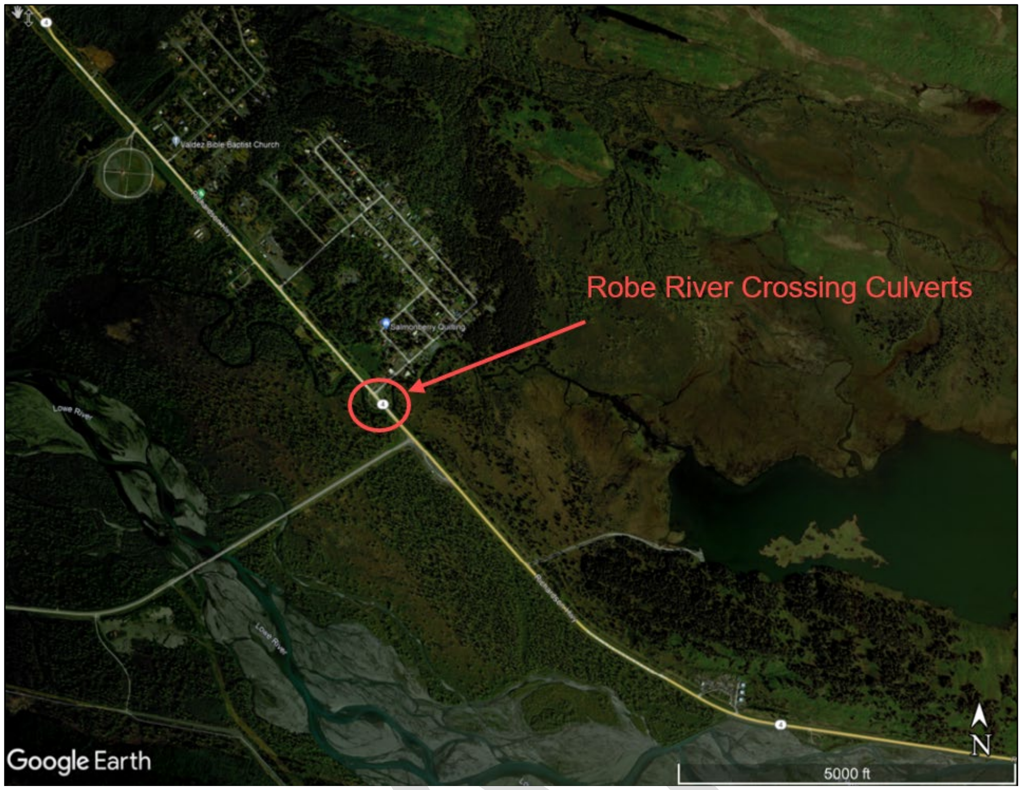

Figure 6-2. Existing Robe River Crossing Culvert Location

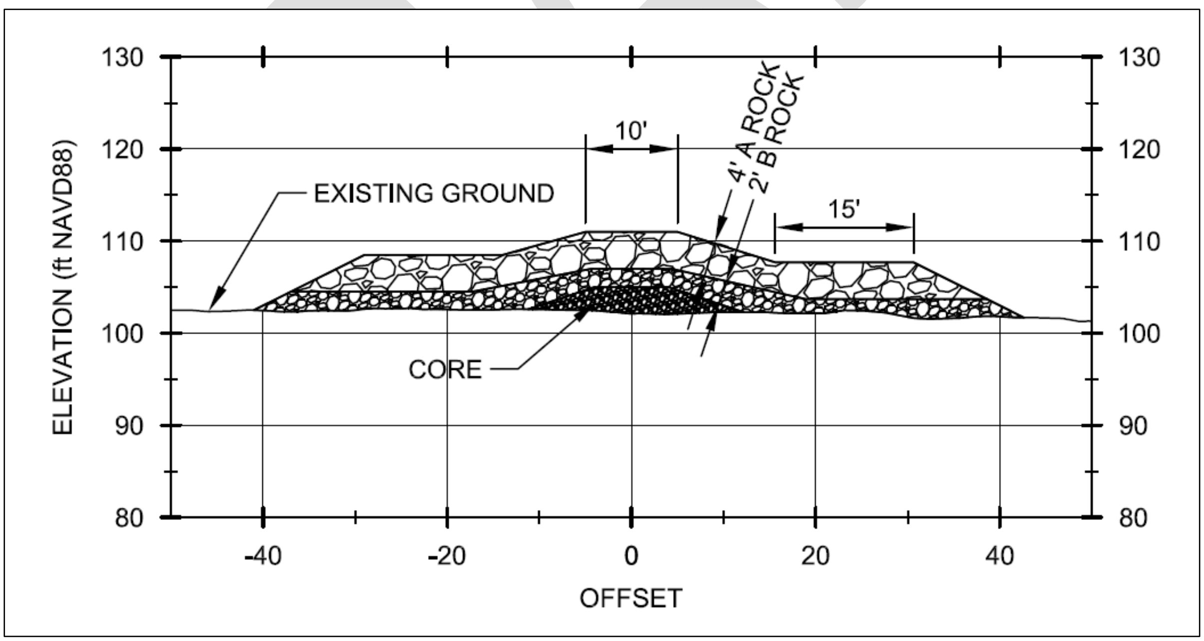

Figure 6-3. Alternatives A, B, and C: Typical Dike Cross Section

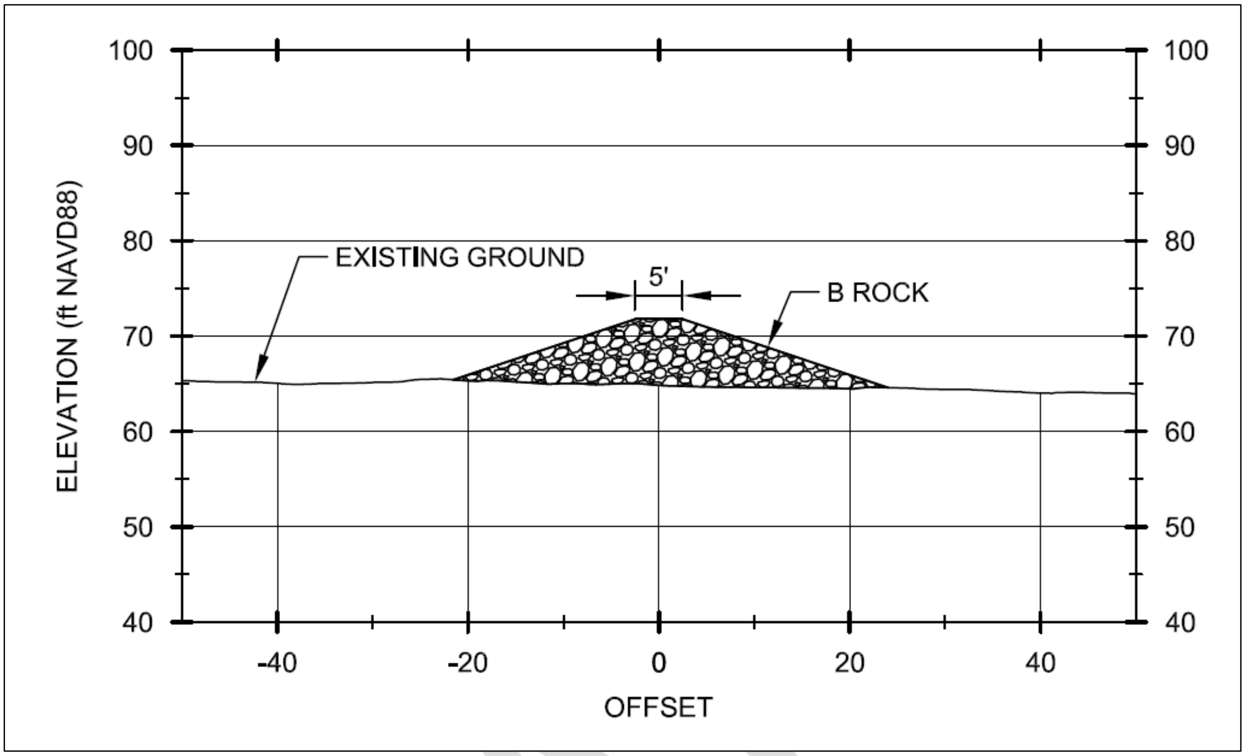

Figure 6-4. Typical Berm Cross Section

6.2 Alternative B

Alternative B consists of constructing a diversion dike parallel to Corbin Creek and perpendicular to Old Corbin Creek to divert all the flow into Old Corbin Creek. The dike would have an approximate crest elevation of 84 feet NAVD88 and be approximately 250 feet long with 3H:1V side slopes, an armored toe, and 10-foot crest width as shown in Figure 6-3. The armor rock (A rock) will have median rock size of 1200 pounds, B rock has a median rock size of 120 pounds, and the C rock (core rock) will have rock less than 120 lbs.

A 30-foot wide, 3 foot deep, approximately 275-foot-long channel will be excavated to connect the relic Old Corbin Creek to Corbin Creek (Figure 6-5). The channel would have 3H:1V side slopes. Additionally, roughly 1.5 miles of the relic Old Corbin Creek channel will be deepened approximately 3 feet, with a channel width of 12 feet and 2H:1V side slopes. The existing culverts under AlPetCo Trail on Old Corbin Creek will be replaced with a 20-foot-wide trail bridge. An approximately 450-foot-long berm (Figure 6-4) will be placed in the low-lying area between the two bluffs near the Old Corbin Creek culverts to prevent overland flow from entering old relic channels that flow towards the Valdez subdivision.

Alternative B has 3 sub-alternatives that pertain to the culverts and drainage. All the sub-alternatives include the diversion dike and channel excavation described above.

Figure 6-5. Alternative B: Excavated Channel Extents

6.2.1 Alternative B-1

Alternative B-1 consists of replacing the existing culverts under the AlPetCo trail system with a 20-foot-wide trail bridge. The two 12.75-foot diameter culverts at the Robe River crossing will be replaced with an approximately 50-foot span Alaska Department of Transportation bridge to increase flow capacity and improve fish passage.

6.2.2 Alternative B-2

Alternative B-2 consists of replacing the existing culverts under the AlPetCo trail system with an approximately 20-foot-wide trail bridge. The two existing 12.75-foot diameter culverts at the Robe River crossing will be replaced with three 12.75-foot diameter culverts.

6.2.3 Alternative B-3 (Tentatively Selected Plan)

Alternative B-3 consists of replacing the culverts under the AlPetCo trail system with a 20-foot-wide trail bridge. The two 12.75-foot diameter culverts at the Robe River crossing will be replaced with three 14-foot diameter culverts.

6.3 Alternative C

Construction of Alternative C consists of constructing a broad crested weir to divert flow into Old Corbin Creek from Corbin Creek. The weir will be constructed from sheet pile with an approximate crest elevation of 78.9 feet NAVD88 and rock placed on both sides to provide scour protection. The weir will span approximately 65-foot. During a 25-year flow event excess water will spill into Corbin Creek over the weir.

An approximately 275-foot-long channel will be excavated to connect the relic Old Corbin Creek to Corbin Creek. The channel will be 30 feet wide, 3 feet deep, and have 3H:1V side slopes. The culverts under AlPetCo Trail on Old Corbin Creek will be replaced with an approximately 20-foot trail bridge. An approximately 450-foot-long berm (Figure 6-4) would be placed in the low-lying area between the two bluffs near the Old Corbin Creek culverts to prevent overland flow from entering old relic channels that flow towards the Valdez subdivision. See Figure 6-1 for locations.

6.4 Alternative D

Alternative D consists of diverting a portion of Corbin Creek into Brownie Creek using a diversion dike constructed across Corbin Creek. The creeks would be connected via an approximately 3,115-foot-long channel. The dike would have an approximate crest elevation of 112 feet NAVD88 and extend approximately 300 feet with 3H:1V side slopes, an armored toe, and a 10-foot crest width as shown in Figure 6-3. Rock properties would conform to Table 5-3.

6.5 Alternative E

Alternative E is a no action alternative and Robe Lake will continue in the present condition. Human intervention and mechanical harvesting of aquatic vegetation would continue. The salmonid habitat within the Robe Lake watershed will continue to degrade. Study objectives would not be met, and no project benefits or opportunities would be realized.

7 Preliminary Geotechnical Analysis of Alternatives

The following analyses are based on information gathered during site visits, review of the historical geophysical survey and geotechnical reports, and assumptions concerning subsurface conditions. These analyses are to evaluate the feasibility of alternatives and are not sufficient for design. A geotechnical investigation is required to evaluate and validate assumptions. A geotechnical investigation should be performed during the preconstruction engineering and design (PED) phase of the project.

7.1 Bearing Capacity Analysis

Trail bridge abutments, diversion dike, berm construction, and culvert bedding require bearing capacity calculations. A geotechnical investigation is required to determine site-specific soil properties to perform bearing capacity analysis.

7.2 Slope Stability Analysis

A slope stability analysis will be required for alternatives involving channel excavation or construction of dikes. Preliminary material parameters presented in Table 5-1 may not be representative of the soils within the project area. A geotechnical site investigation is required to perform slope stability analysis.

7.3 Settlement Analysis

The magnitude of settlement that can be expected within the dike and fill areas is dependent on the applied loads, the density of the foundation soils, and the care with which the fill materials are placed. Settlement can be immediate (cohesionless soils), time-dependent (cohesive soils), or a combination of both for soils exhibiting intermediate cohesionless/cohesive characteristics. Immediate settlement is expected as load is applied to the suspected cohesionless soils underlying the project site. Time dependent settlement may also occur. A geotechnical site investigation is required to perform settlement analysis.

8 Future Geotechnical Site Investigation Recommendations

A geotechnical site investigation consisting of drilling between 15 and 20 test borings is recommended along the line of the Old Corbin Creek channel or selected channel excavation limits. Test borings should be performed within the footprint of any proposed berms, dikes, weirs, and structural features. The preferred drilling method would be able to drill and sample medium dense to loose to dense deposits of sands and gravels with cobbles. A geotechnical site investigation is vital to understanding the physical qualities of the project site, evaluating the soil properties for the proposed alternatives, and to provide design criteria and recommendations for construction. A geotechnical site investigation is typically performed during the preconstruction engineering and design (PED) phase of the project.

9 References

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Coduto, Donald P, Kitch, William A, Yeung, Man-Chu R. (2001). *Foundation Design: Principles and Practices – Third Edition, ISBN: 978-0-13-341189-8*.

ANNEX

HISTORICAL GEOTECHNICAL REPORTS

Test Boring Logs – Refining and Petrochemical Facility 1979 43 Sheets

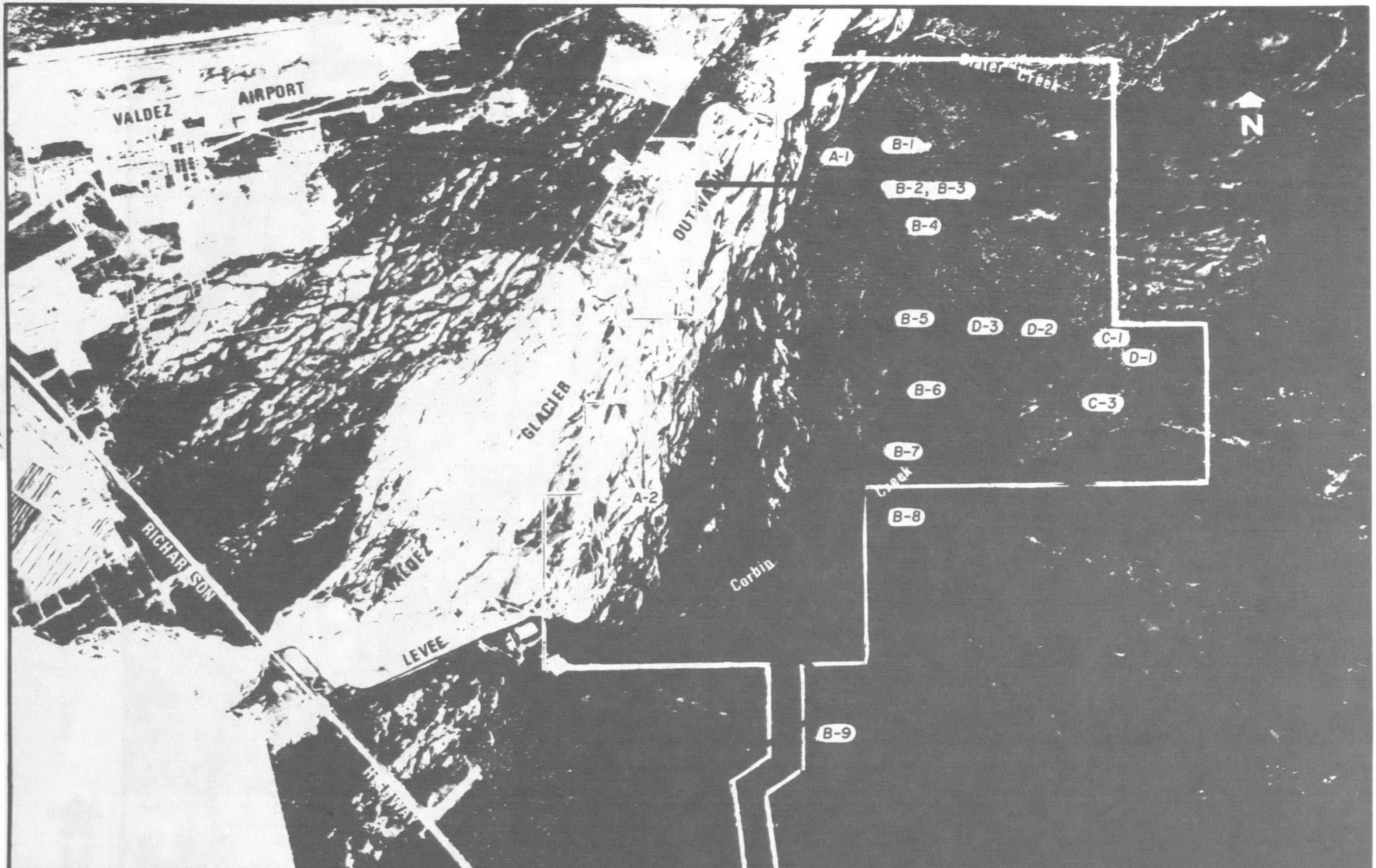


Figure 9

1000 0 2000 4000 feet
200 0 500 1000 meters

SEISMIC LINE AND DRILLING LOCATIONS

soils in the plant site investigation. Use of a temporary Valdez Glacier Stream crossing in June 1979 was discontinued because of erosion. Steep, sharp banks were exposed when the river level dropped in August 1979. At normal summer flow the stream exhibited sufficient velocity to dislodge and transport small to medium boulders. It is expected that particle density and particle size are sufficient to cause pile driving to be difficult. It is theorized that the depth to bedrock is 213 - 274m (700 - 900 ft), based on the seismic refraction studies for the refinery site and the reported depth to bedrock in Port Valdez. State construction of the Richardson Highway bridge across Valdez Glacier Stream revealed no unusual soil conditions which would suggest problems with respect to founding either the bridge or the roadway.

TABLE A

TESTHOLE	PAGE
A1	A-1
A2	A-2
B1	A-4
B2	A-5
B3	A-7
B4	A-8
B5	A-9
B6	A-10
B7	A-11
B8	A-12
B9	A-13
C1	A-15
C2	A-17
D1	A-18
D1	A-19

TABLE A

Test Hole A-1
Date of Drilling 26 June 79

DEPTH IN FEET	SOIL DESCRIPTION
0 to 76	Fl Grey Silty Sandy Gravel, damp to saturated, medium density, subrounded particles 6"-, GW/GM

Bottom of hole: 76.9
Water table: 4.6
Frost line: None observed

TABLE A

Test Hole A-2
Date of Drilling 10-11 July 1979

DEPTH IN FEET	SOIL DESCRIPTION
0 to 23	Fl Grey Silty Sandy Gravel (layers silty sand) damp to saturated, dense, subrounded particles, 3"-, GW/GM; sample #1, SPT at 4'-2" to 7'-2", Blows/6" 30/25/23/33/28/34
23-76.5	NFS/Fl Grey Silty Sandy Gravel, saturated, (cleaner with depth) medium density, subrounded particles, +2", GM/GW
76.5-84.5	Fl Brown Silty Sandy Gravel (with organic matter) saturated, medium density, subrounded particles, 12"- (probably a buried topsoil layer included in this interval), GM/GW
84.5-85	F4 Grey Sandy Silt saturated, stiff, nonplastic, ML
85-96	Fl Grey Silty Sandy Gravel, saturated medium density, subrounded particles, +2", GM/GW
96-104	F2 Grey silty Sand saturated, medium density, (heave in hole 30'), SM/SP
104-121	NFS Grey Sandy Gravel, saturated, medium density, subrounded, +2", GM/GW
121-125	F2 Grey Silty Sand, saturated, medium density, SP/SM
125-148	F4 Grey Silt trace gravel, saturated, dilatent, nonplastic, subrounded 3/8"-, ML, sample #2 grab at 128', ML
148-152	Fl Grey Silty Sandy Gravel, saturated, GM/GW
152-154	F4 Grey Silt with trace gravel, saturated, ML

TABLE A

Test Hole A-2 Cont'd.

154-157	Fl Grey Sandy Gravel, saturated, dense subrounded 2"-, SP/SW/SM

Bottom of hole: 156.9'
Water table: 5.3
Frost line: None observed

TABLE A

Test Hole B-1
Date of Drilling July 1979

DEPTH IN FEET	SOIL DESCRIPTION
0-67	Fl/NFS Grey Silty Sandy Gravel, damp to saturated, dense, subrounded particles 6"+, GM/GP
67-76	Fl Grey Silty Sandy Gravel, saturated, dense, subrounded particles, 2"+, GW/GM
76-98.8	NFS Grey Sandy Gravel, saturated, medium density, subrounded particles, 2"+, GP/GW

Bottom of hole: 98'-9"
Water table: 62'
Frost line: None observed

TABLE A

Test Hole B-2
Date of Drilling 30 June-10 July, 1979

DEPTH IN FEET	SOIL DESCRIPTION
0 to 15	F1 Grey Silty Sandy Gravel, damp, dense, subrounded particles, 4"-, GW/GM
15 to 20	F4 Grey Gravelly Sandy Silt, damp dense, nonplastic ML
20 to 47	F1 Grey Silty Sandy Gravel, damp, dense, subrounded particles, 6"+, GM/GW
47 to 50	F4 Grey Gravelly Sandy Silt damp, stiff to hard, nonplastic, ML
50 to 62	F1 Grey Silty Sandy Gravel, saturated, dense, subrounded, 3/4"-, GP
62 to 68	F2/F1 Silty Gravelly Sand and Silty Sandy Gravel, (layered) saturated medium to dense, subrounded particles SW-SM/GW-GM
68 to 80	NFS Grey Sandy Gravel with trace of silt saturated, medium to high density, subrounded, GW/GP
80 to 83.5	F1 Grey Silty Sandy Gravel, saturated, dense, subrounded particles, GP/GM
83.5 to 122.5	NFS Grey Sandy Gravel with a trace of silt, saturated, dense, subrounded, 4"+, GP/GW
122.5 to 125	F1 Brown Sandy Silt with organic debris saturated, stiff, nonplastic, ML
125 to 147	NFS Grey Sandy Gravel, with trace of silt, saturated, dense, subrounded particles, GP (30' of heave)
147 to 147.5	F4 Grey Sandy Silt, with roots, saturated stiff, nonplastic, ML

TABLE A

Table B-2 Continued

147.5 to 157	NFS Grey Sand (with trace of 3/8" gravel), saturated, medium density, subrounded 3/8"-, SP
157 to 166	NFS Grey Sandy Gravel, saturated, medium density, subrounded, GP

TABLE A

Test Hole B-2 Continued

166 to 173	F4/F2 Grey Silt and Silty Sand with layered, saturated, stiff, nonplastic, ML/SM
173 to 177	F1 Grey Silty Sandy Gravel, saturated, medium to high density, subrounded particles, GP/GM
177 to 181	NFS Grey Sandy Gravel, saturated, medium to high density, subrounded particles, GP
181 to 187	F2 Grey Silty Sand, saturated medium density (tends to heave) SM
187 to 195	NFS Grey Sandy Gravel saturated, medium to high density, subrounded particles, GP
195 to 195.6	F4 Brown Silt, with organic debris, saturated stiff, nonplastic, ML
195.6 to 197	F4 Grey Silt and Gravel, saturated, medium density, nonplastic, GM
197 to 199	NFS Grey Sandy Gravel saturated, medium density, subrounded particles, GP
199 to 201	F2 Grey Silty Sand, saturated, medium density, SM

Bottom of hole: 201'
Water table: 50'+
Frost line: None observed

Remarks: 12' Production testwell near B-3

TABLE A

Test Hole B-3
Date of Drilling 15-20 June 79

DEPTH IN FEET	SOIL DESCRIPTION
0 to 60	Fl/NFS Grey Silty Sandy Gravel with occasional cobbles, damp to saturated, dense, subrounded particles, 12"-, GW/GM
60 to 142	Fl/NFS Silty Sandy Gravel with occasional cobbles, saturated, dense (becomming finer with depth, subrounded particles, 2"+, GM/GW
142 to 145	NFS Grey Gravelly Sand, saturated, medium to high density, subrounded particles, SW/SP
145 to 171	Fl/NFS Grey Silty Sandy Gravel saturated dense, subrounded particles, 2"+, GW/GM
171 to 176	Fl/NFS Brown Silty Sandy Gravel, saturated (may include a silt layer with organic debris), dense, subrounded particles, 2", GW/GM
176 to 181	NFS Grey Silty Sandy Gravel, saturated dense, subrounded, 2", GP/GW
181 to 213	Fl/NFS Grey Silty Sandy Gravel, saturated, dense, subrounded particles, 2", GW/GM (note sulfurous smell 181'-183')
213 to 231	NFS/F2 Grey Sand with gravel, becomes siltier with depth, saurated, medium density, subrounded 1"-, SP/SM
231 to 343	F4 Grey Sandy Silt, moisture changes from saturated to damp to dry by 269', sample 163' to 165', dense (hard), nonplastic, ML
343 to 460	Fl Grey Silty Sandy Gravel, saturated, subrounded particles, GW/GM
460 to 501	Fl/NFS Grey Silty Sandy Gravel, saturated dense, subrounded particles 2"-, GW/GP

Bottom of hole: 501'
Water table: 52'
Frost line: None observed

TABLE A

Test Hole B-4
Date of Drilling 21 June 1979

DEPTH IN FEET	SOIL DESCRIPTION
0 to 52	Fl/NFS Grey Silty Sandy Gravel, damp to saturated, subrounded particles, 3"-, GW/GM
52 to 76	NFS Grey Sandy Gravel, trace silt, dense, subrounded particles, 2"-, GW, GP

Bottom of hole:	76'
Water table:	52'
Frost line:	None observed

TABLE A

Test Hole B-5
Date of Drilling 20-21 June 79

DEPTH IN FEET	SOIL DESCRIPTION
0 to 28	F1/NFS Silty Sandy Gravel with occasional cobbles at 30', damp, medium density, subrounded particles, 12"-, GP/GM
28 to 120	NFS Grey Sandy Gravel, trace silt, saturated, dense, subrounded 2"-, GP/GW
120 to 160	F1/NFS Grey Silty Sandy Gravel, saturated, dense, subrounded particles, 2"-, GP/GM
160 to 182	F1 Grey Silty Sandy Gravel, (layer of sandy silt 157-159) becomes siltier with depth, (sulfurous smell at 180') saturated, dense, subrounded particles, 2"-, GM/ML
182 to 196	F4 Black-Grey Sandy Silt, saturated, hard, nonplastic, tube sample at 192'-193', ML
196 to 198	F1 Grey Silty Sandy Gravel, saturated, dense, subrounded, GM
198 to 241	F1 Brown Silty Sandy Gravel, saturated, medium density, subrounded particles, 2"-, GM
241 to 160	F1 Grey Silty Sandy Gravel, saturated, dense, subrounded particles, 2", GM/GP

Bottom of hole: 260.5'
Water table: 28'
Frost line: None observed

TABLE A

Test Hole B-6
Date of Drilling

DEPTH IN FEET	SOIL DESCRIPTION
0 to 56.5	F1/NFS Grey Silty Sandy Gravel with occasional cobbles, damp to saturated, dense, subrounded particles, 6"-, GP/GM

Bottom of hole: 56.5'
Water table: 15.5'
Frost line: None observed

TABLE A

Test Hole B-7
Date of Drilling 3 July 79

DEPTH IN FEET	SOIL DESCRIPTION
0 to 30	F1/NFS Grey Silty Sandy Gravel, with occasional cobbles, saturated, dense, subrounded particles, 6"+, GW/GM
30 to 60	NFS Grey Sandy Gravel, saturated, dense, 3/4"-, GP/GW
60 to 82	Bedrock

Bottom of hole: 82'
Water table: 0'
Frost line: None observed

TABLE A

Test Hole B-8
Date of Drilling

DEPTH IN FEET	SOIL DESCRIPTION
0 to 5	NFS/Fl Grey Silty Sandy Gravel with cobbles at 4', damp to saturated, subrounded particles, 8"-, GP/GM
5 to 22	NFS Grey Sandy Gravel, with occasional cobbles, saturated, medium density, subrounded particles, 2"-, 5'-8', SPT Blows/6" = 16/60/25/24/18/18 10'-13' SPT Blows/6" = 10/23/13/32/13/11 15'-16.9', SPT Blows/6" = 20/14/40/42+ 20'-23', SPT Blows/6" = 7/10/10/11/11/13
22 to 64.9	Fl Grey Silty Sandy Gravel, saturated, dense, subrounded, 1-1/2"-, GM/GP 23-26 SPT, Blows/6" = 11/16/25/15/20/28
64.9-85	Bedrock

Bottom of hole: 85
Water table: 3.3'
Frost line: None observed

TABLE A

Test Hole B-9
Date of Drilling 3 July 79

DEPTH IN FEET	SOIL DESCRIPTION
0 to 7.7	NFS Grey Sand, saturated, SW/SP
7.7 to 21	NFS Grey Sandy Gravel layered with Sand, saturated, low to medium density, subrounded particles, 2"-, GP/GW
21 to 28	F4 Grey Sandy Silt, saturated, soft to stiff, nonplastic, ML
28 to 42	NFS/F2 Grey Sand to Silty Sand, (trace gravel) saturated, subrounded particles, 1/2"-. SP/SM
42 to 48	F1 Grey Silty Sandy Gravel, saturated, medium density, subrounded particles, 1-1/2"+, GW/GM
48 to 59	F4 Grey-Brown Silt with wood fragments, saturated, medium density, ML
59 to 60.5	F2 Grey Silty Sand, saturated, medium density, SM
60.5 to 80	F4 Grey Sandy Silt (trace roots) saturated, stiff, dilitant, nonplastic, ML, 60.5' to 62.5', SPT, Blows/6" = 8/8/9/18
80 to 85	F4 Grey Silt, trace sand, saturated, stiff, dilitant, moisture content at or near plastic limit, ML, tube sample 81 to 82.5
85 to 95	F4 Grey Sandy Gravelly Silt, damp, stiff to hard, (at 85' gravelly layer with no water) subrounded particles, 3/4"-, ML
95 to 97	F1 Grey Silty Sandy Gravel, damp to wet, dense, subrounded, 1"-, GM
97 to 105	Grey Silty Sandy Gravel, saturated, dense, subangular particles, 2"-, GM/GP

TABLE A

Test Hole B-9 Continued

105 to 105.9   Bedrock, hard drilling, quartz veined Graywacke

Bottom of hole: 105.9'
Water table: 8' above grade
Frost line: None observed

TABLE A

Test Hole C-1
Date of Drilling 4 July 79

DEPTH IN FEET	SOIL DESCRIPTION
0 to 1	F1 Grey, Sandy Silt, damp, soft, nonplastic, ML
1 to 5.6	F2 Grey Silty Sand, trace wood, saturated, medium densiity, SM
5.6 to 48.8	NFS Grey Sandy Gravel, with trace of silt and with layers of silty sandy gravel, saturated, GP/GM 5.6 to 7, SPT, Blows/6" = 16/20/17 8' to 11' SPT, Blows/6" = 8/8/13/32/15/13 11.5 to 14.5 SPT, Blows/6" = 3/14/24/16/3/20/24 18 to 21 SPT, Blows/6" = 4/6/8/12/4/11/16
39.6 to 48.7	F2 Grey Silty Sand, saturated, loose to medium density, SM 39 to 43 SPT, Blows/6" = 5/4/4/5/5/4/5/6
48.7 to 58.7	F2/F4 Grey Silty Sand and Sandy Silt, saturated (also 6" layer in sample that is damp) loose to stiff, SM/ML 54 to 57 SPT, Blows/6" = 4/4/3/4/6/4/5 55 to 56.5, thin wall tube sample
58.7 to 68	F1/NFS Grey Silty Sandy Gravel saturated, medium density, subrounded particles, 1"-, GP/GM 59.5 to 62 SPT, Blows/6" = 6/9/9/12/35
68 to 78	NFS Grey Sandy Gravel, saturated, medium density, subrounded particles
78 to 117	F1 Grey Silty Sandy Gravel, saturated medium density, subrounded particles, GP/GM
117 to 125	F1 Brown Silty Sandy Gravel, (sulfurous smell) saturated, dense, subrounded particles, GM
125 to 130	F2/F3 Brown Gravelly Silty Sand, saturated, medium density, subrounded particles, 2"-, SM
130 to 135	F4 Brown Sandy Silt, with trace organic debris, saturated, stiff, nonplastic, ML

TABLE A

Test Hole C-1 Cont'd.

135 To 169	F1 Grey Silty Sandy Gravel, saturated, dense, subrounded particles, GM
169 to 177	F2 Grey Silty Sand damp, dense, SM 171-172, SPT Blows/6" = 4/9/46/53/58+
177 to 216	F1 Grey Silty Sandy Gravel with cobbles, damp, dense, subrounded particles, 6"-, GM
216 to 281	F1 Grey Silty Sandy Gravel, saturated, dense, subrounded particles, 2"-, GP/GW

Bottom of hole: 281'
Water table: 6.1'
Frost line: None observed

TABLE A

Test Hole C-2
Date of Drilling 6-7 July 1979

DEPTH IN FEET	SOIL DESCRIPTION
0 to 5	NFS Grey Silty Sandy Gravel, GM/GP
5 to 25	NFS Grey Sandy Gravel, saturated, low to medium density, subrounded particles, 3/4"-, GP/GW (sandier with depth 0.5' to 5' of heave in casing at sampling attempts. 7' To 10', SPT Blows/6" 4/7/5/11/15/9 11.5 to 14.5 SPT Blows/6" 3/3/4/2/6/8/12
25 to 35	Fl Grey Silty Sandy Gravel, trace wood, saturated, medium density, (easy drilling 30'-35') GP/GW 30 to 33, SPT Blows/6" = 4/6/15/18/28/39
35 to 37.5	Fl Brown Silty Sandy Gravel saturated, medium density, sharp particles, GP/GM (casing moved freely after drilling ahead) 37-39 SPT, Blows/6" = 3/6/11/18/22/25 (sample included a thin layer of ash)
37.5 to 40	F4 Grey-Brown Sandy Silt, saturated, stiff, nonplastic, ML
40 to 56	Fl Brown Silty Sandy Gravel, with occasional cobbles, saturated, dense, subrounded particles, GP/GM

Bottom of hole: 56'
Water table: 4.8'
Frost line: None observed

TABLE A

Test Hole D-1
Date of Drilling 22-23 June 79

DEPTH IN FEET	SOIL DESCRIPTION
0 to 1.5'	F4 Grey Sandy Silt, dry, soft, nonplastic, ML
1.5 to 15	Fl/NFS Grey Silty Sandy Gravel, damp to wet, medium density, subrounded particles, 1-1/2"-, GP/GM
15 to 40	NFS Grey Sandy Gravel, saturated, dense, subrounded 2"-, GP/GW
40 to 45	Fl Grey Silty Sandy Gravel, saturated, dense, subrounded particles 1/2"-, GP
45 to 59	NFS Grey Sandy Gravel, with cobbles, saturated, dense, subrounded, GP/GW
59 to 93	Fl/F3 Grey Silty Sandy Gravel, damp, dense, subrounded particles, GM
93 to 100	Fl Grey Sandy Gravel saturated, dense, subrounded particles, GM/GP
100 to 327	NFS Grey Sandy Gravel with trace of silt, saturated, medium density, subrounded particles, 2"-, GP
327 to 347	NFS Grey Bedrock, Graywacke

Bottom of hole: 347'
Water table: 8.1'
Frost line: None observed

TABLE A

Test Hole D-2
Date of Drilling

DEPTH IN FEET	SOIL DESCRIPTION
0 to 8	NFS/F1 Grey Sandy Gravel with Sandy Silt layers, damp to wet, medium density subrounded particles, GP/GM 5' to 8', SPT Blows/6" = 7/10/10/12/8/10
8 to 39	NFS Grey Sandy Gravel, trace silt, saturated, dense, subrounded particles, GP 10.5 to 13.5, SPT Blows/6" = 9/13/10/17/26/32 16 to 17, SPT Blows/6" = 22/58 17.6 to 18.6, SPT Blows/6" = 18/68
39 to 41	F2 Grey Silty Sand, saturated, dense, SM 40.5 to 43.5, SPT, Blows/6" = 5/8/27/59/26/25
41 to 41.5	F4 Grey Silt with trace organic debris, saturated, nonplastic, ML
41.5 to 50	F1/NFS Grey Silty Sandy Gravel, saturated, dense, subrounded particles, GM/GW

Bottom of hole: 50'
Water table: 9'
Frost line: None observed

TABLE A

Test Hole D-3
Date of Drilling 7-10 July 1979

DEPTH IN FEET	SOIL DESCRIPTION
0 to 13	F-1 Grey slightly Silty Sandy Gravel damp, low density subrounded/rounded particles 1"- SPT at 7.2' to 12' Blows/6" = 2/4/11/9/6/3/5/13/9/9
13 to 36	F-1 Grey Silty Sandy Gravel damp/saturated medium dense, sharp particles SPT at 14.5' to 17.5' and 17.5 and 18.7' Blows/6" = 4/9/27/32/12/13 and 4/10/26/50 in 0.2'
36 tO 36.8	F-2 Grey slightly Silty Sand saturated, low density
36.8 tO 52.7	F-1 Grey slightly Silty Sandy Gravel saturated high density subrounded/rounded 3"+ SPT at 36.8' to 39.8', Blows/6" = 8/20/38/59/63/65

Bottom of hole: 52.7'
Water table: 16.5'
Frost line: None observed

TABLE B

Test Hole Log – Description Guide

ıe soil descriptions shown on the logs are the best estimate of the soil's :naracteristics at the time of field examination and as such do not achieve the precision of a laboratory testing procedure. If the log includes soils samples, those samples receive an independent textural classification in the laboratory to verify the field examination.

The logs often include the following items:

Depth Interval – usually shown to 0.1 foot, within that zone no significant change in soil type was observed through drill action, direct observation or sampling.

Frost Classification – NFS, F1, F2, F3, F4, see "Soil Classification Chart"

Texture of Soil – An engineering classification of the soils by particle size and proportion, see "Soil Classification Chart", note the proportions are approximate and modifications to the soil group due to stratification, inclusions and changes in properties are included.

Moisture Content – this is a qualitative measure:
dry, no or little apparent surface moisture,
damp, moisture forms portion of color, less than plastic limit,
wet, no free water, often soft, if cohesive soil,
saturated, free water may be squeezed out, if a free draining soil;
dilatent at natural moisture content, if a non-plastic silt or fine sand. (The moisture content is further defined by reference to Pl, Lw, NP, M% or dilatency.)

Density – refers to more-or-less non-cohesive soils, such as sand gravel mixtures with or without a fine fraction, derived from drilling action and/or sample data; usually described as: very loose, loose, medium dense, very dense. General intent is to portray earthwork characteristics.

Stiffness – refers to more-or-less cohesive soils and fine grained silts of the clay-silt groups. Derived from drill action and/or sample data. Very soft, soft, stiff, very stiff and hard are commonly used terms.

Particle size – The largest particle recovered by the split spoon is 1-3/8", Shelby tube 3", auger flights (minute-man) 2", Auger flights (B-50 hollow stem) 6"-8". Larger particles are described indirectly by action of the drilling and are referred to as cobbles, 3" to 8", or boulders 8"+. Therefore when reviewing the gradation sheets, if any, the description on the hole log must be considered for an indication of larger particles.

Unified Soil Classification – This is a two letter code. See Unified Classification sheet for further definition. In some cases AASHO and/or FAA soil classifications may be shown as well as the unified.

Atterberg Limits – useful for fine grained and other plastic soils.

Pl; natural moisture content believed to be less than plastic limit

Pl+; natural moisture content believed to be between plastic and liquid limits

Lw+; natural moisture content believed to be greater than liquid limit

NP; non-plastic, useful as a modifying description of some silty matèrials.

Dilatency – is the ability of water to migrate to the surface of a saturated or nearly saturated soil sample when vibrated or jolted – used as an aid to determine if a fine grained soil is a slightly or non-plastic silt or a volcanic ash.

Rock flour – finely ground soil that is not plastic but otherwise appears similar to a clayey silt.

Organic Content – usually described as Peat, PT, sometimes includes discrete particles such as wood, coal, etc. as a modifier to an inorganic soil. Quantity described as; trace, or an estimate of volume, or, in case of all organic, – as Peat. This may include tundra, muskeg and bog material.

Muck – a modifier used to describe very soft, semi-organic deposits usually occuring below a peat deposit.

Amorphus peat – organic particles nearly or fully disintegrated.

Fibrous Peat – organic particles more-or-less intact.

Bottom of Testhole – includes last sample interval.

Frost Line – seasonal frost depth as described by drilling action and/or samples at the time of drilling.

Frozen Ground – other than frost line, described by samples, usually includes description of ice content, often will include modified Unified Classification for frozen soils – this is a special case related to permafrost studies.

Free Water Level – The free water level noted during drilling. This is not necessarily the static water table at the time of drilling or at other seasons. Static water table determination in other than very permeable soils requires observation wells or piezometer installations, used only in special cases.

Blow/6" – The number of blows of a 140 weight free falling 30" to advance a 2" split spoon 6"; the number of blows for a 12" advance is, by definition, the standard penetration.

M% – natural moisture content of the soil sample, usually not performed on clean sands or gravels below the water table.

Type of Sample –
SP, refers to 2" split spoon driven into the soil by 140 pound weight, a disturbed sample,
S, thin wall tube, "Shelby" used to obtain undisturbed samples of fine grained soil,
G, "grab" disturbed sample from auger flights or wall of trench,
C, cut sample, undisturbed sample from wall of trench.

Dry Strength – a useful indicator of a soil's clayey fraction, N=None, L=Low, M=Medium, H=High

Group – The samples are placed into apparently similar groups based on color and texture and are arbitrarily assigned a group letter. Further disturbed tests including Atterberg Limits, grain size, moisture-density relationship, etc. may be performed on the group and are assumed to reflect the general distrubed characteristics of the soils assigned to the group. This is an important phase of the soil analysis and is used to standardize the various qualitative determinations and to reduce the number of quantitative tests necessary to describe the soil mass.

DESCRIPTION AND CLASSIFICATION OF FROZEN SOILS

PART I DESCRIPTION OF SOIL PHASE (a) (Independent of Frozen State)	Classify Soil Phase by the Univied Soil Classification System							
(1)	Major Group		Sub-Group		Field Identification	Pertinent Properties of Frozen Materials Which May be Measured by Physical Tests to Supplement Field Identification	Guide for Construction on Soils Subject to Freezing and Thawing	
	Description (2)	Designation (3)	Description (4)	Designation (5)	(6)	(7)	Thaw Characteristics (8)	Criteria (9)
PART II DESCRIPTION OF FROZEN SOIL	Segregated ice is not visible by eye (b)	N	Poorly bonded or friable	Nf	Identify by visual examination. To determine presence of excess ice, use procedure under note (c) below and hand magnifying lens as necessary. For soils not fully saturated, estimate degree of ice saturation: Medium, Low. Note presence of crystals, or of ice coatings around larger particles.	In-Place Temperature Density and Void Ratio a. In Frozen State b. After Thawing in Place Water Content (total H_2O, including ice) a. Average b. Distribution Strength a. Compressive b. Tensile c. Shear d. Adfreeze Elastic Properties Plastic Properties Thermal Properties Ice Crystal Structure (using optical instruments) a. Orientation of Axes b. Crystal Size c. Crystal Shape d. Pattern of Arrangement	Usually thaw - stable	The potential intensity of ice segregation in a soil is dependent to a large degree on its void sizes and for pavement design purposes may be expressed as a empirical function of grain size as follows: Most inorganic soils containing 3 percent or more of grains finer than 0.02 mm in diameter by weight are frost-susceptible for pavement design purposes. Gravels, well-graded sands and silty sands, especially those approaching the theoretical maximum density curve, which contain 1-1/2 to 3 percent finer by weight then 0.02 mm size should be considered as possibly frost-susceptible and should be subjected to a standard laboratory frost susceptiblity test to evaluate actual behaviour during freezing. Uniform sandy soils may have as high as 10 percent of grains finer than 0.02 mm by weight without being frost-susceptible. However, their tendency to occur interbedded with other soils usually makes it impractical to consider them separately. Soils classed as frost-susceptible under the above pavement design criteria are likely to develop significant ice segregation and frost heave if frozen at normal rates with free water readily available. Soils so frozen will fall into the thaw-unstable category. However, they may also be classed as thaw-stable if frozen with insufficient water to permit ice segregation. Soils classed as non-frost susceptible under the above criteria usually occur without significant ice segregation and are usually thaw-stable for pavement applications. However, the criteria are not exact and may be inadequate for some structure applications; exceptions may also result from minor soil variations. In permafrost areas, ice wedges, pockets, veins, or other ice bodies may be found whose mode of origin is different from that described above. Such ice may be the result of long-time surface expansion and contraction phenomena or may be glacial or other ice which has been buried under a protective earth cover.
			Well bonded — No excess ice	Nb — n				
			Well bonded — Excess Ice	Nb — e			Usually thaw - unstable	
	Segregated ice is visible by eye (Ice 1 inch or less in thickness) (b)	V	Individual ice crystals or inclusions	Vx	For ice phase record the following as applicable: Location; Orientation; Thickness; Length; Spacing; Hardness, Structure, Color per Part III below Size; Shape; Pattern of arrangement			
			Ice coatings on particles	Vc				
			Random or irregularly oriented ice formations	Vr				
			Stratified or distinctly oriented ice formations	Vs	Estimate volume of visible segregated ice present as percent of total sample volume.			
PART III DESCRIPTION OF SUBSTANTIAL ICE STRATA	Ice (Greater than 1 inch in thickness)	ICE	Ice with soil inclusions	Ice + soil type	Designate material as ICE (d) and use descriptive terms as follows, usually one item from each group, as applicable: Hardness: HARD, SOFT (or mass, not individual crystals) Structure: CLEAR, CLOUDY, POROUS, CANDLED, GRANULAR, STRATIFIED Color (Examples): COLORLESS, GRAY, BLUE Admixtures (Example): CONTAINS FEW THIN SILT INCLUSIONS	Same as Part II above, as applicable, with special emphasis on Ice Crystal Structure		
			Ice without soil inclusions	Ice				

DEFINITIONS:

Ice Coatings on Particles are discernible layers of ice found on or below the larger soil particles in a frozen soil mass. They are sometimes associated with hoarfrost crystals, which have grown into voids produced by the freezing action.

Ice Crystal is a very small individual ice particle visible in the face of a soil mass. Crystals may be present alone or in a combination with other ice formations.

Clear Ice is transparent and contains only a moderate number of air bubbles (e)

Cloudy Ice is relatively opaque due to entrained air bubbles or other reasons, but which is essentially sound and non-pervious. (e)

Porous Ice contains numerous voids, usually interconnected and usually resulting from melting at air bubbles or along crystal interfaces from presence of salt or other materials in the water, or from the freezing of saturated snow. Though porous, the mass retains its structural unity.

Candled Ice is ice which has rotted or otherwise formed into long columnar crystals, very loosely bonded together.

Granular Ice is composed of coarse, more or less equidimensional, ice crystals weakly bonded together.

Ice Lenses are lenticular ice formations in soil occurring essentially parallel to each other, generally normal to the direction of heat loss and commonly in repeated layers.

Ice Segregation is the growth of ice as distinct lenses, layers, veins, and masses in soils, commonly but not always oriented normal to direction of heat loss.

Well-bonded signifies that the soil particles are strongly held together by the ice and that the frozen soil possesses relatively high resistance to chipping or breaking.

Poorly-bonded signifies that the soil particles are weakly held together by the ice and that the frozen soil consequently has poor resistance to chipping or breaking.

Friable denotes extremely weak bond between soil particles. Material is easily broken up.

Thaw-Stable frozen soils do not, on thawing, show loss of strength below normal, long-time thawed values and/or significant settlement, as a direct result of the melting of the excess ice in the soil.

NOTES:

(a) When rock is encountered, standard rock classification terminology should be used.

(b) Frozen soils in the N group may, on close examination, indicate presence of ice within the voids of the material by crystalline reflections or by a sheen on fractured or trimmed surfaces. However, the impression to the unaided eye is that none of the frozen water occupies space in excess of the original voids in the soil. The opposite is true of frozen soils in the V group.

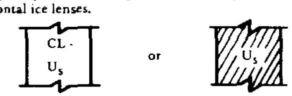
(c) When visual methods may be inadequate, a simple field test to aid evaluation of volume of excess ice can be made by placing some frozen soil in a small jar, allowing it to melt and observing the Quantity of supernatant water as a percent of total volume.

(d) Where special forms of ice, such as hoarfrost, can be distinguished, more explicit description should be given.

(e) Observer should be careful to avoid being misled by surface scratches or frost coating on the ice.

NOTES:

The letter symbols shown are to be affixed to the Unified Soil Classification letter designations, or may be used in conjunction with graphic symbols, in exploration logs or geological profiles. Example — a lean clay with essentially horizontal ice lenses.



The descriptive name of the frozen soil type and a complete description of the frozen material are the fundamental elements of this classification scheme. Additional descriptive data should be added where necessary. The letter symbols are secondary and are intended only for convenience in preparing graphical presentations. Since it is frequently impractical to describe ice formations in frozen soils by means of words alone, sketches and photographs should be used where appropriate, to supplement descriptions.

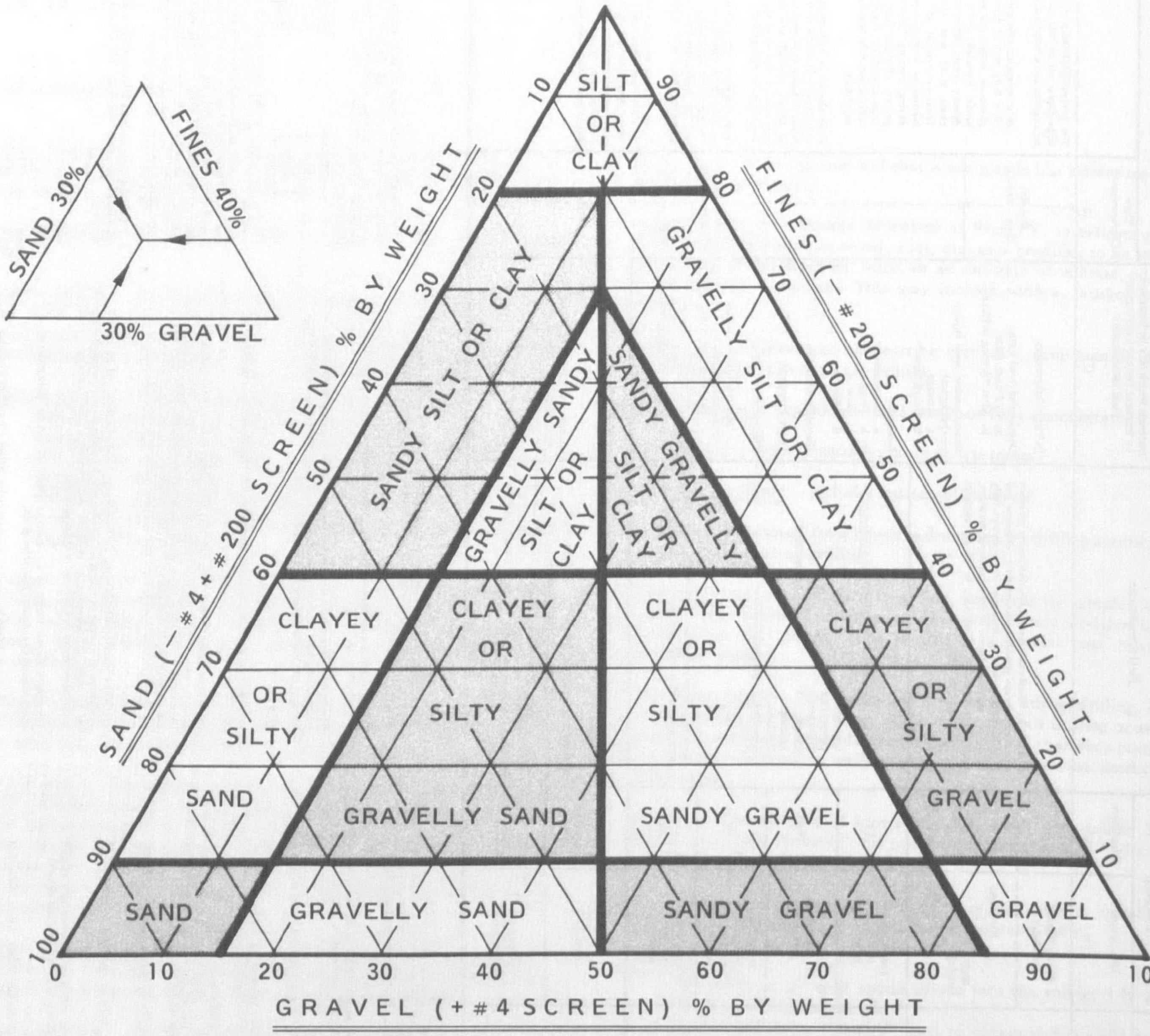
The abbreviation NFS is commonly used to designate non-frost-susceptible materials on exploration logs and drawings.

TABLE B (Continued)

TABLE B

(Continued)

SOIL CLASSIFICATION CHART



NONFROST SUSCEPTIBLE SOILS ARE INORGANIC SOILS CONTAINING LESS THAN 3% FINER THAN 0.02 mm.
GROUPS OF FROST-SUSCEPTIBLE SOILS:

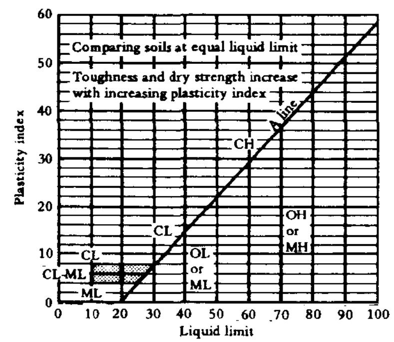
F1 GRAVELLY SOILS CONTAINING BETWEEN 3 AND 20% FINER THAN 0.02 mm.

F2 SANDY SOILS CONTAINING BETWEEN 3 AND 15% FINER THAN 0.02 mm.

F3 a. GRAVELLY SOILS CONTAINING MORE THAN 20% FINER THAN 0.02 mm. AND SANDY SOILS (EXCEPT FINE SILTY, SANDS) CONTAINING MORE THAN 15% FINER THAN 0.02 mm.
b. CLAYS WITH PLASTICITY INDEXES OF MORE THAN 12. EXCEPT VARVED CLAYS.

F4 a. ALL SILTS INCLUDING SANDY SILTS.
b. FINE SILTY SANDS CONTAINING MORE THAN 15% FINER THAN 0.02 mm.
c. LEAN CLAYS WITH PLASTICITY INDEXES OF LESS THAN 12.
d. VARVED CLAYS.

UNIFIED SOIL CLASSIFICATION SYSTEM

Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)						Group Symbols[a]	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria
Coarse-grained soils. More than half of material is larger than No. 200 sieve size[b] (The No. 200 sieve size is about the smallest particle visible to naked eye)	Gravels. More than half of coarse fraction is larger than No. 4 sieve size (For visual claffication, the ¼ in. size may be used as equivalent to the No. 4 sieve size)	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes			GW	Well graded gravels, gravel sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the course grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses. For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics. Example: Silty sand, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine, about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM)	Use grain size curve in identifying the fractions as given under field identification. Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows: Less than 5%: GW, GP, SW, SP; More than 12%: GM, GC, SM, SC; 5% to 12%: Borderline cases requiring use of dual symbols. — $C_U = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see ML below)			GM	Silty gravels, poorly graded gravel-sand-silt mixtures		Atterberg limits below "A" line, or PI less than 4 — Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols
			Plastic fines (for identification procedures, see CL below)			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line, with PI greater than 7
	Sands. More than half of coarse fraction is smaller than No. 4 sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes			SW	Well graded sands, gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing			SP	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see ML below)			SM	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line or PI less than 5 — Above "A" line with P1 between 4 and 7 are borderline cases requiring use of dual symbols
			Plastic fines (for identification procedures, see CL below)			SC	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits below "A" line with PI greater than 7
Fine-grained soils. More than half of material is smaller than No. 200 sieve size	Identification Procedures on Fraction Smaller than No. 40 Sieve Size								
			Dry Strength (crushing character-istics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)				
	Silts and clays liquid limit less than 50		None to slight	Quick to slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses. For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions. Example: Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (ML)	
			Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			Slight to medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity		
	Silts and clays liquid limit greater than 50		Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		
			High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays		
			Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity		
Highly Organic Soils			Readily identified by colour, odour, spongy feel and frequently by fibrous texture			Pt	Peat and other highly organic soils		

Plasticity chart for laboratory classification of fine grained soils

From Wagner, 1957.

a Boundary classifications. Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW – GC, well graded gravel-sand mixture with clay binder.

b All Sieve sizes on this chart are U. S. standard

Field Identification Procedure for Fine Grained Soils or Fractions

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (Reaction to shaking):

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics):

After removing particles larger than No. 40 sieve size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit):

After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eight inch in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

TABLE C

LABORATORY EXAMINATION OF HAND SAMPLES

DEPTH IN FEET	LAB GROUP	FROST CLASS	UNIFIED CLASS	OTHER
TESTHOLE A-1	-----	-----	-----	-----
TESTHOLE A-2				
4.1' to 7.1'	B	F1	GW	
128'	G	F4	CL	
TESTHOLE B-1	-----	-----	-----	-----
TESTHOLE B-2				
142'	G	F4	ML	
TESTHOLE B-3				
280'-281'	G	F4	ML	q_u 3.5+kg/cm^2 V_s 0.9 ksf M=25±1%, Lw=27% P.I.=3, See sample log & gradation sheets C1&L2
TESTHOLE B-4	-----	-----	-----	-----
TESTHOLE B-5				
192.9' to 194.9'	G	F2-F4	SM-ML	M, Silt=15.5%, Lw=24%, P.I.=4, M, Silty Sand= 18.6%, see sample log & gradation sheets C3-C5
TESTHOLE B-6	-----	-----	-----	-----
TESTHOLE B-7	-----	-----	-----	-----
TESTHOLE B-8				
5' to 8'	A	NFS	GW	
10'to 13'	A	NFS	GW	
15'to 16'	A	NFS	GW	
20' to 23'	A	NFS	GW	
23.3' to 25.3'	B	F1	GW	
TESTHOLE B-9				
60.5' to 63.5'	C	F2	SM	
81' to 81.5'	-----	F4	ML	M%=29% to 34% q_u 0.3 to 1.5 kg/cm^2 V_s=0.4 to 1.3 ksf, Lw=30% P.I.=3, see sheets C6&C7

TABLE C (Continued)

TESTHOLE C-1				
4.9' to 7.1'	B	F1	GW	
5' to 6.5'	A	NFS	GW	
11.5' to 14.5'	A	NFS	GW	
18.2' to 27.2'	A	NFS	GW	
43' to 43.5'	C	F2	SM	
54' to 57'	C	F2	SM	
59.5' to 62.5'	G	F4	CL	
170'-8"	E	F2	SP	
170'-8"+	B	F1	GW	
TESTHOLE C-2				
7.1' to 10.1'	B	F1	GW	
36.8' to 39.8'	G	F4	CL	
36.8' to 39.8'	F	F3	GL	
TESTHOLE D-1				
5.7' to 7.8'	-----	F3	SM	Gradation sheet C8
TESTHOLE D-2				
10.4'	A	NFS	GW	
15.9' to 16.9'	B	F1	GW	
40.5' to 43.5'	B	F1	GC	
40.5' to 43.5	G	F4	CL	
45' to 47'	C	F2	SM	
TESTHOLE D-3				
36.9' to 39.9'	A	NFS	GW	

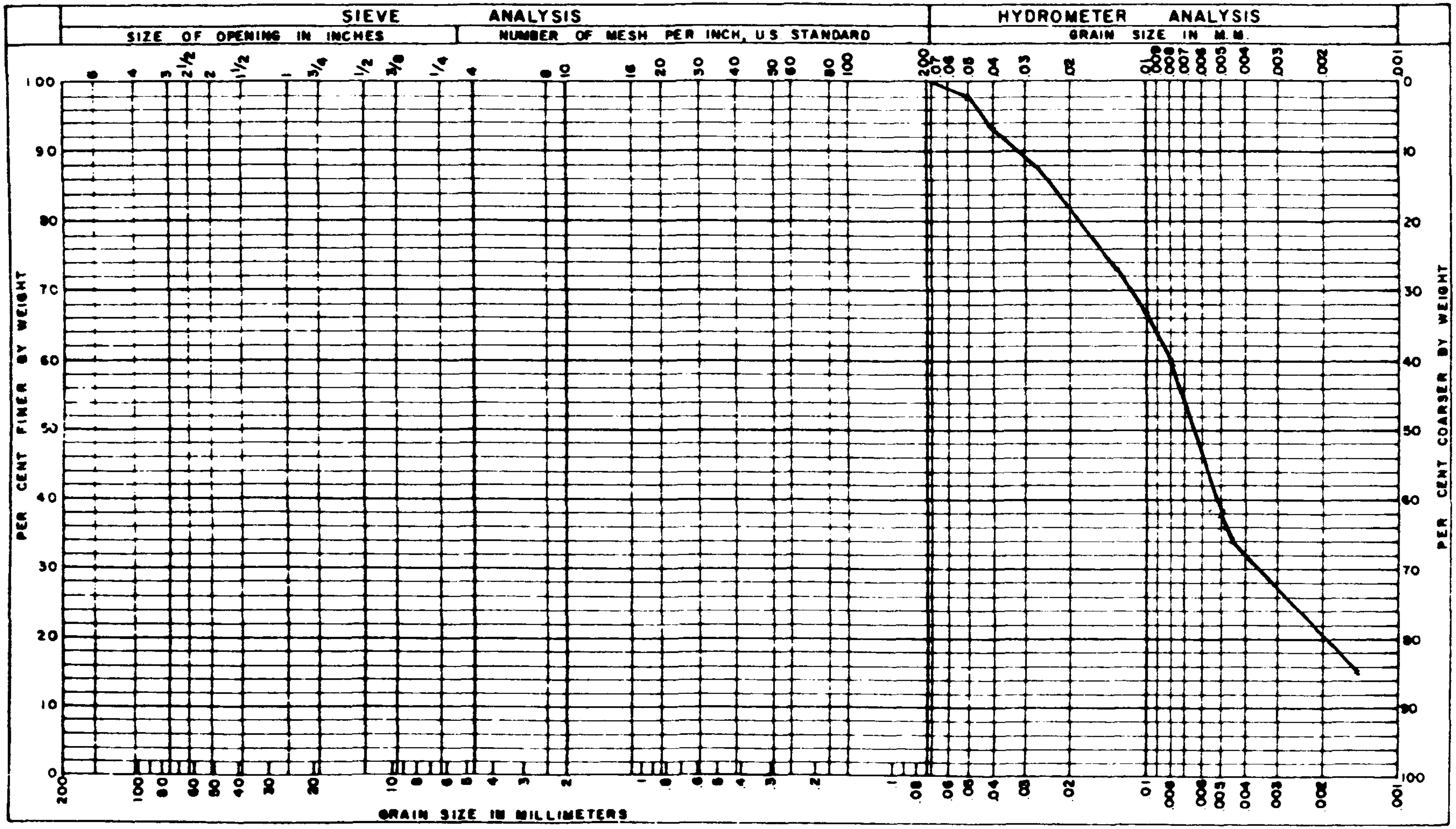
ALASKA TESTLAB

4045 B STREET
ANCHORAGE ALASKA 99501

Sheet C2 of
W. O. No. D11751
Date 6-25-79
Technician JM

Textural Class SILT
Frost Class F4 Unified Class ML
Plastic Properties L_W = 27 P.I. = 3
Date Received 6-19-79

Client DOWL ENGINEERS
Project ALPETCO EIS DRILLING
Sample Number B3 SA 34
Location 280-281 ft.
Sample Taken By ATL-TB



U.S. STD. SIEVE	CUM % PASS
2	
1 1/2	
1	
3/4	
1/2	
3/8	
4	
10	
20	
40	
80	
200	100
0.02 MM	80

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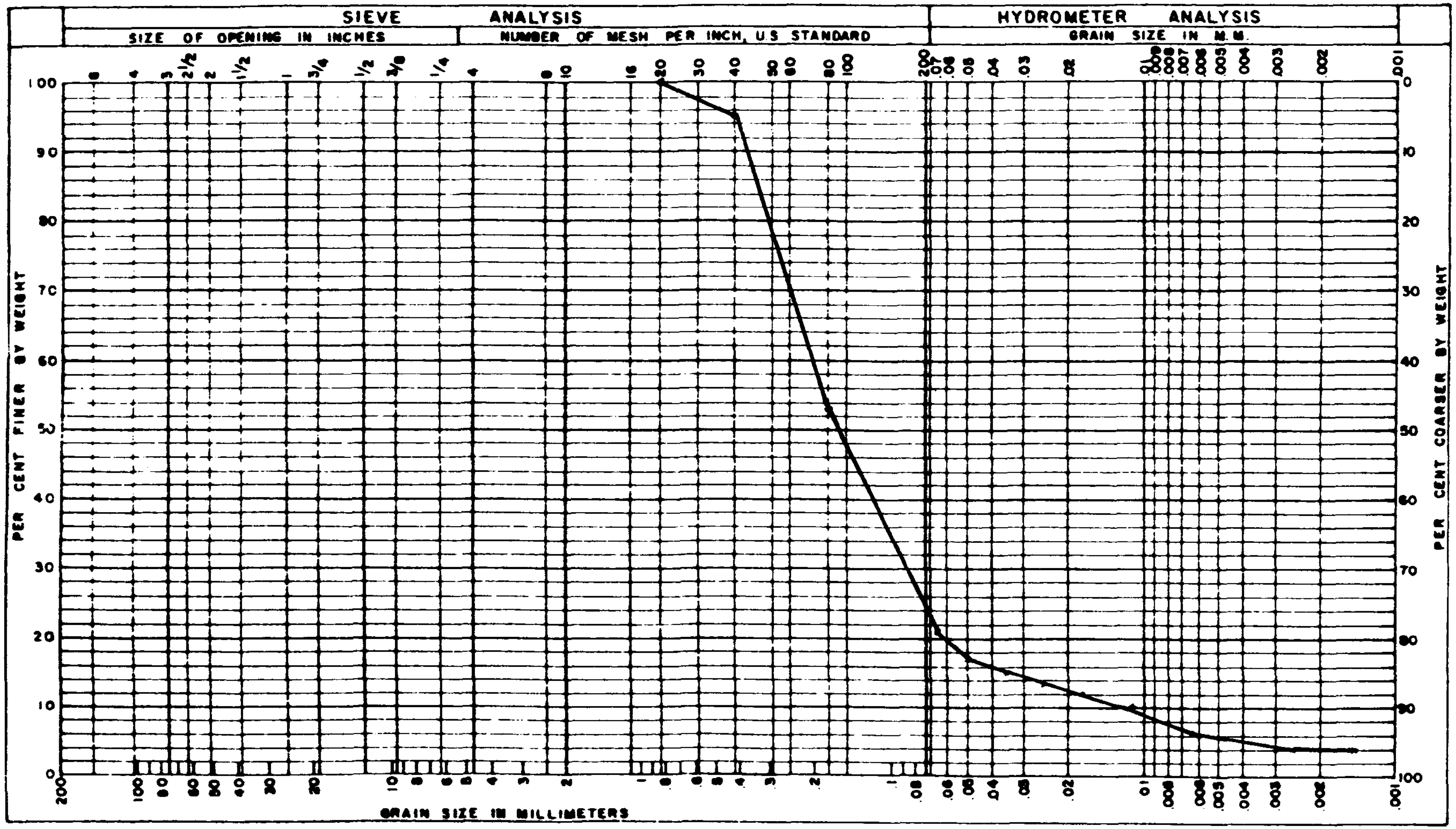
ALASKA TESTLAB

4040 B STREET
ANCHORAGE ALASKA 99503

Sheet C4 of
W. O. No. D11751
Date 6-26-79
Technician TAS

Textural Class SILTY SAND
Frost Class F2 Unified Class SM
Plastic Properties
Date Received

Client ALPETCO
Project VALDEZ EIS DRILLING
Sample Number TH B-5 192.9 to 194.9
Location -193.5 ft. SA #3
Sample Taken By TB



U.S. STD. SIEVE	CUM. % PASS
2	
1 1/2	
1	
3/4	
1/2	
3/8	
4	
10	
20	100
40	95
80	53
200	22
0.02 MM	12

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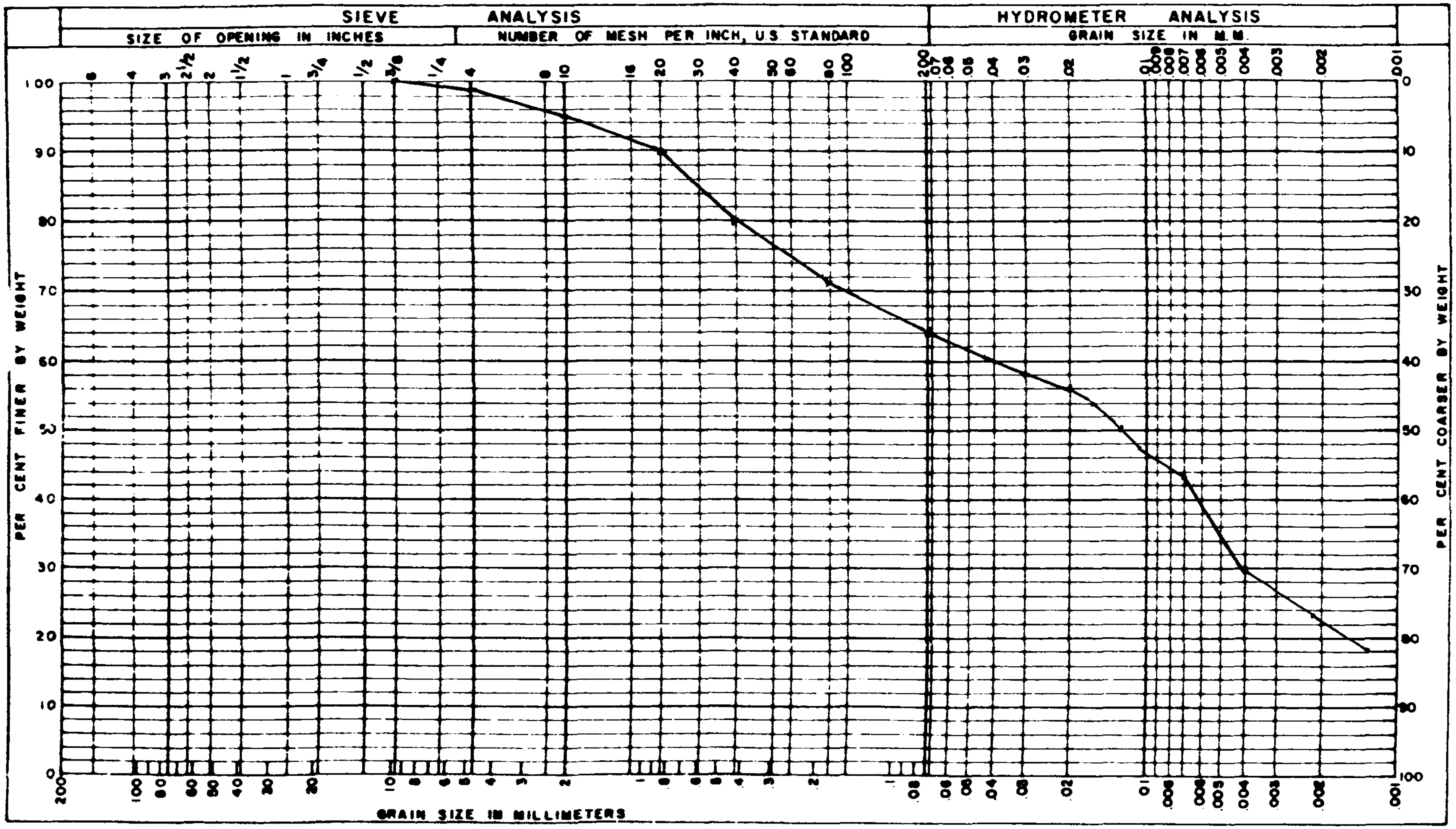
ALASKA TESTLAB

4040 B STREET
ANCHORAGE ALASKA 99501

Sheet C5 of
W. O. No. D11751
Date 6-26-79
Technician TAS

Textural Class SILT
Frost Class F4 Unified Class ML
Plastic Properties L_w = 24 P.I. = 4
Date Received

Client ALPETCO
Project VALDEZ EIS DRILLING
Sample Number TH B-5 192.9 to 194.9
Location -194.5 ft. SA #1
Sample Taken By TB



U.S. STD. SIEVE	CUM % PASS
2	
1 1/2	
1	
3/4	
1/2	
3/8	100
4	99
10	95
20	90
40	80
80	71
200	64
0.02 MM	56

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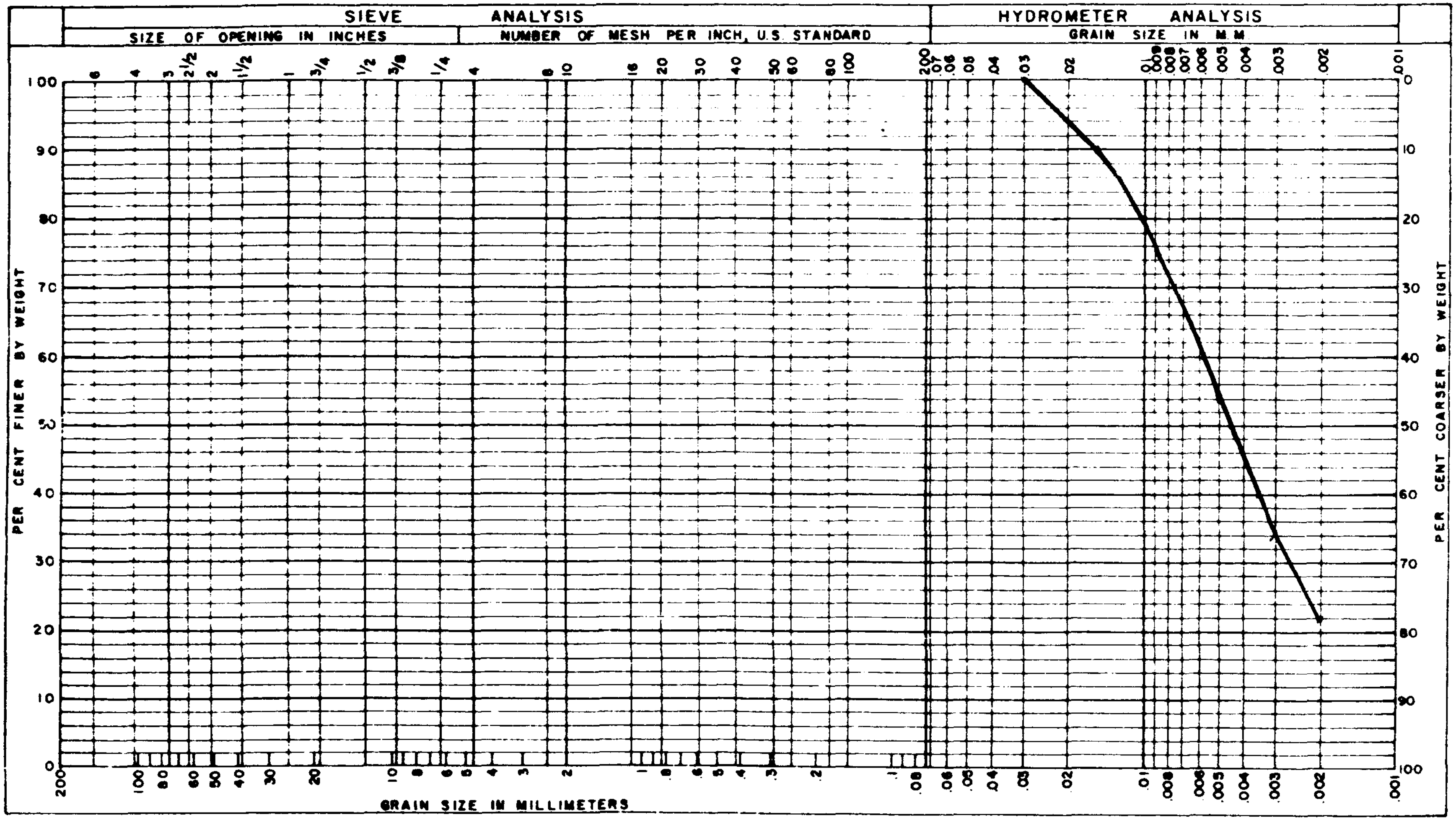
ALASKA TESTLAB

ALASKA TESTLAB

Sheet C7 of ____
W. O. No. 99999
Date 7-17-79
Technician MS-RLS

Textural Class SILT
Frost Class F4 Unified Class ML
Plastic Properties LL = 30, P.I. = 3
Date Received ____

Client ALPETCO
Project ALPETCO EIS
Sample Number #1
Location TB B-9 SAMPLE 13 SPEC. #1
Sample Taken By ATC



U.S STD. SIEVE	CUM % PASS
2	
1 1/2	
1	
3/4	
1/2	
3/8	
4	
10	
20	
40	
80	
100	
200	100
0.02 MM	96.3

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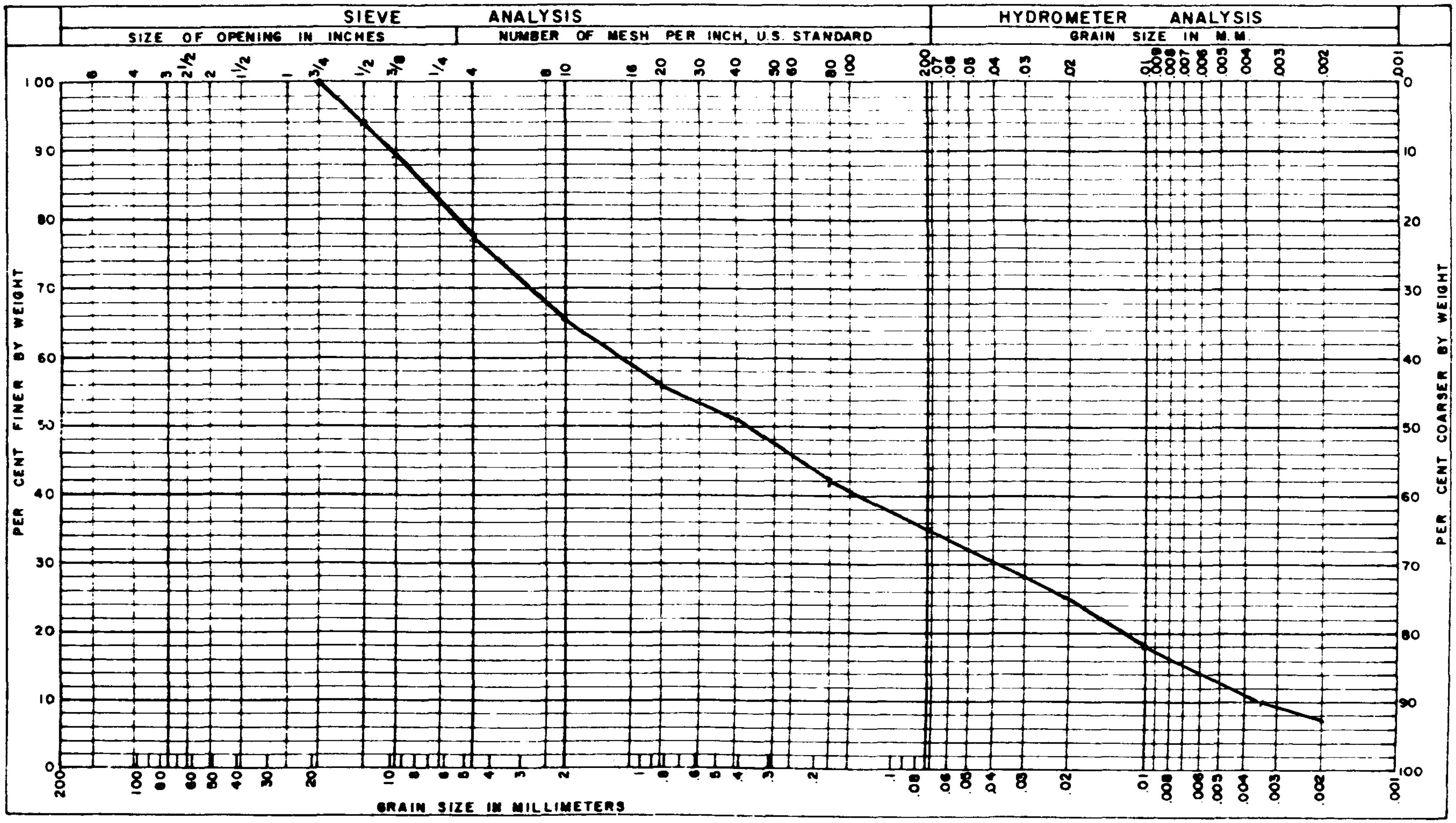
ALASKA TESTLAB

4040 B STREET
ANCHORAGE ALASKA 99503

Sheet C8 of
W. O. No. D11751
Date 7-9-79
Technician MS

Textural Class SILTY GRAVELLY SAND
Frost Class F3 Unified Class SM
Plastic Properties
Date Received

Client ALPETCO
Project VALDEZ EIS
Sample Number
Location THD-1 68"-93"
Sample Taken By TB



US STD. SIEVE	CUM % PASS
2	
1 1/2	
1	
3/4	100
1/2	94
3/8	89
4	77
10	65
20	56
40	51
80	42
100	
200	35
0.02 MM	25.2

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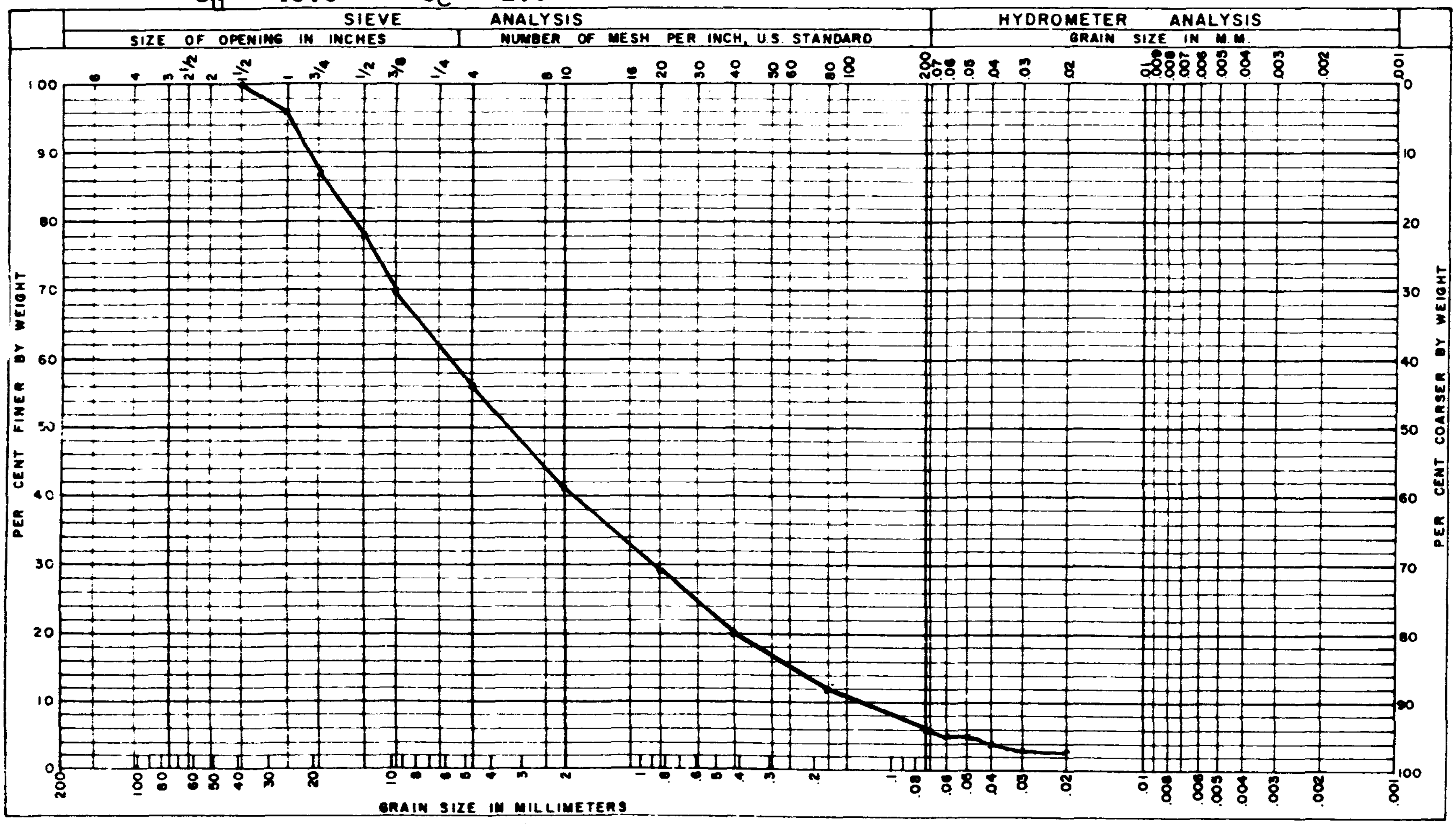
ALASKA TESTLAB

Sheet C9 of
W. O. No. D11751
Date 7-16-79
Technician MS,RS,RM,LS,TK

Textural Class GRAVELLY SAND
Frost Class NFS Unified Class SW/SM
Plastic Properties
Date Received

Client ALPETCO
Project VALDEZ E.I.S.
Sample Number GROUP A
Location
Sample Taken By TB

$C_u = 43.8$ $C_C = 1.0$



U.S. STD. SIEVE	CUM. % PASS
2	
1 1/2	100
1	96
3/4	87
1/2	78
3/8	70
4	56
10	41
20	29
40	20
80	12
100	
200	66
0.02 MM	2.9

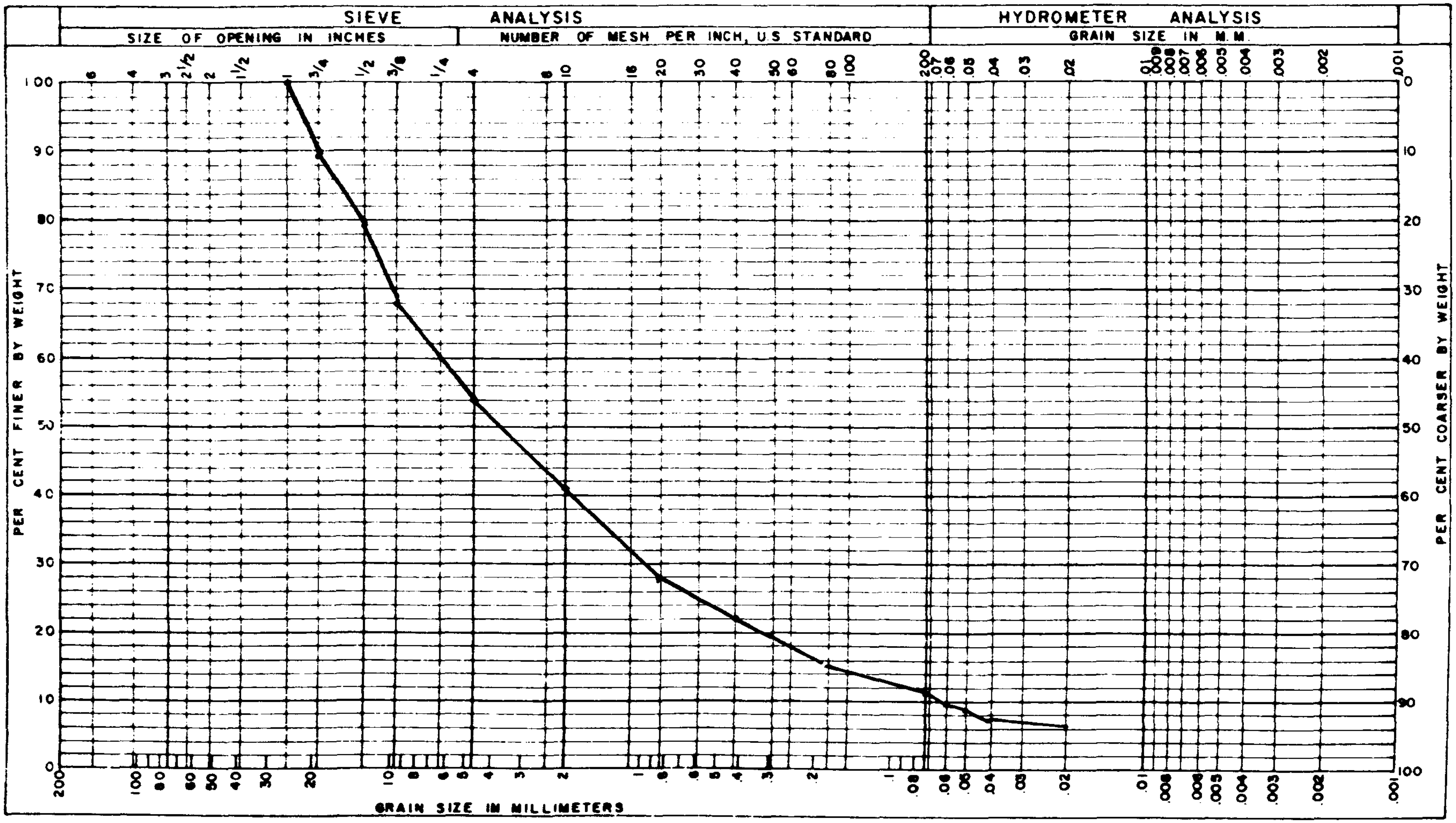
C10

ALASKA TESTLAB

Sheet ______ of ______
W. O. No. D11751
Date 7-16-79
Technician TKK

Textural Class SILTY SANDY GRAVEL
Frost Class F-1 Unified Class GW/GM
Plastic Properties
Date Received
C_u = 96.9 C_c = 2.2

Client ALPETCO
Project VALDEZ E.I.S.
Sample Number GROUP B
Location
Sample Taken By TB



U.S. STD. SIEVE	CUM. % PASS
2	
1 1/2	
1	100
3/4	89
1/2	79
3/8	68
4	54
10	41
20	28
40	22
80	15
100	
200	10.8
0.02 MM	6.3

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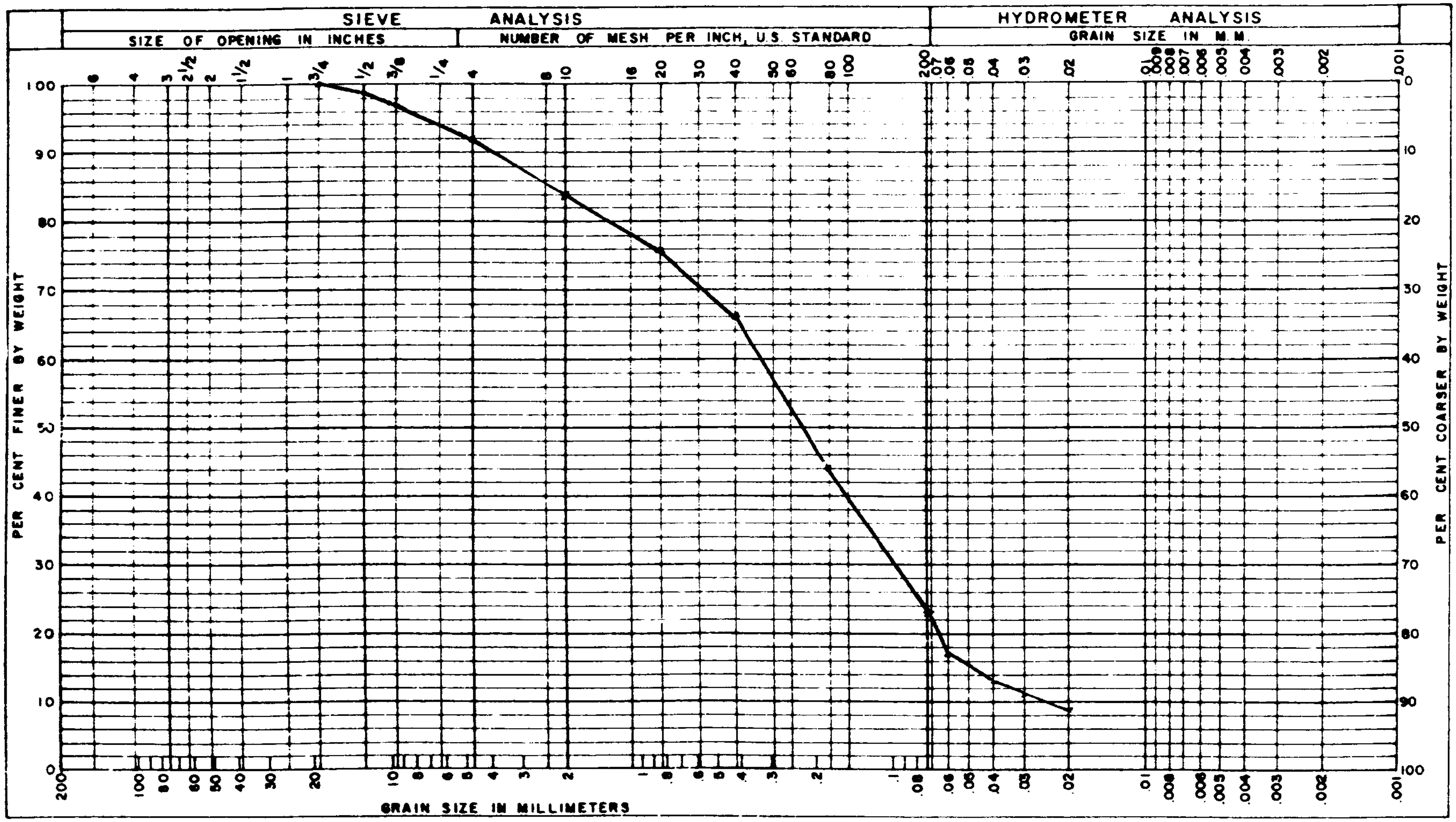
ALASKA TESTLAB

Sheet ______ of ______
W. O. No. D11751
Date 7-16-79
Technician MS

Textural Class SILTY SAND
Frost Class F-2   Unified Class SM
Plastic Properties
Date Received
C_u = 12.2 C_c = 1.12

Client ALPETCO
Project VALDEZ E.I.S.
Sample Number GROUP C
Location
Sample Taken By TB



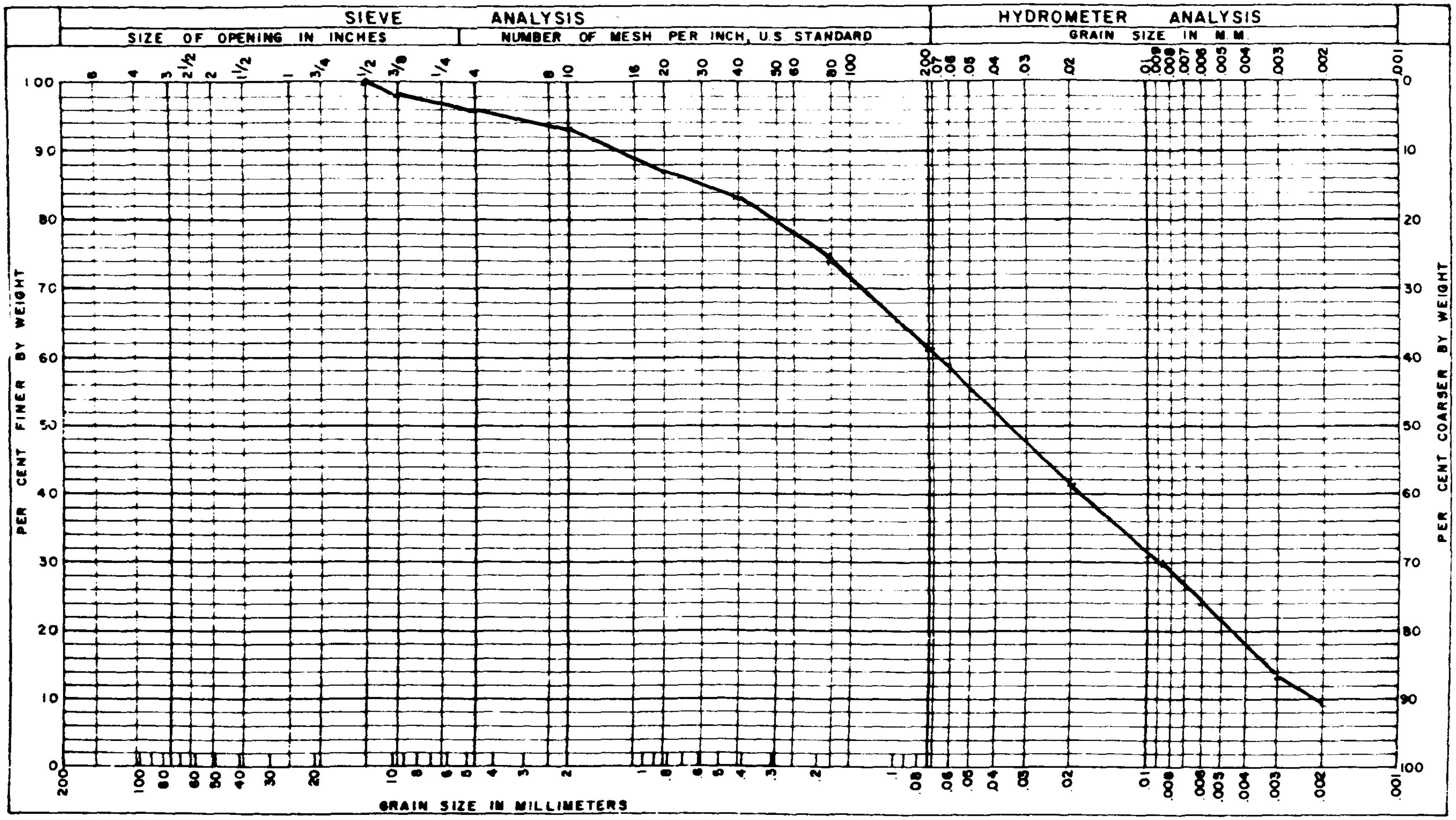
U.S STD SIEVE	CUM % PASS
2	
1 1/2	
1	
3/4	100
1/2	99
3/8	97
4	92
10	84
20	76
40	66
80	44
100	
200	23
0.02 MM	8.2

ALASKA TESTLAB

Sheet C 12 of
W. O. No. D11751
Date 7-16-79
Technician MS

Textural Class SANDY SILT (GLACIAL TILL)
Frost Class F-4 Unified Class ML
Plastic Properties LL = 26 PI = 3
Date Received

Client ALPETCO
Project VALDEZ E.I.S.
Sample Number GROUP G
Location
Sample Taken By TB



U.S. STD. SIEVE	CUM % PASS
2	
1 1/2	
1	
3/4	
1/2	100
3/8	98
4	96
10	93
20	87
40	83
80	74
100	
200	61
0.02 MM	43.2

ALASKA TESTLAB

ALASKA TESTLAB

Sheet C 13 of

W. O. No. D11751

Date 7-25-79

Technician LS

Textural Class SILTY GRAVELLY SAND

Frost Class F2 Unified Class SM

Plastic Properties

Date Received 7-22-79

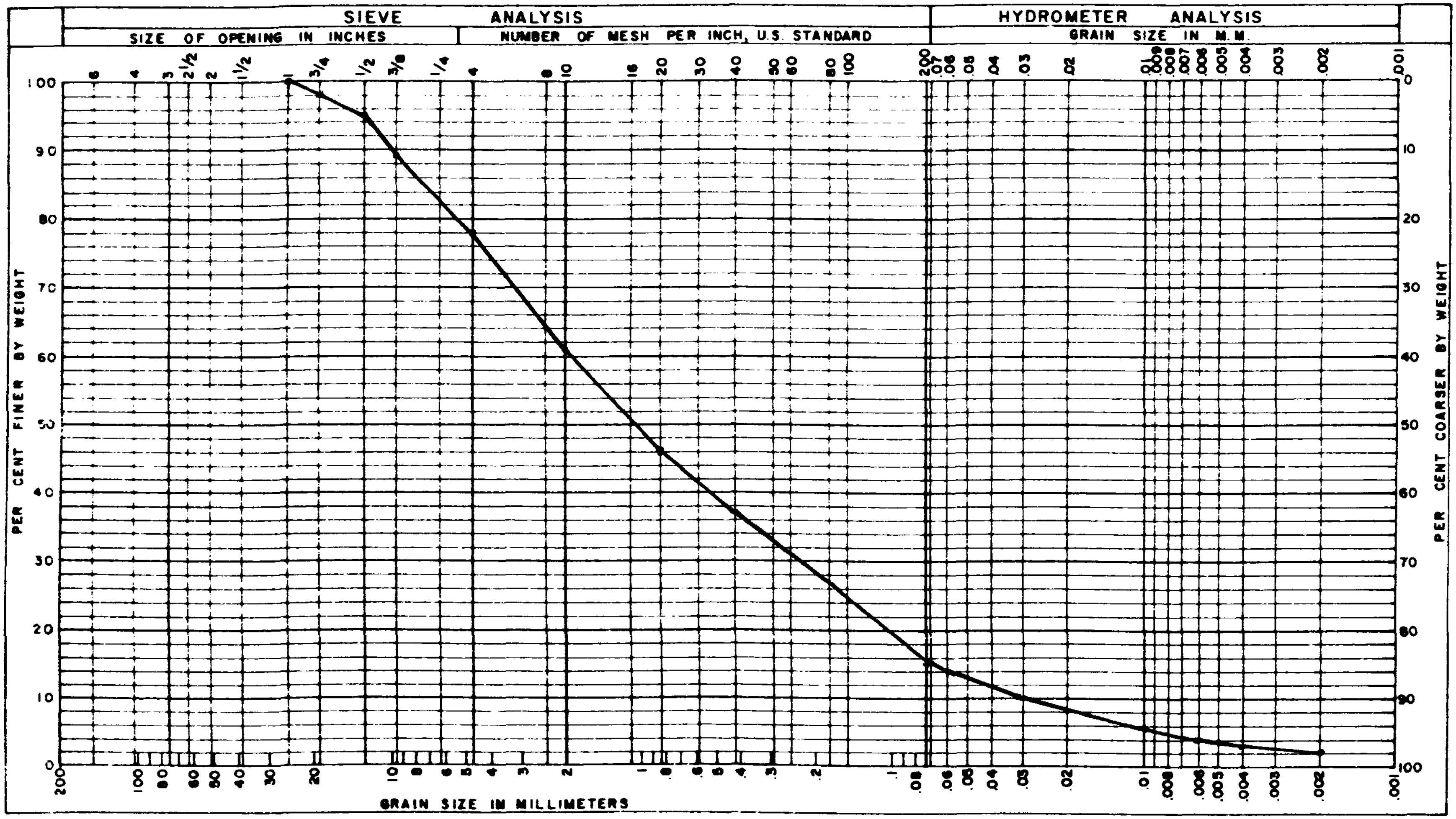
Client ALPETCO

Project ALPETCO EIS

Sample Number #1 PAD C-1

Location TAG DESTROYED

Sample Taken By TB



U.S. STD. SIEVE	CUM. % PASS
2	
1 1/2	
1	100
3/4	98
1/2	95
3/8	89
4	78
10	61
20	46
40	37
80	27
100	
200	15.6
0.02 MM	8.2

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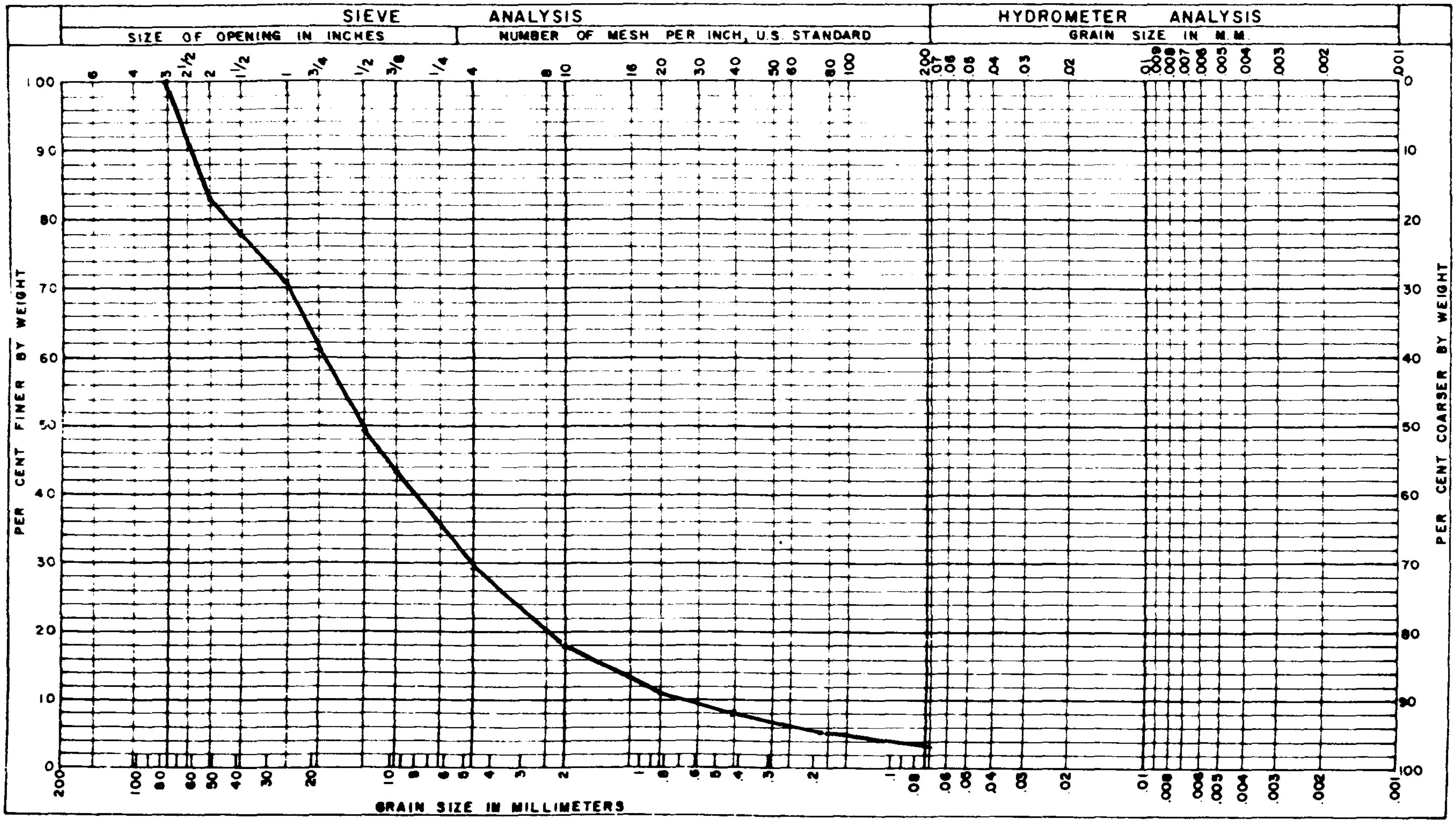
ALASKA TESTLAB

Sheet C 14 of
W. O. No. D11751
Date 7-25-79
Technician LS

Textural Class SANDY GRAVEL
Frost Class NFS Unified Class GW
Plastic Properties NP
Date Received 7-22-79
6" cobble removed from sample; numerous root systems

Client ALPETCO
Project ALPETCO EIS
Sample Number #2
Location 0.1 mile south of A-2
Sample Taken By TB



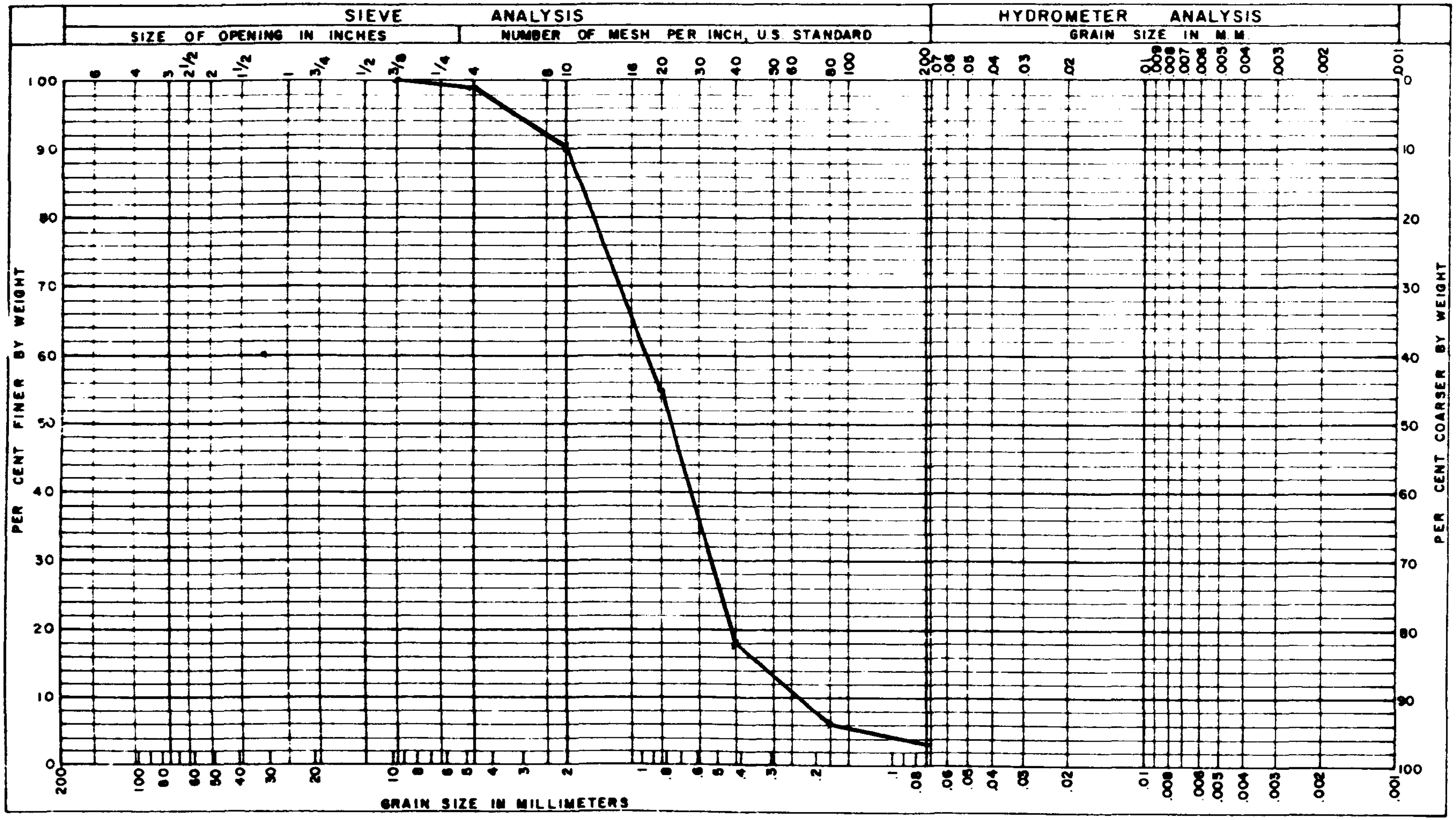
U.S. STD. SIEVE	CUM % PASS
3	100
2	83
1 1/2	78
1	71
3/4	61
1/2	49
3/8	43
4	29
10	18
20	11
40	8
80	5
100	
200	3.5
0.02 MM	

ALASKA TESTLAB

Sheet C 15 of
W. O. No. D11751
Date 7-25-79
Technician LS

Textural Class SAND
Frost Class NFS Unified Class SP
Plastic Properties NP
Date Received 7-22-79

Client ALPETCO
Project ALPETCO EIS
Sample Number #3
Location D-9 PAD MA
Sample Taken By TB



U.S. STD SIEVE	CUM % PASS
2	
1 1/2	
1	
3/4	
1/2	
3/8	100
4	99
10	90
20	55
40	18
80	6
100	
200	3.2
0.02 MM	

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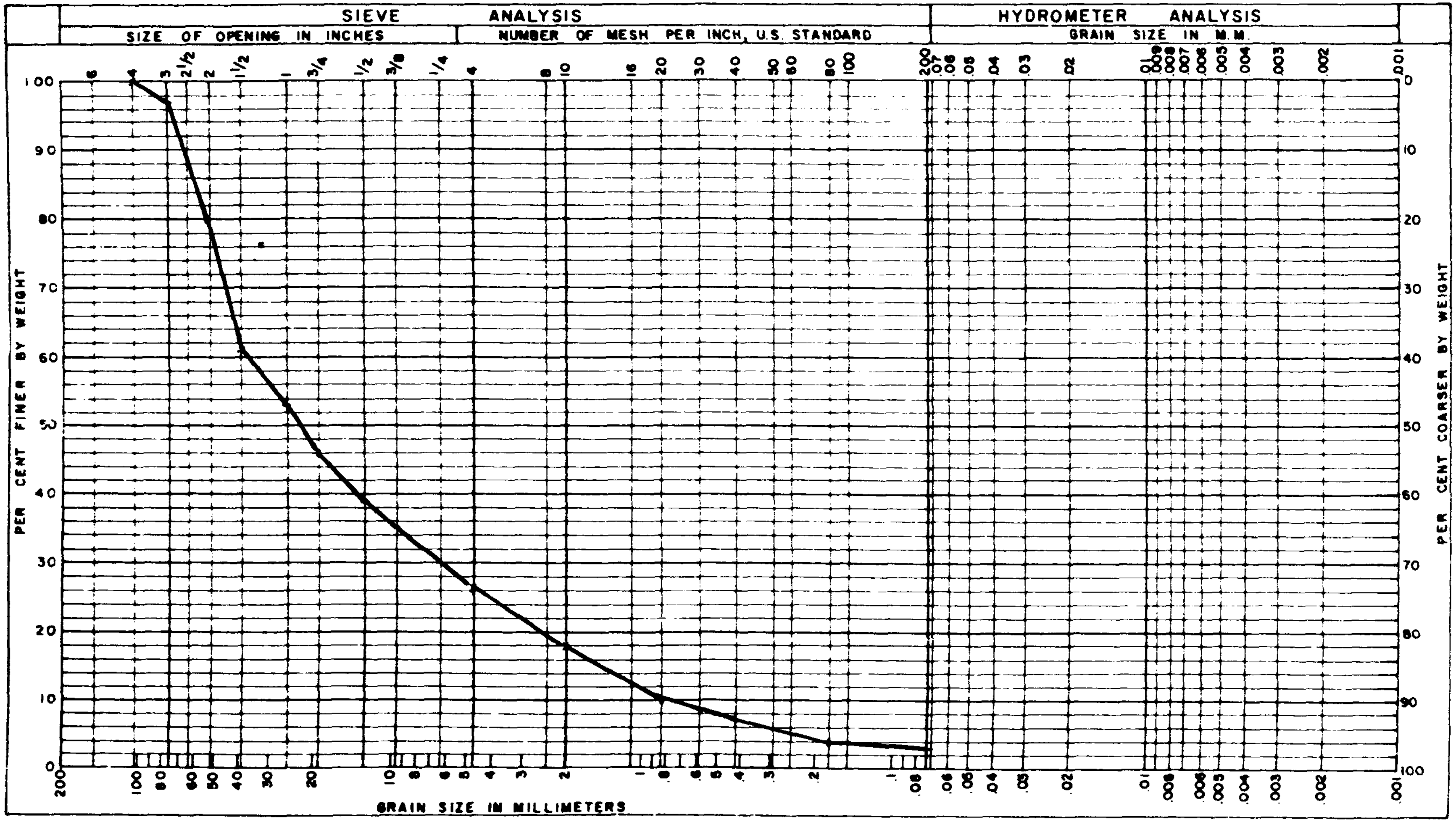
ALASKA TESTLAB

4040 B STREET
ANCHORAGE, ALASKA 99503

Sheet C 16 of ____
W. O. No. D11751
Date 7-25-79
Technician LS

Textural Class SANDY GRAVEL
Frost Class NFS Unified Class GW
Plastic Properties NP
Date Received 7-22-79
6" & 4" cobbles removed from sample

Client ALPETCO
Project ALPETCO EIS
Sample Number #4
Location PAD B, 2 & 3
Sample Taken By TB



U.S. STD SIEVE	CUM % PASS
4	100
3	97
2	80
1 1/2	61
1	53
3/4	46
1/2	39
3/8	35
4	26
10	18
20	10
40	7
80	4
100	
200	2.5
0.02 MM	