SUSITNA HYDROELECTRIC PROJECT
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ALASKA POWER AUTHORITY

SUSITNA HYDROELECTRIC PROJECT

TASK 5 - GEOTECHNICAL EXPLORATION
REPORT ON 1980 STUDIES
DRAFT

MARCH 1981



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Geotechnical Exploration: Tasks

- Replace the following pages back into this report. They are in the originals (gone to copy)
- cover sheet
- Figures 6.7 & 6.8
- Appendix-D
- Figure A.1 from Appendix B-3 of Final report back into Appendix B-2 of the Draft. (schematic using

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SUSITNA HYDROELECTRIC PROJECT

TASK 5 - GEOTECHNICAL EXPLORATION

SUBTASKS 5.01 - 5.04
REPORT ON 1980 STUDIES

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TASK 5 - GEOTECHNICAL EXPLORATION

SUBTASKS 5.01 - 5.04
REPORT ON 1980 STUDIES

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1 - INTRODUCTION

1.1 - Project Description and Location

The Susitna Hydroelectric project is located within the upper reaches of the Susitna River basin in south-central Alaska. The current feasibility studies for a hydroelectric development are being performed by Acres American Incorporated (AAI) under contract to the Alaska Power Authority (APA).

The overall objectives of the study are:

- To establish technical, economic and financial feasibility of the Susitna project to meet future power needs of the Railbelt Region of the State of Alaska;

- To evaluate the environmental consequences of designing and constructing the Susitna project;

- To file a completed license application with the Federal Energy Regulatory Commission (FERC) should the project be deemed feasible.

The Susitna River is a glacially-fed stream which heads on the southern slope the Alaska Range and flows southward through the Talkeetna Mountains, then through a continuously widening valley to Cook Inlet. The area of study is located within the Coastal Trough Province of south-central Alaska, with a drainage of approximately 6,000 square miles. From its proglacial channel in the Alaska Range, the Susitna river passes through a broad glaciated, intermontane valley of knob and kettle and braided channel topography. Swinging westward along the edge of the Copper River lowlands, it enters the deep V-shaped valley of the proposed dam sites winding through the Talkeetna Mountains until it emerges back into the broad glacial valley leading to Cook Inlet (Figure 1.1).

Geotechnical Investigations - Task 5 is an important element of this study. Although the plan of study includes evaluation of the entire basin for potential hydrodevelopment by evaluating the relative merits of several sites, the geotechnical investigations were planned for a two dam scheme. This scheme was determined to be the optimum by previous investigators including the U.S. Army Corps of Engineers (COE) and Water & Power Resources Service (WPRS) (formerly the USBR) plan. It includes a large rockfill dam and underground powerhouse at Watana and a relatively high concrete dam with underground powerhouse at the Devil Canyon site (Figure 1.1).

The Devil Canyon site is located 14 miles upstream from the Gold Creek station on the Alaskan Railroad approximately 140 miles north of Anchorage and 160 miles south of Fairbanks. The site is located at approximately river mile 133.

The Watana site is located at approximately river mile 165 (30 river miles upstream of Devil Canyon site). A transmission line, approximately 365 miles long, is planned to connect the proposed hydrodevelopment with the existing power grids at Fairbanks and Anchorage.

The Watana dam site is located in a relatively broad U-shaped valley rising in steps, with the steep lower portion breaking into somewhat flatter slopes and becoming much gentler near the top (Figure 1.2). Access to the lower sections is very limited due to vertical rock outcrops. However, there are some small gravel bars which can be quite wide at low water level. The proposed dam is located upstream of the Tsusena Creek confluence and downstream of Deadman Creek. The river at this site is wider than at Devil Canyon, but the water is still turbulent and swift flowing.

At the Devil Canyon site, the river enters a very narrow gorge about two miles in length with near vertical walls up to 600 feet high. The dam site is located several hundred feet downstream of the entrance of Devil Canyon (Figure 1.3). The valley is generally asymmetrical in shape, with the north abutment sloping at about 45° and the south abutment steeper at about 60°. The south abutment displays overhanging cliffs and detached blocks of rock, while the north abutment is somewhat less rugged in the upper half but the lower portion is very steep.

The Susitna River in Devil Canyon is very turbulent and approximately 100 feet wide with very little beach. The canyon itself is approximately 1,000 feet wide at dam crest elevation.

1.2 - Plan of Study

(a) Objectives

The objectives of the Task 5 studies are to determine the surface and subsurface geology and geotechnical conditions for the feasibility of:

- A large rockfill dam, powerhouse (underground or surface) and associated structures at Watana site;

- A concrete dam or alternative structure with underground powerhouse and associated structures at Devil Canyon site;

- Transmission lines to connect the proposed development with the existing power grid system and;

- Access roads to the proposed development.

In addition, the river canyon reach which would be flooded by the proposed reservoirs will be studied to determine the potential areas of instability and to identify the major geological features that could affect the feasibility of the projects.

(b) Scope

The task was subdivided into a series of subtasks to meet the overall objectives. The subtasks and their corresponding objectives are:

Subtask	Objectives
5.01 - Data Collection and Review	- To collect and review all existing geological and geotechnical data pertaining to the Susitna project including the access road and transmission line corridors and the upper Susitna River basin
5.02 - Photointerpretation	- Perform air photointerpretation and terrain analysis of the Watana and Devil Canyon dam site areas, reservoir areas, construction material borrow areas and access road and transmission line corridors, and identify adverse geological features and geotechnical conditions that could significantly affect the design and construction of project features
5.03 - Exploratory Program Design (1980)	- Design the geotechnical exploratory investigation programs for 1980 for Watana and Devil Canyon dam sites, dam construction materials, and reservoir areas, and along the access road route
5.04 - Exploratory Program (1980)	- Perform initial surface and subsurface investigations at Watana and Devil Canyon sites and reservoir areas and access road routes to establish general and specific geological and foundation conditions
5.05 - Exploratory Program Design (1981)	- Design the geotechnical exploratory investigation programs for 1981 for Watana and Devil Canyon dam sites, dam construction materials and reservoir areas, and for the selected access road and transmission line routes
5.06 - Exploration Program (1981)	- Complete surface and subsurface investigations at Watana and Devil Canyon dam sites, reservoir areas, access roads and transmission line routes to extent necessary to provide adequate data to confirm project feasibility and for submission of FERC license application

5.07 - Exploratory Program Design (1982-1984)	- Design of the geotechnical Program exploratory investigations program for 1982 to 1984 to obtain basic design data for Watana dam site, dam construction materials and reservoir area, and for the selected access road and transmission line routes
5.08 - Data Compilation	- Assemble all geotechnical exploratory data into documents suitable for inclusion in relevant project reports and licensing documentation.

(c) Approach

To meet the objectives of the task in an orderly and timely manner, the geotechnical exploratory programs are divided into three stages, i.e. the 1980 activities, 1981 activities and the activities during and after 1982 (after the FERC license application is submitted). The 1980 geotechnical activities were planned to identify and investigate in limited detail those geological and geotechnical conditions which have been identified by previous investigators and which could significantly affect the feasibility of the project. The actual field investigations' scope was, therefore, limited in nature. These activities included Subtasks 5.01 through 5.04. The results of these subtasks are presented in this report.

Subtasks 5.05 through 5.07 are to be undertaken during 1981 and early 1982. Under these activities, a more detailed study will be made of those geological and geotechnical conditions identified during 1980 studies. Also, the explorations for the access roads and the transmission lines will be undertaken under these subtasks.

It should be noted that the results presented in this report are preliminary and are subject to revision depending on the results of future investigations. In particular, the geologic history of this region is very complex and has not been studied in sufficient detail. The conclusions drawn are very general and are intended to be used for work of a preliminary layout and engineering feasibility nature. A more complete evaluation will be developed after the completion of Subtasks 5.05 through 5.08.

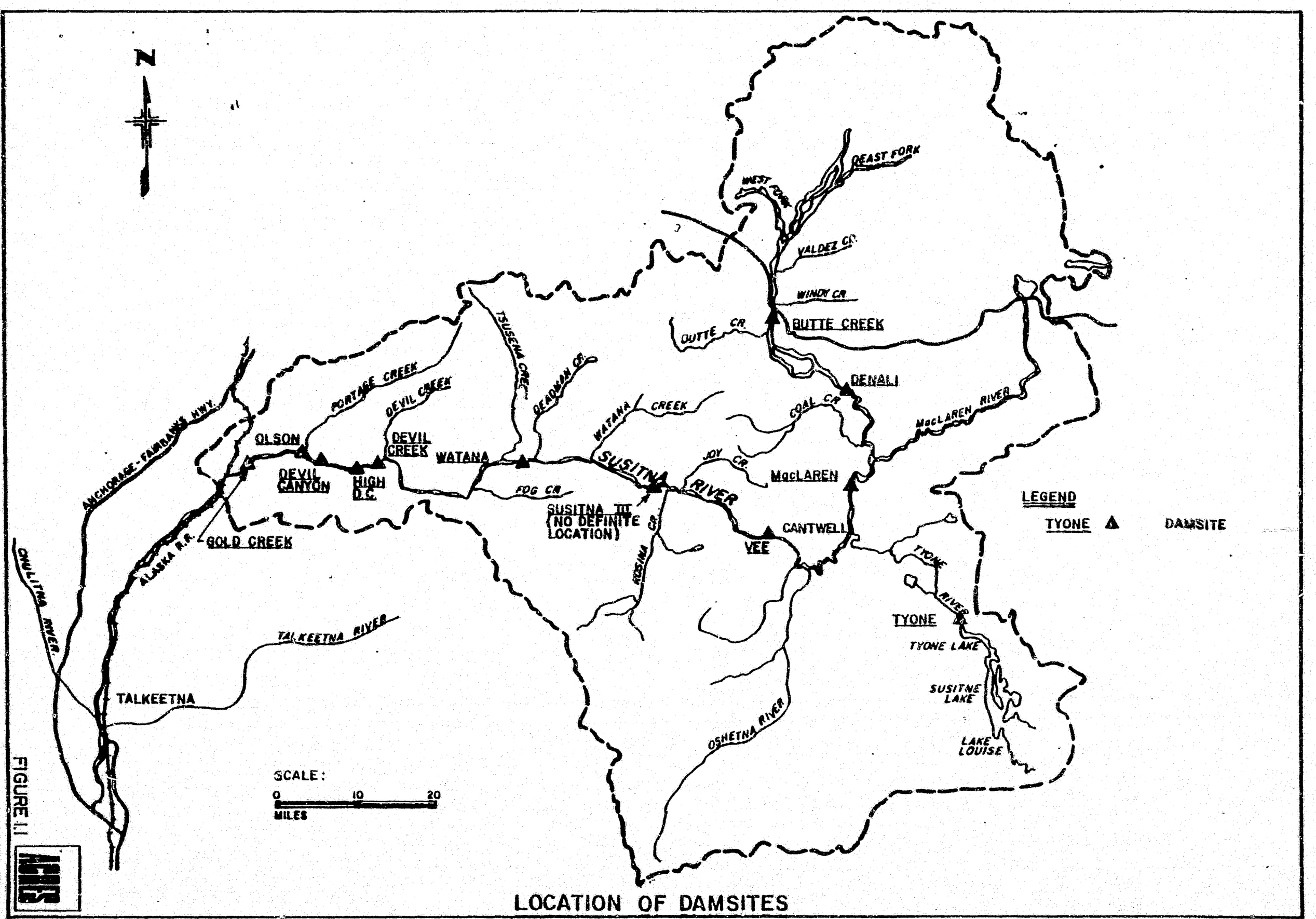
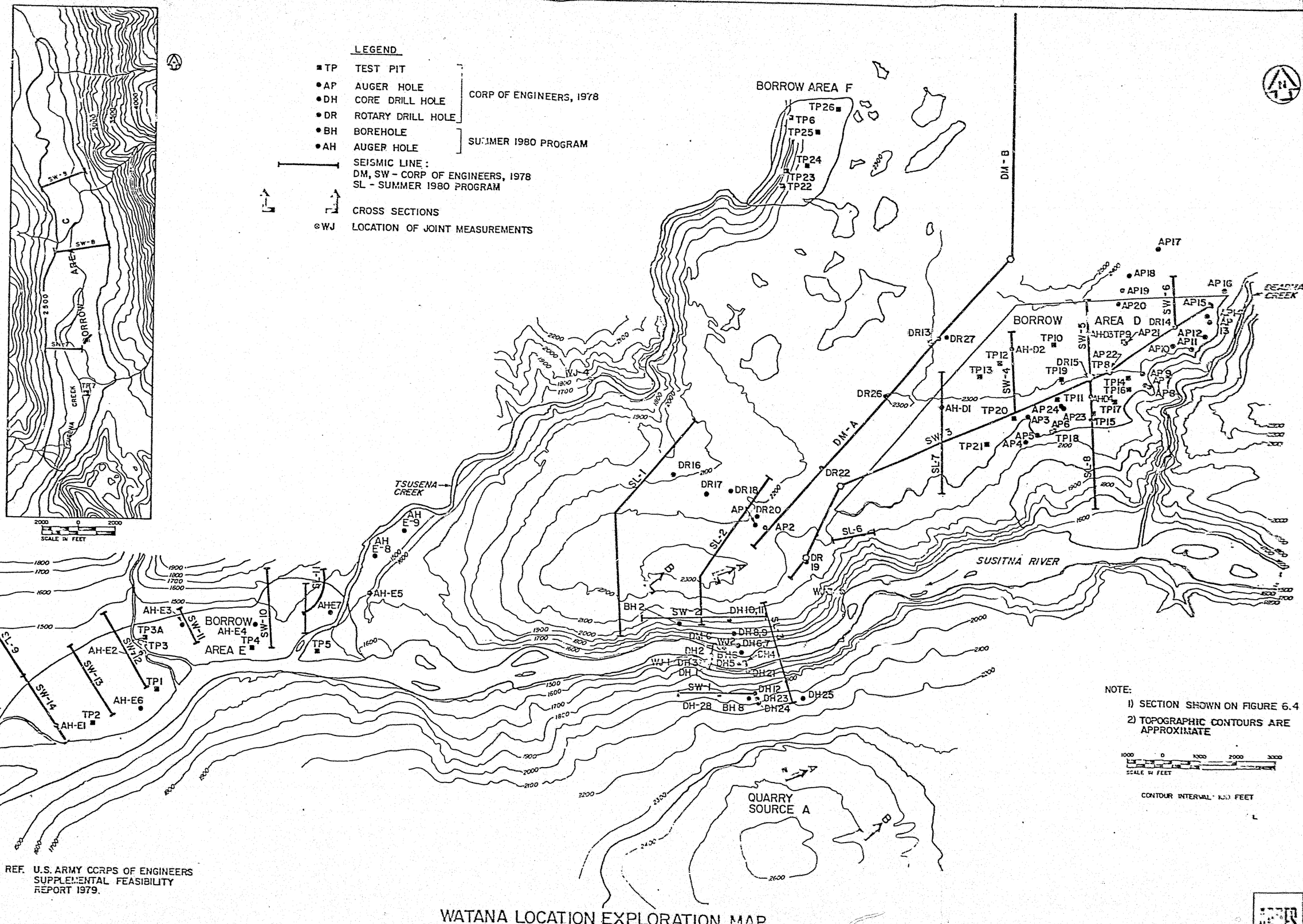


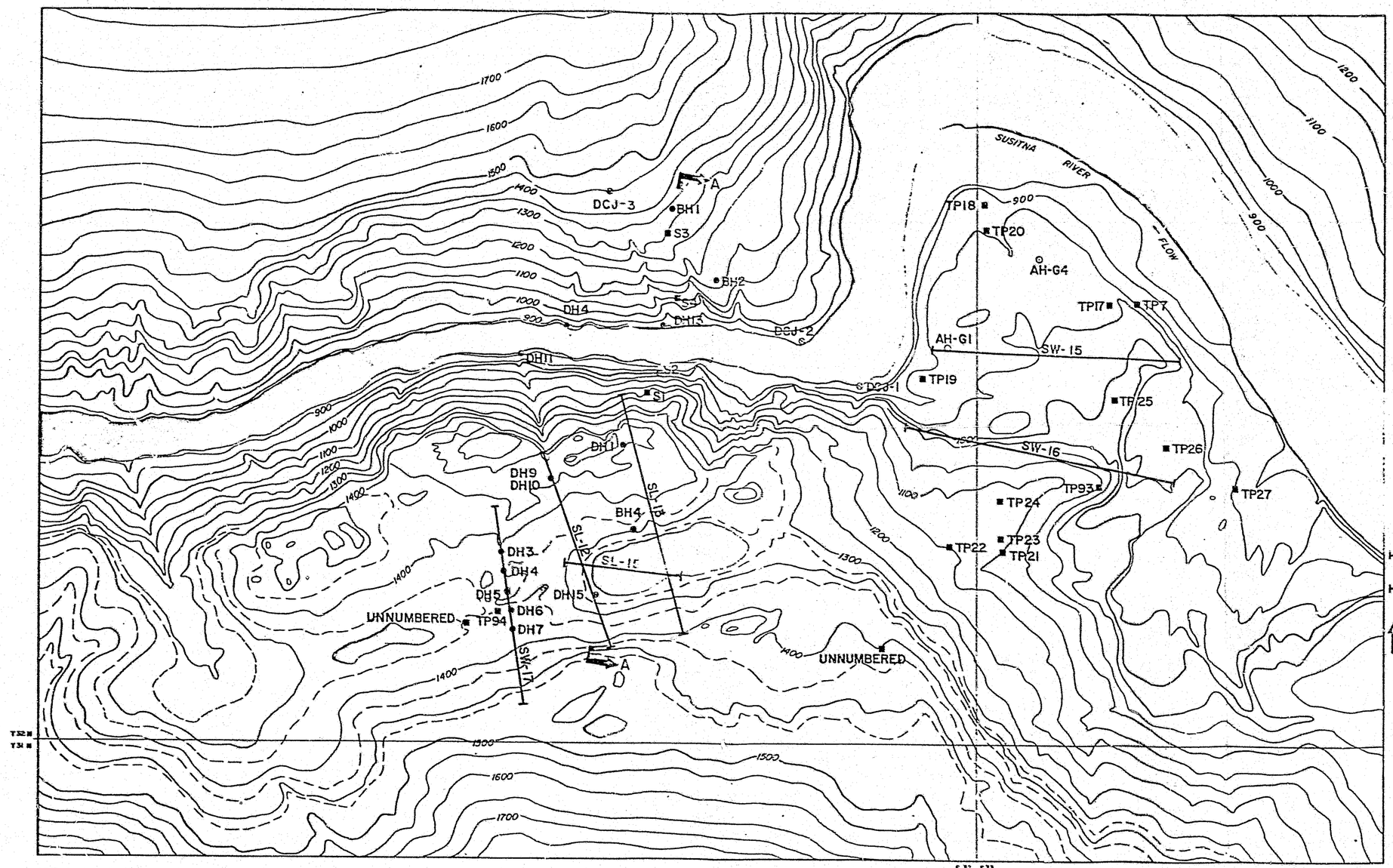
FIGURE 1.1

LOCATION OF DAMSITES



WATANA LOCATION EXPLORATION MAP

FIGURE 1.2



LEGEND

- • DH BOREHOLES-BUREAU OF RECLAMATION, 1960
- • BH BOREHOLES-SUMMER 1980 PROGRAM
- ■ TP,S, TEST PITS AND TRENCHES BUREAU OF RECLAMATION, 1960
- ⊙ AUGER HOLES-SUMMER 1980 PROGRAM
- SW SEISMIC LINES- CORP OF ENGINEERS, 1978
- SL SEISMIC LINES- SUMMER 1980 PROGRAM
- © DCJ LOCATION OF JOINT MEASUREMENT
- CROSS SECTION

NOTE:
TOPOGRAPHIC CONTOURS ARE APPROXIMATE

SECTION SHOWN ON FIGURE 6.15

200 0 200 400 600
SCALE IN FEET

CONTOUR INTERVAL 50 FEET
DASHED CONTOUR 25 FEET

REFERENCE: USGS, TALKEETNA MOUNTAINS (D-5), ALASKA QUADRANGLE, SEWARD MERIDIAN: T 32 N, R1E, S.32 AND 33.

DEVIL CANYON LOCATION EXPLORATION MAP

FIGURE 1.3

2 - SUMMARY AND CONCLUSIONS

2.1 - Introduction

The summary and conclusions presented herein are based on a review of previous investigations completed by other agencies and the data developed by AAI during 1980. It is emphasized that the conclusions presented are subject to revisions following further studies to be performed in 1981.

2.2 - Watana Site

(a) Summary

Based on a review of previous studies and the work performed during 1980, the following technical conditions have been identified regarding the Watana dam site:

(i) The dam site is underlain principally by a diorite intrusive rock which is overlain by an extrusive andesitic rock exposed downstream of the proposed dam axis.

(ii) Bedrock quality is generally good to excellent below the upper 10-40 foot weathered zone.

(iii) Two prominent shear zones, "The Fins" and "Fingerbuster" are exposed on the right abutment upstream and downstream of the proposed dam axis, respectively. Lack of bedrock exposure precludes the mapping of these features on the left abutment.

(iv) Geologic mapping infers the continuation of "The Fins" in a northwesterly direction, outcropping along Tsusena Creek north of the site.

(v) Localized shear and fractured zones were encountered in several of the borings. These zones ranged from 1 to 5 feet in thickness.

(iv) The contact between the extrusive andesite and the diorite was drilled in two of the 1980 borings. The nature of this contact is not clearly defined but believed to be relatively shallow with a decrease in rock quality and weathering at the contact.

(vii) No clear evidence of faulting in the river channel was found.

(viii) Overburden thickness is generally thin along the valley and thickens to the north away from the dam site. Overburden generally consists of glacially derived silts, sands, gravels, boulders and lacustrine clays.

(ix) Depth of river alluvium beneath the dam averages approximately 60 feet and consists of sand, silt, coarse gravels and boulders.

(x) Several localized areas of deeper overburden were encountered on both abutments. Further studies are required to more accurately delineate these areas.

(xi) A possible relic channel identified in previous studies and reconfirmed in the 1980 program extends from approximately 9,000 feet upstream of the dam in a general northwesterly direction towards Tsusena Creek. The depth of this channel extends 500 feet below ground surface. Further study is required to delineate the full extent of this channel.

(xii) The largest geologic tectonic feature mapped in the vicinity of the dam is the Talkeetna thrust fault approximately 4 miles from the dam site. No evidence of recent fault movement has been found, however, further investigation of this feature is planned for 1981. The fault crosses the Susitna River approximately seven miles upstream of the dam site.

(xiii) Permafrost conditions exist on the left abutment. Although the depth of the permafrost has not accurately been determined, measurements indicate that it penetrates to a depth of at least 200 feet. The ground temperatures are believed to be within one degree centigrade of freezing and therefore are relatively marginal. Further work to delineate the extent of permafrost will be performed during 1981. Only sporadic permafrost was encountered on the right abutment.

(xiv) Reconnaissance survey of the Watana reservoir shows that several areas along Watana Creek and other smaller tributaries contain thick deposits of glacially derived material.

(xv) Suitable quantities of rock fill and soil borrow materials have been found within the dam area for construction.

(b) Conclusions

Based on these findings, the following tentative conclusions regarding the Watana site can be made:

(i) The site is geologically and geotechnically feasible for the construction of a rock fill dam and associated structures.

(ii) The general rock conditions are considered favorable for an underground powerhouse provided no large shear zones similar to the "Fingerbuster" are located on the left abutment. Nominal support may be required for general rock conditions.

(iii) The river alluvium is suspected to be loose and potentially unstable under seismic loading conditions.

(iv) Foundation preparation will include the removal of existing alluvium

and weathered rock and performance of consolidation and curtain grouting with the use of drain holes and drainage galleries in the abutment and upstream of the underground structures.

(v) Although the relict channel on the north abutment warrents further study, it is not anticipated to have any major impact on the feasibility of the project. Conventional engineering methods to prevent seepage and associated phenomenon such as piping, will be investigated during 1981 and in subsequent studies.

(vi) Local slumping and landslides may occur in the reservoir during filling and operation in areas of thick, steeply dipping unconsolidated soil as well as along portions of the northfacing slopes where permafrost exists.

2.3 - Devil Canyon Site

(a) Summary

Based on a review of previous studies and the work performed during 1980, the following summary of site conditions at the Devil Canyon site can be made:

(i) The proposed dam site is underlain by a homogeneous argillite and graywacke rock. The rock is generally of good to excellent quality. Overburden in the valley is thin to non-existent.

(ii) The rock has one major and possibly two minor joint sets. The major set strikes approximately 340° and dips 85° NE. Bedding strikes subparallel to the gorge (50-70°) and dips steeply (50°-80°) to the southeast.

(iii) Stress relief and open joints, both paralleling to the gorge and along the major joint sets, extend up to 40-60 feet back from the cliff edge.

(iv) Earlier investigators had postulated the possibility of a geologic fault on the left abutment approximately under the series of lakes. The seismic refraction survey has indicated an anomalous velocity zone; however, the boring (BH-4) did not encounter this feature.

If the boring missed the feature; then it can be postulated that the shear zone, if it exists, will be dipping along the bedding rather than across it. Additional investigations are planned to further investigate this feature.

(v) The possibility of a fault was postulated by earlier investigators along the river channel under the proposed dam. This feature will be explored during the 1981 investigations.

(vi) A several hundred foot step in bedrock surface had been reported by earlier investigators upstream of the proposed dam site, under the alluvial fan where Cheechako Creek joins the Susitna River. The location of this feature is 1,000 feet upstream of the dam site.

(vii) The shear zones postulated by the WPRS to exist subparallel and subperpendicular to the river could not be verified during the 1980 program. Additional work relative to these features will be carried out in 1981.

(viii) No extensive permafrost conditions were found to exist on either abutment.

(b) Conclusions

Based on the above, the following tentative conclusions have been made regarding the Devil Canyon site:

(i) The site appears geologically and geotechnically feasible for the construction of either a rockfill, concrete gravity, or arch dam.

(ii) Further detailed geologic studies are required to determine the suitability of the bedrock for construction of large underground power facilities.

(iii) Further investigations are required to define the potential existence of a fault under the dam along the river channel and a fault on the left abutment.

(iv) The foundation treatment will require grouting and provisions for drainage adits and drain holes for the dam. Extensive dental concrete may be required to treat local areas for concrete dam foundations particularly on the left abutment.

(v) Sufficient quantities of construction material have been identified for the concrete aggregate and the construction of the saddle dam on the left abutment.

3 - REVIEW OF PREVIOUS INVESTIGATIONS

3.1 - Introduction

The development of the Susitna Hydroelectric Project has been studied by several Federal and private agencies in the last 30 years. However, it was not until the late 1950's that any geotechnical investigations were conducted.

Between June 1957 and August 1958, WPRS performed geologic mapping and drilling investigations at the Devil Canyon site and limited geologic mapping at the Watana site (19).

Subsequently during the 1970's, the COE performed additional investigations on both sites. These included seismic refraction surveys, detailed geologic mapping and diamond and auger drilling in the dam sites and potential borrow areas.

This report briefly discusses the findings of these investigations as documented by the WPRS and the COE. These reports are identified as appendices of this summary and are available with APA and AAI for reference. These are not included at this time.

3.2 - Watana

The preliminary work by the WPRS in the 1950's was expanded during the 1970's by the COE investigations of the dam site, reservoir, and potential borrow areas. The location and extent of these investigations are shown on Figure 3.1.

In 1975, a total of 22,500 linear feet of seismic refraction survey was performed by Dames & Moore (6) for the COE. This was expanded by Shannon & Wilson (14) in 1978 with an additional 47,665 feet of survey. This work served to support the results of the drilling and mapping programs.

Also during the 1978 season, the site was explored with 28 diamond drill holes (both vertical and inclined) ranging from 30 to 600 feet deep. A summary of this program is presented in Table 3.1. Six of these diamond drill borings were located in the river valley and reached a maximum depth of 520 feet into rock. Five borings were drilled on the left abutment and six on the right reaching a maximum depth of 300 feet or an elevation of 1,660 feet. On the right abutment, eleven diamond drill borings were located in what was identified as a deep relict channel to determine the thickness and characteristics of the overburden, the depth of the water table and the permafrost conditions.

Four potential borrow areas for construction material were identified and explored using 26 backhoe test pits and 24 auger borings. Fourteen test pits were located in Borrow Area D on the right abutment which was identified as a source of impervious and semi-pervious material for the embankment. Six test pits were located in Borrow Area E identified as a potential source of filter material and concrete aggregate. This area is situated at the confluence of Tsusena Creek and the Susitna River, approximately 15,000 feet downstream of the dam site. Six test pits were located in Borrow Area F on Tsusena Creek, three miles upstream of its confluence with the Susitna River, as a potential source of sandy

materials. The 24 shallow auger borings were drilled in Borrow Area D between Tsusena and Deadman Creeks and ranged from 3 to 59 feet deep.

Detailed geologic mapping was conducted in the dam site area to delineate major structural trends.

Two potential quarry areas were identified and reconnaissance exploration was conducted. Quarry A, was located on the upper part of the left abutment and Quarry B, on the right abutment relatively close to the river. Both areas were mapped as a diorite that would require minimal crushing and sorting for use in construction.

A limited laboratory testing program was conducted on potential filter, core and embankment materials from the various borrow areas to establish the index and engineering characteristics of the borrow materials. These tests included gradation curves, permeability, triaxial shear tests, Modified Proctor density tests and concrete aggregate tests.

The COE also installed a series of ten open well piezometers and thirteen temperature logging devices in the boreholes. These instruments had not stabilized by the end of the COE investigation and, therefore, no definite conclusions were drawn.

3.3 - Devil Canyon

The investigations conducted at the Devil Canyon site were not as extensive as those at Watana. The exploration plan is shown on Figure 3.2 and summarized in Table 3.2

The WPRS performed the bulk of exploration at this site between June 1957 and August 1958 (19). Twenty-one diamond drill borings were drilled in the dam site area. Six holes, from 50 to 110 feet deep, were located in the left abutment within the proposed switchyard area downstream of the proposed saddle dam axis. At the deepest point, rock was encountered at 87 feet below the surface in what was interpreted as an old buried channel. Three holes were drilled upstream of this area with a maximum depth of 120 feet. The remaining twelve holes were drilled along the riverbed near the dam axis to determine the depth and nature of the bedrock under the dam. One other proposed borehole was subsequently trenched as a test pit.

Nineteen test pits were dug in the alluvial fan near Cheechako Creek upstream of the dam axis. This area was considered to be the only source of concrete aggregate material for dam construction. Four additional trenches were dug on the dam abutments to define the rock conditions present.

Laboratory tests, including gradation determinations and petrographic analysis were conducted on samples of the borrow area materials to determine their suitability for use as concrete aggregate. Representative rock samples from the abutments were tested to determine compressive strength, elasticity, absorption, and porosity of the foundation material.

During 1978, Shannon & Wilson (14), under COE contract, ran three seismic refraction lines totaling 3,300 feet in the borrow area and along the proposed saddle dam to expand the drilling information.

3.4 - Conclusions

The investigations conducted by the COE and WPRS were the first detailed efforts, although limited in nature, in establishing the feasibility of the projects. The review of these investigations served as the basis for identifying those geological and geotechnical features that were considered to require further investigation. A brief summary of those features and findings of those investigations is presented as follows.

(a) Watana Site

The Watana site was considered suitable for a large rockfill dam, an underground powerhouse and ancillary structures. However, before the feasibility is conclusively established, certain features must be further investigated.

(i) The overburden in the river was composed of 40 to 80 feet of relatively loose alluvial gravels, cobbles and boulders. The stability of this alluvium was questioned under the seismic loading conditions being considered for the project.

(ii) The underlying rock at the dam site was a diorite intrusion with local andesite dikes. The overall rock was found to be hard and fresh with the fractures becoming tighter with depth. Shear zones were observed both in outcrops and the drill cores but were not considered to be significant.

(iii) The rock in the right abutment was found to be more weathered than the rest of the dam foundation averaging to 40 feet below the bedrock surface.

(iv) The rock along the left abutment was also identified as diorite; however, in a downstream boring, a surface flow of andesite porphory was encountered. The relationship of these two rock types was not delineated and it was recognized that this would require resolution before design of underground structures could be undertaken.

(v) North of the right abutment, a deep bedrock depression filled with glacial material was encountered in the boring and seismic refraction programs. Glacial tills occur in this area in three major sequences separated by layers of sandy gravel alluvial material and two major lake deposits of plastic clays. The lowest bedrock surface encountered in the drilling was 454 feet below the surface (elevation 1,775). This compared with current riverbed rock elevation of 1,395± feet.

(vi) Two prominent shear zones named "Fins" and "Fingerbuster" were mapped as exposures in the dam site area. Both of these zones trend northwest with strikes from N40°W to N60°W and dips to 70° to 90° SW to NE. "The Fins", 3,400 feet upstream of the dam, had an observable width in excess of 400 feet with fins of 5 to 25 feet wide and bounded by severely altered zones. The "Fingerbuster", 2,500 feet

downstream of the axis, was less well defined with rock faces paralleling the shear zone.

(vii) The seismic refraction survey indicated a low velocity zone along the right abutment that could be interpreted as a possible slide block and identified for further investigation.

(viii) The foundation rock at the site was considered of generally good quality with relatively high intact strength. Rock bolts and shotcrete in the underground excavation were considered to provide support.

(ix) Adequate construction material was identified near the dam site. Material from Borrow Area D on the right abutment was classified as semi-pervious to impervious core material. The tests indicated that this material is sensitive to variations in water content and looses strength rapidly with increasing water content. Material from the alluvial deposit downstream of the dam axis (Borrow Area E) was identified as the most likely source of clean aggregate. Processing was considered necessary for all materials.

(x) Two potential quarry areas were identified for sources of rockfill, riprap and coarse filter materials. The rock in both areas was classified as diorite and of good quality. Further mapping was considered necessary to verify the suitability.

(xi) Permafrost was found to be very deep on the left abutment or north facing slope, while somewhat sporadic on the right abutment. Preliminary temperature readings indicated that the permafrost is relatively warm within -1°C to 0°C and could be easily handled during construction. However, these instruments had not stabilized by the end of the COE investigations and further readings will be necessary.

(b) Devil Canyon Site

The investigations conducted to date indicate that the Devil Canyon site would be a feasible location for a high concrete dam, preferably a thin arch dam, with an underground powerhouse. However, certain specific features were identified for further study before the feasibility of concrete structures could be positively established.

(i) The bedrock at the proposed dam site was classified as a thinly bedded, fine grained phyllite. The strike of the bedding was found to be generally east-west paralleling the river and dipping 65° to 75° to the south. The drilling indicated that weathering extends some 40 feet below the rock surface with penetrative weathering restricted to shallow zones along the joints. The rock overall was found to be of good quality. One master joint set was identified striking N25°W and dipping 80°E, with general spacing of 5 feet.

(ii) The valley walls at the dam site are very steep and were found to have only a thin cover of overburden consisting mainly of talus at the base. On the upland areas, a covering of glacial till increased to 5 to 35 feet thick.

(iii) On the left abutment, a series of small lakes were found to exist approximately parallel to the river channel. Deep overburden, up to 800 feet in thickness was encountered in this area. Further, it was stated that possibly a large shear zone or a fault existed along these lakes.

(iv) A number of shear zones were encountered during the investigations both subparallel and subperpendicular to the river channel. It was considered that these shear zones could have an important effect on the design and required further investigation. The zones could have been either local stress relief features or part of more general subregional shear pattern.

(v) It was suspected that possibly a fault or major shear zone may exist under the current river channel; although, no positive evidence was presented.

(vi) The rock conditions were considered adequate for underground excavation. Normal rock support systems such as shotcrete were considered to provide adequate support except at the portals and within zones of very poor quality rock. Further investigation was considered necessary to define the conditions present for the most advantageous alignment of the structures.

(vii) A large fan area near Cheechako Creek, immediately upstream of the proposed dam site, was explored for the availability of materials for concrete aggregate and the saddle dam construction. The exploration in this area also indicated the possible existence of a step in the bedrock surface from 100 to 350 feet below the ground surface within a short distance. The step was also coincident with a sharp bend in the river course.

(viii) The material within this alluvial fan was found to be suitable for concrete aggregate except for a deficiency of 3/4 to 1-1/2 inch size that could come from local morainal material. Laboratory tests conducted on the collected samples confirmed their general suitability provided proper processing was employed. However, the resistance of the material to effects of the cold weather was not properly evaluated.

(ix) Permafrost was encountered as sporadic and shallow. Thin lenses and pockets were encountered during road construction on the left abutment. It was considered doubtful that permafrost would be a problem.

(x) It was concluded that grouting and drainage under the structure and in the abutments will be required. Foundation preparations were to include approximately 40 feet of rock excavation to achieve sound

rock, and consolidation grouting and dental concrete work to treat local shear zones and poor rock conditions.

It was concluded by both agencies that additional detailed investigations were required to better define the subsurface conditions, to evaluate the extend and characteristics of geological features, and to supplement the preliminary conclusions in order to establish positively and conclusively the feasibility of this project.

TABLE 3.1

SUMMARY OF PREVIOUS DRILLING
WATANA DAM SITE

Drill Hole Number	Location	Depth of Boring, ft. (Overburden)	Angle W/Vertical	Orientation
DH-1	River Valley	122.8 (44)	Vertical	--
DH-2	River Valley	29 (29)	Vertical	--
DH-3	River Valley	174.5 (77.6)	Vertical	--
DH-4	River Valley	122.9 (77.7)	Vertical	--
DH-5	River Valley	176.9 (59.6)	Vertical	--
DH-6	Right Abutment	149.5 (3.5)	Vertical	--
DH-7	Right Abutment	122.2 (8.5)	31°	S30°W
DH-8	Right Abutment	150.0 (16.2)	Vertical	--
DH-9	Right Abutment	293.3 (5.6)	45°	N43°W
DH-10	Right Abutment	203.5 (19.6)	Vertical	--
DH-11	Right Abutment	300.0 (22.7)	45°	N32°E
DH-12	Left Abutment	301.1 (9.5)	Vertical	--
DH-13	Relict Channel	84 (84)	Vertical	--
DH-14	Relict Channel	75 (75)	Vertical	--
DH-15	Relict Channel	316.5 (286)	Vertical	--
DH-16	Left Abutment	91.5 (67)	Vertical	--
DH-17	Left Abutment	35.7 (9.0)	Vertical	--
DH-18	Left Abutment	248.3 (231.0)	Vertical	--
DH-19	Relict Channel	78.3 (55)	Vertical	--
DH-20	Intake Structure	252.6 (210)	Vertical	--
DH-21	River Valley	603.7 (84.5)	32.4°	N4°E
DH-22	Relict Channel	493.6 (454)	Vertical	--
DH-23	Left Abutment	119.2 (7.0)	45°	S30°W
DH-24	Left Abutment	139.9 (6.9)	Vertical	--
DH-25	Left Abutment	79.9 (79.9)	46°	N47°E
DH-26	Relict Channel	94.8 (94.8)	Vertical	--
DH-27	Relict Channel	44.0 (44)	Vertical	--
DH-28	Left Abutment	125.2 (9.2)	Vertical	--

TABLE 3.2

SUMMARY OF PREVIOUS DRILLING
DEVIL CANYON DAM SITE

Drill Hole Number	Location	Depth of Boring, ft. (Overburden)	Angle W/Vertical	Orientation
DH-1	Left Abutment	117.3 (0)	45°	S23° E
DH-3	Left Abutment	(Hole Trenched)	Vertical	--
DH-4	Left Abutment	52.5 (25)	Vertical	--
DH-5	Left Abutment	86.2 (55)	Vertical	--
DH-6	Left Abutment	107.3 (87)	Vertical	--
DH-7	Left Abutment	59.5 (34)	Vertical	--
DH-8	Left Abutment	150.4 (0)	60°	N9°W
DH-9	Left Abutment	87.0 (0)	45°	Due North
DH-10	Left Abutment	121.7 (15)	38°	N65°E
DH-11	Left Abutment	30.5 (0)	48°	N5°W
DH-11A	Left Abutment	29.1 (0)	45°	N5°W
DH-11B	Left Abutment	33.9 (0)	39°	N5°W
DH-11C	Left Abutment	150.1 (0)	33°	N5°W
DH-12	Left Abutment	127.5 (0)	30°	N45°E
DH-12A	Left Abutment	149.3 (0)	45°	N45°E
DH-13	Right Abutment	137.0 (0)	45°	S18°E
DH-13A	Right Abutment	80.7 (0)	37°	S18°E
DH-14	Right Abutment	50.0 (0)	45°	S45°W
DH-14A	Right Abutment	130.4 (0)	37°	S45°W
DH-14B	Right Abutment	146.2 (0)	60°	S45°W
DH-14C	Right Abutment	82.0 (0)	35°	S4°E
DH-15	Right Abutment	47.6 (48)	Vertical	--

LEGEND

- TP — TEST PIT
- AP — AUGER HOLE
- DH — CORE DRILL HOLE
- DR — ROTARY DRILL HOLE

CORP OF ENGINEERS, 1978

- BH — BOREHOLE
- AH — AUGER HOLE

SUMMER 1980 PROGRAM

SEISMIC LINE :
DM, SW - CORP OF ENGINEERS, 1978
... - SUMMER 1980 PROGRAM

CROSS SECTIONS

WJ — LOCATION OF JOINT MEASUREMENTS

BORROW AREA F

BORROW AREA D

BORROW AREA E

QUARRY SOURCE A

TSUSENA CREEK

SUSITNA RIVER

DEVIL'S CANYON

NOTE:

1) SECTION SHOWN ON FIGURE 6.4

2) TOPOGRAPHIC CONTOURS ARE APPROXIMATE

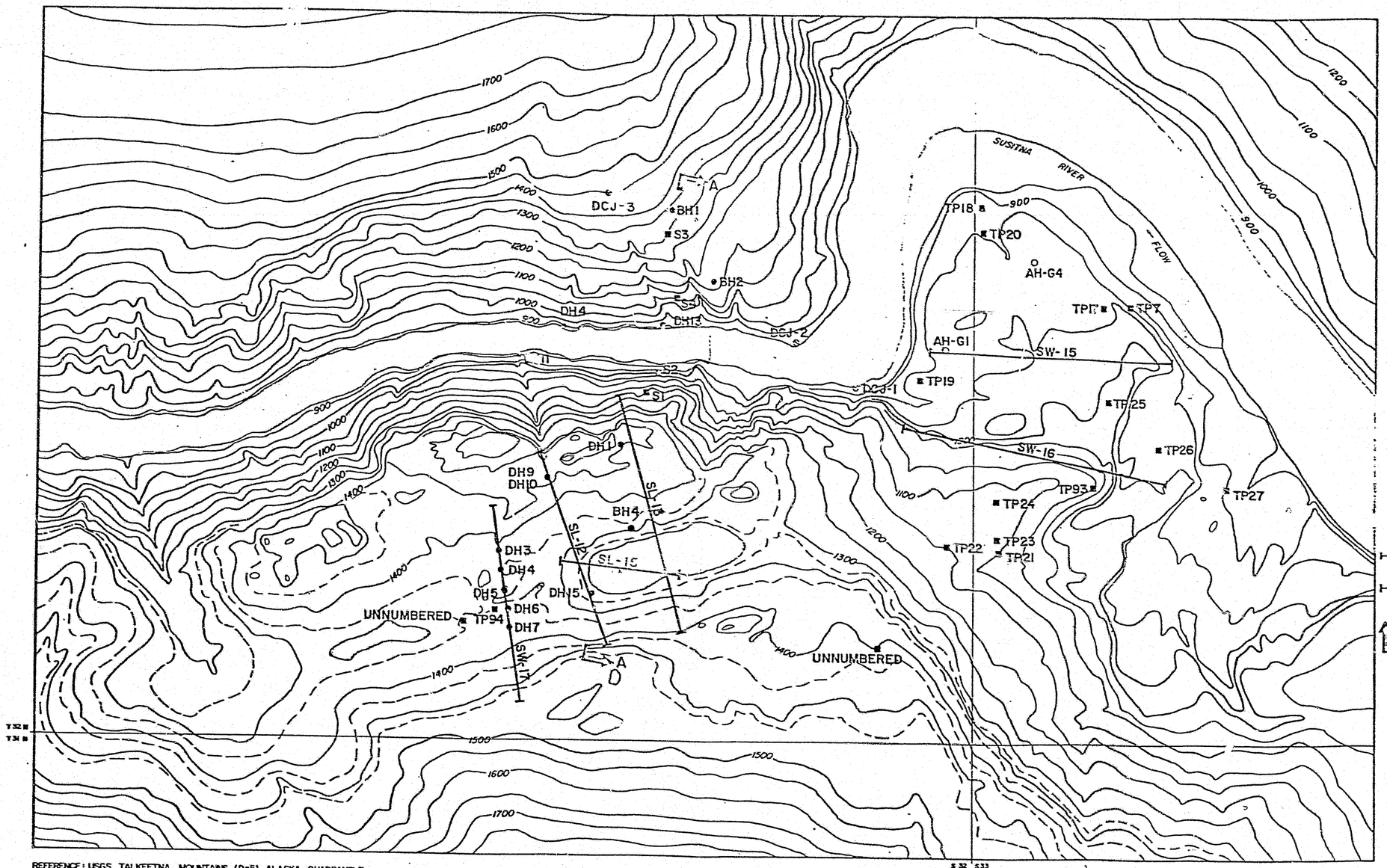
SCALE IN FEET

CONTOUR INTERVAL: 100 FEET

REF. U.S. ARMY CORPS OF ENGINEERS SUPPLEMENTAL FEASIBILITY REPORT 1979.

WATANA LOCATION EXPLORATION MAP

FIGURE 3.1



LEGEND

- DH BOREHOLES-BUREAU OF RECLAMATION 1950
- BH BOREHOLES-SUMMER 1980 PROGRAM
- TP,S, TEST PITS AND TRENCHES BUREAU OF RECLAMATION, 1950
- AUGER HOLES-SUMMER 1980 PROGRAM
- SW SEISMIC LINES-CORP OF ENGINEERS, 1978
- SL SEISMIC LINES-SUMMER 1980 PROGRAM
- DCJ LOCATION OF JOINT MEASUREMENT
- CROSS SECTION

NOTE:
TOPOGRAPHIC CONTOURS ARE APPROXIMATE

SECTION SHOWN ON FIGURE 6.13

200 0 300 400 600
SCALE IN FEET

CONTOUR INTERVAL 50 FEET
DASHED CONTOUR 25 FEET

REFERENCE: USGS, TALKEETNA MOUNTAINS (D-5), ALASKA QUADRANGLE, SEWARD MERIDIAN: T32N, R1E, S32 AND 33.

DEVIL CANYON LOCATION EXPLORATION MAP

FIGURE 3.2

4 - REGIONAL GEOLOGY

4.1 - General

The geology of the Talkeetna Mountains and the adjacent Susitna River basin is extremely complex due to several periods of intense folding and faulting, intrusion of volcanics and plutons, regional metamorphism, differential uplift and repeated glaciations (Figure 4.1). The following is a brief summary of the geologic setting of the region. A detailed discussion of the regional geology has been compiled by Woodward-Clyde Consultants (21).

4.2 - Geologic Setting

The oldest rocks which outcrop in the area are an upper Paleozoic (Table 4.1) metavolcanic rock sequence consisting of coarse to fine grained clastic flows and tuffs of basaltic to andesitic composition, locally containing limestone interbeds (2). This old volcanic system is exposed as a continuous northeastward trending belt across the eastern part of the Susitna River basin, with Triassic and Jurassic volcanic, intrusive and sedimentary rocks unconformably overlying (Figure 4.1). These rocks consist of a shallow marine sequence of metabasalt flows. These flows are interbedded with chert, argillite, marble and volcaniclastic rocks and are best exposed in the Portage and Watana Creeks area (Figure 4.2). The rocks of Jurassic age include amphibolites, greenschists, diorites and granodiorites of the intruding batholithic complexes of the Talkeetna Mountains (2). The uplift and subsequent rapid erosion associated with these plutonic rocks was followed by the marine deposition of a turbidite sequence of lower Cretaceous argillites and lithic graywackes (4). These rocks were subsequently faulted and compressed into tight isoclinal folds and subjected to low grade metamorphism during the late Cretaceous. This sequence of rock outcrops in the Devil Canyon area.

During the early Tertiary, the country rocks were again intruded by Paleocene plutons comprised of biotite granodiorite and other small granitic bodies. Concurrent with and following these intrusions, a thick sequence of felsic to mafic volcanics and shallow intrusives of Palecoene to Miocene age were deposited.

4.3 - Regional Structure

At least three major periods of deformation are recognized for the project area (4):

- a period of intense metamorphism, plutonism, and uplifting in the Jurassic;
- an orogeny during the middle to late Cretaceous;
- a period of extensive uplift and denudation in the middle Tertiary to Quaternary.

The first period, which was during the early to middle Jurassic, involved the first major orogenic event in the now existing Susitna basin. It was characterized by the intrusion of plutons and accompanied by crustal uplift and regional

metamorphism. The rapid erosional period following this uplift was accompanied by marine deposition within the narrowing Cretaceous basin.

This period was followed by complex faulting and folding of the rocks during the middle to late Cretaceous that produced a pronounced northeast-southwest structural grain across the region (4, 5, 8, 9, 13). The majority of the structural features in the Talkeetna Mountains are a consequence of this orogeny of which the Talkeetna Thrust fault is the most dominant. The Talkeetna Thrust which is postulated as representing an old suture zone, involves the thrusting of Paleozic, Triassic and Jurassic rocks over the Cretaceous sedimentary rocks. (4, 5, 8). Other compressional structures related to this orogeny are evidenced in the intense shear zones roughly parallel to and southeast of the Talkeetna Thrust.

The third major series of events shaping the region involved a period of extensive uplift and denudation from the middle Tertiary to Quaternary (4). Two dominant tectonic features of this period bracket the basin area. The Denali fault, a right-lateral strike-slip fault 25 miles north of the Susitna River, exhibits evidence of fault displacement during Cenozoic time and the Castle Mountain-Caribou fault system, which borders the Talkeetna Mountains to the south approximately 70 miles southeast of the sites is a normal fault which has had fault displacement during the Holocene (7).

4.4 - Glacial History

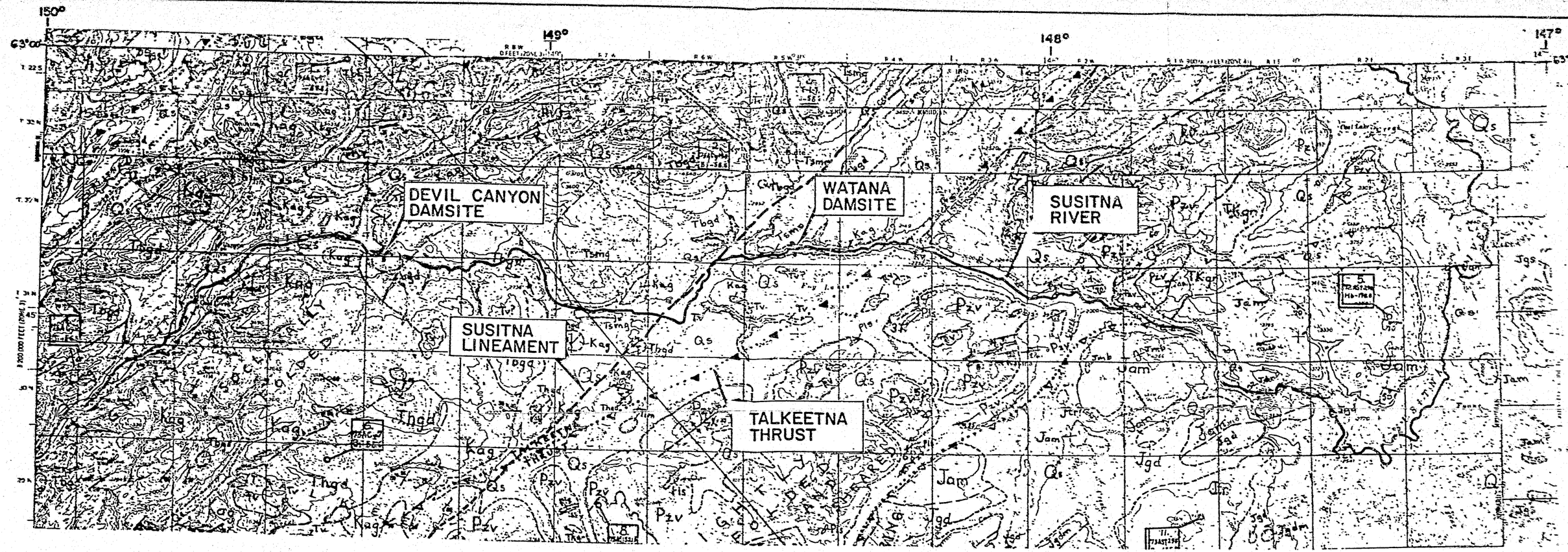
A period of cyclic climatic cooling during the Quaternary resulted in repeated glaciation of southern Alaska. Little information is available regarding the glacial history in the upper Susitna River basin. Unlike the north side of the Alaska Range which is characterized by alpine-type glaciation, the Susitna basin experienced coalescing glaciers from both the Alaska Range and the Talkeetna Mountains that merged and filled the upper basin area.

At least three periods of glaciation have been delineated for the region based on the glacial stratigraphy (11, 12). During the most recent period, (late Wisconsin glaciation) glaciers filled the adjoining lowland basins and spread onto the continental shelf (11). Waning of the ice masses from the Alaska Range and Talkeetna Mountains formed ice barriers which blocked the drainage of glacial meltwater and produced proglacial lakes. As a consequence of this repeated glaciation, the Susitna and Copper River basins are covered by varying thicknesses of lodgement and ablation tills and lacustrine deposits.

TABLE 4.1

GEOLOGIC TIME SCALE

ERA	PERIOD	EPOCH	Millions of Years Ago
	Quaternary	Holocene Pleistocene	2
Cenozoic	Tertiary	Pliocene Miocene Oligocene Eocene Paleocene	65
Mesozoic	Cretaceous Jurassic Triassic		225
Paleozoic	Permian Pennsylvanian Mississippian Devonian Silurian Ordovician Cambrian		600
Precambrian			



EXPLANATION OF MAP SYMBOLS

Contact, approximately located

Approximate contact of surficial deposits

Fault

Long dashed where approximately located; short dashed where inferred; dotted where concealed. U indicates upthrown side where direction of displacement is known. Arrows indicate relative lateral movement.

Thrust fault

Long dashed where approximately located, short dashed where inferred, dotted where concealed. Teeth indicate upthrown side.

Approximate axis of intense shear zone of variable width, possibly marking a thrust fault

Dotted where concealed; teeth indicate possible upthrown side of postulated thrust.

Anticline, showing crest line ; Syncline, showing trough line

Long dashed where approximately located; arrow indicates plunge.

Location of sample dated by the U.S. Geological Survey using the potassium-argon or the lead-alpha method, showing map number, field number, and the calculated mineral age. Bi - biotite, Hb - hornblende, Mu - muscovite, Act - actinolite, Zr - zircon, wr - whole rock.

Location of sample dated by Turner and Smith (1974) using the potassium-argon method, showing map number, field number, and the calculated mineral age. Bi - biotite, Hb - hornblende.

x 4. Fossil locality in units Trv, Pls, and DSls.

Strike and dip of beds

- Inclined
- Overturned
- Vertical
- Approximate, estimated from distant observations

Strike and dip of fracture cleavage

- Inclined
- Vertical

Strike and dip of slaty or axial plane cleavage

- Inclined
- Vertical

Strike and dip of shear planes, metamorphic foliation or schistosity

- Inclined
- Vertical

Strike and dip of igneous flow foliation

- Inclined
- Vertical

Bearing and plunge of lineation

- Inclined
- Horizontal

Strike and dip of joints

- Inclined
- Vertical

0 3 6 12
SCALE IN MILES

NOTE:
ROCK UNITS ARE LISTED IN FIGURE 4 1 b

REFERENCE: CSEJTEY, B. ET AL. RECONNAISSANCE GEOLOGIC MAP & GEOCHRONOLOGY, TALKEETNA MOUNTAINS QUADRANGLE, NORTHERN PART OF ANCHORAGE QUADRANGLE, AND SOUTHWEST CORNER OF HEALY QUADRANGLE, ALASKA. U.S.G.S. OPEN FILE REPORT 78-558A. 1978.

REGIONAL GEOLOGY

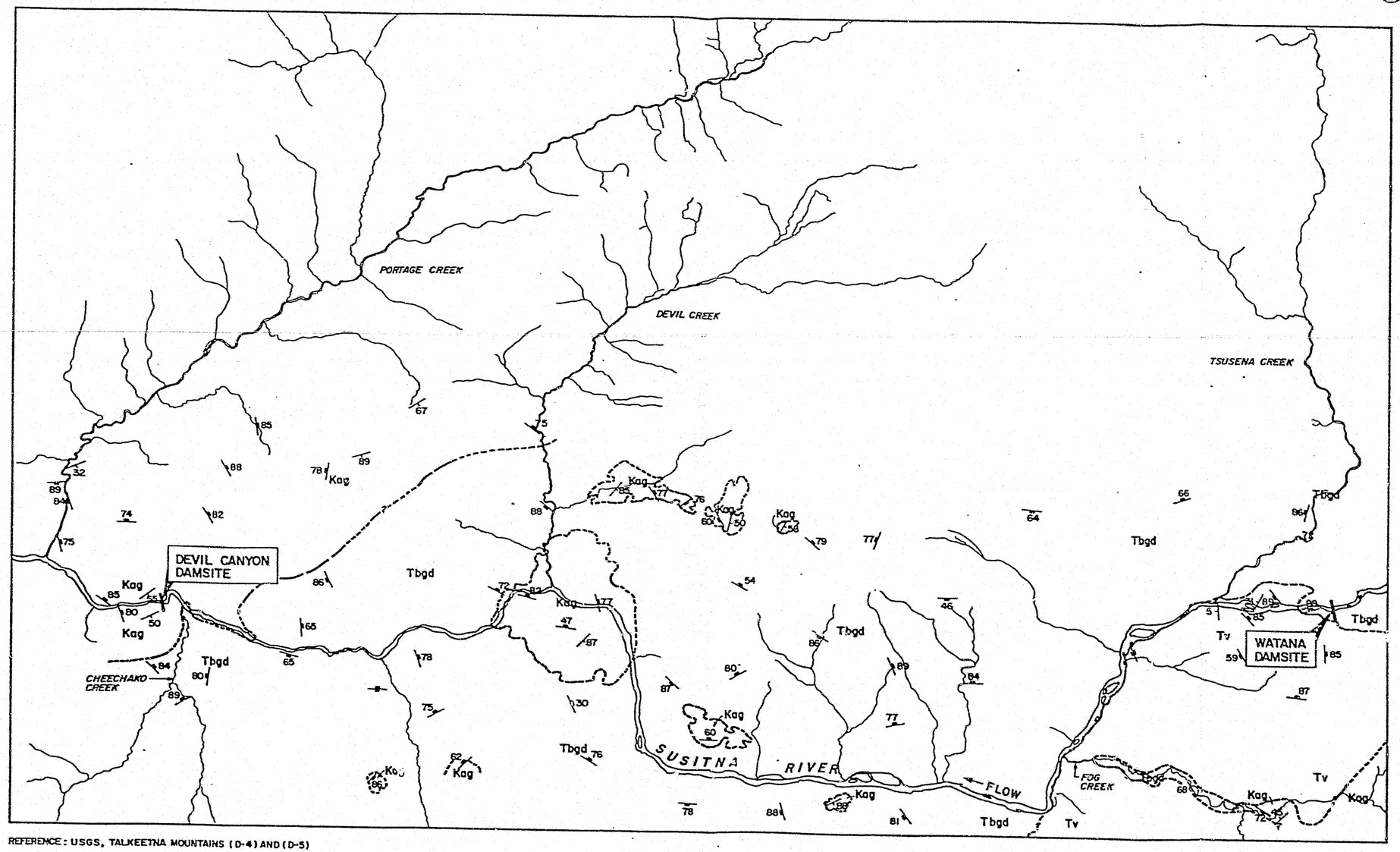
FIGURE 4 1

REGIONAL GEOLOGY
MAP UNITS

Cenozoic	Qs	Undifferentiated Surficial Deposits
	Tsu	Undifferentiated Sedimentary Rocks
	Tv	Undifferentiated Volcanic Rocks
	Tbgd/Thgd	Biotite & Biotite-Hornblende Granodiorite
	Tsmg/Tkgr	Granites and Schists
Mesozoic	Kag	Argillite and Graywacke
	Jtr/Jgd/Jgdm	Quartz Diorites & Granodiorites
	Jam	Amphibolites
	Rv	Basaltic Metavolcanic Rocks
	Rvs	Metabasalt and Slate
Paleozoic	Pzv/Pls	Basaltic to Andesitic Metavolcanogenic Rocks with Interbedded Limestone

Modified after Csejtey and others, 1978.

FIGURE 4.1 b



REFERENCE: USGS, TALKEETNA MOUNTAINS (D-4) AND (D-5)

LEGEND

- Tv — ANDESITE AND ANDESITIC BASALT FLOWS, VOLCANIC CLASTIC SEDIMENTS
- Tbgd — BIOTITE GRANODIORITE, QUARTZ DIORITE, DIORITE
- Kag — ARGILLITE
- 15 — STRIKE AND DIP OF BEDS
- 75 — STRIKE AND DIP OF JOINTS
- ---- CONTACT, LOCATED APPROXIMATELY

NOTE:

1) GEOLOGIC MAPPING UNDERTAKEN AT A SCALE OF 1:12,000 & 1:63,360

0 1 2 3 4
SCALE IN MILES

GEOLOGIC MAP OF DEVIL CANYON RESERVOIR

5 - 1980 GEOTECHNICAL INVESTIGATION

5.1 - General

The 1980 investigation program was developed as the first phase in defining the geologic and subsurface features identified by previous investigators at the Watana and Devil Canyon dam sites. In addition to the review of information published, discussions were held with people knowledgeable of the area. In particular, meetings were held with the COE to discuss details of their 1978 program and the experiences of those people directly involved with the investigations.

The 1980 program was developed to consist of air photointerpretation, surficial geological mapping, diamond core drilling, permeability testing, in-hole geophysical logging, borehole photography, instrumentation, auger drilling and seismic refraction surveys.

The program was designed to provide the maximum amount of information relative to site geologic and geotechnical conditions towards establishing the feasibility of the project within the budgetary restraints of the program.

The scope of the 1980 program was principally directed to define:

- Site geology.
- Rock type and quality.
- Engineering evaluation of rock conditions.
- Borrow sources for construction material.
- Groundwater regime.
- Permafrost.

Specific geologic and/or geotechnical features or conditions that were delineated during previous studies and considered to warrant further investigation have been discussed earlier in this report. The particular features selected for study during the 1980 program were:

(a) Watana Site

- Shear zones called "The Fins" and "Fingerbuster" located upstream and downstream of the proposed dam site.
- "Buried stream channel" located on the right abutment (north of the dam site.
- A possible slide block on the right abutment.
- Potential for a shear zone beneath the river channel.

(b) Devil Canyon Site

- Stress relief joints and shear zones along left (south) abutment.

- Rock discontinuity through the Cheechako Creek borrow area upstream of dam.

- Possible shear zone or buried channel beneath saddle dam on left abutment.

To fulfill the objectives of the 1980 program, the following work was undertaken at both dam sites:

- Air photointerpretation.
- Geologic mapping.
- Diamond core drilling.
- Auger drilling and sampling.
- In-hole geophysical and water pressure testing.
- Seismic refraction survey.
- Laboratory testing.
- Installation of piezometer and thermal probes.

Detailed scope and methodology for the work performed are presented in the following sections. A detailed discussion of the results of the program are presented in Section 6. The air photointerpretation was subcontracted to R&M Consultants and was scheduled to be completed prior to the field geology program. However, due to scheduling problems, the work was not completed as planned; therefore, this program had to be planned on the basis of the previous site investigations only. The airphoto work is scheduled to be completed soon, and the results will be presented in Appendix F of this report within a separate volume.

5.2 - Scope and Methodology

(a) Geologic Mapping

The 1980 field program was directed at the mapping of the dam sites. Geologic mapping of each of the proposed dam sites included walking selected ground traverses and noting all bedrock outcrops and unconsolidated material to expand and verify the previous geologic mapping. Aerial photographic base maps at scales of 1:6,000 and 1:24,000 were used in mapping the Watana and Devil Canyon dam sites respectively. At each exposure, the lithology, type of material, bedding, jointing, weathering, outcrop size and elevation was noted and plotted on the base maps.

Geologic reconnaissance of the Devil Canyon reservoir and potential tunnel routes, being studied during project definition studies, was performed between Portage and Tsusena Creeks and extended up to 5 miles north and south of the Susitna River. A helicopter reconnaissance was made within a 10-mile radius of the Watana dam site to delineate unconsolidated materials as potential borrow sources. The mapping of the reservoir areas were plotted on either 1:12,000 aerial photographic or a 1:63,360 USGS topographic base map.

(b) Subsurface Investigations

(i) Diamond Core Drilling

Diamond core drilling was performed in the foundations and abutments of both dam sites utilizing a skid-mounted Longyear-34 diamond drill with a two or three man crew to operate and maintain the rig. A total of 3800 feet of drilling was performed. All logging and supervision was conducted by a geologist who described, photographed and packed the rock core and supervised testing and instrument installation.

Prior to the start of diamond core drilling, all holes were cased through the overburden into sound rock. The casing was left in the hole to permit subsequent testing and installation of instrumentation.

All drilling and testing was conducted by R&M Consultants and their subcontractor, The Drilling Company, under the direction of Acres American Incorporated.

A summary of the drilling activity for the 1980 field season is shown on Table 5.1 and Figures 5.1, and 5.2. Drilling summary logs and reports are contained in Appendix B.

(ii) Permeability Testing

Permeability testing was conducted in all the diamond drill holes upon completion of the core drilling. Prior to testing, each hole

was thoroughly flushed with clear water and the drill string withdrawn. Following flushing of the hole, a packer assembly consisting of two inflatable packer elements separated by a perforated section of pipe and connected to the surface by a steel riser pipe and rubber inflation hose was lowered into the borehole to the desired depth. The test procedure involved inflating the packers with nitrogen to isolate a section of the borehole, pumping water under pressure into the test zone and recording the flow rates. Based on the flow rates, hydraulic head, hole diameter and length of test section, the permeability of the rock over the test section was calculated. In general, the packer assembly was installed to the bottom of the hole with tests being run over 16.1 foot intervals as the assembly was withdrawn.

The permeability for each test section was calculated using the following formulas:

$$k = 0.0679 \frac{Q}{2 \pi LH} \ln \frac{1}{r}$$

Where: k = permeability, cm/sec
Q = constant rate of flow, gpm
L = length of test section, ft and $L \geq 10r$
H = differential head of water, ft
r = radius of hole, ft
ln = natural logarithm

A maximum test pressure equal to 1 psi per foot of vertical depth below the ground surface to the water table, plus 0.5 per foot of vertical depth below the water table down to the center of the test section, was used. However, in no case was the pressure allowed to exceed 200 psi. The actual gauge pressure was adjusted to take into consideration the depth of water table.

The test data and calculations are presented in Appendix B for Watana and Devil Canyon sites.

(iii) In-Hole Geophysical Logging

In-hole geophysical logging was carried out in all three diamond drill holes at the Devil Canyon site and two holes at the Watana site. BH-2 at the Watana site caved badly and was not tested. A total of 3,225 linear feet of logging was completed. The logging procedure involved lowering a geophysical probe in the hole on a wireline with the data being returned to the surface and recorded on a self-contained logging unit. The logs run in each hole included: temperature, caliper, resistivity and velocity. This information is now being incorporated into the comprehensive logs. The work performed by EDCON, Exploration Data Consultants Incorporated, under

a subcontract to R&M Consultants.

The results of the geophysical logging will be contained in the final report as an appendix.

(iv) Borehole Photography

Borehole photography was attempted in three of the diamond drill holes, BH-6 and BH-8 at Watana, and BH-1 at Devil Canyon without success. Prior to using the real camera, a "dummy" camera unit was lowered in the holes to check for any obstructions and safe passage of the unit. In all three cases, it became lodged in the hole. The "dummy" unit was recovered in all cases, but it was not considered advisable to lower the real camera, as chances of it being lost in the hole or damaged were very high. The problems apparently were related to the inclination of the holes and the fractured nature of the rock.

(v) Instrumentation

To monitor the groundwater and permafrost conditions in the bedrock, piezometers and thermistor strings were installed in all three boreholes at Devil Canyon (Figure 5.2) and BH-6 at Watana (Figure 5.1).

The piezometers used were a pneumatic type assembly manufactured by Petur Instrument Company. The pneumatic type piezometers were selected based on the fact that subfreezing temperatures were likely to be encountered in the upper portions of the holes which would cause blockage in conventional standpipe piezometers. Pneumatic type piezometers are also quick and easy to read as well as being accurate which is a prime consideration during winter months.

The thermistor strings were manufactured by Instrumentation Services in Fairbanks, Alaska. The thermistor strings were each 250 feet long with redundant thermistor points installed at 3, 6, 9, 12, 15, 18, 21, 25, 50, 75, 100, 125, 150, 175, 200 and 250 feet. A 40 strand cable was used to connect the thermistors to the surface where a quick connect plug on the cable is plugged into a switch box that in turn is connected to a portable readout box. The system is designed such that two readings are obtained at each depth so readings can be cross checked. Each thermistor point was initially calibrated in the laboratory before installation and a computer program set up to convert readings to temperature, taking into account the correction factors for each thermistor. An accuracy of $\pm$.05°C is obtained with this equipment.

The installation details are shown on Figure 5.3 and 5.4 for Watana and Devil Canyon, respectively.

(vi) Auger Drilling

Auger drilling was conducted at both sites to expand the work done by the previous investigators to define the potential borrow areas. At Watana (Figure 5.1), four holes were drilled in Borrow Area D and nine in Borrow Area E, while two were drilled at Devil Canyon (Figure 5.2) for 260 linear feet total. The original program was more extensive; however, difficulties were encountered in advancing the auger due to boulders, cobbles, and hard ground conditions.

The program initially used a platform-mounted CME-45 rig that was replaced by a CME-55 for the difficult drilling conditions. Drilling was performed using a hollow stem continuous flight auger string, having an 8-inch and a 3-1/4 inch I.D., to a maximum depth of 35 feet. Material samples were collected continuously in the upper 10 feet of the hole and then at 5-foot intervals using a split-spoon sampler. The sampling procedures consisted of drilling the augers down to the required sampling depth, removing the inner plug and stem, installing the split-spoon sampler and advancing it 18 inches into the soil below the cutting head by driving it with a 140 lb hammer falling freely 30 inches (Standard Penetration Test). The samples were returned to the surface, logged by a geologist and prepared for transport and storage. In most cases, 4 to 6-inch long thin brass liners were used inside the split-spoon sampler which allowed selected samples to be capped and sealed for future testing. Following completion of the hole, the auger string was withdrawn and the hole backfilled with the drill cuttings.

The logs for these holes are given in Appendix C-1. The properties of the borrow materials are discussed in Section 6.

(vii) Seismic Refraction Surveys

Seismic refraction surveys (seismic lines) were performed on the abutments of both dam sites and in the borrow areas and relict channel near Watana to extend the previous studies. Eleven traverses totalling 27,800 feet were run under this program. The work was performed by Woodward-Clyde Consultants (WCC) under a subcontract to R&M Consultants, and the results are presented in Appendix D. The locations of the lines are also shown on Figure 5.1 for Watana and Figure 5.2 for Devil Canyon.

At the Watana dam site, four traverses were shot in the immediate dam site. Two of these lines crossed the right abutment and the relict channel area. A third line is located upstream of the proposed axis on both abutments, and the fourth investigated a topographic depression a mile upstream of the axis on the north side of the river. Borrow Areas D and E at Watana were explored by four seismic lines (two within each area).

At Devil Canyon, the three seismic lines were run on the left

(south) abutment across the small lake and adjacent slopes to investigate the overburden thickness in the proposed saddle dam area and the existence of a possible large shear zone

(c) Laboratory Testing

Representative soil samples obtained from the potential borrow sites of the Watana area were tested to determine their physical properties and verify field classification. A total of 21 samples were tested to determine the soil's moisture content, Atterberg limit, grain size distribution and Modified Proctor density. A summary of the testing program is given in Table 5.2. All twenty-one samples were tested using the appliable ASTM or AASHTO standard procedures. The results of the testing program are summarized and the data is presented in Appendix C2.

TABLE 5.1

SUMMARY OF DRILLING ACTIVITY - 1980

HOLE NO.	LOCATION	GROUND ELEVATION, FT	DEPTH FT	ORIENTATION	ANGLE WITH VERTICAL	SIGNIFICANCE
Watana						
BH-2	Right Abutment	1,835	401.0	N45E	55°	Fingerbuster shear zone
BH-6	Right Abutment	1,605	740.4	S45W	60°	Suspected fault
BH-8	Left Abutment	1,976	750.55	N60E	60°	Powerhouse geology
Devil Canyon						
BH-1	Right Abutment	1,415	750.3	S45W	67°	Powerhouse geology
BH-2	Right Abutment	1,214	656.2	N	60°	Dam foundation
BH-4	Left Abutment	1,353	501.0	S15W	60°	Suspected shear zone

Note: Drill hole locations are shown on Figure 5.1 (Watana)
Figure 5.2 (Devil Canyon)

TABLE 5.2

SUMMARY OF LABORATORY TESTING

TEST (PROCEDURE)	NUMBER OF TESTS				
	Borrow Area				
	D	E	H	Deadman Creek	River Channel
Grain Size Distribution ASTM: D422-63	8	8	2	2	1
Natural Moisture Contents ASTM: D2216-71	8	8	2	2	1
Liquid Limits ASTM: D423-66	6	--	2	2	--
Plasticity Index ASTM: D424-59	6	--	2	2	--
Modified Proctor Density AASHTO T-180 Method "A"	--	--	--	1	--
AASHTO T-180 Method "D"	--	--	1	1	--

NOTE: Laboratory test results are included in Appendix C-2.

LEGEND

■TP	TEST PIT	CORP OF ENGINEERS, 1978
•AP	AUGER HOLE	
•DH	CORE DRILL HOLE	
•DR	ROTARY DRILL HOLE	
•BH	BOREHOLE	SUMMER 1980 PROGRAM
•AH	AUGER HOLE	

SEISMIC LINE :
DM, SW - CORP OF ENGINEERS, 1978
SL - SUMMER 1980 PROGRAM

CROSS SECTIONS

•WJ LOCATION OF JOINT MEASUREMENTS

BORROW AREA F

BORROW AREA E

BORROW AREA D

QUARRY SOURCE A

TSUSENA CREEK

SUSITNA RIVER

DEADMAN CREEK

NOTE:
1) SECTION SHOWN ON FIGURE 6.4
2) TOPOGRAPHIC CONTOURS ARE APPROXIMATE

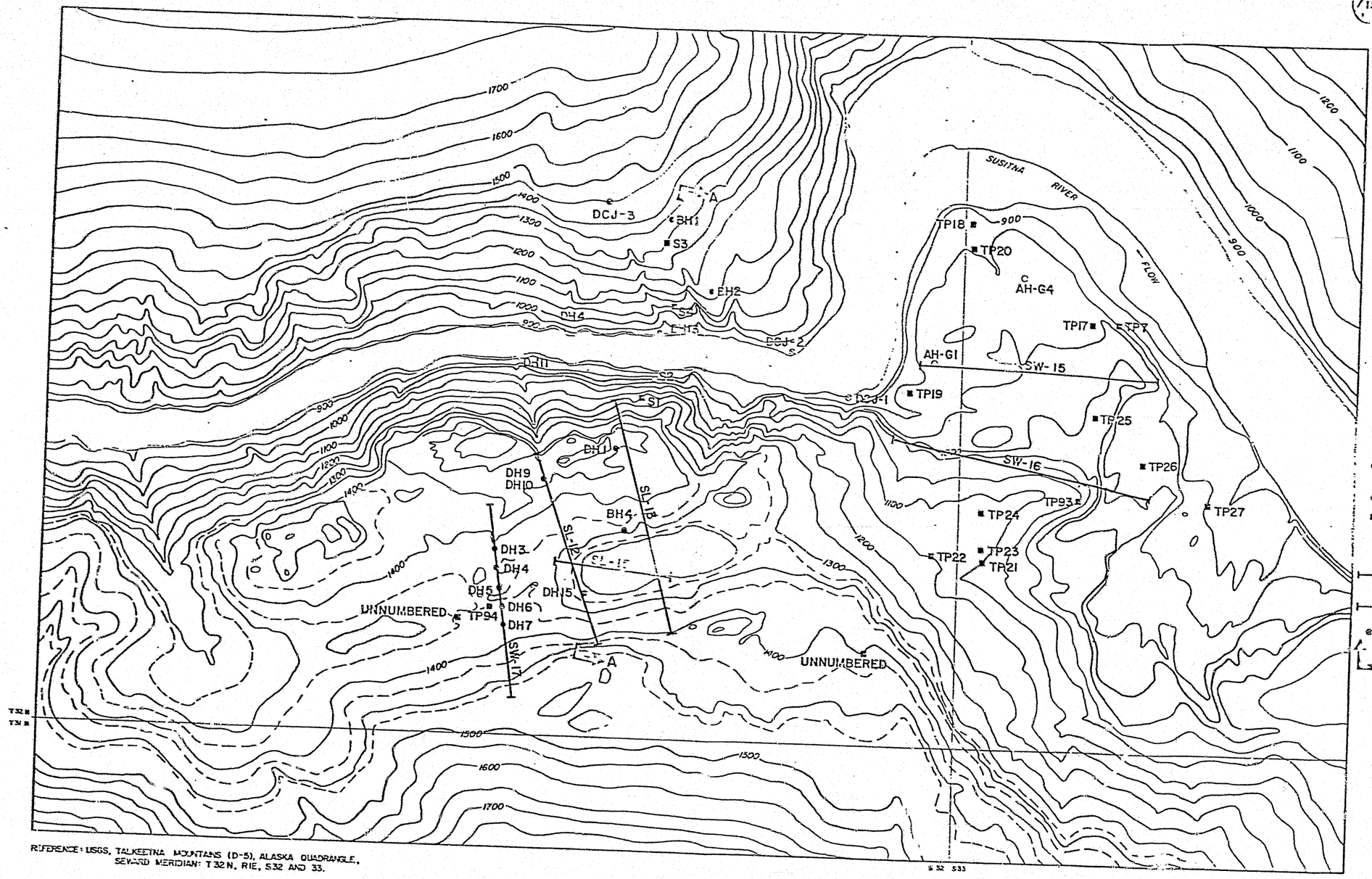
SCALE IN FEET

CONTOUR INTERVAL : 100 FEET

REF. U.S. ARMY CORPS OF ENGINEERS SUPPLEMENTAL FEASIBILITY REPORT 1979.

WATANA LOCATION EXPLORATION MAP

FIGURE 5.1



LEGEND

- DH BOREHOLES-BUREAU OF RECLAMATION 1950
- BH BOREHOLES-SUMMER 1950 PROGRAM
- TP, S, TEST PITS AND TRENCHES BUREAU OF RECLAMATION, 1950
- AUGER HOLES-SUMMER 1950 PROGRAM
- SW SEISMIC LINES-CORP OF ENGINEERS, 1976
- SL SEISMIC LINES-SUMMER 1950 PROGRAM
- DCJ LOCATION OF JOINT MEASUREMENT
- CROSS SECTION

NOTE:
TOPOGRAPHIC CONTOURS ARE APPROXIMATE
SECTION SHOWN ON FIGURE 6.13

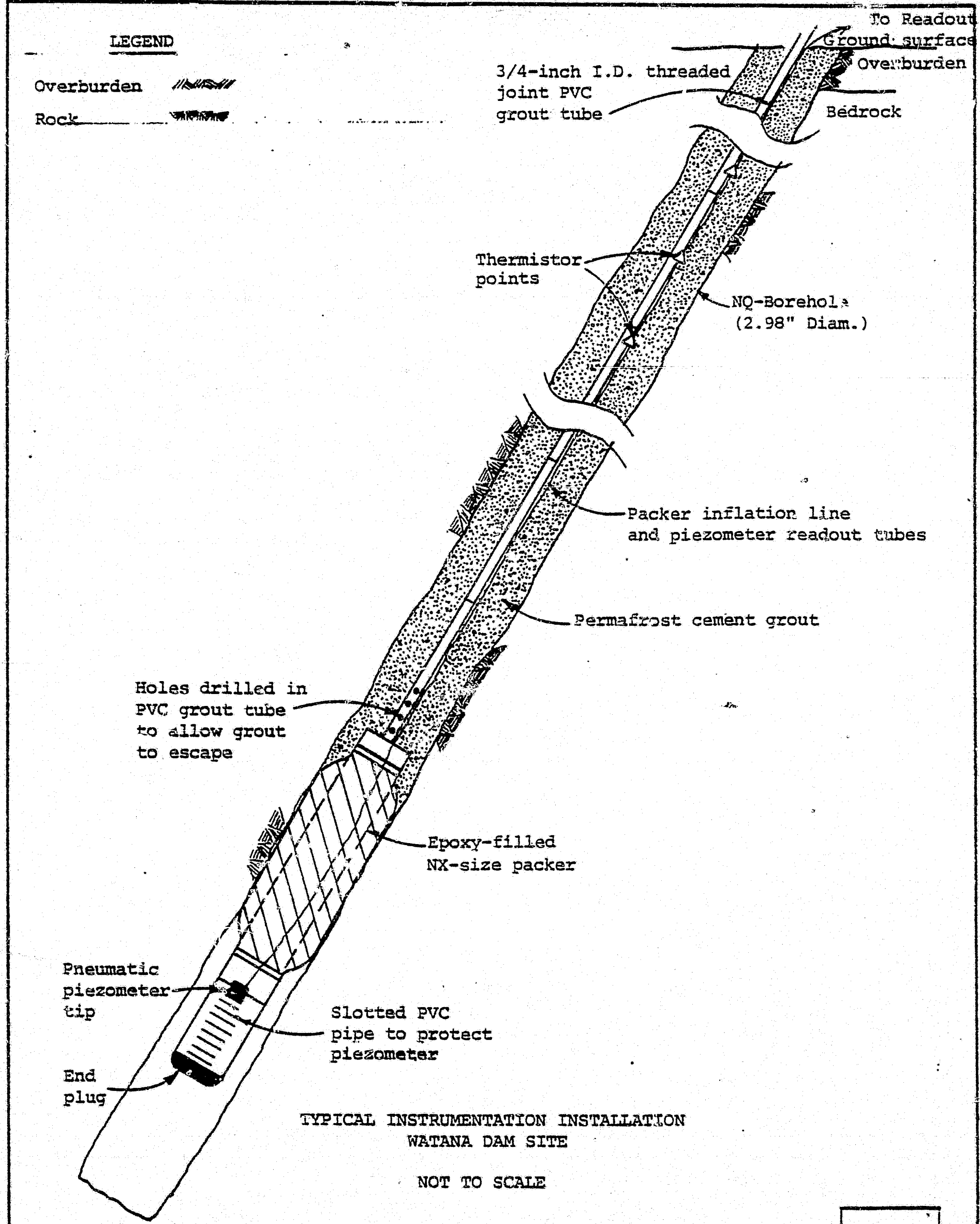
200 0 200 400 600
SCALE IN FEET

CONTOUR INTERVAL 50 FEET
DASHED CONTOUR 25 FEET

REFERENCE: USGS, TALKEETNA MOUNTAINS (D-5), ALASKA QUADRANGLE, SEWARD MERIDIAN: T32N, R1E, S32 AND 33.

DEVIL CANYON LOCATION EXPLORATION MAP

FIGURE 5.2



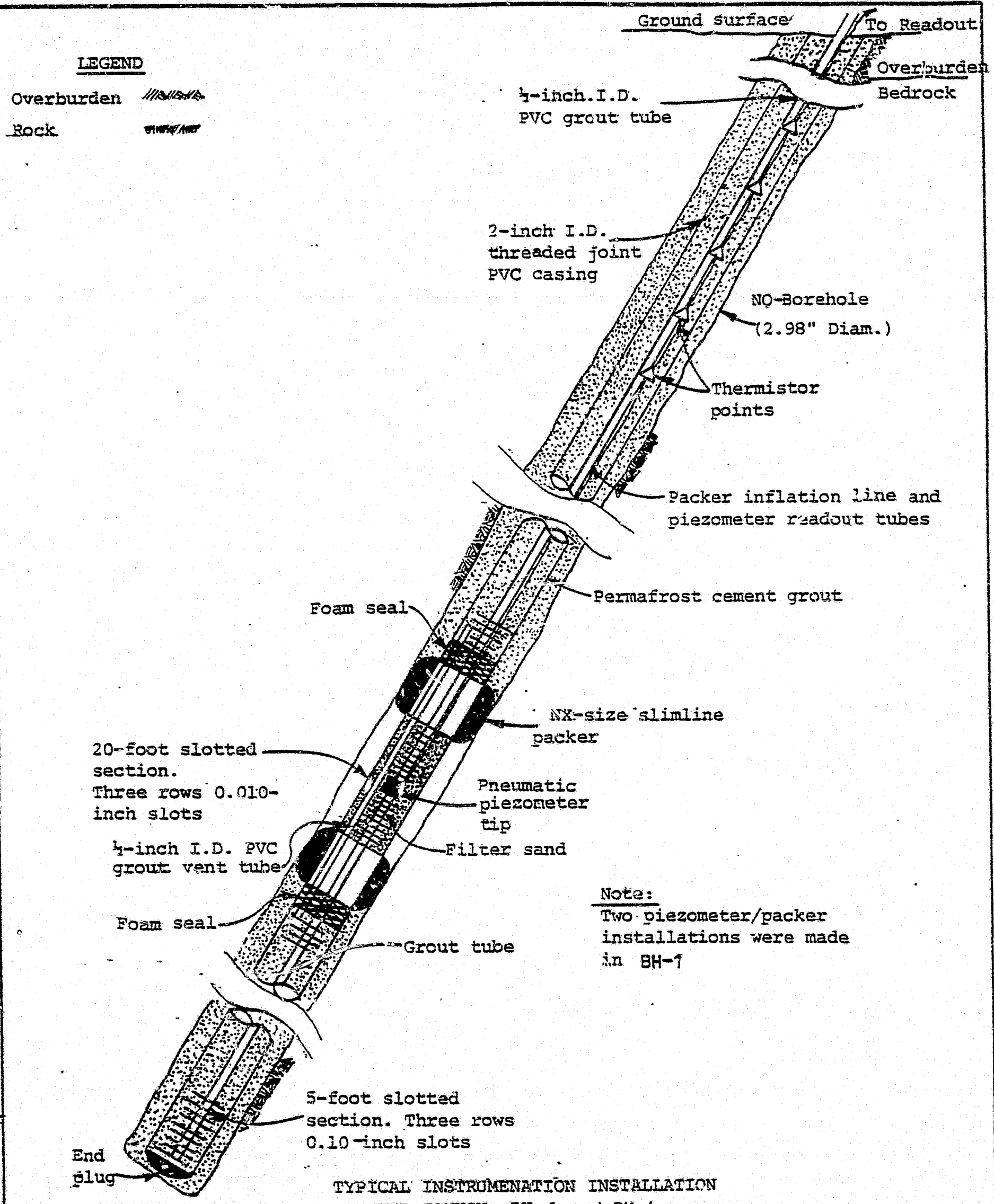
TYPICAL INSTRUMENTATION INSTALLATION
WATANA DAM SITE

NOT TO SCALE

R&M CONSULTANTS, INC.
ENGINEERS · GEOLOGISTS PLANNERS SURVEYORS

FIGURE 5.3

ACRES



Note:
Two piezometer/packer installations were made in BH-1

TYPICAL INSTRUMENATION INSTALLATION
DEVIL CANYON: BH-1 and BH-4

NOT TO SCALE

R&M CONSULTANTS, INC.
ENGINEERS · GEOLOGISTS PLANNERS SURVEYORS

FIGURE 5.4

ACRES

6 - RESULTS OF THE GEOTECHNICAL INVESTIGATIONS

6.1 - Watana

(a) General

As discussed in Section 3, the Watana dam site had been explored by previous investigators on a reconnaissance level (6, 5, 18, 19). This information was then expanded by the 1980 Program using detailed geologic mapping, three diamond drill holes, auger holes and seismic refraction surveys. The location of all exploration stations are shown on Figure 6.1.

(b) Overburden Conditions

Overburden thickness in the dam site area ranges from very thin to non-existent along portions of the valley slope to greater than 450 feet away from the valley walls. The type of overburden varies from weathered rock and talus to glacially derived tills with lacustrine clays to organic materials. The type and thickness of overburden in the site area has been delineated by geologic mapping, drilling, excavation of test pits and seismic refraction surveys. A detailed discussion of soil conditions and properties in selected borrow source areas are presented in Section 6.1 (f).

An isopach map of overburden thickness is shown in Figure 6.2. In general, the overburden on the valley walls and abutments in and around the Watana site is thin, varying in thickness from 0 to about 10 feet. On the lower slopes, in the V-shaped portion of the valley, overburden is almost non-existent consisting primarily of talus. Above the break in slope on the north side of the river, the overburden thickens and consists primarily of glacial material.

Several local areas of thick overburden were encountered on both dam abutments during the various phases of investigation. Seismic line SW-2 (Figure 6.1) shows a thickening of overburden to approximately 100 feet upslope of BH-2. A similar thick pocket of overburden was found on the south abutment at DH-25 (COE, 1978) (Figure 6.1) where over 80 feet of till was drilled without reaching bedrock.

Away from the valley walls, the overburden consists principally of glacial silts, sands, gravels and boulders. Where drilled, the contact between the overburden and bedrock is sharp. Seismic velocity of the unconsolidated silts, sands and gravels generally average in the range of 6,000 - 7,000 ft/sec whereas the denser tills, boulders, and weathered rock range between 13,000 - 14,000 ft/sec.

A deep bedrock depression has been delineated on the north side of the river extending from approximately 9,000 feet upstream and trending northwest toward Tsusena Creek. The evidence for this channel is based on seismic refraction studies (14, 17, 18) and several drill holes (18) as

shown on Figure 6.1. The lowest bedrock elevation encountered in the channel was 1,775 feet or 454 feet below the surface (DR-22). The overburden in the buried channel consists of several sequences of till, lacustrine and alluvial (including outwash) materials. At least two sequences of fine grained lacustrine material have been encountered. In DR-13, the COE reported encountering a significant artesian condition, however the source of the artesian pressure and relief on the cliffs was not addressed. In another boring, DR-22, an interval of pervious sands and gravels was encountered at elevation 2,000 (200 feet below ground surface). Discussions with COE people who supervised the investigations revealed that during a falling head permeability test on the interval composed of these materials had takes as high as 50 gpm/foot of head. Based on the limited information on the statigraphy, it is very difficult to draw conclusions on whether the till, glacial material or outwash deposits are continuous over large areas and as such, a reasonable assessment of the overall permeability of the channel materials is not feasible at this time.

Previous borings performed in the river channel within the dam area show alluvium thickness on the order of 40-80 feet. The material consists of coarse sands, gravels and boulders. Several boulders, in excess of several feet thick, were encountered during the investigation.

(c) Bedrock Geology

(i) Lithology

The bedrock at the Watana dam site consists of granite and quartz diorite, andesite porphory, and tuffaceous siltstones and sandstones (Figure 6.3). Areas of bedrock exposure are shown on Figures 6.2 and 6.3. The dam site is primarily underlain by an intrusive diorite body which varies in composition from a granodiorite to quartz diorite.

The diorite is a pink gray-green, medium grained rock composed of feldspar, hornblende, biotite and quartz, and is generally fresh, massive, competent and hard. The most common mafic mineral is hornblende. The diorite has been intruded by felsic and andesite porphory dikes, and zones of hydrothermal alteration and secondary mineralization consisting of quartz and calcite are commonly found in rock fractures.

An extrusive porphoritic andesite flow stratigraphically overlies the diorite and crops out downstream along the left abutment of the proposed dam axis. Field mapping indicates that the thickness of this unit may range up to 100 feet downstream of the dam area. The andesite is a green to gray-green rock which generally contains phenocrysts of plagioclase with occasional small fragments of argillite. It is generally fresh, hard and competent. Occasional inclusions of diorite have been delineated within the andesite in the western part of Quarry "A". Variations within the flow have been

observed in this area that indicate its composition may include some rhyodacite and dacite. Near the downstream end of the dam area, the mafic content of the rock increases making it more basaltic in composition.

The contact between the andesite flow and the diorite was encountered in BH-2 and BH-8 (Figures 6.1 and 6.4). Similarly the COE borings DH-21 and 24 penetrated andesite dikes on the left abutment. The nature of the contact in BH-2 is unclear, in that a secondary shear zone corresponds with this contact resulting in poor quality rock. The contact in BH-8 was intersected at a depth of approximately 50 feet. The rock is this zone was highly fractured and jointed with clay seams extending over a distance of 10-15 feet. Core recovery was on the order of 70-80 percent.

A sequence of tuffaceous siltstone and sandstones are exposed in the cliffs approximately 5,000 feet downstream of the dam site which are overlain by the andesitic (basaltic) rocks (see Figure 6.5). These rocks are composed essentially of volcanic debris, the siltstone being a medium gray, fine grained rock that exhibits some shaly weathering while the sandstone has a buff colored groundmass with inclusions of feldspar, quartz and argillite. The rock in the area is generally sound and unweathered.

(ii) Bedrock Structure

Detailed joint surveys were performed at four stations around the Watana site. Three of these stations (WJ-1 through WJ-3, Figure 6.1) were performed in the diorite along Susitna River in the vicinity of the proposed dam foundation, while WJ-4 (Figure 6.1) was performed north of the site on Tsusena Creek. Contoured stereographic plots of these joints are shown on Figures 6.6 (a-d). Although correlation between joint readings vary between stations, it appears that the most common joint set ranges from 320° to 350° with an average dip of 80° NE. Joint spacings range from 1 to 5 feet. Several pronounced joint sets mapped at one station were not found at others. An example of this is the 45° NW dipping set identified at WJ-3 which was not found at the other 3 stations. The reasons for these variations may be due to local variation in rock type and exposure. However, additional work will be required to more accurately define local and regional joint orientations.

Jointing was found in all the boreholes. The joints were generally closely spaced, open and moderately weathered at the surface becoming more widely spaced, tighter and less weathered with depth. Many of the joint surfaces were covered or revealed by secondary mineralization of calcite, quartz and limonite.

Several shear and/or fracture zones of varying sizes were mapped during the 1980 field program. The surface locations of these fractures is shown on the geologic map. Similar shear and fracture

zones were identified during the drilling program (see Appendix B). Where drilled, these zones are typified by highly fractured rock, clay gouge, slickensides and overall poor rock quality.

The two largest shear zones which were identified in previous studies and were verified by this program are located upstream and downstream of the proposed dam (Figure 6.3). The first of these shear zones is evidenced in a bedrock exposure on the north abutment approximately 3,000 feet upstream of the proposed dam axis. This feature, called "The Fins" by the COE, occurs within the diorite pluton, and is mapped in excess of 400 feet wide. The major shears within this zone strike 310° and dips 65° NE. No evidence for this zone has been observed on the south abutment due to poor bedrock exposure. The trace of this zone to the northwest may correlate with a highly oxidized and sheared diorite outcrop on Tsusena Creek. This outcrop, which has undergone hydrothermal alteration, is characterized by clay gouge, mylonite and numerous slickensided surfaces. Other evidence which may support a northwest continuation of "The Fins" is seen in the seismic refraction surveys on the north abutment which show a lower bedrock velocity associated with the trace of this feature (14, 18). Additionally, the trace of the feature closely coincides with a morphologic depression.

The second shear zone, called the "Fingerbuster" by the COE, is located 2,500 feet downstream of the proposed dam axis on the north abutment. BH-2 intersected this feature on the right abutment. The boring drilled through approximately 100 feet of highly fractured, sheared rock which contained clay seams and gouge. The shear zone is coincidental with the andesite/diorite contact. This feature was not mapped on the left abutment due to lack of rock exposure.

Other smaller fracture or shear zones were mapped along the left abutment. These fractures were limited in exposure and will require further investigation during the 1981 program.

(iii) Rock Quality

The Rock Quality Designation (RQD) was determined for all rock cores and is graphically shown on the Summary Logs in Appendix B-3. The rock quality encountered in the drilling was generally good to excellent with RQD's averaging between 75 and 100% (see Table 6.1). In general, rock quality increased with depth, with the upper 50-80 feet of the surface being weathered and more fractured. Below this weathered zone, rock quality tends to increase with only localized zones of fractured and sheared rock. These zones generally range in thickness from 1 to 4 feet.

The poorest quality rock was found in BH-2 which drilled through the "Fingerbuster" shear zone. This boring was sited downstream of the fracture and directed N45E at an inclination of 55°. As seen in the boring logs, the shear zone was intersected at an approximate depth

of 70 feet and continued to an approximate hole length of 100 feet (vertical depth 65 to 80 feet). The zone, which corresponds with the andesite/diorite contact, consists of highly fractured, brecciated and sheared rock. Repeated grouting was required to maintain hole stability. Below this zone, rock quality improved with only localized zones of low RQD's encountered around 200-210 and 250 feet depths, respectively.

(iv) Rock Permeability

Water pressure tests were performed in all of the borings, however no testing was performed below 850 feet in BH-6 and below 70 feet in BH-2 due to unstable hole conditions (Appendix B-3). Graphic representation of the calculated permeabilities are shown on the Summary Logs (Appendix B-3). Overall, rock permeability is relatively low, ranging from 10^{-4} to 10^{-6} cm/sec. Water losses were somewhat higher in the shallower portion of the holes.

(d) Groundwater

The groundwater regime in bedrock is confined to movement along fractures and joints within the rock. Water levels, as measured during the drilling program, ranged from 16 feet below ground surface in hole BH-8 to 147 feet in BH-6. Although very little data is currently available relative to the groundwater, it is assumed that the groundwater in the non-permafrost areas of the north abutment is a subdued replica of the topography with groundwater gradients being towards the Susitna River and its tributaries.

(e) Permafrost

A limited amount of data is currently available regarding permafrost condition at the Watana site.

Ten thermal probes, consisting of 3/4 inch galvanized steel pipes filled with diesel fuel, were installed by the COE in boreholes on both abutments to monitor ground temperatures. Multiple readings performed over a 5 month period on several of these thermisters showed permafrost conditions on the south (left) abutment. Of four holes instrumented, all but hole DH-21 which was drilled beneath the river gave temperatures below freezing to the bottom of the hole. The deepest hole was DH-28 drilled to a depth of 125 feet. Maximum cold temperatures ranged around -0.7 to -0.6°C.

During the early phases of this program, an attempt was made to read these instruments with the results summarized in Figures 6.7 and 6.8. Most of the probes on the (left) south abutment were blocked with ice or showed sub-zero temperatures at depths of 15 to 30 feet below ground surface; and it is, therefore, evident that permafrost exists in the south abutment at relatively shallow depths. Because of the ice blockage, and shallow probes, it was not possible to determine the bottom depth of the permafrost. Temperatures within this shallow zone ranged from -0.01 to -0.52°C. No evidence of permafrost was observed from probes on the north abutment. However, it was determined that ground temperatures are within 0.5°C of the

freezing point to considerable depths.

Auger drilling in Borrow Area D by both the COE and AAI indicates that discontinuous permafrost may exist throughout the area. Visible ice was identified in several of the soil samples to depths of 10 feet or more. On the south abutment BH-8 (AAI, 1980), which has remained open from July, was observed to "freeze back". It was first noted in September during the geophysical logging that the hole was "necked down" at about 175 feet and the temperature at that depth was less than 0°C. The hole was next checked in November and found to be completely frozen. In preparation for installation of the present (1980) instrumentation, warm water was pumped down the hole to thaw the ice. At the start of the melting operation, ice was encountered at a depth of 50 feet. Melting proceeded to a depth of 170 feet where the hole was blocked by caving. A thermistor string was installed in BH-6 on the north abutment to a depth of 250 feet. However, temperatures have not yet stabilized in the hole. It is to be noted that this hole remained open and unfrozen from the time of its completion in July until instrumentation was installed in November, therefore, the hole does not appear to penetrate a permafrost zone.

(f) Borrow Areas

The 1980 investigation program was planned to confirm the material sources previously identified by the COE and to provide additional information as to their geotechnical properties, thickness and areal extent. Primary emphasis was placed on defining the core and filter material sources and verifying the quantities of rock fill previously identified near the dam site. The explorations conducted included geologic mapping, auger drilling, seismic refraction surveys, and laboratory testing. The location map for all the exploration programs is given as Figure 6.1. The boring logs are shown in Appendix C-1, the laboratory test program in Appendix C-2, and the seismic refraction study in Appendix D.

(i) Rockfill Material

Two quarries previously designated "Quarry A" and "Quarry B" by the COE (Figures 6.1 and 6.9) were investigated. Additional surficial mapping was performed in Quarry A on the south (left) abutment and indicated the exposed rock is primarily andesite overlying diorite (Figure 6.3). This differs from the interpretation of the earlier exploration with diamond core drilling and detailed mapping to confirm the thickness and extent of the various rock units. Quarry B was investigated by additional surficial mapping and a seismic line across the central section of the area (Figure 6.1). The data collected indicates that overburden in this area may be as much as 300 feet thick which would preclude exploitation of this quarry.

(ii) Core Material - Borrow Area D

This borrow area was identified by the earlier investigations as a primary source of impervious and semi-pervious material for the dam construction. The area is located 1.5 miles upstream of the dam

axis on the north (right) abutment (Figures 6.1 and 6.9). Four additional auger holes and two additional seismic lines performed during the 1980 program generally confirm the earlier findings.

Overburden throughout the area is very thick, ranging from 150 to as much as 350 feet thick (14). The material in this area is composed of a surface layer of natural ground cover of organic material, two to three feet of boulders and organic silts underlain by glacial tills of dense gravel silty sands. The tills range from 15 to 25 feet thick and usually overlie a clay to sandy gravelly clay.

Grain size distribution curves of the till samples tested in this investigation (Appendix C-2) and the COE program (18) show that the material is well graded ranging from silt and gravelly sand. The material is generally dense to very dense in-situ and has a natural moisture content ranging from 6.6 to 25.7 percent with an average of 11 percent. The finer fraction of the material is generally non-plastic to very low plasiticity (PI ranges 2 to 12). The shape of the compaction curves indicate that moisture content will be critical in obtaining maximum density and strength.

(iii) Filter Material - Borrow Area E

This borrow area was identified as the main source of filter and concrete aggregate material by the COE (18). Borrow Area E is an alluvial deposit formed at the mouth of Tsusena Creek on the right bank of the Susitna River approximately four miles downstream of the dam site (Figures 6.1 and 6.9). Nine auger holes ranging from 5 to 31 feet deep were drilled in this area to expand the previous work (Appendix C-1). As well additional seismic refraction lines (18) were run to confirm the thickness of the alluvial material and the limits of the proposed Borrow area.

The auger drilling indicated a thin layer of organic material and silt over most of area varying from 0.5 to 2.0 feet thick. This layer is underlain by 0.5 to 3.0 feet of silty sand to clean sand, below which is a 6 foot thick layer of sandy gravel. The sand and gravel materials are well rounded particles up to 4 inches and diameter and are clean and well graded. The size of the particles appears to increase below 10 feet with variable cobble and boulder content that hindered the drilling. The water table in this area varies from 7 to 16.5 feet below the ground surface and near the base of the sandy gravel layer.

Two holes were drilled on a sand bar further upstream on Tsuser Creek (Figure 6.1) in an attempt to expand the limits of Borrow Area E and provide additional quantities of material. Both holes were terminated at less than 10 feet deep due to a high concentration of boulders. However the overburden profiles compare favorably with the work from the main section of the borrow area. The two new seismic lines ran on the northwest portion of the area confirm that the alluvial materials vary in thickness from 30 feet to as much as

200 feet locally with an average thickness of 30 to 50 feet.

Grain size distribution curves of the bag sample material show that the upper few feet of material consists of sandy silt grading downwards to silty sand. This layer is generally poorly graded and relatively fine grained with 30 to 60 percent passing the No. 200 sieve.

The underlying material is classified as sandy gravel to gravelly sand with trace to some silt. This material is relatively clean with a few fines and well graded. The grain size distributions for this layer show very good correlation with the results obtained by the COE for Borrow Area E. Natural moisture content for the sandy silt layer range from 15.7 to 27.3 percent. The gravelly sand layer by comparison has natural moisture content ranging from 4.4 to 9.8 percent (all samples were taken from above the water table).

All the new data is consistent with the earlier data gathered by the COE. However, based on the additional holes and seismic lines the borrow area can be expanded upstream along Tsusena Creek.

(iv) Other Potential Material Sources

During the course of the current and previous investigations within the dam site area, several potential sources of materials, other than those discussed above, were identified (Figure 6.9). However, considerable additional investigation will be required to evaluate the type, suitability and quantities of materials available from these areas. The various source areas are discussed below in terms of the types of materials which might be obtained from them.

- Sources of Rockfill Material

Considerable rock excavation will be required during construction for the dam foundation, underground powerhouse, penstocks and spillway. This rock and soil from the various excavations may be suitable for use in the rockfill portions of the dam depending on the quality of the material and the construction schedule.

- Sources of Core Material

Based on reconnaissance mapping and exploration, three areas were identified as potential sources of core material. Several bag samples were collected to aid in the preliminary definition of the materials. The first area, designated as Borrow Area H, is located southwest of the Fog Lakes area (Figure 6.9) and is approximately five to seven miles from the dam site. The topography of this area is generally flat to gently rolling. Most of the surface is covered by shallow swamps and marshes indicating poor drainage and relatively impervious underlying materials. Slump exposures along Fog Creek and the Susitna River indicate the

underlying materials to be a relatively thick layer of lodgement till consisting of silt, sand, and gravel and some cobbles with a trace of clay. A large ice wedge was observed in a slump exposure on the west end of the site indicating that the till may be frozen locally.

The second area is located to the east of Borrow Area D on Deadman Creek one to two miles upstream from the confluence with the Susitna River and approximately three miles from the dam site. Based on cliff and slump exposures along Deadman Creek and the morphology of the site, three types of materials were identified in this area. These materials consist of glacial outwash, ablation till and lodgement till. The outwash consists of a relatively clean, medium to coarse grained sand with some gravel, cobbles and boulders. The ablation till is composed primarily of silt and sand with minor amounts of gravel, cobbles and clay, while the lodgement till is a sandy, clayey silt with some gravel and cobbles and generally very compact.

The topography of this area is generally flat to gently rolling with several old channels superimposed on the surface. These old channels are indicative of fluvial processes and it is, therefore, assumed that much of this site is blanketed with a layer of outwash material of variable thickness overlying a series of tills.

The third area is located directly west of the present Borrow Area D. A review of the previous data suggests that the percentage of tills and clay-rich material increases to the west. Additional investigation will be required to verify this.

- Sources of Filter Material

In the upper reaches of Tsusena Creek, the COE delineated two areas designated Borrow Area C and Borrow Area F (Figure 6.9) which may be suitable sources of filter material. To date only a limited amount of investigation, consisting of test pits in area "F" and three seismic lines in area "C", has been performed (Figure 6.1). Additional investigations and testing will be required to verify the type and quantities of materials in each area.

Based on surficial mapping and general reconnaissance in the vicinity of the dam site, it would appear that the area surrounding the confluence of Clark Creek and Tsusena Creek, approximately five to six miles north of the dam site, may provide a potential source of filter material. This area appears to be composed primarily of alluvial materials and re-worked glacial outwash.

One sample of material was also collected from a gravel bar

exposed in the river channel slightly upstream of the dam. The grain size distribution curve shows that this sample is a gravel in a sand matrix with a few cobbles but few fines. This is a near surface sample and may not be representative at depth but does show that further investigation of this material for filter material is warranted.

(g) Reservoir Geology

Preliminary reconnaissance mapping of the Watana Reservoir was performed for the 1980 field program. This consisted of flying over the reservoir area and identifying principal rock types and general types of surficial material.

The topography of the Watana Reservoir and adjacent slopes is characterized by a narrow V-shaped stream-cut valley superimposed on a broad U-shaped glacial valley. Surficial deposits mask much of the bedrock in the area, primarily in the lower and uppermost reaches of the reservoir. A surficial geology map of the reservoir, prepared by the COE, distinguishes till, lacustrine and alluvial deposits (18).

(i) Surficial Deposits

Generally, the lower section of the Watana Reservoir and adjacent slopes are covered by a veneer of predominantly glacial till with scattered outwash deposits. Two main types of till have been identified for the area; ablation and basal tills. The basal till is overconsolidated, has a fine grained matrix (more silt and clay) and has a low permeability. The ablation till has less fines and a somewhat higher permeability. Outwash deposits consist of cobbles, gravels, and sands that exhibit a crude stratification and are well drained.

On the south side of the Susitna River, the Fog Lake area is characteristic of a fluted ground moraine surface. Upstream in the Watana Creek area, glaciolacustrine material forms a broad, flat plain which mantles the underlying glacial till and the semi-consolidated Tertiary sediments. This material consists predominantly of stratified, poorly graded, fine grained sands and silts with lesser amounts of clay. Significant alluvial deposits exist in the river valley and consist of re-worked outwash and alluvium. Deglaciation of the area was accompanied by the filling in of the Susitna River valley and subsequent modification by alluvial processes resulting in the formation of floodplain terraces. Ice disintegration features such as kames and eskers have been observed in the river valley.

Permafrost exists in the area as evidenced by ice wedge polygons, stone nets and slumping of the glacial till overlying permafrost. Numerous slumps have been identified in the Watana Reservoir area, especially in sediments comprised of basal till and in some instances the Tertiary sediments. The majority of the slumps occur in frozen glacial tills of Watana Creek area and on an unnamed creek

between Deadman and Watana Creek.

(ii) Bedrock Geology

As previously discussed, the Watana dam site is underlain by a dio-rite pluton. Approximately three miles upstream of the Watana dam site, a non-conformable contact between argillite and the dioritic pluton crosses the Susitna River. An approximate location of this contact has also been delineated on Fog Creek, 4 miles to the south of the dam site. Just downstream of the Watana CreekSusitna River confluence, the bedrock consists of semi-consolidated, Tertiary, sedimentary rocks (15) and volcanics of the Triassic age (Figure 6.5). These Triassic volcanics consist of metabasalt flows with minor thin interbeds of metachert, argillite, metavolcaniclastic rocks and marble (21). From just upstream of Watana Creek to Jay Creek, the rock unit consists of a metavolcanogenic sequence dominantly composed of metamorphosed flows and tuffs of basaltic to andesitic composition. From Jay Creek to just downstream of the Oshetna River, the reservoir is underlain by a metamorphic terrain of amphibolite and minor amounts of greenchist and foliated diorite. To the east of the Oshetna River, glacial deposits predominate.

The main structural feature of the Watana Reservoir is a thrust which trends northeast-southwest and is known as the Talkeetna Thrust (4). This thrust fault crosses the Susitna River approxi-mately eight miles upstream of the Watana dam site. The dip of this fault is uncertain as Csejtey and others (4) have interpreted it to have a southeast dip, while Turner and Smith (17) suggest a nothwest dip. To date, there is no evidence for recent displacement along this fault. At the southwest end of the fault, unfaulted Tertiary volcanics overlie the fault (4). Evidence of possible faulting has been observed in the sedimentary and volcanic rock of Jurassic age, north of Watana Creek (4, 17). Investigations of the Tertiary sedi-ments in Watana Creek, by members of the University of Alaska Geo-logy Department, however, did not uncover any direct evidence of faulting.

Additional work on the reservoir geology is planned for the 1981 program.

6.2 - Devil Canyon

(a) General

This section discusses the overburden and geologic conditions at the Devil Canyon site as investigated by the 1980 program and earlier explorers.

(b) Overburden Conditions

The Devil Canyon has near vertical walls which are generally covered by a thin veneer of overburden. The overburden varies from a few inches to several feet in thickness (Figure 6.10). The overburden consists primarily of talus on or at the base of the near vertical valley walls. On the flat upland areas above 1,500 feet, the slopes are covered by glacial till that varies from 5 to 35 feet thick. An overburden isopach map constructed from seismic survey and boring data is shown on Figure 6.11. On the left abutment (south), there is a topographic depression paralleling the elongated lakes in this region. The overburden in this area reaches a depth of more than 85 feet and consists principally of glacial till material. A terrace or point bar deposit is located approximately 900 feet upstream of the proposed dam axis at the confluence of the Susitna River and Cheechako Creek. The thickness of alluvial material approaches 350 feet (Figure 6.11). Overburden along this point bar thickens rapidly from 100 feet to greater than 300 feet over a distance of less than 400 feet. This steep dropoff in bedrock was identified in previous studies and will be further investigated during the 1981 program.

(c) Bedrock Geology

(i) Lithology

The bedrock at the Devil Canyon dam site primarily consists of a sequence of argillite of Cretageous age. The argillite is well exposed along the canyon walls and in scattered outcrops throughout the area (Figure 6.12). It is a dark gray to charcoal gray, fine grained argillite which is phyllitic in places due to low grade metamorphism. The argillite is chiefly composed of grains of quartz and biotite with pyrite as an accessory. The argillite weathers to a medium gray color. A light to medium gray, fine grained matrix with coarse sand graywacke is interstratified in the argillite sequence. Syndepositional flow structures are evident within the rock core where coarse graywacke particles have been incorporated within a shale matrix. The argillite is thinly bedded, homogeneous, hard, blocky and competent. It contains numerous quartz stringers and veins and aplitic dikes. The aplitic dikes are composed of a white, fine grained siliceous material. Differential weathering of the dikes has produced notches or gullies along the canyon walls. Diorite was encountered in BH-2 (Figures 6.10 and 6.13) at a depth of approximately 640 feet. This material was probably intruded at the same time as the diorite pluton at the Watana site. The extent of the intrusion beneath the Devil Canyon site has not been delineated.

(ii) Bedrock Structure

The thinly bedded argillite unit at the dam site has a strike which varies from 53° to 70° (subparallel to the river) and dips from 50° to 80°SE (Figure 6.12). The dip of the strata has resulted in overhanging cliffs on the south abutment; and in some places, cliff faces parallel to bedding, have formed on the north abutment.

The steep gouge in the area of the dam site appears to be controlled by the bedding resulting in steeper slopes (60°) on the north abutment than the south (45°).

A detailed joint survey was performed at 3 stations near the site (DCJ-1, DCJ-2, DCJ-3), (Figure 6.10). A density contour plot of these joints is shown in Figures 6.14 (a-c). The survey showed one major and two minor sets in the dam site area. The strike of the major set varies from 320° to 350° (approximately NW) and dips an average of 85°NE. The joint spacing associated with this set is generally 3 inches to 3 feet. On the left abutment, some of these joints show as much as 6 inches of opening at the surface; however, the extent of the vertical openness is unknown. One of the minor sets strikes from 70° to 105° and dips 15° to the south. Another set strikes in a similar direction from 60° to 90° with dips ranging from subhorizontal to 65° northwest.

Additional survey mapping will be performed to more accurately define the joint sets.

Several open fractures can be traced along the upper surface of the abutment from near the proposed dam axis to some 1,600 feet downstream and extend 100 feet back from the cliff edge. These fractures are open as much as several feet. In Table 6.2, the orientation of the open joints are listed. Two of the open fracture orientations correlate with a major and one of the minor joint sets. No open fractures have been delineated in mapping the north abutment, as joints are generally tight.

Joint spacing in the borings is moderately close to wide and ranges from less than one to 10 feet with spacing and tightness increasing with depth. Iron staining is common along the joint surfaces and numerous calcite "healed" joints were also encountered.

Several closely fractured or shear zones have been mapped along the canyon walls and in the drill holes (Figure 6.12 and Appendix B-3). In general, these zones are characterized by highly fractured and crushed rock, moderate to high weathering depending on location, clay gouge, higher permeability and core loss during drilling. With depth, these zones become considerably narrower, tighter and further spaced. The trend of these zones is approximately northwest-southeast corresponding to the major joint set. The 1981 program will be to delineate these zones in more detail. These zones are

marked by highly fractured and sheared rock with clay gouge. Of the 3 holes drilled, the poorest quality rock was encountered in BH-4 (Table 6.3), which was drilled beneath the pond on the south abutment for the purpose of determining the existence of a shear zone in that area. Although the quality of the rock in this hole was not as high as the other holes, no evidence could be found in the boring for any major shearing. Additional drilling will, however, be required in this area to insure that shearing was not responsible for forming the topographic depression.

(iii) Rock Permeability

The permeability values computed from the water pressure tests show relatively low permeabilities on the order of 10^{-4} to 10^{-6} cm/sec (Appendix B-2). In most cases, the zones of higher permeability correlate with the upper weathered zones and the more fractured zones at depth. Examination of the tests performed in BH-4 showed minimal water losses in more highly fractured zone showing the overall tightness of the rock mass.

(d) Groundwater

Groundwater migration is restricted to joints and fractures within the rock. As described in Section 5, several piezometers have been installed to define the site groundwater regime. Data collected thus far at the site has been insufficient to accurately define the groundwater conditions; however, it is assumed that the groundwater level is a subdued replica of the surface topography with the gradients being towards the river and ponds.

(e) Permafrost

Preliminary temperature measurements made in the borings showed no permafrost conditions on either of the abutments. Additional monitoring of the instrumentation will be carried out throughout the project to accurately define a temperature profile.

(f) Borrow Areas

The 1980 investigations at the Devil Canyon site were designed to confirm the concrete aggregate source near Cheechako Creek previously identified by the WPRS. As well reconnaissance mapping of the surrounding area was conducted to identify sources of impervious materials for the cofferdam and the saddle dam.

(i) Concrete Aggregate

The previous investigations had identified the alluvial fan near the Cheechako Creek confluence approximately 1,000 feet upstream of the proposed dam. However, due to limitations an accessibility at the site only two auger holes were drilled during this investigation.

These holes, located in the western side of the fan, were drilled to depths of 11 and 23 feet respectively. Data from these holes indicate a thin mantle of organic material overlies three to four feet of silty sand. Below the sand is a layer of sandy gravel with a trace of silt and scattered boulders and cobbles that hinder the drilling progress. Seismic lines run by Shannon & Wilson for the COE (14, 18) indicate that this layer is as much as 80 feet thick, extending to approximately elevation 870 feet.

Results of the laboratory testing conducted by WPRS (19) indicate that the material from this fan is of adequate quality for use as concrete aggregate. The gravel particles are stream worn and generally rounded, with the accompanying subangular sands. Petrographic analyses of the sand and gravel indicates that the fan composition includes quartz diorites, granites, andesites, diorites, dacites, metavolcanic rocks, aplites, breccias, schists, phyllites, argillites, and amphibolites. Generally the material is of good quality with less than 2 percent deleterious constituants such as chert, muscovite, and argillite. The particles are generally fresh with only 13 percent of the material tested showing deterioration or weathering effects.

From the tests conducted to date, there appears to be a deficiency of 3/4 to 1-1/2 inch gravel. However this could be accommodated by the selective processing of local morainal materials.

(ii) Impervious Material

Reconnaissance mapping of the areas adjacent to the canyon by this and previous investigations has shown that the area is mantled with outwash and till materials several feet thick. In addition, the buried channel area on the south abutment is filled with some 90 feet of glacial material. This material was described during the field programs as generally dense, well graded and composed of particles ranging in size from rock flour to boulders. This material may provide a source of impervious fill but will require screening and blending to produce a satisfactory product.

(iii) Additional Material Source

Two terraces have been mapped on the east side of Cheechako Creek (Figure 6.4) southeast of the proposed dam axis. The gravel in these terraces is coarser than in the alluvial fan, but may provide additional granular material after processing.

(g) Reservoir Geology

The containment area of the Devil Canyon Reservoir will be confined to the narrow canyon of the Susitna River (Figure 6.5). The topography in and around is bedrock controlled with only thin to non-existent overburden except at the upper reaches of the reservoir where alluvial deposits cover the valley floor.

The large intrusive plutonic body, which underlies the Watana site (see Section 6.1) also extends over adjacent slopes (Figure 6.5). It is predominantly a biotite granodiorite with localized areas of quartz diorite and diorite. It is an off-white to pink light gray generally medium grained rock composed of quartz, feldspar, biotite and hornblende. The most common mafic mineral is biotite. When weathered, the rock has a light yellow gray or pink yellow gray color except where it is highly oxidized and, therefore, iron stained. The granodiorite is generally massive, competent, and hard with the exception of the rock exposed on the upland north of the Susitna River where the biotite granodiorite has been badly decomposed as a result of physical weathering.

The other principal rock type in the reservoir area is the argillite and graywacke, which is exposed at the Devil Canyon dam site. In summary, the argillite has been intruded by the massive granodiorite and as a result, large isolated roof pendants of the argillite and graywacke are found locally throughout the reservoir and surrounding areas. The argillite/graywacke varies to a phyllite of low metamorphic regime.

The rock has been isoclinally folded into steeply, dipping structures which generally strike northeast-southwest. The contact between the argillite and the biotite granodiorite crosses the Susitna River just upstream of the Devil Canyon dam site. It is non-conformable and characterized by an almost aphanitic texture with an apparent wide chilled zone. The trend of the contact is roughly northeast-southwest as it crosses the river. Several large outcrop areas of the argillite which are completely surrounded by the biotite granodiorite are located in the Devil Creek area (see Figure 6.12).

Preliminary joint measurements made in the reservoir area indicate structural trends similar to those encountered at the dam site (Table 6.2). Joint spacing at these stations ranged up to 3.0 feet.

TABLE 6.1

WATER BOREHOLE ROCK QUALITY DISTRIBUTION

BOREHOLE NUMBER	PERCENTAGE OF RECOVERED CORE IN SPECIFIC RQD RANGES					
	0-25%	25-50%	50-75%	75-90%	90-95%	95-100%
BH-2	19	15	22	17	13	14
BH-6	5	2	13	22	15	43
BH-8	4	7	18	16	18	38

ROCK QUALITY CLASSIFICATION (MODIFIED FROM DEERE, 1963)

0-25%	-	Very Poor
25-50%	-	Poor
50-75%	-	Fair
75-90%	-	Good
90-95%	-	Very Good
95-100%	-	Excellent

TABLE 6.2

DEVIL CANYON
ORIENTATION OF DISCONTINUITIES

	STRIKE (AVERAGE)	DIP (AVERAGE)
Joints, Major	320° to 350° (335°)	78°NE to 77°SW
Joints, Major	70° to 105° (83°)	0 to 35°S
Joints, Minor	60° to 90° (79°)	55° to 75°SE
Fractures, Open	300° to 338°	87°SW to 74°NE
	28° to 55°	68°SE to 82°W
	75° to 100°	43°SE to 86°SE
	135° to 140°	Vertical

Note: Joint stereonets are shown on Figures 6.14, a to c.

TABLE 6.3

DEVIL CANYON BOREHOLE ROCK QUALITY DISTRIBUTION

BOREHOLE NUMBER	PERCENTAGE OF RECOVERED CORE IN SPECIFIC RQD RANGES					
	0-25%	25-50%	50-75%	75-90%	90-95%	95-100%
BH-1	2	2	9	21	15	51
BH-2	3	1	7	14	20	55
BH-4	1	8	16	22	16	37

ROCK QUALITY CLASSIFICATION (MODIFIED FROM DEERE, 1963)

0-25%	-	Very Poor
25-50%	-	Poor
50-75%	-	Fair
75-90%	-	Good
90-95%	-	Very Good
95-100%	-	Excellent

LEGEND

■TP	TEST PIT	
●AP	AUGER HOLE	CORP OF ENGINEERS, 1978
●DH	CORE DRILL HOLE	
●DR	ROTARY DRILL HOLE	
●BH	BOREHOLE	SUMMER 1980 PROGRAM
●AH	AUGER HOLE	

SEISMIC LINE :
DM, SW - CORP OF ENGINEERS, 1978
SL - SUMMER 1980 PROGRAM

CROSS SECTIONS

⊕WJ LOCATION OF JOINT MEASUREMENTS

BORROW AREA F

BORROW AREA C

BORROW AREA D

BORROW AREA E

QUARRY SOURCE A

QUARRY B

TSUSENA CREEK

DEADHORSE CREEK

SUSITNA RIVER

NOTE:

1) SECTION SHOWN ON FIGURE 6.4

2) TOPOGRAPHIC CONTOURS ARE APPROXIMATE

SCALE IN FEET 1000 0 1000 2000 3000

CONTOUR INTERVAL: 100 FEET

REF. U.S. ARMY CORPS OF ENGINEERS SUPPLEMENTAL FEASIBILITY REPORT 1979.

WATANA LOCATION EXPLORATION MAP

FIGURE 6.1

LEGEND

DATA POINTS

• DRILL HOLE

△ SEISMIC LINE STATION

---- DEPTH TO BEDROCK CONTOUR APPROXIMATE

BURIED CHANNEL THALWEG

MAJOR BEDROCK OUTCROPS

SUSITNA RIVER

NOTE:
TOPOGRAPHIC CONTOURS ARE APPROXIMATE

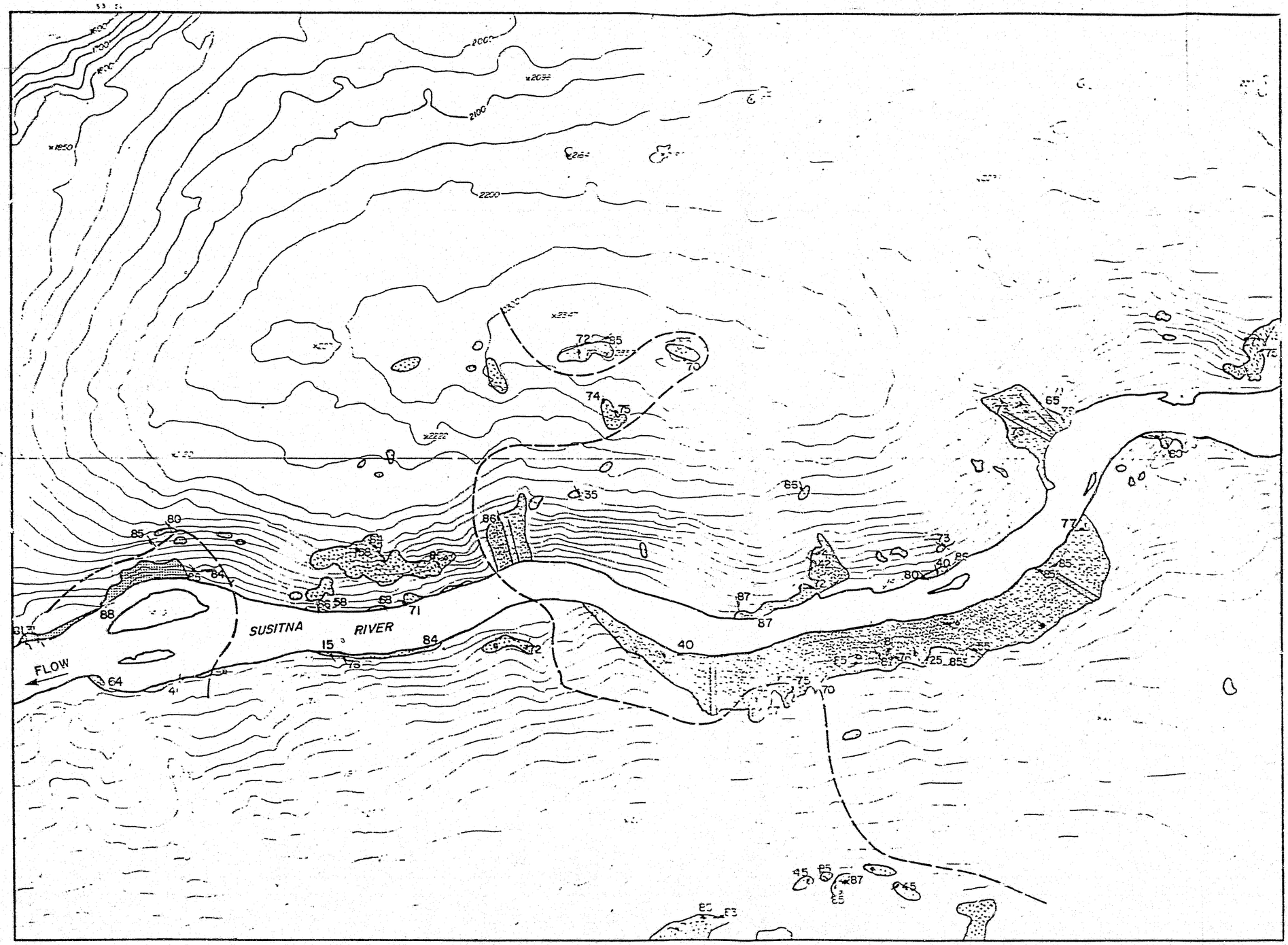
1000 0 1000 2000 3000
SCALE IN FEET

CONTOUR INTERVAL: 100 FEET

REF. U.S. ARMY CORPS OF ENGINEERS
SUPPLEMENTAL FEASIBILITY REPORT 1979.

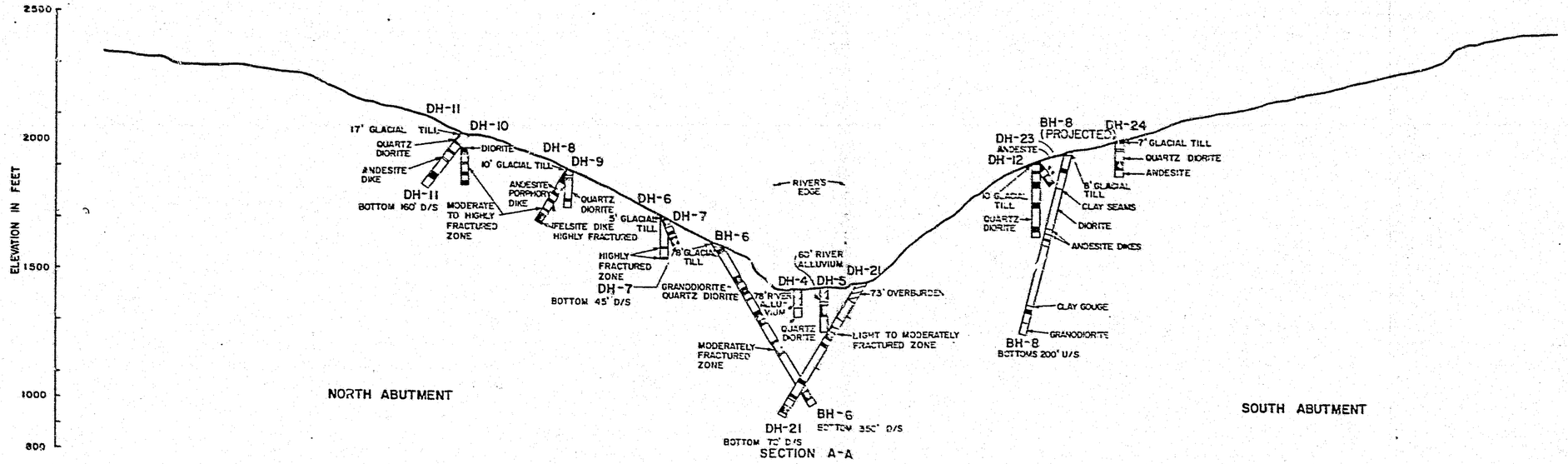
ISOPACH MAP OF OVERBURDEN - WATANA

FIGURE 6.2



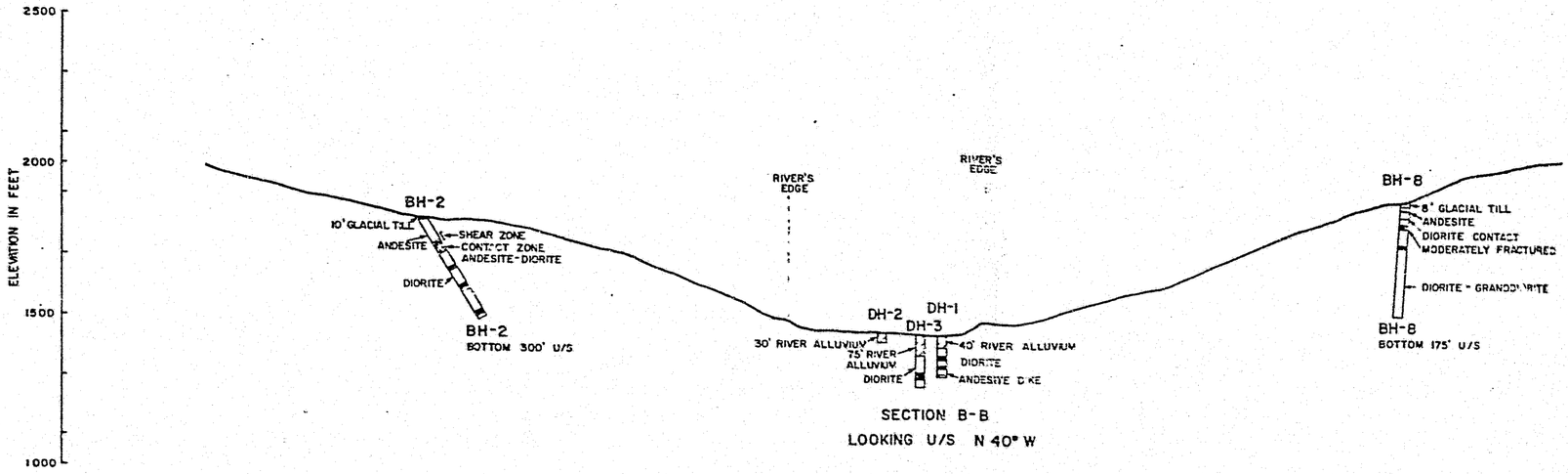
GEOLOGIC MAP OF WATANA

FIGURE 6.3



SECTION A-A

LOOKING U/S N 15° W



SECTION B-B

LOOKING U/S N 40° W

LEGEND

- RIVER ALLUVIUM
- GLACIAL TILL
- SHEAR AND FRACTURE ZONES
- ROCK

NOTES:

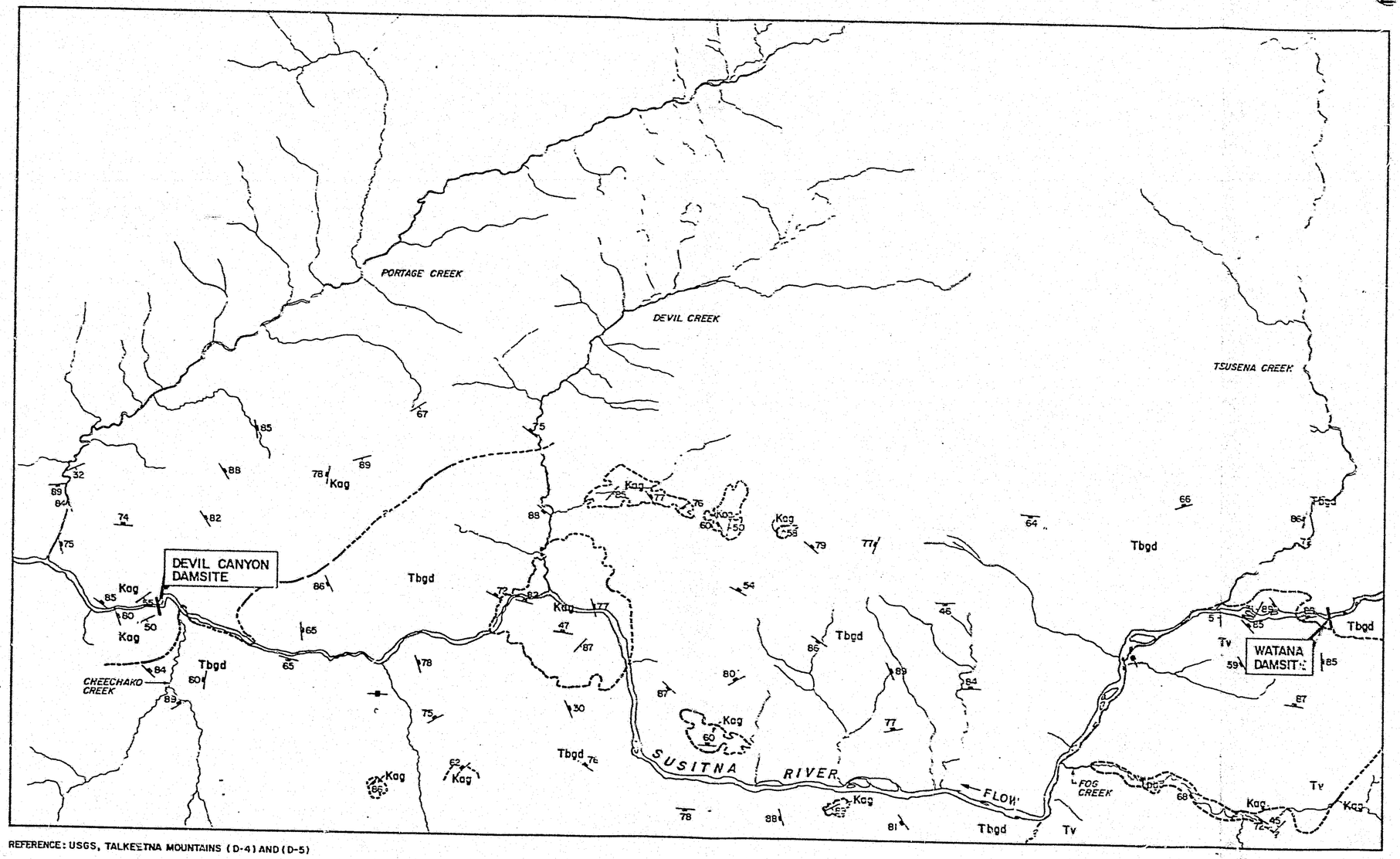
1) VERTICAL AND HORIZONTAL SCALE 1:1
2) SECTION LINE SHOWN ON FIGURE 6.1

200 100 0 200 400
SCALE IN FEET

REFERENCES 1 CORP OF ENGINEERS, 1978 PLATE D-7
2 SUMMER 1980 PROGRAM

GEOLOGIC CROSS SECTIONS - WATANA

FIGURE 64



REFERENCE: USGS, TALKEETNA MOUNTAINS (D-4) AND (D-5)

LEGEND

- Tv — ANDESITE AND ANDESITIC BASALT FLOWS, VOLCANIC CLASTIC SEDIMENTS
- Tbgd — BIOTITE GRANODIORITE, QUARTZ DIORITE, DIORITE
- Kag — ARGILLITE

15 STRIKE AND DIP OF BEDS

75 STRIKE AND DIP OF JOINTS

CONTACT, LOCATED APPROXIMATELY

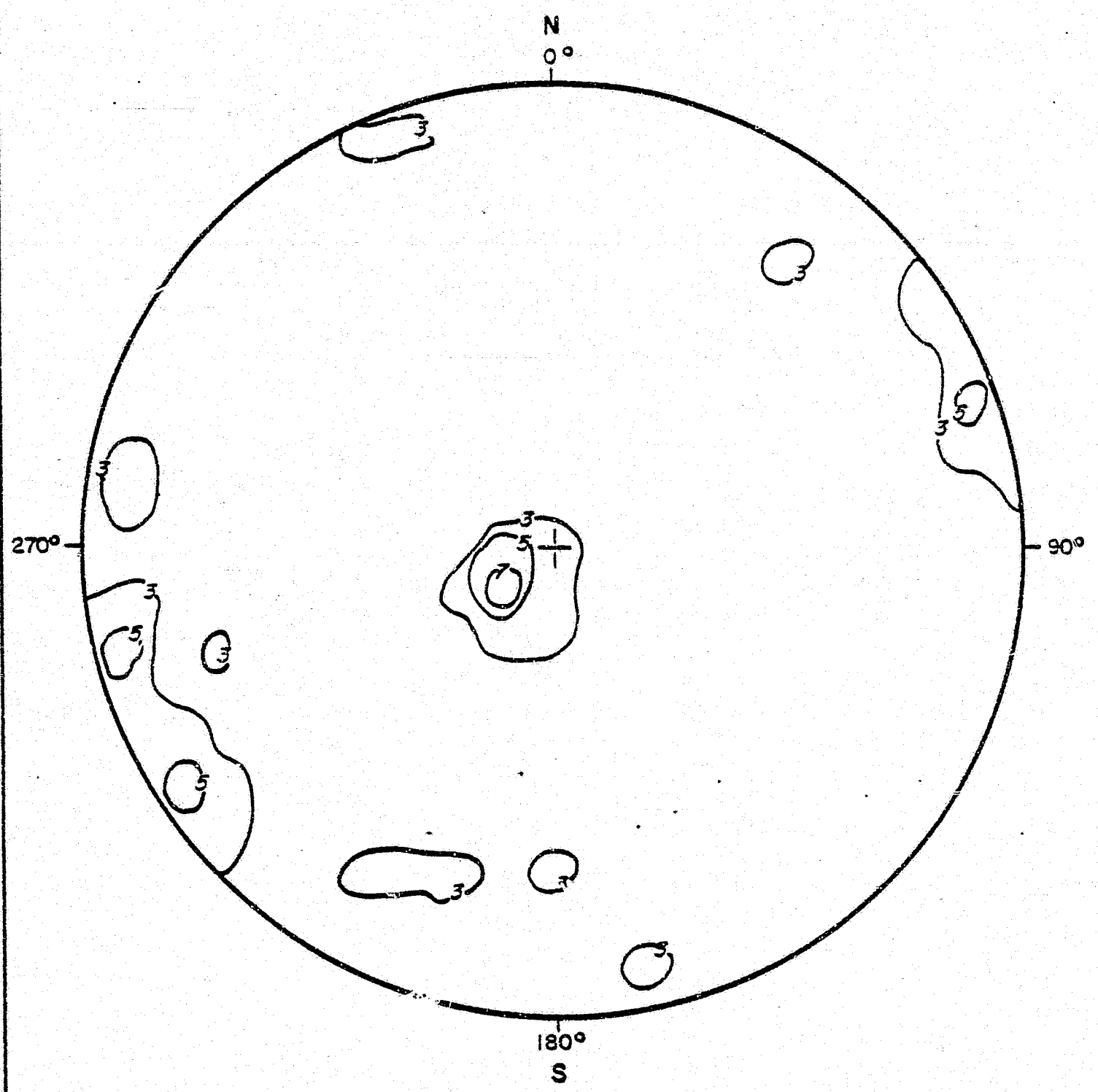
NOTE:

1) GEOLOGIC MAPPING UNDERTAKEN AT A SCALE OF 1:12,000 & 1:63,360

SCALE IN MILES

GEOLOGIC MAP OF DEVIL CANYON RESERVOIR

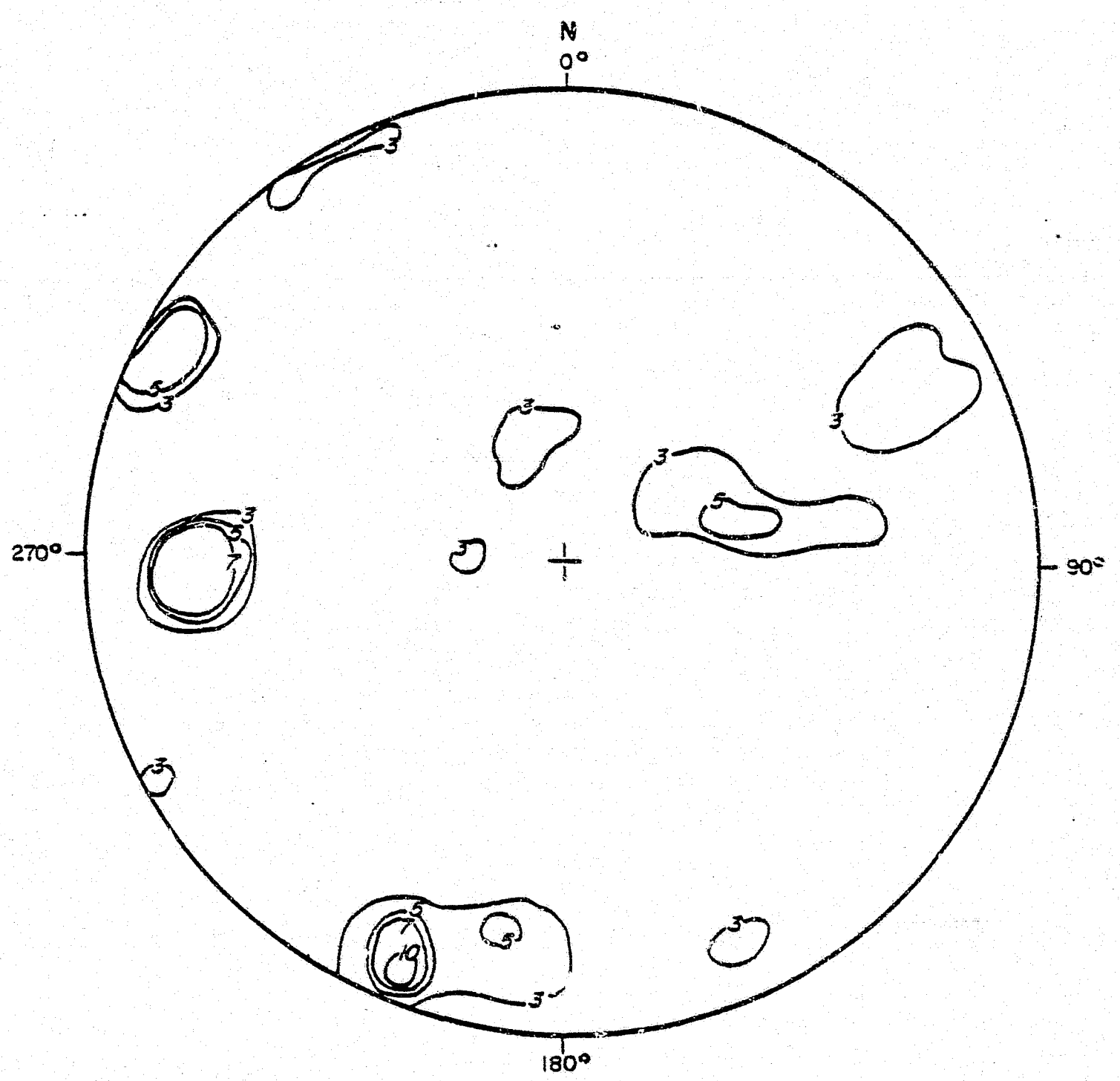
FIGURE 6.5



STATION WJ-1
ELEV. 1470'
n = 86
CONTOUR INTERVAL IS PER 1% OF AREA

JOINT STEREO PLOTS - WATANA

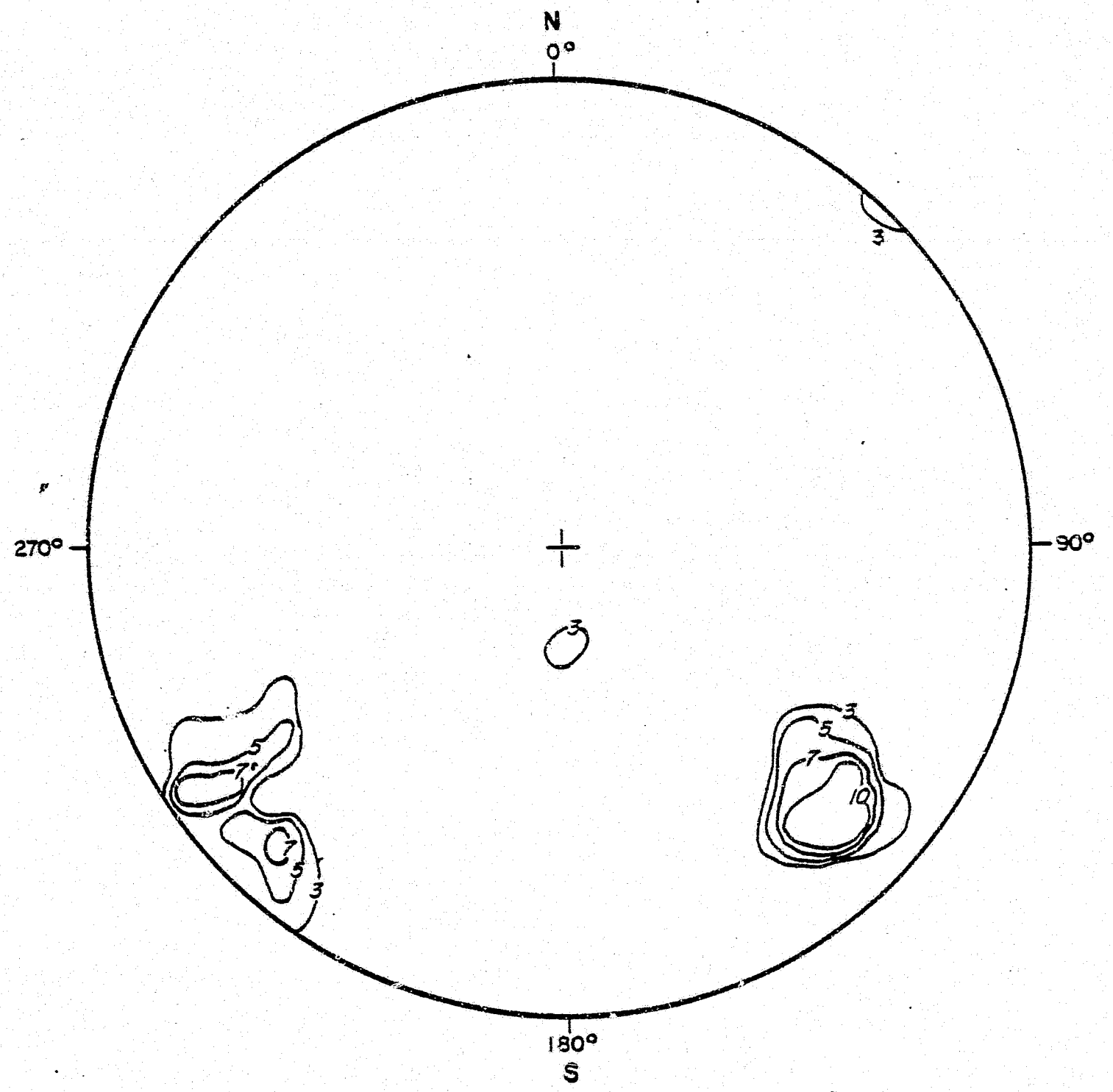
FIGURE 66a



STATION WJ-2
ELEV. 1470'
n = 60
CONTOUR INTERVAL IS PER 1% OF AREA

JOINT STEREO PLOTS - WATANA

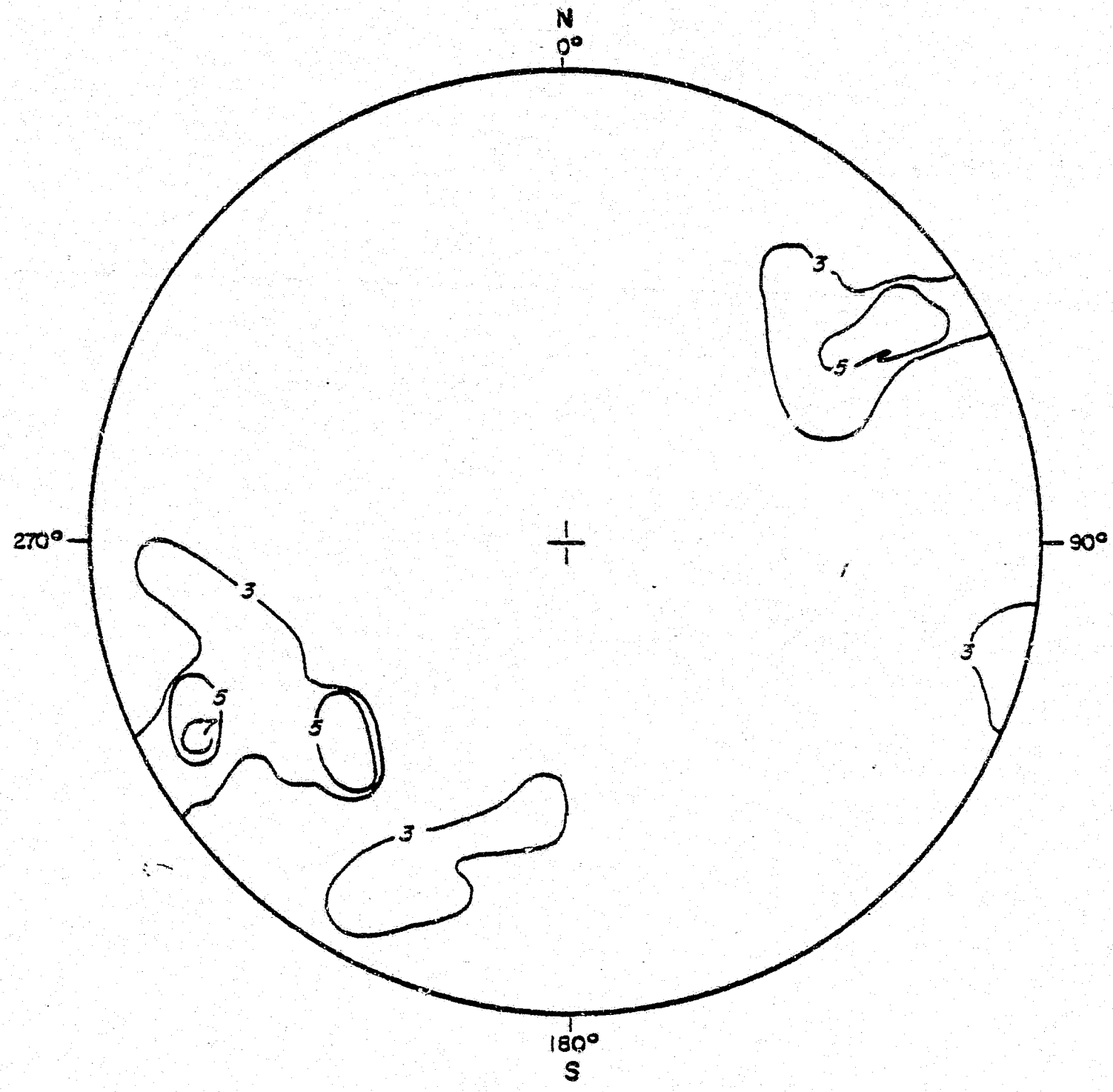
FIGURE 6.6b



STATION WJ-3
ELEV. 1470'
n = 60
CONTOUR INTERVAL IS PER 1% OF AREA

JOINT STEREO PLOTS - WATANA

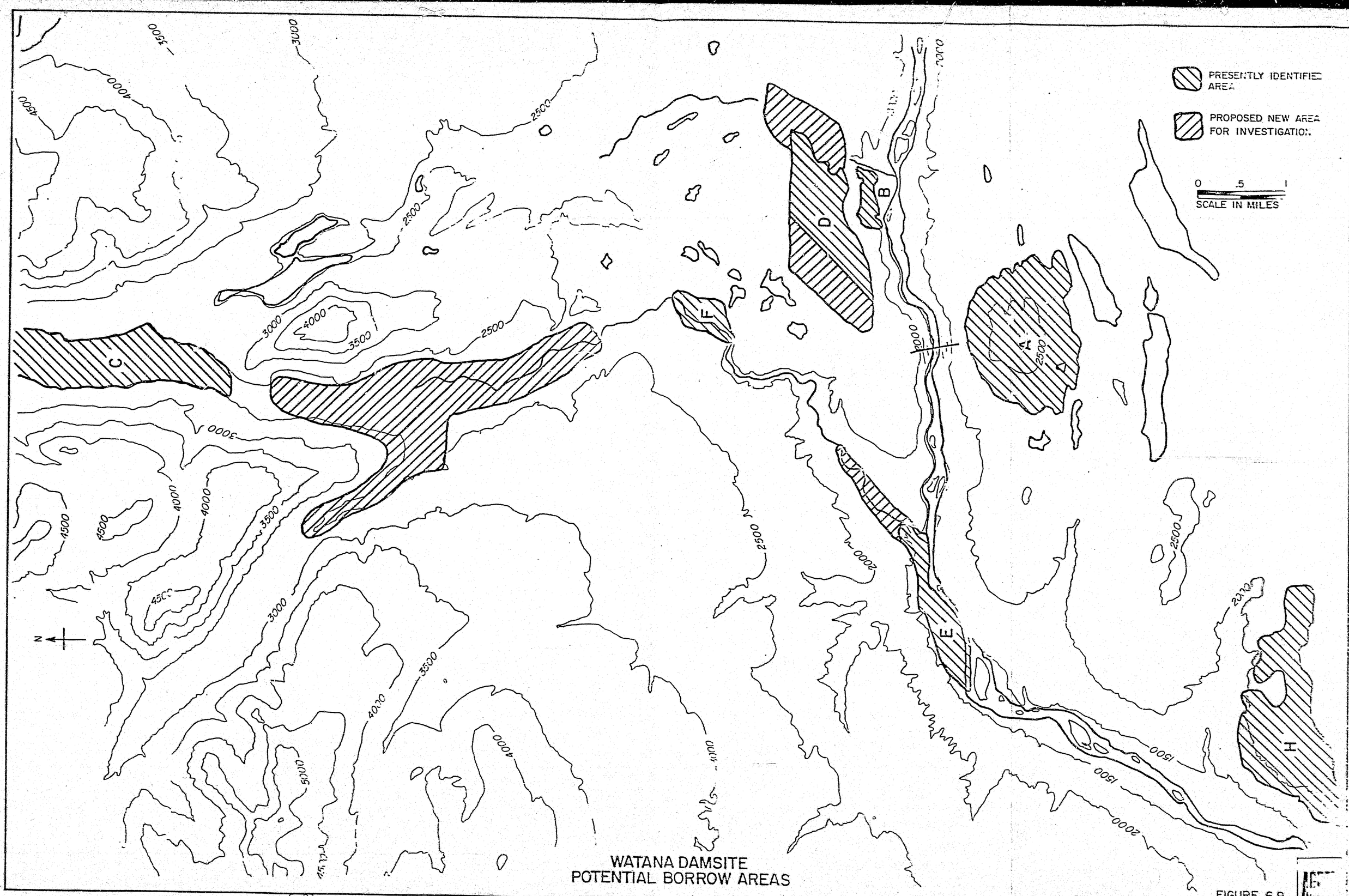
FIGURE 6.6c



STATION WJ-4
ELEV. 1750'
n = 100
CONTOUR INTERVAL IS PER 1% OF AREA

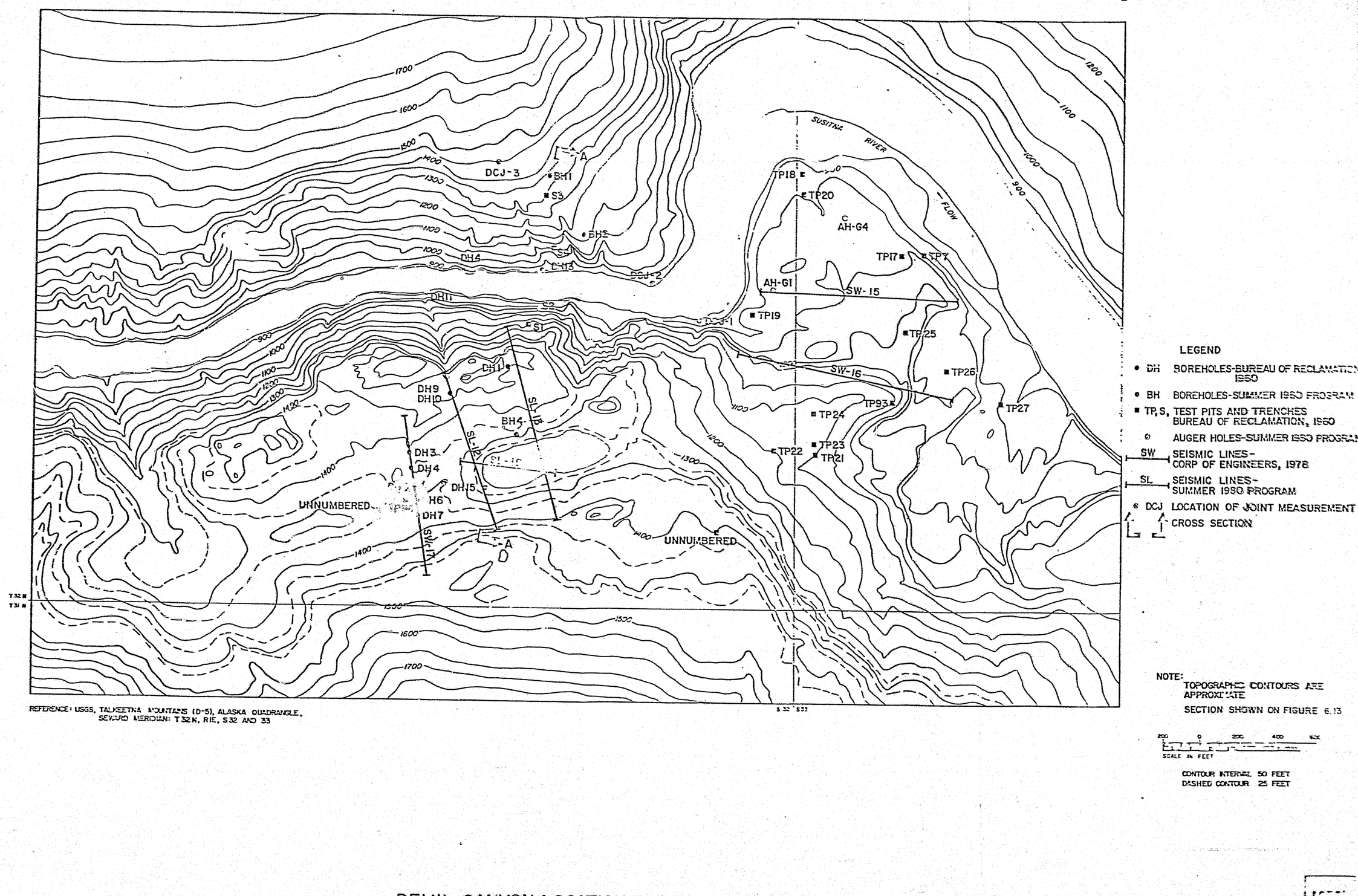
JOINT STEREO PLOTS - WATANA

FIGURE 6.6d



WATANA DAMSITE
POTENTIAL BORROW AREAS

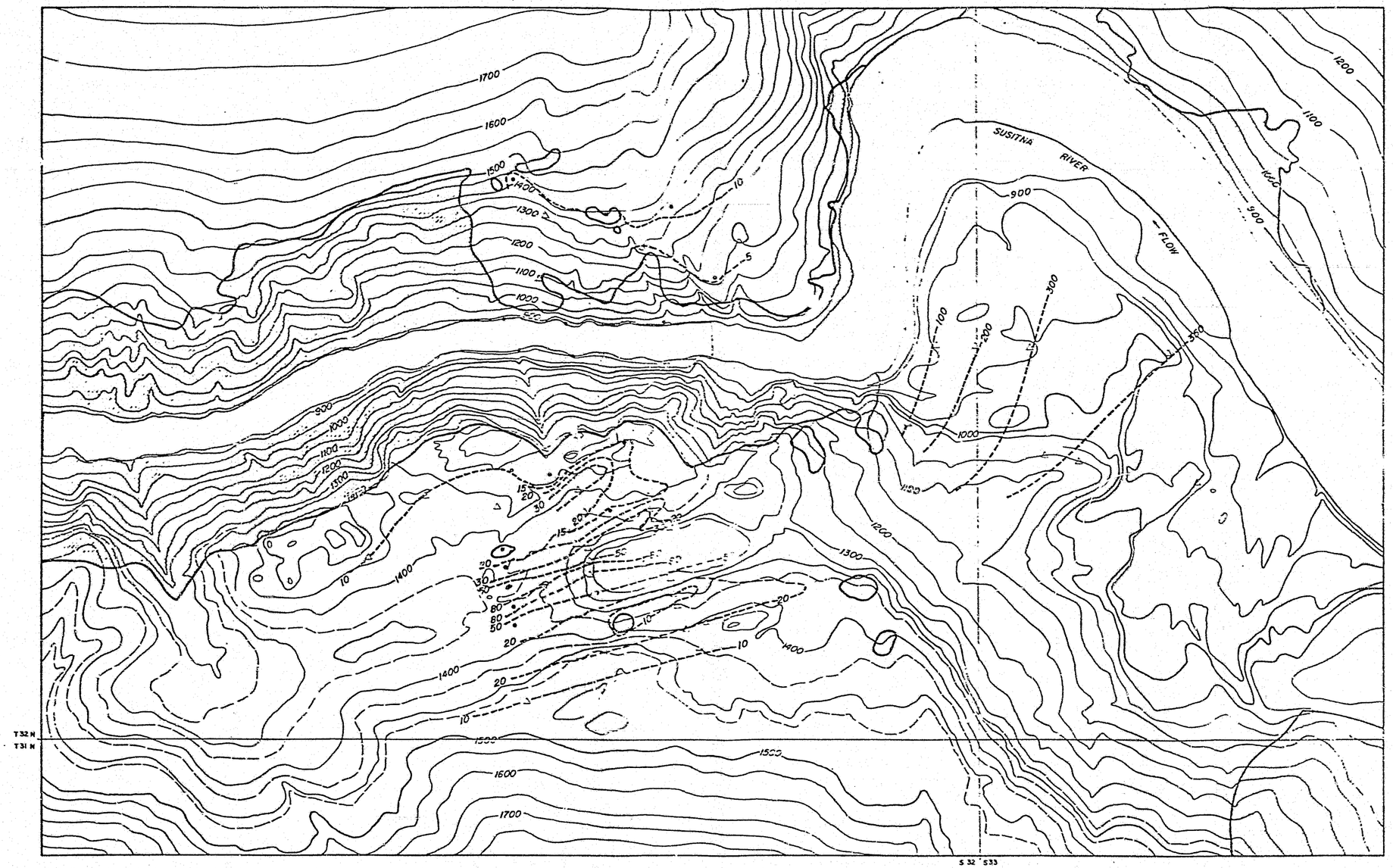
FIGURE 6.9



REFERENCE: USGS, TALKEETNA MOUNTAINS (D-5), ALASKA QUADRANGLE, SEWARD MERIDIAN: T32N, R1E, S32 AND 33

DEVIL CANYON LOCATION EXPLORATION MAP

FIGURE 6.10



LEGEND

DATA POINTS

- DRILL HOLE
- △ SEISMIC LINE STATION

---- DEPTH TO BEDROCK CONTOUR APPROXIMATE

MAJOR BEDROCK OUTCROPS

NOTE:

1) CONTOURS HAVE BEEN ADJUSTED TO TOPOGRAPHY
2) TOPOGRAPHIC CONTOURS ARE APPROXIMATE

200 0 200 400 600

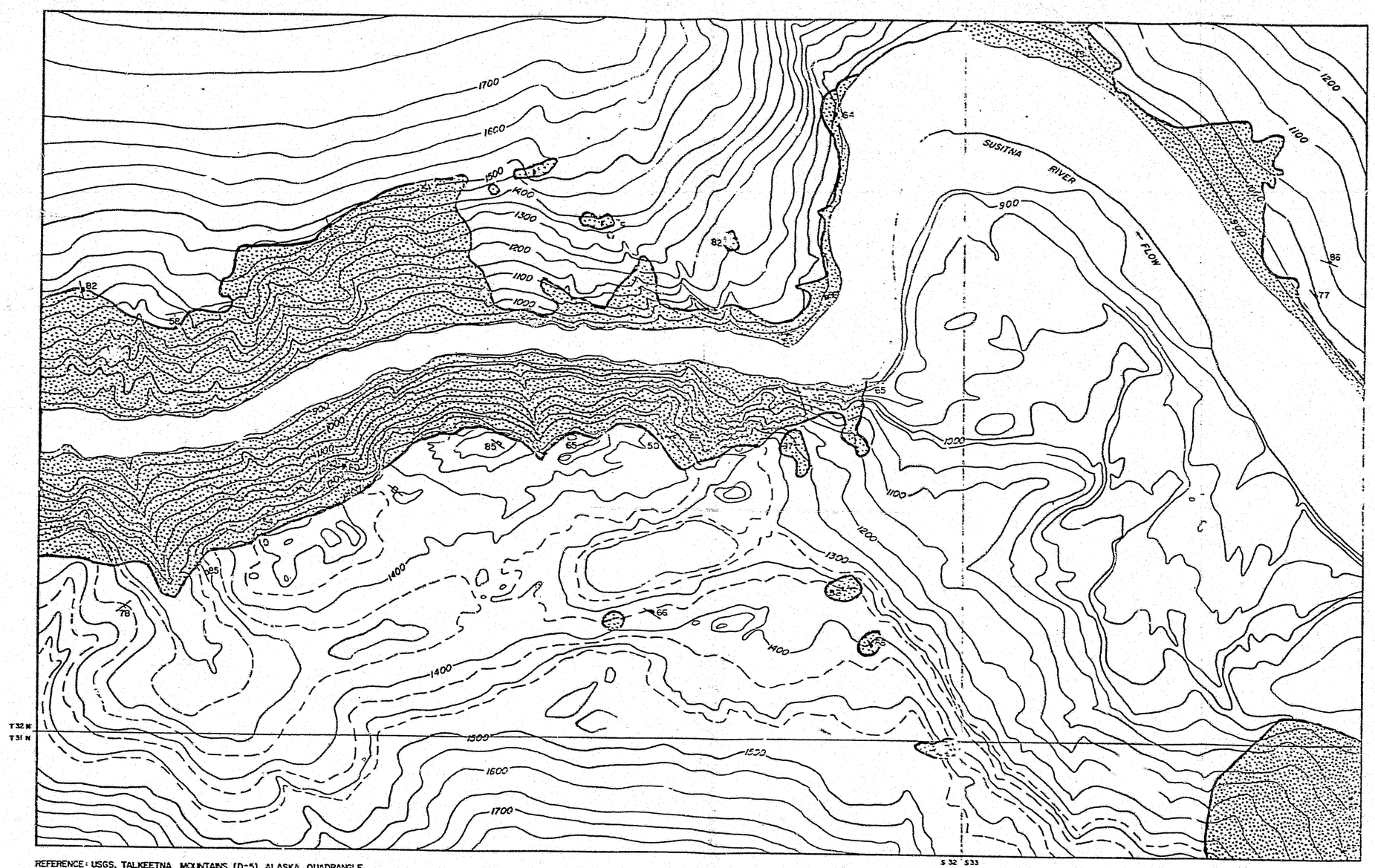
SCALE IN FEET

CONTOUR INTERVAL 50 FEET
DASHED CONTOUR 25 FEET

REFERENCE: USGS, TALKEETNA MOUNTAINS (D-5), ALASKA QUADRANGLE, SEWARD MERIDIAN T32N, R1E, S32 AND 33

ISOPACH MAP OF OVERBURDEN - DEVIL CANYON

FIGURE 6.11



REFERENCE: USGS, TALKEETNA MOUNTAINS (D-5), ALASKA QUADRANGLE, SEWARD MERIDIAN: T32N, R1E, S32 AND 33.

LEGEND

- MAJOR OUTCROPS OF ARGILLITE UNIT
- STRIKE AND DIP OF BEDS
- STRIKE AND DIP OF JOINTS
- STRIKE AND DIP OF OPEN JOINTS
- SHEAR AND FRACTURE ZONES

NOTE:

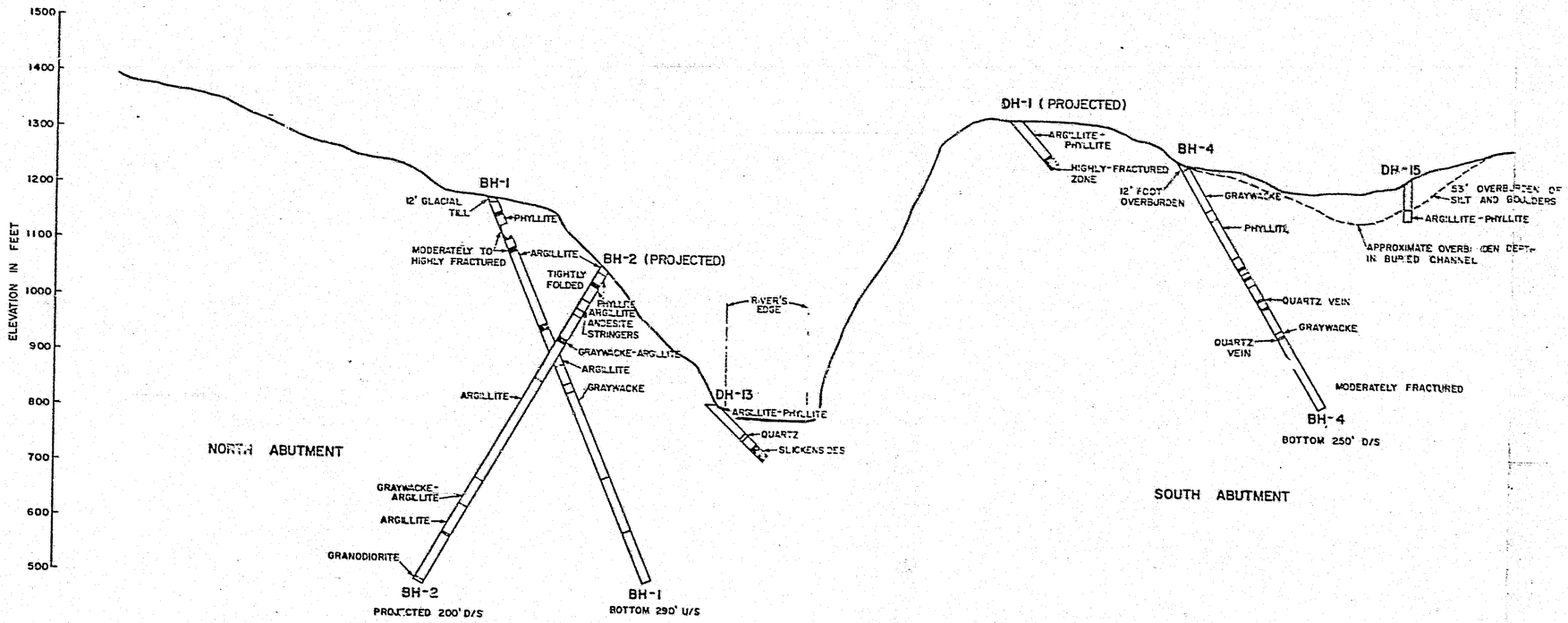
1) GEOLOGIC MAPPING UNDERTAKEN AT THE SCALE OF 1:24,000 (AERIAL PHOTOGRAPHS)
2) TOPOGRAPHIC CONTOURS ARE APPROXIMATE

200 0 200 400 600
SCALE IN FEET

CONTOUR INTERVAL 50 FEET
DASHED CONTOUR 25 FEET

GEOLOGIC MAP OF DEVIL CANYON

FIGURE 6.12



LEGEND

- GLACIAL TILL OR OVERBURDEN
- ROCK
- SHEAR AND FRACTURE ZONES
- CONTACT

NOTES

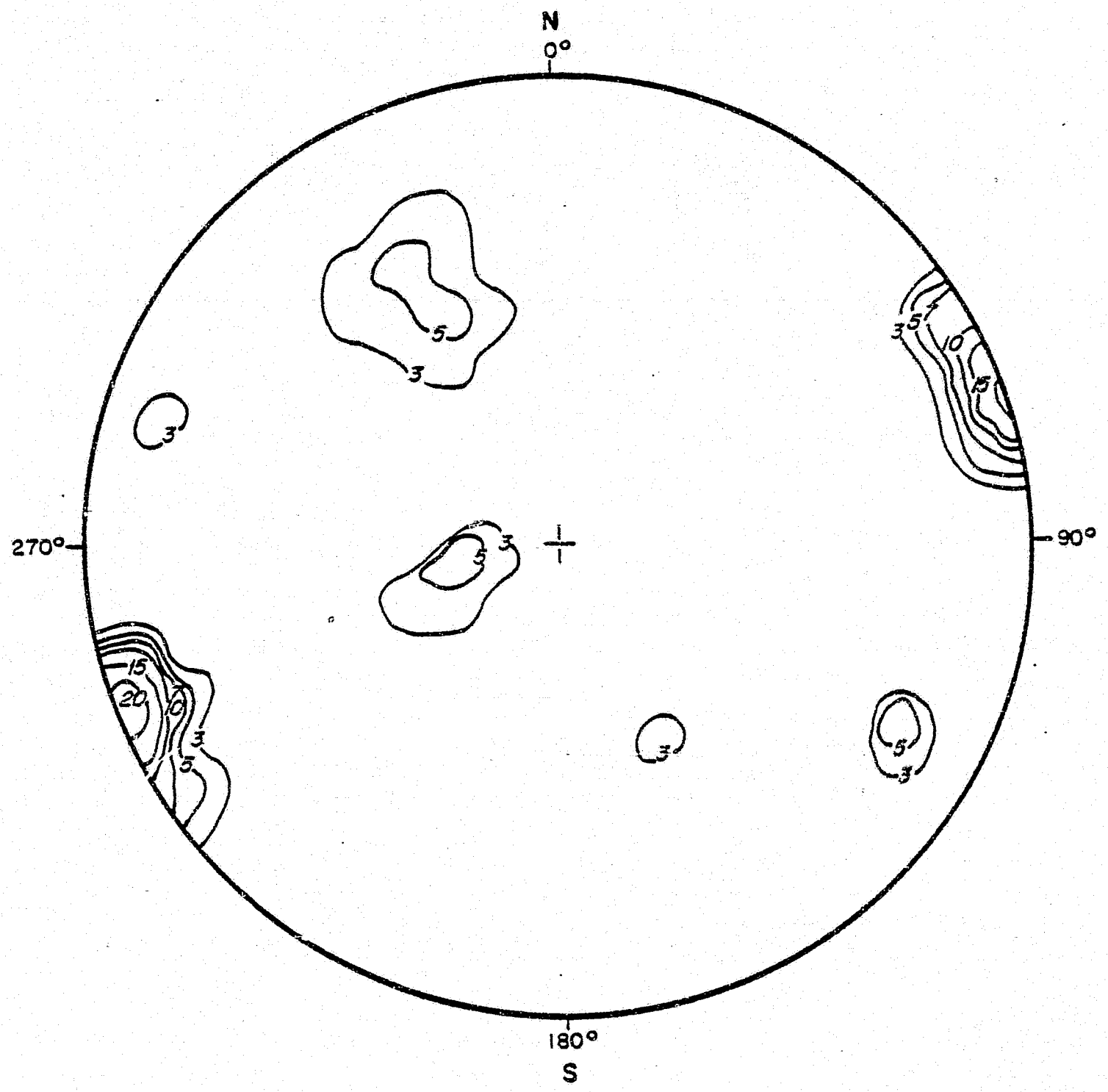
1) VERTICAL AND HORIZONTAL SCALE 1:1
2) SECTION LINE SHOWN ON FIGURE 6.10

100 50 0 100 200
SCALE IN FEET

REFERENCES
1 BUREAU OF RECLAMATION, 1980
2 CORPS OF ENGINEERS, 1978
3 SUMMER 1980 INVESTIGATION

GEOLOGIC CROSS-SECTION DEVIL CANYON

FIGURE 6.13

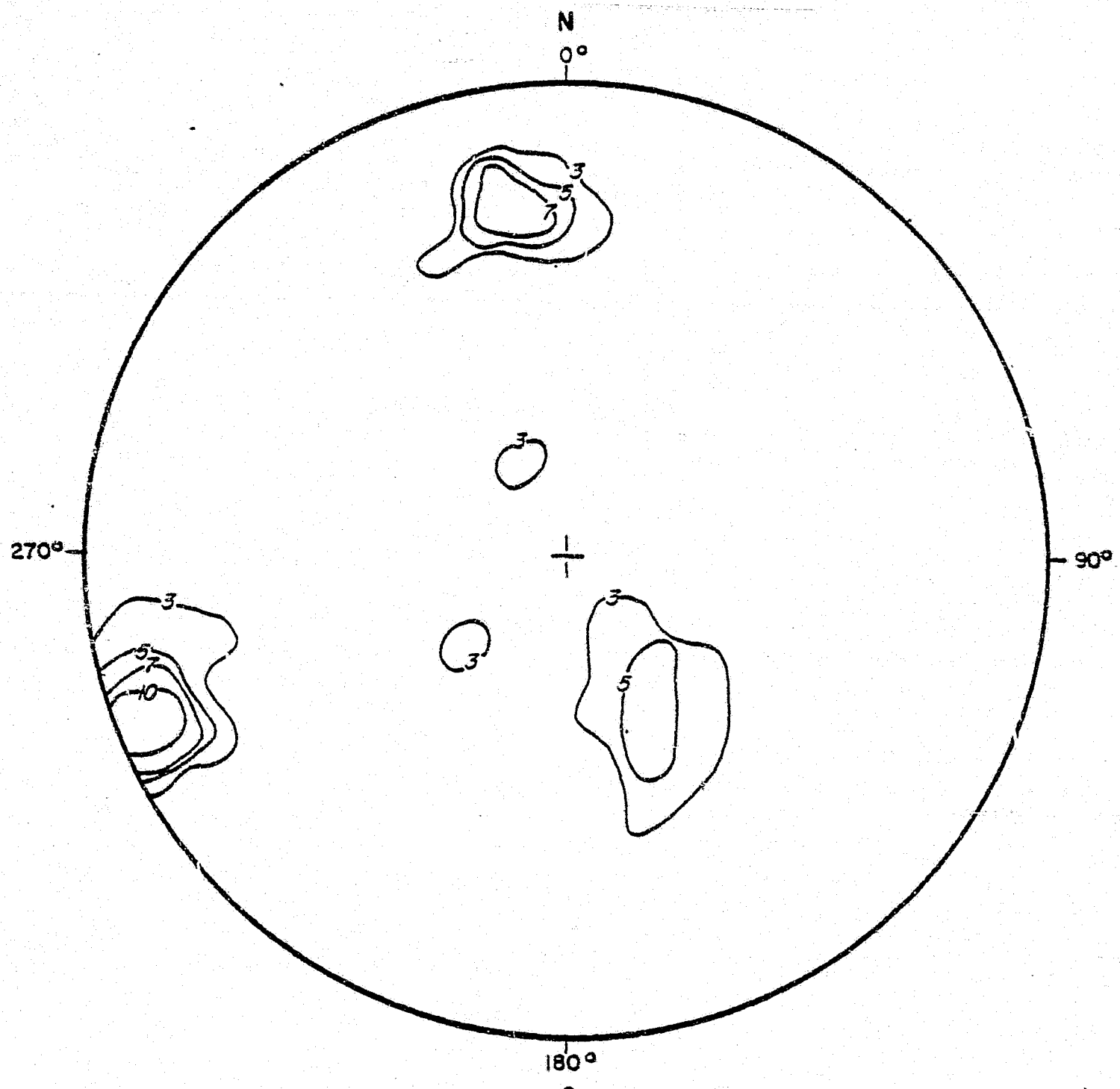


STATION DCJ-1
ELEV. 900'
n = 93
CONTOUR INTERVAL IS PER 1% OF AREA

JOINT STEREO PLOTS - DEVIL CANYON

FIGURE 6.14 a

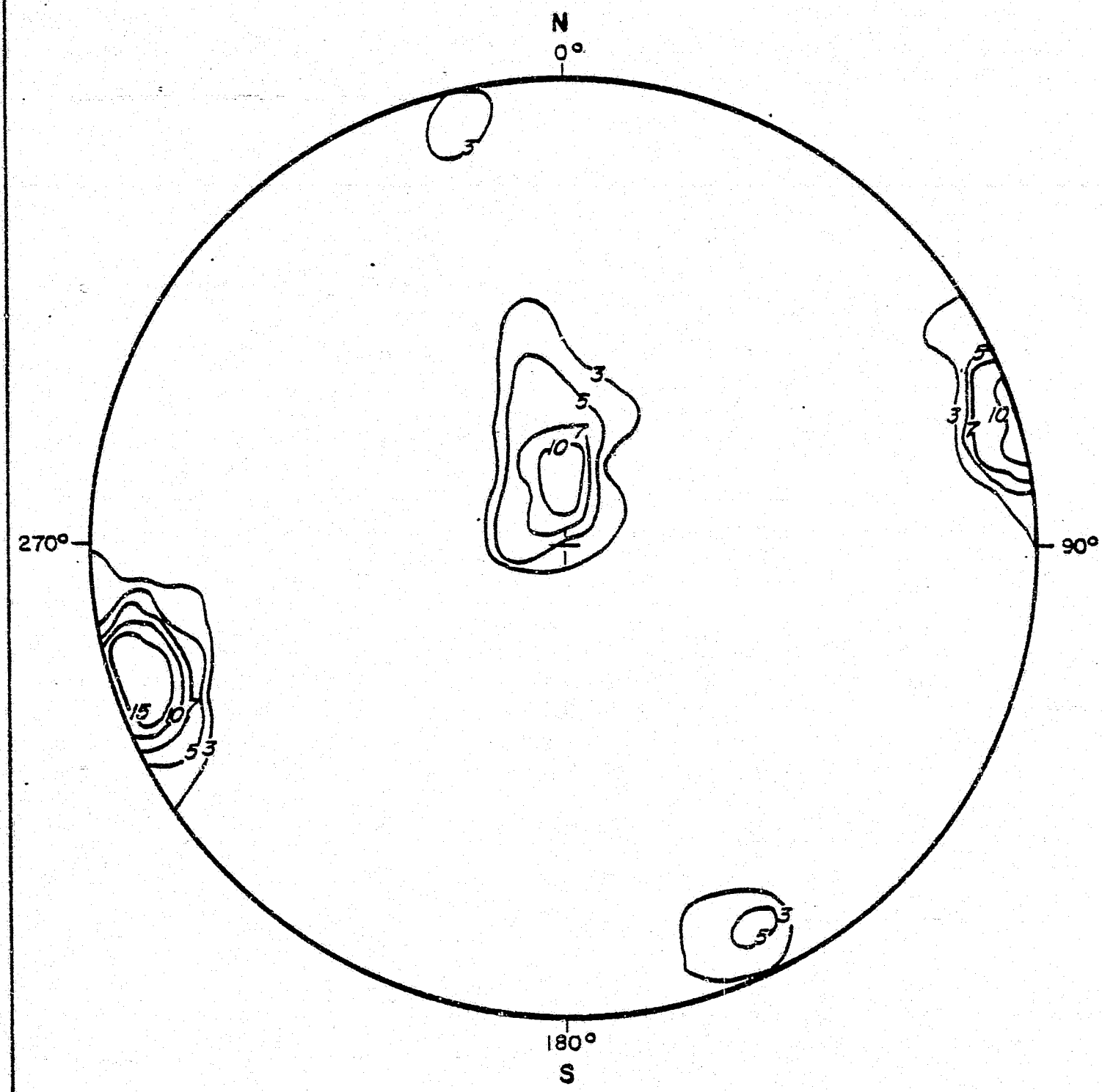
ACRES



STATION DCJ-2
ELEV. 900'
n = 100
CONTOUR INTERVAL IS PER 1% OF AREA

JOINT STEREO PLOTS - DEVIL CANYON

FIGURE 6.14 b



STATION DCJ-3
ELEV. 1400'-1500'
n = 100
CONTOUR INTERVAL IS PER 1% OF AREA

JOINT STEREO PLOTS - DEVIL CANYON

FIGURE 6.14c

REFERENCES

LIST OF REFERENCES

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APPENDIX A

SUMMARY OF PREVIOUS WORK

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APPENDIX B

RESULTS OF DIAMOND DRILLING PROGRAM

APPENDIX B-1

DRILLING REPORTS - R&M

WATANA

ACRES AMERICAN INCORPORATED
CONSULTING ENGINEERS
BUFFALO, NEW YORK

R&M CONSULTANTS, INC.
ANCHORAGE, ALASKA

DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT

for **ALASKA POWER AUTHORITY**

HOLE NO. BH-2
SHEET NO. 1 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

CONTRACTOR THE DRILLING COMPANY
STARTED 11:30 P.M. July 14 1980
FINISHED 4:00 P.M. July 27 1980

DRILLING METHOD
SOIL CASING ADVANCER — CASING DIAM. NW 4" I.D.
ROCK DIAMOND CORE DRILL — CORE DIAM. NQ - 3(1.75")

LOCATION:
LATITUDE N 62° 49' 33.281"
DEPARTURE W 148° 33' 9.157"
BEARING 45°
INITIAL DIP 55°
OTHER DIPS

ELEVATIONS:
DATUM
DRILL PLATFORM
GROUND SURFACE 1835
ROCK SURFACE 1826.8
BOTTOM OF HOLE 1506.5
WATER TABLE 1765 (7-28-80)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD.)
0.0	Overburden	Soil matrix containing some green igneous rock, fine to medium grained with small white crystals. Grades downward to residual, highly weathered bedrock. 0.0 - 10.0' No samples taken.		
10.0	Andesite	Greenish to dark bluish-gra , fine to medium grained groundmass with white plagioclase phenocrysts. Flow structures. Very hard. Fresh to slightly weathered. Joint spacing very close to close. Joint and fracture surfaces rough, with Iron-oxide staining, often thin clay coatings. Disseminated sulfides throughout. 16.7 Gouge. Core loss 0.2'.	Run 1 10.0 to 15.0	100 (54)
			Run 2 15.0 to 20.0	96 (50)
			Run 3 20.0 to 25.0	100 (66)
			Run 4 25.0 to 25.5	100 (0)

LOGGED BY Rahaim - Hagen (R&M)
Summary by Feldman
(ACRES)

APPROVED (R&M)
DATE
APPROVED (ACRES)
DATE

ACRES AMERICAN INCORPORATED
CONSULTING ENGINEERS
BUFFALO , NEW YORK

R&M CONSULTANTS, INC.
ANCHORAGE , ALASKA

DRILLING REPORT

SUSITNA HYDROELECTRIC PROJECT

for **ALASKA POWER AUTHORITY**

HOLE NO. BH-2
SHEET NO. 2 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. R5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		29.6 Fracture with clay.	R 5 25.5 to 30.5	100 (42)
			R 6 30.5 to 35.5	100 (42)
			R 7 35.5 to 40.5	100 (74)
		40.5 - 60.8 Mafic and ultramafic inclusions. Calcite coatings common on fracture surfaces.	R 8 40.5 to 45.7	100 (73)
			R 9 45.7 to 50.5	102 (92)
			R 10 50.5 to 55.7	100 (92)
		(55.7 - 60.8) Core loss 0.7'.	R 11 55.7 to 60.8	86 (73)
		60.8 - 71.2 Incompetent, highly fractured. Many fractures healed with carbonate. (62.2) Faint slickensides.	R 12 60.8 to 63.7	100 (62)
			R 13 63.7 to 66.9	100 (72)

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SUSITNA HYDROELECTRIC PROJECT

for **ALASKA POWER AUTHORITY**

HOLE NO. BH-2
SHEET NO. 3 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 14 66.9 to 68.9	100 (50)
			R 15 68.9 to 71.2	113 (73)
		71.2 - 72.0 Altered. Clay zone.	R 16 71.2 to 72.0	75 (0)
		71.2 - 81.0 Highly fractured and sheared, core loss 4.7'. Highly weathered and altered. Hole caving, core badly ground during drilling. Core loss 5.3'.	R 17 72.0 to 75.5	26 (0)
			R 18 75.5 to 77.5	35 (0)
			R 19 77.5 to 81.0	66 (46)
		81.0 - 97.8 Highly fractured throughout, moderately hard to soft and friable locally, moderately to slightly weathered, more competent than rock above.	R 20 81.0 to 84.5	100 (71)
			R 21 84.5 to 85.0	100 (0)
			R 22 85.0 to 90.2	100 (77)

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SUSITNA HYDROELECTRIC PROJECT

for **ALASKA POWER AUTHORITY**

HOLE NO. BH-2

SHEET NO. 4 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 23 90.2 to 92.0	100 (0)
		(92.0 - 95.0) Core loss 0.5'.	R 24 92.0 to 95.0	83 (27)
		(95.0) Brecciated zone with clay and carbonate. Soft.	R 25 95.0 to 96.5	100 (47)
		(96.8) Slickensides	R 26 96.5 to 97.8	100 (32)
		97.8 - 121.0 Highly fractured and sheared, core loss 8.4'. Zone is highly altered and weathered throughout, moderately hard to soft and friable, clay gouge and slickensides throughout. Permeated by carbonate.	R 27 97.8 to 100.1	35 (0)
			R 28 100.1 to 101.8	53 (0)
		(101.8 - 109.6) Shear zone. Core loss 7.2'. Calcareous clay gouge with angular rock fragments.	R 29 101.8 to 108.0	3 (0)
			R 30 108.0 to 109.6	19 (0)
			R 31 109.6 to 115.2	97 (36)

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for **ALASKA POWER AUTHORITY**

HOLE NO. BH-2
SHEET NO. 5 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 32 115.2 to 118.2	80 (30)
		(118.2) Highly oxidized.		
118.2	Andesite and Diorite (Transitional Zone)	Light green to gray, fine grained andesite (as described above) interlayered with light to dark green, fine to medium grained diorite (with hornblende, plagioclase, biotite, orthoclase). Rock types alternate throughout. Locally competent, slightly weathered. Very close joint spacing, numerous healed fractures. Iron staining on fracture surfaces. Calcite present in joints and fractures.	R 33 118.2 to 121.0	82 (54)
			R 34 121.0 to 125.7	89 (70)
		121.0 - 141.9' Highly fractured and sheared locally. More competent than rock above, slightly to moderately weathered, with iron staining on joint surfaces.	R 35 125.7 to 128.4	100 (30)
		(123 - 128.4) Possible shear zone.	R 36 128.4 to 131.0	100 (54)
		(131.0' - 134.8) Core loss 0.2'.	R 37 131.0 to 134.8	95 (0)
			R 38 134.8 to 139.8	100 (84)
			R 39 139.8 to 141.9	100 (0)
		141.9 - 167.9 Highly fractured and sheared, moderately hard to soft and friable locally. Generally incompetent, slightly to highly weathered, iron stained throughout.	R 40 141.9 to 144.4	80 (60)
		(141.9 - 153.7) Shear zone, core loss greater than 3 feet.		

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for **ALASKA POWER AUTHORITY**

HOLE NO. BH-2
SHEET NO. 6 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
		(144.4 - 148.0) No core recovered. Triconed through caved section.	R 41 144.4 to 148.0	Tri-coned
		(148.0 - 151.0) Very hard but incompetent. Core loss 2.0'.	R 42 148.0 to 151.0	33 (0)
151.0	Diorite	Greenish gray, very fined to medium grained with porphyritic texture. Visible compositional zoning. Moderately hard to soft, moderately competent to weak and friable locally. Fresh to slightly weathered with iron staining on joint surfaces. Carbonate common throughout. Joint spacing very close to wide. Numerous fractures cemented with calcite.	R 43 151.0 to 153.7	67 (0)
		(151.0 - 153.7) Highly fractured and weathered, with 0.9' clay seam. Core loss 0.9'.	R 44 153.7 to 155.7	100 (20)
		(155.7 - 158.2) Core loss 0.5'.	R 45 155.7 to 158.2	80 (0)
		(158.2 - 159.5) Highly fractured and weathered. Extensive oxidation within fractures.	R 46 158.2 to 160.2	100 (20)
		160.2 - 167.9 Core loss 0.4'.	R 47 160.2 to 162.2	80 (20)
			R 48 162.2 to 167.9	88 (51)
		167.9 - 170.5 Abundant calcite within fractures and joints. Rock becoming more competent.	R 49 167.9 to 170.5	100 (92)

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HOLE NO. BH-2

SHEET NO. 7 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
		170.5 - 172.5 Altered. Coarse grained, friable, highly fractured and sheared. Chloritized.	R 50 170.5 to 175.8	100 (47)
		172.5 - 175.8 More competent. Fine to medium grained, joint spacing moderately close. Numerous fractures healed with calcite.	R 51 175.8 to 177.0	100 (0)
		175.8 - 177.0 Sheared, incompetent, calcareous.		
		177.0 - 196.4 Light green to light blue-gray. Very hard, competent, fresh. Joint spacing moderately close with occasional calcite fillings. minor sulfide mineralization throughout.	R 52 177.0 to 181.0	90 (87)
		(177.0 - 181.0) Core loss 0.4'.	R 53 181.0 to 182.8	100 (100)
			R 54 182.8 to 186.9	100 (100)
			R 55 186.9 to 189.2	100 (100)
			R 56 189.2 to 191.0	100 (100)
		(191 - 196.4) Core loss 0.7'.	R 57 191.0 to 196.4	89 (74)
		196.4 - 197.4 Alteration zone. Highly weathered, sheared. Core loss 0.3'.	R 58 196.4 to 201.0	94 (48)

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HOLE NO. BH-2
SHEET NO. 8 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 59 201.0 to 203.8	100 (54)
		205.0 - 205.3 Highly fractured.	R 60 203.8 to 207.1	100 (30)
		207.1 - 209.3 Brecciated, healed. Core loss 0.4'.	R 61 207.1 to 209.3	82 (41)
			R 62 209.3 to 214.4	100 (88)
		214.4 - 218.5 Core loss 0.3'.	R 63 214.4 to 218.5	93 (93)
			R 64 218.5 to 223.7	100 (92)
		223.7 - 228.7 Medium grained. Joint spacing close. Iron staining and calcite on fracture surfaces. Core loss 0.2'.	R 65 223.7 to 228.7	96 (78)
		228.7 - 230.7 Joint spacing moderately close, rock more competent.	R 66 228.7 to 232.5	100 (82)
		230.7 - 241.0 Altered, bleached. Soft. Joint spacing close, slightly to moderately weathered. Penetrative (to approximately 1 cm) iron staining along joints. Sulfide mineralization.	R 67 232.5 to 237.7	100 (90)

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HOLE NO. BH-2
SHEET NO. 9 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		241.0 - 241.9 Altered, very soft, slick clay.	R 68 237.7 to 241.9	105 (57)
		241.9 - 252.2 Highly fractured and altered. Contains numerous soft, friable zones throughout with calcareous clay common. Many joints weakly healed with carbonate. Zone is generally incompetent (possible shear zone).	R 69 241.9 to 247.2	111 (20)
			R 70 247.2 to 252.2	104 (38)
		252.2 - 257.2 Slightly more competent.	R 71 252.2 to 257.2	100 (82)
		257.2 - 262.2 Rock weakened and slightly friable. Fractures filled with carbonate and/or clay.	R 72 257.2 to 262.2	96 (80)
		262.2 - 285.8 Light green to white. Very hard, competent, fresh. Joint spacing very close to close, calcite and pyrite on joint surfaces.	R 73 262.2 to 265.0	100 (71)
		(265.0 - 271.0) Core loss 0.5'.	R 74 265.0 to 269.0	93 (75)
			R 75 269.0 to 271.0	90 (90)
			R 76 [illegible] to 276.3	100 (100)

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SHEET NO. 10 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 77 276.1 to 280.6	100 (89)
			R 78 280.6 to 285.8	98 (87)
		285.8 - 287.8 Highly fractured, incompetent. Core loss 0.1'.	R 79 285.8 to 287.8	95 (40)
		289.1 Calcareous zone.	R 80 287.8 to 291.1	100 (91)
			R 81 291.1 to 296.1	100 (80)
			R 82 296.1 to 301.1	100 (94)
		301.1 - 306.1 Core loss 0.4'.	R 83 301.1 to 306.1	92 (80)
		306.1 - 310.0 Joint spacing moderately close to wide.	R 84 306.1 to 310.2	100 (100)
			R 85 310.2 to 315.4	100 (88)

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HOLE NO. BH-2
SHEET NO. 11 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 86 315.4 to 320.6	100 (98)
		322.0 Highly altered zone. Friable.	R 87 320.6 to 325.3	100 (91)
			R 88 325.3 to 328.0	100 (85)
		328.0 - 348.6 Alteration zone, joint spacing very close to moderately close, moderately hard to soft and friable locally. Sulfide mineralization throughout. Minor calcite and chlorite on joints.	R 89 328.0 to 332.4	100 (62)
		(328.0, 331.4) Slickensides.	R 90 332.4 to 337.5	100 (90)
		(334.4 - 335.8) Highly altered and friable.	R 91 337.5 to 341.0	100 (97)
			R 92 341.0 to 341.4	100 (100)
			R 93 341.4 to 346.6	100 (100)
		348.6 - 365.5 Fresh to slightly weathered, hard to very hard. Joint spacing moderately close to wide.	R 94 346.6 to 351.0	100 (84)

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HOLE NO. BH-2

SHEET NO. 12 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 95 351.0 to 356.0	100 (96)
			R 96 356.0 to 361.0	100 (100)
362.5	Diorite and Andesite	Intermixed, transitional rock types. Pale green or white, to gray. Phaneritic to aphanitic texture. Fresh with some alteration zones as noted below. Hard. Joints very closely spaced.	R 361.0 to 366.0	92 (92)
		361.0 - 366.0 Core loss 0.4'.	R 98 366.0 to 370.6	100 (100)
		362.5 - 363.5 Quartz vein.	R 99 370.6 to 375.8	100 (100)
		370.3 - 381.0 Calcite and sulfides in joints.	R 100 375.8 to 381.0	94 (87)
		(375.8 - 318.0) Core loss 0.3'.	R 101 381.0 to 386.2	100 (65)
		386.2 - 386.8 Highly altered and soft.	R 102 386.2 to 391.2	100 (88)
		386.8 - 401.0 Hard, fairly competent. Joint spacing very close to close. Numerous healed joints throughout.	R 103 391.2 to 396.3	100 (Es)

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HOLE NO. BH-2
SHEET NO. 13 OF 13

SITE WATANA NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 104 396.3 to 398.8	100 (80)
			R 105 398.8 to 401.0	100 (100)
401.0		End of Hole		

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for **ALASKA POWER AUTHORITY**

HOLE NO. B.H. 6
SHEET NO. 1 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

CONTRACTOR The Drilling Company STARTED 07:00 M. June 26 19 80
FINISHED - M. July 9 19 80

DRILLING METHOD: SOIL Casing Advancer; ROCK Diamond Core Drilling
CASING DIAM. NW -(4" I.D.)
CORE DIAM. NQ -3- (1.75")

LOCATION: LATITUDE N62° 49' 24.891; DEPARTURE W148° 32' 21.862; BEARING 225°; INITIAL DIP 60°; OTHER DIPS
ELEVATIONS: DATUM; DRILL PLATFORM; GROUND SURFACE 1605; ROCK SURFACE 1598.1; BOTTOM OF HOLE 963.8; WATER TABLE 1458 12-06-80

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD.)
0.0	Overburden	Brown sandy gravel with cobbles and boulders.		
8.0	Quartz Diorite	Pale green to gray biotite, hornblende, Quartz Diorite. Mafics approximately 30%, medium grained, nonfoliated. Slightly to moderately weathered. Joint spacing very close to moderately close. Iron staining present along some joints, occasional healed fractures. 8.0 - 10.7 Core loss 0.7'.	Run 1 8.0 to 10.7	74 (74)
			Run 2 10.7 to 15.0	93 (74)
16.5	Quartz Monzonite	Light tan to light grey, hornblende, Quartz Monzonite. Fine to medium grained, nonfoliated. Slightly to highly weathered, locally friable, and porous. Iron staining and solution cavities common. Rock generally incompetent. Joint spacing very close to close. 17.2 - 18.0 Highly fractured. 19.6 - 27 Highly fractured, core loss 0.7'.	Run 3 15.0 to 19.6	102 (57)
			Run 4 19.6 to 23.8	83 (0)
24.5	Granodiorite	Pale green to gray biotite hornblende quartz Granodiorite. Mafics average approximately 20%. Fine to medium grained. Moderately hard to very	Run 5 23.8 to 26.8	100 (0)

LOGGED BY R. RAHAIM - J. HAGAN (R&M)
SUMMARY - L. ACOMB
(ACRES)

APPROVED (R&M)
DATE
APPROVED (ACRES)
DATE

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SUSITNA HYDROELECTRIC PROJECT

for **ALASKA POWER AUTHORITY**

HOLE NO. B.H. 6
SHEET NO. 2 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
		hard, fresh to slightly weathered. Limonite staining and clay residue on some joint surfaces. Joint spacing very close to moderately close with joints oriented approximately 40° to 55° to core axis. Occasional highly fractured zones 0.1' to 1.1' thick, with clay gouge. Healed fractures throughout.	R 6 26.8 to 30.0	85 (78)
		26.8 - 30.0 Core loss 0.5'.	R 7 30.0 to 32.8	100 (67)
		29.5 - 30.0 Highly fractured and weathered. Clay filling common.	R 8 32.8 to 37.8	100 (74)
			R 9 37.8 to 40.5	100 (78)
		40.5 - 45.0 Core loss 0.2'.	R 10 40.5 to 45.0	95 (91)
		45.0 - 49.1 Highly fractured zone.	R 11 45.0 to 49.1	100 (66)
		49.1 - 51.4 Shear zone, highly fractured with clay gouge.	R 12 49.1 to 50.4	100 (31)
			R 13 50.4 to 51.4	100 (0)
			R 14 51.4 to 55.5	100 (85)

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HOLE NO. B.H. 6
SHEET NO. 3 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 15 55.5 to 59.3	100 (53)
			R 16 59.3 to 63.2	100 (79)
		65.3 - 75.3 Highly fractured and sheared zone slight to highly weathered, moderately hard to sof. and friable locally. Joint spacing very close to close. Hole caving during drilling.	R 17 63.2 to 66.5	100 (52)
		(65.5) Very friable.	R 18 66.5 to 67.3	0 (0)
		(66.5 -67.3) Core loss 0.8'.	R 19 67.3 to 67.7	100 (0)
			R 20 67.7 to 70.4	100 (59)
		(71.5 - 73.0) Shear zone, slickenslides and clay gouge.	R 21 70.4 to 75.3	104 (59)
		75.3 - 149.4 Competent, hard to very hard fresh to slightly weathered. Joint spacing very close to wide.	R 22 75.3 to 80.3	100 (88)
			R 23 80.3 to 84.2	100 (92)

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HOLE NO. B.H. 6
SHEET NO. 4 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 24 84.2 to 89.3	100 (96)
		89.3 - 94.6 Core loss 0.2'.	R 25 89.3 to 94.6	96 (85)
			R 26 94.6 to 98.5	100 (92)
		98.5 - 100.3 Core loss 0.1'.	R 27 98.5 to 100.3	94 (89)
			R 28 100.3 to 101.5	100 (75)
			R 29 101.5 to 102.5	100 (100)
			R 30 102.5 to 103.1	100 (83)
			R 31 103.1 to 108.2	100 (71)
		108.2 - 111.7 Core loss 0.1'.	R 32 108.2 to 111.7	97 (97)

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HOLE NO. B.H. 6
SHEET NO. 5 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 33 111.7 to 112.7	100 (91)
		112.7 - 122.1 Core loss 0.4'.	R 34 112.7 to 117.2	93 (91)
			R 35 117.2 to 122.1	98 (98)
			R 36 122.1 to 127.2	100 (100)
			R 37 127.2 to 128.7	100 (100)
			R 38 128.7 to 130.8	100 (100)
			R 39 130.8 to 135.8	100 (86)
			R 40 135.8 to 140.8	100 (78)
			R 41 140.8 to 145.6	104 (98)

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HOLE NO. B.H. 6
SHEET NO. 6 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		149.4 - 149.6 Highly fractured.	R 42 145.6 to 150.6	100 (90)
		152.5, 154.5 Altered, weathered zones, friable.	R 43 150.6 to 155.6	100 (78)
			R 44 155.6 to 160.6	100 (92)
		160.6 - 187.0 Higaly altered and weathered. Moderately hard to soft and very friable locally. Joint spacing very close to close. Minor sulfide mineralization and carbonate throughout. Rock is generally incompetent.	R 45 160.6 to 165.6	104 (78)
		165.6 - 175.2 Core loss 0.3'.	R 46 165.6 to 170.0	98 (61)
			R 47 170.0 to 175.2	96 (46)
			R 48 175.2 to 179.8	100 (33)
			R 49 179.8 to 184.9	100 (73)
		187.0 - 240.3 Generally hard and fresh except for very slight weathering along joints and fractures.	R 50 184.9 to 190.0	100 (88)

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HOLE NO. B.H. 6
SHEET NO. 7 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 51 190.0 to 195.1	100 (100)
			R 52 195.1 to 200.2	100 (100)
			R 53 200.2 to 205.0	100 (88)
			R 54 205.0 to 210.0	100 (100)
		210.0 - 215.0 Core loss 0.3'.	R 55 210.0 to 215.0	94 (96)
		215.4 - 215.7 Highly fractured and moderately weathered.	R 56 215.0 to 220.0	100 (90)
			R 57 220.0 to 225.2	100 (100)
			R 58 225.2 to 230.1	100 (98)
			R 59 230.1 to 235.4	100 (100)

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HOLE NO. B.H. 6
SHEET NO. 8 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 60 235.4 to 240.3	100 (100)
		240.3 - 260.0 Transitional zone into underlying quartz diorite. Contains thin altered friable zones locally. Numerous very thin veins of calcite throughout.	R 61 240.3 to 245.5	102 (96)
			R 62 245.5 to 249.7	100 (95)
			R 63 249.7 to 255.0	100 (89)
		(256.0 - 256.7) Highly altered, very friable. Clay filling (possible shear zone). (256.8) Slickensides.	R 64 255.0 to 260.0	102 (84)
260	Quartz Diorite	Light green, to pink and gray hornblende Quartz Diorite. Fine to medium grained, nonfoliated with approximately 30% mafics. Generally hard and fresh, clay and pyrite crystals common on fractured surfaces. Occasional thin (less than 0.1') calcite veins and healed joints throughout. Joint spacing close to moderately close.	R 65 260.0 to 265.1	100 (100)
			R 66 265.1 to 270.2	100 (100)
		273 -273.7 Altered zone, friable, sandy locally.	R 67 270.2 to 275.0	100 (81)
		275 -325.6 Generally hard, fresh and competent. Joint spacing close to moderately close.	R 68 275.0 to 280.3	100 (96)

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HOLE NO. B.H. 6

SHEET NO. 9 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 05[illegible]04 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 69 280.3 to 281.6	100 (100)
			R 70 281.6 to 284.6	100 (100)
		284.6 - 290.6 Core loss 0.2'.	R 71 284.6 to 286.6	95 (95)
			R 72 286.6 to 290.6	98 (98)
			R 73 290.6 to 295.6	100 (100)
			R 74 295.6 to 300.7	100 (96)
			R 75 300.7 to 305.0	100 (100)
			R 76 305.0 to 310.2	100 (100)
			R 77 310.2 to 315.4	100 (96)

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HOLE NO. BE-6
SHEET NO. 10 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
		318.6 - 320.1 Altered zone, chalky, bleached, friable along joints.	R 78 315.4 to 320.6	100 (96)
		320.6 - 325.6 Core loss 0.2'.	R 79 320.6 to 325.6	96 (80)
		325.6 - 332.7 Highly fractured and altered, very soft and friable. Core loss 3.0'.	R 80 325.6 to 330.2	78 (70)
			R 81 330.2 to 332.7	20 (0)
			R 82 332.7 to 337.9	98 (77)
		342.0 Altered zone, friable, weakly healed with carbonate.	R 83 337.9 to 342.9	104 (90)
		343.0 - 343.2 Highly fractured. Core loss 0.2'.	R 84 342.9 to 348.8	100 (97)
		352.9 - 362.5 Highly fractured, friable, soft.	R 85 348.8 to 353.8	104 (100)
			R 86 353.8 to 358.9	100 (96)

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HOLE NO. B.H. 6
SHEET NO. 11 OF 20

SITE Watana North Abutment JOB NO. 25701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% RE. REC. (RQD)
			R 87 358.9 to 363.9	100 (52)
		367.9 Highly fractured, friable, soft.	R 88 363.9 to 368.2	107 (98)
		368.2 - 373.2 Core loss 0.2'.	R 89 368.2 to 373.2	96 (96)
		374.5, 377.0, 380.4, and 382.0 Highly fractured, friable, soft.	R 90 373.2 to 378.4	100 (77)
		382 - 490.5 Generally hard fresh and competent. Joint spacing close to wide.	R 91 378.4 to 383.3	100 (94)
		(383.3 - 388.3) Core loss 0.1'.	R 92 383.3 to 388.3	98 (98)
			R 93 388.3 to 393.3	100 (100)
			R 94 393.3 to 398.3	100 (92)
			R 95 398.3 to 400.6	100 (100)

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HOLE NO. B.H. 6

SHEET NO. 12 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 96 400.6 to 403.4	100 (100)
			R 97 403.4 to 406.2	100 (100)
			R 98 406.2 to 411.1	100 (100)
			R 99 411.1 to 416.3	100 (100)
			R 100 416.3 to 421.1	100 (100)
			R 101 421.1 to 425.6	100 (100)
			R 102 425.6 to 430.2	100 (98)
			R 103 430.2 to 435.4	100 (100)
			R 104 435.4 to 440.4	100 (100)

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HOLE NO. B.H. 6
SHEET NO. 13 OF 20

SITE: Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 105 440.4 to 445.6	100 (100)
			R 106 445.6 to 450.4	100 (100)
		454.5 -454.9 Highly fractured, friable, minor sulfide mineralization.	R 107 450.4 to 455.8	101 (91)
			R 108 455.8 to 458.2	100 (100)
		461.6 Fractured zone.	R 109 458.2 to 463.2	100 (100)
		463.2 - 464 Mineralized zone, very soft, core loss 0.4'.	R 110 463.2 to 464.0	13 (0)
			R 111 464.0 to 468.4	100 (100)
			R 112 468.4 to 473.3	100 (100)
		476.2 - 476.4 Fractured zone.	R 113 473.3 to 477.8	100 (98)

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HOLE NO. B.H. 6
SHEET NO. 14 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
		479.1 Slickensides.	R 114 477.8 to 480.3	100 (96)
			R 115 480.3 to 485.3	100 (92)
		485.3 - 490.5 Core barrel mislatched during drilling. Had to pull rods and redrill; core loss 1.4'.	R 116 485.3 to 490.5	73 (73)
		490.5 - 650.0 Generally fresh, hard, competent.	R 117 490.5 to 495.5	100 (100)
		498.5, 502.1 Joints filled with calcareous clay.	R 118 495.5 to 500.5	100 (90)
			R 119 500.5 to 505.6	100 (78)
			R 120 505.6 to 510.6	100 (100)
			R 121 510.6 to 515.6	100 (100)
			R 122 515.6 to 520.2	100 (100)

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HOLE NO. B.H. 6
SHEET NO. 15 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		520.2 - 521.0 Slightly friable. Core loss 0.1'.	R 123 520.2 to 525.6	98 (83)
			R 124 525.6 to 530.4	104 (92)
		530.5 - 532.5 Altered zone, soft, clayey; hole caved during drilling.	R 125 530.4 to 531.8	100 (50)
			R 126 531.8 to 532.0	100 (0)
			R 127 532.0 to 533.5	100 (67)
		533.5 - 539.5 Core loss 0.8'.	R 128 533.5 to 539.5	87 (87)
		539.5 - 547.5 Core loss 0.4'.	R 129 539.5 to 544.6	96 (86)
			R 130 544.6 to 547.5	93 (66)
			R 131 547.5 to 550.4	100 (83)

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HOLE NO. B.H. 6
SHEET NO. 16 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 132 550.4 to 555.4	100 (88)
			R 133 555.4 to 560.4	100 (98)
		562.7, 565.0 Slickensides.	R 134 560.4 to 565.7	100 (100)
		565.7 - 570.7 Core loss 0.8'.	R 135 565.7 to 570.7	84 (80)
		(569.0) Highly fractured and sheared, clay gouge.		
		572.3 - 573.1 Brecciated, clay gouge.	R 136 570.7 to 575.9	100 (77)
			R 137 575.9 to 580.7	100 (94)
			R 138 580.7 to 585.8	100 (86)
			R 139 585.8 to 590.8	100 (84)
		590.8 - 592.8 Core barrel mislatched during drilling, had to pull rods, core loss 0.5.	R 140 590.8 to 592.8	75 (75)

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HOLE NO. B.H. 6
SHEET NO. 17 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 141 592.8 to 597.8	100 (80)
			R 142 597.8 to 602.6	100 (83)
			R 143 602.6 to 608.3	100 (65)
			R 144 608.3 to 611.5	100 (97)
		613 - 615 Altered and friable, soft, numerous healed joints. Core loss 0.9'.	R 145 611.5 to 615.4	77 (64)
			R 146 615.4 to 620.2	100 (96)
			R 147 620.2 to 625.2	100 (100)
		625.2 - 630.2 Core loss 0.2'.	R 148 625.2 to 630.2	96 (92)
			R 149 630.2 to 631.8	100 (88)

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HOLE NO. B.H. 6
SHEET NO. 18 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 150 631.8 to 636.7	100 (90)
			R 151 636.7 to 640.5	100 (100)
			R 152 640.5 to 645.6	100 (94)
		646.7 Joint filled with crushed rock.	R 153 645.6 to 650.0	100 (100)
650	Granite	Light gray to white, fine to medium grained, nonfoliated with approximately 5% to 10% mafics. Hard, fresh and competent. Minor sulfide mineralization throughout. Numerous healed fractures and joints, carbonate coating on joints common. Joint spacing close to moderately close with joints oriented approximately 40° to 60° to core axis.	R 154 650.0 to 655.8	100 (92)
			R 155 655.8 to 660.6	100 (63)
			R 156 660.6 to 665.8	100 (67)
			R 157 665.8 to 670.8	100 (88)
			R 158 670.8 to 676.0	100 (77)

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HOLE NO. B.H. 6
SHEET NO. 19 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 159 676.0 to 680.6	100 (98)
			R 160 680.6 to 685.4	100 (94)
		686.2 - 712.2 Shear zone, joint spacing very close to close, moderately hard to soft and friable locally. Rock generally less competent, minor sulfide mineralization throughout. Carbonate common.	R 161 685.4 to 687.9	84 (80)
		686.2 - 687.9 Core loss 0.4'.	R 162 687.9 to 692.5	104 (89)
		(686.2, 690.0, 695.7, 699.3, 704.0, 708.2) Slickensides with clay gouge, soft, friable.	R 163 692.5 to 697.5	104 (74)
			R 164 697.5 to 702.5	100 (92)
			R 165 702.5 to 707.4	100 (67)
			R 166 707.4 to 712.2	100 (94)
			R 167 712.2 to 717.1	102 (100)

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HOLE NO. B.H. 6
SHEET NO. 20 OF 20

SITE Watana North Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 168 717.1 to 722.0	104 (92)
		722.0 - 727.1 Core loss 0.1'.	R 169 722.0 to 727.1	98 (88)
			R 170 727.1 to 730.5	100 (100)
			R 171 730.5 to 735.4	100 (96)
			R 172 735.4 to 740.4	100 (80)
740.4		End of hole		

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SUSITNA HYDROELECTRIC PROJECT

for **ALASKA POWER AUTHORITY**

HOLE NO. BH-8
SHEET NO. 1 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

CONTRACTOR The Drilling Company STARTED 1:00 P.M. 7/29 19 80
FINISHED M. 8/9 19 80

DRILLING METHOD — SOIL: Casing Advancer — CASING DIAM.: NW 4" I.D.
ROCK: Diamond Core Drilling — CORE DIAM.: NQ-3 (1.75")

LOCATION:
LATITUDE N62° 49' 11.686
DEPARTURE W148° 32' 17.664
BEARING 60°
INITIAL DIP 60°
OTHER DIPS

ELEVATIONS:
DATUM
DRILL PLATFORM
GROUND SURFACE 1976
ROCK SURFACE 1964
BOTTOM OF HOLE 1326
WATER TABLE 1960

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD.)
0.0	Overburden	0.0 - 1.0 Organic materials. 1.0 - 8.0 Brown sandy gravel with silt and boulders, grading into angular cobbles. Not sampled.		
8.0-13.8		Weathered bedrock.		
13.8	Porphyritic Andesite	Pale tan to gray, very fine to fine grained groundmass with numerous light colored phenocrysts. Generally hard to very hard, friable locally. Slightly to moderately weathered with iron staining on joint surfaces and penetrative staining and weakening up to 1 cm immediately adjacent to joints. Less weathering with depth. Joint spacing very close to close. Occasional joints healed with carbonate.	Run 1 13.8 to 18.0	71 (10)
			Run 2 18.0 to 23.8	91 (22)
		13.8 - 28.8 Core loss 2.0'.	Run 3 23.8 to 28.8	94 (54)
		13.8 - 33.8 Moderately to highly weathered, friable locally. Penetrative iron staining throughout. (13.8 - 18.0) Some residual interstitial sand and silt.	Run 4 28.8 to 33.8	100 (30)

LOGGED BY: Hagen - Rahaim (R&M)
Summary by Feldman, Acomb
(ACRES)

APPROVED (R&M)
DATE
APPROVED (ACRES)
DATE

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HOLE NO. BH-8
SHEET NO. 2 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		33.8 - 49.6 Rock becoming more competent. Slightly to moderately weathered with iron staining on joint surfaces. 33.8 - 38.8 Core loss 0.3'.	Run 5 33.8 to 38.8	94 (40)
			Run 6 38.8 to 43.9	100 (61)
			Run 7 43.9 to 45.6	100 (0)
		(48.3 - 50.6) Sandy clay material along contact with underlying diorite. Soft and friable. Core loss 1.5 feet.	Run 8 45.6 to 49.6	73 (0)
49.6	Diorite	Pale pink to greenish gray, fine to medium grained crystalline rock. Non-foliated, approximately 20% to 30% mafics. Generally hard to very hard, fresh to slightly weathered, with iron staining on some joint and fracture surfaces. Carbonate common throughout. Joint spacing very close to moderately close. Occasional joints healed with carbonate.	Run 9 49.6 to 52.5	86 (0)
			Run 10 52.5 to 56.5	100 (28)
		49.6 - 65.0 Moderately weathered and altered with some bleaching. Locally soft, clayey zones.	Run 11 56.5 to 59.5	113 (67)
		(59.5 - 63.6) Dark gray fine grained basalt dike containing inclusions of brecciated, altered diorite, and carbonate veins. Core loss 0.1'.	Run 12 59.5 to 63.6	98 (29)
			Run 13 63.6 to 68.0	100 (64)

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HOLE NO. BH-8
SHEET NO. 3 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			Run 14 68.0 to 73.0	104 (100)
		76.0 Thin altered zone.	Run 15 73.0 to 77.7	100 (43)
		77.7 - 89.0 Highly fractured. Some faint slickensides.	Run 16 77.7 to 80.7	103 (57)
			Run 17 80.7 to 84.0	100 (57)
			Run 18 84.0 to 89.3	100 (64)
		89.3 - 91.6 Highly fractured, friable locally.	Run 19 89.3 to 91.6	100 (43)
		91.6 - 96.6 Core loss 0.2'.	Run 20 91.6 to 96.6	96 (60)
			Run 21 96.6 to 101.0	100 (100)
			Run 22 101.0 to 106.2	100 (83)

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HOLE NO. BH-8
SHEET NO. 4 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			Run 23 106.2 to 111.0	100 (100)
			Run 24 111.0 to 116.1	100 (92)
		116.1 - 121.1 C..e loss 0.1'.	Run 25 116.1 to 121.1	98 (98)
		123.0 - 124.0 Highly fractured zone. Slightly altered and bleached.	Run 26 121.1 to 126.1	100 (94)
		129.0 Faint slickensides.	Run 27 126.1 to 131.1	100 (100)
			Run 28 131.1 to 135.6	100 (96)
		135.6 - 140.8 Core loss 0.2'.	Run 29 135.6 to 140.8	96 (88)
		140.0 Rock generally fresh to bottom of hole.		
		140.8 - 142.9 Prominent joint sets at 25° and 35° to core axis. Core oss 2.1'.	Run 30 140.8 to 142.9	86 (43)
		146.0 Slickensides.	Run 31 142.9 to 148.0	100 (88)

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HOLE NO. BH-8

SHEET NO. 5 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			Run 32 148.0 to 152.6	100 (98)
			Run 33 152.6 to 157.7	100 (100)
		157.7 - 167.5 Core loss 0.6 .	Run 34 157.7 to 162.7	96 (96)
			Run 35 162.7 to 167.5	92 (63)
			Run 36 167.5 to 171.9	100 (70)
		171.9 - 173.6 Altered and brecciated zone with clay and sand filling. Soft and friable. Calcareous. Core loss 0.6 feet.	Run 37 171.9 to 176.5	87 (52)
			Run 38 176.5 to 181.0	98 (91)
			Run 39 181.0 to 185.9	100 (100)
		185.9 - 194.2 Core loss 0.6'.	Run 40 185.9 to 189.2	91 (88)

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HOLE NO. BH-8
SHEET NO. 6 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			Run 41 189.2 to 194.2	94 (88)
			Run 42 194.2 to 199.2	100 (98)
			Run 43 199.2 to 201.0	100 (100)
			Run 44 201.0 to 206.2	100 (100)
		206.2 - 211.0, 213.0 Some alteration and minor sulfide mineralization.	Run 45 206.2 to 211.0	100 (92)
			Run 46 211.0 to 215.1	100 (90)
			Run 47 215.1 to 219.3	100 (95)
			Run 48 219.3 to 221.2	100 (84)
		221.2 - 225.4 Some hydrothermal alteration, locally fractured and friable.	Run 49 221.2 to 225.4	102 (98)

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HOLE NO. BH-8
SHEET NO. 7 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			Run 50 225.4 to 230.6	100 (100)
		230.6 - 235.6 Core loss 0.2'.	Run 51 230.6 to 235.6	96 (96)
		238.0 Slightly altered, bleached and somewhat softer.	Run 52 235.6 to 240.9	100 (91)
			Run 53 240.9 to 245.6	100 (100)
		245.6 - 251.0 Core loss 0.1'.	Run 54 245.6 to 251.0	98 (87)
		251.0 Thin clay seam.	Run 55 251.0 to 255.2	100 (93)
			Run 56 255.2 to 260.1	100 (100)
		261.5, 270.0 Highly fractured zones.	Run 57 260.1 to 265.1	100 (84)
			Run 58 265.1 to 270.1	100 (90)

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HOLE NO. BH-8

SHEET NO. 8 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			Run 59 270.1 to 275.3	100 (88)
			Run 60 275.3 to 280.2	100 (100)
			Run 61 280.2 to 284.4	100 (100)
		284.4 - 287.8 Core loss 0.1'.	Run 62 284.4 to 287.8	97 (94)
		287.8 - 291.0 Mislatch of core barrel during drilling. Core badly ground. Core loss 0.8 feet.	Run 63 287.8 to 291.0	75 (69)
			Run 64 291.0 to 296.1	100 (100)
			Run 65 296.1 to 300.8	100 (98)
			Run 66 300.8 to 303.7	100 (97)
		307.8 - 308.8 Highly fractured, moderately weathered, soft.	Run 67 303.7 to 308.8	100 (100)

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HOLE NO. BH-8
SHEET NO. 9 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			Run 68 308.8 to 313.2	100 (93)
			Run 69 313.2 to 318.2	100 (100)
318.8	Granodiorite	Pale green to pink and gray, fine to medium grained crystalline rock. Non-foliated with approximately 20% mafics. Hard to very hard, fresh and generally competent. Joint spacing close to moderately close. Occasional carbonate coating.	Run 70 318.2 to 321.5	100 (94)
		324.5 Thin felsic dike.	Run 71 321.5 to 326.9	100 (100)
		326.9 - 330.8 Core loss 0.1'.	Run 72 326.9 to 330.8	97 (97)
		332.4 - 332.8 Felsic dike.	Run 73 330.8 to 335.8	100 (90)
340.0	Diorite	Gray to pale green and pink, fine to medium grained crystalline rock. Non-foliated with 20% to 30% mafics. Hard to very hard, fresh. Generally competent. Minor sulfide mineralization. Joint spacing very close to moderately close. Occasional joints healed with calcite.	Run 74 335.8 to 340.1	100 (93)
		341.0 - 344.0 Highly fractured zone.	Run 75 340.1 to 343.2	100 (58)
		343.2 - 375.5 Localized dikes and veins of gray, fine grained andesite.	Run 76 343.2 to 348.4	100 (92)

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for **ALASKA POWER AUTHORITY**

HOLE NO. BH-8

SHEET NO. 10 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 77 348.4 to 351.8	100 (71)
			R 78 351.8 to 356.8	100 (100)
			R 79 356.8 to 360.9	100 (100)
			R 80 360.9 to 364.2	100 (67)
		364.2 - 365.5 Core loss 0.1'.	R 81 364.2 to 365.5	92 (92)
			R 82 365.5 to 370.5	100 (90)
			R 83 370.5 to 375.5	100 (90)
			R 84 375.5 to 380.4	100 (96)
			R 85 380.4 to 384.0	100 (94)

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HOLE NO. BH-8
SHEET NO. 11 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		384.0 - 386.0 Possible shear zone, soft and friable with clay and sand infilling along joints.	R 86 384.0 to 389.0	102 (46)
			R 87 389.0 to 393.4	100 (86)
			R 88 393.4 to 397.7	100 (100)
			R 89 397.7 to 402.3	100 (96)
		406.0 - 408.7 Alteration zone, soft, and friable. Core loss 0.4 feet.	R 90 402.3 to 407.8	93 (45)
			R 91 407.8 to 411.9	100 (58)
			R 92 411.9 to 417.1	100 (96)
			R 93 417.1 to 421.0	100 (90)
			R 94 421.0 to 426.4	100 (96)

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HOLE NO. BH-8
SHEET NO. 12 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		430.4 to 436.0 Highly fractured and altered zone, friable with some chloritized joints. Core loss 0.7 feet.	R 95 426.4 to 431.0	100 (65)
			R 96 431.0 to 433.6	107 (35)
		(435.6) Shear zone, rock brecciated with clay gouge, very soft. Core loss 0.2'.	R 97 433.6 to 436.3	93 (33)
		440.0 - 443.5 Highly fractured and sheared zone. Core loss 0.3 feet.	R 98 436.3 to 441.0	98 (79)
			R 99 441.0 to 446.0	94 (70)
		446.0 - 451.0 Core loss 0.7 feet.	R 100 446.0 to 451.0	86 (90)
			R 101 451.0 to 456.2	100 (100)
			R 102 456.2 to 461.0	100 (100)
			R 103 461.0 to 465.4	100 (100)

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HOLE NO. BH-8

SHEET NO. 13 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 104 465.4 to 467.2	100 (89)
			R 105 467.2 to 470.2	100 (100)
			R 106 470.2 to 475.4	100 (90)
		476.6 - 476.9 altered zone soft, friable.	R 107 475.4 to 480.6	100 (90)
			R 108 480.6 to 481.7	100 (100)
			R 109 481.7 to 485.5	100 (81)
			R 110 485.5 to 490.0	100 (100)
		491.5 - 495.0 Altered zone, soft, core loss 0.2 feet.	R 111 490.0 to 495.0	96 (90)
			R 112 495.0 to 499.9	100 (100)

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HOLE NO. BH-8
SHEET NO. 14 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 113 499.9 to 505.2	100 (96)
		505.2 - 520.6 Altered zone, bleached, minor sulfide mineralization.	R 114 505.2 to 510.2	104 (78)
		510.2 - 515.6 Core loss 0.1'.	R 115 510.2 to 515.6	98 (72)
		(515.6 - 518.6) Soft and friable.	R 116 515.6 to 520.6	100 (80)
			R 117 520.6 to 525.7	100 (98)
			R 118 525.7 to 530.8	100 (92)
			R 119 530.8 to 536.1	100 (57)
			R 120 536.1 to 541.1	100 (94)
			R 121 541.1 to 546.3	100 (100)

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HOLE NO. BH-8
SHEET NO. 15 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 122 546.3 to 551.2	100 (100)
		551.2 - 552.6, 664.0 - 556.4 Highly fractured zones.	R 123 551.2 to 552.6	100 (50)
			R 124 552.6 to 556.4	100 (50)
			R 125 556.4 to 561.2	100 (42)
			R 126 561.2 to 566.2	100 (100)
			R 127 566.2 to 571.6	100 (89)
		571.6 - 596.0 Altered zone, sulfide mineralization.	R 128 571.6 to 575.4	100 (95)
		(580.0 - 580.5, 587.6) Highly altered, soft and friable with some carbonaceous clay filling.	R 129 575.4 to 580.5	100 (100)
			R 130 580.5 to 585.6	100 (96)

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HOLE NO. BH-8
SHEET NO. 16 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 131 585.6 to 590.7	100 (76)
		(592.2) Brecciated zone. Core loss 0.1'.	R 132 590.7 to 596.0	98 (77)
			R 133 596.0 to 601.0	100 (82)
			R 134 601.0 to 604.0	100 (80)
			R 135 604.0 to 609.0	102 (94)
		609.0 - 634.0 Highly fractured zone, with clayey filling along some joints, numerous joints healed with carbonate. Core loss 0.1'.	R 136 609.0 to 612.4	97 (50)
			R 137 612.4 to 617.6	100 (56)
		(619.6, 633.3) Slickensides.	R 138 617.6 to 621.0	100 (56)
			R 139 621.0 to 626.2	100 (62)

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HOLE NO. BH-8
SHEET NO. 17 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 140 626.2 to 628.8	100 (69)
			R 141 628.8 to 634.0	100 (75)
			R 142 634.0 to 639.3	100 (98)
			R 143 639.3 to 643.5	100 (95)
		643.5 - 648.8 Medium to coarse grained brecciated rock with clay gouge, friable and soft locally, partially healed with carbonate.	R 144 643.5 to 648.8	100 (94)
			R 145 648.8 to 653.8	100 (100)
			R 146 653.8 to 659.1	100 (100)
			R 147 659.1 to 664.1	100 (94)
			R 148 664.1 to 669.4	100 (100)

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HOLE NO. BH-8

SHEET NO. 18 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
		669.4 - 674.7 Localized clay filling along joints. Core loss 0.3 feet.	R 149 669.4 to 674.7	94 (91)
			R 150 674.7 to 679.9	100 (94)
			R 151 679.9 to 685.2	100 (98)
			R 152 685.2 to 690.2	100 (100)
		690.2 - 693.0 Mislatch of core barrel during drilling, core badly ground. Core loss 0.4 feet.	R 153 690.2 to 693.0	86 (86)
			R 154 693.0 to 698.0	100 (74)
			R 155 698.0 to 703.1	100 (73)
			R 156 703.1 to 708.5	100 (74)
			R 157 708.5 to 713.1	100 (100)

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SHEET NO. 19 OF 19

SITE Watana South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		713.1 - 719.4 Mislatch of core barrel during drilling, core badly ground, core loss 0.6 feet some carbonaceous clay along joints.	R 158 713.1 to 719.4	90 (59)
		719.4 - 724.7 Altered zone, bleached, locally soft and friable, pitted. Core loss 0.2'.	R 159 719.4 to 724.7	96 (79)
			R 160 724.7 to 729.3	100 (98)
			R 161 729.3 to 734.3	100 (100)
			R 162 734.3 to 739.3	102 (98)
			R 163 739.3 to 744.3	104 (90)
			R 164 744.3 to 749.4	100 (80)
		749.4 Soft, friable zone.	R 165 749.4 to 750.5	100 (82)
750.5		End of Hole		

DEVIL CANYON

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SUSITNA HYDROELECTRIC PROJECT

for **ALASKA POWER AUTHORITY**

HOLE NO. BH-1
SHEET NO. 1 OF 20

SITE DEVIL CANYON NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

CONTRACTOR THE DRILLING COMPANY STARTED 12:00 P.M. AUG. 23 1980
FINISHED M. AUG. 31 1980

DRILLING METHOD: SOIL Casing Advancer; ROCK DIAMOND CORE DRILL
CASING DIAM. NW (4" I.D.); CORE DIAM. NQ-3 (1.75")

LOCATION: LATITUDE N 62° 49' 11.427; DEPARTURE W 149° 18' 24.797; BEARING 225°; INITIAL DIP 67°; OTHER DIPS
ELEVATIONS: DATUM; DRILL PLATFORM; GROUND SURFACE 1415; ROCK SURFACE 1404.1; BOTTOM OF HOLE 724.4; WATER TABLE 1223 (11-21-80)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD.)
0.0	Overburden	Sandy gravel with some silt and scattered cobbles. Not sampled.		
11.8	Phyllite	Gray-brown with intercalated quartz stringers forming 30% of rock. Foliation regular to swirling at 60° to 90° to core axis. Moderately hard to hard; slightly to moderately weathered. fractured and friable throughout. Becomes less weathered with depth. Limonite staining and minor clay or sand along discontinuities.	Run 1 11.8 to 15.8	85 (20)
0		12.8 - 14.8 Highly fractured. Core loss 0.6'.	Run 2 15.8 to 20.8	100 (88)
		17.5 - 18.3 Highly fractured.	Run 3 20.8 to 26.2	85 (59)
20.8	Argillite	Medium gray to dark gray, very fine to medium grained. Laminae oriented approximately 30° to core axis. Contorted quartz stringers and irregular bedding throughout. Generally hard to soft and friable locally. Fresh to slightly weathered along joints and fractures with limonite staining common and occasional clay filling. Minor sulfide mineralization and carbonate throughout. Joint spacing close to very close.	Run 4 26.2 to 31.3	86 (82)

LOGGED BY R. RAHAIM - J HAGAN (R&M); SUMMARY - B. HOLM; (ACRES)

APPROVED (R&M)
DATE
APPROVED (ACRES)
DATE

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SUSITNA HYDROELECTRIC PROJECT

for **ALASKA POWER AUTHORITY**

HOLE NO. BH-1
SHEET NO. 2 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		20.8 - 31.3 Core loss 1.5'. (21.8 - 22.3) Quartz-carbonate-pyrite mineralization with bleaching from weathering. (25.0, 26.4 - 26.6) Soft zones. 31.3 - 35.0 Slightly fissile. Core loss 0.3'.	R 5 31.3 to 35.0	92 (68)
			R 6 35.0 to 40.0	100 (86)
			R 7 40.0 to 45.0	100 (90)
			R 8 45.0 to 49.0	100 (88)
49.0	Meta-Argillite	Dark gray pelitic rock with occasional bluish gray laminae. Sheen along irregular fracture surfaces. Very fine to fine grained. Laminae oriented at approximately 0° to 30° to core axis. Moderately hard to very hard. Well indurated with slight fissility locally. Fresh to slightly weathered with limonite staining on joints common. Elongated quartz grains scattered throughout. Euhedral pyrite commonly associated with bluish zones. Some open voids from leached sulfides. Joint spacing very close to moderately close, with occassional chlorite or clay filling. Numerous old fractures rehealed by quartz throughout.	R 9 49.0 to 53.2	100 (69)
			R 10 53.2 to 58.3	98 (92)
			R 11 58.3 to 63.5	100 (86)
		49.0 - 84.0 Quartz, irregular veins and cement along old partings, 4% to 12% of rock. 63.5 - 68.9 Highly fractured. Core loss 1.1'.	R 12 63.5 to 64.5	50 (0)
		68.1 - 69.2 Quartz vein with sulfides and some voids from sulfide leaching.	R 13 64.5 to 68.9	86 (66)

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HOLE NO. BH-1
SHEET NO. 3 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 14 68.9 to 72.3	100 (88)
			R 15 72.3 to 77.2	100 (92)
		79.0 - 109.1 Highly fractured and sheared zone. Poor core recovery with core loss of 4.6 feet. Slightly to highly weathered throughout, residual soil locally.	R 16 77.2 to 80.7	94 (83)
			R 17 80.7 to 84.0	94 (48)
		84.0 - 101.5 Quartz stringers and veins forming 40% to 60% of rock. Numerous small cavities.	R 18 84.0 to 90.0	87 (70)
			R 19 90.0 to 94.4	91 (50)
			R 20 94.4 to 97.8	88 (29)
			R 21 97.8 to 101.5	54 (0)
			R 22 101.5 to 105.0	71 (23)

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HOLE NO. BH-1
SHEET NO. 4 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
105.0	Argillite	Medium to dark gray, very fine to fine grained laminae oriented approximately 0° to 20° to core axis. Contorted quartz stringers and irregular bedding throughout. Generally hard; soft and friable locally. Fresh to slightly weathered, with limonite staining on joint and fracture surfaces. Minor sulfide mineralization throughout. Joint spacing very close to moderately close.	R 23 105.0 to 109.1	95 (32)
		109.1 - 265.6 Sulfides 3% to 8% of rock.	R 24 109.1 to 112.5	100 (85)
		109.1 - 175.0 Most joints at 60° to core axis. Limonite common along joints. Numerous drilling breaks.	R 25 112.5 to 117.6	86 (80)
		112.5 - 117.6 Core loss 0.7'.	R 26 117.6 to 120.9	100 (79)
		(114.0 - 114.8) Quartz vein.		
		117.6 - 118.6 Vertical quartz inclusion.	R 27 120.9 to 125.0	100 (73)
		120.9 - 129.0 Clay filling in joints. (Possible gouge).		
		(125.0 - 129.0) Joints and fractures open to 0.05' within run. Core loss 0.5'.	R 28 125.0 to 129.0	87 (63)
		129.0 - 148.0 Joint spacing very close to close.	R 29 129.0 to 134.0	100 (94)
			R 30 134.0 to 139.2	100 (90)
			R 31 139.2 to 144.3	100 (90)

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HOLE NO. BH-1
SHEET NO. 5 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
		(144.3 - 148.3) Core loss 0.4'.	R 32 144.3 to 148.0	89 (81)
		148.0 - 166.3 Joint spacing very close to moderately close.	R 33 148.0 to 153.2	100 (92)
			R 34 153.2 to 156.2	100 (83)
		(156.2 - 161.5) Core loss 0.2'.	R 35 156.2 to 161.5	96 (89)
			R 36 161.5 to 166.3	100 (100)
			R 37 166.3 to 171.5	100 (100)
		175.0 - 276.1 Numerous fractures cemented with calcite, minor chlorite. Core frequently broken along these surfaces by drilling.	R 38 171.5 to 176.3	100 (100)
			R 39 176.3 to 181.4	100 (100)
			R 40 181.4 to 186.3	100 (100)

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HOLE NO. BH-1
SHEET NO. 6 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 41 186.3 to 191.5	100 (94)
			R 42 191.5 to 196.4	100 (100)
			R 43 196.4 to 201.5	100 (100)
			R 44 201.5 to 204.9	100 (100)
			R 45 204.9 to 209.9	98 (98)
			R 46 209.9 to 214.9	100 (100)
			R 47 214.9 to 220.0	100 (90)
		220.0 - 221.2 Joints oriented parallel to core axis, with clay gouge.	R 48 220.0 to 225.1	100 (76)
			R 49 225.1 to 230.0	100 (100)

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HOLE NO. BH-1
SHEET NO. 7 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 50 230.0 to 235.0	100 (100)
			R 51 235.0 to 240.1	100 (98)
		240.1 - 241.0. Minor clay along partings within run.	R 52 240.1 to 241.8	100 (94)
		241.8 Core is fresh below this point.	R 53 241.8 to 246.9	100 (100)
			R 54 246.9 to 251.5	100 (100)
			R 55 251.5 to 255.9	100 (91)
			R 56 255.9 to 260.5	100 (100)
		260.5 - 276.1 Joint spacing very close to close.	R 57 260.5 to 262.5	100 (100)
			R 58 262.5 to 265.6	100 (87)

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HOLE NO. BH-1
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SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 59 265.6 to 270.3	100 (100)
		(270.3 - 274.2) Core loss 0.8'.	R 60 270.3 to 274.2	79 (77)
			R 61 274.2 to 276.1	100 (79)
276.2	Lithic Graywacke	Dark gray to black; fine to medium grained with crystalline like texture. 3% to 7% green carbonate crystals, quartz rich. Fresh to moderately weathered hard to very hard. Joint spacing very close to moderately close.	R 62 276.1 to 280.3	100 (95)
		276.1 - 280.3 Slickensided partings.	R 63 280.3 to 285.2	100 (82)
		285.2 - 286.6 Core loss 0.2'.	R 64 285.2 to 286.6	86 (71)
		(285.3) 0.1' layer of clay gouge.		
			R 65 286.6 to 291.5	100 (84)
			R 66 291.5 to 296.0	100 (82)
296.5	Meta Argillite	Medium to dark gray, mottled bluish-gray locally. Fine grained; moderately hard to very hard, fresh and competent. Minor sulfide mineralization. Carbonates common. Joint spacing very close to moderately close. Numerous healed joints throughout.	R 67 296.0 to 298.9	79 (34)

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SUSITNA HYDROELECTRIC PROJECT

for **ALASKA POWER AUTHORITY**

HOLE NO. BH-1
SHEET NO. 9 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		296.0 - 298.9 Shear zone, highly fractured, weathered and slickensided. Core loss 0.6'	R 68 298.0 to 303.0	100 (85)
			R 69 303.0 to 305.0	100 (90)
		305.0 - 311.0 Core loss 0.3'.	R 70 305.0 to 306.1	82 (68)
		(306.1 - 311.0) Joint spacing very close.	R 71 306.1 to 311.0	98 (71)
			R 72 311.0 to 315.7	100 (85)
			R 73 315.7 to 320.0	100 (100)
		320.0 - 325.0 Core loss 0.3'.	R 74 320.0 to 325.0	94 (92)
329.0	Graywacke (Breccia-Conglomerate)	Medium to dark gray clayey matrix containing coarse, angular and sub-rounded clasts of quartz, phyllite, argillite, and other rock types ranging in size from 0.01' to 0.1' and constituting 50% to 60% of rock mass. Well indurated, hard to very hard, competent, fresh. Contains thin layers (1 to 2 feet thick) of Argillite locally. Joint spacing very close to moderately close. Chlorite and carbonate coating on joints common. Occasional healed joints.	R 75 325.0 to 329.7	100 (85)
			R 76 329.7 to 334.7	100 (80)

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HOLE NO. BH-1
SHEET NO. 10 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 77 334.7 to 339.8	100 (88)
		343.0 Joint with clay gouge.	R 78 339.8 to 345.0	100 (96)
			R 79 345.0 to 349.7	(100) (94)
			R 80 349.7 to 355.0	100 (100)
			R 81 355.0 to 359.6	100 (100)
			R 82 359.6 to 361.3	100 (100)
			R 83 361.3 to 363.4	100 (100)
			R 84 363.4 to 364.4	100 (100)
			R 85 364.4 to 369.3	100 (98)

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HOLE NO. BH-1
SHEET NO. 11 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
		373.3 to 373.6 Shear zone with clay gouge.	R 86 369.3 to 373.6	100 (93)
			R 87 373.6 to 378.6	100 (100)
		378.7 Clay filled joint.	R 88 378.6 to 381.5	100 (86)
		381.5 - 401.5 Numerous healed joints broken by drilling.	R 89 381.5 to 386.5	100 (100)
		(386.5 - 391.4) Core loss 0.2'.	R 90 386.5 to 391.4	95 (94)
			R 91 391.4 to 396.5	100 (98)
			R 92 396.5 to 401.5	100 (90)
		406.0 - 424.0 Joint spacing very close to close.	R 93 401.5 to 406.6	100 (96)
			R 94 406.6 to 411.5	100 (82)

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HOLE NO. BH-1

SHEET NO. 12 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		(413.3 - 415.3) Highly fractured zone.	R 95 411.5 to 415.3	100 (68)
			R 96 415.3 to 420.3	100 (80)
		(423.9 - 424.1) Highly fractured zone, trace of clay gouge.	R 97 420.3 to 424.1	100 (76)
			R 98 424.1 to 429.3	100 (96)
			R 99 429.3 to 434.3	100 (100)
			R 100 434.3 to 439.4	100 (98)
			R 101 439.4 to 444.4	100 (98)
			R 102 444.4 to 449.5	100 (100)
			R 103 449.5 to 454.7	100 (100)

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HOLE NO. BH-1
SHEET NO. 13 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 104 454.7 to 459.8	100 (100
			R 105 459.8 to 463.8	100 (100)
			R 106 463.8 to 468.6	100 (100)
			R 107 468.6 to 473.1	100 (100)
			R 108 473.1 to 475.4	100 (100)
			R 109 475.4 to 480.5	100 (82)
			R 110 480.5 to 485.5	100 (100)
			R 111 485.5 to 488.8	100 (85)
		488.8 - 491.5 Core loss 0.1'.	R 112 488.8 to 491.5	96 (70)

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HOLE NO. BH-1
SHEET NO. 14 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 113 491.5 to 496.7	100 (92)
			R 114 496.7 to 501.2	100 (93)
			R 115 501.2 to 506.5	100 (100)
			R 116 506.5 to 511.5	100 (100)
			R 117 511.5 to 514.8	100 (97)
			R 118 514.8 to 519.9	100 (96)
			R 119 519.9 to 525.1	100 (94)
			R 120 525.1 to 530.4	100 (100)
		530.4 - 534.0 Core loss 0.2'. (533.5) Joint with carbonate and clay gouge.	R 121 530.4 to 534.0	94 (89)

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HOLE NO. BR-1
SHEET NO. 15 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 122 534.0 to 539.0	100 (98)
		540 - 750.2 Generally hard, fresh, competent.	R 123 539.0 to 544.3	100 (89)
			R 124 544.3 to 549.5	100 (100)
			R 125 549.5 to 554.5	100 (100)
			R 126 554.5 to 559.7	100 (90)
			R 127 559.7 to 564.8	100 (100)
			R 128 564.8 to 569.7	100 (100)
			R 129 569.7 to 575.1	100 (100)
			R 130 575.1 to 579.9	100 (92)

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HOLE NO. BH-1
SHEET NO. 16 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 131 579.9 to 585.1	100 (100)
			R 132 585.1 to 590.1	100 (100)
			R 133 590.1 to 595.1	100 (100)
		(598.7 - 599.1) Core shattered.	R 134 595.1 to 599.1	100 (100)
			R 135 599.1 to 604.2	100 (98)
			R 136 604.2 to 609.1	100 (100)
			R 137 609.1 to 610.5	100 (100)
			R 138 610.5 to 614.8	100 (100)
			R 139 614.8 to 619.8	100 (100)

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HOLE NO. CH-1
SHEET NO. 17 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		(621.6 - 621.7) Core shattered.	R 140 619.8 to 621.7	100 (95)
			R 141 621.7 to 626.8	100 (98)
			R 142 626.8 to 631.7	100 (100)
			R 143 631.7 to 636.7	100 (100)
			R 144 636.7 to 641.6	100 (100)
			R 145 641.6 to 645.2	100 (100)
			R 146 645.2 to 650.0	100 (100)
			R 147 650.0 to 655.2	100 (100)
			R 148 655.2 to 660.4	100 (96)

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HOLE NO. BH-1

SHEET NO. 18 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 149 660.4 to 665.6	100 (96)
			R 150 665.6 to 670.8	100 (96)
			R 151 670.8 to 675.8	100 (100)
			R 152 675.8 to 680.5	100 (96)
			R 153 680.5 to 683.9	100 (74)
		(683.9 - 690.0) Core loss 0.7'.	R 154 683.9 to 690.0	88 (82)
			R 155 690.0 to 695.2	100 (100)
			R 156 695.2 to 700.5	100 (98)
			R 157 700.5 to 705.7	100 (98)

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HOLE NO. BH-1

SHEET NO. 19 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 158 705.7 to 710.6	100 (100)
			R 159 710.6 to 715.7	100 (100)
			R 160 715.7 to 721.0	100 (98)
			R 161 721.0 to 725.4	100 (100)
		(727.1) Joint with clay coating.	R 162 725.4 to 727.4	100 (95)
			R 163 727.4 to 731.8	100 (91)
		(731.8 - 732.5) Highly fractured zone.	R 164 731.8 to 737.1	100 (85)
		(733.0) Joint with clay gouge.		
		(737.4) Joint with ½" clay gouge.	R 165 737.1 to 741.5	100 (91)
			R 166 741.5 to 745.7	100 (98)

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HOLE NO. BH-1

SHEET NO. 20 OF 20

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 167 745.7 to 750.2	100 (87)
750.2		End of Hole		

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for **ALASKA POWER AUTHORITY**

HOLE NO. BH-2
SHEET NO. 1 OF 18

SITE DEVIL CANYON NORTH ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

CONTRACTOR THE DRILLING COMPANY
STARTED 11:00 A.M. Sept. 10 19 80
FINISHED M. Sept. 15 19 80

DRILLING METHOD
SOIL CASING ADVANCER — CASING DIAM. NW 4" I.D.
ROCK DIAMOND CORE DRILLING — CORE DIAM. NQ - 3 (1.75")

LOCATION:
LATITUDE N 62° 49' 8.737"
DEPARTURE W 149° 18' 21.179"
BEARING 0°
INITIAL DIP 60°
OTHER DIPS

ELEVATIONS:
DATUM
DRILL PLATFORM
GROUND SURFACE 1214
ROCK SURFACE 1211
BOTTOM OF HOLE 6
WATER TABLE 1209

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD.)
0.0	Overburden	Dark brown organic silt with trace light gray ash, angular cobbles. 0.0 - 2.0 No samples taken.		
2.0	Argillite	Gray, siliceous, very fine grained. Thinly bedded, with laminae oriented 55° to 60° to core axis. Very hard to moderately hard. Fresh to slightly weathered, with iron-oxide staining on fracture and joint surfaces. Joints very close to closely spaced. Pyrite cubes common. Occasional quartz intrusions. 2.0 - 16.0 Core loss 2.9'. (6.0 - 10.5) Highly fractured interval, friable 10.5 - 16.0 Silvery sheen. Grading into phyllite. Laminae offset.	Run 1 2.0 to 6.0 Run 2 6.0 to 7.0 Run 3 7.0 to 8.1 Run 4 8.1 to 10.5 Run 5 10.5 to 16.0	95 (53) 40 (0) 73 (0) 79 (0) 76 (40)

LOGGED BY Rahaim, Hagen - field (R&M)
Feldman - Summary
(ACRES)

APPROVED (R&M)
DATE December 1980
APPROVED (ACRES)
DATE

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HOLE NO. BH-2

SHEET NO. 2 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
16.0	Phyllite	Dark gray, thinly bedded. Wavy laminae oriented at 40° to 60° to core axis. Very hard to hard. Fresh to moderately weathered, with Iron-staining on joints and fracture surfaces. Joint spacing very close to moderately close. Trace to frequent pyrite. Minor quartz in healed fractures.	Run 6 16.0 to 21.0	100 (92)
		21.0 - 26.0 Slightly fissile.	Run 7 21.0 to 26.0	100 (90)
			Run 8 26.0 to 28.0	100 (90)
		28.0 - 33.0 Thin quartz veins. Healed brecciated zone at approximately 31 feet.	Run 9 28.0 to 33.0	100 (90)
		33.0 - 38.0 Argillaceous zone. Fractures oriented at approximately 0° to core axis.	Run 10 33.0 to 38.0	100 (92)
			Run 11 38.0 to 42.0	100 (92)
		42.0 - 46.9 Joint spacing close to moderately close.	Run 12 42.0 to 46.9	100 (100)
			Run 13 46.9 to 51.8	100 (96)
		51.8 - 57.1 Graywacke intermixed with phyllite.	Run 14 51.8 to 57.1	100 (100)

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HOLE NO. BH-2
SHEET NO. 3 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			Run 15 57.1 to 62.1	100 (100)
			Run 16 62.1 to 67.0	100 (98)
			Run 17 67.0 to 71.9	100 (100)
			Run 18 71.9 to 76.8	100 (100)
		71.9 - 76.8 Intermixed argillite.	Run 19 76.8 to 81.8	100 (80)
		81.8 - 86.9 Predominantly phyllite. Wavy and irregular bedding at 50° to 60° to core axis. Closely spaced joints.	Run 20 81.8 to 86.9	100 (96)
		86.9 - 91.6 Joint spacing very close to close.	Run 21 86.9 to 91.6	100 (83)
91.6	Argillaceous Graywacke	Brown, folded, very hard and fresh. Joint spacing very close to moderately close. Pyrite common. Some quartz intrusions. Argillite, laminae oriented at 40° to 50° to core axis.	Run 22 91.6 to 96.9	100 (89)
			Run 23 96.9 to 101.7	100 (96)

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HOLE NO. BH-2
SHEET NO. 4 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			Run 24 101.7 to 105.0	100 (100)
			Run 25 105.0 to 107.9	100 (93)
		107.9 - 112.0 Rock less competent, highly fractured and broken by drilling.	Run 26 107.9 to 109.5	100 (94)
		(109.5 - 112.0) Core loss 1.5'.	Run 27 109.5 to 112.0	40 (0)
112.0	Argillite	Gray, very fine grained. Generally very hard, friable locally. Fresh to slightly weathered, with trace of Iron-staining and some chlorite and calcite scale in joints and fractures. Very close to closely spaced joints. Occasional quartz intrusions.	Run 28 112.0 to 114.6	100 (100)
		114.6 - 119.4 Some interlayered graywacke. Slickensides at 117.5'.	Run 29 114.6 to 119.4	100 (96)
		119.4 - 123.2 Highly fractured. Some fractures healed with bluish quartz. Clay on vertical joint. Core loss 0.3'.	Run 30 119.4 to 123.2	92 (79)
			Run 31 123.2 to 125.9	100 (100)
		125.9 - 132.0 Poor recovery. Core badly ground by drilling. Core loss 4.1 feet.	Run 32 125.9 to 132.0	36 (0)

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HOLE NO. BH-2
SHEET NO. 5 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			Run 33 132.0 to 135.0	100 (100)
			Run 34 135.0 to 137.0	100 (90)
		137.0 - 140.3 Joints moderately close spaced.	Run 35 137.0 to 140.3	100 (76)
		140.3 - 145.4 Oolitic zone. Numerous soft, white, noncalcareous Oolites in dark gray calcareous argillite matrix.	Run 36 140.3 to 143.4	100 (81)
		(141.3, 144.0) Slickensides.	Run 37 143.4 to 145.4	100 (90)
145.4	Graywacke	Dark gray, medium to coarse grained. Moderately hard to soft, fresh to moderately weathered. Numerous cream-colored, rounded, siliceous blebs (greater than 3 mm) throughout. Joint spacing very close to moderately close.	Run 38 145.4 to 147.5	100 (100)
		147.5 - 152.0 Core loss 0.2'.	Run 39 147.5 to 152.0	96 (95)
		152.0 - 155.0 Gouge zone. Moderately hard to soft, moderately weathered. Residual soil present. Very friable. Core loss 0.2'.	Run 40 152.0 to 155.0	93 (0,
		155.0 - 178.6 Dark gray to green, with crystals of gypsum(?) [up to 5 mm diameter] and quartz. Abundant biotite mica noted. Moderately hard, slightly to moderately weathered.	Run 41 155.0 to 160.0	100 (92)
		(155.0 - 160.0) Slickensides.	Run 42 160.0 to 165.4	100 (93)

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HOLE NO. BH-2
SHEET NO. 6 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			Run 43 165.4 to 170.5	100 (98)
			Run 44 170.5 to 175.6	100 (98)
			Run 45 175.6 to 178.6	100 (90)
		178.6 - 182.8 Highly fractured, some clay gouge on joint surfaces.	Run 46 178.6 to 181.8	100 (56)
182.8	Interbedded Graywacke and Argillite	Interbedded graywacke and dark gray, fine grained argillite. Hard to moderately hard. Fresh. Joints closely spaced. Many healed fractures filled with calcite, some quartz.	Run 47 181.8 to 185.9	100 (93)
			Run 48 185.9 to 190.8	100 (100)
			Run 49 190.8 to 193.8	100 (100)
			Run 50 193.8 to 198.9	100 (100)
			Run 51 198.9 to 203.4	100 (100)

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HOLE NO. BH-2
SHEET NO. 7 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			Run 52 203.4 to 208.6	100 (100)
			Run 53 208.6 to 211.7	100 (100)
		213.0 - 213.6 Broken and healed zone.	Run 54 211.7 to 216.9	100 (96)
			Run 55 216.9 to 220.4	100 (100)
		220.4 - 231.2 Joint spacing close to moderately close.	Run 56 220.4 to 226.0	100 (98)
			Run 57 226.0 to 231.2	100 (100)
			Run 58 231.2 to 236.3	100 (100)
236.3	Argillite	Gray, very fine grained. Laminae oriented 50° to core axis. Oriented, platy minerals evident. Very hard to moderately hard. Fresh. Joint spacing very close to moderately close. Traces of pyrite (cubes), and minor quartz in irregular veins.	Run 59 236.3 to 241.0	100 (100)
			Run 60 241.0 to 244.7	100 (97)

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HOLE NO. BH-2
SHEET NO. 8 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			Run 61 244.7 to 249.8	100 (100)
			Run 62 249.8 to 255.0	100 (100)
			Run 63 255.0 to 260.0	100 (100)
		260.0 - 262.5 Core loss 0.2'.	Run 64 260.0 to 262.5	92 (80)
			Run 65 262.5 to 267.3	100 (92)
			Run 66 267.3 to 269.5	100 (82)
		270.5 Joint with clay gouge.	Run 67 269.5 to 274.7	100 (100)
		274.7 - 281.8 Core loss 0.4'.	Run 68 274.7 to 277.5	96 (86)
			Run 69 277.5 to 281.8	93 (81)

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for **ALASKA POWER AUTHORITY**

HOLE NO. BH-2

SHEET NO. 9 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			Run 70 281.8 to 287.0	100 (100)
			Run 71 287.0 to 292.0	100 (100)
			Run 72 292.0 to 297.0	100 (100)
		300.0 Joint with clay gouge.	Run 73 297.0 to 301.7	100 (100)
		301.7 - 306.7 Quartz intrusion parallel to bedding - constitutes 15% of the interval.	Run 74 301.7 to 306.7	100 (100)
			Run 75 306.7 to 309.4	100 (100)
			Run 76 309.4 to 310.5	100 (100)
			Run 77 310.5 to 315.5	100 (100)
			Run 78 315.5 to 318.7	100 (100)

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HOLE NO. BH-2

SHEET NO. 10 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
		318.7 - 325.8 Wavy laminae, generally oriented at 45° to 50° to core axis.	Run 79 318.7 to 322.5	100 (97)
			Run 80 322.5 to 325.8	100 (100)
		327.8 - 329.0 Interbedded graywacke numerous contorted quartz stringers throughout.	Run 81 325.8 to 329.0	100 (97)
		329.0 - 336.4 Contorted quartz stringers throughout.	Run 82 329.0 to 331.5	100 (96)
		(331.5 - 336.4) Core loss 1.6'.	Run 83 331.5 to 336.4	67 (57)
		336.4 - 365.6 Intercalated graywacke and argillite, dark gray to light grayish brown. Irregular, wavy laminae at 50° to core axis. Very hard to hard, fresh, joint spacing very close to moderately close.	Run 84 336.4 to 338.4	[illegible] (50)
		(341.5) Joint with clay gouge.	Run 85 338.4 to 342.0	100 (100)
			Run 86 342.0 to 346.0	100 (100)
			Run 87 346.0 to 351.1	100 (100)

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HOLE NO. BH-2
SHEET NO. 11 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			Run 88 351.1 to 356.0	100 (100)
			Run 89 356.0 to 360.8	100 (100)
			Run 90 360.8 to 365.6	100 (98)
		365.6 - 385.1 Trace of pyrite with cubes to 5 mm.	Run 91 365.6 to 370.9	98 (96)
		(365.6 - 370.9) Core loss 0.1'.		
		(374.4) Clay filled joint.	Run 92 370.9 to 375.0	100 (85)
			Run 93 375.0 to 380.0	100 (100)
			Run 94 380.0 to 385.1	100 (100)
		385.1 - 390.3 Deformed laminae.	Run 95 385.1 to 390.3	100 (98)
			Run 96 390.3 to 395.5	100 (94)

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HOLE NO. BH-2
SHEET NO. 12 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			Run 97 395.5 to 400.7	100 (96)
		400.7 - 406.0 Core loss 0.1'.	Run 98 400.7 to 406.0	98 (91)
		406.3 Clay gouge on joint.	Run 99 406.0 to 411.0	100 (94)
		411.0 - 444.9 Argillite grading into phyllite. Quartz intrusions common. Chlorite mineralization.	R 100 411.0 to 416.3	100 (100)
			R 101 416.3 to 421.3	100 (92)
			R 102 421.3 to 426.6	100 (100)
		(426.6 - 431.9) Core loss 0.4'.	R 103 426.6 to 431.9	92 (100)
			R 104 431.9 to 437.2	100 (95)
			R 105 437.2 to 442.2	100 (100)

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HOLE NO. BH-2
SHEET NO. 13 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 106 442.2 to 444.9	100 (100)
444.9	Graywacke with Argillite	Graywacke interlayered with (varying amounts) argillite. Dark gray to brown, fine grained. Very hard, fresh, joint spacing very close to close. Minor quartz intrusions with chlorite.	R 107 444.9 to 450.0	100 (100)
			R 108 450.0 to 455.3	100 (94)
			R 109 455.3 to 460.2	100 (100)
			R 110 460.2 to 465.3	100 (100)
			R 111 465.3 to 470.3	100 (100)
			R 112 470.3 to 475.0	100 (96)
		475.0 - 492.5 Numerous healed fractures filled with calcite. Argillite has wavy laminae.	R 113 475.0 to 477.3	100 (100)
			R 114 477.3 to 481.9	100 (100)

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HOLE NO. BH-2

SHEET NO. 14 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 115 481.9 to 485.4	100 (86)
			R 116 485.4 to 490.3	100 (96)
		(491.8 - 492.5) Shear zone with clay gouge.	R 117 490.3 to 492.5	100 (59)
		494.4 - 498.0 Joints with clay gouge.	R 118 492.5 to 495.4	100 (73)
495.4	Argillite	Dark gray argillite with distorted, irregular laminae oriented approximately 45° to 50° to core axis. Fresh, very hard. Joint spacing very close to close. Frequent irregular quartz intrusions with some chlorite.	R 119 495.4 to 498.5	100 (90)
		498.0 Joint with clay coating at 45° to core axis.	R 120 498.5 to 503.8	100 (100)
			R 121 503.8 509.1	100 (100)
		509.1 - 519.1 Irregular fragments of graywacke throughout.	R 122 509.1 to 514.0	100 (88)
			R 123 514.0 to 519.1	100 (90)

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HOLE NO. BH-2
SHEET NO. 15 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 124 519.1 to 524.3	100 (100)
		529.0 Joi[illegible]with clay gouge.	R 125 524.3 to 529.5	100 '94)
		529.5 - 534.7 Slight alteration zone associated with quartz vein.	R 126 529.5 to 534.7	100 (97)
		534.7 - 538.3 Core loss 0.3'.	R 127 534.7 to 538.3	91 (83)
			R 128 538.3 to 542.0	100 (78)
		542.0 - 557.1 Laminae very irregular to core axis. (546.0, 548.7) Highly fractured with clay gouge.	R 129 542.0 to 547.2	100 (71)
			R 130 547.2 to 552.0	100 (100)
			R 131 552.0 to 557.1	100 (94)
		557.1 - [illegible]8.7, 560.5 - 562.0 Highly fractured.	R 132 557.1 to 562.0	100 (72)

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HOLE NO. BH-2
SHEET NO. 16 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052304 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		562.0 - 582.9 Many rehealed fractures filled with calcite and quartz. Irregular orientations.	R 133 562.0 to 567.0	100 (98)
			R 134 567.0 to 572.1	100 (100)
			R 135 572.1 to 574.9	100 (92)
			R 136 574.9 to 579.9	100 (94)
			R 137 579.9 to 582.9	100 (93)
		582.9 - 627.8 Numerous thin bands of highly fractured rock rehealed with quartz throughout. Rehealed zones are less competent and badly broken by drilling. Hard to soft and friable locally.	R 138 582.9 to 584.9	100 (60)
		(584.9 - 589.6) Core loss 0.2'.	R 139 584.9 to 589.6	96 (83)
		(594.2 - 594.6) Shear zone with clay gouge.	R 140 589.6 to 594.6	100 (78)
			R 141 594.6 to 599.6	100 (94)

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HOLE NO. BH-2
SHEET NO. 17 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 142 599.6 to 601.8	100 (91)
			R 143 601.8 to 604.0	100 (91)
			R 144 604.0 to 609.2	100 (81)
		(611.2 - 611.7) Shear zone.	R 145 609.2 to 614.2	100 (80)
			R 146 614.2 to 619.5	100 (93)
			R 147 619.5 to 624.8	100 (93)
		(626.8 - 627.8) Shear zone, friable, core loss 0.2'.	R 148 624.8 to 630.8	85 (70)
632.9	Quartz Granodiorite	Light grayish brown, fine to med. grained, composed primarily of feldspars and quartz with 2 to 5% mafics. Massive, very hard. Joint spacing wide. Fairly sharp contact with overlying argillite. 1" wide contact zone with no apparent contact metamorphism in argillitte.	R 149 630.8 to 636.0	100 (100)
			R 150 636.0 to 641.2	100 (100)

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HOLE NO. BH-2
SHEET NO. 18 OF 18

SITE DEVIL CANYON N. ABUTMENT JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
		645.3 - 650.0 Argillite, with blebs and bands of quartz throughout. No bedding structure evident. Fresh, very hard, joint spacing close to wide.	R 151 641.2 to 646.5	100 (98)
			R 152 646.5 to 651.5	100 (100)
			R 153 651.5 to 656.2	100 (100)
656.2		End of Hole		

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for **ALASKA POWER AUTHORITY**

HOLE NO. BH-4
SHEET NO. 1 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

CONTRACTOR The Drilling Company STARTED M. AUG 14 19 80
FINISHED M. AUG 19 19 80

DRILLING METHOD — SOIL: Casing Advancer — CASING DIAM.: NW -(4" I.D.)
ROCK: Diamond Core Drill — CORE DIAM.: NQ-3(1.75")

LOCATION: LATITUDE 624857.593 — ELEVATIONS: DATUM
DEPARTURE 1491823.795 — DRILL PLATFORM
BEARING 195° — GROUND SURFACE 1353
INITIAL DIP 60° — ROCK SURFACE 1346
OTHER DIPS — BOTTOM OF HOLE 912.1
WATER TABLE 1322

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD.)
0.0	Overburden			
7.0	Bedrock	0.0 - 12.0 No samples taken.		
12.0	Interbedded Graywacke & Argillite	Graywacke - medium to dark gray, clayey matrix containing fine to medium sand grains and sub-rounded clasts of quartz, argillite and other rock types. Interbedded with argillite - medium to dark gray, fine grained. Laminae oriented at approximately 20° to core axis. Rock is well indurated, moderatly hard to hard, and competent. Fresh to slightly weathered with limonite staining on joint surfaces. Minor sulfide mineralization. Joint spacing very close to moderately close. Occasional joints healed with quartz and carbonate.	Run 1 12.0 to 15.2	75 (17)
			Run 2 15.2 to 18.8	100 (67)
			Run 3 18.8 to 20.4	101 (38)
		12.0 - 15.2 Core loss 0.8'.		
		20.0, 23.4, 29.8 Slickensides and iron staining. Joints parallel texture at 20° to 30° to core axis. Some clay filling.	Run 4 20.4 to 25.4	101 (70)

LOGGED BY: Hagen - Rahaim (R&M); Summary by Acomb; Summary by Henschel (ACRES)

APPROVED (R&M) DATE

APPROVED (ACRES) DATE

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HOLE NO. BH-4

SHEET NO. 2 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		25.4 - 30.5 Core loss 0.2'.	R 5 25.4 to 30.5	96 (78)
30.7	Graywacke	Medium gray to dark gray, siliceous. Clayey matrix containing fine to coarse sand grains and elipsoid clasts approximately 2mm x 1mm in size. Well indurated moderately hard to hard, competent. Fresh to slightly weathered with some iron staining on joint surfaces. Minor sulfide mineralization throughtout. Joint spacing very close to moderately close. Numerous joints healed with calcite, oriented at approximately 15° to 30° to core axis.	R 6 30.5 to 34.0	100 (37)
			R 7 34.0 to 39.0	100 (98)
		30.7 - 45.0 Minor interbedded argillite	R 8 39.0 to 44.0	100 (90)
		(30.7, 30.9, 38.8, 39.1) Slickensides and iron staining in joints.		
		45.0 - 46.2 Numerous joints at 15° to 20° to core axis. Open, highly weathered and clay filled.	R 9 44.0 to 48.0	100 (43)
			R 10 48.0 to 53.1	100 (96)
			R 11 53.1 to 58.1	100 (92)
			R 12 58.1 to 61.0	125 (59)
		62.7 Friable zone.	R 13 61.0 to 65.2	100 (71)

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HOLE NO. BH-4

SHEET NO. 3 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
		65.2 - 70.2 Core loss 0.1'.	R 14 65.2 to 70.2	98 (84)
			R 15 70.2 to 75.0	100 (98)
			R 16 75.0 to 80.2	100 (87)
		80.2 - 80.9 Core loss 0.1'.	R 17 80.2 to 80.9	89 (57)
			R 18 80.9 tl 84.1	100 (84)
		86.0 Quartz vein with sulfides 0.01' thick.	R 19 84.1 to 89.4	100 (100)
			R 20 89.4 to 93.2	100 (100)
			R 21 93.2 to 98.2	100 (68)
		102.0 - 103.0 Numerous quartz veins and stringers.	R 22 98.2 to 103.4	100 (83)

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HOLE NO. BH-4
SHEET NO. 4 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		104.4 - 104.6 Joint with slickensides and clay filling.	R 23 103.4 to 108.4	100 (92)
108.4	Graywacke w/ Interbedded Argillite	Graywacke (as described above) with some interbedded Argillite. Transitional to underlying phyllite. Argillite is medium to dark gray, fine grained. Laminae oriented approximately 20° to core axis. Moderately hard to very hard, fresh, generally competent. Numerous contorted quartz stringers throughout. Joint spacing close to moderately close.	R 24 108.4 to 113.3	100 (100)
			R 25 113.3 to 117.7	100 (95)
114.9	Phyllite	Dark gray to black, very fine to fine grained. Foliation approximately 5° to 10° to core axis, with microfolds crosscutting foliation at approximately 30° (microfolds 20° to 30° to core axis). Hard to very hard, fresh. Minor sulfide mineralization throughout. Quartz and carbonate veins common. Joint spacing close to moderately close. Numerous healed joints throughout.	R 26 117.7 to 120.0	100 (87)
			R 27 120.0 to 125.0	100 (100)
			R 28 125.0 to 130.2	100 (87)
		130.2 - 135.5 Core loss 0.2'.	R 29 130.2 to 135.5	96 (96)
			R 30 135.5 to 140.5	100 (90)
			R 31 140.5 to 145.6	100 (96)

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HOLE NO. BH-4
SHEET NO. 5 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 05250-4 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 32 145.6 to 150.8	100 (92)
151.5	Meta-Argillite	Dark gray to black, very fine grained, non-foliated to indistinct foliation. Hard to very hard, well indurated, fresh and competent. Very gradational contact with overlying phyllite. Joint spacing close to moderately close.	R 33 150.8 to 156.0	100 (100)
			R 34 156.0 to 161.0	100 (96)
			R 35 161.0 to 166.0	100 (100)
		166.0 - 171.0 · Core loss 0.1'.	R 36 166.0 to 171.0	98 (84)
		169.5 - 170.4 Quartz veins.		
		171.3 - 172.3 Quartz veins and stringers, sulfide mineralization - core badly broken and ground by drilling; weak zone.	R 37 171.0 to 176.1	100 (84)
		178.1 - 181.6 Core badly broken and ground by drilling. Pieces 0.05' to 0.1' inches diameter. Joints have chlorite or talc coating.	R 38 176.1 to 179.6	100 (67)
		(179.6 - 184.0) Core loss 0.1'.	R 39 179.6 to 184.0	98 (45)
			R 40 184.0 to 189.1	100 (98)

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HOLE NO. BH-4
SHEET NO. 6 OF 13

SITE Devil Canyon South Abutment JOB NO P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 41 189.1 to 194.3	100 (79)
			R 42 194.3 to 199.6	100 (100)
		199.6 - 201.6 Quartz vein 0.02' thick at approximately 10° to 20° to core axis. Sulfide mineralization.	R 43 199.6 to 204.6	100 (96)
205.0	Phyllite	Gray brown to dark gray to black, very fine to fine grained, well developed foliation, with characteristic silvery luster (white-mica phyllite) on clearage surfaces. The rock contains highly contorted quartz veins and stringers throughout, which crosscut the foliation. Orientation of foliation is highly irregular in these zones. Rock is hard to very hard, fresh and competent. Joint spacing close to moderately close. Numerous healed joints.	R 44 204.6 to 209.6	100 (100)
			R 45 209.6 to 214.9	100 (77)
			R 46 214.9 to 220.0	100 (100)
		222.3 - 250.0 Contorted quartz stringers and veins form 20% to 40% of rock. Foliation highly irregular.	R 47 220.0 to 225.3	100 (92)
			R 48 225.3 to 230.1	100 (87)
			R 49 230.1 to 235.5	100 (91)

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HOLE NO. BH-4
SHEET NO. 7 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 50 235.5 to 240.3	100 (58)
			R 51 240.3 to 245.6	100 (96)
		(246.3 - 246.8) Quartz vein, highly mineralized with sulfides.	R 52 245.6 to 247.8	100 (100)
			R 53 247.8 to 250.3	100 (98)
		252.0 - 267.0 Zone contains intermixed layers of spotted phyllite.	R 54 250.3 to 255.2	100 (98)
			R 55 255.2 to 260.3	100 (82)
		262.1 - 262.5, 263.9 - 264.5, 271.1 - 271.8 Quartz veins, highly mineralized with sulfides.	R 56 260.3 to 262.6	100 (69)
			R 57 262.6 to 267.6	100 (90)
			R 58 267.6 to 271.9	100 (84)

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HOLE NO. BH-4

SHEET NO. 8 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
		271.9 - 277.3 Core loss 0.3'.	59 271.9 to 277.3	94 (91)
		282.2 - 287.5 Massive quartz vein.	R 60 277.3 to 289.0	100 (92)
			R 61 281.0 to 286.0	100 (94)
			R 62 286.0 to 291.0	100 (94)
		292.9 - 295.6 Shear zone. Rock is highly brecciated with clay gouge. Very friable. Rock fragments range from 0.01' to 0.1'. Core loss 2.0'.	R 63 291.0 to 293.5	80 (8)
			R 64 293.5 to 297.9	66 (55)
			R 65 297.9 to 301.9	95 (90)
			R 66 301.9 to 307.0	100 (71)
		307.0 - 312.2 Core loss 0.1'. 308.1 - 311.5, 318.3 - 319.2 High angle joints with chlorite and calcite coatings.	R 67 307.0 to 312.2	98 (58)

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for **ALASKA POWER AUTHORITY**

HOLE NO. BH-4
SHEET NO. 9 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 68 312.2 to 317.0	100 (81)
			R 69 317.0 to 322.0	100 (84)
			R 70 322.0 to 327.0	100 (100)
		330.4 - 331.1 Open joints at 20° to core axis.	R 71 327.2 to 332.2	100 (100)
			R 72 332.2 to 337.3	100 (94)
		343.9 - 345.0 Quartz vein.	R 73 337.3 to 347.0	100 (94)
			R 74 342.4 to 347.0	100 (89)
			R 75 347.0 to 350.0	100 (83)
		352.0 - 376.3 Zone contains intermixed layers of spotted phyllite.	R 76 350.0 to 353.3	100 (10[illegible]

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SUSITNA HYDROELECTRIC PROJECT

for **ALASKA POWER AUTHORITY**

HOLE NO. BH-4

SHEET NO. 10 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
		(353.3 - 356.5) Core loss 0.2'.	R 77 353.3 to 356.5	93 (83)
			R 78 356.5 to 361.0	100 (98)
		(362.5 - 364.8) Massive quartz vein.	R 79 361.0 to 366.5	100 (95)
		(370.0 - 376.3) Quartz vein with some intermixed spotted phyllite.	R 80 366.5 to 371.0	100 (89)
			R 81 371.0 to 376.3	100 (58)
		376.3 - 387.0 Dark gray to black, well developed foliation at 10° to 20° to core axis. Contains no quartz stringers.	R 82 376.3 to 379.4	52 (35)
		(376.3 - 379.4) Core loss 1.4'		
		379.4 - 386.0 Mislatch of core barrel, section badly broken, core badly ground during drilling.	R 83 379.4 to 386.0	100 (N/A)
		386.0 - 396.0 Core loss 0.5'.	R 84 386.0 to 390.8	92 (92)
		387.1 - 399.0 Spotted phyllite.		
			R 85 390.8 to 396.0	98 (85)

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SUSITNA HYDROELECTRIC PROJECT

for **ALASKA POWER AUTHORITY**

HOLE NO. BH-4
SHEET NO. 11 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE REC. (RQD)
			R 86 396.0 to 401.1	100 (94)
			R 87 401.1 to 406.1	100 (100)
		406.5 - 411.7 Zone contains occasional layers of spotted phyllite.	R 88 406.1 to 411.1	100 (86)
			R 89 411.1 to 416.2	100 (100)
			R 90 416.2 to 420.0	100 (100)
			R 91 420.0 to 425.0	100 (100)
		(425.0 - 430.3) Core loss 0.1'.	R 92 425.0 to 430.3	98 (96)
			R 93 430.3 to 435.6	100 (81)
			R 94 435.6 to 440.6	100 (92)

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SUSITNA HYDROELECTRIC PROJECT

for **ALASKA POWER AUTHORITY**

HOLE NO. BH-4

SHEET NO. 12 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 95 440.6 to 445.7	100 (94)
			R 96 445.7 to 450.7	100 (90)
			R 97 450.7 to 454.3	100 (83)
			R 98 454.3 to 456.1	100 (72)
			R 99 456.1 to 456.7	100 (100)
			R 100 456.7 to 461.0	100 (63)
			R 101 461.0 to 466.0	100 (76)
			R 102 466.0 to 471.0	100 (100)
			R 103 471.0 to 476.0	100 (98)

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for **ALASKA POWER AUTHORITY**

HOLE NO. BH-4
SHEET NO. 13 OF 13

SITE Devil Canyon South Abutment JOB NO. P5701.05 (ACRES) 052504 (R&M)

DEPTH	ROCK TYPE	DESCRIPTION:	LENGTH OF RUN	% CORE. REC. (RQD)
			R 104 476.0 to 481.0	100 (98)
			R 105 481.0 to 486.0	100 (100)
			R 106 486.0 to 491.0	100 (100)
			R 107 491.0 to 495.8	100 (94)
			R 108 495.8 to 501.0	100 (96)
501.0		End of Hole		

APPENDIX B-2

WATER PRESSURE TESTS - R&M

WATER PRESSURE TESTING DETAILS

Water Pressure Testing Details

This section expands on the mechanical details of Section 5.2a (ii) of the report by describing the actual procedures used.

Calculations

To calculate the maximum water pressure to be applied in a given test section, the following steps were undertaken. The vertical depth to the static water table in the hole and to the center of the test section was calculated. The maximum test pressure was equal to 1 psi per foot of vertical depth from the ground surface to the water table, plus 0.5 psi per foot of vertical depth from the water table down to the center of the test section to a maximum value of 200 psi.

In calculating the actual gauge pressure to be applied at the surface, the hydrostatic pressure generated by the column of the water in the riser pipe from the water table to the top of the riser was subtracted from the calculated test pressure.

Accurate Measurements

In order to obtain accurate permeability values, it was necessary that the applied pressure and flow rates be measured accurately. A panel of four Fisher-Porter glass tube variable flow meters was set up as shown in Figure A.1. These meters have an accuracy of 1% over full scale and individual ranges of 0.021-0.267 gpm, 0.095-1.19 gpm, 0.34-4.25 gpm and 0.88-11.0 gpm. The panel was set up to use any of the four meters or to bypass them altogether.

Water pressure was supplied by a Bean fixed-displacement, piston pump. Test pressure was monitored using a liquid-filled Ashcroft model 1279 pressure gauge with a 0 to 300 psi range and 2 psi divisions. The accuracy of this gauge is $\pm$ 0.5% of full scale.

To eliminate pressure surging in the line, a surge tank was installed and pressure snubbers were used between the pressure gauge and the main line.

CALCULATIONS

WATANA

SUMMARY OF WATER PRESSURE TEST RESULTS

Borehole Number: B.H. - 2

Location: Watana

Ground Surface Elevation: 1835

Static Water Level: Greater than 70'

Dip of Hole: 55°

Stickup: None

Depth Tested From (feet)	Depth Tested To (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
23.9	40	20	20	.32	2.26×10^{-5}
38.9	55	26	10	.18	9.80×10^{-6}
53.9	70	30	20	.42 to 2.5	1.98×10^{-5} to 1.17×10^{-4}

SUMMARY OF WATER PRESSURE TEST RESULTS

Borehole Number: B.H.- 6

Location: Watana

Ground Surface Elevation: 1605

Static Water Level: 147 feet (Vertical)

Dip of Hole: 60°

Stickup: None

Depth Tested From (feet)	Depth Tested To (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
33.9	50	16 to 18	10	11	1.93×10^{-4}
48.9	65	22 to 24	10	10.8	1.76×10^{-4}
63.9	80	28 to 30	10	6.4 to 8	9.77×10^{-5} To 1.22×10^{-4}
78.9	95	35 to 36	10	2.4	3.44×10^{-5}
93.9	110	41 to 44	10	2.2	2.97×10^{-5}
108.9	125	48 to 50	10	3.9	3.64×10^{-5}
123.9	140	54 to 58	10	4.4	5.11×10^{-5} To 5.29×10^{-5}
138.9	155	61 to 62	10	3.7 to 3.8	4.28×10^{-5}
153.9	170	66 to 68	10	4.3	4.65×10^{-5}
168.9	185	76 to 78	10	4.0	4.02×10^{-5}
183.9	200	82 to 84	10	1.3	1.25×10^{-5}
198.9	215	92 to 98	15	1.7	1.54×10^{-5} To 1.49×10^{-5}

Borehole B-6 Watana - (Continued)

Depth Tested From (feet)	Depth Tested To (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
213.9	230	98 to 104	10	1.4	1.22×10^{-5} To 1.18×10^{-5}
228.9	245	108	15	1.75	1.44×10^{-5}
243.9	260	114	25	1.0	7.96×10^{-6}
258.9	275	125	25	1.2	9.00×10^{-6}
273.9	290	125	45	1.2	9.00×10^{-6}
288.9	305	130	145	.54	3.94×10^{-6}
303.9	320	140	25	4.9	3.40×10^{-5}
318.9	335	140	10	6.2	4.31×10^{-5}
333.9	350	200	10	10 to 30	5.36×10^{-5} To 1.61×10^{-4}
348.9	365	200	50	.31 to 14.7	1.66×10^{-6} To 7.89×10^{-5}
363.9	380	204	10	15 to 30	7.93×10^{-5} To 1.59×10^{-4}
378.9	395	202	10	15 to 30	7.99×10^{-5} To 1.60×10^{-4}
393.9	410	204	10	6.6	3.49×10^{-5}
408.9	425	202	10	3.75	2.00×10^{-5}
423.9	440	202	10	5.7	3.03×10^{-5}
438.9	455	200	15	11 to 30	5.90×10^{-5} To 1.61×10^{-4}
453.9	470	200	10	11 to 30	5.90×10^{-5} To 1.61×10^{-4}

Borehole BH-6 Watana - (Continued)

Depth Tested From (feet)	Depth Tested To (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
468.9	485	202	15	11 to 30	5.86×10^{-5} To 1.60×10^{-4}
483.9	500	200	10	11 to 30	5.90×10^{-5} To 1.61×10^{-4}
498.9	515	202	15	7.8	4.15×10^{-5}
513.9	530	204	15	7.5	3.96×10^{-5}
528.9	545	195	15	5.2	2.84×10^{-5}
543.9	560	205	15	3.8	2.00×10^{-5}
558.9	575	200	15	1.45	7.78×10^{-6}
573.9	590	195	10	5.2	2.84 x 10-5
588.9	605	200	15	8.5	4.56×10^{-5}
603.9	620	205	10	2.95	1.55×10^{-5}
618.9	635	203	10	3.35	1.78×10^{-5}
633.9	650	198	20	.55	2.97×10^{-6}

SUMMARY OF WATER PRESSURE TEST RESULTS

Borehole Number: B.H. - 8

Location: Watana

Ground Surface Elevation: 1976

Static Water Level: 18 feet (Inclined)

Dip of Hole: 60°

Stickup: None

Depth Tested From (feet)	Depth Tested To (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
31.9	48	20	13	4.55	2.41×10^{-4}
46.9	63	25	20	2.1	9.36×10^{-5}
61.9	78	31	5	.34	1.27×10^{-5}
76.9	93	38	10	4.0	1.26×10^{-4}
91.9	108	45	15	6.2	1.69×10^{-4}
106.9	123	51	20	3.2	7.84×10^{-5}
121.9	138	57	10	.8	1.78×10^{-5}
136.9	153	64	5	3.2	6.40×10^{-5}
151.9	168	70	9	6.6	1.22×10^{-4}
166.9	183	77	10	3.0	5.07×10^{-5}
181.9	198	84	10	.38	5.92×10^{-6}
196.9	213	90	10	1.2	1.75×10^{-5}
226.9	243	104	8	3.7	4.73×10^{-5}
241.9	258	110	6	10.3	1.25×10^{-4}
256.9	273	116	5	7.5	8.64×10^{-5}
271.9	288	50	6	7.0	1.74×10^{-4}
286.9	303	50	7	3.85	9.60×10^{-5}
301.9	318	50	6	2.95	7.35×10^{-5}
316.9	333	142	5	7.8	7.42×10^{-5}

susi5/a2

Depth Tested From (feet)	Depth Tested To (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
331.9	348	149	5	7.3	6.63×10^{-5}
346.9	363	155	6	2.45	2.14×10^{-5}
361.9	378	162	5	2.75	2.31×10^{-5}
376.9	393	150	35	12.7	1.15×10^{-4}
391.9	408	110	40	10.9	1.32×10^{-4}
406.9	423	50	5	1.7	4.24×10^{-5}
421.9	438	188	6	.4	2.91×10^{-6}
436.9	453	195	5	.24	1.68×10^{-6}
451.9	468	200	8	.36	2.46×10^{-6}
466.9	483	200	6	.54	3.70×10^{-6}
481.9	498	200	7	.54	3.70×10^{-6}
496.9	513	200	7	.60	4.11×10^{-6}
511.9	528	200	5	.55	3.76×10^{-6}
526.9	543	200	5	.96	6.57×10^{-6}
541.9	558	200	6	.85	5.82×10^{-6}
556.9	573	200	6	.76	5.20×10^{-6}
571.9	588	200	7	2.05	1.40×10^{-5}
586.9	603	200	6	.85	5.82×10^{-6}
601.9	618	200	7	2.8	1.92×10^{-5}
616.9	633	200	6	.75	5.13×10^{-6}
631.9	648	200	6	.82	5.61×10^{-6}
646.9	663	225	8	1.60	9.77×10^{-6}
661.9	678	200	6	.80	5.47×10^{-6}
669.9	671	200	7	1.1	7.53×10^{-6}
691.9	708	200	6	1.08	7.39×10^{-6}
706.9	723	200	6	1.2	8.21×10^{-6}
721.9	738	200	12	1.0	6.84×10^{-6}

DEVIL CANYON

SUMMARY OF WATER PRESSURE TEST RESULTS

Borehole Number BH-1

Location Devil Canyon

Ground Surface Elevation 1415

Static Water Level 192 feet (Vertical)

Dip of Hole 67°

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
38.9	55	8	20	11	.70	9.31×10^{-6}
53.9	70	3	30	11	4.1	5.07×10^{-5}
68.9	85	8	40	10	6.2	6.94×10^{-5}
83.9	100	3	45	10	.78	8.53×10^{-6}
98.9	115	8	55	10	.50	5.00×10^{-6}
113.9	130	3	60	46	.90 to 5.40	8.82×10^{-6} To 5.29×10^{-5}
128.9	145	8	70	21	.65 to .95	5.88×10^{-6} To 8.59×10^{-6}
143.9	160	3	75	14	.80	7.10×10^{-6}
158.9	175	8	85	10	.84 to 1.25	6.93×10^{-6} To 1.03×10^{-5}
173.9	190	3	90	10	.02 to .15	1.62×10^{-7} To 1.22×10^{-6}

Borehole BH-1 Devil Canyon - (Continued)

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
188.9	205	8	100	10	1.65 to 2.45	1.25×10^{-5} To 1.86×10^{-5}
203.9	220	3	105	10	2.1	1.57×10^{-5}
218.9	235	8	115	10	.6 to 1.2	4.21×10^{-6} To 8.43×10^{-6}
233.9	250	3	120	10	2.3 to 3.0	1.59×10^{-5} To 2.08×10^{-5}
248.9	265	8	130	10	5.25	3.43×10^{-5}
263.9	280	3	135	10	.1 to .4	6.45×10^{-7} To 2.58×10^{-6}
278.9	295	8	145	10	2 to 5.8	1.22×10^{-5} To 3.55×10^{-5}
293.9	310	3	150	10	1.1 to 2.8	6.64×10^{-6} To 1.69×10^{-5}
308.9	325	8	160	10	.26 to 2.2	1.49×10^{-6} To 1.26×10^{-5}
323.9	340	3	165	10	.40	2.27×10^{-6}
338.9	355	8	170	10	1.6	8.83×10^{-6}
353.9	370	3	180	10	1.5	8.03×10^{-6}
368.9	385	8	190	10	2.2	1.13×10^{-5}
383.9	400	3	195	10	.20 to .32	1.01×10^{-6} To 1.62×10^{-6}
398.9	415	8	200	10	.30 to .70	1.48×10^{-6} To 3.46×10^{-6}

Borehole BH-1 Devil Canyon - (Continued)

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
413.9	430	3	200	10	1.3 to 2.9	6.47×10^{-6} To 1.44×10^{-5}
428.9	445	8	200	10	.30	1.48×10^{-6}
443.9	460	3	200	10	.62 to 1.65	3.08×10^{-6} To 8.21×10^{-6}
458.9	475	8	200	10	.55	2.72×10^{-6}
473.9	490	3	200	10	.74	3.68×10^{-6}
488.9	505	8	200	10	2.6	1.28×10^{-5}
503.9	520	3	200	10	.50 to 2.0	2.49×10^{-6} To 9.95×10^{-6}
518.9	535	8	200	10	.2 to .5	9.88×10^{-7} To 2.47×10^{-6}
533.9	550	3	200	10	2.4 to 5.0	1.19×10^{-5} To 2.49×10^{-5}
548.9	565	8	200	10	4.5	2.22×10^{-5}
563.9	580	3	200	10	3.8	1.89×10^{-5}
578.9	595	8	200	1	3.9	1.93×10^{-5}
593.9	610	3	200	10	9.7	4.83×10^{-5}
608.9	625	8	150	13	2.55	1.53×10^{-5}
622.9	639	3	130	18	1.21	7.98×10^{-6}
638.9	655	8	130	11	.55	3.60×10^{-6}
653.9	670	3	200	10	7.4	3.68×10^{-5}
668.9	685	8	130	10	1.02	6.67×10^{-6}

Borehole BH-1 Devil Canyon - (Continued)

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
683.9	700	3	150	27	.34 to .48	2.05×10^{-6} To 2.90×10^{-6}
698.9	715	8	150	19	.4 to 1.12	2.39×10^{-6} To 6.70×10^{-6}
713.9	730	3	150	13	.40	2.41×10^{-6}
728.9	745	8	150	14	.80	4.79×10^{-6}

SUMMARY OF WATER PRESSURE TEST RESULTS

Borehole Number BH-2

Location Devil Canyon

Ground Surface Elevation 1214

Static Water Level 5 feet (Inclined)

Dip of Hole 60°

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
13.9	30	7	12	10	.60 to .82	5.14×10^{-5} To 7.03×10^{-5}
28.9	45	2	18	10	1.1	7.89×10^{-5}
43.9	60	7	22	10	4.0	2.14×10^{-4}
58.9	75	2	25	10	1.15	6.15×10^{-5}
73.9	90	7	35	10	1.45	5.37×10^{-6}
88.9	105	2	42	12	.67	2.25×10^{-5}
103.9	120	7	50	10	.30	8.57×10^{-6}
118.9	135	2	55	10	.25	5.40×10^{-6}
133.9	150	7	65	10	2.90	6.01×10^{-5}
148.9	165	2	70	10	1.25	2.44×10^{-5}
163.9	180	7	82	10	.34	5.89×10^{-6}
178.9	195	2	85	10	.15	2.58×10^{-6}
193.9	210	7	100	10	.48	6.50×10^{-6}

Borehole BH-2 Devil Canyon - (Continued)

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
208.9	225	2	105	10	.45	6.78×10^{-6}
223.9	240	7	110	10	.38	4.32×10^{-6}
238.9	255	2	115	10	.08	1.08×10^{-6}
253.9	270	7	125	10	.20	2.51×10^{-6}
268.9	285	2	130	32	.68 to 3.1	7.25×10^{-6} To 3.31×10^{-5}
283.9	300	7	100	10	.98	1.35×10^{-5}
298.9	315	2	145	10	.21	1.92×10^{-6}
313.9	330	7	155	10	.25	2.39×10^{-6}
328.9	345	2	160	10	.38	3.31×10^{-6}
343.9	360	7	170	10	.26	2.11×10^{-6}
358.9	375	2	175	10	.68	4.78×10^{-6}
373.9	390	7	185	10	.58	4.33×10^{-6}
388.9	405	2	190	10	.38	2.79×10^{-6}
403.9	420	7	200	10	.56	3.87×10^{-6}
418.9	435	2	200	10	.36	2.51×10^{-6}
433.9	450	7	200	10	.60	4.70×10^{-6}
448.9	465	2	200	10	.60	4.33×10^{-6}
463.9	480	7	200	10	.38	2.63×10^{-6}
478.9	495	2	200	10	.56	4.05×10^{-6}
493.9	510	7	200	10	.30	2.08×10^{-6}
508.9	525	2	200	10	.58	3.91×10^{-6}
523.9	540	7	200	10	.30	2.08×10^{-6}
538.9	555	2	200	10	.25	1.82×10^{-6}

Borehole BH-2 , Devil Canyon - (Continued)

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
553.9	570	7	200	10	.36	2.63×10^{-6}
568.9	585	2	200	10	.64	4.49×10^{-6}
583.9	600	7	200	10	.56	4.15×10^{-6}
598.9	615	2	200	10	.40	2.79×10^{-6}
613.9	630	7	200	10	.40	2.77×10^{-6}
628.9	645	2	200	10	.46	3.21×10^{-6}
638.9	655	11	200	10	.38	2.75×10^{-6}

SUMMARY OF WATER PRESSURE TEST RESULTS

Borehole Number BH-4

Location Devil Canyon

Ground Surface Elevation 1353

Static Water Level 31 feet (Vertical)

Dip of Hole 60°

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
13.9	30	1	10	10	.045	2.67×10^{-6}
28.9	45	6	15	10	.24	1.20×10^{-5}
43.9	60	1	20	10	.25	1.05×10^{-5}
58.9	75	6	24	10	.04	1.43×10^{-6}
73.9	90	1	34	10	3.25	9.82×10^{-5}
88.9	110*	6				
108.9	125	14	50	10	.26	5.36×10^{-6}
118.9	135	1	55	10	3.65	7.31×10^{-5}
123.9	140	1	56	10	4.25	8.61×10^{-5}
138.9	155*	6				
148.9	165	6	70	10	.050	8.26×10^{-7}
153.9	170	1	50	10	1.03	2.35×10^{-5}

* Unable to test section - packer problems - high flow rate - water flow from top of borehole.

susi5/e7

Borehole BH-4 Devil Canyon - (Continued)

Depth Tested From (feet)	Depth Tested To (feet)	Stickup (feet)	Gauge Pressure (psi)	Duration of Test (min)	Flow Rate (gpm)	Coefficient of Permeability (cm/sec)
163.9	180	1	80	10	.64	9.84×10^{-6}
178.9	195	6	85	10	.04	5.75×10^{-7}
193.9	210	1	95	10	.04	5.22×10^{-7}
208.9	225	6	100	10	.02	2.49×10^{-7}
223.9	240	1	105	10	.03	3.58×10^{-7}
238.9	255	6	115	10	.05	5.51×10^{-7}
253.9	270	1	125	10	.035	3.58×10^{-7}
268.9	285	6	130	10	.035	4.28×10^{-7}
283.9	300	1	140	10	.025	2.76×10^{-7}
298.9	315	6	145	10	.105	9.69×10^{-7}
313.9	330	1	150	10	.035	3.02×10^{-7}
328.9	345	6	160	12	.45	3.62×10^{-6}
343.9	360	1	170	10	.20	1.54×10^{-6}
358.9	375	6	175	10	.11	8.53×10^{-7}
373.9	390	1	185	10	.90	6.40×10^{-6}
388.9	405	6	190	10	.09	6.19×10^{-7}
403.9	420	1	200	10	.14	9.93×10^{-7}
418.9	435	6	200	10	.12	7.87×10^{-7}
433.9	450	1	200	10	.12	7.94×10^{-7}
448.9	465	6	200	10	.10	6.56×10^{-7}
458.9	475	1	200	10	.105	6.95×10^{-7}

APPENDIX B-3

SUMMARY LOGS

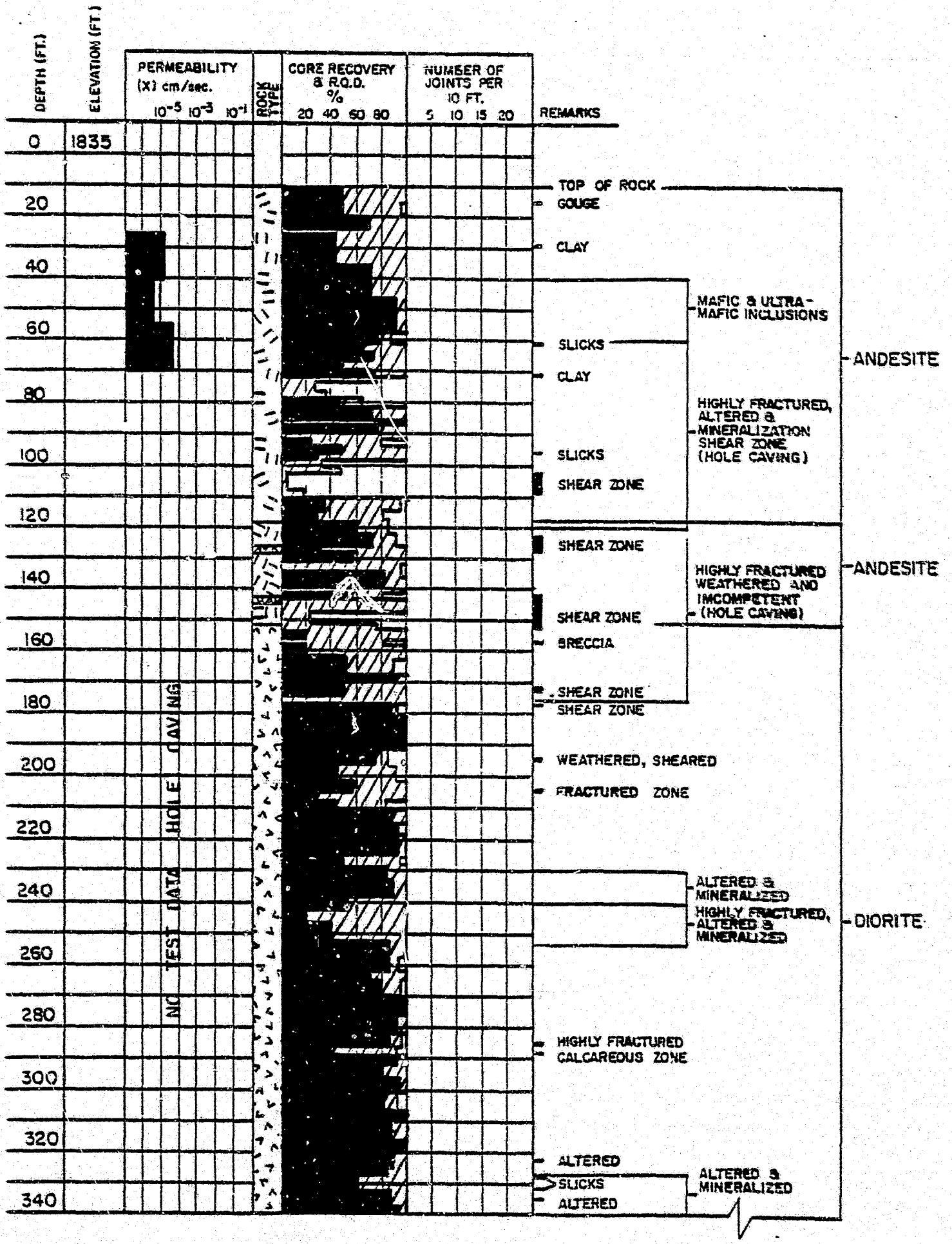
WATANA

ACRES AMERICAN INCORPORATED

BEDROCK LOG

HOLE NO. BH-2 DATE JULY 1980

LOCATION NORTH ABUTMENT - WATANA

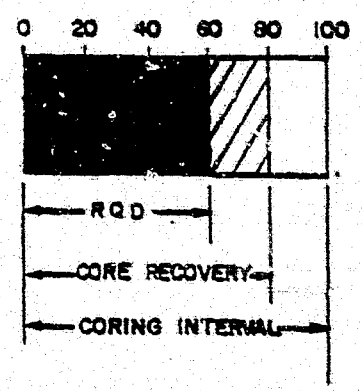


LEGEND

ANDESITE

DIORITE

CORE RECOVERY & RQD(%)

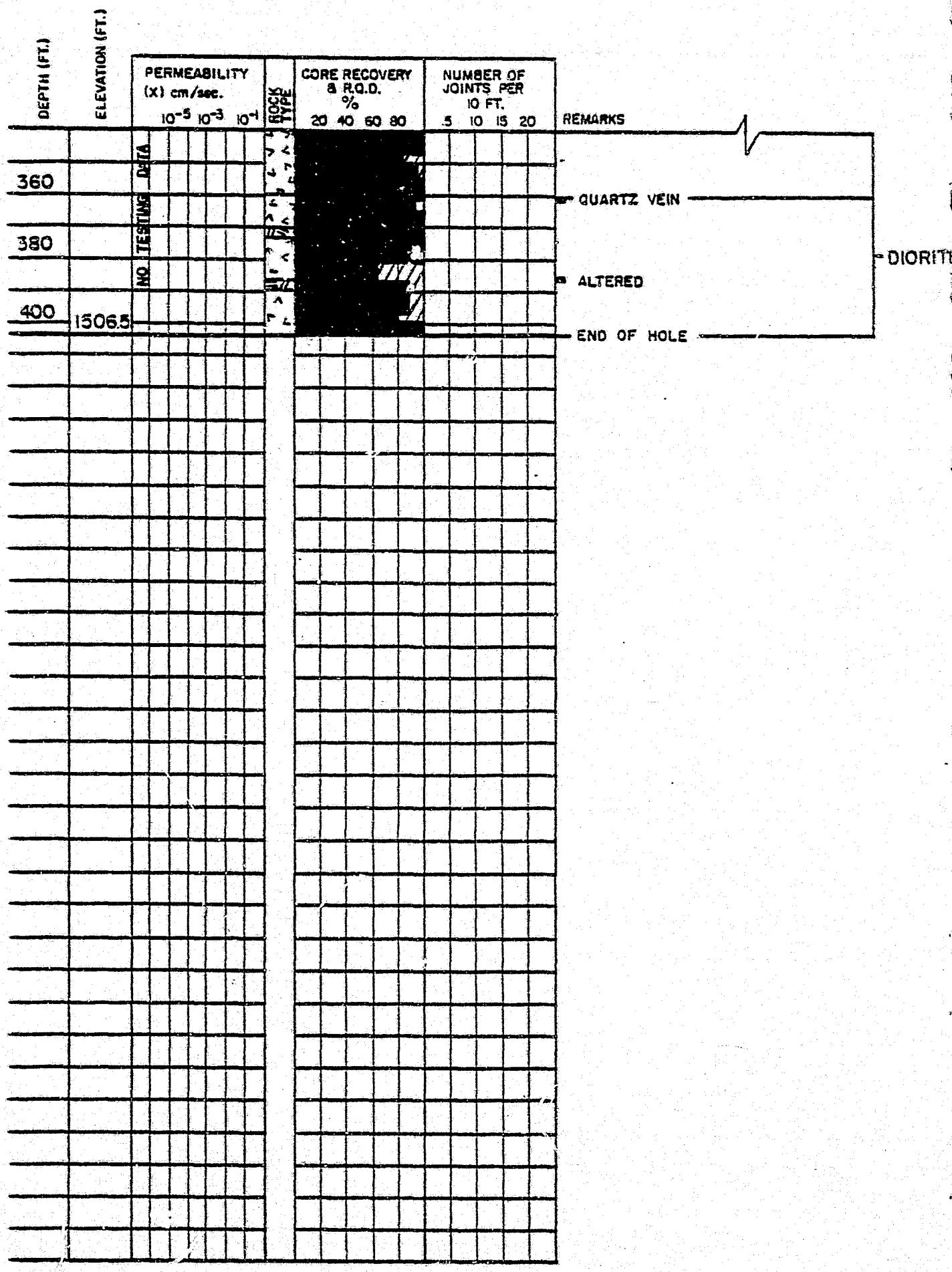


ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-2 DATE JULY 1980

LOCATION NORTH ABUTMENT - WATANA

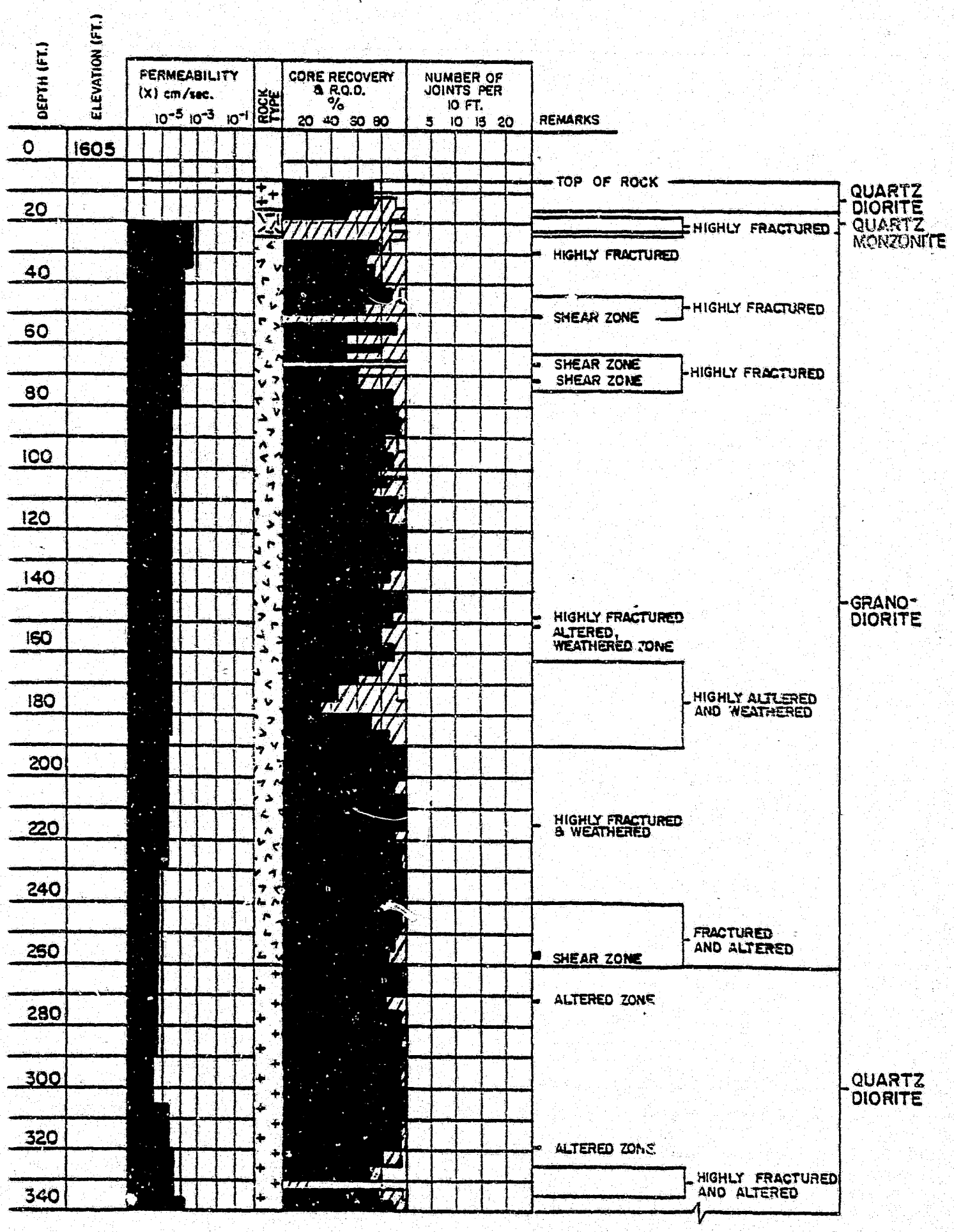


ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-6 DATE JULY 1980

LOCATION NORTH ABUTMENT - WATANA



LEGEND

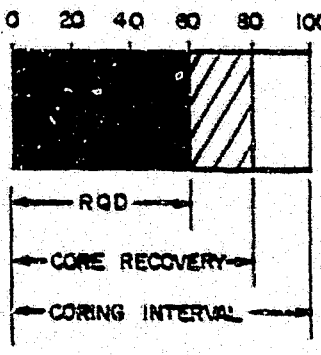
QUARTZ DIORITE

QUARTZ MONZONITE

GRANITE

DIORITE

CORE RECOVERY & RQD(%)

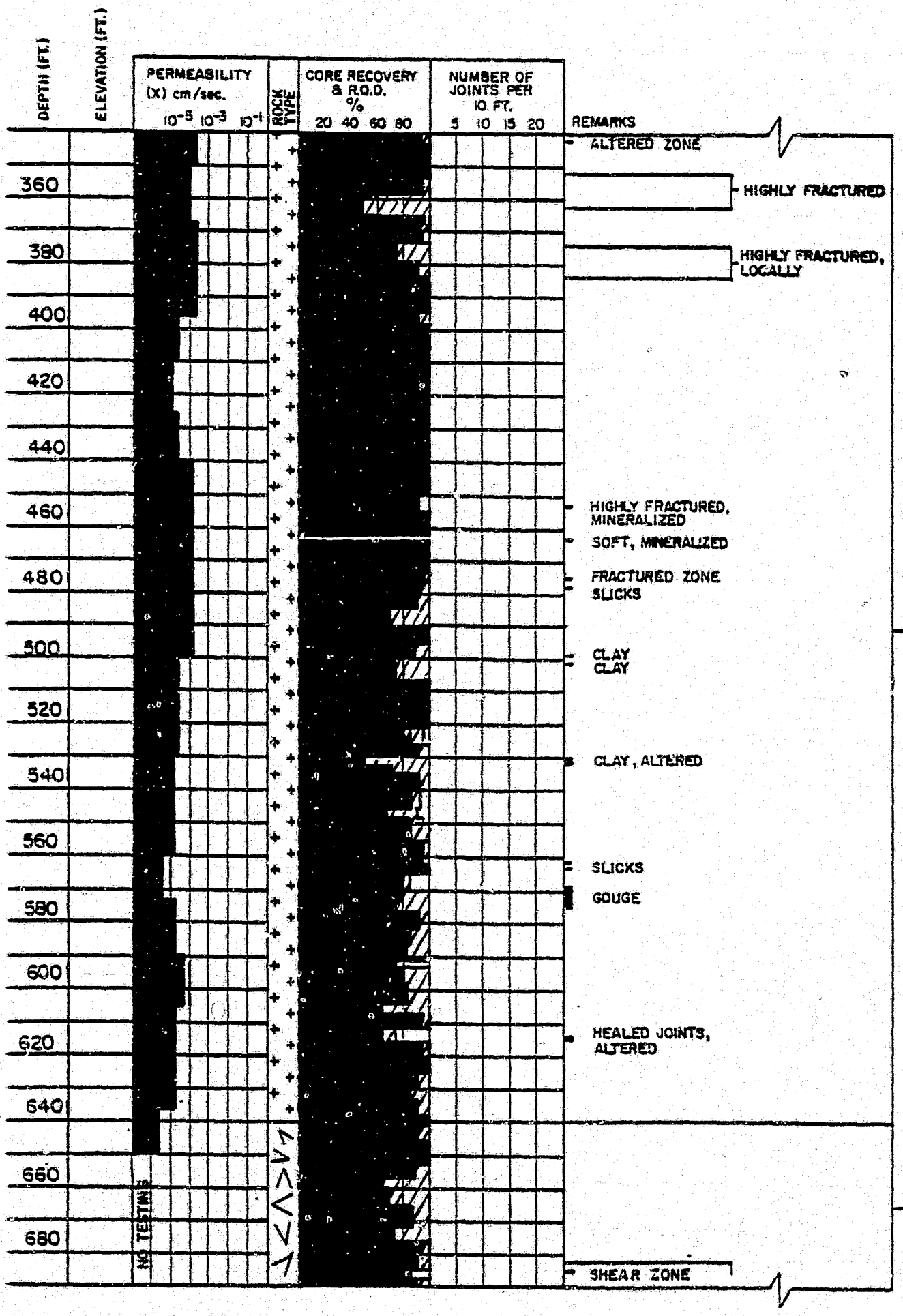


ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-6 DATE JULY 1980

LOCATION NORTH ABUTMENT - WATANA

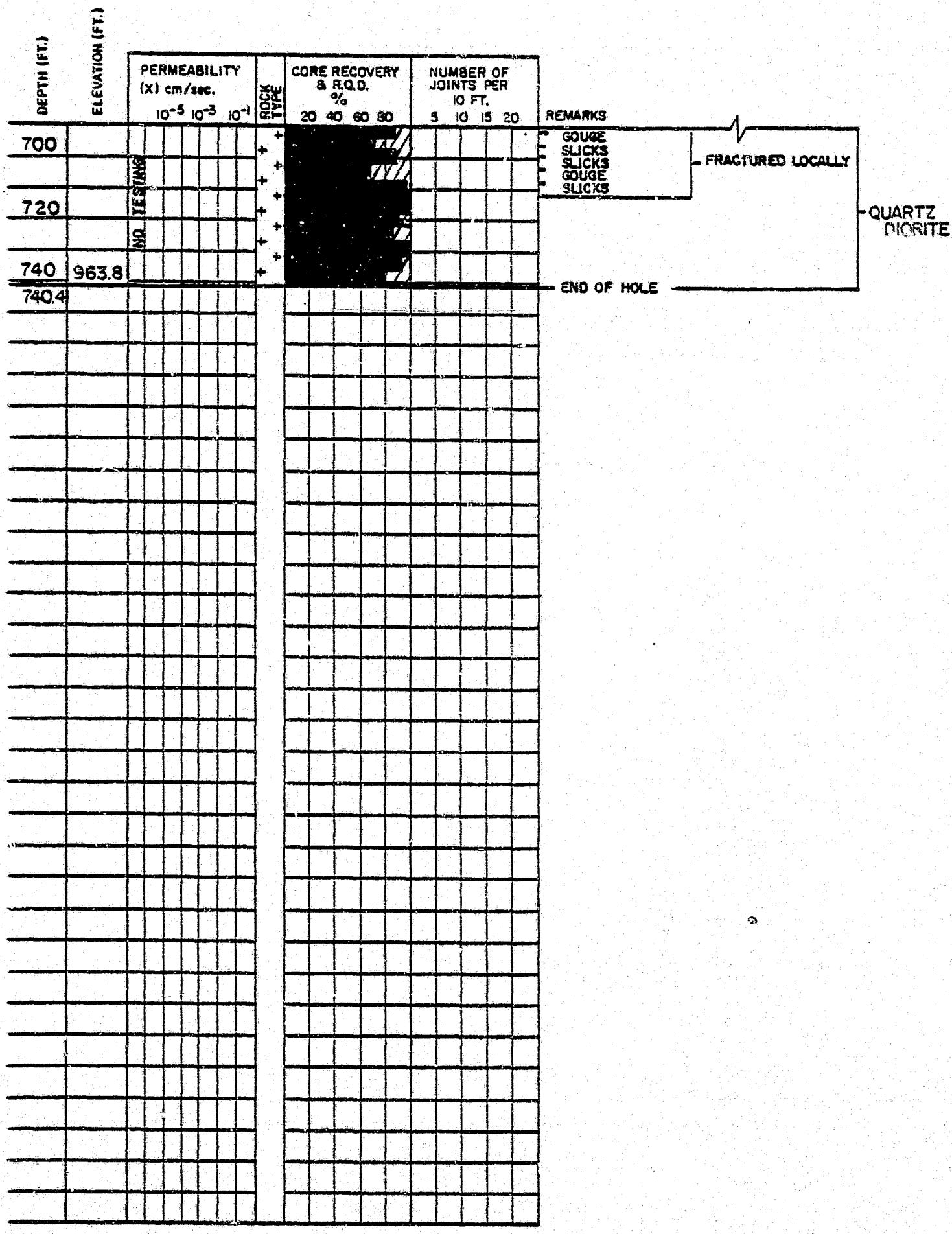


ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-6 DATE JULY 1980

LOCATION NORTH ABUTMENT - WATANA

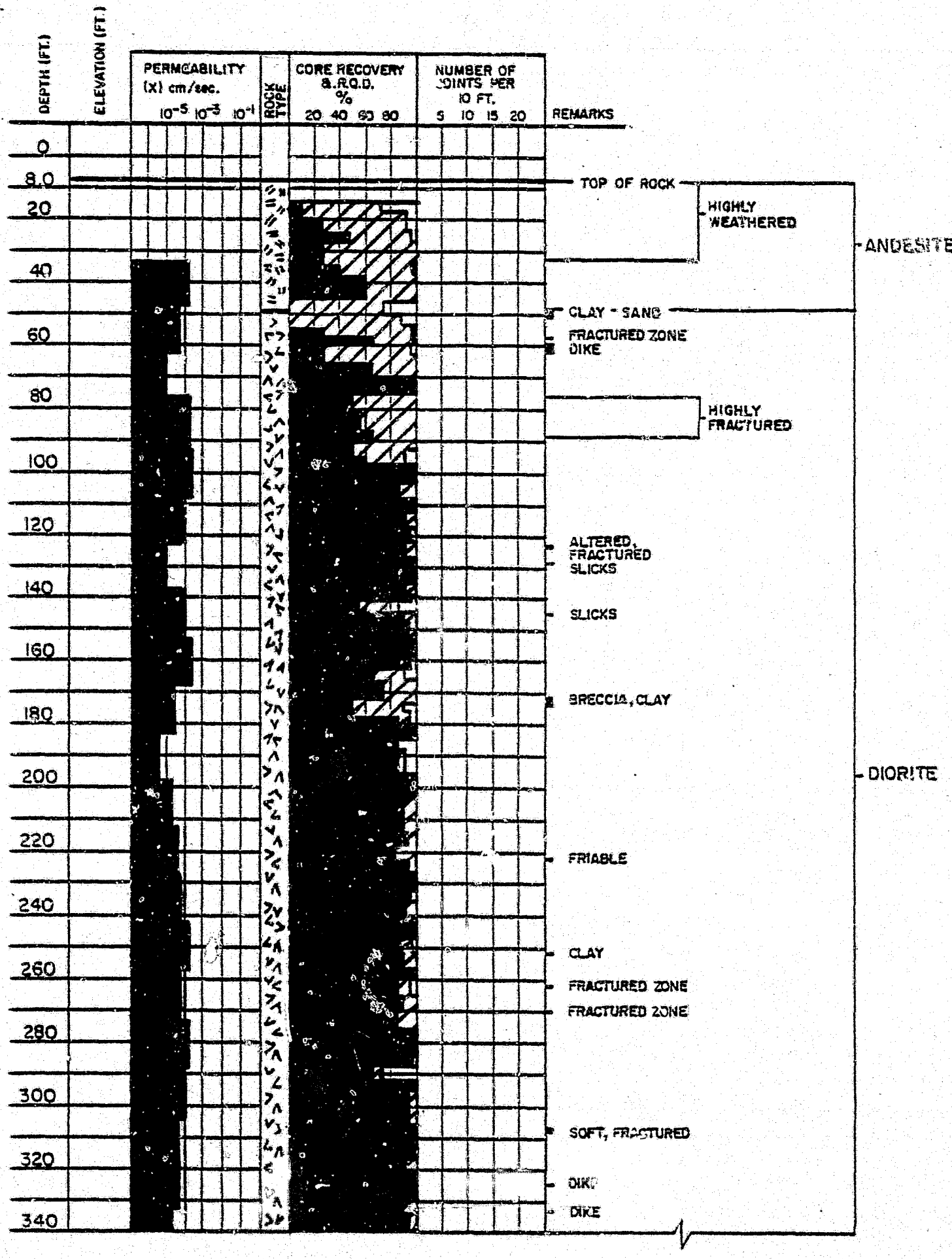


ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-8 DATE JULY 1980

LOCATION SOUTH ABUTMENT - WATANA

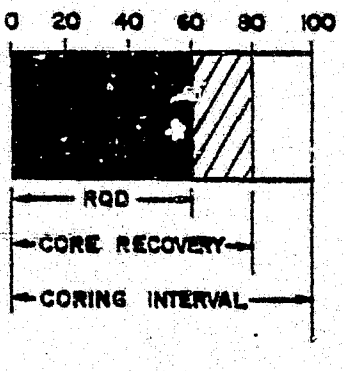


LEGEND

ANDESITE

DIORITE

CORE RECOVERY & RQD(%)

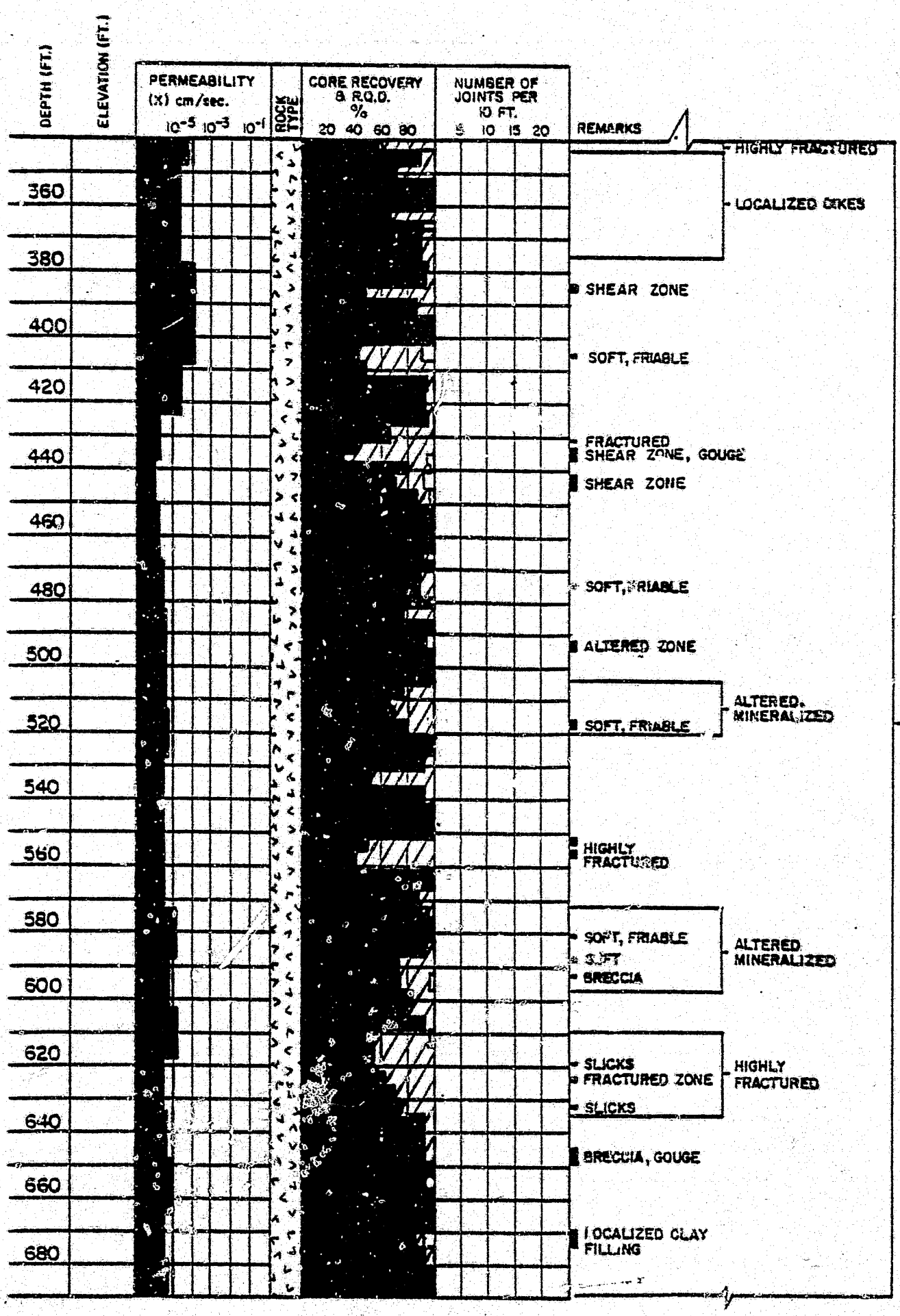


ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-8 DATE JULY 1980

LOCATION SOUTH ABUTMENT - WATANA

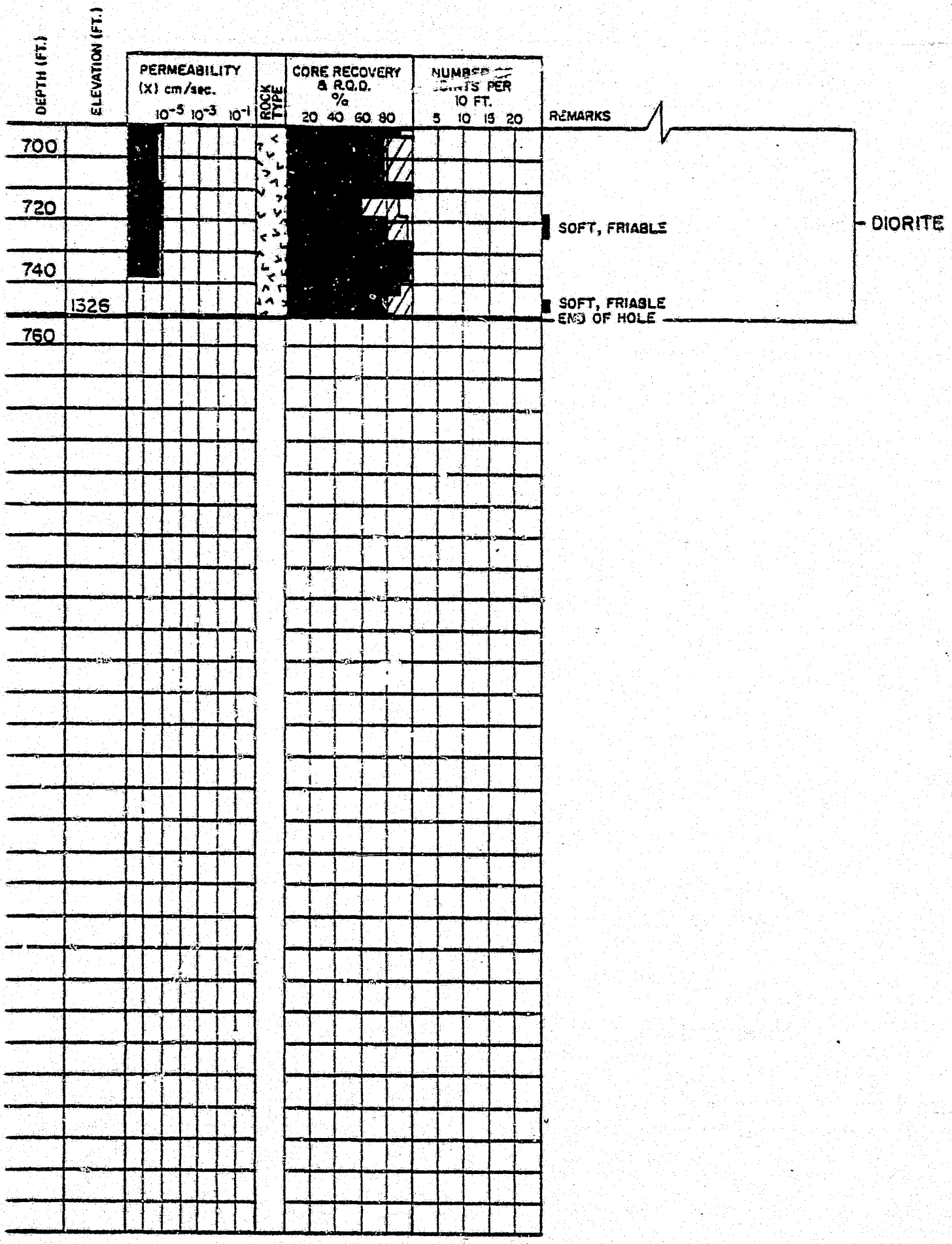


ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-8 DATE JULY 1980

LOCATION SOUTH ABUTMENT - WATANA



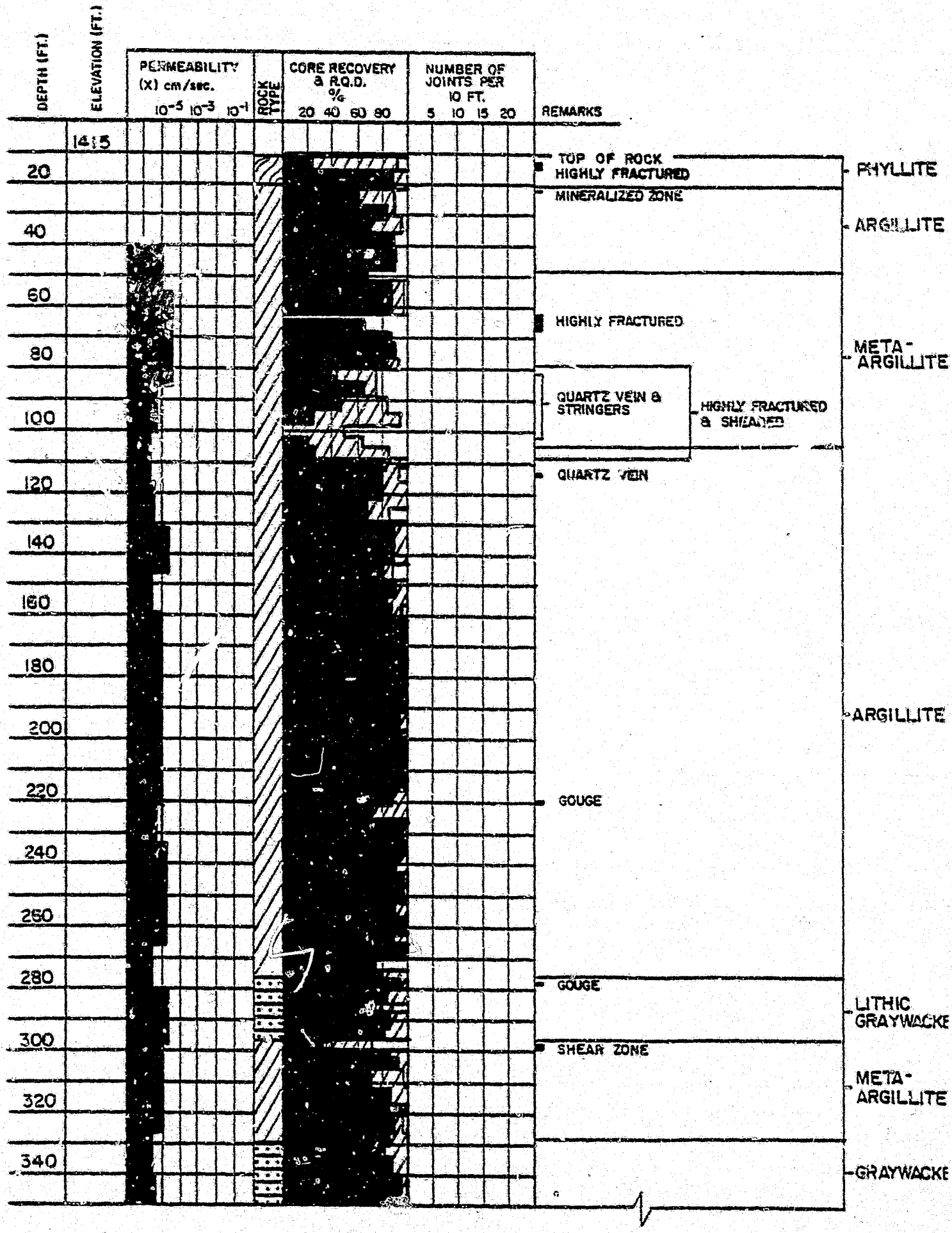
DEVIL CANYON

ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-1 DATE AUG 1980

LOCATION DEVIL CANYON



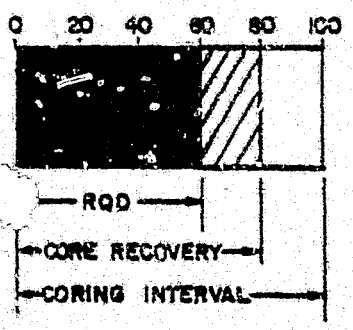
LEGEND

PHYLLITE

ARGILLITE

GRAYWACKE

CORE RECOVERY & RQD (%)

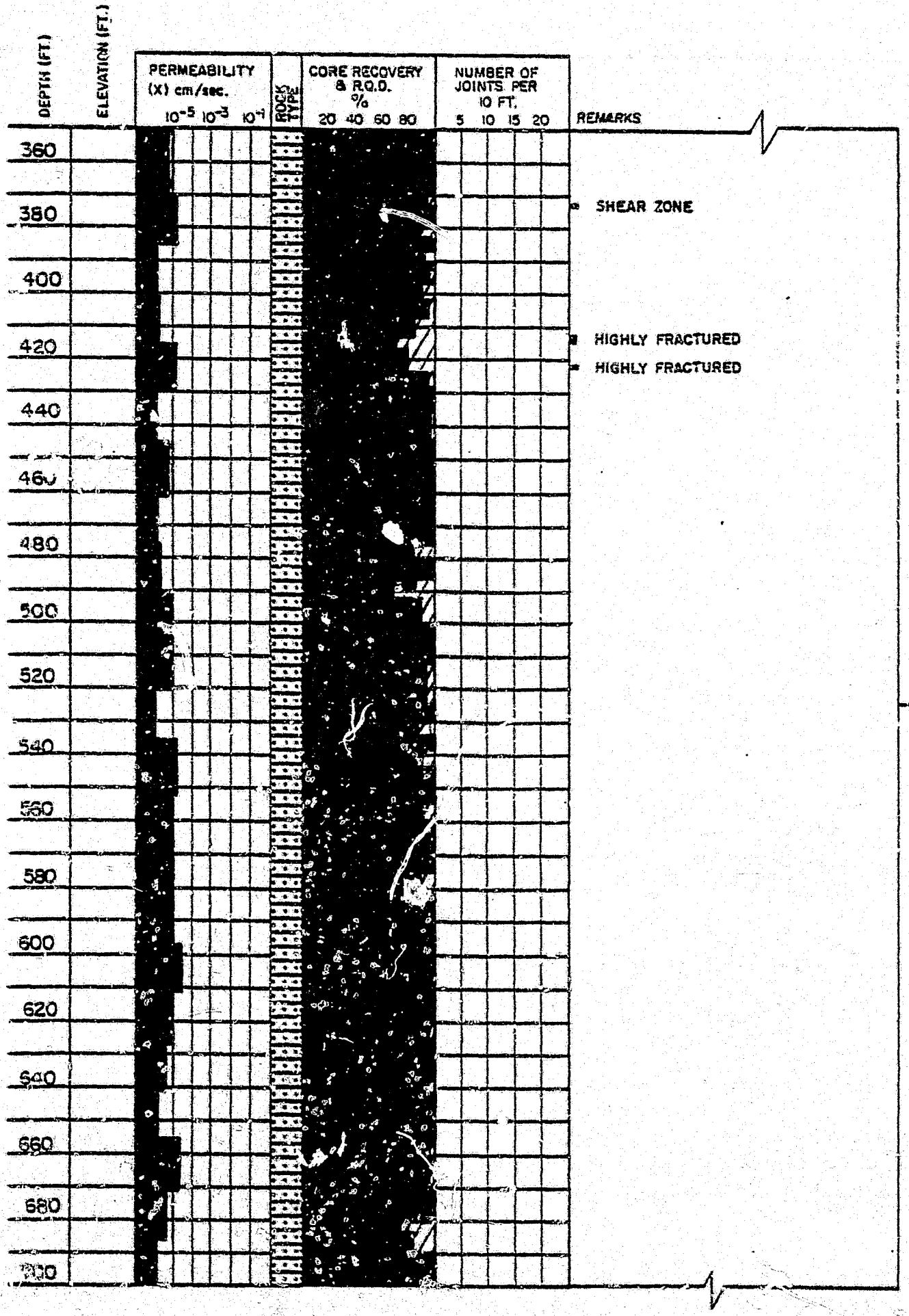


ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH - 1 DATE AUGUST, 80

LOCATION DEVIL CANYON

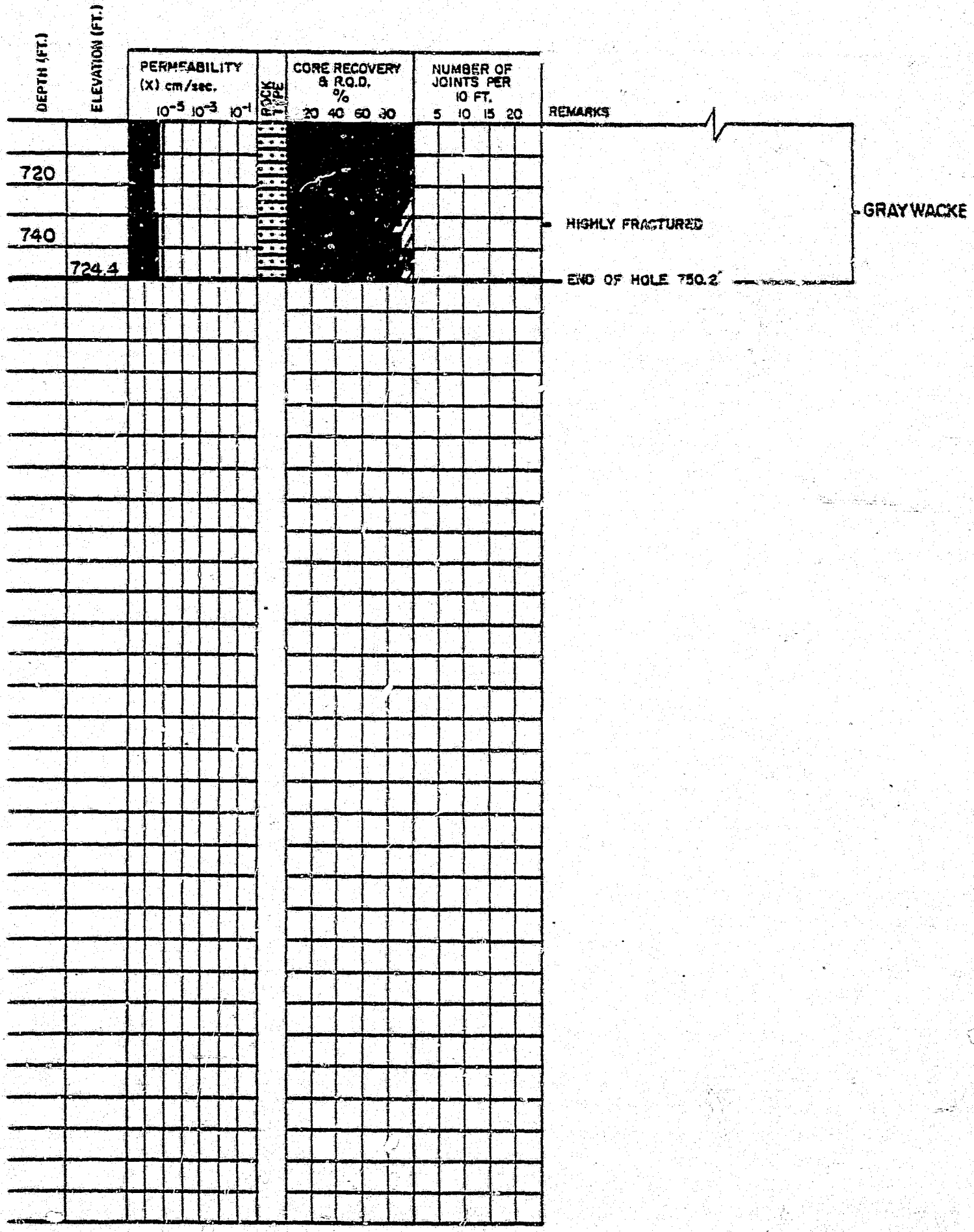


ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-1 DATE AUG 1980

LOCATION DEVIL CANYON

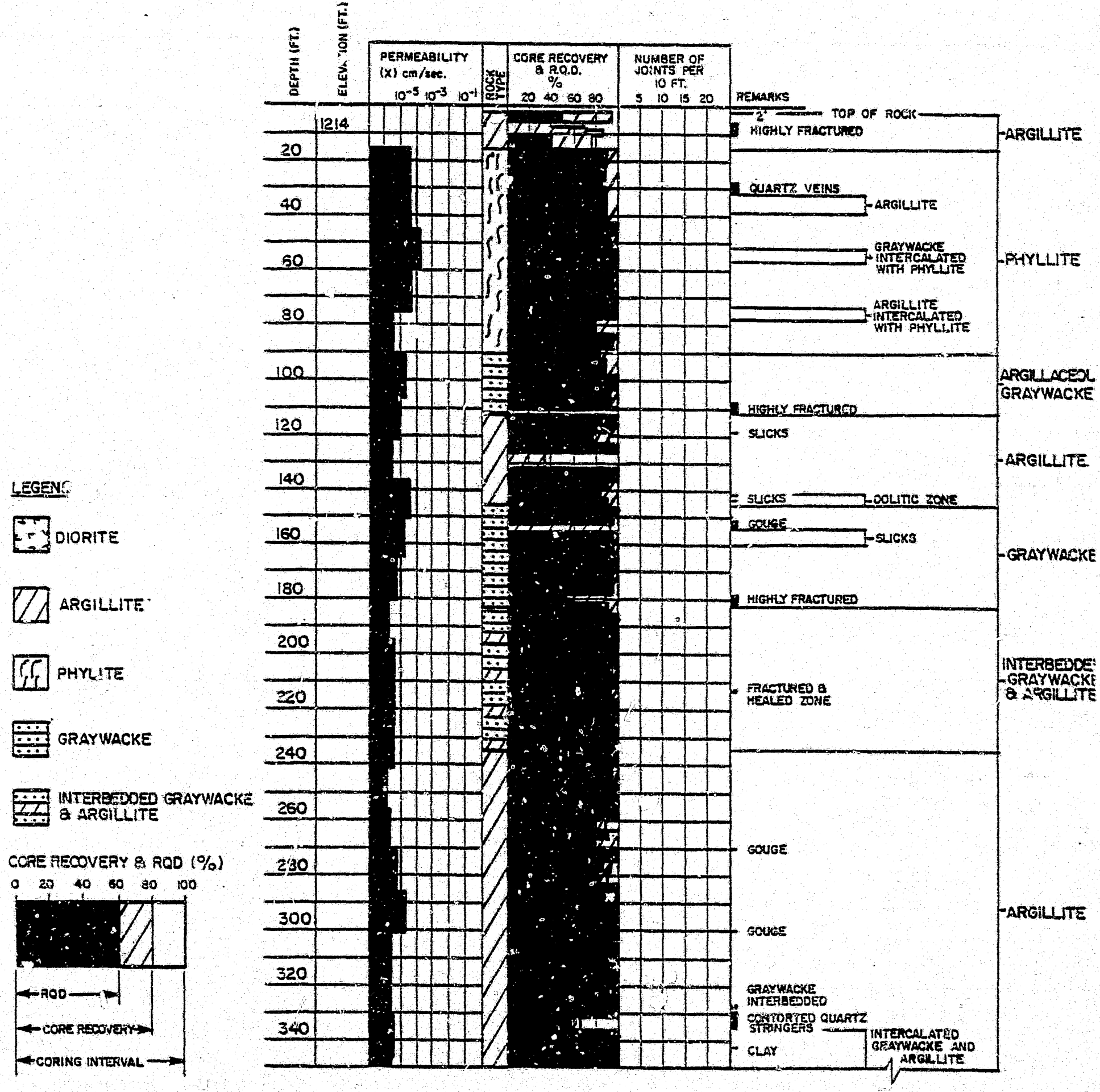


ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-2 DATE SEPT 1980

LOCATION DEVIL CANYON



LEGEND

- DIORITE
- ARGILLITE
- PHYLITE
- GRAYWACKE
- INTERBEDDED GRAYWACKE & ARGILLITE

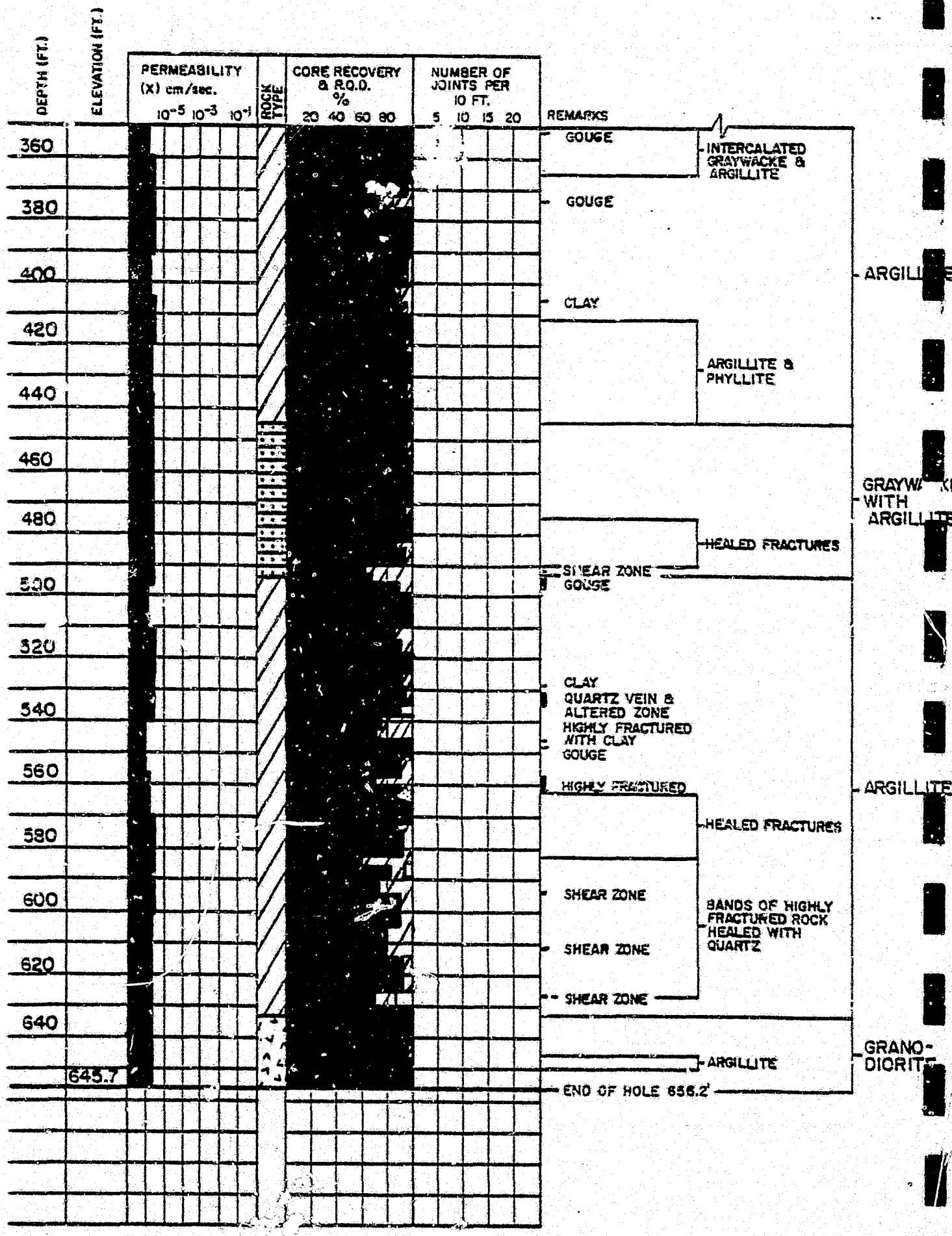
CORE RECOVERY & RQD (%)

ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-2 DATE SEPT 1980

LOCATION DEVIL CANYON

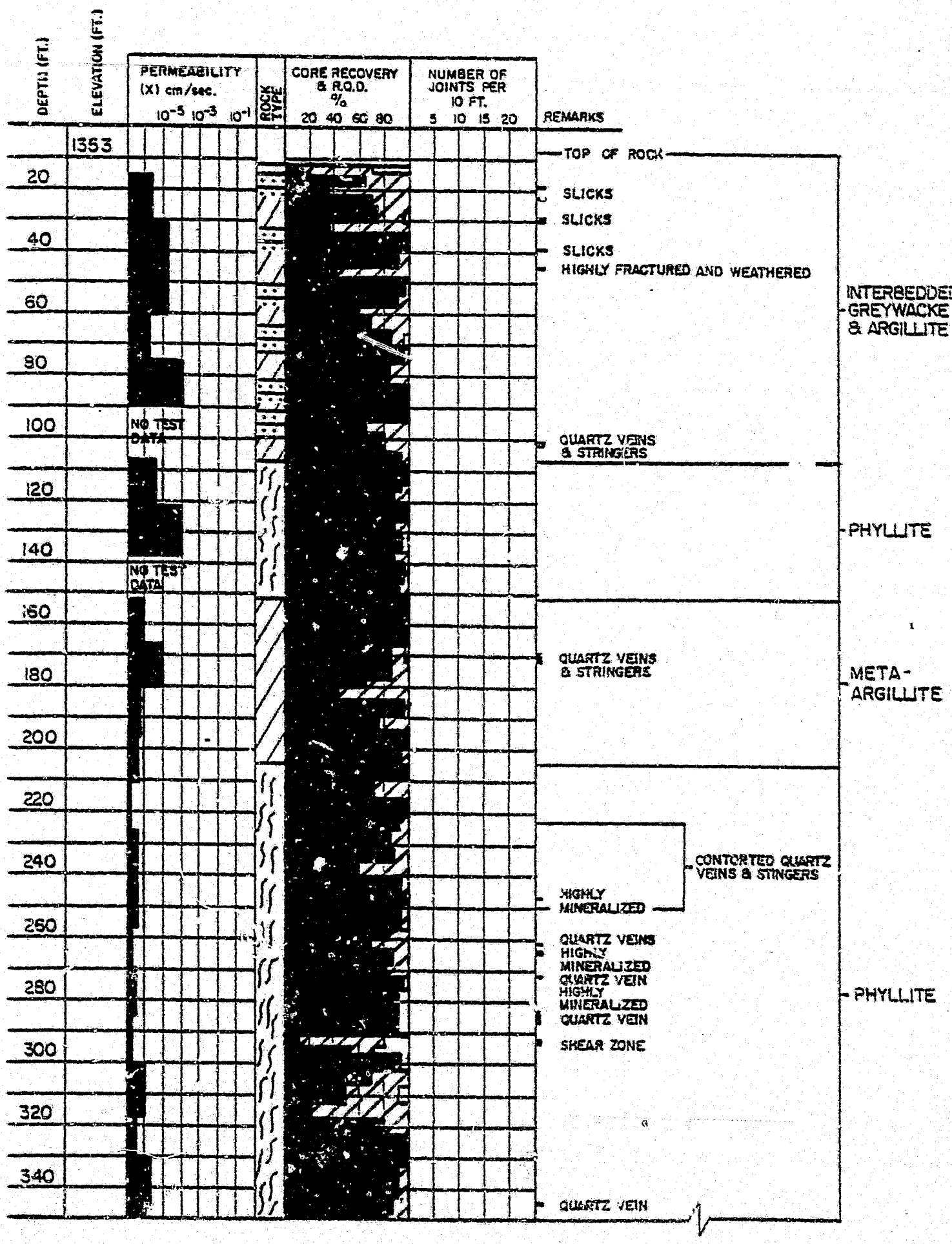


ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-4 DATE JULY 1980

LOCATION DEVIL CANYON



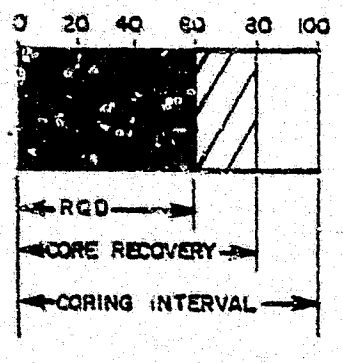
LEGEND

INBEDDED GRAYWACKE & ARGILLITE

PHYLLITE

ARGILLITE

CORE RECOVERY & RQD (%)

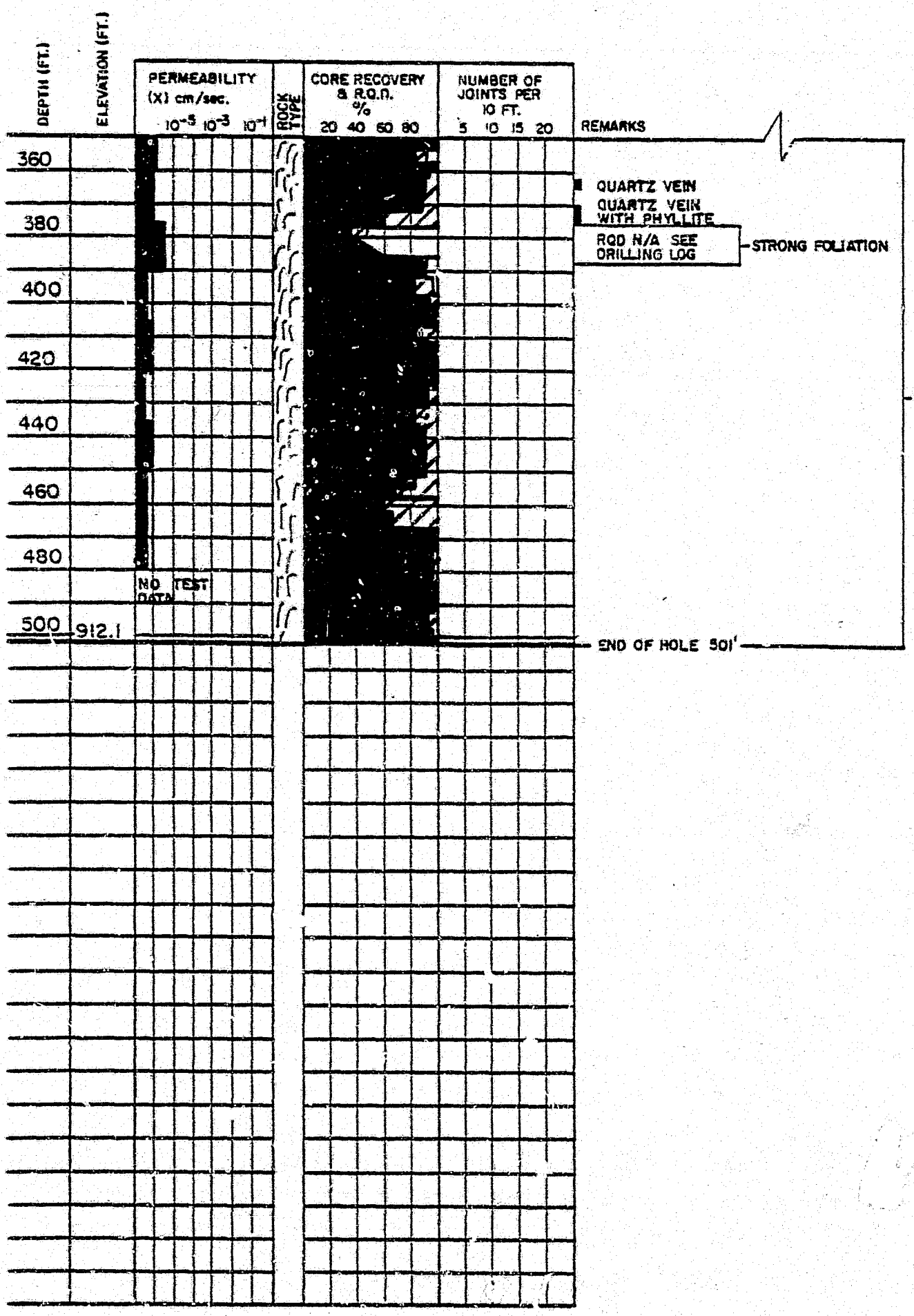


ACRES AMERICAN INCORPORATED

BEDROCK LOGS

HOLE NO. BH-4 DATE JULY 1980

LOCATION DEVIL CANYON



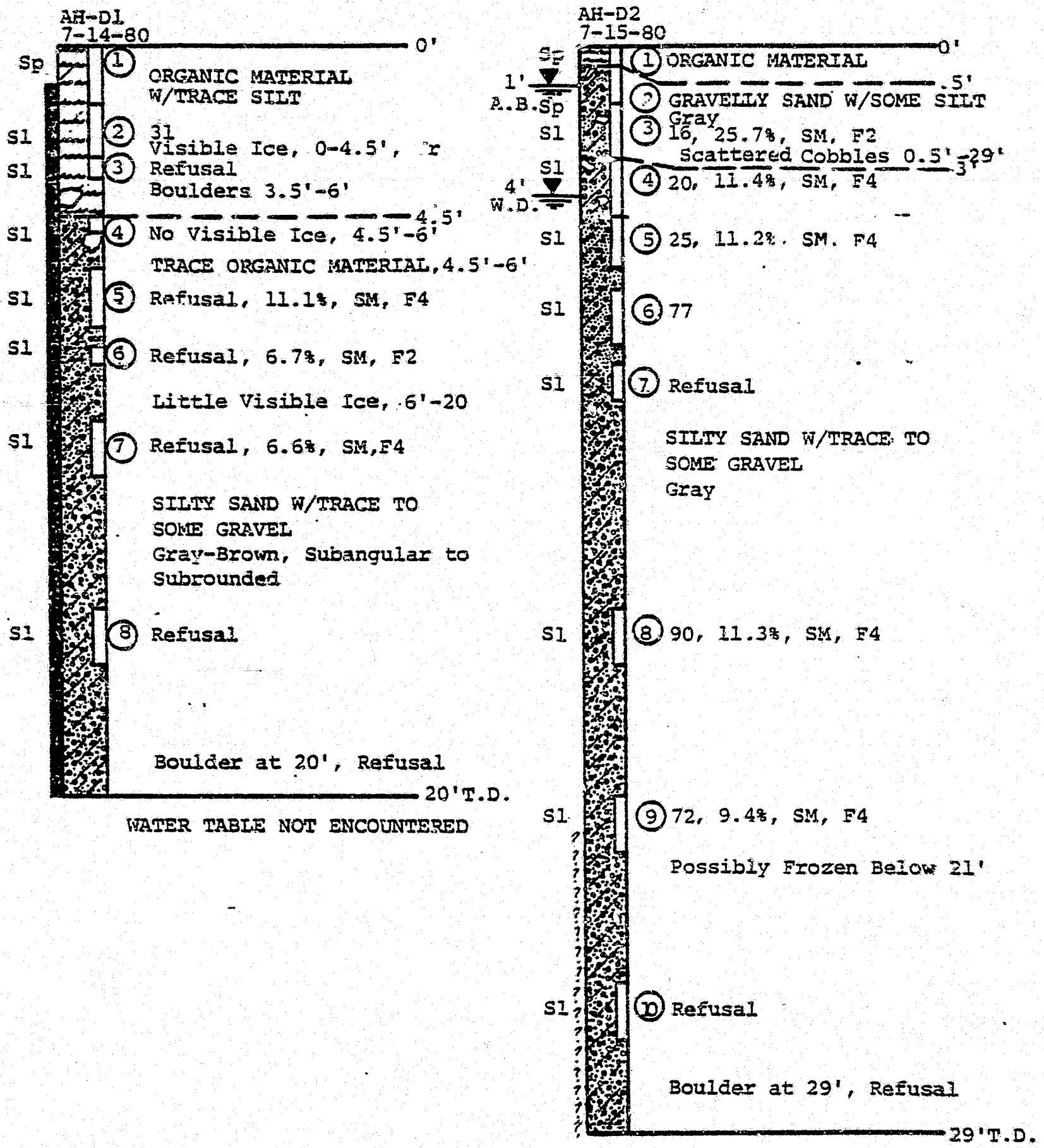
APPENDIX C

BORROW AREA INVESTIGATIONS

APPENDIX C-1

AUGER DRILLING REPORTS - R&M

WATANA

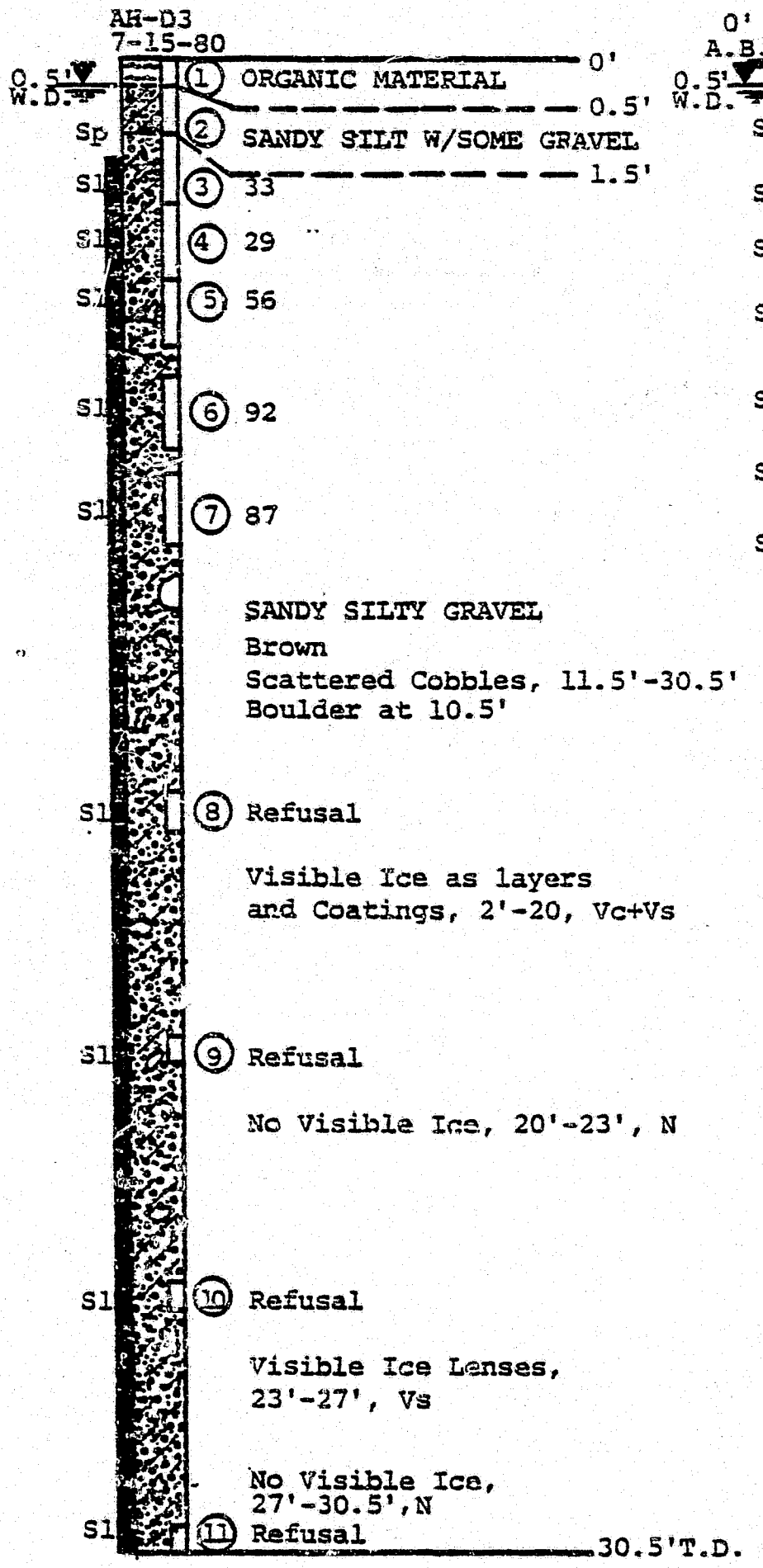


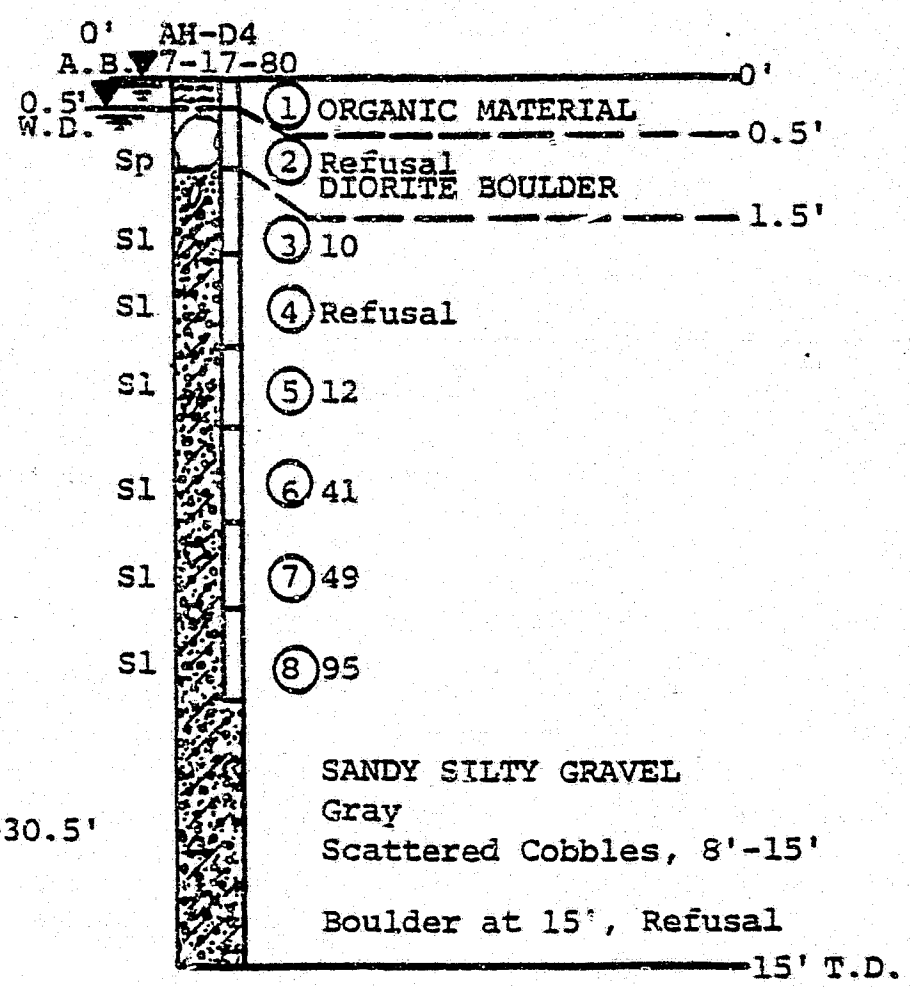
DWN.	KW
CKD.	MH
DATE.	Aug-. 80
SCALE	1"=4'

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ENGINEERS · GEOLOGISTS PLANNERS SURVEYORS

SUSITNA RIVER
HYDROELECTRIC PROJECT
GEOTECHNICAL INVESTIGATIONS

F.B.	
GRID	
PROJ.NO.	052504
DWG.NO.	





DWN.	KW
CKD.	MH
DATE.	Aug. 80
SCALE.	1"=4'

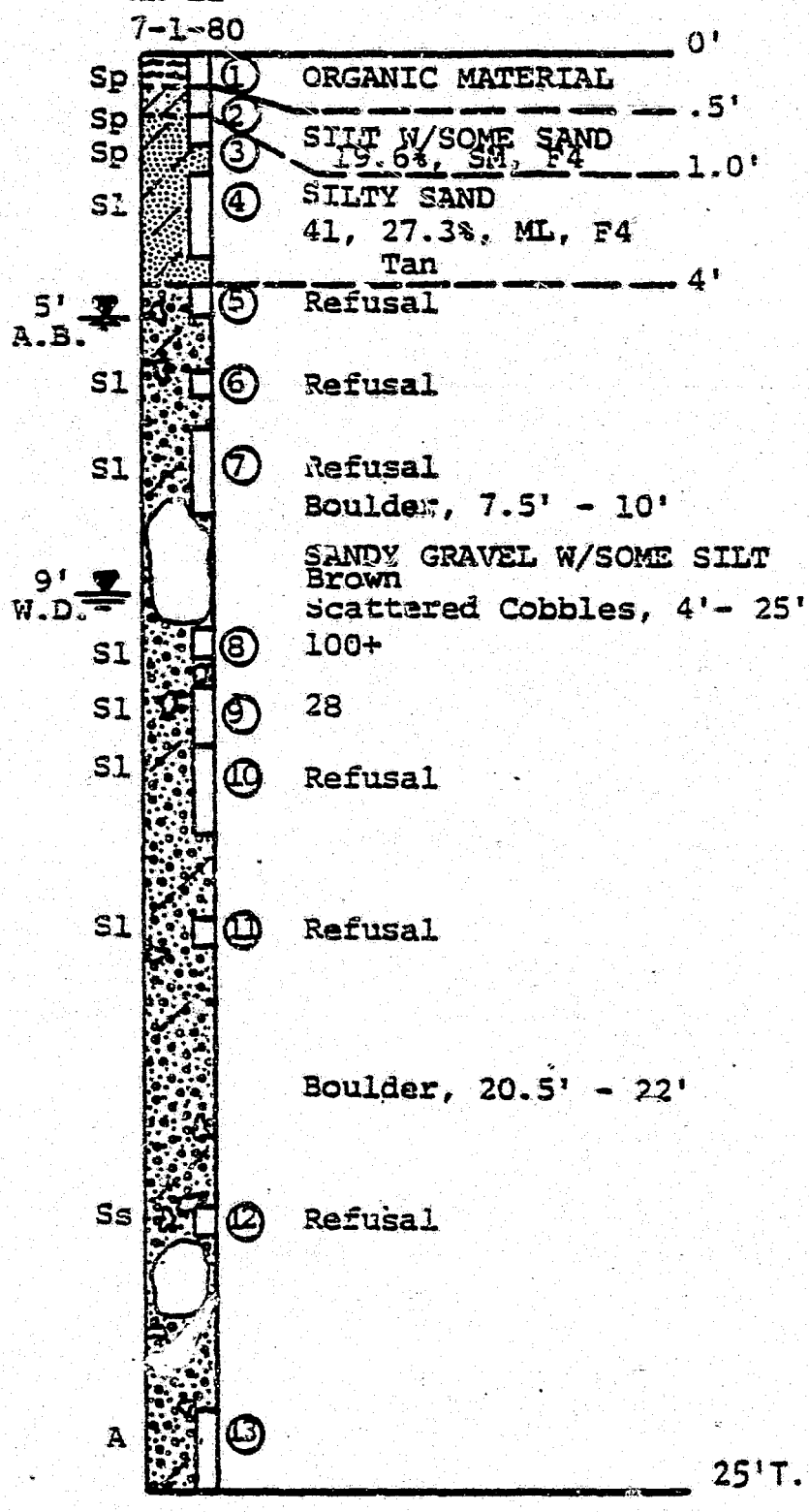
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SUSITNA RIVER
HYDROELECTRIC PROJECT
GEOTECHNICAL INVESTIGATIONS

F.B.	
GRID.	
PROJ.NO.	052504
DWG.NO.	

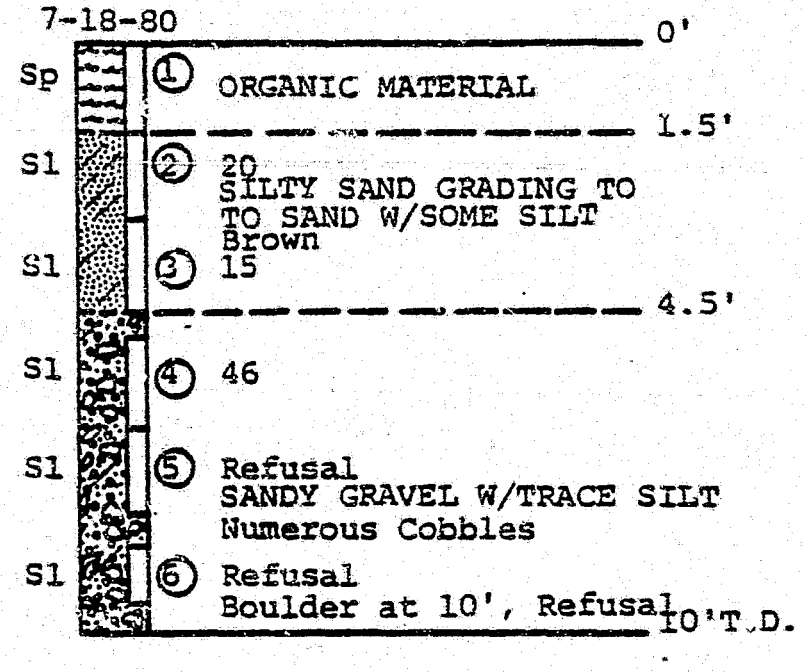
AH-E1

7-1-80



AH-E2

7-18-80

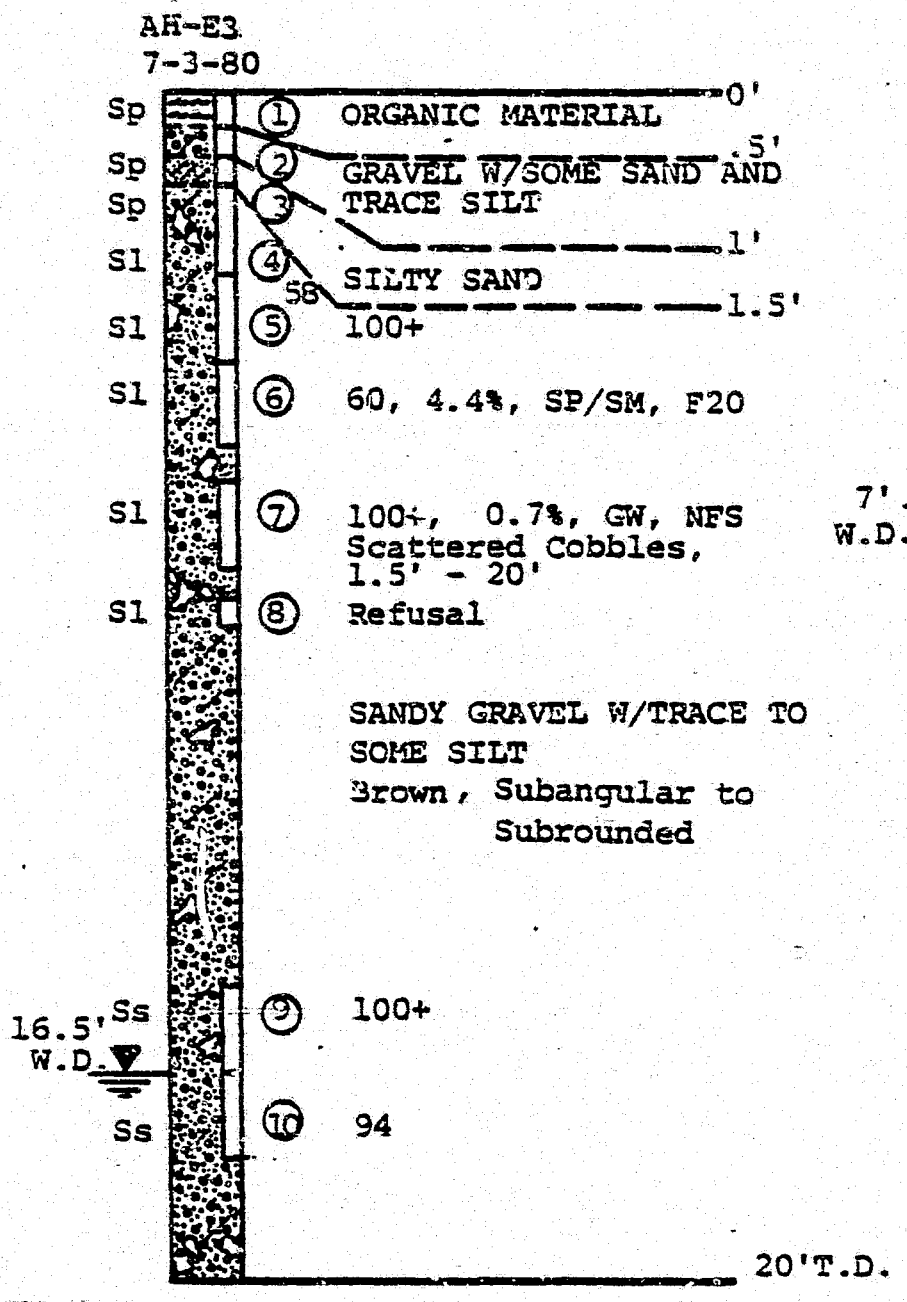


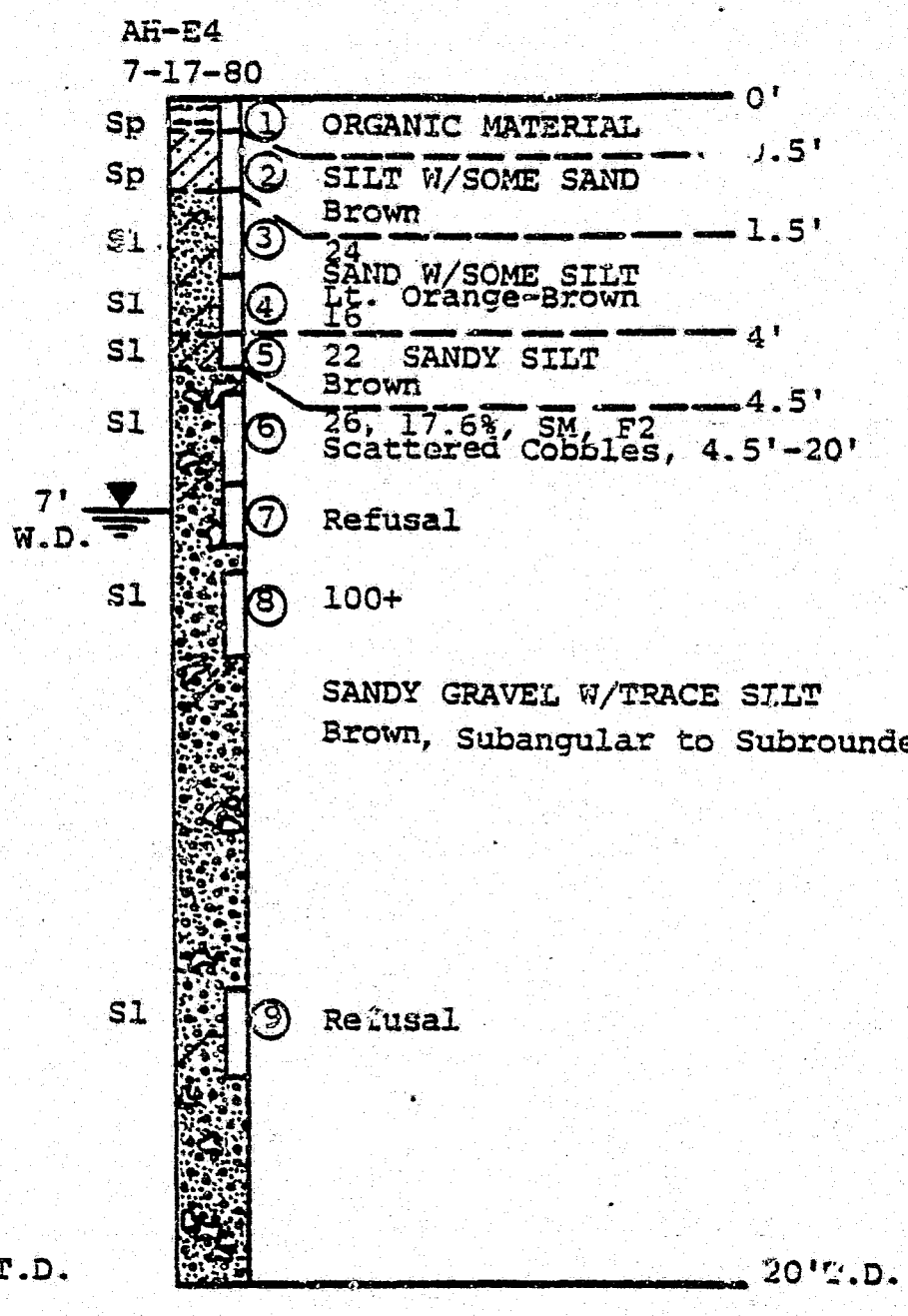
DWN.	KW
CKD.	MH
DATE.	Aug. 80
SCALE	1"=4'

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SUSITNA RIVER
HYDROELECTRIC PROJECT
GEOTECHNICAL INVESTIGATIONS

F.B.	
GRID.	
PROJ.NO.	052504
DWG.NO.	



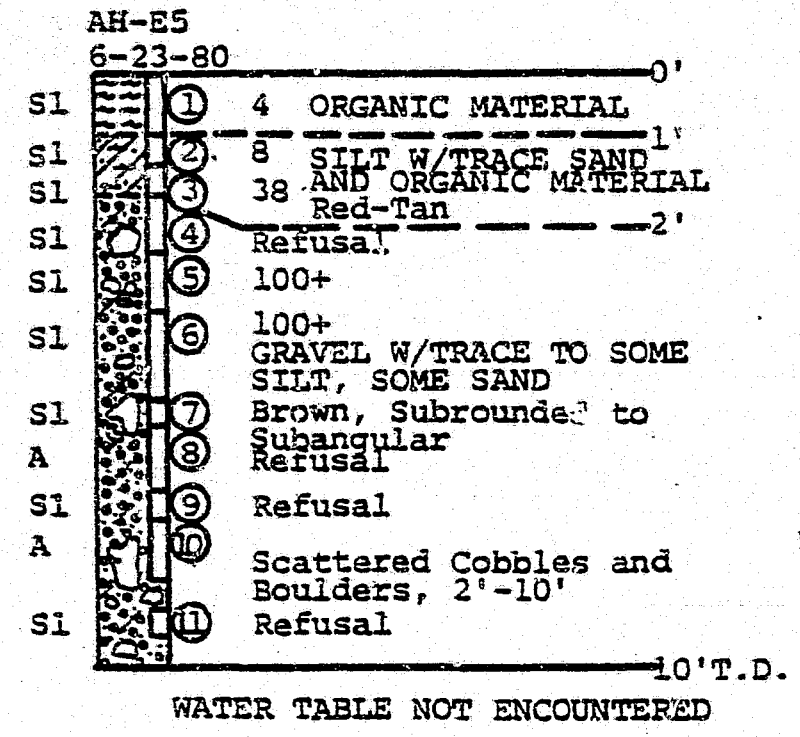


DWN.	KW
CKD.	MH
DATE.	Aug. 80
SCALE	1'=4'

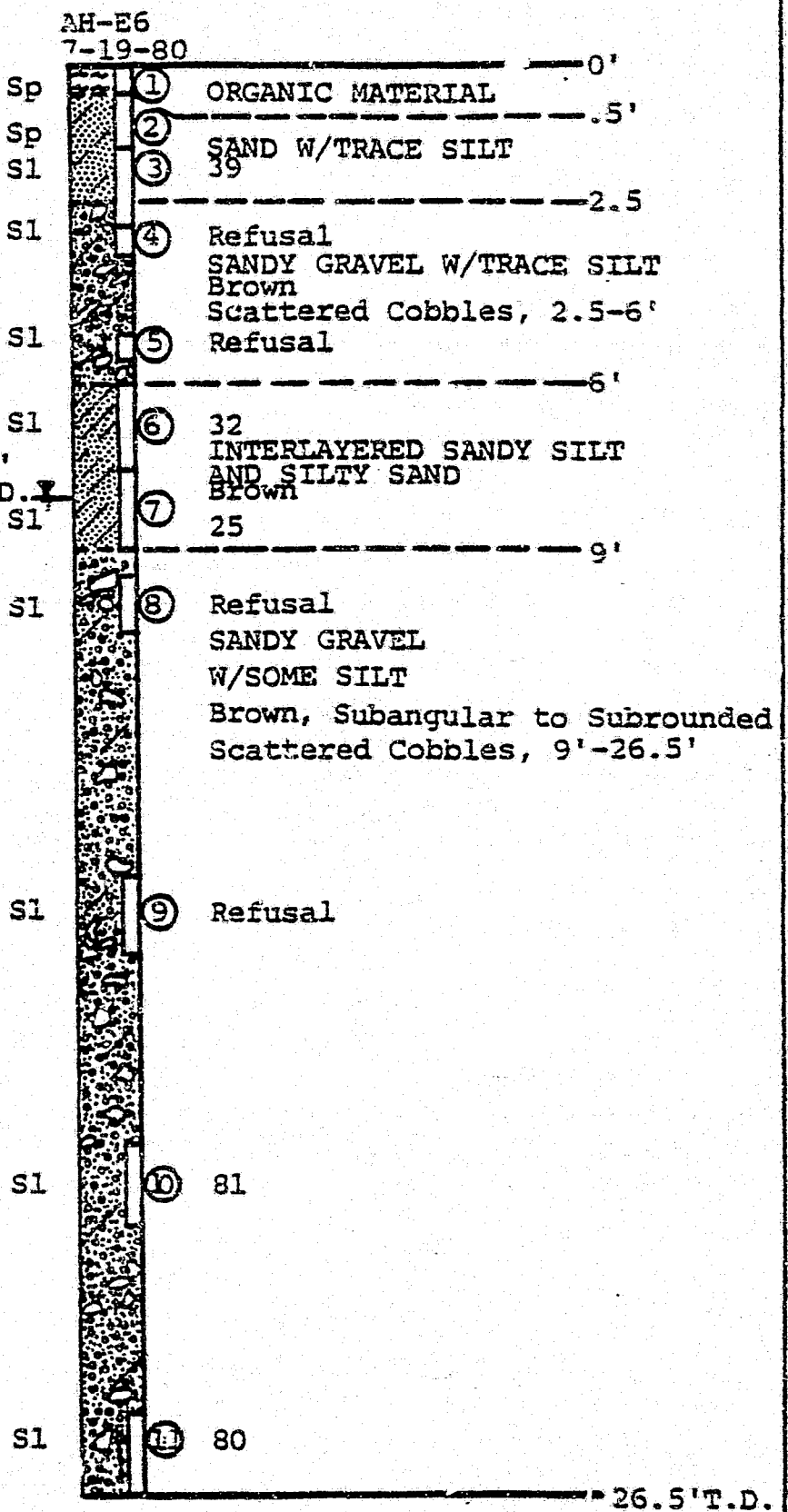
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SUSITNA RIVER
HYDROELECTRIC PROJECT
GEOTECHNICAL INVESTIGATIONS

F.B.	
GRID.	
PROJ.NO.	052504
DWG.NO.	



WATER TABLE NOT ENCOUNTERED



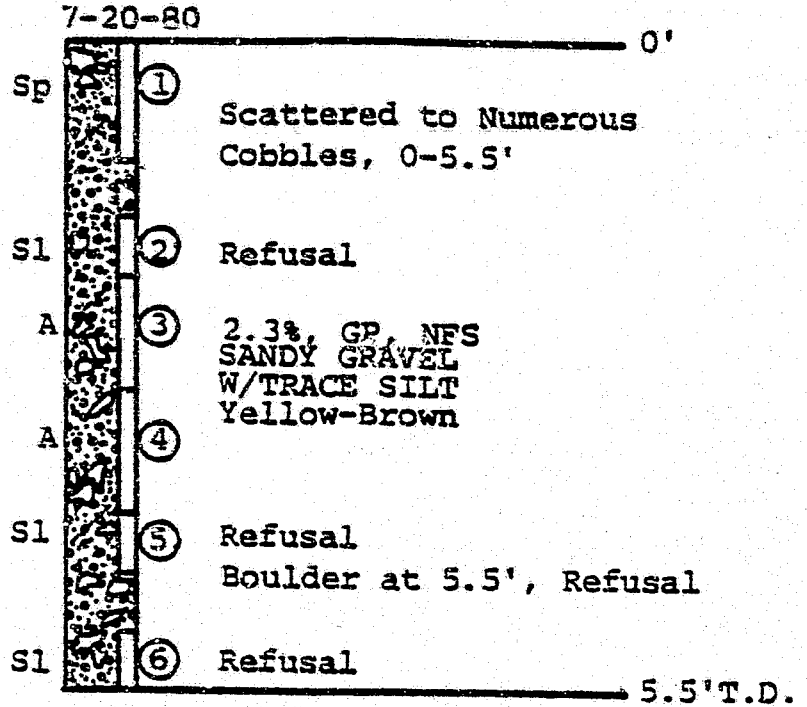
DWN.	KW
CKD.	MH
DATE.	Aug. 80
SCALE	1"=4'

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SUSITNA RIVER
HYDROELECTRIC PROJECT
GEOTECHNICAL INVESTIGATIONS

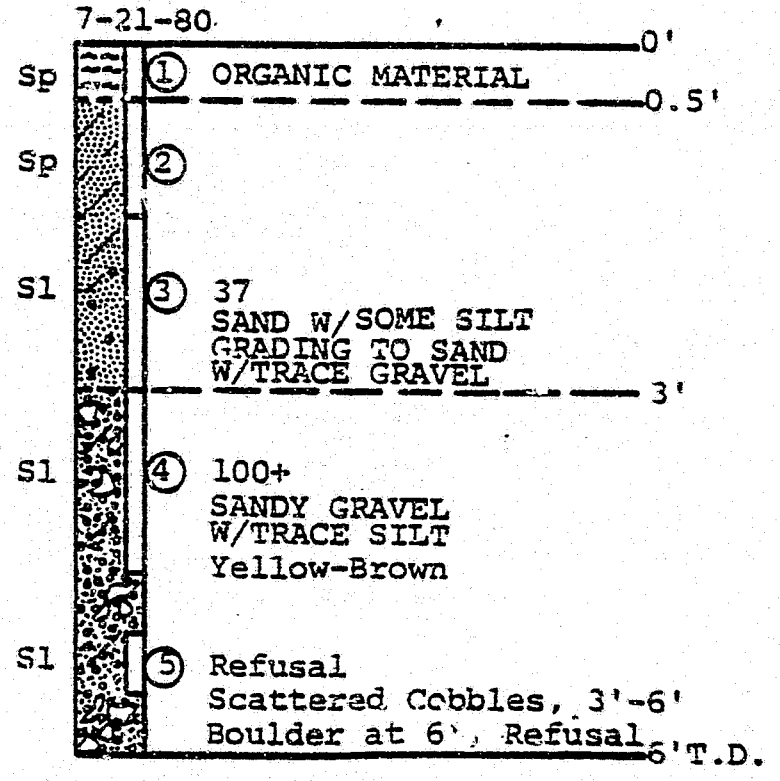
FB.	
GRID.	
PROJ. NO.	052504
DWG. NO.	

AH-27
7-20-80



WATER TABLE NOT ENCOUNTERED

AH-E8
7-21-80



WATER TABLE NOT ENCOUNTERED

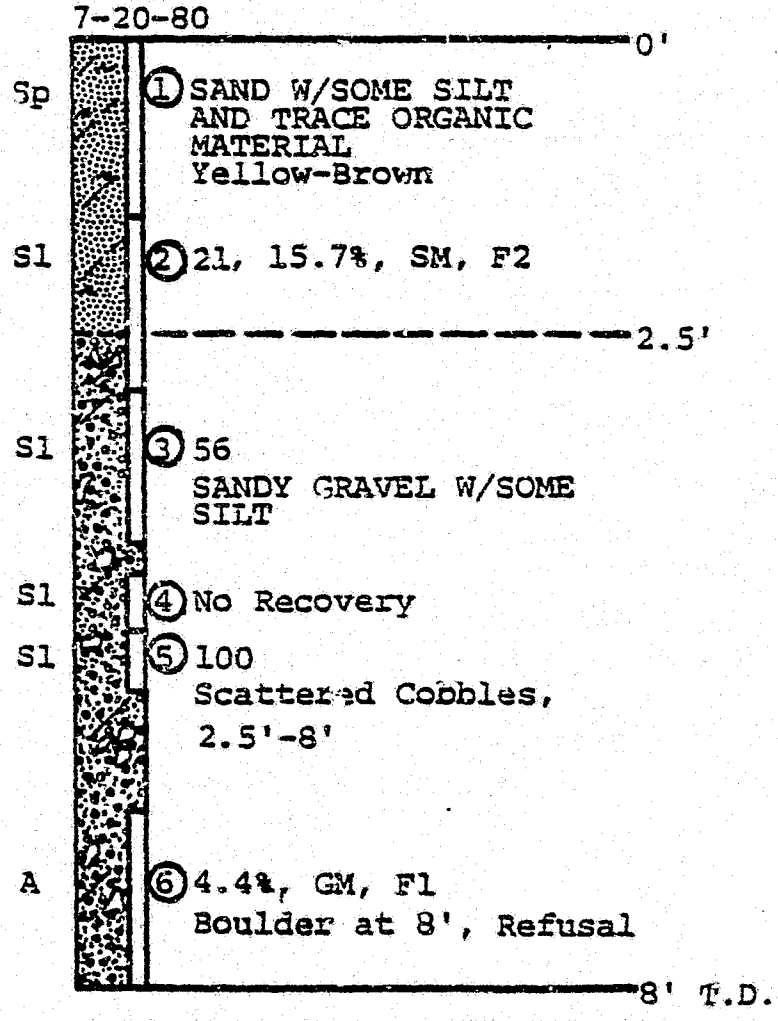
DWN.	KW
CKD.	MH
DATE.	Aug. 80
SCALE	1"=2'

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ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

SUSITNA RIVER
HYDROELECTRIC PROJECT
GEOTECHNICAL INVESTIGATIONS

FB.	
ORIG.	
PROJ.NO.	052504
DWG.NO.	

AH-E9
7-20-80



WATER TABLE NOT ENCOUNTERED

DWN.	KW
CKD.	MH
DATE.	Aug. 80
SCALE	1"=2'

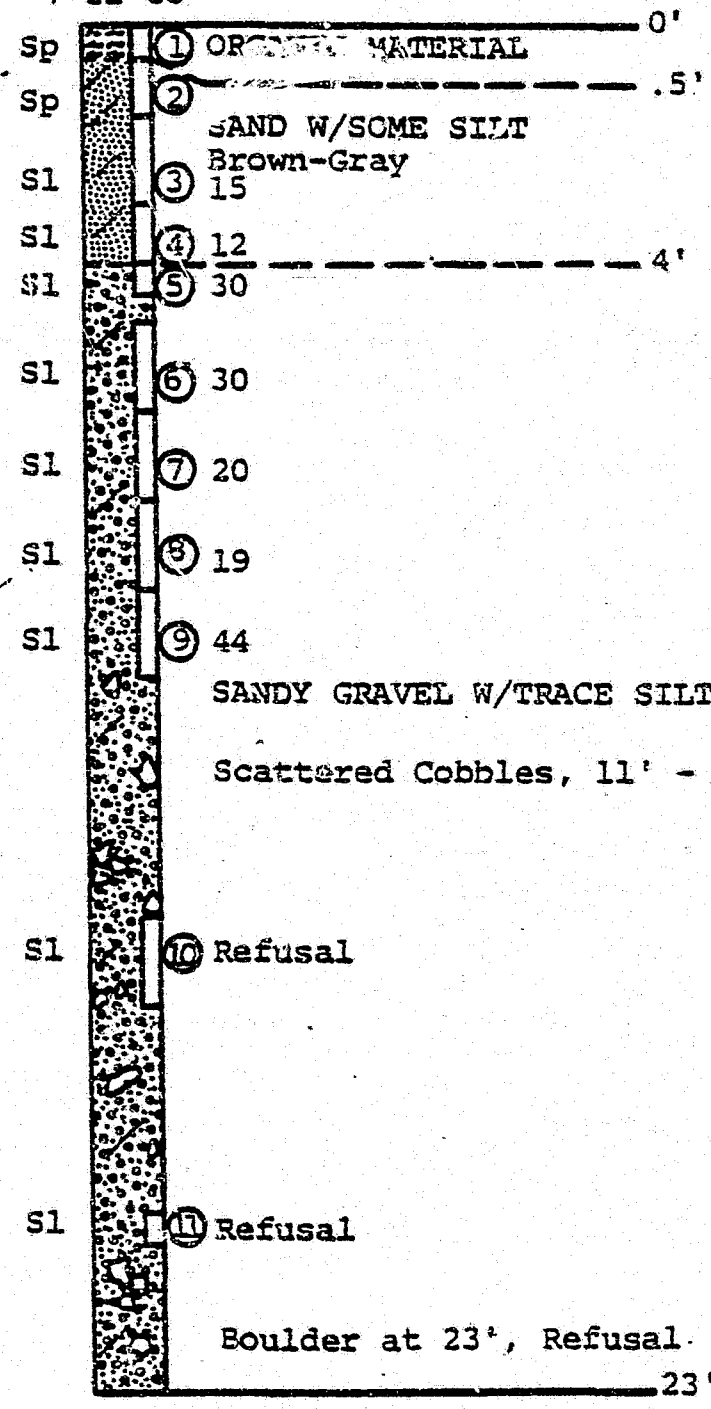
R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

SUSITNA RIVER
HYDROELECTRIC PROJECT
GEOTECHNICAL INVERSTIGATIONS

F.B.	
GRID	
PROJ. NO.	052504
DWG. NO.	

DEVIL CANYON

AH-G1
7-22-80



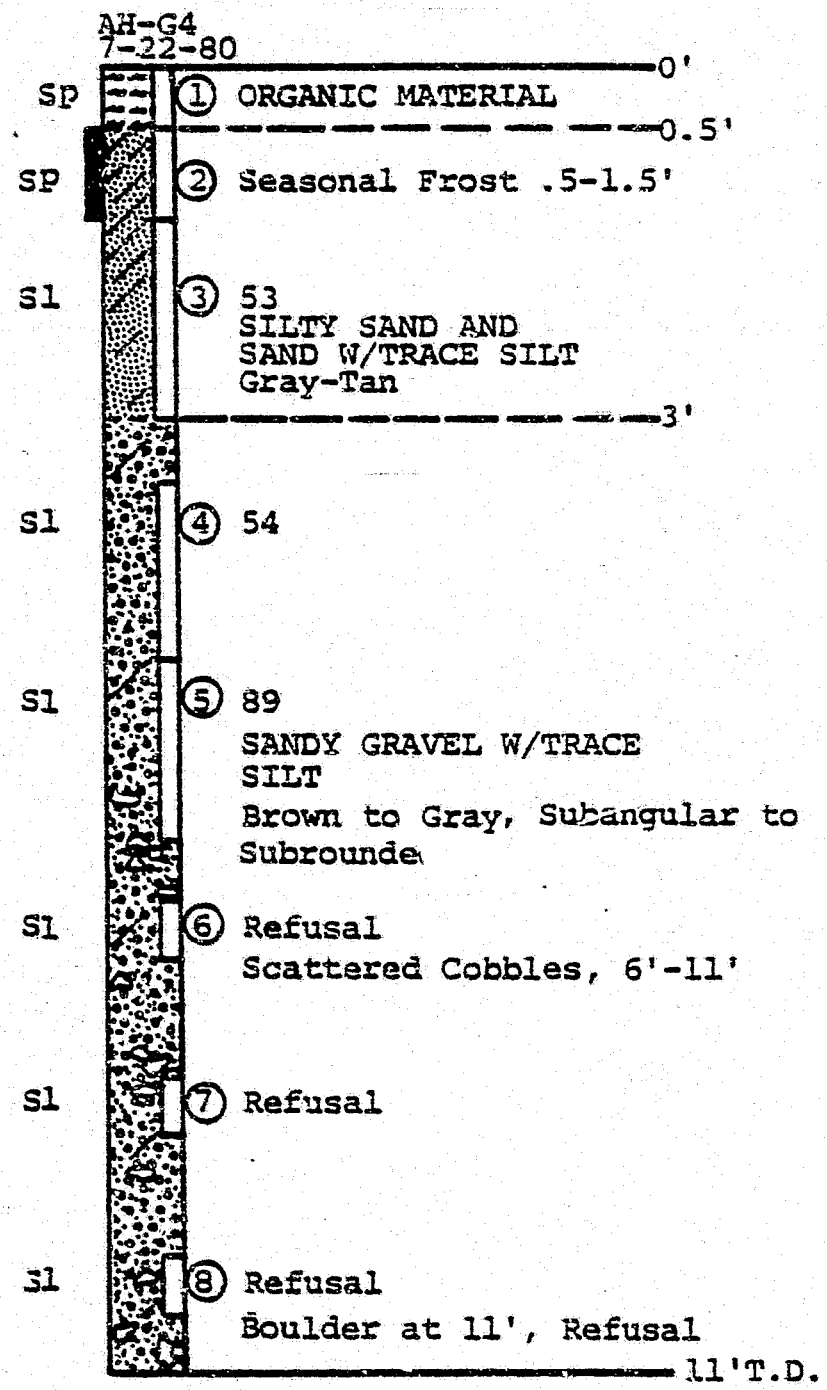
WATER TABLE NOT ENCOUNTERED

DWN.	KW
CKD.	MH
DATE.	Aug. 80
SCALE.	1"=4'

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ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

SUSITNA RIVER
HYDROELECTRIC PROJECT
GEOTECHNICAL INVESTIGATIONS

FIG.	
GRID.	
PROJ.NO.	052504
DWG.NO.	



WATER TABLE NOT ENCOUNTERED

DWN.	KW
CKD.	MH
DATE.	Aug. 80
SCALE	1'=2'

R&M CONSULTANTS, INC.
ENGINEERS GEOLOGISTS PLANNERS SURVEYORS

SUSITNA RIVER
HYDROELECTRIC PROJECT
GEOTECHNICAL INVESTIGATIONS

F.B.	
GRID	
PROJ. NO.	052504
DWG. NO.	

APPENDIX C-2

LABORATORY TEST DATA - R&M

SUMMARY OF LABORATORY TEST DATA

PROJECT NO. 052504
CLIENT Acres
PROJECT NAME Sunitsa (Watana Dam Site)

R & M CONSULTANTS, INC.

SUMMARY OF LABORATORY TEST DATA

DATE 10-17-80
PARTY NO. _____ PAGE NO. C-01

LAB NO.	BORING NO	SAMPLE NO	DEPTH	4"	3"	2"	1½"	1"	3/4"	1/2"	3/8"	#4	#10	#40	#200	.02	.005	.002	% Moist.	LL	PI	Unified Class.
BORROW		H	W-80-256			100	95	89	84	81	78	73	64	53	38.2	24.3	13.6	8.6	10.9	21.7	9.2	GC-SC
			(Grab sample)																			
BORROW		H	W-80-257			100	97	92	89	84	81	73	66	54	36.0	19.6	8.9	5.2	12.3	17.1	2.5	GM-SM
			(Grab sample)																			
DRAINAGE			W-80-282											100	99.5	81.3	69.6	50.8	42.1	55.9	33.2	CL-CH
			(Grab sample)																			
DRAINAGE			W-80-300			100	95	93	89	87	86	80	76	58	26.9	9.2	3.0	1.3	6.6	NV **	NP **	SM
			(Grab sample)																			
STREAM ALLUVIUM			W-80-302	100	92	90	82	69	58	45	38	27	23	14	2.6							GP
			(Grab sample)																			
BORROW		D	AH-01 #5					100	99	95	94	90	84	69	42.3	19.0	5.1	2.6	13.1	NV	NP	SM
			(6.0 - 7.5')																			
BORROW		D	AH-01 #6				100	87	87	83	80	75	69	54	28.3	14.4	6.1	3.3	6.7			SM*
			(8.0 - 8.5')																			
BORROW		D	AH-01 #7						100	91	91	87	76	62	35.7	18.2	8.2	4.9	6.6			SM*
			(10.0 - 10.3')																			
BORROW		D	AH-02 #3		100	80	80	80	77	73	72	67	61	47	28.5	12.0	3.2	2.9	25.7	NV	NP	SM
			(1.5 - 3.0')																			
BORROW		D	AH-02 #4				100	94	92	90	89	86	79	62	35.0	21.2	4.1	2.4	11.4	13.9	NP	SM
			(3.0 - 4.5')																			

REMARKS: * Estimated Value
** NV = Non Viscous NP = Non Plastic

NOTE: SIEVE ANALYSIS = PERCENT PASSIN

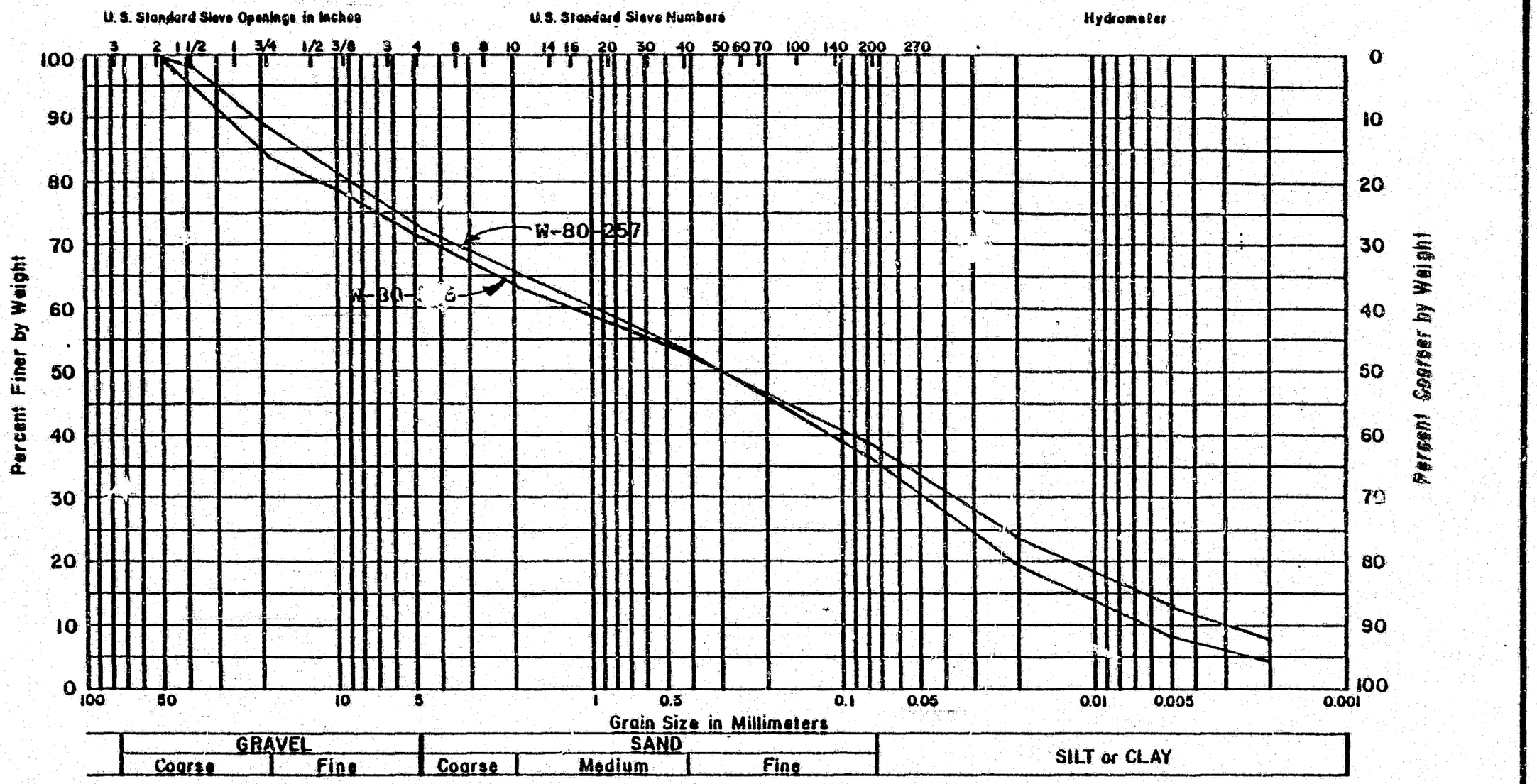
APPROVED

LAB NO.	BORING NO	SAMPLE NO	DEPTH	4"	3"	2"	1½"	1"	3/4"	1/2"	3/8	#4	#10	#40	#200	.02	.005	.002	% Moist.	LL	PI	Unified Class.
BORROW		D	AH-02 #5					100	98	96	92	87	80	59	30.7	13.8	3.9	1.6	11.2	NV	NP	SM
			(4.5 - 6.0')																			
BORROW		D	AH-02 #8						100	99	97	93	87	70	44.0	22.5	8.9	4.0	11.3	15.5	2.2	SM
			(15.0 - 16.5')																			
BORROW		D	AH-02 #9				100	96	94	93	91	85	78	61	38.6	21.3	10.3	4.2	9.4	17.5	4.2	SM
			(20.0 - 21.5')																			
BARROW		E	AH-E1 #3										100	99	48.0				19.6			SM
			(1.0 - 1.5')																			
BORROW		E	AH-E1 #4										100	98	59.5				27.1			ML*
			(2.0 - 3.5')																			
BORROW		E	AH-E3 #6		100	89	89	83	80	76	72	62	52	28	6.2				4.4			SP/SM
			(4.5 - 6.0')																			
BORROW		E	AH-E3 #7			**	100	90	76	62	57	40	31	16	3.7				0.7			GW
			(6.5 - 8.0')																			
BORROW		E	AH-E4 #6							100	99	98	92	66	22.1				17.6			SM
			(5.0 - 6.5')																			
BORROW		E	AH-E7 #3				100	85	73	56	49	39	31	12	2.1				2.3			GP
			(2.0 - 3.0')																			
BORROW		E	AH-E9 #2 (1.5 - 3.0')										100	99	28.6				15.7			SM
BORROW		E	AH-E9 #6 (6.5 - 8.0')					100	98	97	79	57	44	33	17.0				4.4			GM

REMARKS: ** 1-2" Rock Present in Sample
* Estimated Value

NOTE: SIEVE ANALYSIS = PERCENT PASSIN

APPROVED



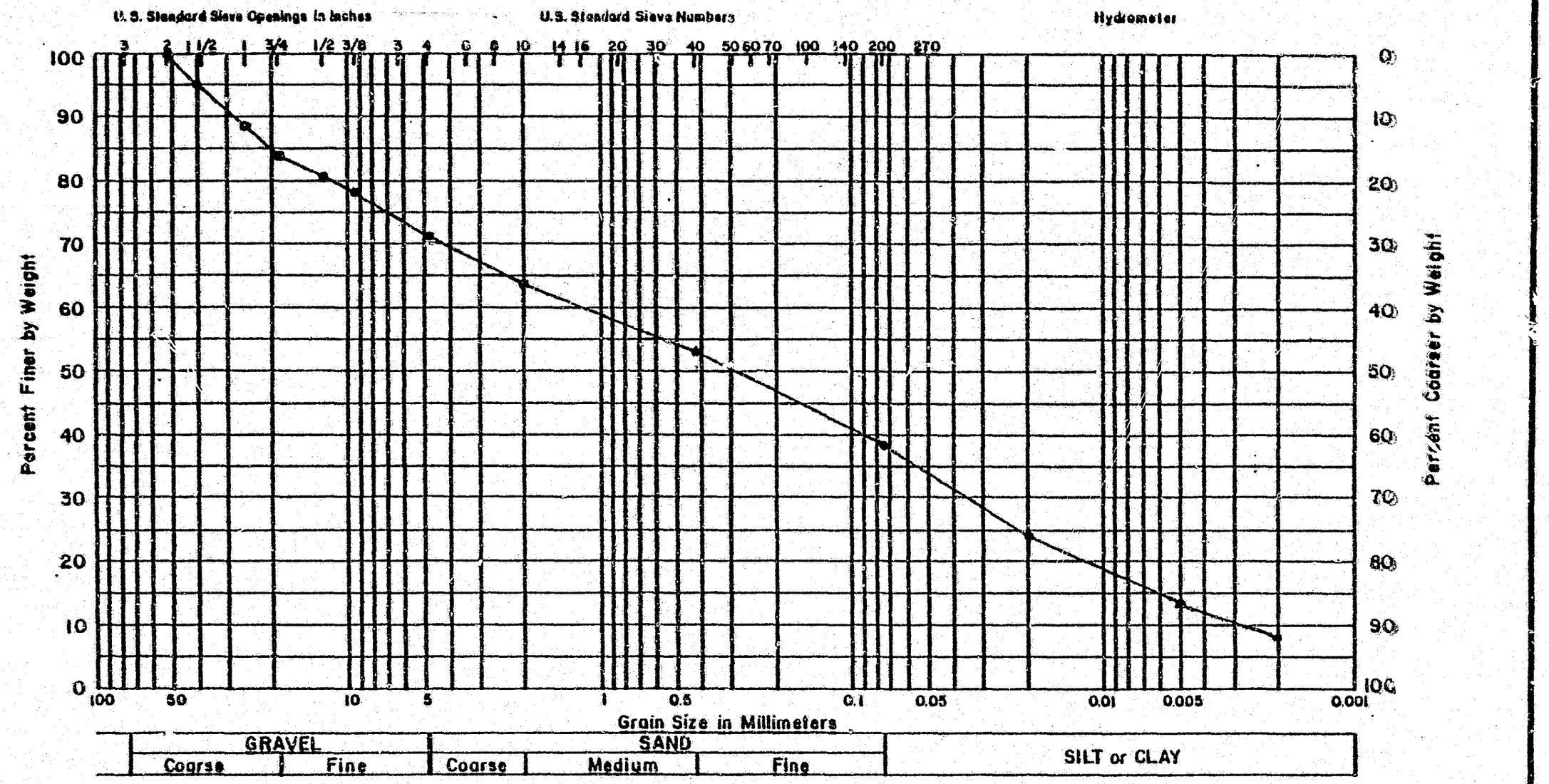
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION
W-80-256					
W-80-257					

R & M CONSULTANTS, INC.

BORROW AREA H

SUMMARY OF GRAIN SIZE DISTRIBUTION

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	052504



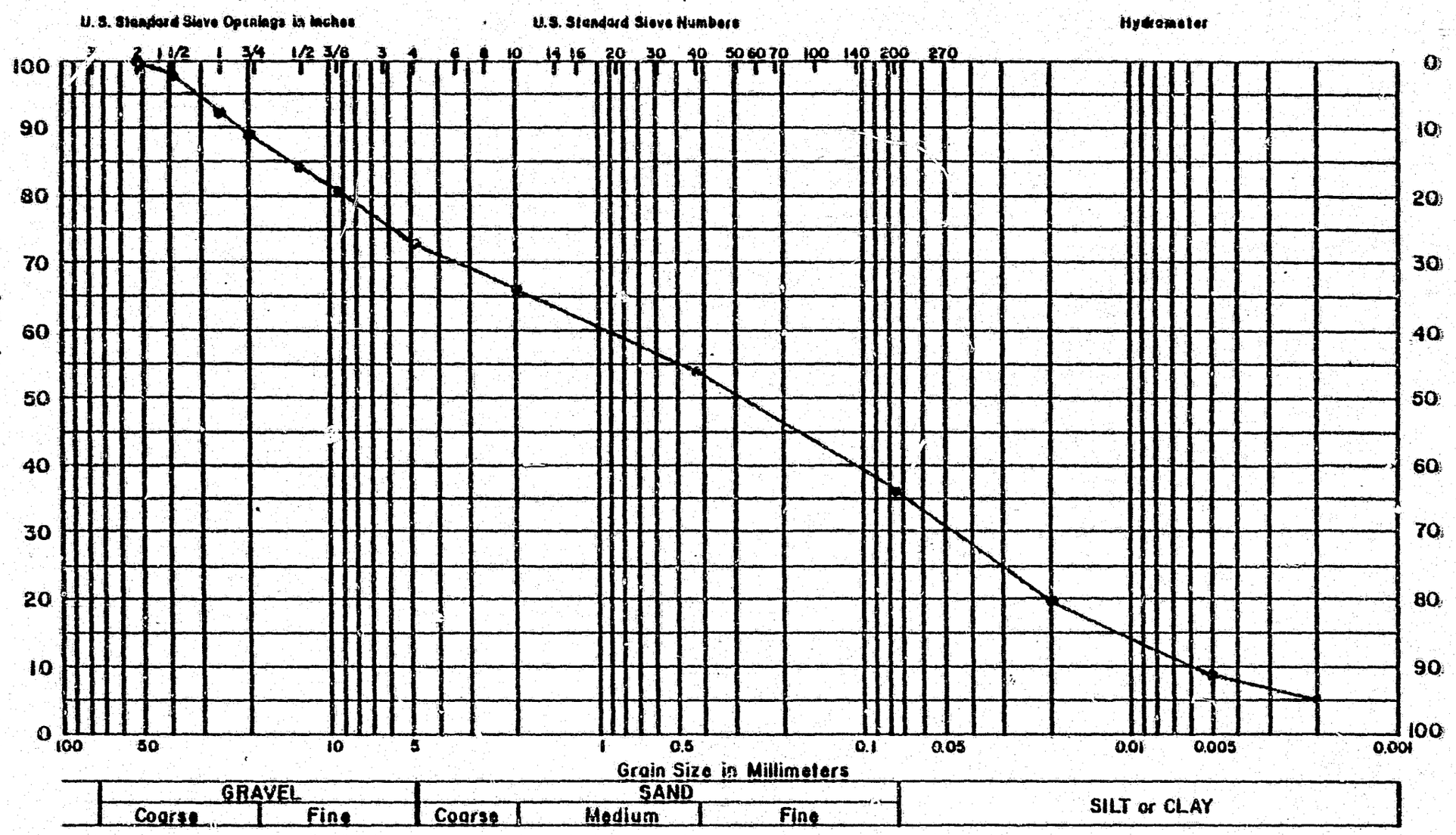
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI		CLASSIFICATION & DESCRIPTION
W-80-256	10.9%		21.7	9.2	GC-SC	Poorly graded 'Till' with low Plasticity
(Grab Sample)						SILTY GRAVEL AND SAND WITH TRACE CLAY

R & M CONSULTANTS, INC.

BORROW AREA H

DRAWN BY DL
APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504

.010272



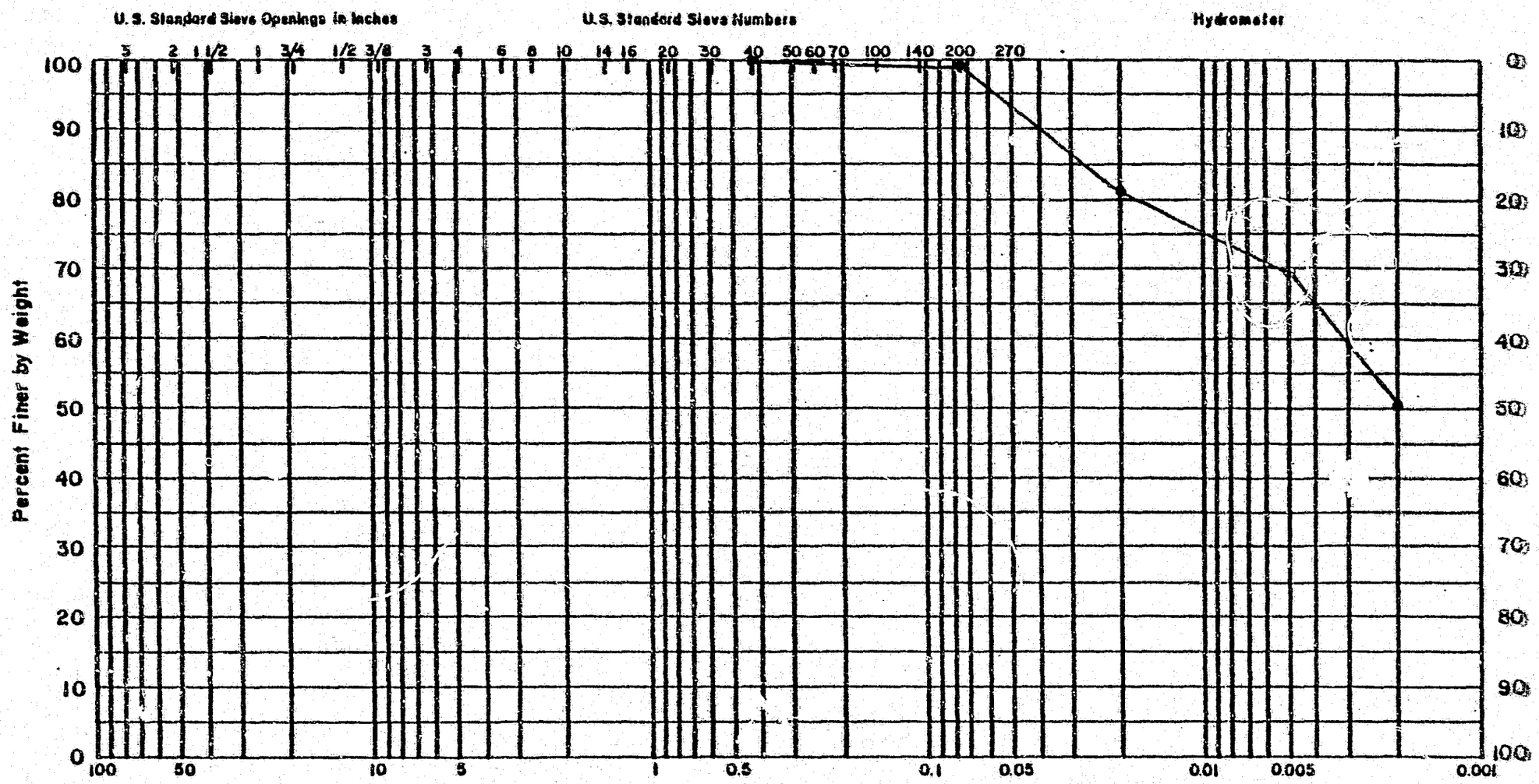
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI		CLASSIFICATION & DESCRIPTION
W-80-257	12.3		17.1	2.5	GM-SM	Poorly graded 'Till' with Non-Plastic Fines
(Grab Sample)						SILTY GRAVEL AND SAND WITH TRACE CLAY

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BORROW AREA H

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	052504

0272



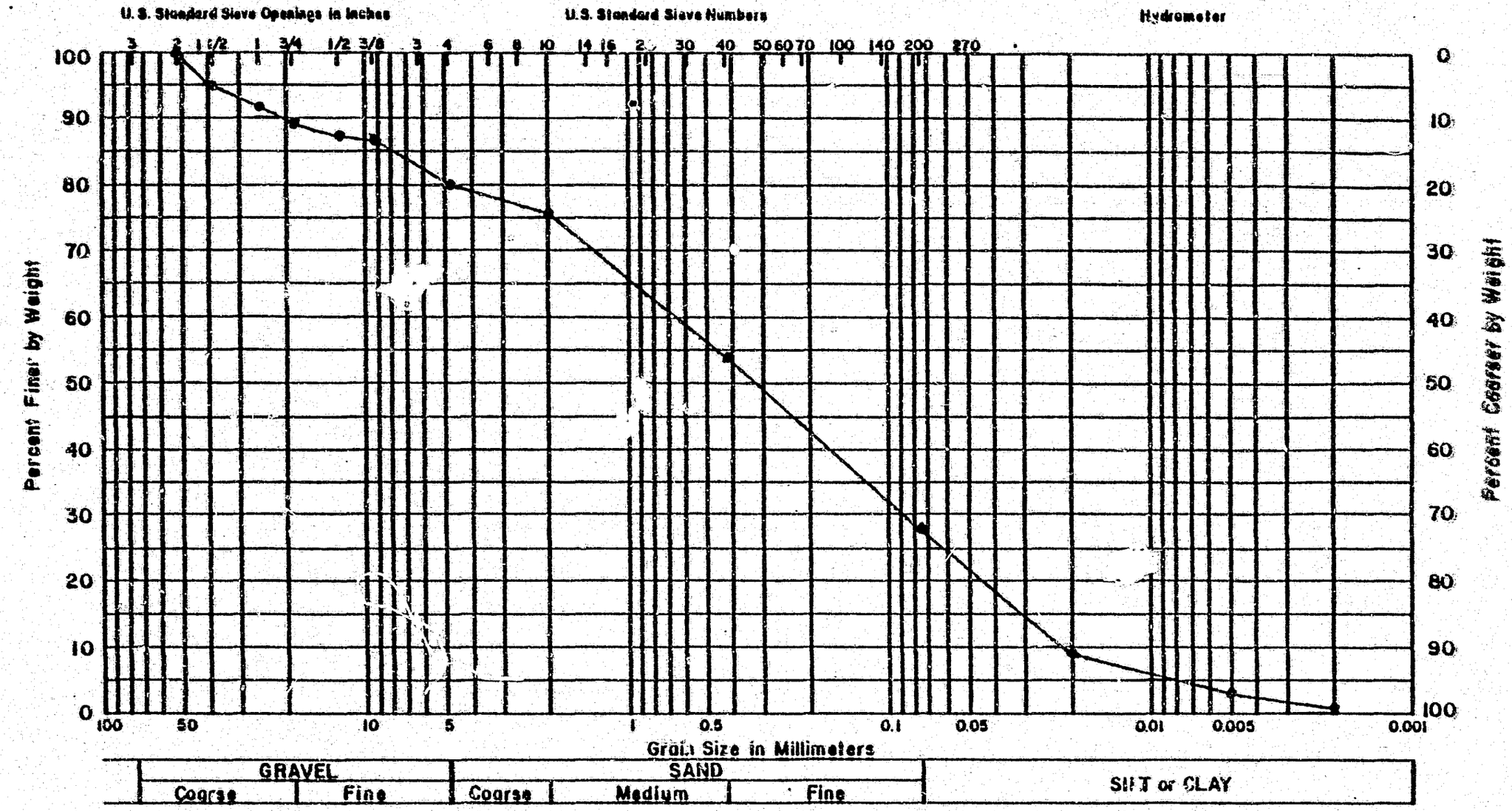
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI		CLASSIFICATION & DESCRIPTION
W-80-282	42.1%		55.9	33.2	CL-CH	SILT AND CLAY Medium to High Plasticity
(Grab Sample)						

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DEADMAN BORROW AREA

DRAWN BY DL
APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504

210272



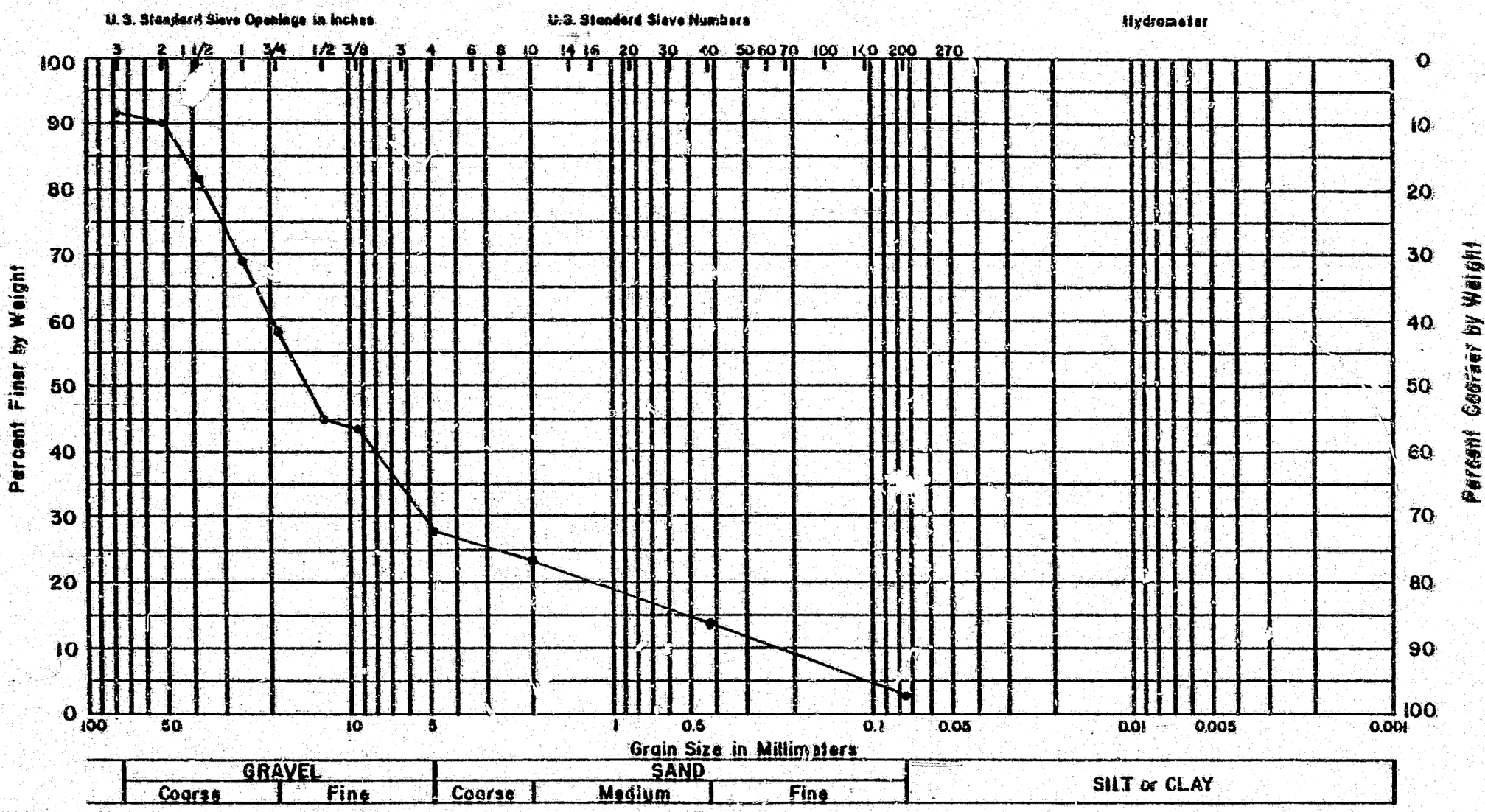
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI		CLASSIFICATION & DESCRIPTION
W-80-300	6.6%		NV	NP	SM	Sandy 'Till' with non plastic fines
(Grab Sample)						GRAVELLY SILTY SAND WITH TRACE CLAY
						Well graded

R & M CONSULTANTS, INC.

DEADMAN BORROW AREA

DRAWN BY DL
APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504

2720

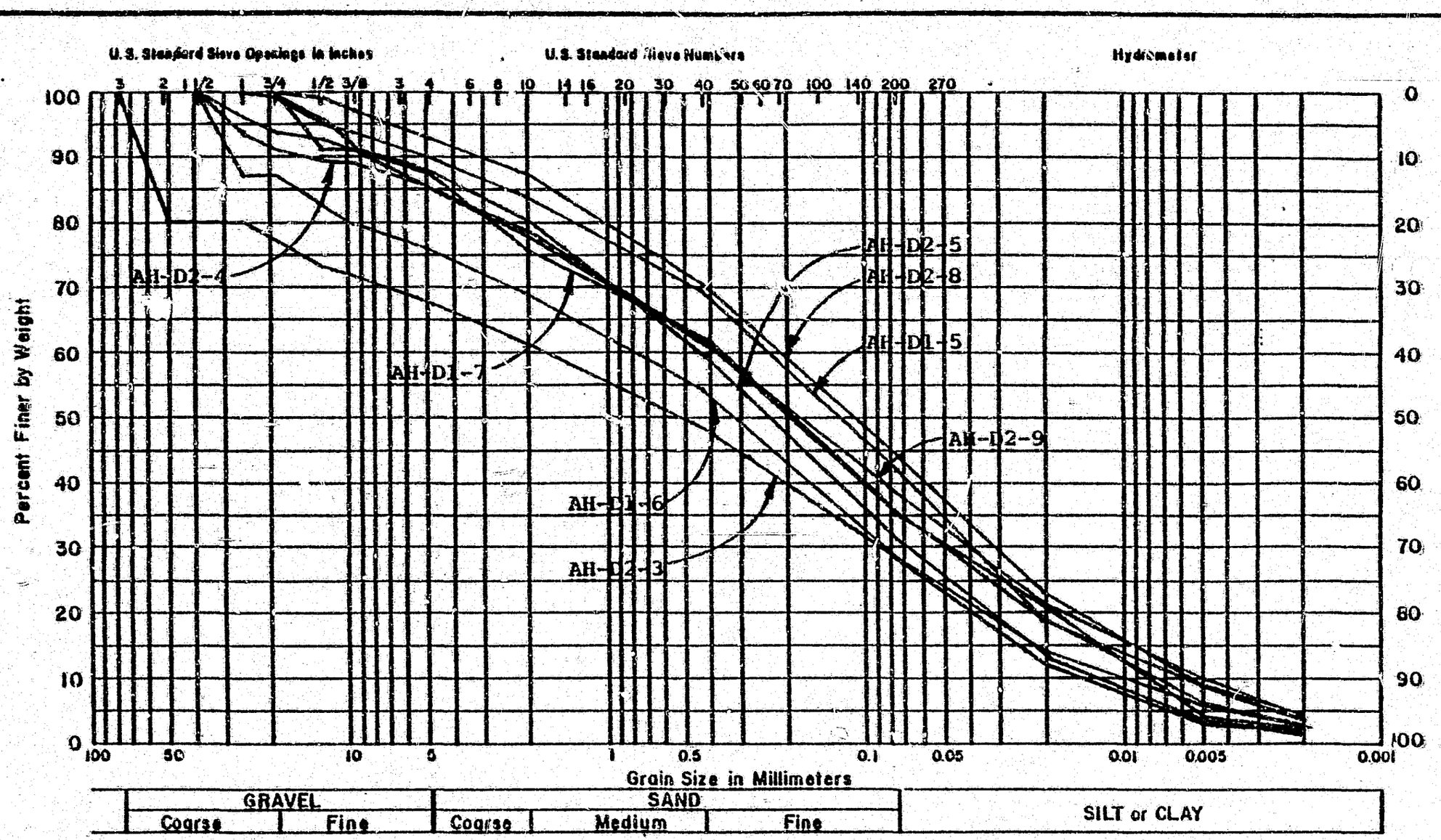


SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
W-80-302					GP	SANDY GRAVEL W/TRACE SILT
(Grab Sample)						Poorly Graded

R & M CONSULTANTS, INC.

STREAM ALLUVIUM

DRAWN BY DL
APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-D1-5					SM	
AH-D1-6					SM	
AH-D1-7					SM	
AH-D2-3					SM	
AH-D2-4					SM	
AH-D2-5					SM	
AH-D2-8					SM	
AH-D2-9					SM	

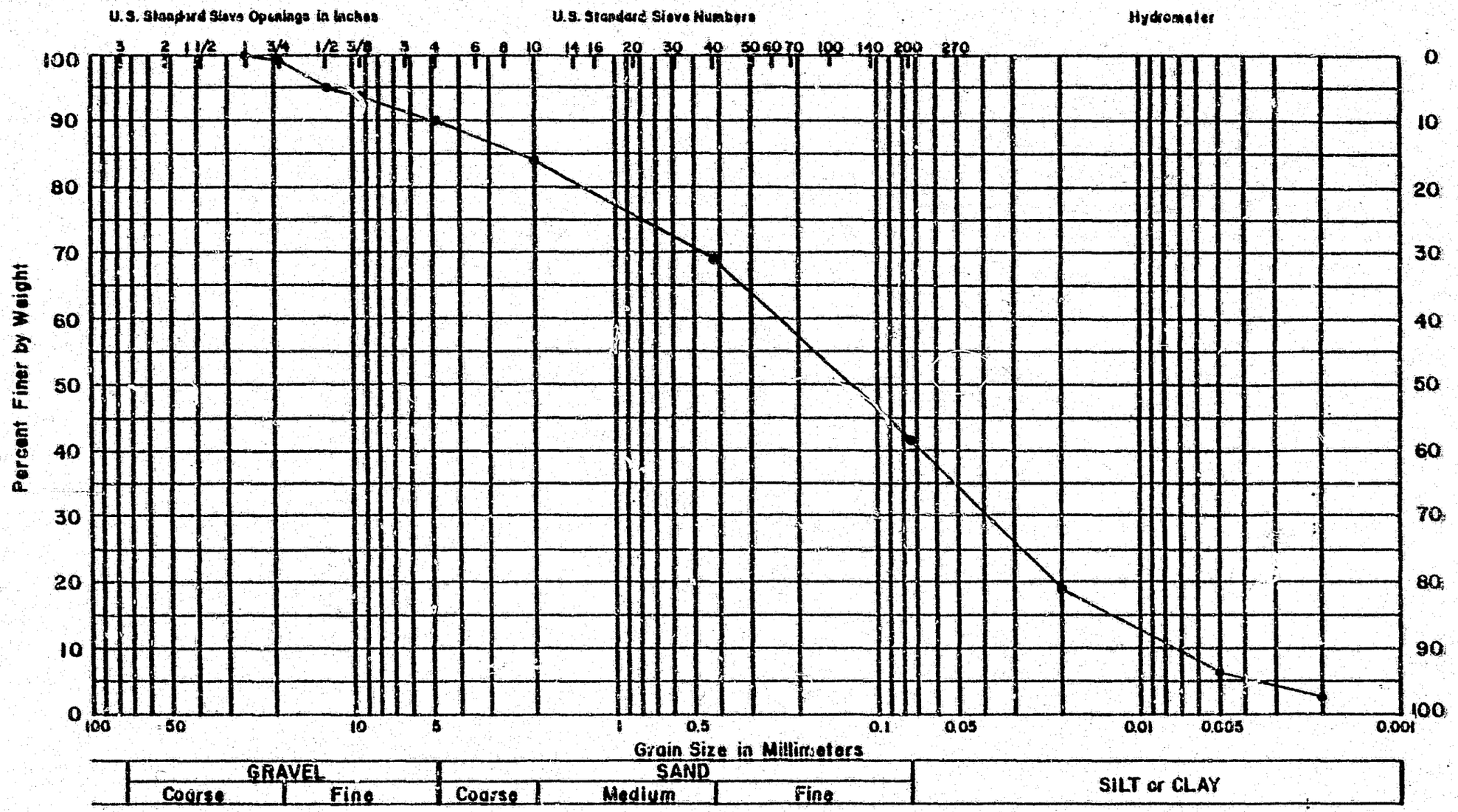
R & M CONSULTANTS, INC.

BORROW AREA D

SUMMARY OF GRAIN SIZE DISTRIBUTIONS

DRAWN BY DL
APPROVED BY
DATE DEC. 1
PROJECT NO. 052504

10272



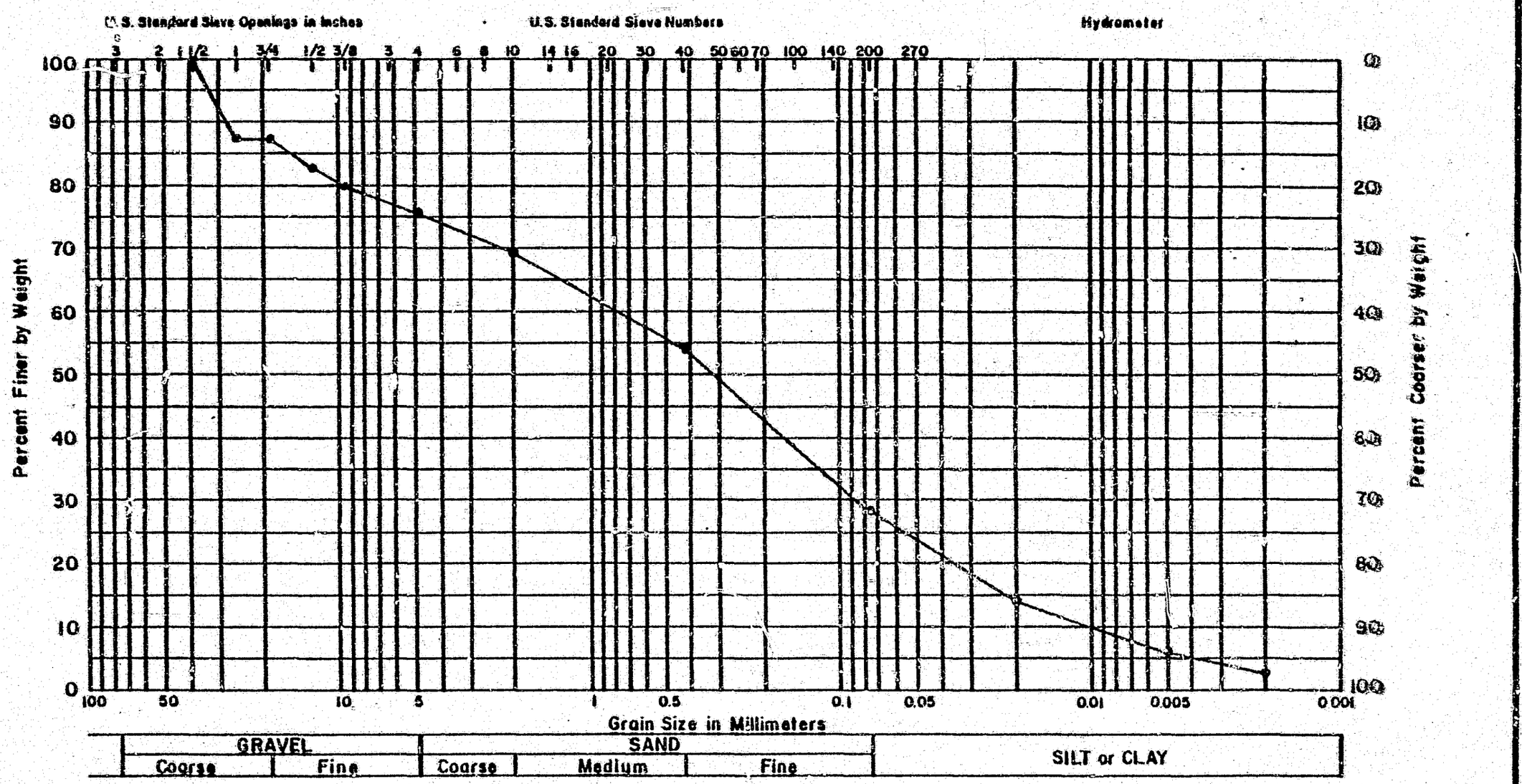
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH- DI-5	11.1%		NV	NP	SM	SILT AND SAND WITH TRACE GRAVEL AND TRACE CLAY
(6.0-7.5')						Non Viscous, Non Plastic

R & M CONSULTANTS, INC.

BORROW AREA D

DRAWN BY DL
APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504

010272



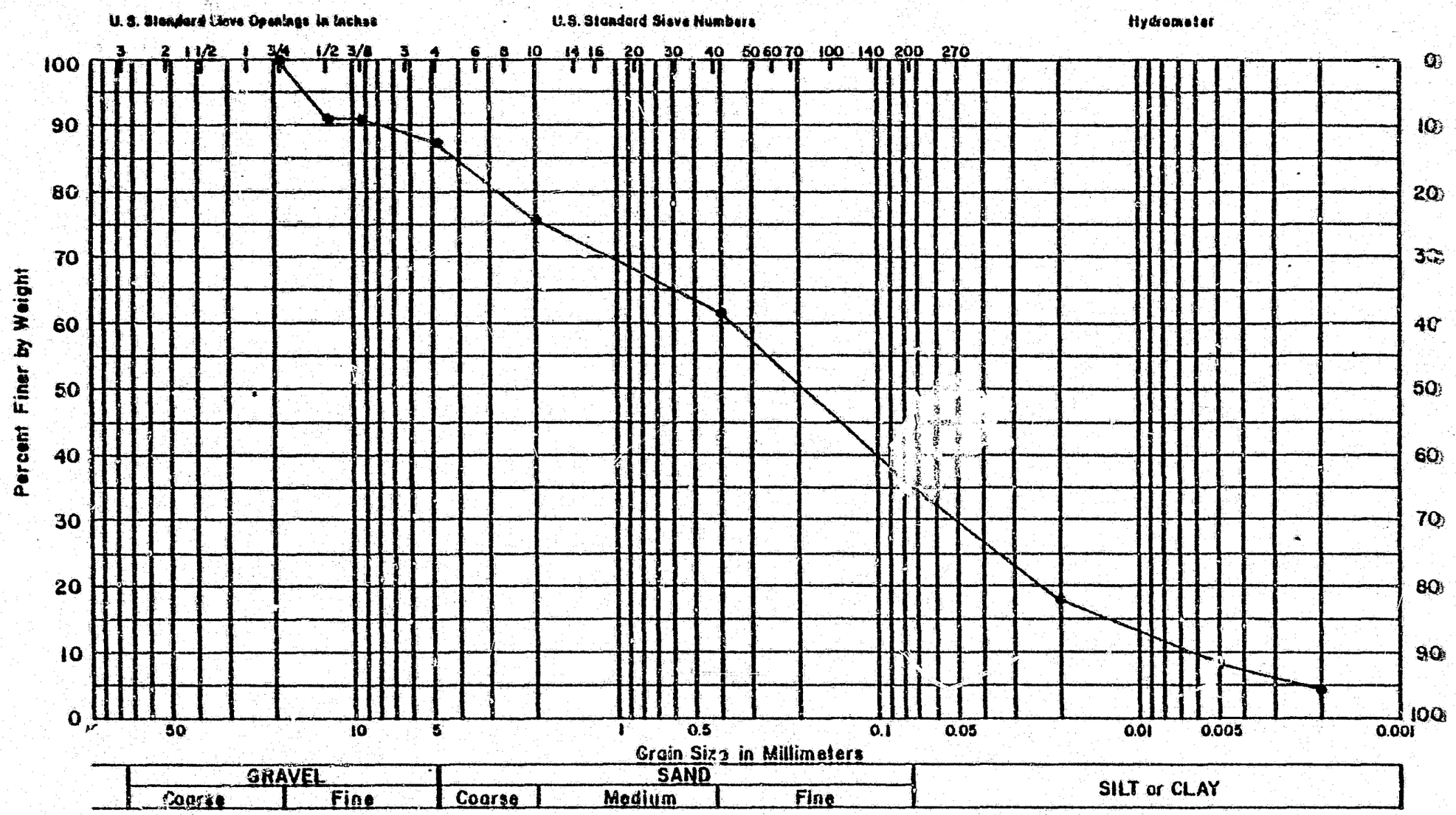
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH- D1-6 (8.0-8.5')	6.7%				SM	GRAVELLY SILTY SAND WITH TRACE CLAY

R & M CONSULTANTS, INC.

BORROW AREA D

DRAWN BY DL
APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504

2220

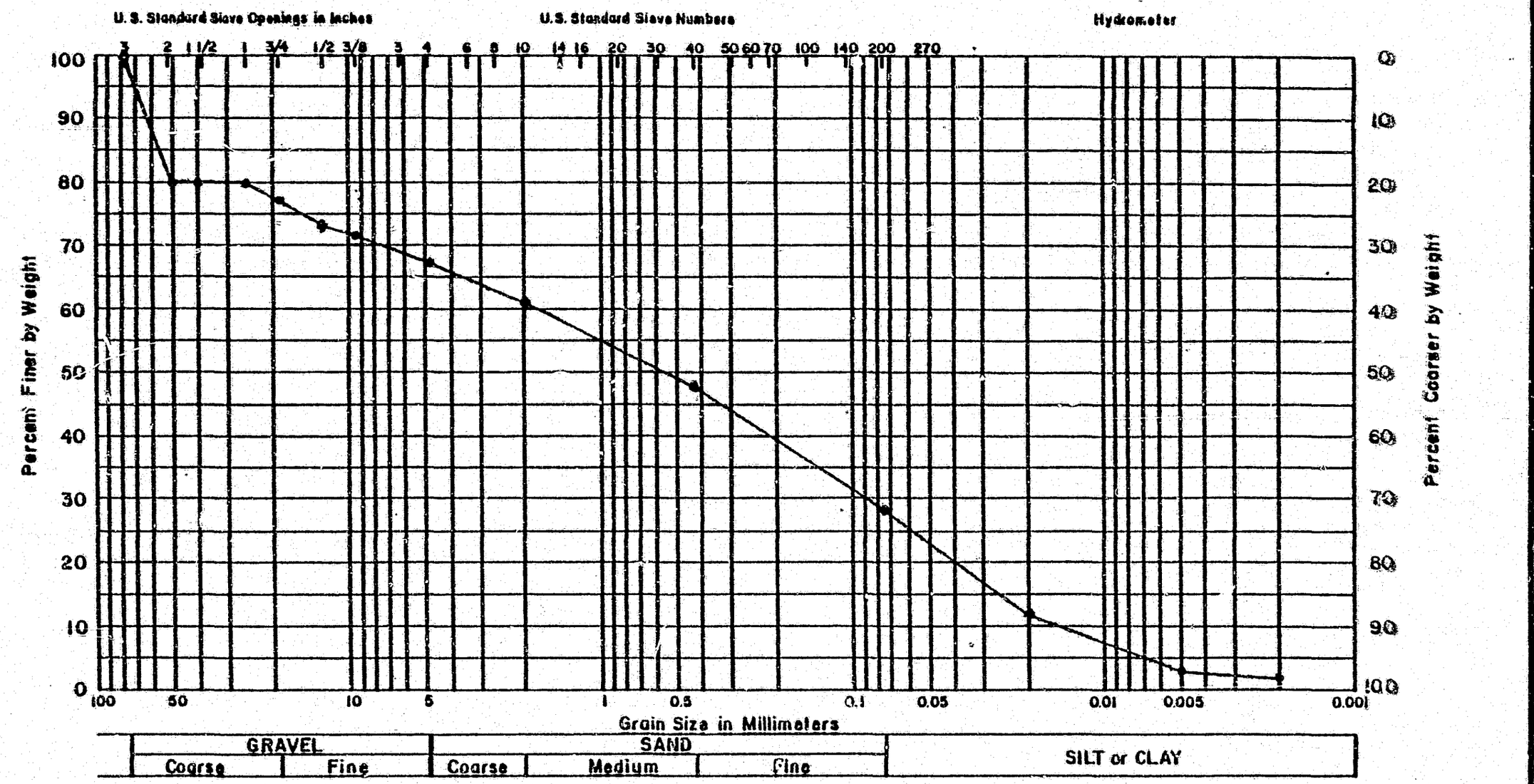


SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-D1-7	6.6%				SM	SILTY SAND WITH SOME GRAVEL, TRACE CLAY
(10.0-10.3')						

R & M CONSULTANTS, INC.

BORROW AREA D

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	052504



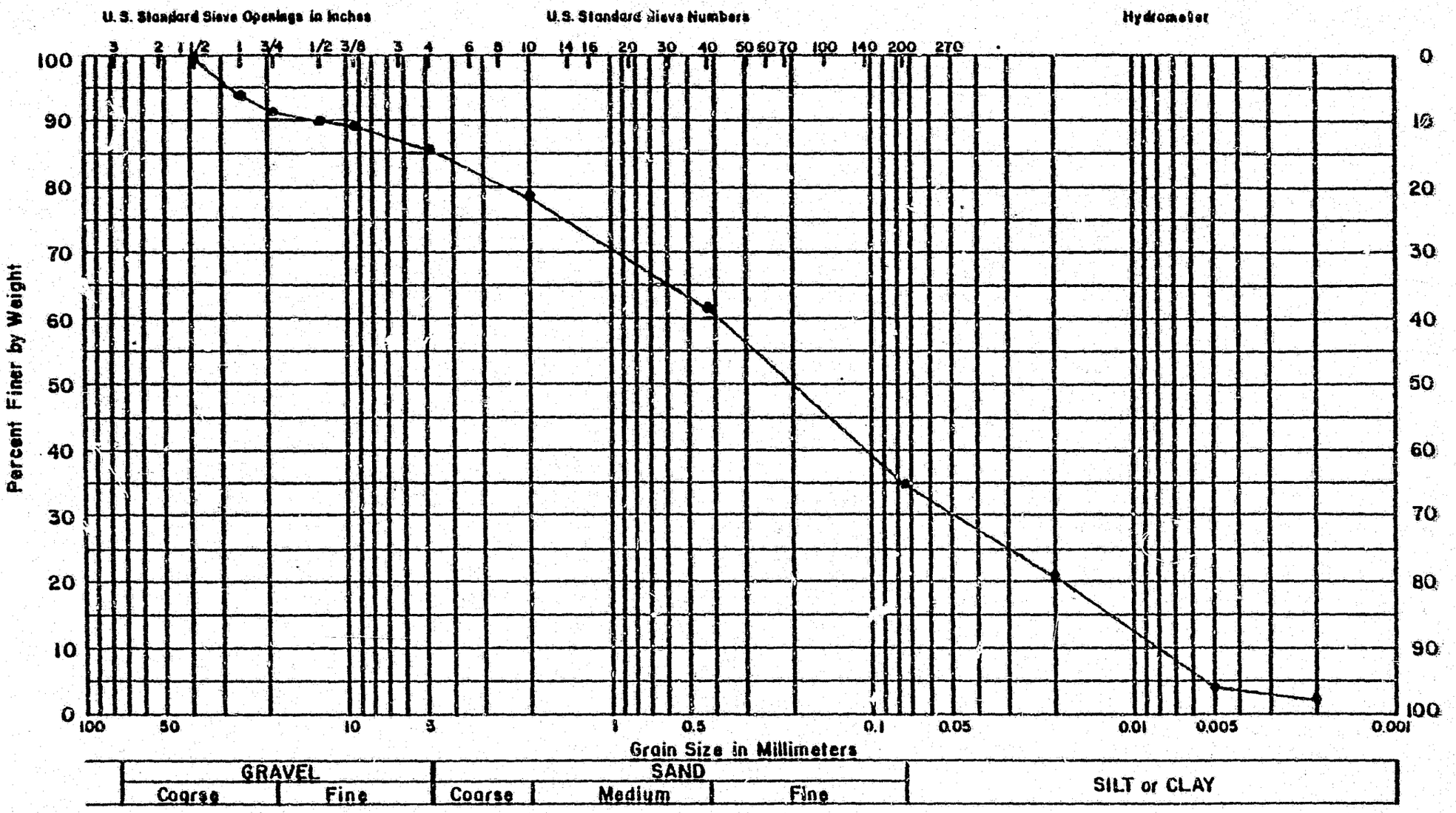
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-D2-3	25.7%		NV	NP	SM	SILTY GRAVELLY SAND W/TRACE CLAY
(1.5-3.0')						

R & M CONSULTANTS, INC.

BORROW AREA D

DRAWN BY DL
APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504

2720



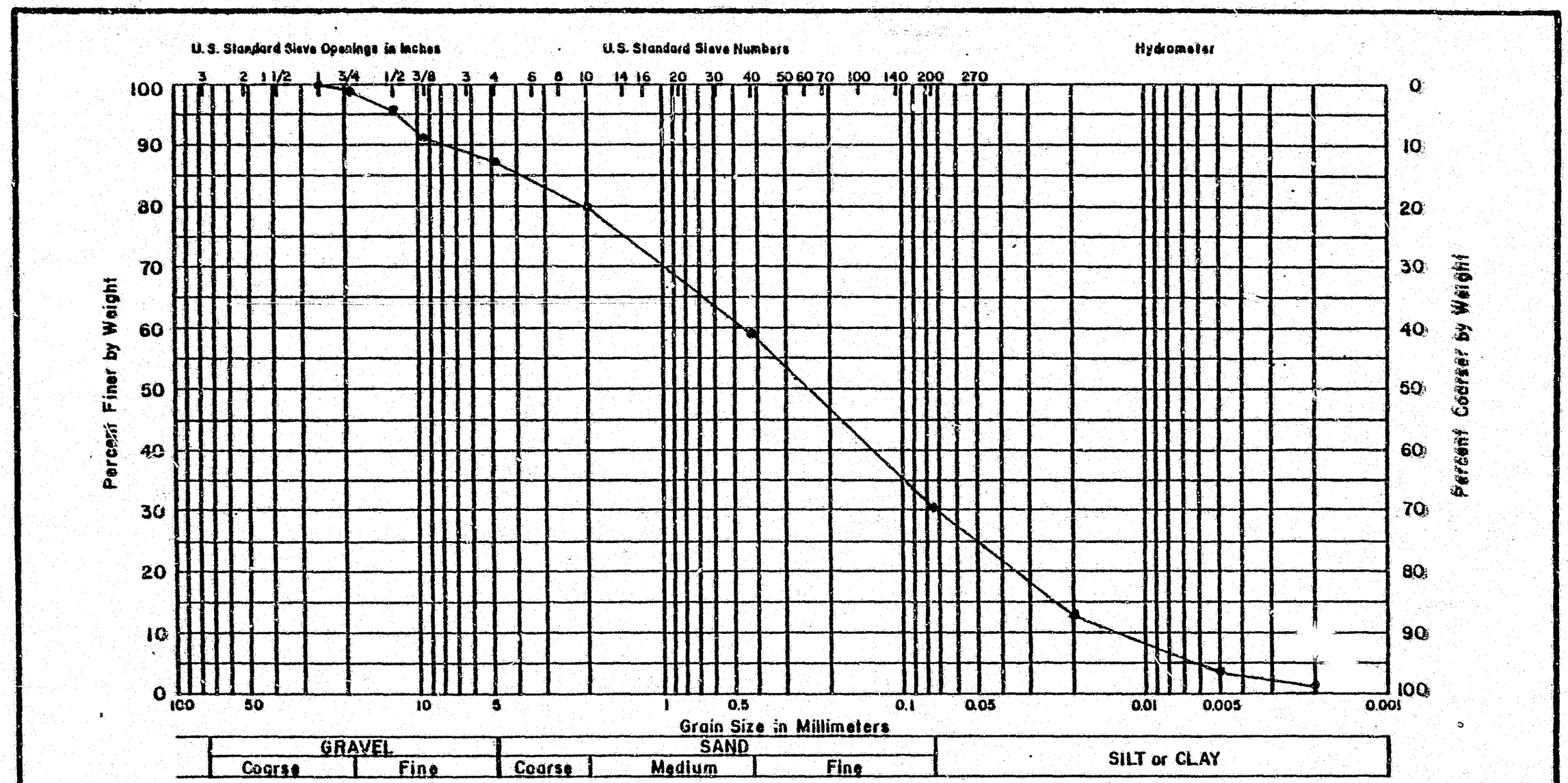
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-D2-4	11.4%		13.9	NP	SM	SILTY SAND WITH SOME GRAVEL, TRACE CLAY
(3.0-4.5')						Non Plastic

R & M CONSULTANTS, INC.

BORROW AREA D

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	052504

00272



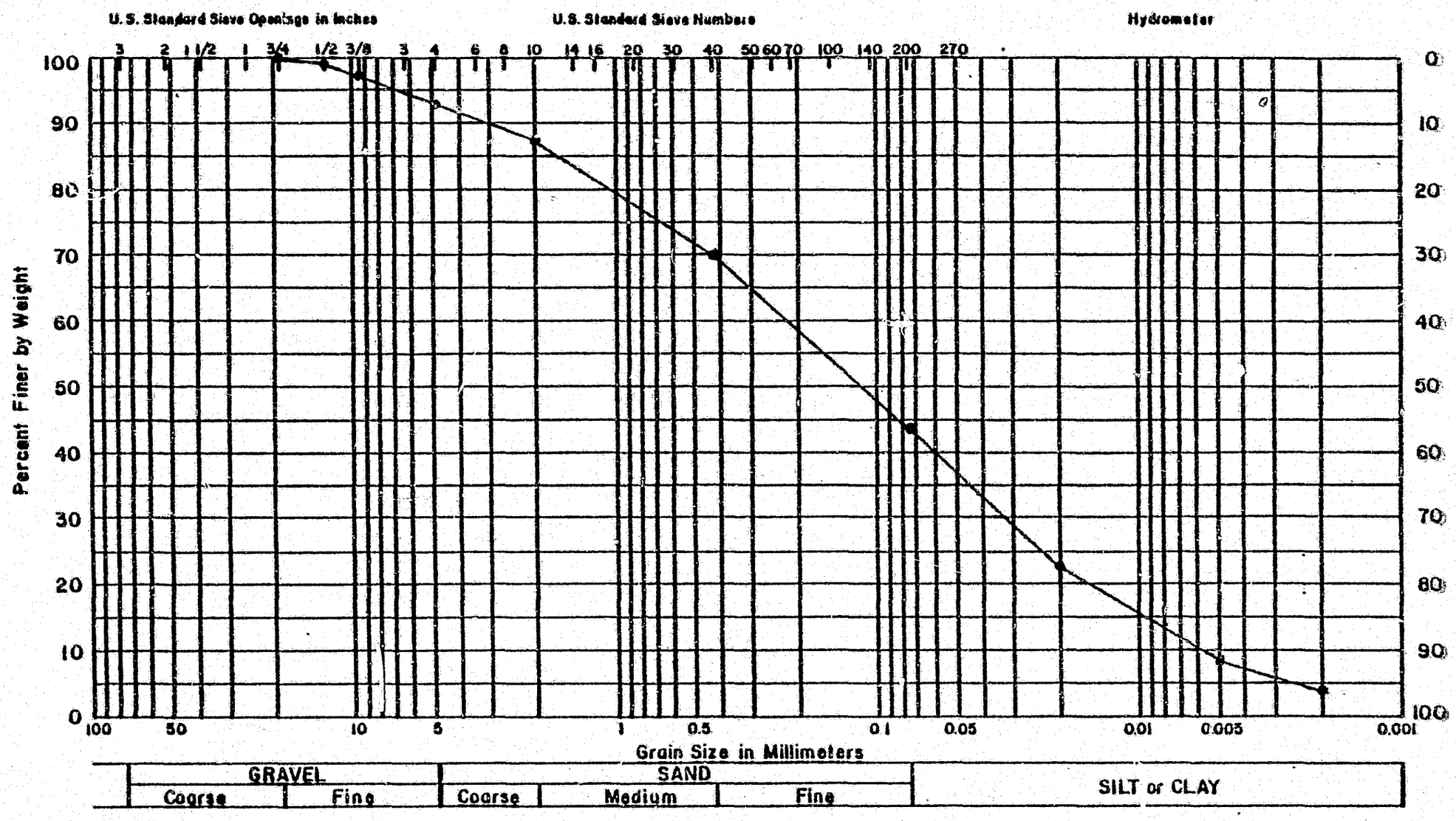
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-D2-5	11.2%		NV	NP	SM	SILTY SAND WITH SOME GRAVEL, TRACE CLAY
(4.5-6.0')						Non Viscous, Non Plastic

R & M CONSULTANTS, INC.

BORROW AREA D

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	05250[illegible]

0172



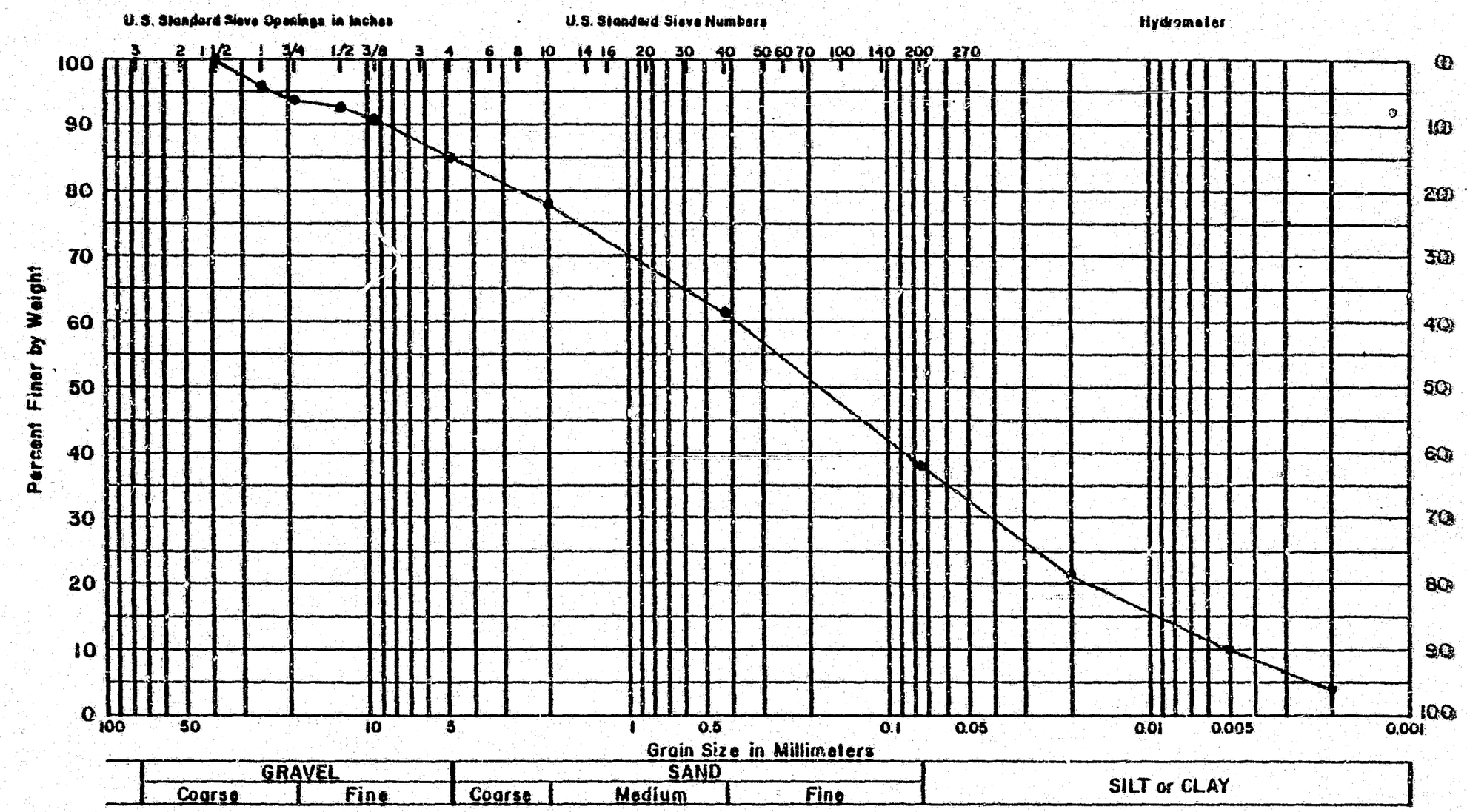
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI		CLASSIFICATION & DESCRIPTION
AH-D2-8	11.3%		15.5	2.2	SM	SILTY SAND WITH TRACE GRAVEL, TRACE CLAY
(15.0-16.5')						

R & M CONSULTANTS, INC.

BORROW AREA D

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	052504

.010272

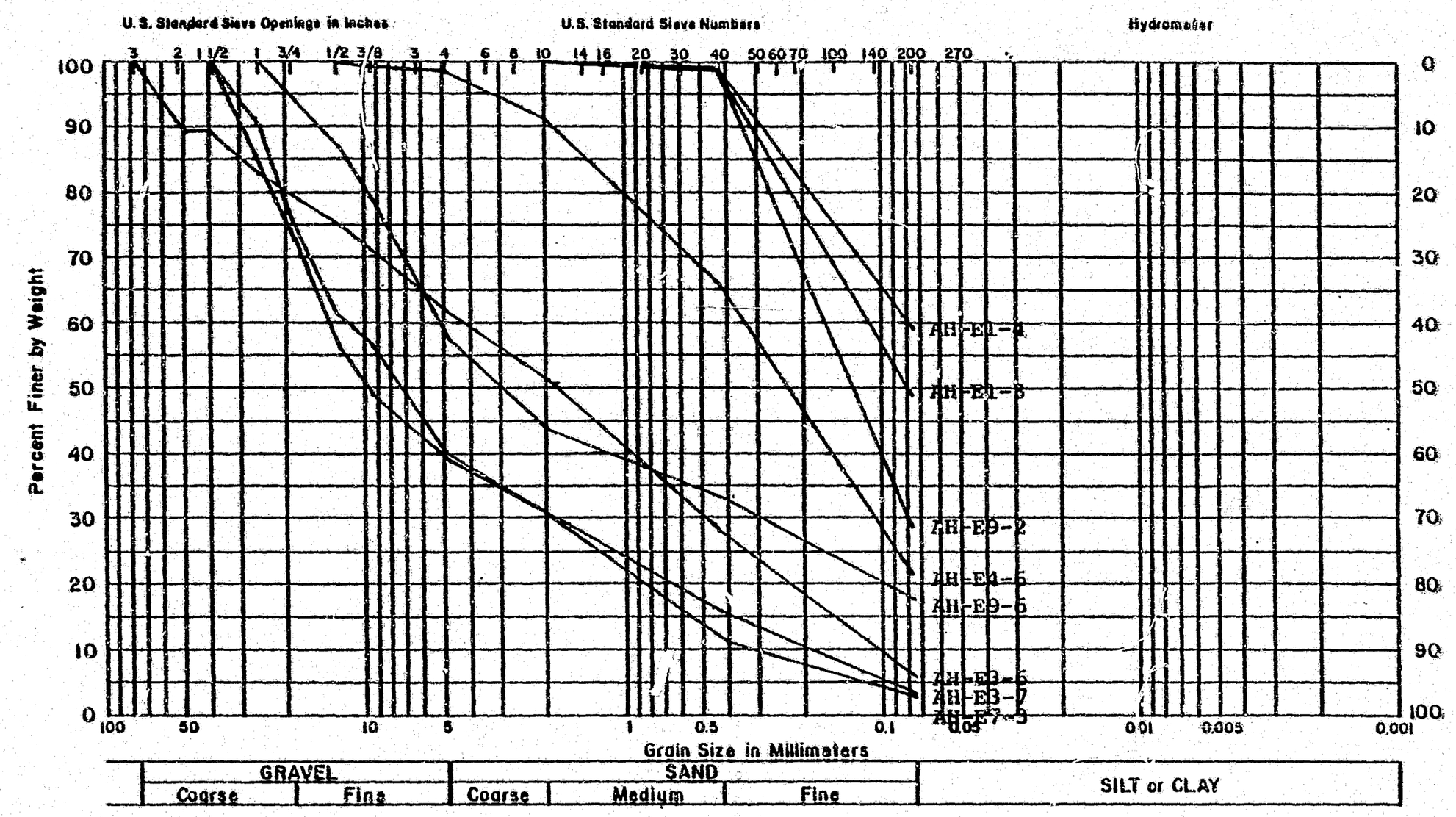


SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI		CLASSIFICATION & DESCRIPTION
AH-D2-9 (20.0-21.5')	[redacted]		[redacted]	[redacted]	SM	[redacted] SILTY SAND WITH SOME GRAVEL, TRACE CLAY

R & M CONSULTANTS, INC.

BORROW AREA D

DRAWN BY DL
APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504



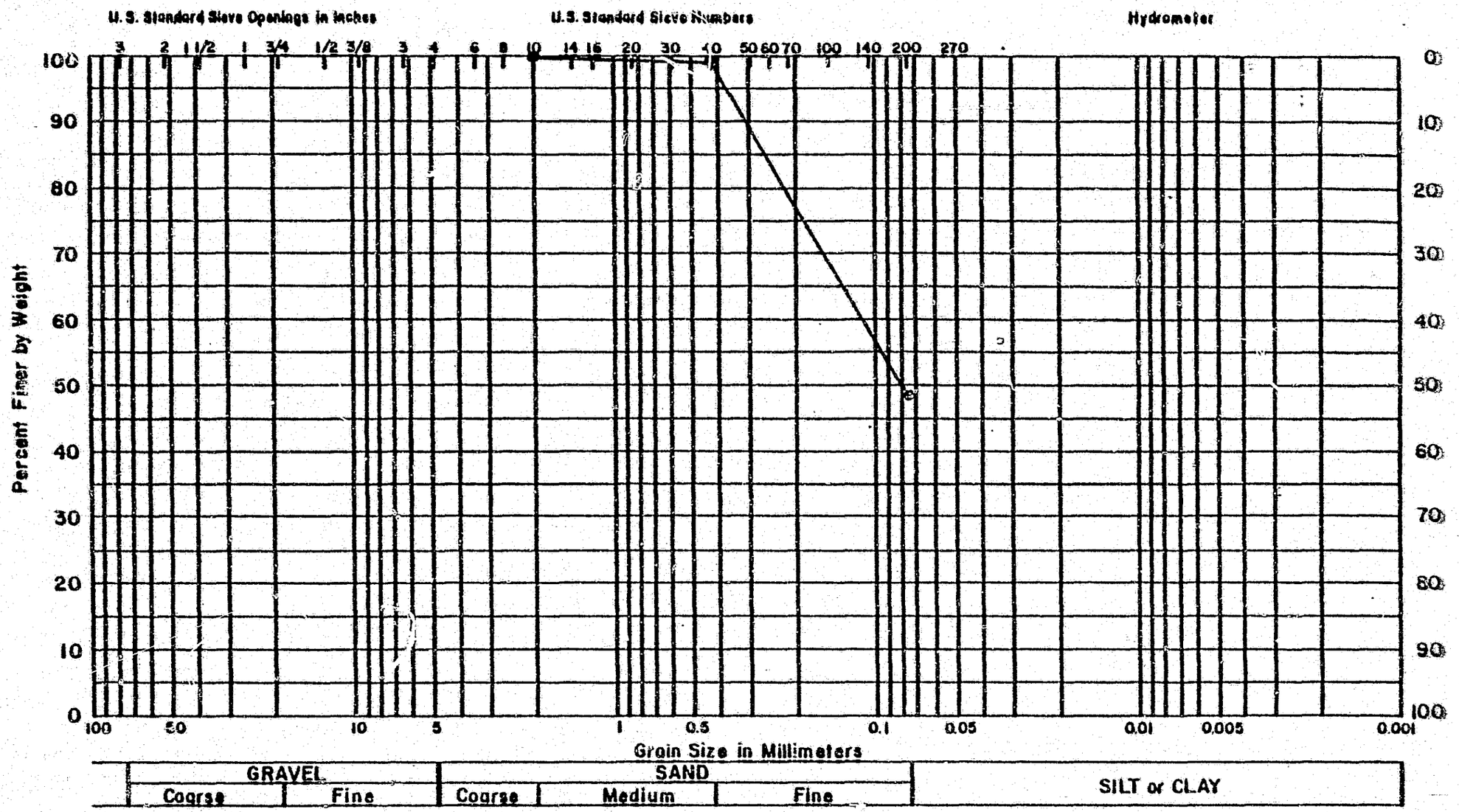
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION
AH-E1-3					
AH-E1-4					
AH-E3-6					
AH-E3-7					
AH-E4-6					
AH-E7-3					
AH-E9-2					
AH-E9-6					

R & M CONSULTANTS, INC.

BORROW AREA E
SUMMARY OF GRAIN SIZE DISTRIBUTIONS

DRAWN BY DL
APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504

27010

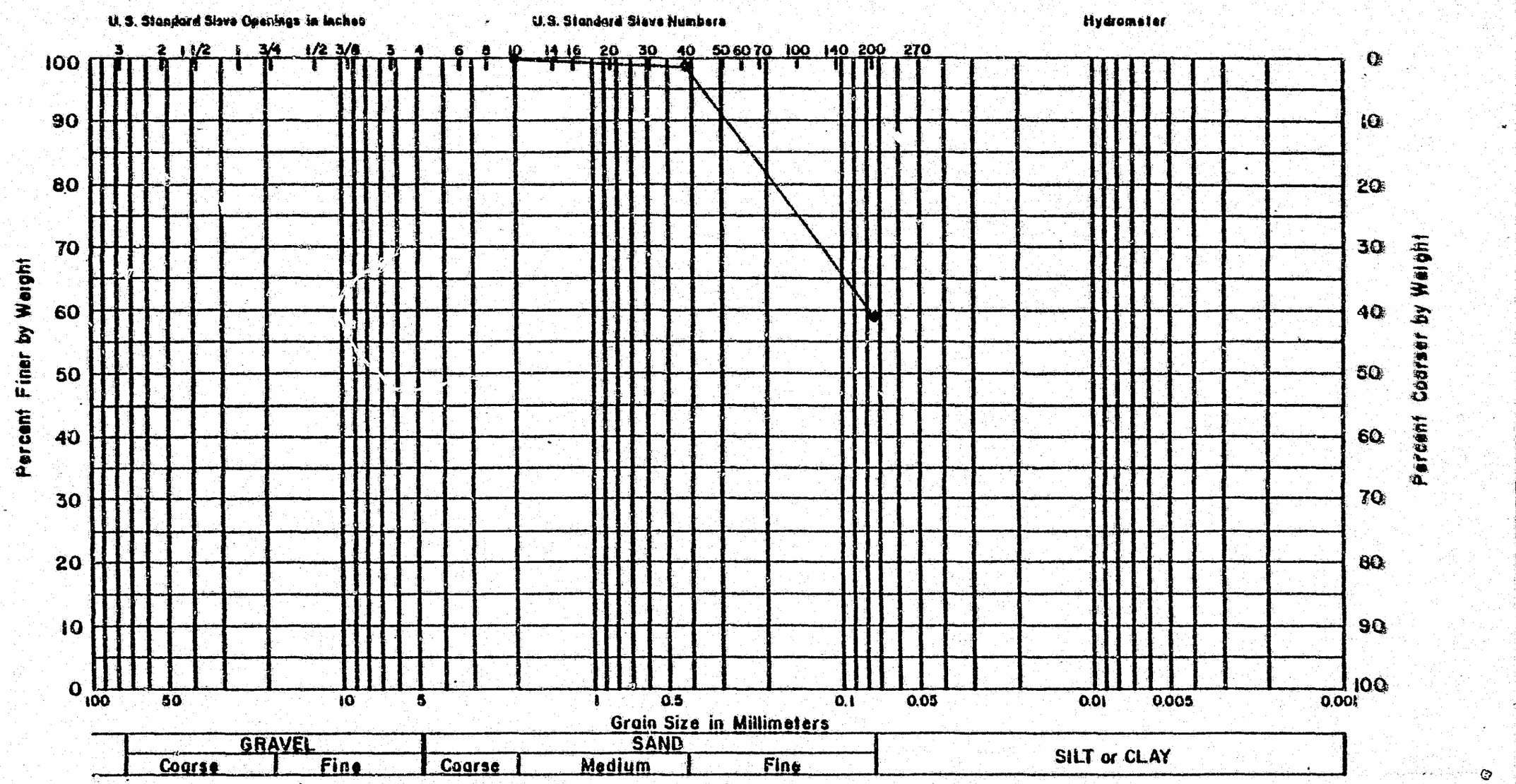


SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-E1-3	19.6%				SM	SILTY SAND
(1.0-1.5')						

R & M CONSULTANTS, INC.

BORROW AREA E

DRAWN BY DL
APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504



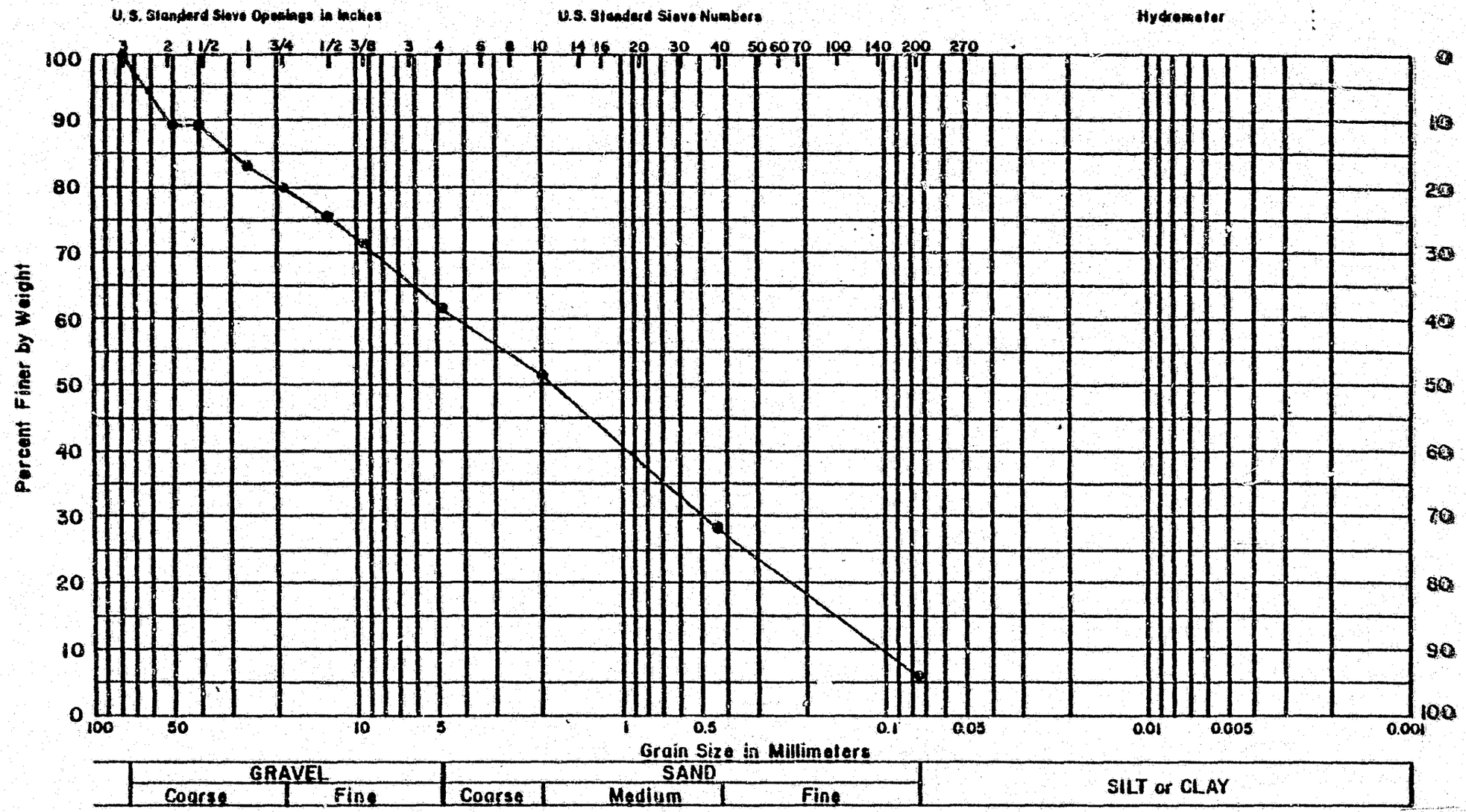
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-E1-4	27.3				ML	SANDY SILT
(2.0-3.5')						

R & M CONSULTANTS, INC.

BORROW AREA E

DRAWN BY DL.
APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504

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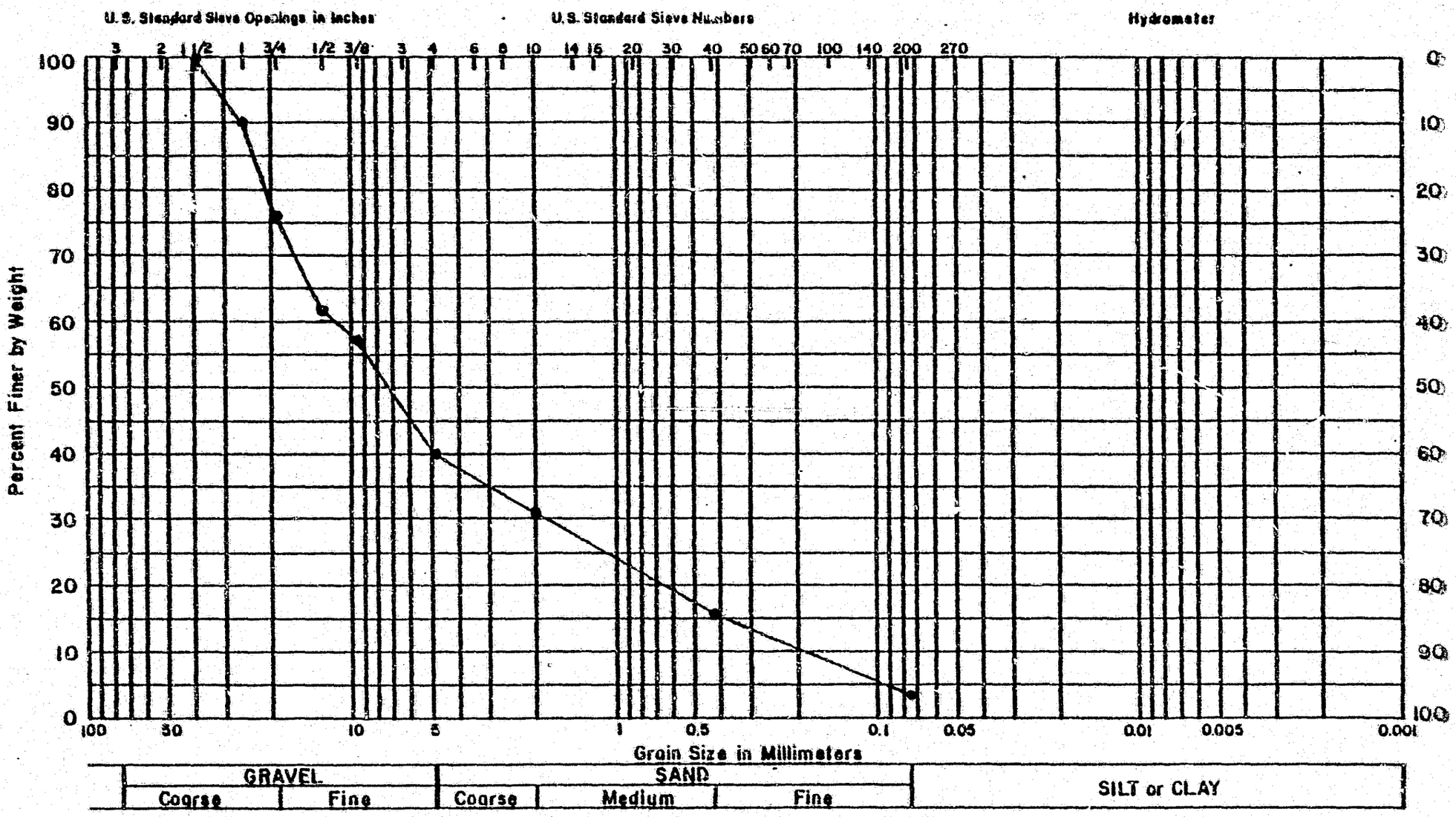


SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-E3-6	4.4%				SP-SM	GRAVELLY SAND
(4.5-6.0')						Poorly Graded

R & M CONSULTANTS, INC.

BORROW AREA E

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	052504



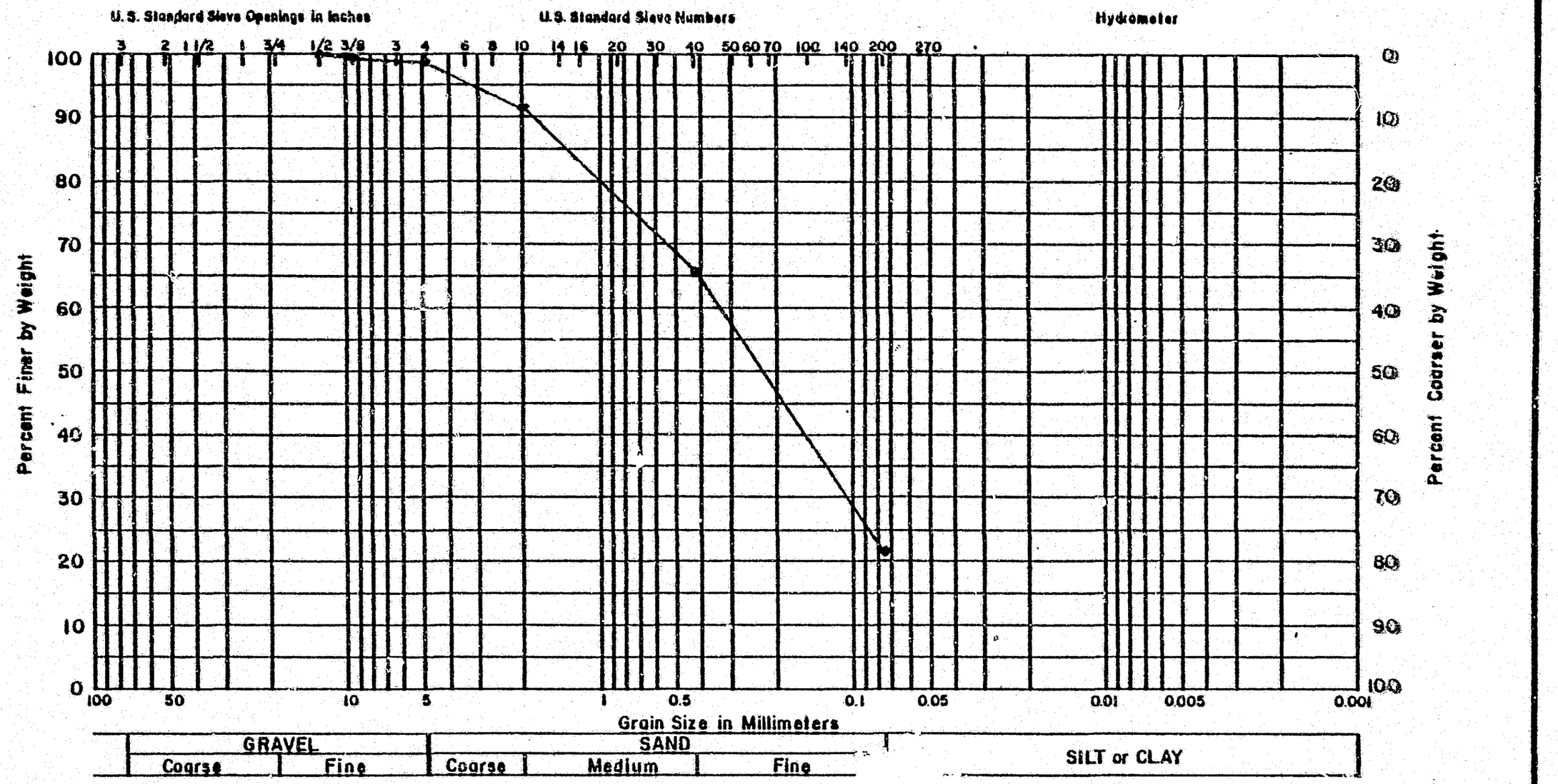
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-E3-7	0.7%				GW	SANDY GRAVEL
(6.5-8.0')						Well Graded

R & M CONSULTANTS, INC.

BORROW AREA E

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	052504

010272



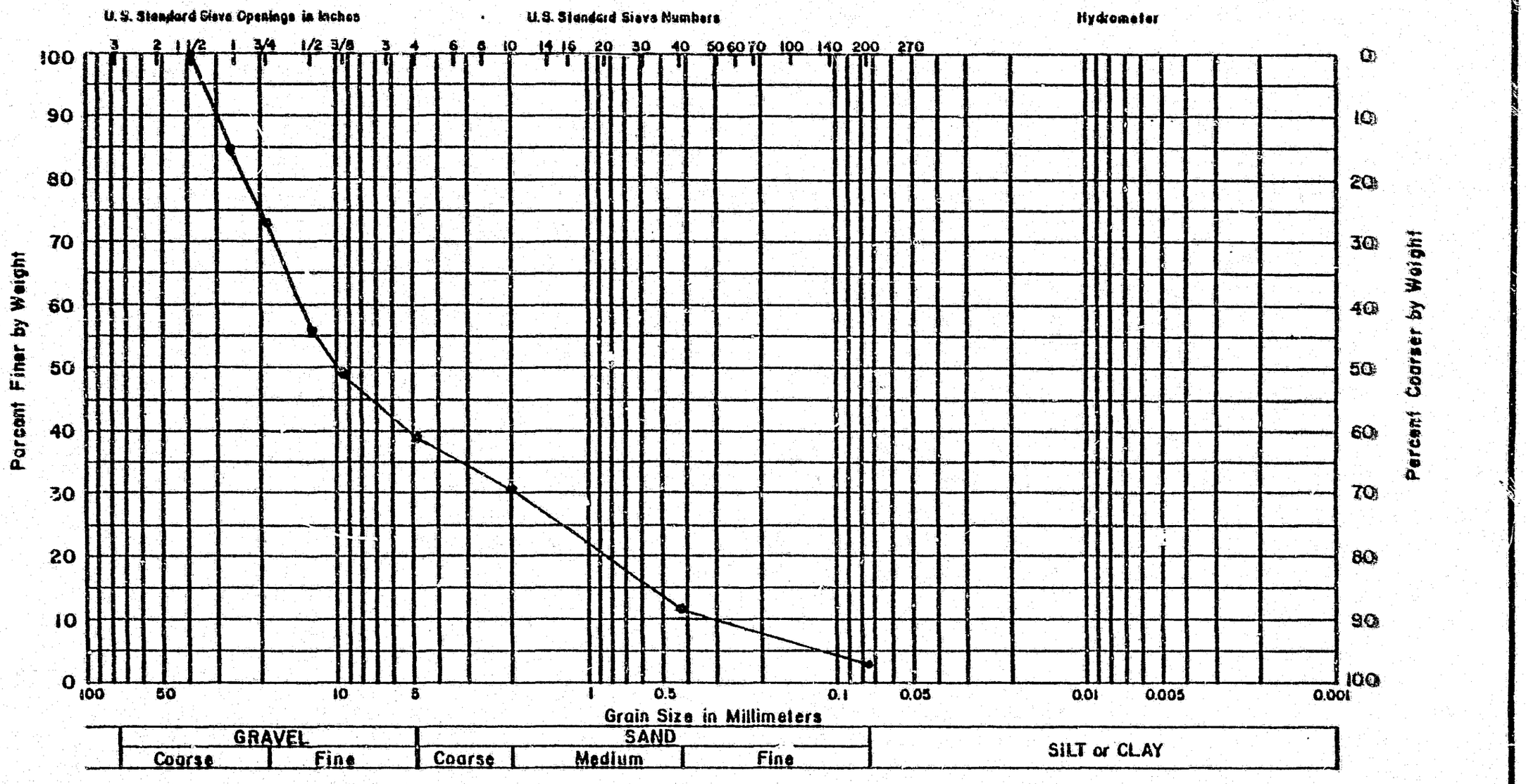
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION	DESCRIPTION
AH-E4-6	17.6%				SM	SILTY SAND WITH TRACE GRAVEL
(5.0-6.5')						

R & M CONSULTANTS, INC.

BORROW AREA E

DRAWN BY DL
APPROVED BY
DATE DEC. 1980
PROJECT NO. 052504

0272



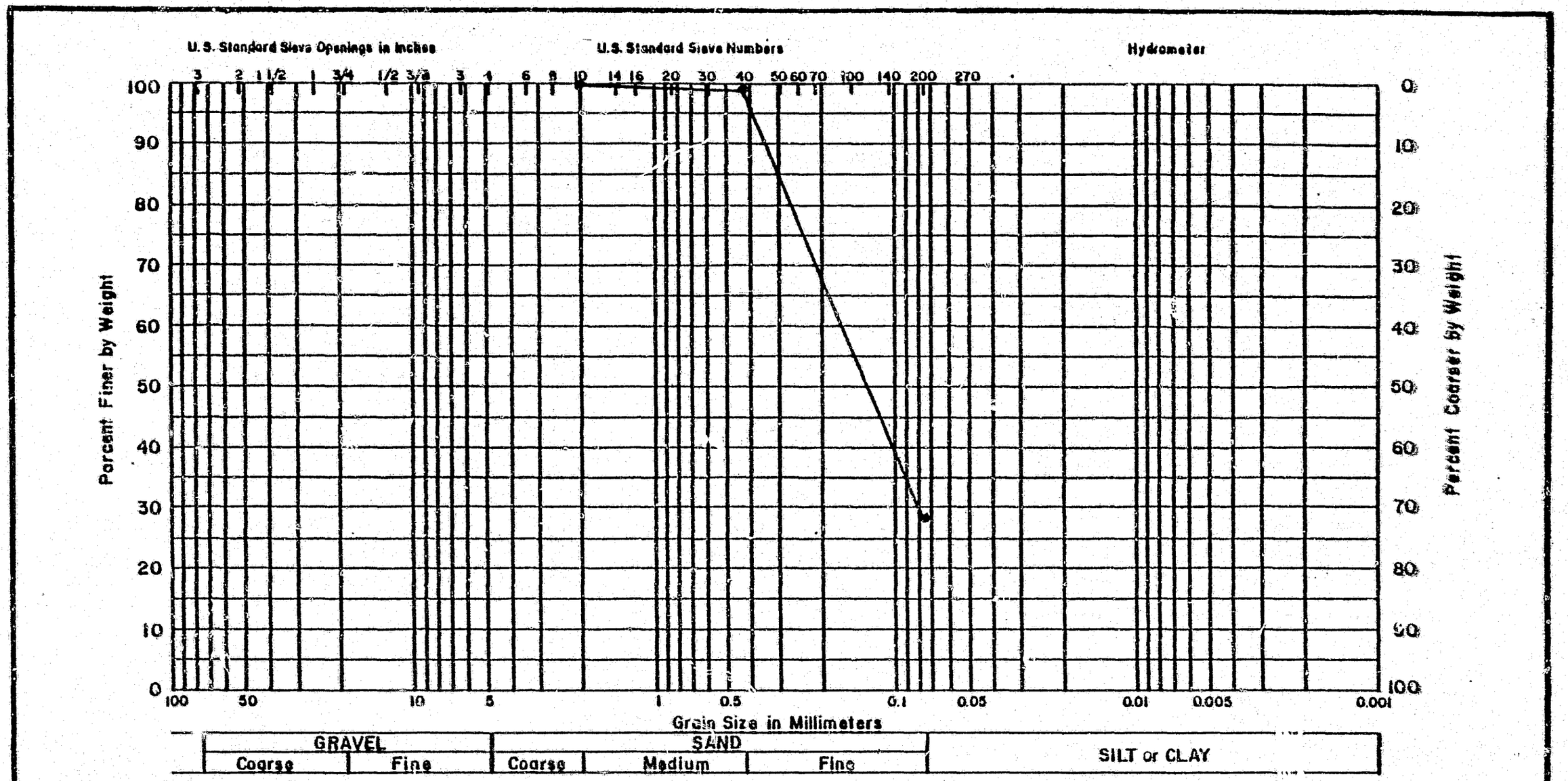
SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-E7-3	2.3%				GP	SANDY GRAVEL WITH TRACE SILT
(2.0-3.0')						

R & M CONSULTANTS, INC.

BORROW AREA E

DRAWN BY	DL
APPROVED BY	
DATE	DEC. 1980
PROJECT NO.	052504

242010



SAMPLE NO.	MOISTURE CONTENT	DRY DENSITY	LL	PI	CLASSIFICATION & DESCRIPTION	
AH-E9-2	15.7%				SM	SILTY SAND
(1.5-3.0')						Poorly Graded

R & M CONSULTANTS, INC.

BORROW AREA E

DRAWN BY DL
APPROVED BY
DATE DEC. 1900
PROJECT NO. 052504

APPENDIX D

SEISMIC REFRACTION SURVEY - WCC