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SUITABILITY OF NATURAL SOILS FOR FOUNDATIONS FOR SURFACE FACILITIES AT THE PROSPECTIVE YUCCA MOUNTAIN NUCLEAR WASTE REPOSITORY

By

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ABSTRACT

In this report, the natural soils at the Yucca Mountain site are evaluated for the purpose of assessing the suitability of the soils for the foundations of the surface facilities at the prospective repository. The areas being considered for locating the surface facilities are situated on an alluvial plain at the base of Yucca Mountain. Preliminary parameters for foundation design have been developed on the basis of limited field and laboratory study of soils at four test pit locations conducted during May and June 1984. Preliminary recommendations for construction are also included in this report. The gravel-sand alluvial deposits were found to be in a dense to very dense state, which is suitable for foundations of the surface facilities. The design parameters described in this report have been developed for conceptual design, but need to be verified before final design.

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EXECUTIVE SUMMARY

This study evaluates the conditions of the natural alluvial soils which are expected to support the foundations of the surface facilities at the prospective Yucca Mountain repository near the Nevada Test Site in Nye County, Nevada. Preliminary parameters for design of the foundations are developed on the basis of limited field and laboratory study.

Soil properties at six potential surface facility sites, located on an alluvial plain between Yucca Mountain and Fortymile Wash, were investigated. A test pit was excavated at four of the potential sites. The four test pits were located to provide a representative sample of local soil conditions and were excavated to a depth of about 12 feet.

Detailed logs of the test pits were prepared, in-situ density tests were performed at selected depths in the test pits, and bulk samples were collected from the test pits for laboratory testing. Laboratory testing was conducted to determine the index properties of the soil for classification purposes and to obtain moisture-density relationships of the site soils.

The gravelly soils exposed at the four test pit locations were essentially similar. The differences observed between the locations were minor and do not significantly affect the basis for establishing preliminary parameters for foundation design.

The alluvial material at the potential surface facility sites varies from about 35 to 150 feet in thickness. Generally, the soil in the top 1.5 to 2 feet contains a high percentage of fine sand and silt, and is quite loose. Below this layer, to a depth of about 8 feet, is a soil horizon (termed the K horizon) that is partly to wholly cemented with well-developed secondary calcite. The remaining alluvium to the top of bedrock is a gravel-sand mixture with little or no cementation.

Index properties; engineering properties including permeability, compressibility, and shear strength; and the derived recommended bearing capacity and estimated settlement of footings are evaluated and discussed in Section 5.0.

The soils at the potential sites were found to be satisfactory for the conceptual design of foundations for the repository surface facilities. However, the foundation design parameters described in this report are preliminary and need to be verified before final design.

1.0 INTRODUCTION

The work described in this report was performed for Sandia National Laboratories (SNL) as a part of the Nevada Nuclear Waste Storage Investigations (NNWSI) project. Sandia is one of the principal organizations participating in the project, which is managed by the U.S. Department of Energy's (DOE) Nevada Operations Office (NVO). The project is a part of the DOE program to safely dispose of the radioactive waste from nuclear power plants.

The DOE has determined that the safest and most feasible method currently known for the disposal of such wastes is to emplace them in mined geologic repositories. The NNWSI project is conducting detailed studies of the Yucca Mountain area on and near the Nevada Test Site (NTS) in southern Nevada to determine the feasibility of developing a repository.

This study, conducted by Bechtel National, Inc. with the cooperation of Holmes and Narver, Inc., contains an evaluation of the soils in the vicinity of the foundations for surface facilities for the prospective repository in tuff. Limited field sampling and testing and laboratory testing were performed for six prospective locations for the surface facilities. The six prospective locations for surface facilities are the "candidate sites" evaluated by Neal (1985). Results from earlier sampling and testing reported by Holmes and Narver in 1983 were also considered.

Five major sections follow this introduction. A description of the potential sites for the repository surface facilities is given in Section 2.0. The methods of data collection, including field investigations and sampling, and laboratory testing are included in Section 3.0. Results from field and laboratory testing are given in Section 4.0. Based on the results of testing and field observations, an evaluation of the local soils, including soil index properties, engineering properties, and a derivation of recommended bearing capacity, is given in Section 5.0. Conclusions regarding the suitability of the soils and recommendations for design and construction are given in Section 6.0. Sources of information used in the preparation of this report are referenced by author throughout the text and are listed in alphabetical order in Section 7.0. Photographs that show the general site conditions and the test pit excavations are presented in Appendix A, and a report of laboratory test results by Holmes and Narver, dated May 16, 1984, is included in Appendix B.

2.0 SURFACE FACILITIES SITE DESCRIPTION

The potential sites for the surface repository facilities are located near the western margin of the NTS, between Yucca Mountain and Fortymile Wash. Elevations at the Yucca Mountain site vary between about 5,000 feet at the crest of Yucca Mountain and 3,400 feet in Fortymile Wash. North-south trending ridges and the north-south trend of Fortymile Wash dominate the local topography. Photograph 1 shows Fortymile Wash; both Fortymile Wash and Yucca Mountain are visible in Photograph 2. (All photographs referenced in this report are contained in Appendix A.)

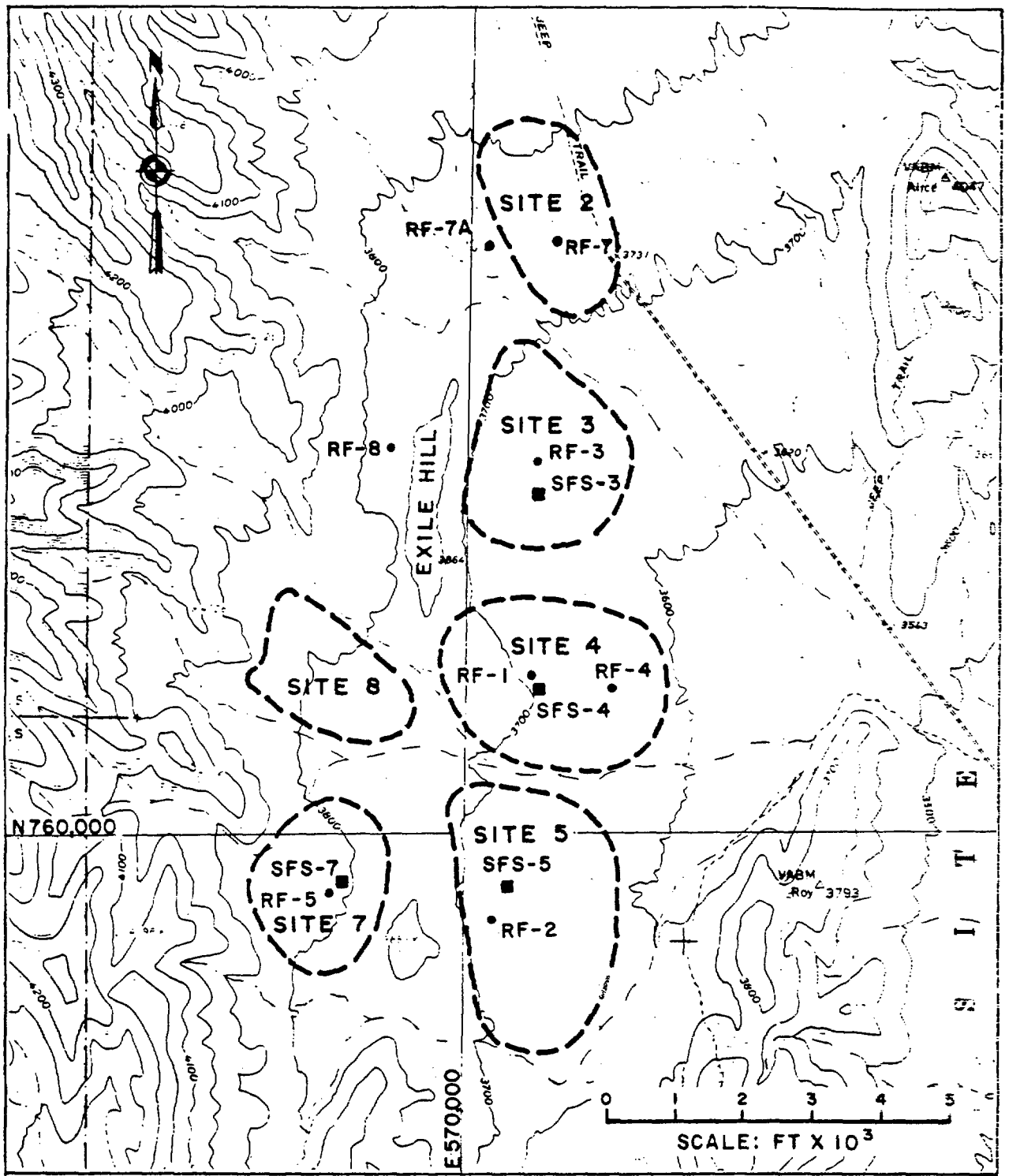
All six potential sites are situated on a moderately east-sloping (about 200 feet per mile) alluvial plain (bajada) between an elevation of 3,600 and 3,840 feet (Figure 1). The sites are covered with sparse xerophytic vegetation typical of a semi-desert environment. Photograph 3 shows the typical surface appearance. Small, intermittent, flood-type drainage washes cross the site area from west to east.

The alluvial slope was built up by coalescing alluvial fans that spread outward from the base of Yucca Mountain and fill the original, fault-controlled valleys to a depth of several hundred feet. Exploratory borings (Figure 1) indicate an alluvial thickness of about 35 feet to more than 150 feet at the prospective locations for the surface facilities.

Bedrock in the site area is almost entirely ashflow tuff (fragmental, or pyroclastic, rock formed from explosive volcanic eruptions) composed of several thousand feet of multi-flow compound units, generally gray in color. The upper 1,000 feet of this sequence, the Paintbrush Tuff, is about 13 million years old. Locally, beneath the alluvium, a younger (11-million-year-old) white or pink tuff (Ranier Mesa Member of Timber Mountain Tuff) and an unnamed white ash or mudflow deposit have been penetrated.

Rock fragments in the overlying alluvium are derived from the exposed Paintbrush and Timber Mountain tuffs and hence have lithologies representative of these formations. Deposition was typically by debris flows during flash flooding. Some of the earlier debris flows may be Tertiary in age (older than about 2 million years) (Hoover et al, 1981).

The pedogenic surficial soil generally displays a well-defined horizon development. The top 1 or 2 feet (A and B horizons) are loose and generally fine-grained. The underlying alluvium typically is partly to wholly cemented with a laminated calcite deposit termed "caliche," which often extends to a depth of several feet. When this soil layer is well cemented with laminated calcite, it is termed the K horizon (Hoover et al, 1981). An example of the K horizon in a trench excavation in the site area is shown in Photograph 4. A thick K horizon is characteristic of mature, very old soils in an arid climate (Hoover et al, 1981; Swadley et al, 1983). Partial to incipient calcite cementation, as evidenced by caliche coatings on rock fragments, has been found in exploratory drill holes throughout the entire thickness of the alluvial deposits. An example of soil excavated from a surface trench, incorporating material from the top 6 feet of soil, is shown in Photograph 5.



KEY

■ SFS TEST PITS

• RF BORINGS

(SOURCE OF DATA: SNL)

TUFF REPOSITORY SURFACE FACILITIES			
LOCATION OF TEST PITS			
BECHTEL	JOB No.	DRAWING No.	REV.
	16039	FIGURE 1	

Rainfall in this region averages less than 6 inches per year. The water table is at an approximate elevation of 2,400 feet, or approximately 1,250 feet below ground surface (DOE, 1984).

Additional detailed information on geologic and non-geologic conditions at the Yucca Mountain site is included in DOE (1984).

3.0 DATA COLLECTION

3.1 Field Investigation and Sampling

The subsurface exploration program consisted of excavating and logging test pits, obtaining bulk samples for laboratory testing, and performing field density testing.

Field exploration was conducted during May and June 1984. A Gradall G-1000 backhoe and a Bantam 4-26 backhoe (Photograph 6) were used to excavate one test pit at each of four of the potential sites to provide a representative sampling of local soil conditions. Bulk samples were collected from the pits for laboratory testing. The four test pits were designated SFS-3, SFS-4, SFS-5, and SFS-7, and their maximum depth was 13 feet. The locations of the pits are listed in Table 1 and shown in Figure 1.

Field in-situ density tests were performed at selected depths in the test pits. The in-situ densities were determined by both sand-cone (ASTM D-1556) and nuclear (ASTM D-2922, Method B) methods whenever feasible. However, when the material was predominantly gravel and cobbles, in-situ density tests were not feasible.

3.2 Laboratory Testing

Laboratory testing measured the index properties of the soil for classification purposes and obtained compaction characteristics to determine the relative compaction of in-place soil deposits relative to maximum dry densities.

Testing of index properties included visual classification (ASTM D-2487), natural moisture content (ASTM C-566), gradation (ASTM C-136), and specific gravity and absorption (ASTM C-127/C-128). Laboratory compaction tests were performed on bulk samples in accordance with ASTM D-1557, Method D. The compaction test results were used to compare the results of in-place density tests and to evaluate the moisture-density relationships of site soils.

TABLE 1

Location of Test Pits
Tuff Repository Surface Facilities
Potential Site Investigation
May 1 - 4, 1984

ALTERNATE SURFACE FACILITY SITE NO.	TEST PIT NO.	APPROXIMATE COORDINATES	ELEVATION (ft)	DATE COMPLETED
3	SFS-3(1)	N764,850 E570,941	3,641	5/2/84
4	SFS-4	N762,190 E570,890(2)	3,688	5/1/85
5	SFS-5(3)	N759,308 E570,698	3,642	5/4/84
7	SFS-7	N759,200 E568,100(4)	3,813	5/3/84

Source: Neal, 1985

Notes:

(1) SFS-3 deepened pre-existing test pit 2, dug May 1983.

(2) Coordinates are those of adjacent drill hole RF-1.

(3) SFS-5 deepened pre-existing test pit 1, dug May 1983.

(4) Coordinates are those of adjacent drill hole RF-5.

4.0 RESULTS

4.1 Geologic Logs of Test Pits

Geologic logs of the four test pits are presented in Figure 2. The material in all pits is a tan to light gray, silty to sandy gravel, with numerous blocky cobbles and boulders. Primary depositional layering (as differentiated from secondary caliche layering) is indistinct as a rule, but may be locally prominent.

A photographic record of test pit excavation was made to document the visual appearance of the actual field occurrences. Photographs 8 through 24 in Appendix A show general views and selected details of the test pit excavations.

Pronounced soil horizon development markedly affects the character of the soil material. Above a depth of about 1.5 to 2 feet, the soil consists of loose brown, fine silty sand or sandy silt significantly depleted in coarser material compared to the underlying soil. This zone constitutes the A and B soil horizons. Below a depth of 1.5 to 2 feet, the soil is moderately indurated to well indurated with caliche (calcium carbonate) to a depth of about 8 feet. This induration imparts a rocklike character to the soil, making excavation by backhoe slow and difficult. This zone of secondary layering by calcite cementation is the K horizon. Rock fragments in this zone tended to break apart during removal. Therefore, the percentage of large fragments in the excavated soil was smaller than that found in the in-situ condition, as shown in Photographs 23 and 24.

Below about 8 feet, the gravel is not appreciably cemented by caliche, except for thin laminae and isolated pockets. However, rock fragments generally are at least partly coated with white caliche, evidence of persistent secondary carbonate precipitation.

Rock types represented in the gravels consist of the more competent volcanic tuffs in the Paintbrush and Timber Mountain formations, namely gray to blue-gray welded tuffs of low porosity. However, significant amounts of more porous tuffs with lithophysae are present, and occasional highly pumiceous rocks were noted. Photographs 18 and 22 show the piles of material excavated from test pits SFS-5 and SFS-7, respectively. It was visually estimated that rocks larger than 6 inches in size comprise from 10 to as much as 40 percent of the in-situ material by volume.

4.2 Results of Field and Laboratory Testing

4.2.1 Field Test Results

In-place densities were determined by both sand-cone and nuclear methods. The results are summarized in Table 2.

4.2.2 Laboratory Test Results

Bulk samples obtained from test pits were tested for their index properties and compaction characteristics. The results are provided in Appendix B.

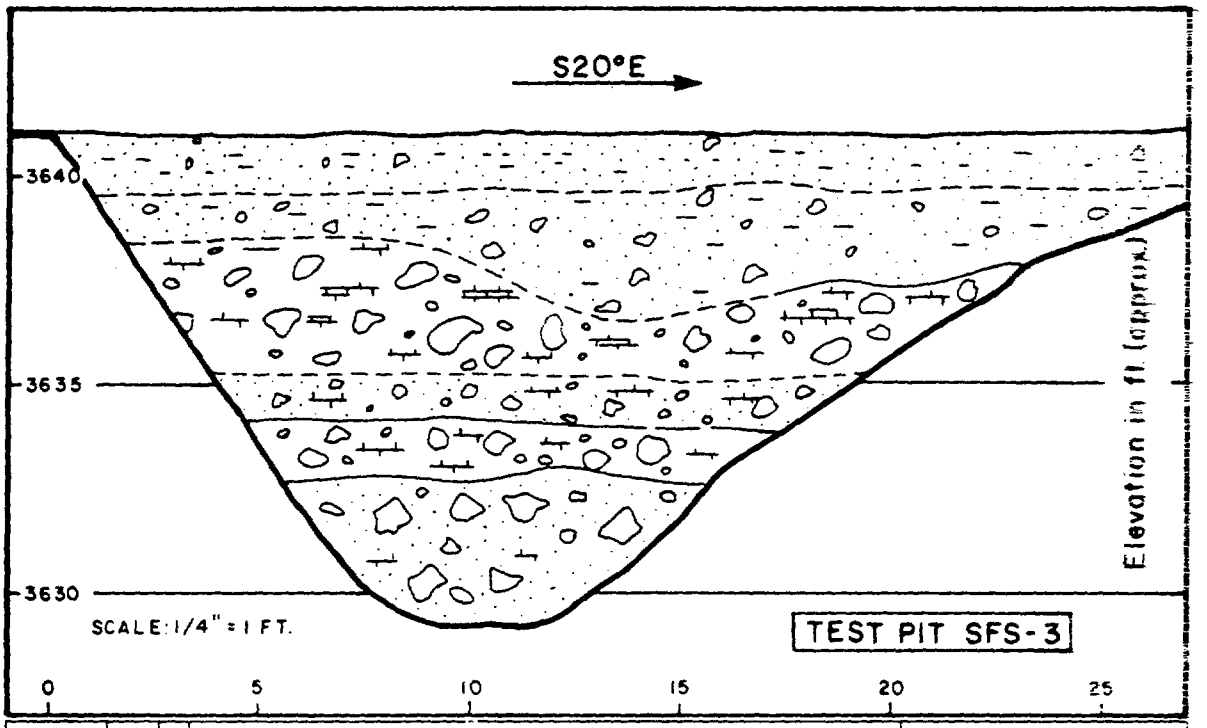
TEST PIT LOG

Project TUFF REPOSITORY-SURF. FACILITIES Job No 16039 **TEST PIT NO.** SFS-3

Ground El. 3641 Location N 764, 850

Depth of Pit 12 FT E 570, 941

Date Excavated 5/2/84 Method of Excavation BANTAM 4-26 BACKHOE



Depth Feet	Sample Type and Number	Symbol	Description	Remarks
0-4 ±			SAND, light brown, fine-grained, silty, with some gravel, cobbles and boulders; uncemented, firm, non-bedded, bottom contact undulatory. 0-1.5ft: Loose; less gravel (A&B soil horizons)	
4 ± - 8	B-1 SC ND		GRAVEL, light gray to tan, with fine sand, volcanic cobbles and boulders to 20" dia.; hard, well cemented with caliche, boulders break apart on excavation; bedding indistinct. 6-7ft: Brownish gravelly sand, poorly bedded; lamina of white caliche marks prominent bedding plane at 7ft.	K-horizon, 4 ± - 8ft. Gravels mostly subangular.
8-12	B-2 SC ND		GRAVEL, light brown to tan, with fine sand, cobbles and boulders to 20" dia.; dense, slightly cemented with caliche; bedding indistinct	Samples collected at 5.5, 8 & 12 ft.
	B-3 SC ND		Note: B, bulk sample SC, sand cone test ND, nuclear density test	

FIGURE 2

GEOLOGIC LOGS OF TEST PITS

SHEET 1 OF 4 | TEST PIT SFS 3

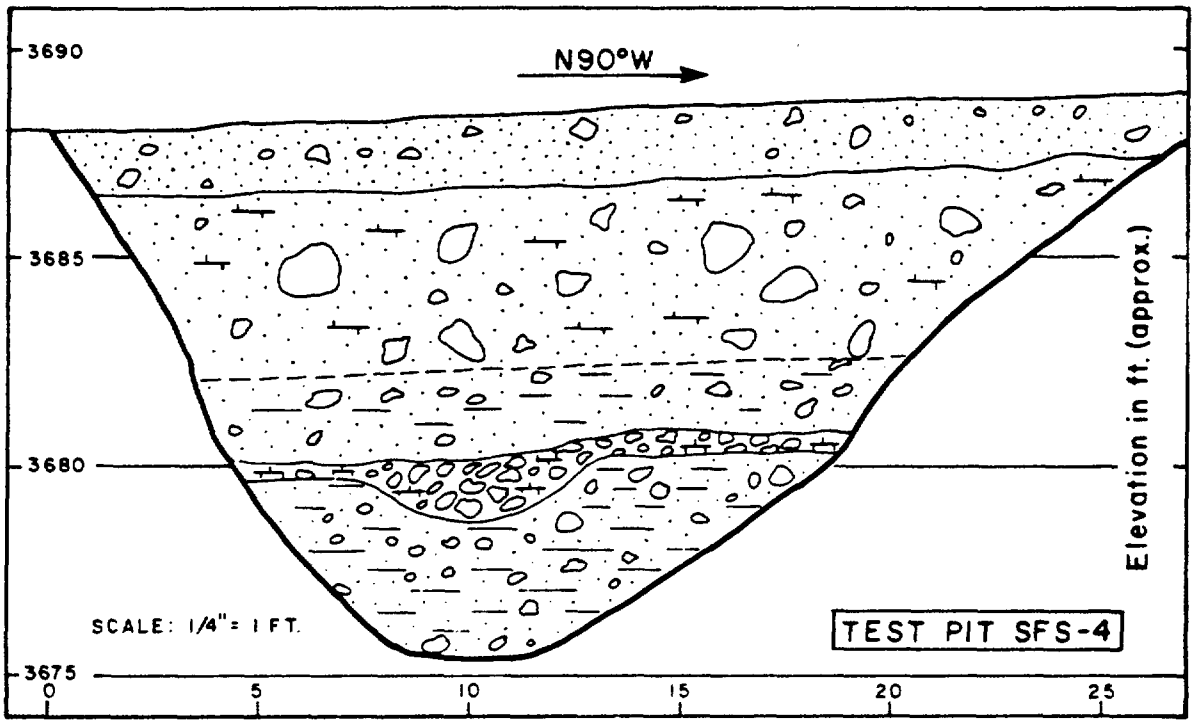
TEST PIT LOG

Project TUFF REPOSITORY-SURF.FACILITIES Job No 16039 **TEST PIT NO.** SFS-4

Ground El. 3688 FT Location N 762, 190

Depth of Pit 13 FT E 570, 890

Date Excavated 5/1/84 Method of Excavation BANTAM 4-26 BACKHOE



Depth Feet	Sample Type and Number	Symbol	Description	Remarks
0-1.5			SAND, brown, fine-grained, silty, loose, with scattered, subangular, volcanic cobbles and boulders.	Topsoil; A and B soil horizons
1.5-5	B-1		GRAVEL, tan, with fine silty sand and subangular volcanic cobbles and boulders to 24" dia; moderately cemented with caliche; bedding indistinct.	SC, ND attempted unsuccessfully K soil horizon
5-8±	B-2 SC		GRAVEL, tan, sandy, little fines; slightly cemented with caliche; bedded, bottom contact irregular.	ND unsuccessful (cobbles and boulders)
8±-9±			GRAVEL, tan to gray, coarse, subrounded to subangular, moderately cemented with caliche; undulatory contacts (channel scour and fill); some pumiceous cobbles evident.	
9±-13			GRAVEL, light gray, medium size, uncemented, dense, bedded; with a few thin white laminae of caliche.	ND unsuccessful -- caving in hole
			Note: B, bulk sample SC, sand cone test	

FIGURE 2

GEOLOGIC LOGS OF TEST PITS

SHEET 2 OF 4 | TEST PIT SFS-4

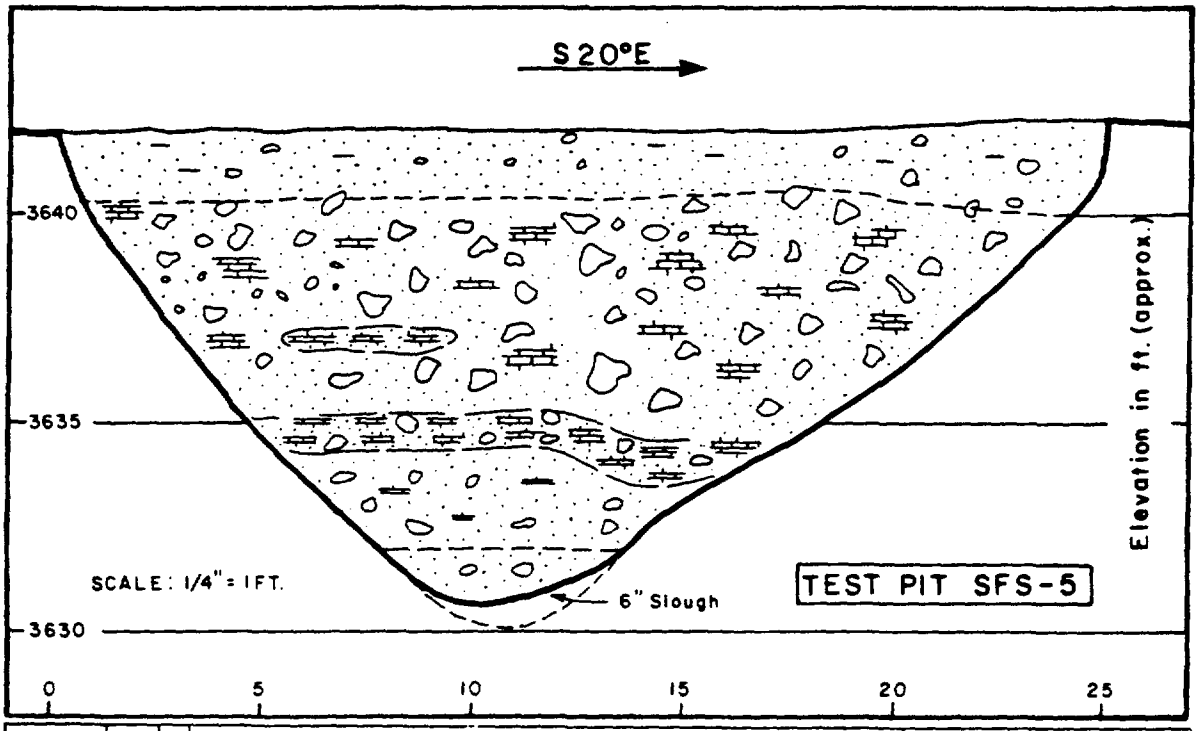
TEST PIT LOG

Project TUFF REPOSITORY, SURF.FACILITIES Job No. 16039 **TEST PIT NO.** SFS-5

Ground El. 3642 FT Location N 759, 308

Depth of Pit 12 FT E 570, 698

Date Excavated 5/4/84 Method of Excavation GRADALL G-1000 BACKHOE



Depth Feet	Sample Type and Number	Symbol	Description	Remarks
0-1.5			SAND, brown to slightly reddish-brown, fine-grained, silty, with some gravel and cobbles; loose.	A and B soil horizons (20" thick)
1.5-8±	B-1 B-2 SC ND		GRAVEL, light grayish tan, with angular/subangular volcanic cobbles and boulders up to 14" dia.; very dense, well cemented with caliche, with 1-ft zone of highly cemented, rock-like gravel at base; bedding indistinct; bottom contact undulatory.	K horizon
8±-12	B-3 SC ND		SANDY GRAVEL, light brown, fine to medium grained sand matrix with some cobbles and boulders; dense, slightly cemented in top part (8-10 ft), uncemented below; bedding indistinct.	

Note: B, bulk sample
SC, sand cone test
ND, nuclear density test

FIGURE 2

GEOLOGIC LOGS OF TEST PITS

SHEET 3 OF 4 | TEST PIT SFS-5

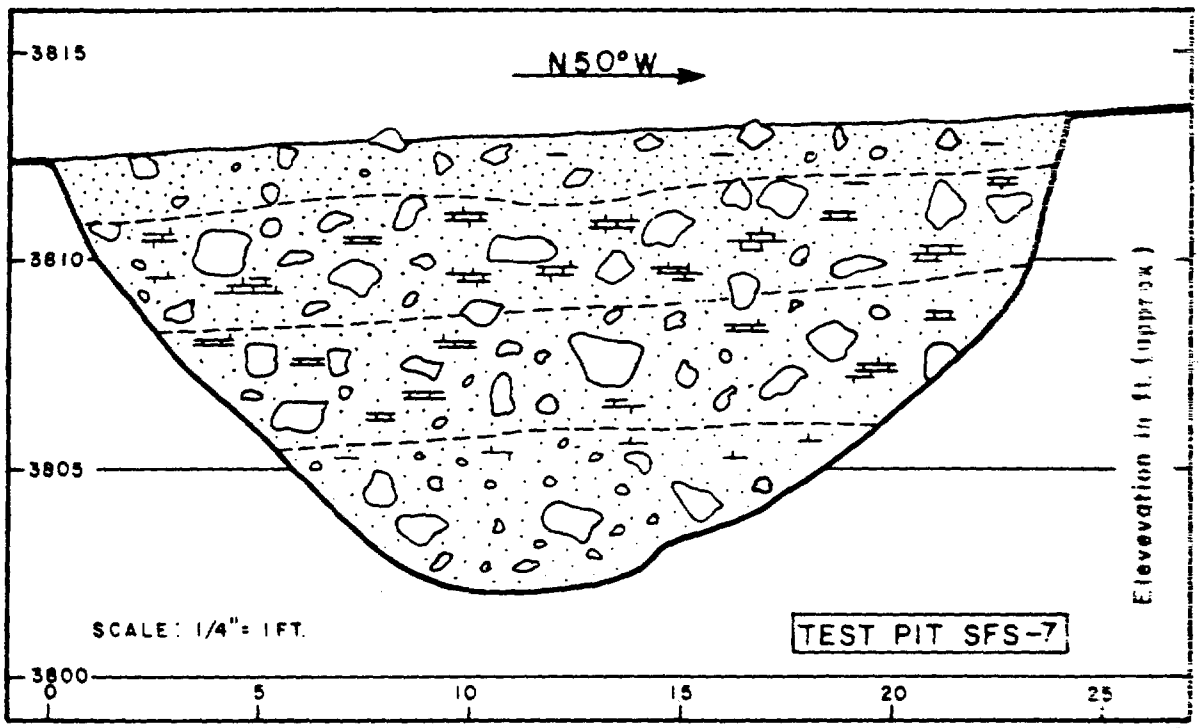
TEST PIT LOG

Project TUFF REPOSITORY SURF.FACILITIES Job No. 16039 **TEST PIT NO.** SFS-7

Ground El. 3813 FT Location N 759, 200

Depth of Pit 11 FT E 565, 100

Date Excavated 5/3/84 Method of Excavation BANTAM 4-26 BACKHOE



Depth Feet	Sample Type and Number	Symbol	Description	Remarks
0-1.5			SAND, grayish-brown, fine-grained, silty, with gravel, cobbles and boulders (topsoil).	A and B horizons
1.5-7	B-1		GRAVEL, tan to light brown, with numerous angular volcanic cobbles and boulders to 24" dia. in matrix of medium to fine sand; very dense, well cemented with caliche, boulders break apart during excavation; bedding indistinct, bottom contact indistinct. White caliche very prominent, 1-1/2-4ft.	K horizon, 1.5-[illegible] SC, ND tests not feasible due to cementation and large rocks
7-11	B-2 B-3		GRAVEL, light gray-brown, with cobbles and boulders as above; medium to coarse sandy matrix, little fines; dense; uncemented except cemented fine gravel in top 1 ft (depth 7-8ft); bedding indistinct.	

Note: B, bulk sample (taken at 3, 7 and 11 ft)

FIGURE 2

GEOLOGIC LOGS OF TEST PITS

SHEET 4 OF 4 | TEST PIT SFS-7

Gradation curves for soil samples obtained from each of the tests pits are shown separately in Figures 3a through 3d. The combined gradation curves are shown in Figure 3e.

Specific gravity and absorption of soil samples were determined separately for coarse and fine fractions separated by the no. 4 sieve. Results are given in Appendix B. Average values for the soil samples were computed as the weighted average of the values using the following equations (ASTM C-127/C-128):

$$G = \frac{1}{\frac{P_1}{100G_1} + \frac{P_2}{100G_2}}, \quad \text{and}$$

$$A = (P_1A_1/100) + (P_2A_2/100)$$

where

G = average specific gravity of soil solids

G_1, G_2 = specific gravity values for coarse and fine fractions, respectively

P_1, P_2 = weight percentage of coarse and fine fractions, respectively

A = average absorption, percent

A_1, A_2 = absorption percentage for coarse and fine fractions, respectively

Specific gravity and absorption values along with other index properties were computed for soil samples and are listed in Table 3.

Compaction tests determined the moisture-density relationship of the site soils; compaction curves of the soils are shown in Figure 4. The maximum dry densities determined by the tests were compared with the in-place densities (sand-cone method). The comparison is summarized in Table 4.

TABLE 2

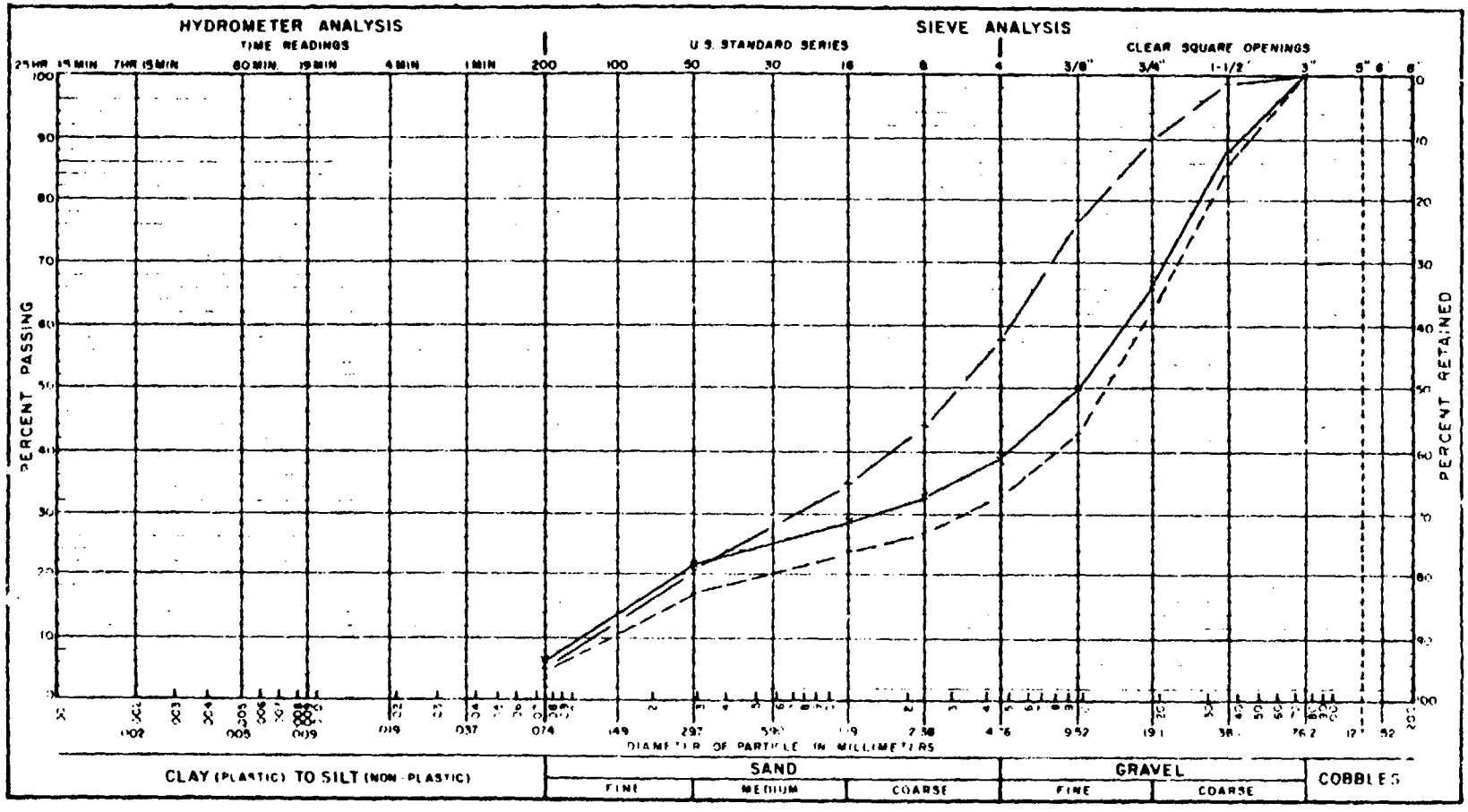
Summary of In-Place Density Tests

TEST PIT NO.	DEPTH (ft)	CLASSIFICATION (1)	IN-PLACE DENSITY TESTS (2) SAND-CONE DRY DENSITY (pcf)	SAND-CONE MOISTURE (%)	NUCLEAR DRY DENSITY (pcf)	NUCLEAR MOISTURE (%)
SFS-3	4.5-5.5	GP-GM	101.0	8.2	95.4	10.5
	8	GP-GM	110.2	7.7	107.3	9.3
	12	GP	111.6	6.0	105.4	7.6
SFS-4	2-4	GP-GM	--	--	--	--
	4-8	GP	--	--	90.2	10.0
SFS-5	2-4	GP	--	--	--	--
	6	GP	106.9	6.2	108.8	5.0
	12	GP	106.9	6.2	108.8	7.8
SFS-7	3	GP	--	--	--	--
	7	GP	--	--	--	--
	11	GP	--	--	--	--

Notes:

(1) GP - Poorly graded gravels
GM - Silty gravels

(2) When material encountered was predominantly gravel and cobbles, in-situ density tests were not feasible.



SFS-3

X———X 4.5'-5.5'
— — — — 8'
- - - - - 12'

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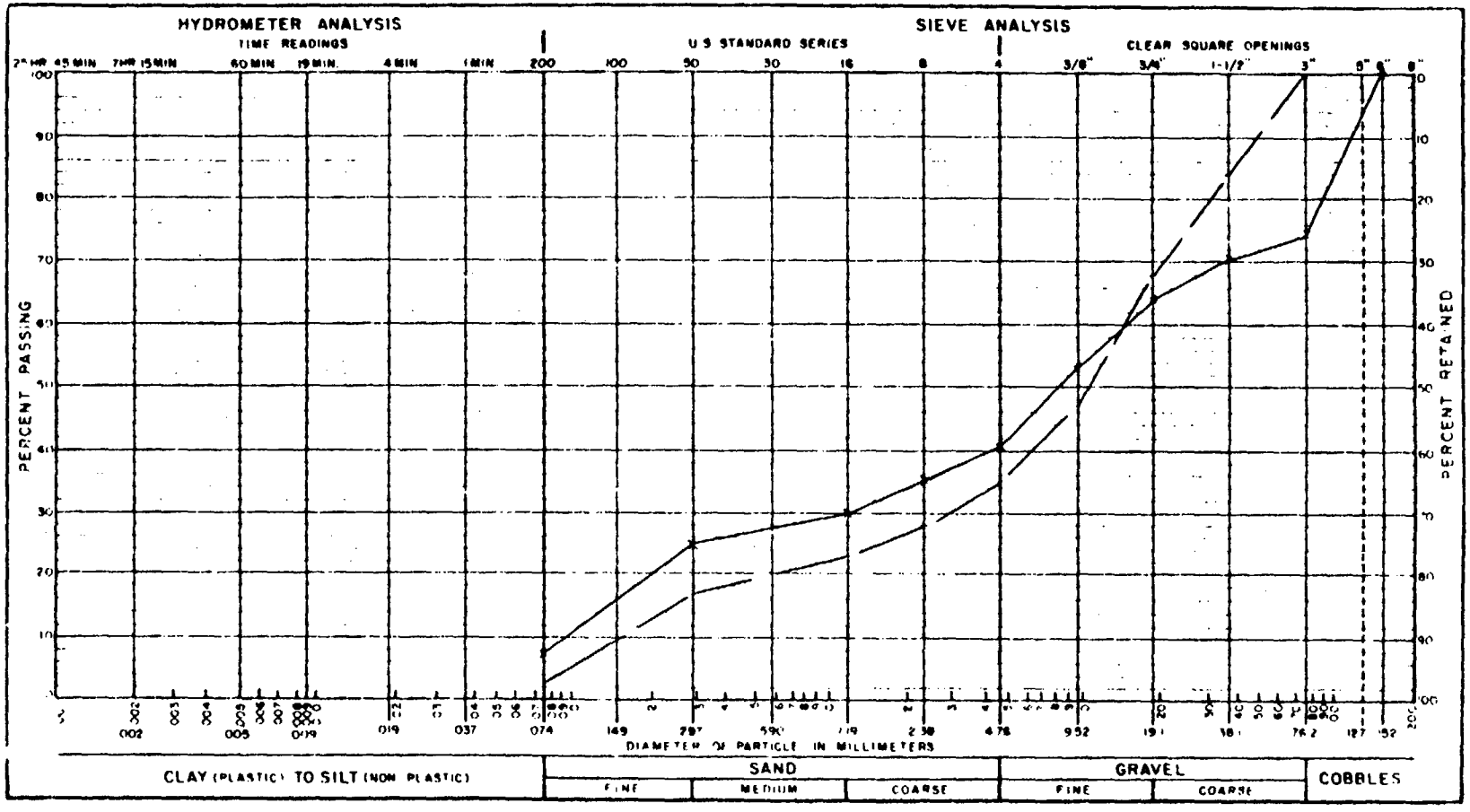
TUFF REPOSITORY SURFACE FACILITIES

GRADATION CURVES OF SITE SOILS TEST PIT SFS-3

JOB No.	DRAWING No.	REV.
16039	FIGURE 3a	



SFS-4

X——X 2'-4'

— — — 4'-8'

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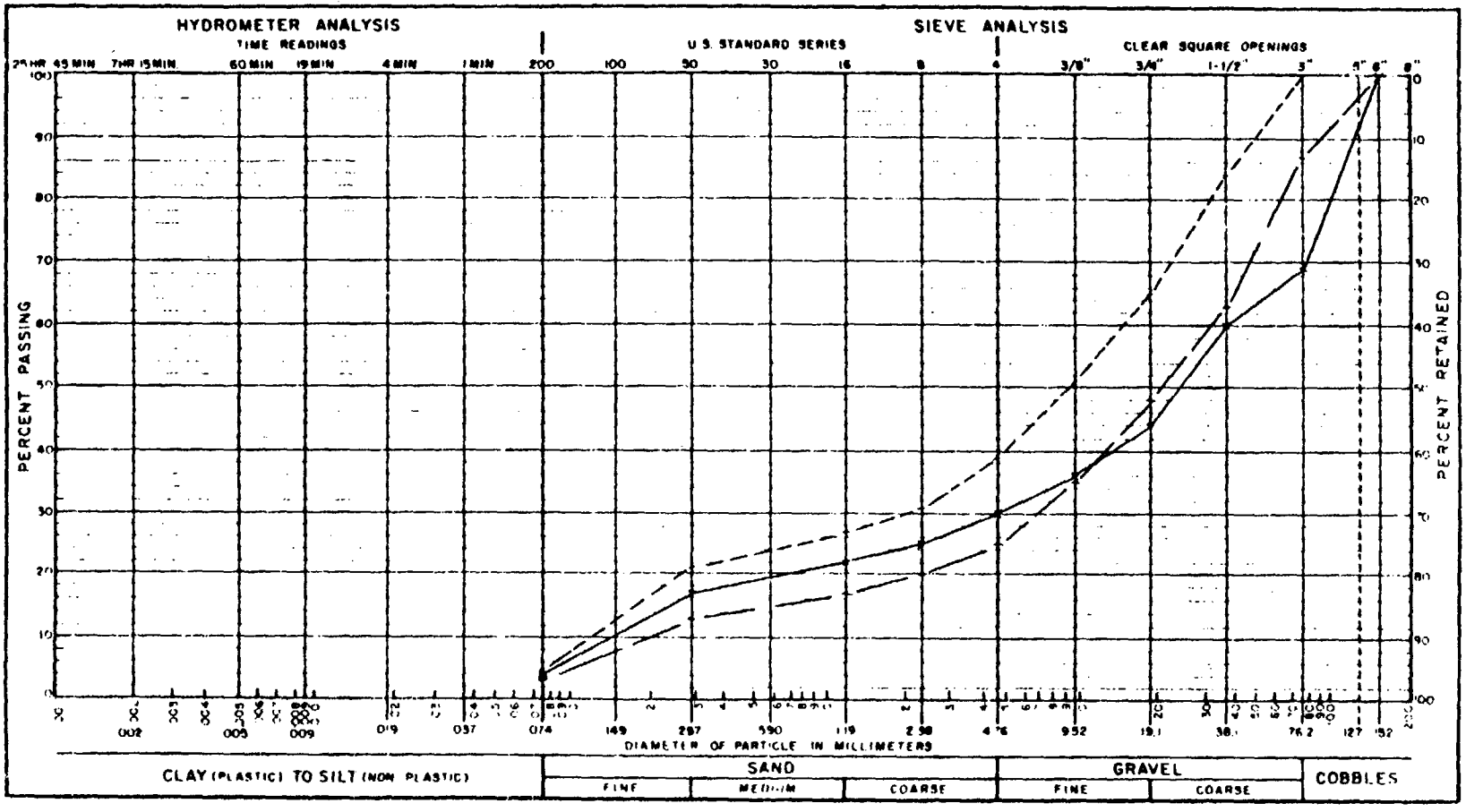
TUFF REPOSITORY SURFACE FACILITIES

GRADATION CURVES OF
SITE SOILS
TEST PIT SFS-4

JOB No.	DRAWING No.	REV
16039	FIGURE 3 b	



SFS-5

2'-4'
6'
12'

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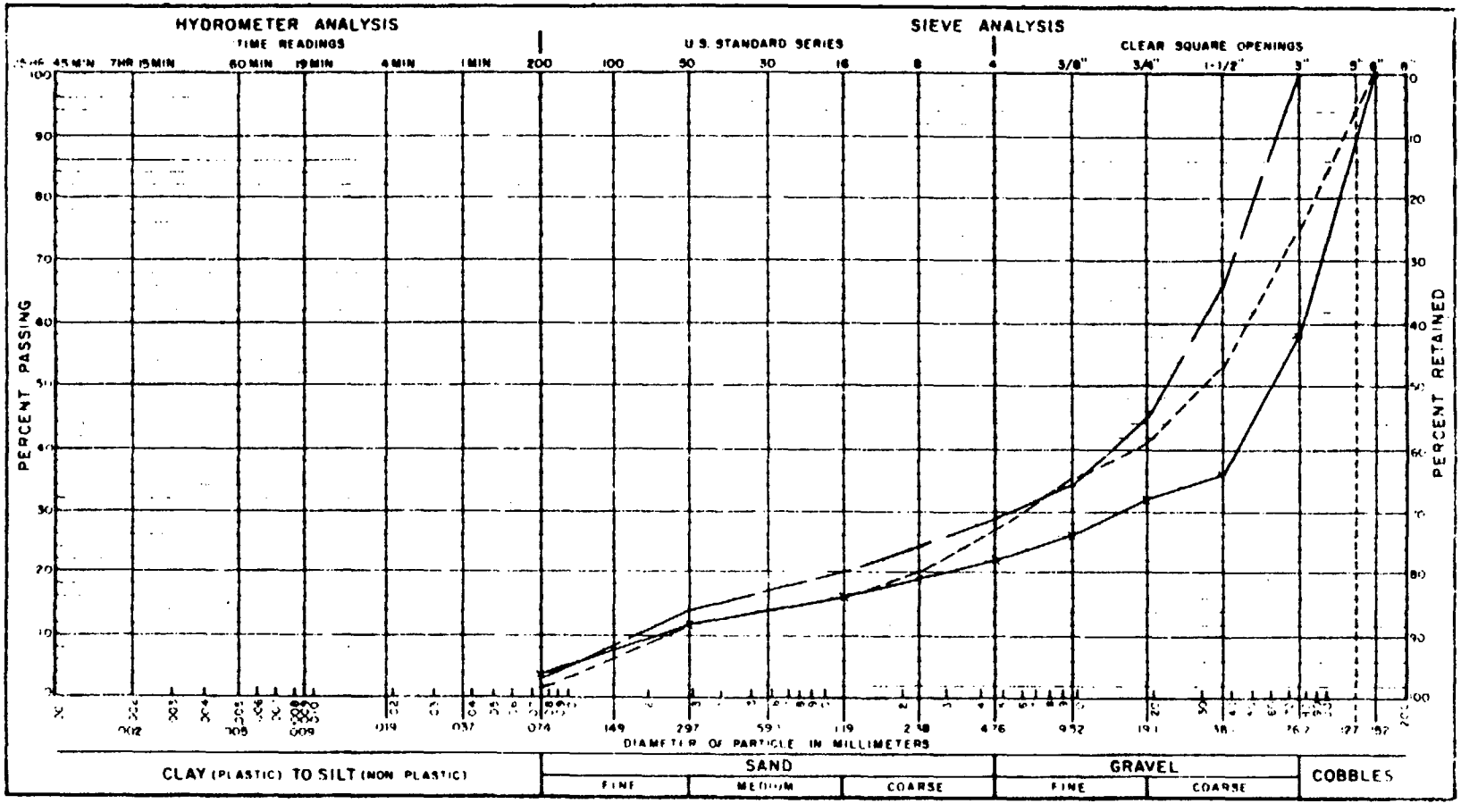
TUFF REPOSITORY SURFACE FACILITIES

GRADATION CURVES OF
SITE SOILS
TEST PIT SFS-5

JOB NO.	DRAWING NO.	REV.
15039	FIGURE 3c	



SFS-7

3'
7'
11'

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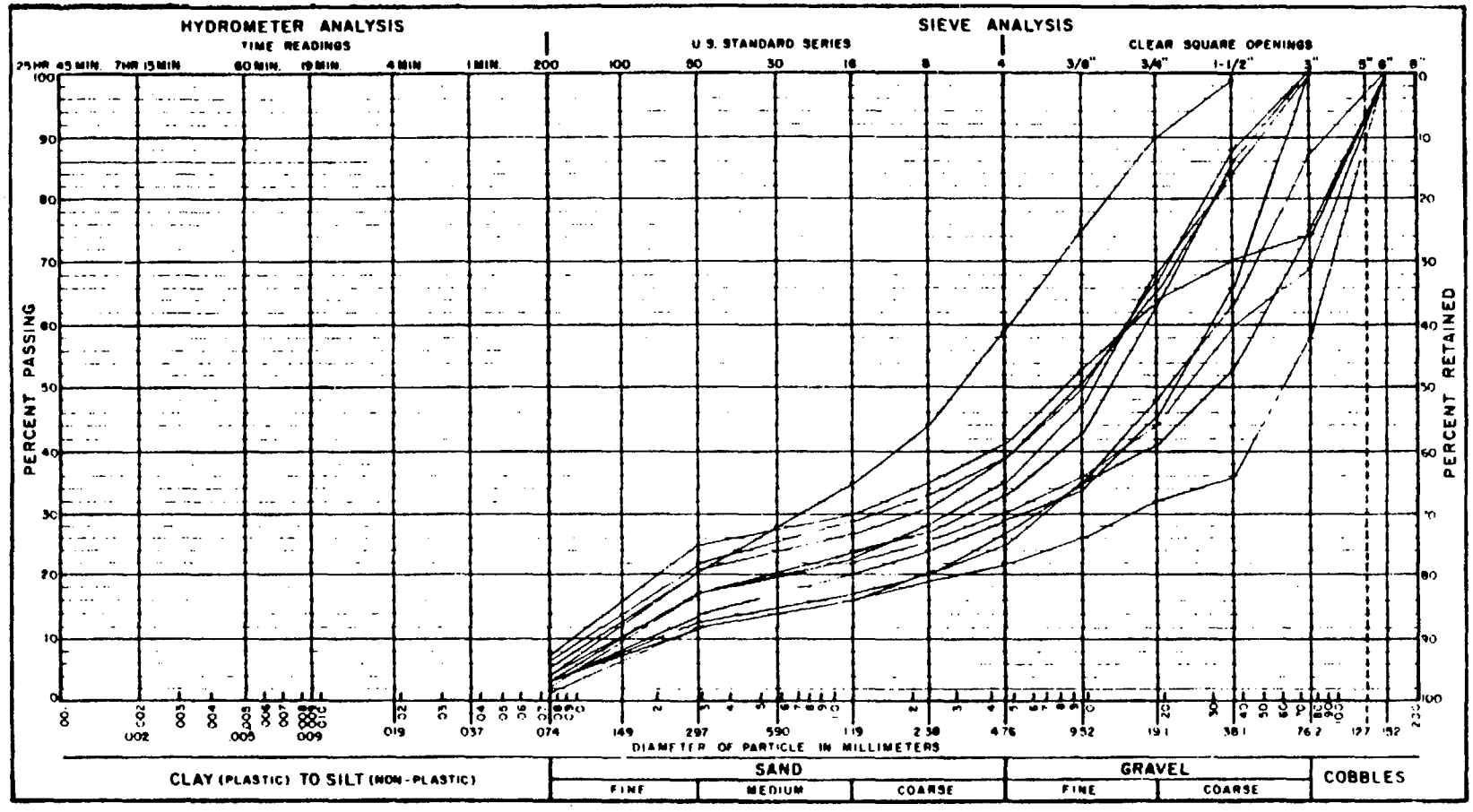
TUFF REPOSITORY SURFACE FACILITIES

GRADATION CURVES OF
SITE SOILS
TEST PIT SFS-7

JOB No.	DRAWING No.	REV
16039	FIGURE 3d	



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TUFF REPOSITORY SURFACE FACILITIES

GRADATION CURVES OF SITE SOILS SUMMARY

JOB No.	DRAWING No.	REV.
16039	FIGURE 3e	

TABLE 3

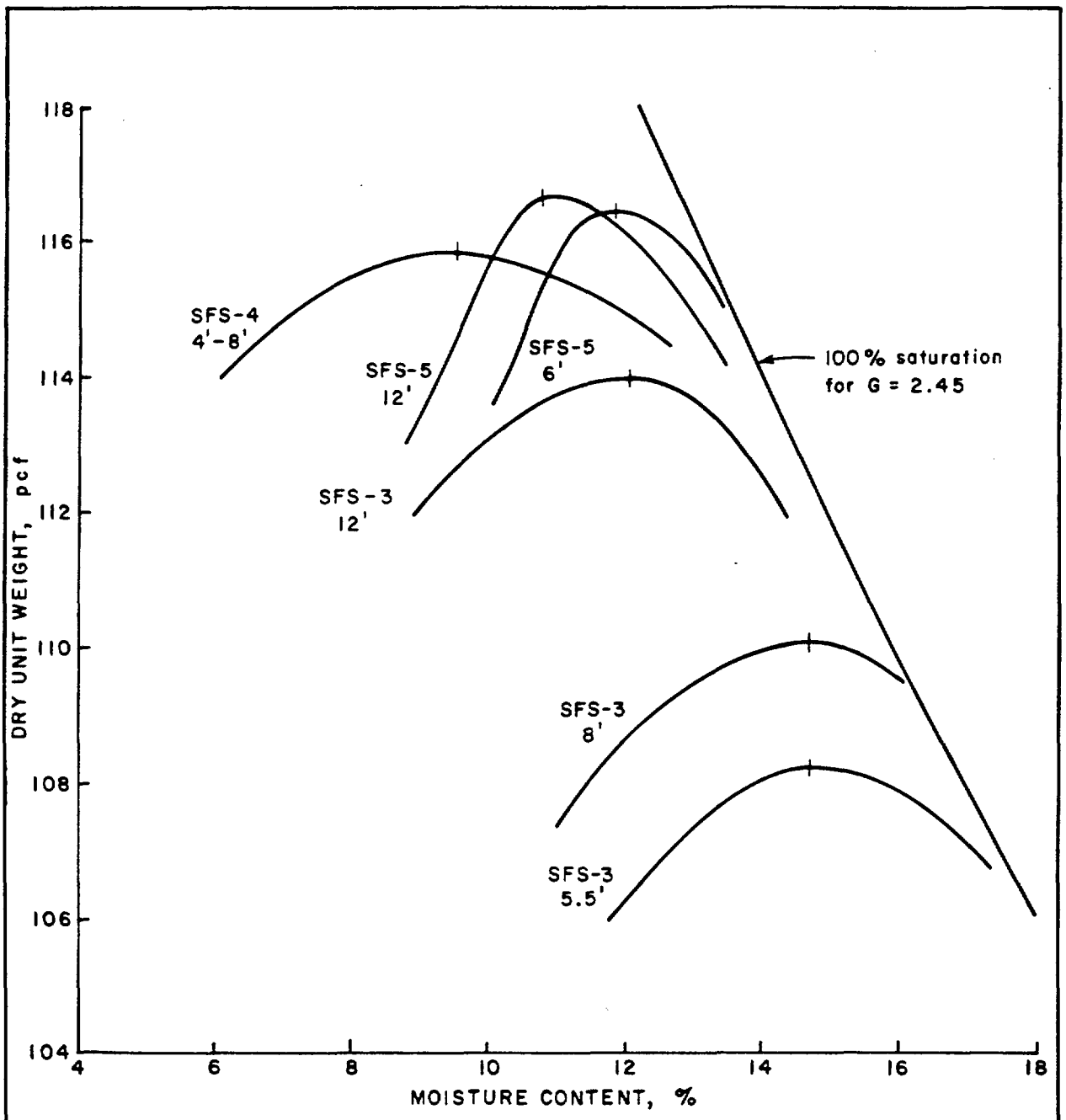
Summary of Soil Index Properties

Alternate Site No.	3	4	5	7
Test Pit No.	SFS-3	SFS-4	SFS-5	SFS-7
Soil Classification(1)	GP-GM	GP-GM	GP	GP
Natural Moisture Content (%)(2)	5.1-9.2 (7.2)	2.8-3.6 (3.2)	3.7-6.5 (4.9)	2.2-4.2 (3.5)
Size Distribution (%)(2)				
Cobble (3 inch)	0	0-26 (13)	0-31 (15)	0-42 (22)
Gravel (no. 4 to 3 inch)	42-67 (57)	33-65 (49)	39-62 (54)	36-71 (52)
Sand (no. 200 to no. 4)	29-53 (38)	32-34 (33)	22-34 (27)	18-26 (23)
Silt (less than no. 200)	4-7 (5)	3-7 (5)	3-5 (4)	2-4 (3)
Specific Gravity	2.43	2.43	2.40	--
Absorption (%)	7.9	3.2	4.2	--
Void Ratio	0.37	0.31	0.29	--

Notes:

(1) GP - Poorly graded gravels
GM - Silty gravels

(2) The values in parentheses represents the average.



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TUFF REPOSITORY SURFACE FACILITIES

COMPACTION CURVES OF SITE SOILS

JOB No.	DRAWING No.	REV.
16039	FIGURE 4	

TABLE 4

Comparison of In-Place and Laboratory Density Test Results

TEST PIT NO.	TEST DEPTH (ft)	SOIL CLASSIFICATION (1)	NATURAL MOISTURE CONTENT (%)	IN-PLACE TEST RESULTS DRY DENSITY (pfc)	IN-PLACE TEST RESULTS % OF LAB. MAX. DRY DENSITY (%) (2)	LABORATORY COMPACTION MAX. DRY DENSITY (pcf)	LABORATORY COMPACTION OPT. MOISTURE CONTENT (%)
SFS-3	4.5-5.5	GP-GM	7.2	101.0	93.4	108.1	14.7
	8	GP-GM	9.2	110.2	100.1	110.1	14.7
	12	GP	5.1	111.6	97.9	114.0	12.0
SFS-4	4-8	GP	3.6	--	--	115.9	9.5
SFS-5	6	GP	4.6	106.9	91.8	116.5	11.8
	12	GP	3.7	106.9	91.8	116.5	10.7
	Average Values		5.6	107.3	95.0	113.5	12.2

Notes:

(1) GP - Poorly graded gravels
GM - Silty gravels

(2) Dry density values from sand-cone method test results.

5.0 EVALUATION AND DISCUSSION OF DATA

5.1 Geologic Evaluation

The gravelly soils exposed at the four test pit locations are essentially similar in physical appearance, texture, classification, character of bedding, lithologic composition, origin, mode of deposition, and the type and degree of near-surface pedogenic modification. Their moderately high content of sand with some silt, and numerous cobble- and boulder-size rock fragments, their general lack of distinct bedding or sorted layers, and their absence of rounded particles are all consistent with deposition by flash floods or debris flows. The gravelly soils at the test pit locations are in contrast to sorted and layered gravel deposits exposed in Fortymile Wash (Photograph 25).

Comparison of test pits revealed minor differences. The gravel in test pit SFS-4 is somewhat better layered and less well cemented; the boulders in test pit SFS-7 are slightly larger and more abundant, consistent with its location closer to the head of an alluvial fan. None of these differences is significant for foundation design.

Since the soils were formed by rapid deposition, such as from mudflows and flash flooding, the potential for instability of the site soils was considered. The high relative density values of these soils indicate that there is little or no potential for collapse from hydrocompaction or other potential causes. However, this possibility should be evaluated thoroughly in future design work.

There is no potential for the gravel-sand alluvial deposits to liquefy. Liquefaction of soils is known to occur in saturated sand or gravel deposits, where the relative densities of the soil deposits are low. Since the soils at the potential sites were found to be dense to very dense and the ground water level is very deep, there is no potential for liquefaction.

The top 1.5 to 2 feet of soil comprise the A and B horizons. The character of the soil in these horizons is quite unlike the underlying materials: it is darker brown in color, contains a high percentage of fine sand and silt, is depleted of large rock fragments, and is quite loose.

All of the test pits reveal well-developed secondary calcite (caliche) cementation between a depth of 1.5 or 2 feet and about 8 feet; this K horizon is typical of very old soils (tens of thousands of years or more). The strength of cemented or partly cemented gravelly soils is not easily determined. Sampling and testing of undisturbed deposits would be very difficult; testing of remolded samples even at the same density as in-situ deposits is conservative and would result in lower measured strengths than the actual undisturbed soil capacity, since the additional strength due to cementation cannot be measured.

To evaluate the elastic properties of the cemented zone, special tests, such as plate-load tests, are necessary. Cross-hole seismic velocity data could also be obtained from close-spaced shallow holes within the zone to calculate dynamic moduli. Detailed inspection and testing are required to determine if the zone contains pockets of weaker deposits. Since the foundations of major surface facilities are expected to be below the cemented zone, such further investigation of this zone is not warranted.

5.2 Evaluation of Field and Laboratory Tests

The index properties and compaction data discussed below are based on field and laboratory test results. Engineering properties, such as permeability, compressibility, and shear strength, are evaluated indirectly from field observation, knowledge of the nature of soil deposition and cementation, soil index properties, and density test results.

5.2.1 Index Properties

Grain Size

The predominant soil deposits are gravel-sand mixtures and contain a small amount of silt (2 to 7 percent) and occasional boulders, 12 to 24 inches in size. The particles are subrounded to subangular in shape. The gradation curves shown in Figure 3 indicate the range of grain sizes of soils in the test pits. However, due to the nature of flood deposits, a wider variation in grain size can be expected throughout the site.

In-Place Density

In-place density tests by the sand-cone method were made during field exploration. Such tests are normally limited to the deposits with a maximum size of less than 2 inches. Therefore, density tests were not attempted for gravels and boulders larger than 3 inches. For the gravel-sand mixtures, the in-place density test results ranged from 101.0 to 111.6 pcf (Table 2) or about 91.8 to 100.1 percent of the maximum dry densities, as determined in accordance with ASTM D1557, Method D (Table 4). This means that the gravel-sand deposits are in a dense to very dense state.

In-place densities were also determined by the nuclear method in accordance with ASTM D2922, Method B. The determination of density by the nuclear method is indirect and is based on a pre-established correlation between nuclear-count rate and density for any particular type of material.

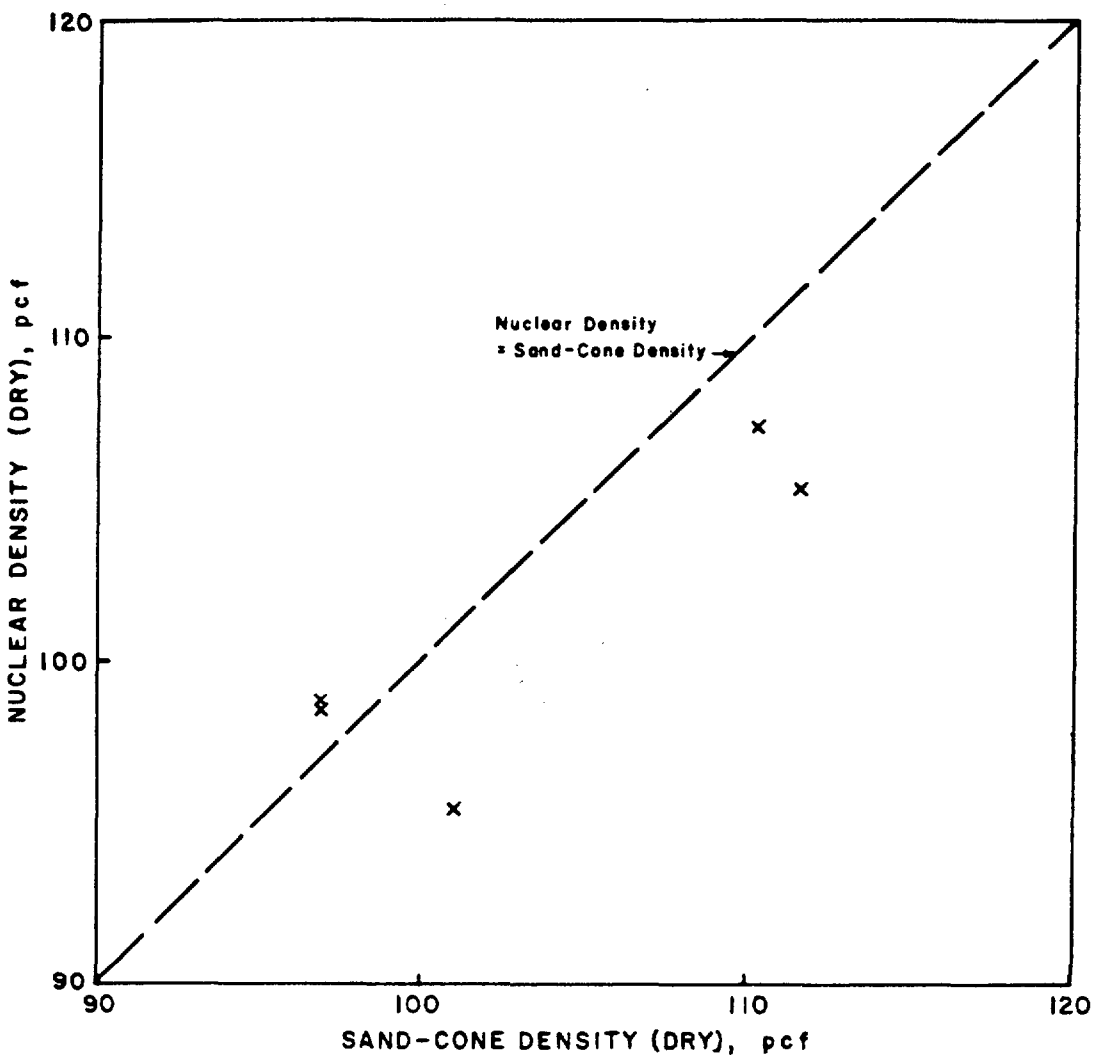
In-place densities determined by both sand-cone (direct) and nuclear (indirect) methods are given in Table 2 and shown in Figure 5. Differences in dry density ranged from 2 to 5 percent.

Moisture Content

All site soils were found to be dry. The moisture content of the soil samples ranged from 2.2 to 9.2 percent, values which are invariably below or very close to the absorption limit of the material.

Specific Gravity and Absorption

The specific gravity of solids in the soil samples was quite low, ranging from 2.40 to 2.43 (Table 4). As reported in Appendix B, the specific gravity of the coarse fraction (larger than no. 4 sieve size) varied from 2.32 to 2.39, and the fine fraction (smaller than no. 4 sieve size) varied from 2.50 to 2.53. The low specific gravity may be due to the presence of many lightweight and porous particles in the soil deposits, rather than of low specific gravity minerals.



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TUFF REPOSITORY SURFACE FACILITIES

COMPARISON OF IN-PLACE DENSITIES DETERMINED BY SAND-CONE AND NUCLEAR METHODS

JOB No.	DRAWING No.	REV.
16039	FIGURE 5	

The absorptions of soil samples were found to be in the range of 3.8 to 10.5 for the coarse fractions and 2.3 to 9.6 for the fine fractions, as indicated in Appendix B. The average absorption at each potential site is given in Table 3.

5.2.2 Compaction

The compaction test results provided in Appendix B and shown in Figure 4 indicate that the compacted site gravel and sand have a wide range of maximum dry density (from 108.1 to 116.5 pcf) and an optimum moisture of 9.5 to 14.7 percent.

5.2.3 Engineering Properties

Engineering properties of soil deposits, which include permeability, compressibility, and shear strength, are required in foundation design and construction considerations. The engineering properties provided below are preliminary and are based on the site conditions, the results of the index property tests of the site soil samples, and their classification. Typical engineering properties are related to various soil groups in the Unified Soil Classification system (Department of the Navy, 1982). Because a wide range of values is normally given in the charts, selection of a valid value pertinent to the site requires that consideration be given to the site conditions, such as variation of soil deposits, degree of cementation, in-place density, and index properties of the site soils.

Since foundations for the facilities will be supported by the sand and gravel deposits below the loose surface material, the engineering properties given below are for the sand and gravel materials below the loose topsoil.

Permeability

The sand-gravel deposits, classified as GP (poorly graded gravel) and GW (well graded gravel), are normally quite pervious when clean. The 3 to 7 percent silt content (Table 3) may reduce the permeability somewhat (Department of the Navy, 1982, p 7.1-277). However, the permeability of cemented soils (K horizon) would be reduced significantly by carbonate deposits filling voids between particles. It is estimated that the permeability of the uncemented gravels is in the range of 10^{-3} to 10^{-1} cm/s (1,000 to 100,000 ft/yr); much lower permeability is expected in the cemented zone.

Compressibility

The sand-gravel deposits behave like elastic solids; settlement of deposits occurs more or less simultaneously with the applied loads. Because the site soils are predominantly dense to very dense sand-gravel, with slight to moderate cementation, the settlement is expected to be small.

The following equation may be used for estimating elastic settlement under a loaded area with a uniform pressure of q:

$$s = \frac{q\ b\ (1 - \mu^2)}{E}\ I,$$

where

s = elastic settlement

q = uniform pressure

b = diameter of a loaded circular area, or the least dimension of a loaded rectangular area

E = Young's modulus

μ = Poisson's ratio

I = a shape and rigidity parameter which accounts for the shape of the loaded area and the position of the point for which the settlement is being calculated (see Department of the Navy, 1982, Table 1, p 7.1-212)

Young's modulus for dense sand and gravel is typically in the range of 14,000 to 28,000 psi (Winterkorn et al, 1975). Due to limited exploration, no testing for determining Young's modulus was performed. A range of 10,000 to 20,000 psi is recommended for the conceptual design. No typical values of Poisson's ratio for sand-gravel deposits are available in published literature. However, since the value of Poisson's ratio has a relatively small effect on the determination of settlement, a range of values from 0.3 to 0.35 for sand (Winterkorn et al, 1975) is recommended.

An estimated elastic settlement also can be based on the modulus of subgrade reaction. Typical values of 200 to 300 pci (derived from Department of the Navy, 1982, Figure 6, p 7.1-219) can be used for a preliminary estimate of settlement or a soil-structure interaction study.

Shear Strength

Bearing capacity of footings and piles, the stability of natural and cut slopes, and earth pressures against retaining walls and tunnels are all dependent on the shear strength of soils. The shear strength of soils is normally expressed by the Coulomb equation:

$$s = c + \sigma \tan \phi,$$

where

s = shear strength

c = cohesion

σ = normal stress on the shear plane

ϕ = angle of internal friction

An angle of internal friction of 33 to 37 degrees is conservative for the alluvial sand-gravel deposits (Winterkorn et al, 1975), and is therefore recommended for conceptual design. Any cementation in the deposits would result in cohesion and an increase in shear strength. Cemented soil is estimated to have a cohesion of 500 psf; however, it would be conservative to assume zero cohesion in preliminary design.

5.3 Bearing Capacity and Settlement

The predominant slightly to moderately cemented sand-gravel deposits will provide high bearing capacity and low compressibility for the load carrying of moderate- to high-capacity foundations.

The ultimate bearing capacity q of a spread footing can be computed in general by the following equation:

$$q = \frac{\gamma b}{2} N_\gamma + cN_c + q'N_q$$ (Department of the Navy, 1982)

where

N_γ, N_c, and N_q = dimensionless bearing capacity factors that depend on angle of internal friction, ϕ

c = cohesion

γ = effective soil unit weight

b = footing width

q' = surcharge above the footing

Because the cemented soil has both cohesion and internal friction, the bearing capacity is likely to be very high. For an angle of internal friction of 35 degrees and a cohesion of 500 psf for the foundation soil, with a factor of safety of 3, the allowable bearing pressure for a footing 4 feet wide and 2 feet below site grade would be more than 10 kips per square foot (ksf). For the more general condition appropriate to uncemented or weakly cemented soils, the allowable bearing pressure would be about 6 ksf. If the footing is larger than 4 feet or the footing depth is more than 2 feet, the allowable bearing pressure would be greater. However, in the case of larger footings, allowable settlement may control the bearing pressure that can be permitted.

Settlement of the footing would be elastic but it may be estimated from the equation cited previously for compressibility. For example, the settlement for a 4-foot-wide footing with a load of 10 ksf would be about 0.5 inch; using a design load of 6 ksf would imply a settlement of about 0.3 inch for the same footing width. Elastic settlement is directly proportional to footing pressure as well as the width of the footing; therefore, for a larger footing, it is desirable to reduce the footing pressure in order to minimize settlement to within allowable limits. The minimum footing width should be 2 feet.

5.4 Evaluation of Data at Site 3

Conceptual design studies in progress indicate that the site 3 location for surface facilities is favored because of its proximity to proposed locations of mine portals and other factors (Neal, 1985). Consideration is therefore given to the specific applicability of data presented in this report to site 3.

As shown in Figure 1, one test pit (SFS-3) and one drill hole (RF-3) are at site 3. Soil conditions at site 3 are similar to those at the other sites, particularly with regard to engineering properties of the uncemented soils. Minor differences in test results for test pit 3 (such as a smaller percentage of larger rock sizes) are not significant.

The ground surface at site 3 slopes at about a 3 percent grade to the southeast, slightly less than at other sites. Depth to rock is approximately 90 feet according to boring RF-3, but this may vary considerably across the site; in any event, site excavations for footings (to a depth of about 30 feet below grade) are not expected to encounter bedrock.

Foundations for the principal surface facility, the waste handling building, are expected to entail excavation to a depth of about 30 feet below grade, a depth considerably greater than that of the test pits. However, the uncemented soils encountered in the test pits are expected to be similar to those encountered at depths greater than the test pits, based on indications from the exploratory drill holes. Therefore, for the purpose of conceptual design it is conservative to apply the uncemented soils data obtained from the test pits to both deep and shallow foundations.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Conclusions regarding the suitability of the soils for the foundations of the surface facilities, and recommendations for design and construction are summarized below:

1. Limited field exploration and laboratory testing show that the soils at the potential sites for the repository surface facilities are satisfactory for foundations.

2. The gravelly soils exposed at the four test pit locations are essentially similar in physical appearance, texture, classification, character of bedding, lithologic composition, origin, mode of deposition, and type and degree of near-surface pedogenic modification. Although minor differences exist, they are not significant for conceptual foundation design.

3. There is no liquefaction potential for the gravel-sand alluvial deposits because the ground water level is very deep and the deposits are in a dense to very dense state.

4. The engineering properties and preliminary parameters recommended for foundation design are summarized below:

o Young's modulus	10,000 - 20,000 psi
o Poisson's ratio	0.3 - 0.35
o Modulus of subgrade reaction	200-300 pci
o Shear strength:	
- Internal friction angle	33-37°
- Cohesion (no cementation)	0 psf
(cemented soil)	500 psf
o Bearing pressure (for footings wider than 4 feet):	
- Uncemented soil	6 ksf
- Cemented soil	10 ksf

(Note that bearing pressures are subject to the verification that settlements are tolerable in the case of large structures. Minimum footing width should be 2 feet.)

The engineering properties and foundation design parameters recommended above are preliminary and are estimated from the soil index properties and engineering judgment as discussed in Section 5.0. Additional soils investigations are required to develop site-specific design parameters prior to final design.

5. During construction, the loose material in the top 1.5 to 2 feet should be removed and stockpiled as topsoil.

6. The sand-gravel deposits are suitable for fills. For structural backfills, oversized rocks should be removed and materials compacted

to 95 percent of the maximum dry density determined in accordance with ASTM D-1557, Method D. Optimum moisture content for compaction will be in the range of 10 to 15 percent, depending on the material used.

Large quantities of fill materials may be obtained from cliffs of alluvial deposits along the Fortymile Wash (Photographs 2 and 25). However, additional exploration would be required to provide specifications for their use in construction.

7. Permanent slopes in cut should not be steeper than 1.5 horizontal to 1 vertical where the soil deposits are cemented and 2 horizontal to 1 vertical where the cementation is absent. Fill slopes should be 2 horizontal to 1 vertical.

   It is expected that excavation through the cemented zone will not require blasting but will require the use of ripping equipment. Behavior of this cemented material on excavation should be determined in field trials prior to the specification of material gradation for use as backfill.

8. The gravels excavated from the test pits and the tuffaceous rocks in general would be unsuitable for use as concrete aggregrate because of their porosity, potential alkali reactivity, coatings on rock particles, and other factors. Boulders on local talus slopes would probably be a suitable source of rock for rip rap, armoring, gabions, and similar uses.

7.0 REFERENCES

ASTM (American Society for Testing and Materials) C-127-84, Standard Test Method for Specific Gravity and Absorption of Coarse Aggregate

ASTM (American Society for Testing and Materials) C-128-84, Standard Test Method for Specific Gravity and Absorption of Fine Aggregate

ASTM (American Society for Testing and Materials) C-136-84, Standard Method for Sieve Analysis of Fine and Coarse Aggregates

ASTM (American Society for Testing and Materials) C-566-84, Standard Test Method for Moisture Content of Aggregate by Drying

ASTM (American Society for Testing and Materials) D-1556-82, Standard Test Method for Density of Soil in Place by the Sand Cone Method

ASTM (American Society for Testing and Materials) D-1557-78, Standard Test Methods for Moisture-Density Relations of Soil and Soil-Aggregate Mixtures Using 10-lb Rammer and 18-in. Drop

ASTM (American Society for Testing and Materials) D-2487-83, Standard Test Methods for Classification of Soils for Engineering Purposes

ASTM (American Society for Testing and Materials) D-2922-81, Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)

DOE (Department of Energy), Draft Environmental Assessment, "Yucca Mountain Site, Nevada Research and Development Area, Nevada," DOE/RW-0012, December 1984

Department of Navy, Soil Mechanics, NAVFAC DM-7-1, May 1982

Holmes and Narver, Inc., "Soils Investigation for Sandia Laboratories, NNWSI Area 25, Nevada Test Site," July 1983

Hoover, D.L., Swadley, W.C., and Gordon, A.J., "Correlation Characteristics of Surficial Deposits with a Description of Surficial Stratigraphy in the Nevada Test Site Region," U.S. Geological Survey, Open-File Report 81-512, 1981

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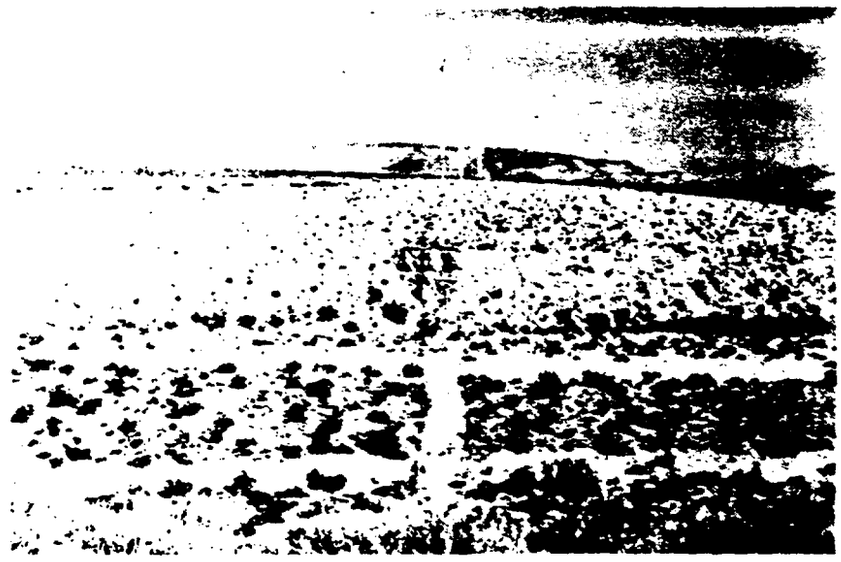
Swadley, W.C., and Hoover, D.L., "Geology of Faults Exposed in Trenches in Crater Flat, Nye County, Nevada," U.S. Geological Survey, Open-File Report 83-608, 1983

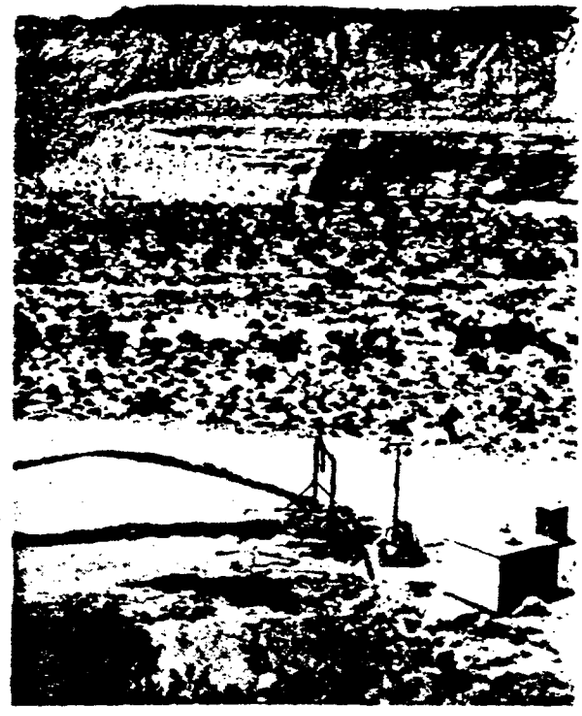
Winterkorn, H.F. and Fang, N.Y., Foundation Engineering Handbook, Van Nostrand Reinhold Co., New York, 1975

APPENDIX A

PHOTOGRAPHS



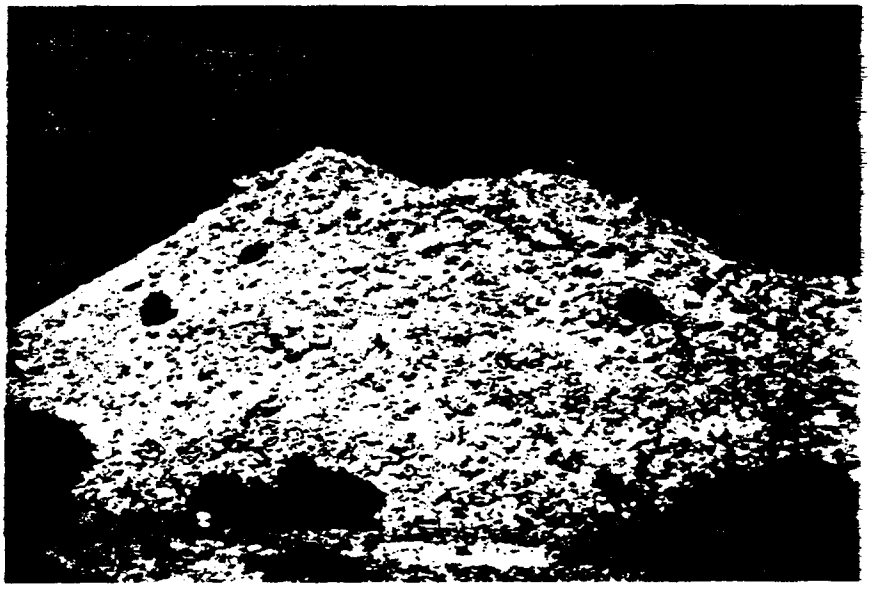
Photograph 1. Powerline crossing at Fortymile Wash; potential site for proposed railroad crossing.



Photograph 2. Water truck loading facility in Fortymile Wash. Water is pumped from nearby Well J-13 into a holding pond (lower left).

Photograph 3. Tire ruts in loose topsoil, near test pit SFS-4. Such soft topsoil, usually overlying hard caliche, could mire vehicles when soil is wet.

Photograph 4. Well-developed desert soil profile, exposed in exploratory trench, west side of Exile Hill. Soft, silty topsoil nearly 2 feet thick (B horizon) overlies hard, cemented caliche (K horizon), which extends to the bottom of the trench.



Photograph 5. Typical upland alluvium, dozed from 1983 exploratory trench, west side of Exile Hill (notepad gives scale, lower center).

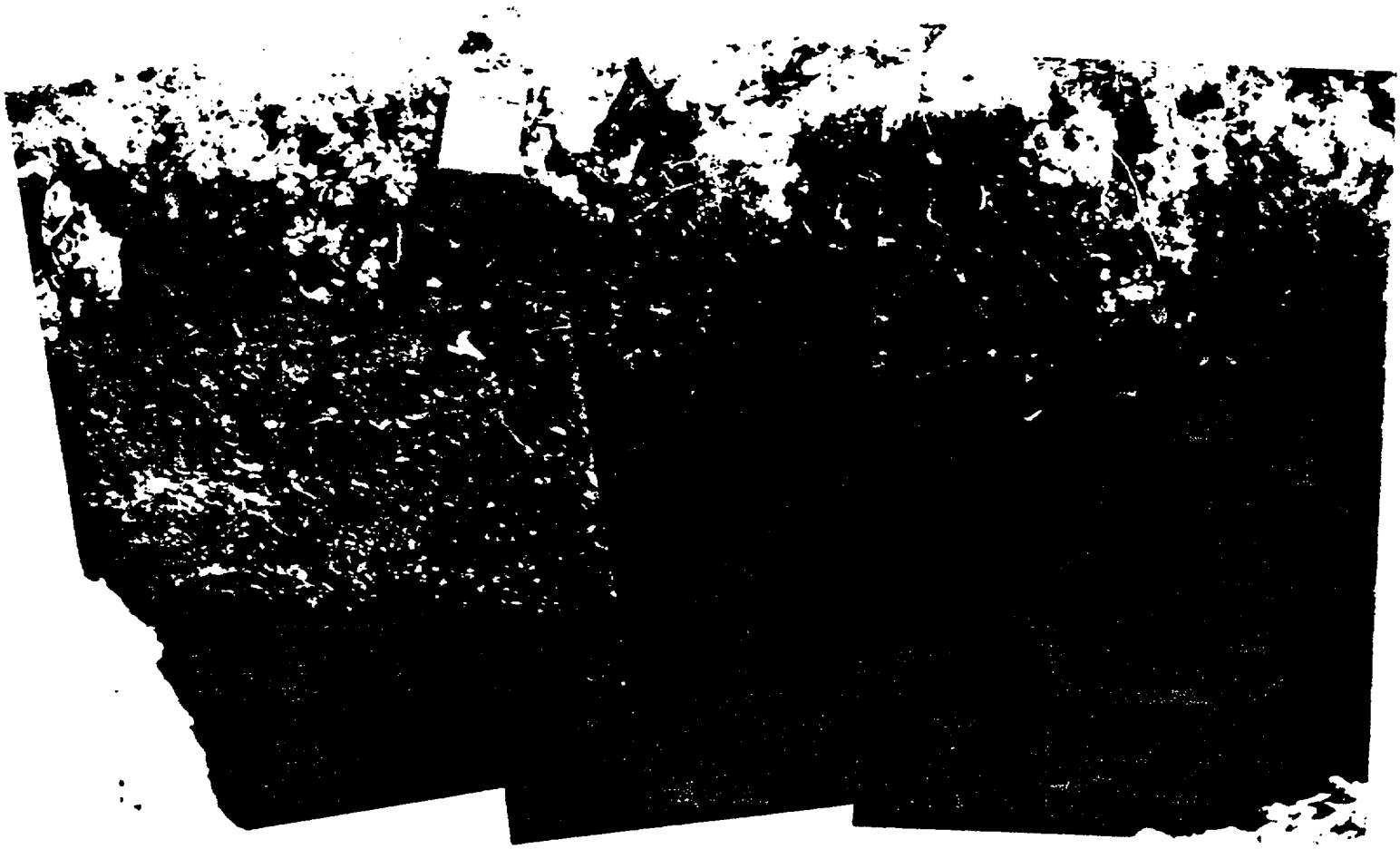
Photograph 6. Bantam 4-26 backhoe on the site, test pit SFS-4.

Photographs 7 and 8. Excavating test pit SFS-3.

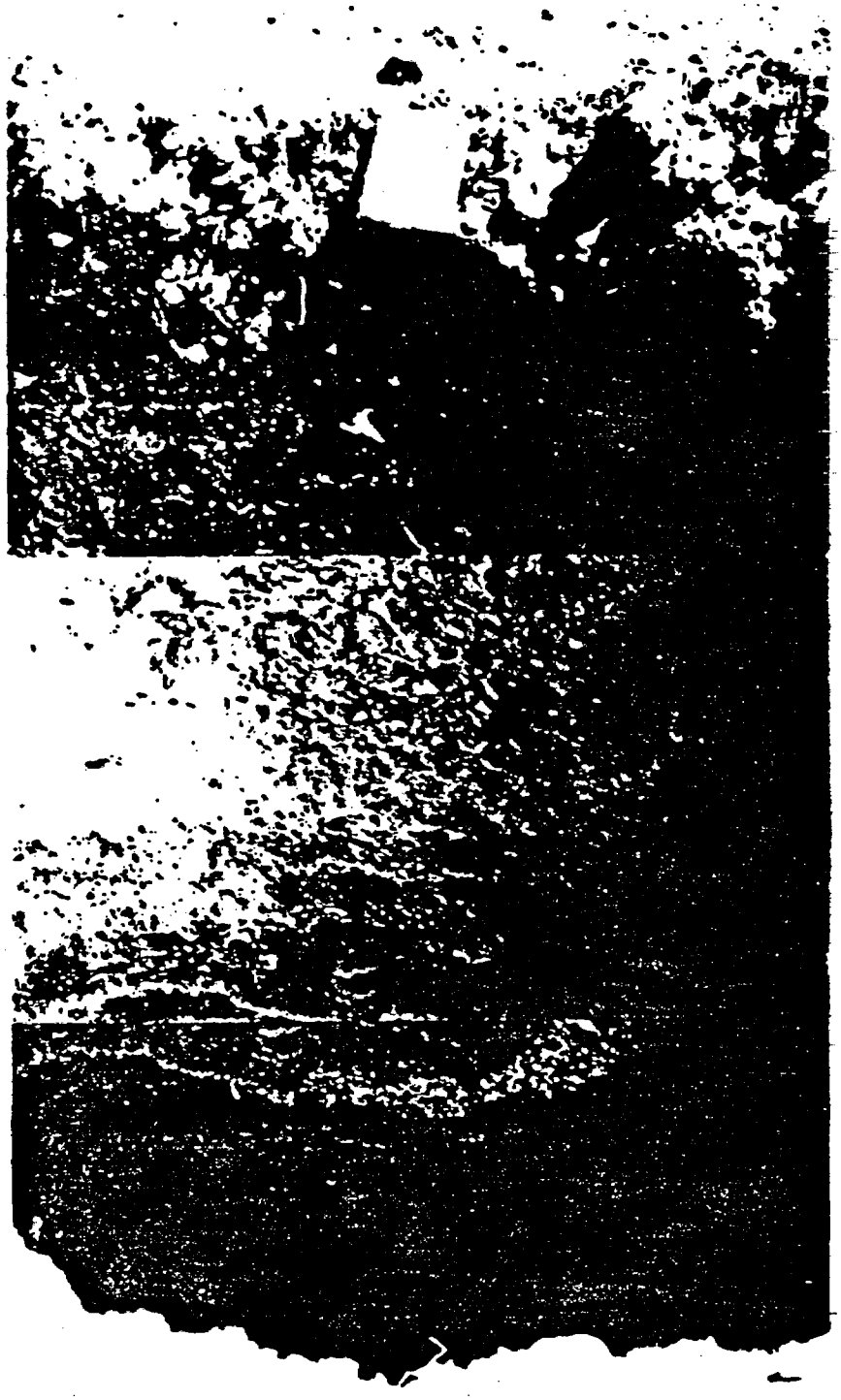
Photograph 9. Test pit SFS-3 excavated to final depth of 12 feet. Looking northeast at east wall of trench.

Photograph 10. Looking northeast at completed test pit SFS-3.

Photograph 11. Excavating test pit SFS-4. Photograph 12. Detail of wall of test pit SFS-4, exposing soil moderately cemented with caliche. Angular, cobble-size volcanic rock fragments are embedded in sandy matrix. Most cobbles were not broken apart during excavation.



Photograph 13. West wall of test pit SFS-4, upper portion. The top silty, sandy zone, relatively free of boulders and caliche (B horizon), is underlain by a zone (K horizon) partly cemented with caliche. Note the broken cobble fragments near the top of the caliche zone.

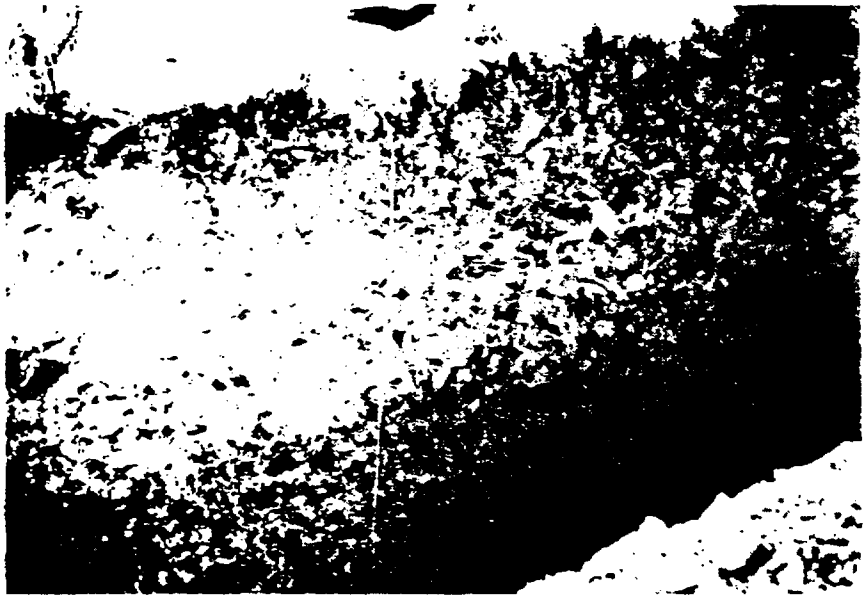


Photograph 14. West wall of test pit SFS-4, showing total depth of about 12.5 feet.

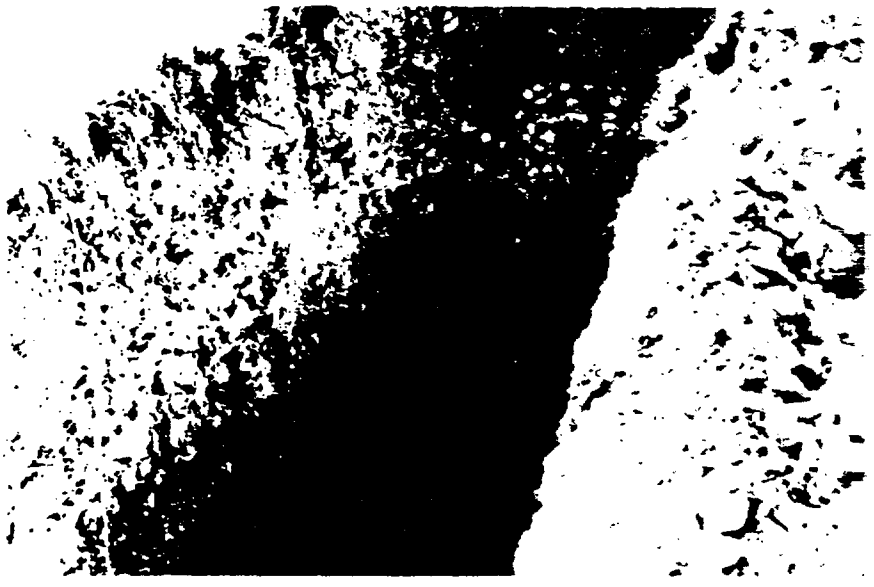
Photograph 15. West wall of test pit SFS-5. B horizon is about 20 inches thick. Pit is about 11.5 feet deep.

Photographs 16 and 17. View north along test pit SFS-5. Note remnant of smaller test pit no. 2, excavated in 1983. Pit was excavated by a Gradall G-1000.

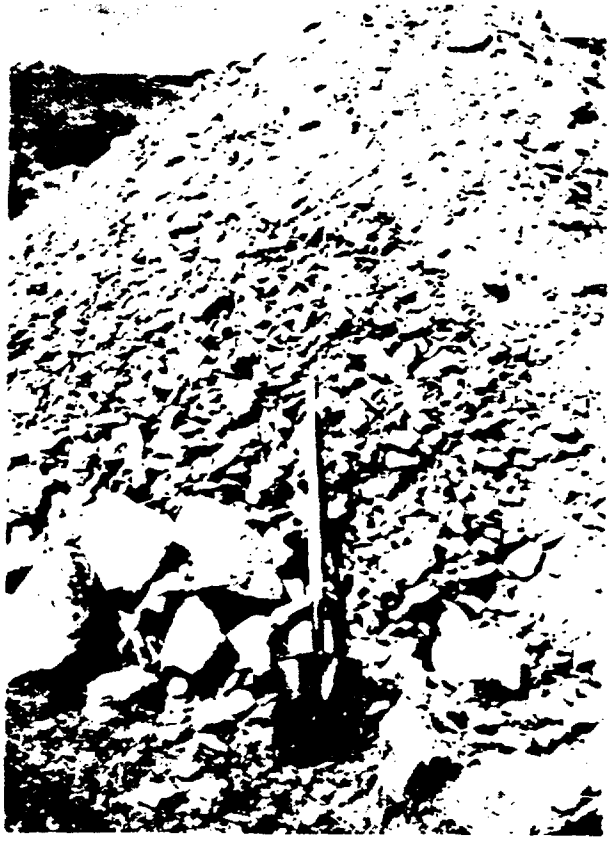
Photograph 18. Pile of excavated soil from test pit SFS-5. The amount and size of boulders are typical for the area.



Photographs 19 and 20. Southeast wall of test pit SFS-7. The pit is about 11 feet deep.



Photograph 21. Looking toward the northwest end of test pit SFS-7.



Photograph 22. Pile of excavated soil from test pit SFS-7. The size and amount of boulders are unusually large for the area.

Photograph 23. Details of wall of test pit SFS-7, looking toward the southeast end. Most cobbles and boulders exposed in pit wall were broken during excavation except in the lower 1.5 feet (compare with Photograph 12).

Photograph 24. Details of wall of test pit SFS-7, looking toward the northwest (compare with Photograph 12).

Photograph 25. Cliff exposure of alluvial gravel and sand in Drill Hole Wash near Fortymile Wash (notepad at lower left gives scale).

APPENDIX B

LABORATORY TEST RESULTS
BY HOLMES AND NARVER, INC.,

DATED MAY 16, 1984

HOLMES & NARVER, INC.
ENGINEERS · CONSTRUCTORS
A RESOURCE SCIENCES COMPANY

MATERIALS TESTING LABORATORY
Nevada Test Site

Transmitted to
Bechtel 21 May 84
James T. Neal

In Reply Refer To: NTS-TEC:MTL/84-40

May 16, 1984

Jim Neal
Sandia National Laboratories
P. O. Box 238, M/S 944
Mercury, NV 89023

SUBJECT: SURFACE FACILITY SITE TESTING RESULTS

Attached please find the results of the testing performed for the Surface Facility Site.

If we may be of further assistance, please contact this laboratory.

Brent R. Woolsey
Brent R. Woolsey
Supervisor, Materials Testing

Alfred H. Westall
Alfred H. Westall
Chief, Materials Testing Laboratory

BRW:AHW:df

Enclosures
As Stated

P.O. BOX 1 | MERCURY, NEVADA 89023 | (702) 986-0860

SURFACE FACILITY SITE INVESTIGATION TESTING RESULTS

LAB NO.	TEST PIT NO.	SAMPLE NO.	DEPTH FT.	CLASS. ASTM D-2487	NATURAL MOISTURE % ASTM C-566	ASTM C-127 SP. GR.	ASTM C-127 % ABS.	ASTM C-128 SP. GR.	ASTM C-128 % ABS.	MOISTURE/DENSITY ASTM D-1557 METHOD D	IN PLACE DENSITIES NUCLEAR ASTM D-2922	IN PLACE DENSITIES SAND CONE ASTM D-1556
84-001A	SFS-4	S-1	2-4	GP-GM	2.8							
84-001B	SFS-4	S-2	4-8	GP	3.6	2.38	3.8	2.52	2.3	115.9 lb @ 9.5%	90.2 lb @ 10.0%	
84-002A	SFS-3	S-1	4.5-5.5	GP-GM	7.2	2.32	7.8	2.53	9.6	108.1 lb @ 14.7%	95.4 lb @ 10.5%	101.0 lb @ 8.2%
84-002B	SFS-3	S-2	8	GP-GM	9.2	2.39	10.5	2.52	7.1	110.1 lb @ 14.7%	107.3 lb @ 9.3%	110.2 lb @ 7.7%
84-002C	SFS-3	S-3	12	GP	5.1	2.39	4.6	2.50	8.4	114.0 lb @ 12.0%	105.4 lb @ 7.6%	111.6 lb @ 6.0%
84-003A	SFS-7	S-1	3	GP	2.2							
84-003B	SFS-7	S-2	7	GP	4.2							
84-003C	SFS-7	S-3	11	GP	4.2							
84-004A	SFS-5	S-1	2-4	GP	6.5							
84-004B	SFS-5	S-2	6	GP	4.6	2.35	4.5	2.50	4.3	116.5 lb @ 11.8%	108.8 lb @ 5.0%	106.9 lb @ 6.2%
84-004C	SFS-5	S-3	12	GP	3.7	2.37	4.2	2.52	3.6	116.5 lb @ 10.7%	108.8 lb @ 7.8%	106.9 lb @ 6.0%

FOR GRADATION ASTM C-136 AND C-117, MOISTURE DENSITY ASTM D-1557, SEE ATTACHMENTS

☒ SIEVE ANALYSIS (ASTM C-138-) ☒ MOISTURE CONTENT (ASTM C-566-) ☐ UNIT WEIGHT (ASTM C-29-)	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-002A Date May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/3/84 Tested by TJS Computed by TJS Checked by BW

Information transmitted to _____ By _____ How _____ Date _____

SIEVE ANALYSIS

U. S. STANDARD SIEVE NO.	% PASSING	SPEC. % PASSING
12"	100	
6"	100	
3"	100	Max Size 3½"
1-1/2"	88	
3/4"	67	
3/8"	50	
#4	39	
#8	33	
#16	29	
#50	22	
#200	6.6	

MOISTURE CONTENT

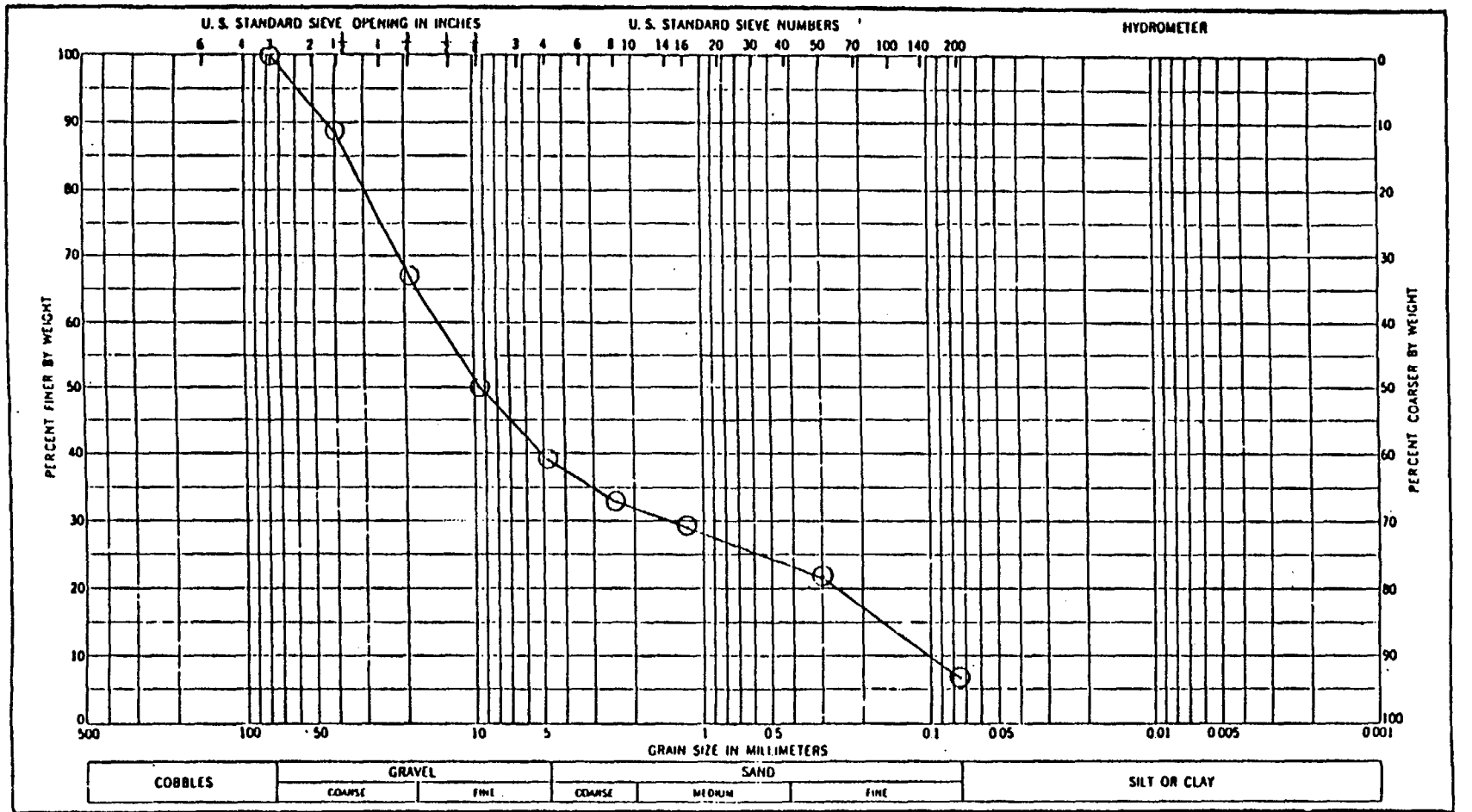
% Moisture 7.2

UNIT WEIGHT

Loose Rodded

Unit Weight (P.C.F.) _____ _____

REMARKS: SFS-3 S-1 4.5'-5.5'



Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
S-1	4.5'-5.5'	GP-GM	7.2			

Project SURFACE FAC. SITE INVEST.
SANDIA/BECHTEL
Area A-25/400
Boring No. SFS-3
Date 5/10/84

GRADATION CURVES

ENG FORM 1 MAY 63 2087

☒ SIEVE ANALYSIS (ASTM C-138-) ☒ MOISTURE CONTENT (ASTM C-566-) ☐ UNIT WEIGHT (ASTM C-29-)	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-00[illegible] Date May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/3/84 Tested by TJS Computed by TJS Checked by [illegible]

Information transmitted to _____ By _____ How _____ Date _____

SIEVE ANALYSIS

U. S. STANDARD SIEVE NO.	% PASSING	SPEC. % PASSING
12"	100	
6"	100	
3"	100	Max Size 4"
1-1/2"	99	
3/4"	90	
3/8"	75	
#4	58	
#8	44	
#16	35	
#50	21	
#200	5.2	

MOISTURE CONTENT

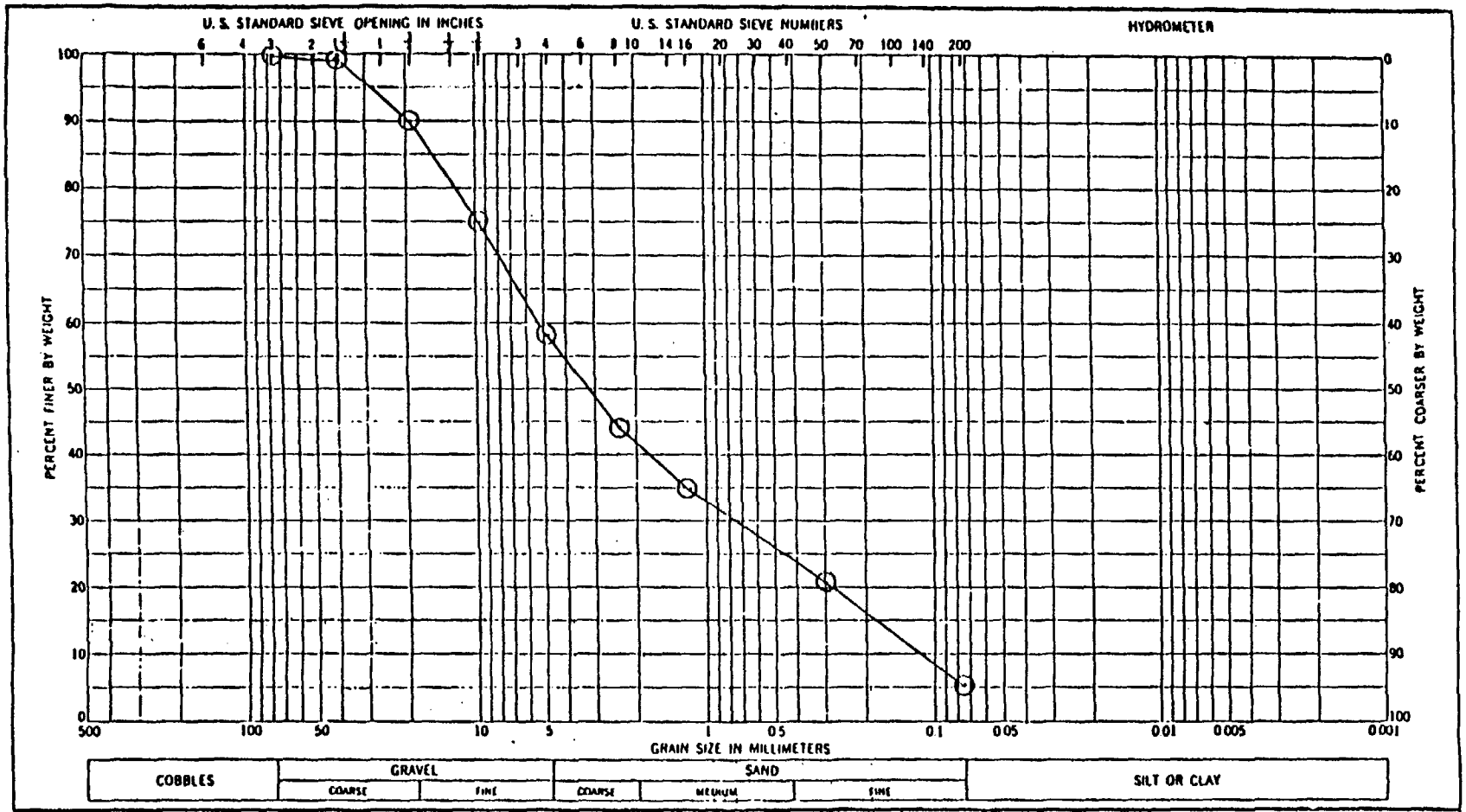
% Moisture 9.2

UNIT WEIGHT

Loose Rodded

Unit Weight (P.C.F.) _____ _____

REMARKS: SFS-3 S-2 8.0'



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
S-2	8.0'	GP-GM	7.2			

Project SURFACE FAC. SITE INVEST.
SANDIA / BECHTEL
Area A-25/400
Boring No. SFS-3
Date 5/10/94

GRADATION CURVES

ENG FORM 1 MAY 63 2087

☒ SIEVE ANALYSIS (ASTM C-138-) ☒ MOISTURE CONTENT (ASTM C-566-) ☐ UNIT WEIGHT (ASTM C-29-)	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-0020 Date May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/3/84 Tested by TJS Computed by TJS Checked by BW

Information transmitted to _____ By _____ How _____ Date _____

SIEVE ANALYSIS

U. S. STANDARD SIEVE NO.	% PASSING	SPEC. % PASSING
12"	100	
6"	100	
3"	100	Max Size 5"
1-1/2"	86	
3/4"	63	
3/8"	43	
#4	33	
#8	27	
#16	24	
#50	17	
#200	3.7	

MOISTURE CONTENT

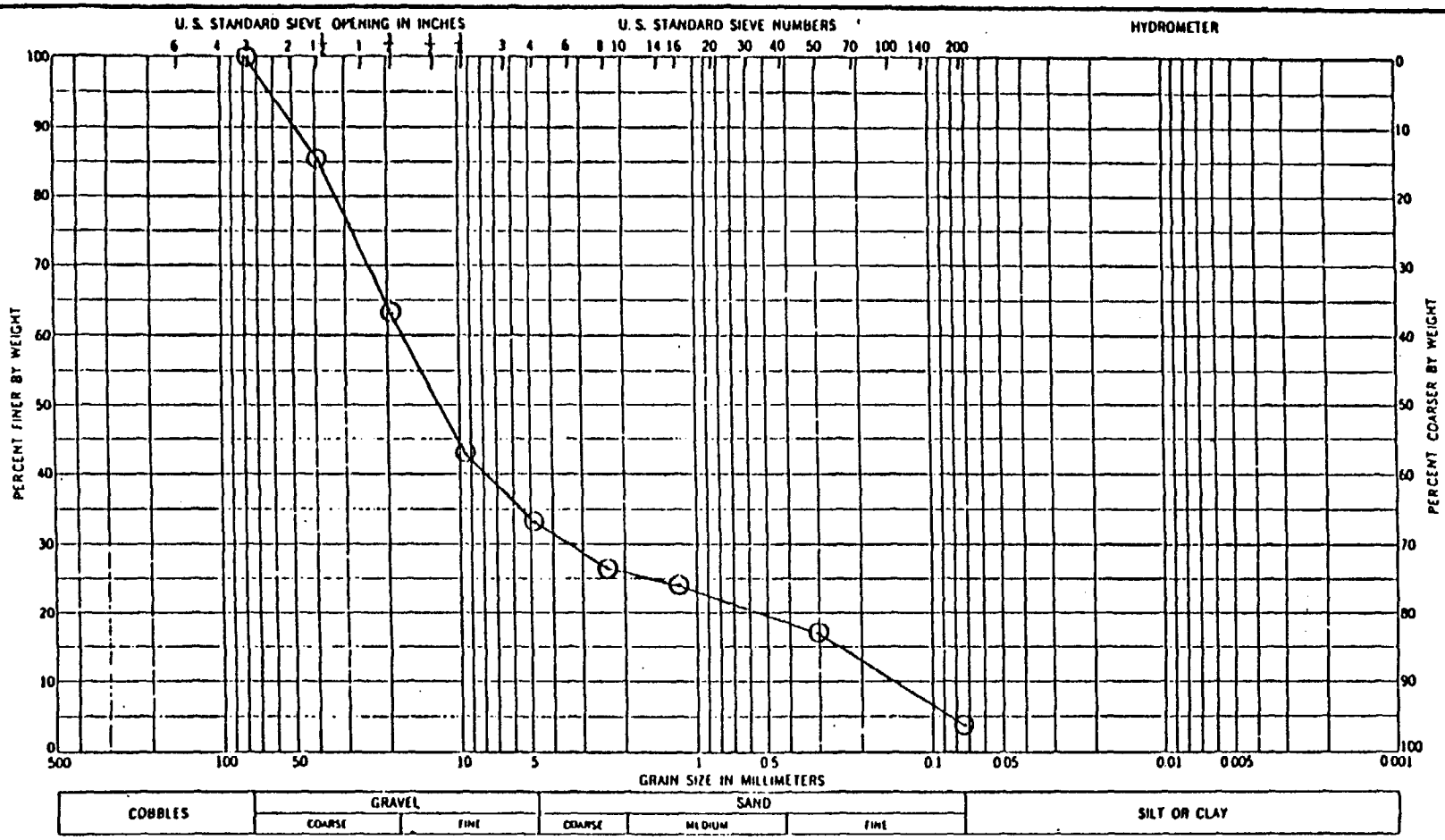
% Moisture 5.1

UNIT WEIGHT

Loose Rodded

Unit Weight (P.C.F.) _____ _____

REMARKS: SFS-3 S-3 12.0'



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
S-3	12.0'	GP	5.1			

Project SURFACE FAC. SITE INVEST.
SANDIA / BECHTEL
Area A-25/400
Boring No. SFS-3
Date 5/10/84

GRADATION CURVES

ENG FORM 1 MAY 83 2087

☒ SIEVE ANALYSIS (ASTM C-138-) ☒ MOISTURE CONTENT (ASTM C-566-) ☐ UNIT WEIGHT (ASTM C-29-)	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-001A Date May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/2/84 Tested by SL Computed by SL Checked by BW

Information transmitted to _____ By _____ How _____ Date _____

SIEVE ANALYSIS

U. S. STANDARD SIEVE NO.	% PASSING	SPEC. % PASSING
12"	100	
6"	100	
3"	74	Max Size 5"
1-1/2"	70	
3/4"	64	
3/8"	53	
#4	41	
#8	35	
#16	30	
#50	25	
#200	7.4	

MOISTURE CONTENT

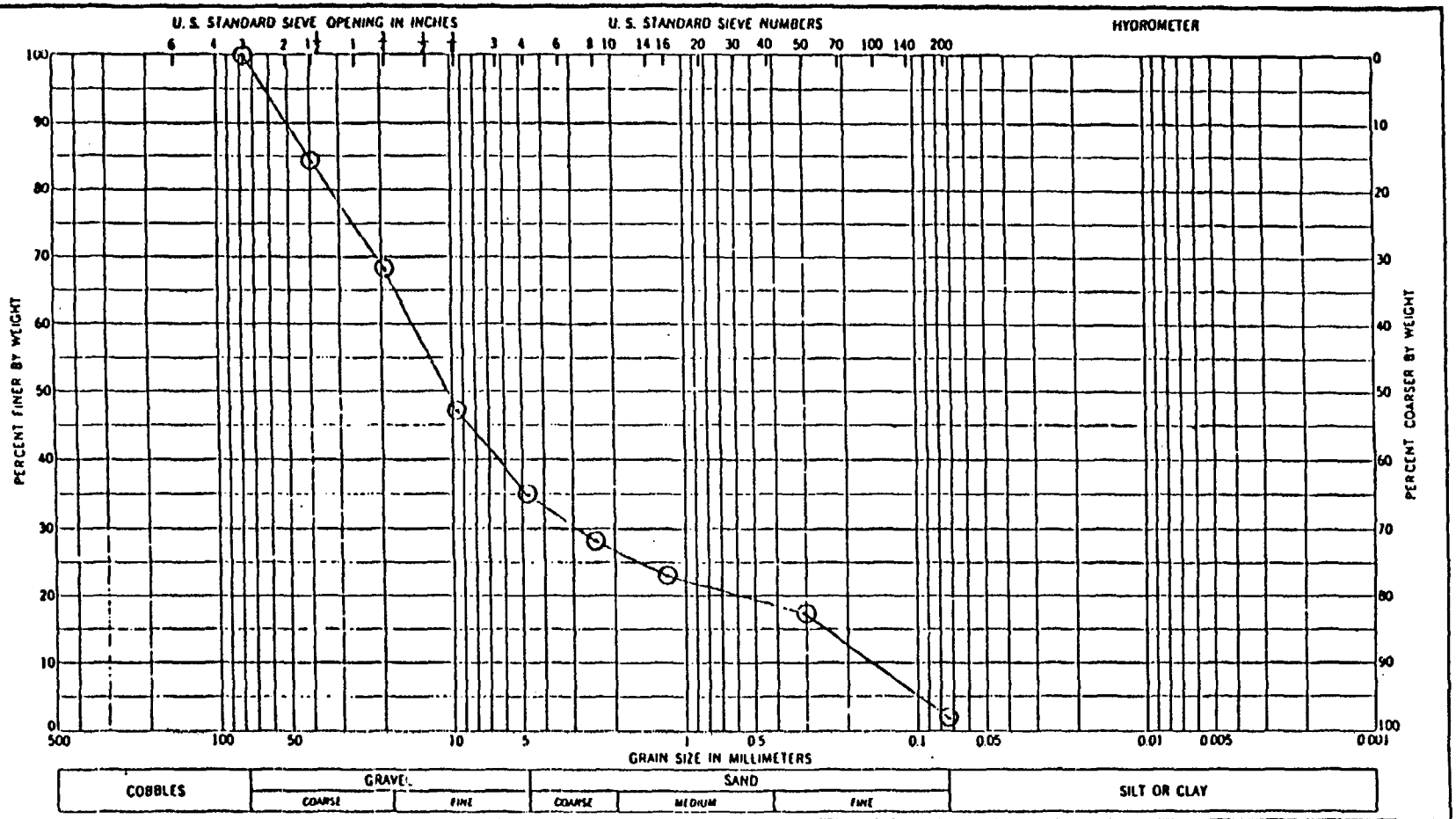
% Moisture 2.8

UNIT WEIGHT

Loose Rodded

Unit Weight (P.C.F.) _____ _____

REMARKS: SFS-4 S-1 2'-4'



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
S-1	2'-4'	GP	3.6			

Project SURFACE FAC. SITE INVEST.
SANDIA/BECHTEL
Area A-25/400
Boring No. SES-4 S-1
Date 5/10/84

GRADATION CURVES

ENG FORM 2087

☒ SIEVE ANALYSIS (ASTM C-138) ☒ MOISTURE CONTENT (ASTM C-566-) ☐ UNIT WEIGHT (ASTM C-29)	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-001E Date May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/2/84 Tested by SL Computed by SL Checked by BW

Information transmitted to _____ By _____ How _____ Date _____

SIEVE ANALYSIS

U. S. STANDARD SIEVE NO.	% PASSING	SPEC. % PASSING
12"	100	
6"	100	
3"	100	Max Size 4½"
1-1/2"	84	
3/4"	68	
3/8"	47	
#4	35	
#8	28	
#16	23	
#50	17	
#200	2.7	

MOISTURE CONTENT

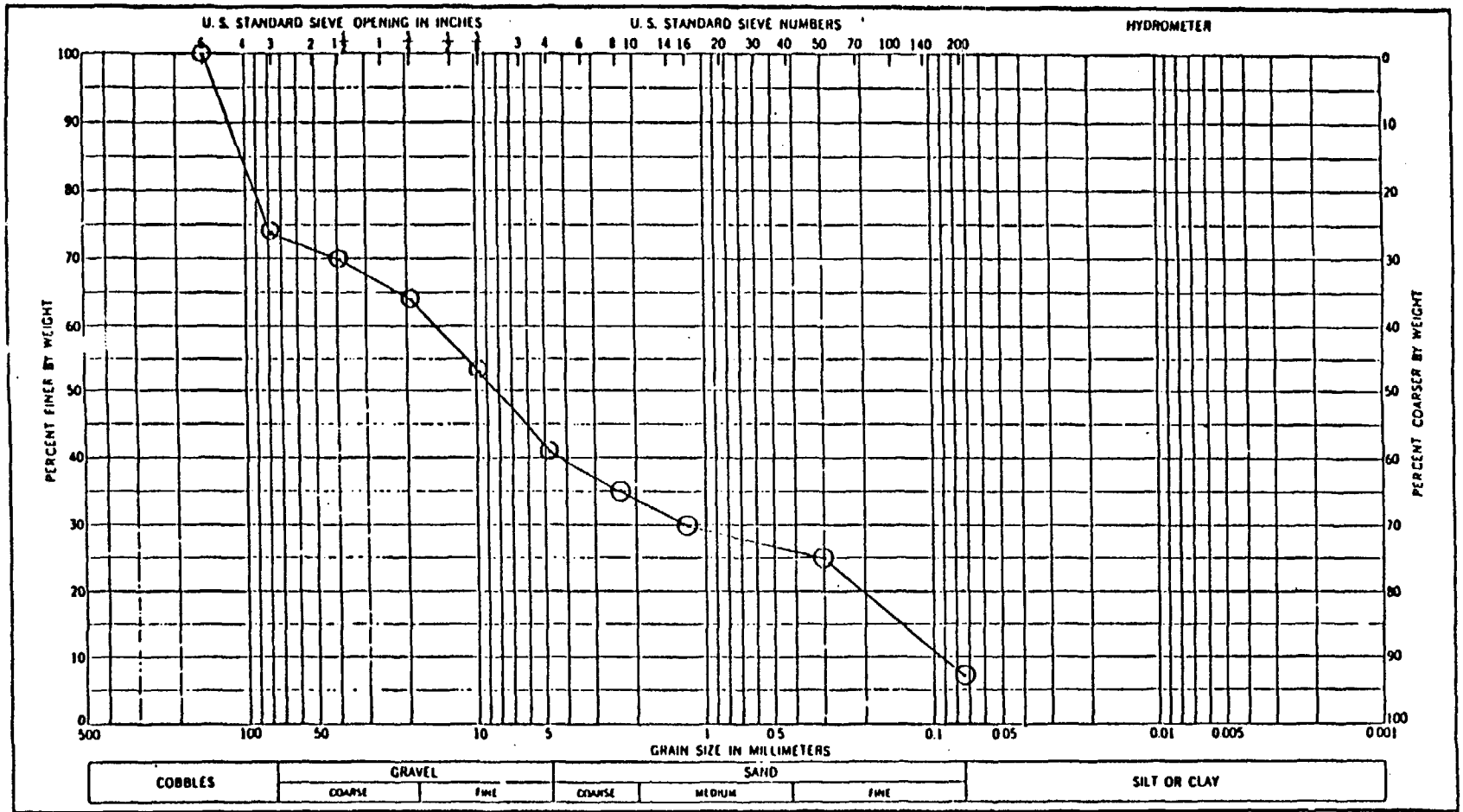
% Moisture 3.6

UNIT WEIGHT

Loose Rodded

Unit Weight (P.C.F.) _____ _____

REMARKS: SFS-4 S-2 4'-8'



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
S-2	4'-8'	GP-GM	2.8			

Project SURFACE FAC. SITE INVEST.
SANDIA / BECHTEL
Area A-25/400
Boring No. SFS-4
Date 5/10/84

GRADATION CURVES

ENG FORM 1 MAY 63 2087

☒ SIEVE ANALYSIS (ASTM C-138- .) ☒ MOISTURE CONTENT (ASTM C-566-) ☐ UNIT WEIGHT (ASTM C-29 ')	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-004 Date May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/4/84 Tested by TJS Computed by TJS Checked by BW

Information transmitted to _____ By _____ How _____ Date _____

SIEVE ANALYSIS

U. S. STANDARD SIEVE NO.	% PASSING	SPEC. % PASSING
12"	100	
6"	100	
3"	69	Max Size 4½"
1-1/2"	60	
3/4"	44	
3/8"	36	
#4	30	
#8	25	
#16	22	
#50	17	
#200	4.2	

MOISTURE CONTENT

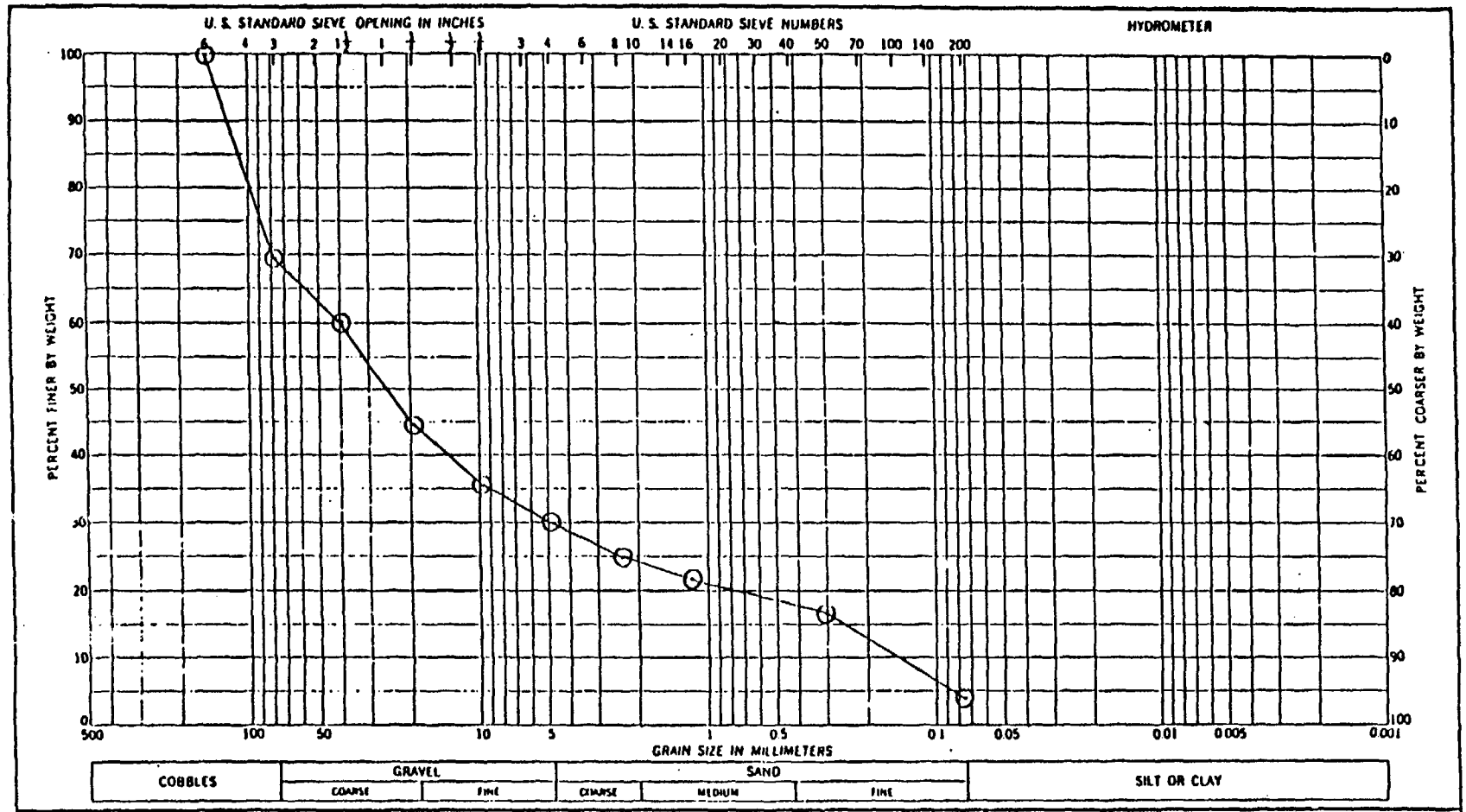
% Moisture 6.5

UNIT WEIGHT

Loose Rodded

Unit Weight (P.C.F.) _____ _____

REMARKS: SFS-5 S-1 2'-4'



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
S-1	2'-4'	GP	6.5			

Project SURFACE FAC. SITE INVEST.
SANDIA/BECHTEL
Area A-25/400
Boring No. SFS-5
Date 5/10/84

GRADATION CURVES

ENG FORM 1 MAY 83 2087

☒ SIEVE ANALYSIS (ASTM C-138 . .) ☒ MOISTURE CONTENT (ASTM C-566- .) ☐ UNIT WEIGHT (ASTM C-29- .)	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-00- Date May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/4/84 Tested by TJS Computed by TJS Checked by BW

Information transmitted to _____ By _____ How _____ Date _____

SIEVE ANALYSIS

U. S. STANDARD SIEVE NO.	% PASSING	SPEC. % PASSING
12"	100	
6"	100	Max Size 5"
3"	87	
1-1/2"	63	
3/4"	48	
3/8"	35	
#4	25	
#8	20	
#16	17	
#50	13	
#200	3.2	

MOISTURE CONTENT

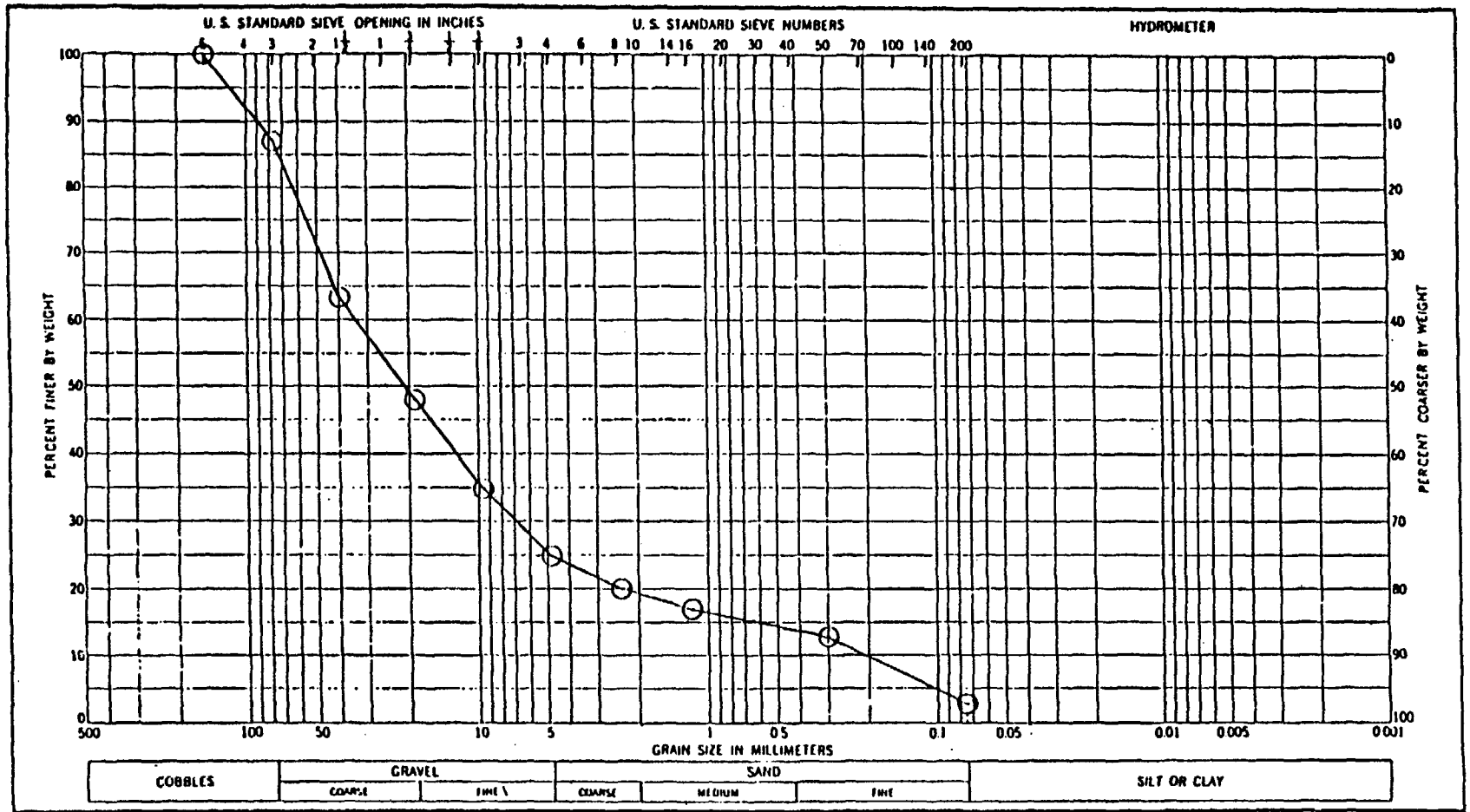
% Moisture 4.6

UNIT WEIGHT

Loose Rodded

Unit Weight (P.C.F.) _____ _____

REMARKS: SFS-5 S-2 6'



Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI
S-2	6.0'	GP				

Project SURFACE FAC. SITE INVEST
SANDIA/BECHTEL
Area A-25/400
Boring No. SFS-5
Date 5/10/84

GRADATION CURVES

ENG FORM 1 MAY 63 2087

☒ SIEVE ANALYSIS (ASTM C-138- .) ☒ MOISTURE CONTENT (ASTM C-566-) ☐ UNIT WEIGHT (ASTM C-29-)	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-004 Date May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/4/84 Tested by TJS Computed by TJS Checked by BW

Information transmitted to _____ By _____ How _____ Date _____

SIEVE ANALYSIS

U. S. STANDARD SIEVE NO.	% PASSING	SPEC. % PASSING
12"	100	
6"	100	
3"	100	Max Size 4½"
1-1/2"	84	
3/4"	65	
3/8"	51	
#4	39	
#8	31	
#16	27	
#50	21	
#200	4.6	

MOISTURE CONTENT

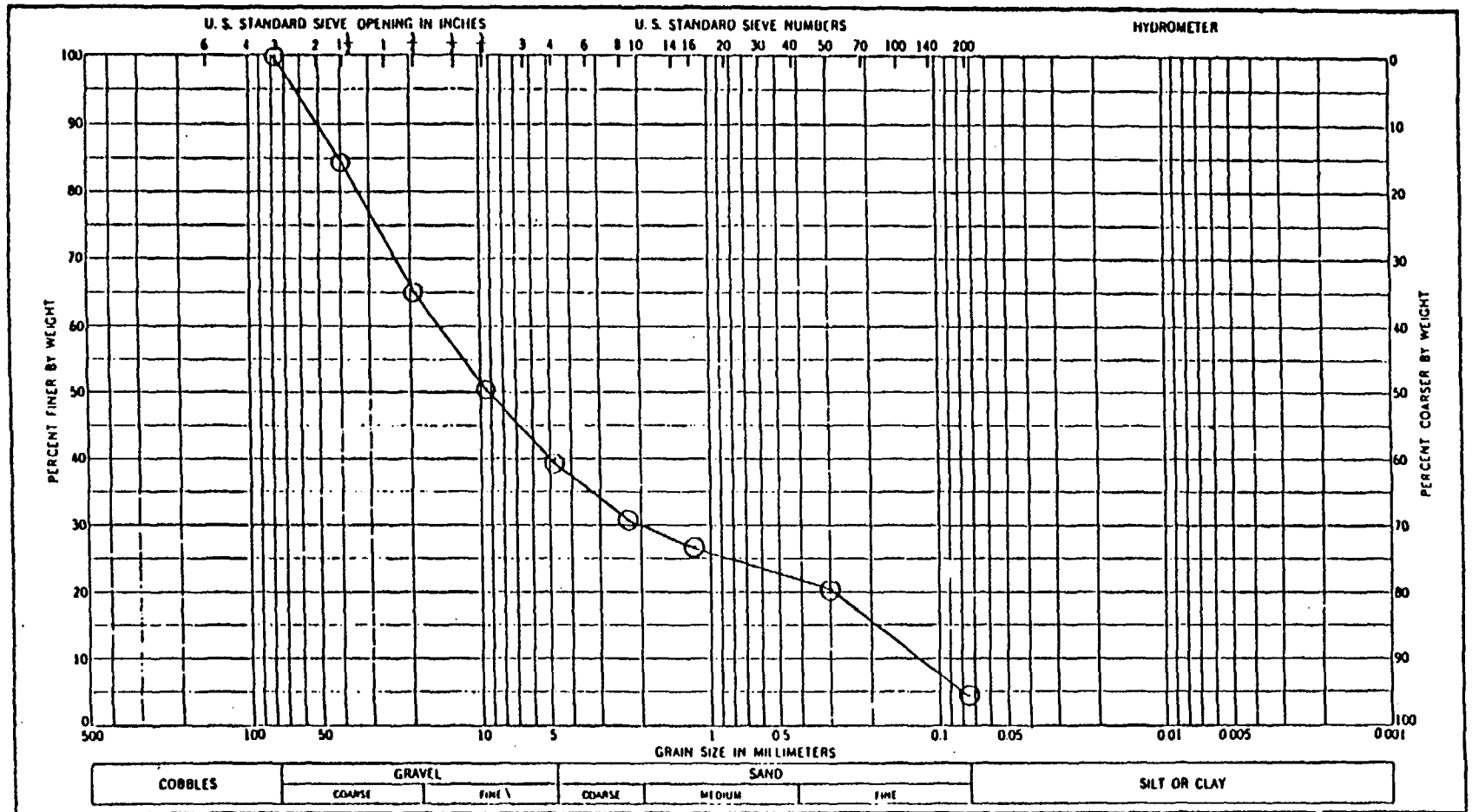
% Moisture 3.7

UNIT WEIGHT

Loose Rodded

Unit Weight (P.C.F.) _____ _____

REMARKS: SFS-5 S-3 12.0'



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
S-3	12.0	GP	3.7			

Project SURFACE FAC. SITE INVEST.
SANDIA/BECHTEL
Area A-25/400
Boring No. SFS-5
Date 5/10/84

GRADATION CURVES

ENG FORM 1 MAY 63 2087

☒ SIEVE ANALYSIS (ASTM C-138-) ☒ MOISTURE CONTENT (ASTM C-566-) ☐ UNIT WEIGHT (ASTM C-29-)	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-0059 Date May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/4/84 Tested by TJS Computed by TJS Checked by BW

Information transmitted to _____ By _____ How _____ Date _____

SIEVE ANALYSIS

U. S. STANDARD SIEVE NO.	% PASSING	SPEC. % PASSING
12"	100	
6"	100	Max Size 5"
3"	58	
1-1/2"	36	
3/4"	32	
3/8"	26	
#4	22	
#8	19	
#16	16	
#50	12	
#200	3.9	

MOISTURE CONTENT

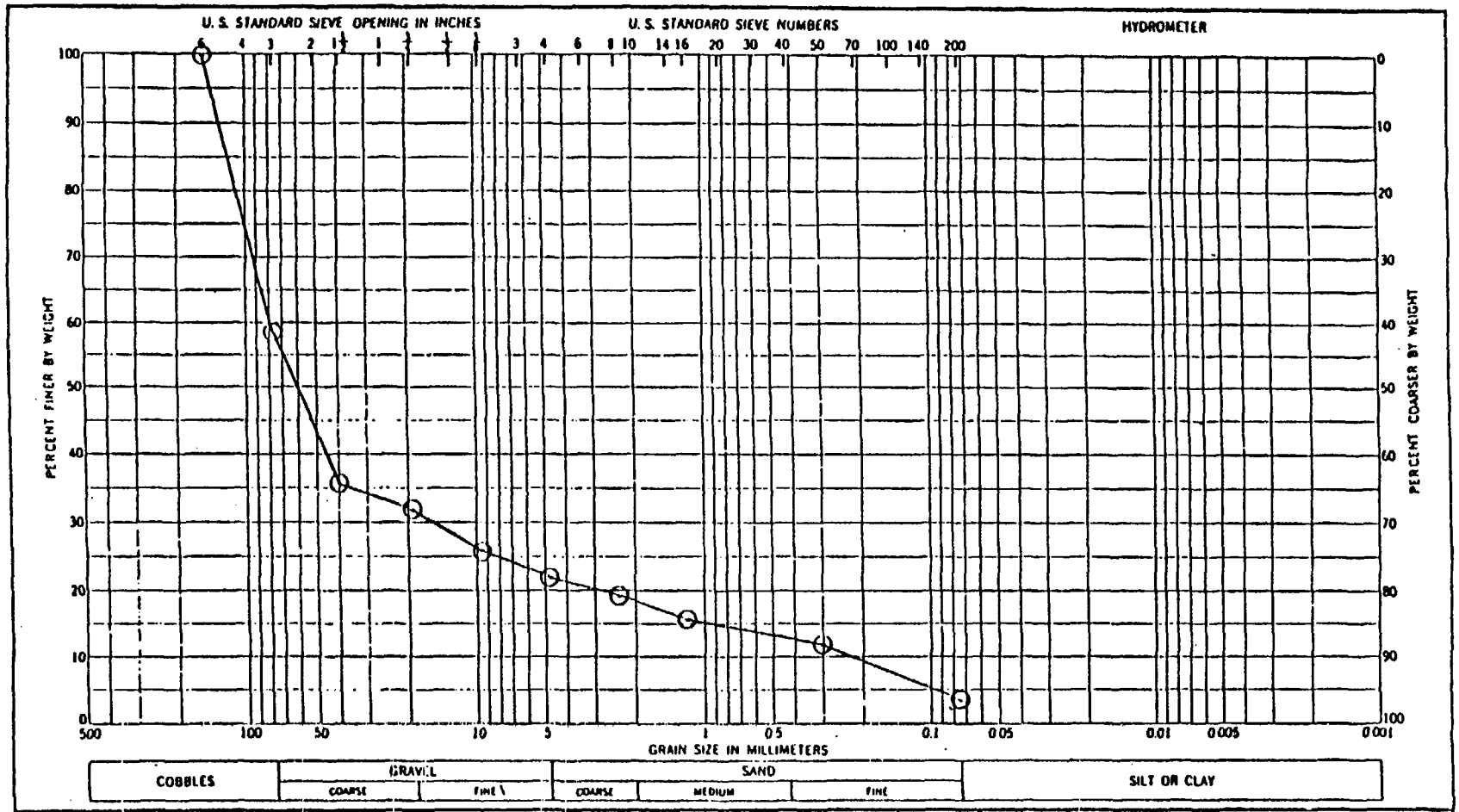
% Moisture 2.2

UNIT WEIGHT

Loose Rodded

Unit Weight (P.C.F.) _____ _____

REMARKS: SFS-7 S-1 3.0'



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
S-1	3.0'	GP	2.2			

Project SURFACE FAC. SITE INVGST. SANDIA / BECHTEL

Area A-25/400

Borehole No SFS-7

Date

GRADATION CURVES

ENG FORM 2087

☒ SIEVE ANALYSIS (ASTM C-138-) ☒ MOISTURE CONTENT (ASTM C-566- .) ☐ UNIT WEIGHT (ASTM C-29)	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-001 Date May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/4/84 Tested by TJS Computed by TJS Checked by BW

Information transmitted to _____ By _____ How _____ Date _____

SIEVE ANALYSIS

U. S. STANDARD SIEVE NO.	% PASSING	SPEC. % PASSING
12"	100	
6"	100	
3"	100	Max Size 4½"
1-1/2"	66	
3/4"	45	
3/8"	34	
#4	29	
#8	24	
#16	20	
#50	14	
#200	3.0	

MOISTURE CONTENT

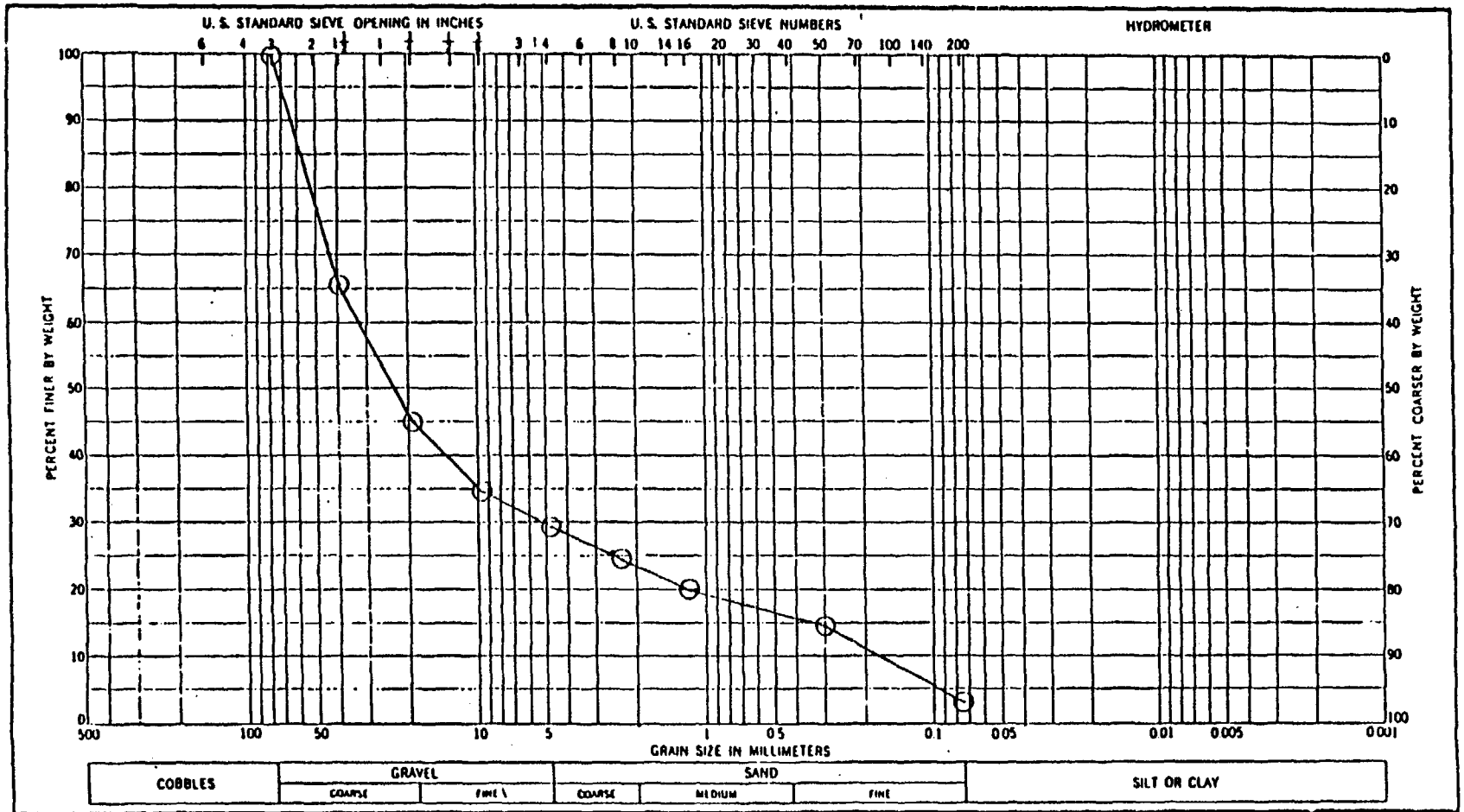
% Moisture 4.2

UNIT WEIGHT

Loose Rodded

Unit Weight (P.C.F.) _____ _____

REMARKS: SFS-7 S-2 7.0'



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
S-2	7.0'	GP	4.2			

Project SITE FAC. SURFACE INVEST
SANDIA/BECHTEL
Area A-25/400
Boring No. SFS-7
Date 5/10/84

GRADATION CURVES

ENG FORM 1 MAY 63 2087

☒ SIEVE ANALYSIS (ASTM C-138-) ☒ MOISTURE CONTENT (ASTM C-566-) ☐ UNIT WEIGHT (ASTM C-29-)	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-003 Date May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/4/84 Tested by TJS Computed by TJS Checked by BW

Information transmitted to _____ By _____ How _____ Date _____

SIEVE ANALYSIS

U. S. STANDARD SIEVE NO.	% PASSING	SPEC. % PASSING
12"	100	
6"	100	
3"	75	
1-1/2"	53	
3/4"	41	
3/8"	35	
#4	27	
#8	20	
#16	16	
#50	12	
#200	1.7	

MOISTURE CONTENT

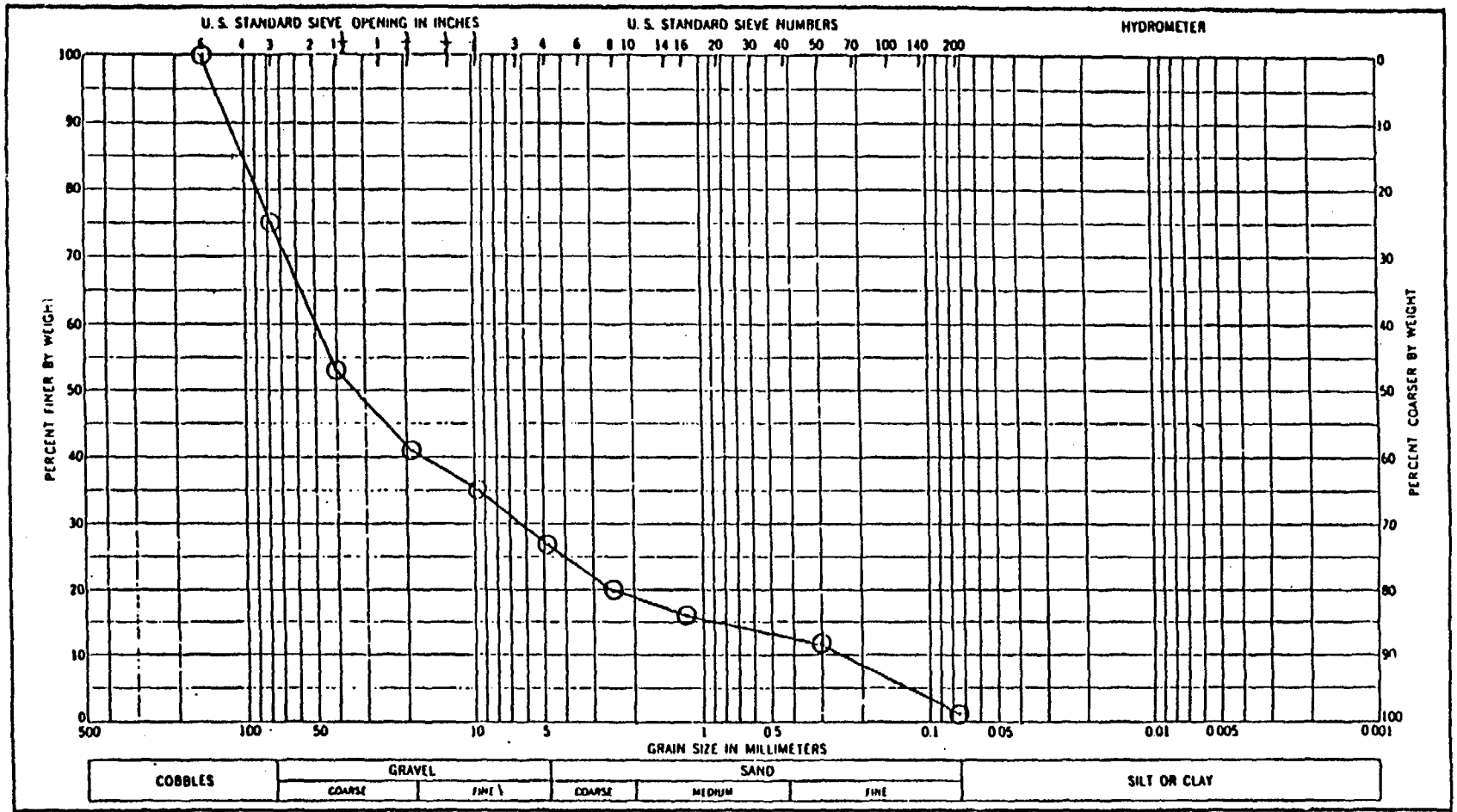
% Moisture 4.2

UNIT WEIGHT

Loose Rodded

Unit Weight (P.C.F.) _____ _____

REMARKS: SFS-7 S-3 11.0'



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
S-3	11.0'	GP	4.2			

Project SITE FAC. SURFACE INVEST. SANDIA/BECHTEL

Area A-25/400

Boring No. SFS-7

Date 5/10/84

GRADATION CURVES

ENG FORM 1 MAY 62 2087

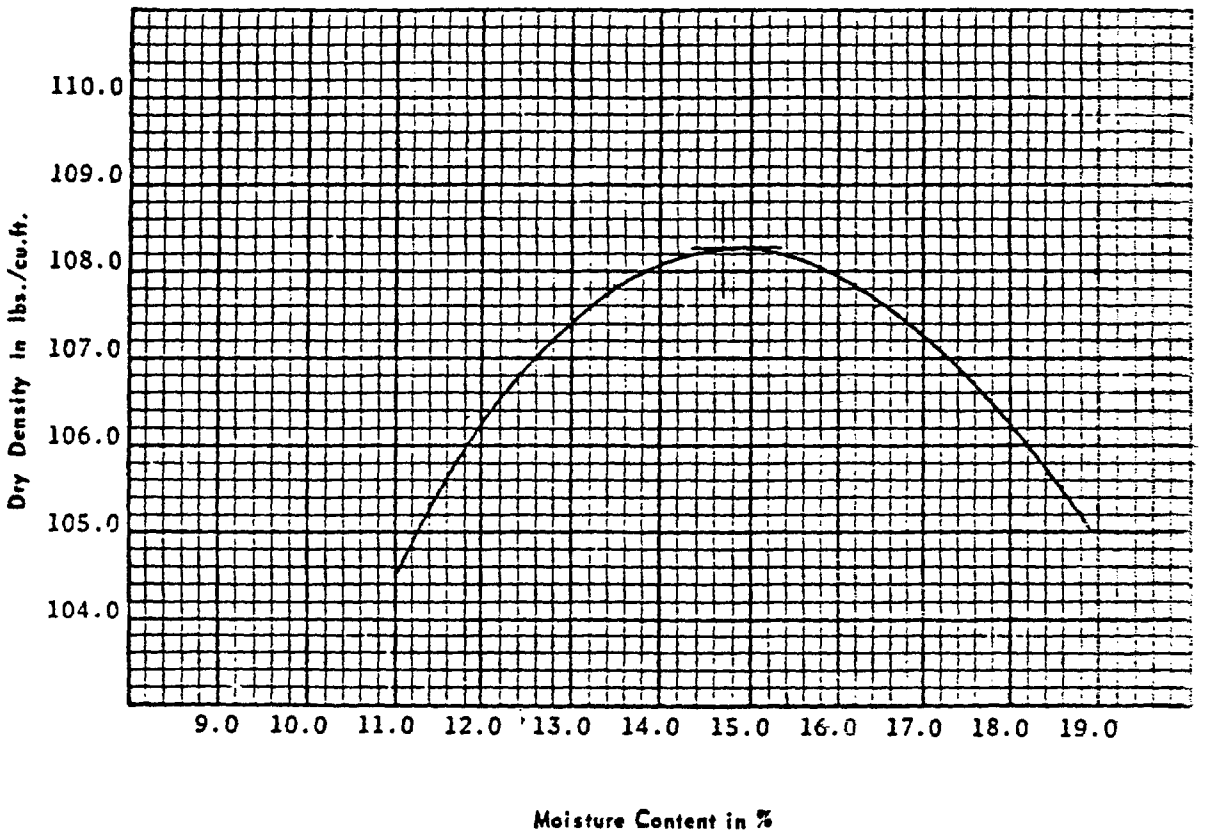
COMPACTION TEST ASTM D 1557 METHOD D	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-002A DATE May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/3/84 Tested by SL Computed by SL Checked by RW

Information transmitted to _____ By _____ How _____ Date _____



Max. Density = 108.1 lbs./cu. ft.

Opt. Moisture = 14.7 %

REMARKS: SFS #3 S-1 5.5'
NOTE: 33% retained on 3/4", proctor invalid.

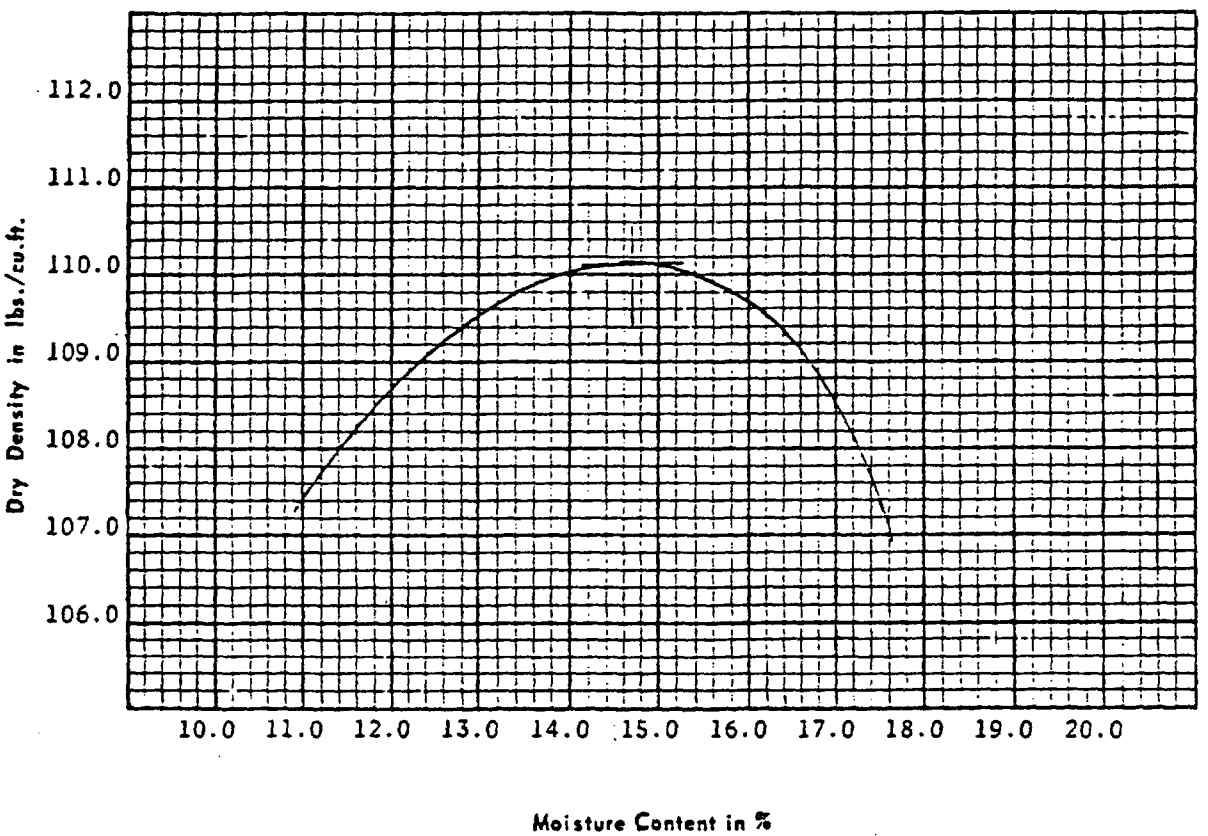
COMPACTION TEST ASTM D 1557 METHOD D	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-002B DATE May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/3/84 Tested by SL Computed by SL Checked by BW

Information transmitted to _____ By _____ How _____ Date _____



Max. Density = 110.1 lbs./cu. ft.

Opt. Moisture = 14.7 %

REMARKS: SFS #3 S-2 8.0'

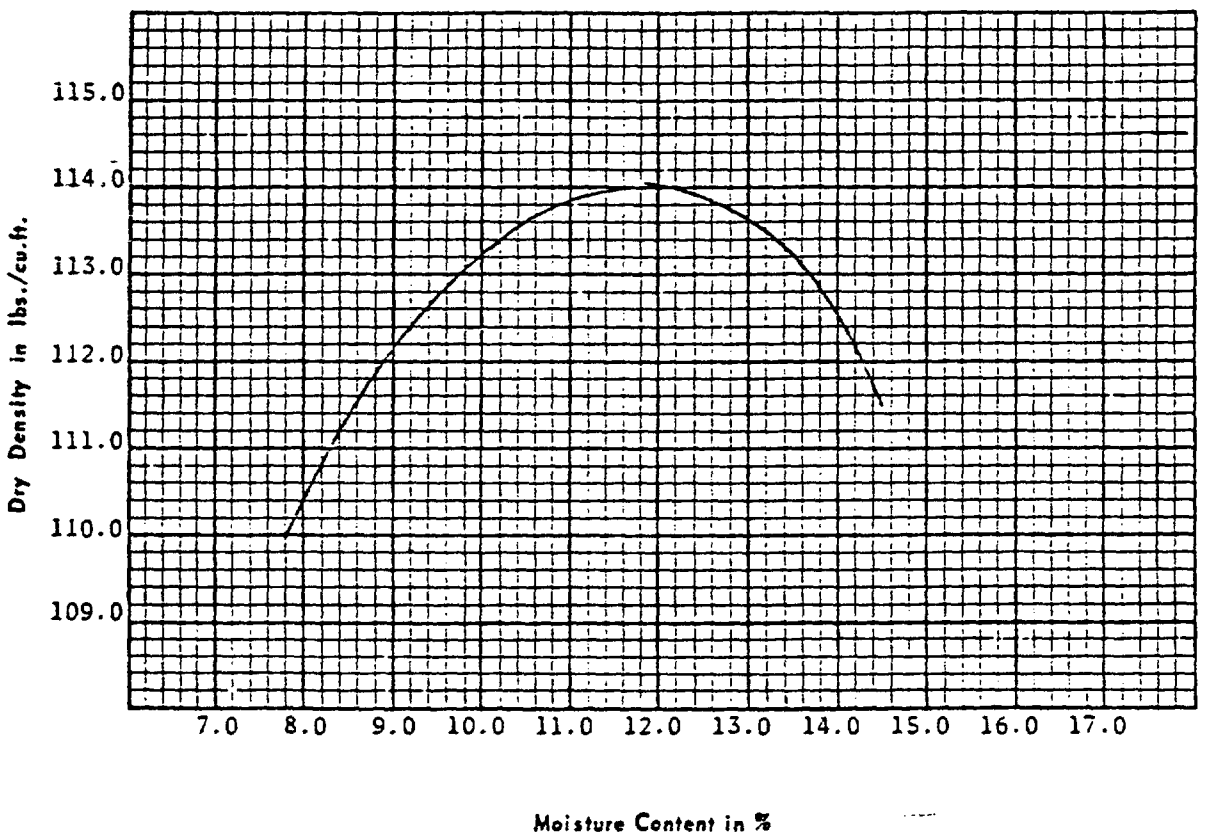
COMPACTION TEST ASTM D 1557 METHOD D	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-002C DATE May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtal Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/3/84 Tested by SL Computed by SL Checked by BW

Information transmitted to _____ By _____ How _____ Date _____



Max. Density = 114.0 lbs./cu. ft.

Opt. Moisture = 12.0 %

REMARKS: SFS-3 S-3 12.0'

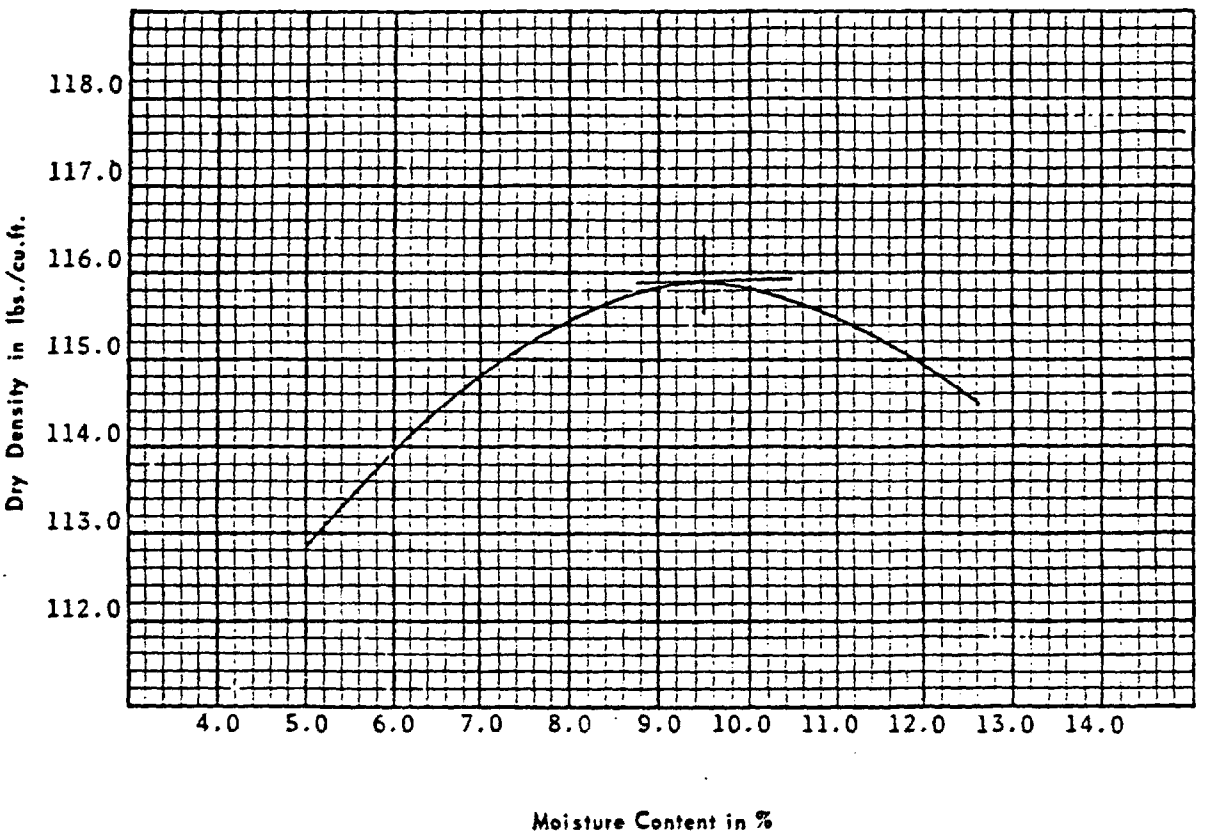
COMPACTION TEST ASTM D 1557 METHOD D	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-001B DATE May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by CK/SL

Date Sampled 5/2/84 Tested by SL Computed by SL Checked by BW

Information transmitted to _____ By _____ How _____ Date _____



Max. Density = 115.9 lbs./cu. ft.

Opt. Moisture = 9.5 %

REMARKS: SFS-4 S-2 4'-8'
NOTE: 32% retained on 3/4" sieve, proctor invalid.

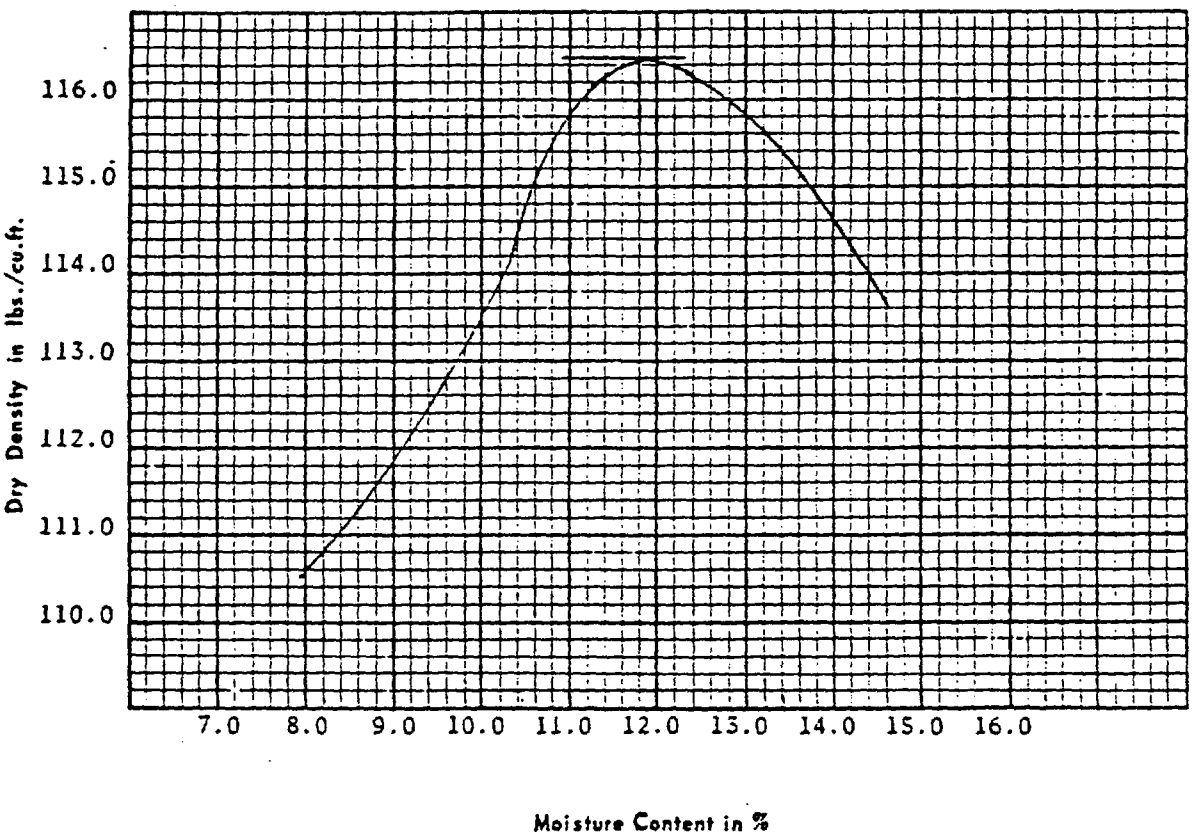
COMPACTION TEST ASTM D 1557 METHOD D	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. 84-004E DATE May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtel Material Native

Project Surface Facility Site Inv Location Area 25 Sampled by SL

Date Sampled 5/4/84 Tested by TJS Computed by TJS Checked by BW

Information transmitted to _____ By _____ How _____ Date _____



Max. Density = 116.5 lbs./cu. ft.

Opt. Moisture = 11.8 %

REMARKS: SFS #5 S-2 6.0'
NOTE: 52% retained on 3/4", proctor invalid.

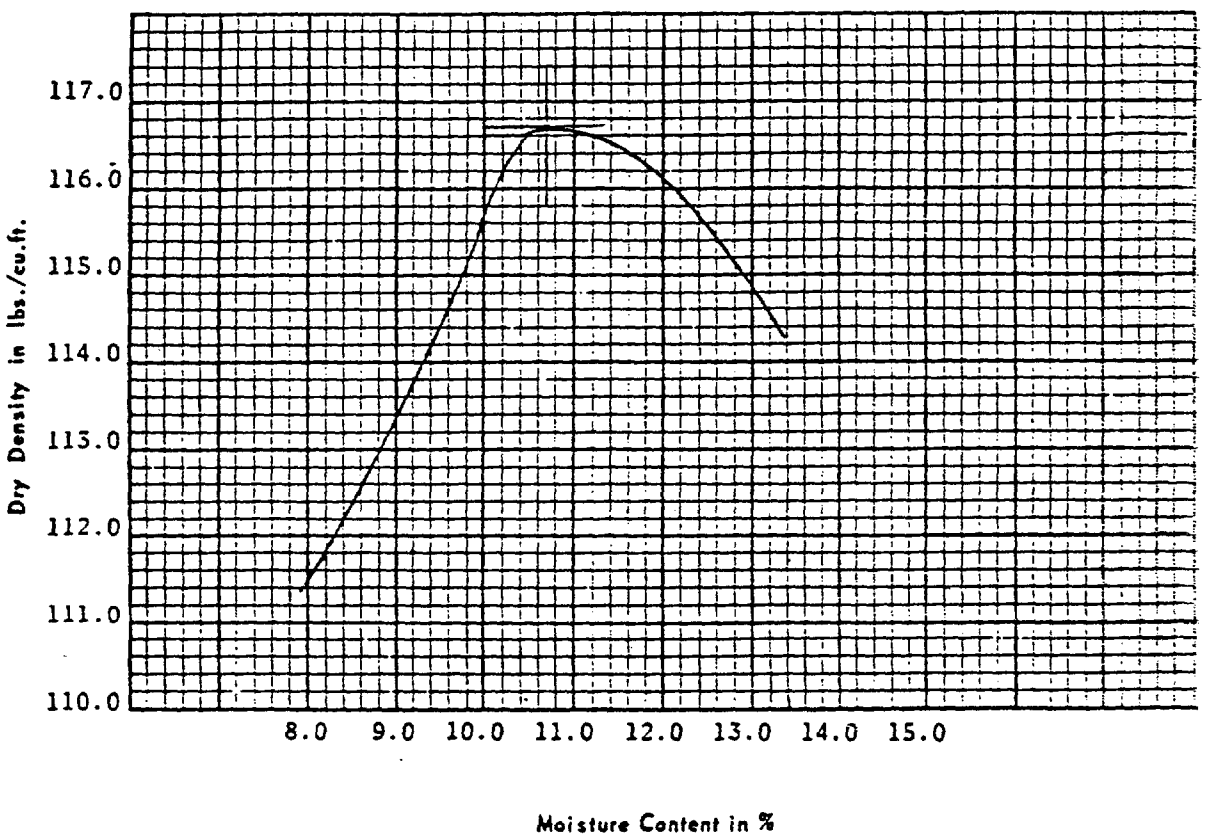
COMPACTION TEST ASTM D 1557 METHOD D	HOLMES & NARVER, INC. MATERIALS TESTING LABORATORY NEVADA TEST SITE	I.D. NO. 612440 LAB NO. [illegible] 004L DATE May 16, 1984

Requested by J. Neal User/Agency Sandia/Bechtal Material Native

Project Surface Facility Site Inv. Location Area 25 Sampled by [illegible]

Date Sampled 5/4/84 Tested by TJS Computed by TJS Checked by [illegible]

Information transmitted to _____ By _____ How _____ Date _____



Max. Density = 116.7 lbs./cu. ft.

Opt. Moisture = 10.7 %

REMARKS: SFS-5 S-3 12.0'
NOTE: 35% retained on 3/4", proctor invalid.

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