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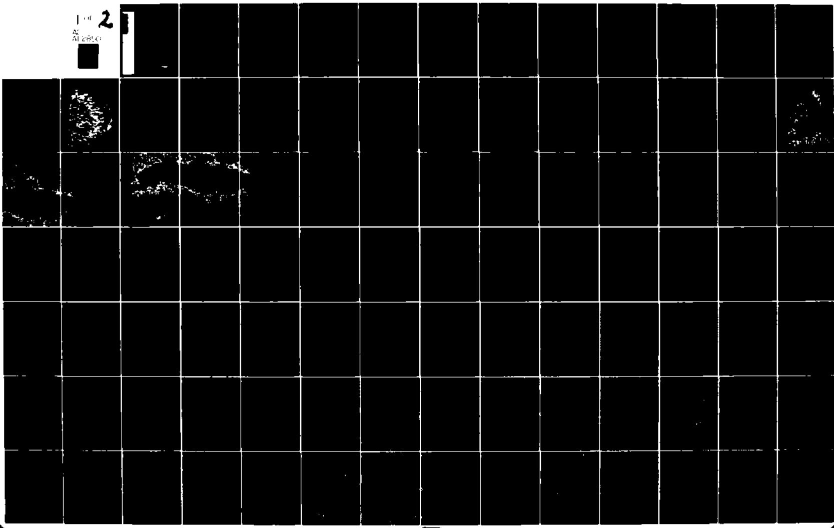

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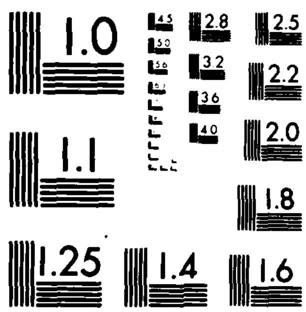

MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

VERIFICATION STUDY
DRY LAKE VALLEY, NEVADA
VOLUME I - SYNTHESIS

PREPARED FOR
BALLISTIC MISSILE OFFICE (BMO)
NORTON AIR FORCE BASE, CALIFORNIA

FUGRO NATIONAL, INC.
Consulting Engineers and Geologists

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MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

VERIFICATION STUDY - DRY LAKE VALLEY, NEVADA

VOLUME I - SYNTHESIS

Prepared for:

U.S. Department of the Air Force
Ballistic Missile Office (BMO)
Norton Air Force Base, California 92409

Prepared by:

Fugro National, Inc.
3777 Long Beach Boulevard
Long Beach, California 90807

14 March 1980

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents results of geotechnical studies which were conducted in Dry Lake Valley, Nevada. Included are basin-fill characteristics, construction considerations, geologic setting, soils, terrain, and water.

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FOREWORD

This report was prepared for the Department of the Air Force, Ballistic Missile Office (BMO), in compliance with Contract No. F04704-80-C-0006, CDRL Item 004A2. It contains an evaluation of the suitability of Dry Lake Valley, Nevada, for siting the MX Land Mobile Advanced ICBM system and presents the geological, geophysical, and soil engineering data upon which the evaluation is based.

This report is one of several being prepared to describe Verification studies in the Nevada-Utah region. The Verification studies are the final phase of a site-selection process which was begun in 1977. The Verification objectives are to define sufficient suitable area for deployment of the MX system. Previous phases of the site selection process were Screening, Characterization, and Ranking. In preparing this report, it has been assumed that the reader will be familiar with the previous studies.

The report contains discussions relative to the horizontal and vertical shelter basing modes.

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LIST OF DRAWINGS

1.0 INTRODUCTION

1.1 PURPOSE AND BACKGROUND

This report presents the results of geotechnical studies which were conducted in Dry Lake Valley, Nevada, during the summer of 1977 and fall, 1979. The results of work done in 1977 as part of geotechnical Characterization Studies were summarized in report FN-TR-26e. The Supplemental field work, in 1979, was done so that the data base in Dry Lake Valley would be comparable to those in other valleys studied during the Verification Program, which started in 1978.

The Verification Program is the final phase of a site selection process which started in 1977. The previous phases were called Screening, Characterization, and Ranking. The objective of the site selection process is to identify and rank geotechnically suitable areas which are sufficiently large for deploying the Missile-X (MX), an advanced intercontinental ballistic missile system. The Verification program uses field studies to refine and improve confidence in suitable area boundaries that were drawn, mainly from literature, during the Screening studies. Table 1-1 summarizes the investigative techniques being employed during Verification studies.

The site selection schedule and the Fugro National, Inc. (FNI) Report covering each phase are shown in the diagram on page 3.

In FY 79, Verification Studies were made in seven valleys (Whirlwind, Snake East, Hamlin, White River, Garden-Coal,

OBJECTIVES → VERIFICATION OF INTERMEDIATE/FINE SCREENING SUITABLE

DATA FOR EVALUATIONS → TERRAIN PARAMETERS | 50'/150' DEPTH TO ROCK | 5 DEPTH TO

FIELD TECHNIQUES AND APPLICATIONS →

TERRAIN PARAMETERS

Geologic mapping

- Identification and limits of areas with slopes greater than 10% grade
- Identification and limits of areas with high incidence of 10% slopes (rolling terrain)

50'/150' DEPTH TO ROCK

Geologic mapping

- Surface limits of rock
- Subsurface limits of rock from topographic and geologic interpretation
- Geomorphic expression and erosion history

Seismic refraction surveys

- Subsurface projection of rock limits
- Delineation of rock from high (> 7000 fps) p-wave velocities

Borings

- Occurrence of rock

Gravity profiles (DMA)

- Overall basin shape and relationships
- Range-bounding faults

Existing data

- Published literature

5 DEPTH TO

Existing da

- Available interpret

Borings

- Occurrenc

Electrical seismic ref

- Provide s to suppor absence c

Geologic ma

- Obtain wa wells enc

TABLE AREA

CHARACTERISTICS OF BASIN FILL

50'/150'
EPTH TO GROUND WATER

ting data

- vailable well records and nterpretation

ngs

- ccurrence of ground water

trical resistivity/*
mic refraction surveys

- rovide supplemental data o support presence or bsence of ground water

ogic mapping

- btain water depths from ells encountered in field

EXTENT AND
CHARACTERISTICS OF SOILS

Geologic mapping

- Extent of surficial soil units
- Surficial soil types

Borings

- Identification of subsurface soil types
- In situ soil density and consistency
- Samples for laboratory testing

Trenches, test pits, and surficial samples

- Identification of surface and subsurface soil types
- Degree of induration and cementation of soils
- In situ moisture and density of soils
- Samples for laboratory testing

Cone penetrometer tests

- In situ soil strength

Laboratory tests

- Physical properties
- Engineering properties - shear strength, compressibility
- Chemical properties

GEOPHYSICAL PROPERTIES

Seismic refraction surveys

- Compressional wave velocities

Electrical resistivity * surveys

- Electrical conductivity of soils
- Layering of soil

ROAD DESIGN DATA

Trenches, test pits, and Surficial samples

- Identification of soil types
- In situ soil density and moisture
- Thickness of low strength surficial soil

Cone penetrometer tests

- In situ soil strength
- Thickness of low strength surficial soils

Laboratory tests

- Physical properties
- Compaction and CBR data
- Suitability of soils for use as road subgrade, subbase or base

Existing data

- Suitability of soils for use as road subgrade, subbbase, or base
- Behavior of compacted soils

Bo

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* There were no electrical resistivity measureme

OF BASIN FILL → RECOMMENDATIONS FOR FUTURE VERIFICATION STUDIES

ROAD DESIGN DATA

Trenches, test pits, and Surficial samples

- Identification of soil types
- In situ soil density and moisture
- Thickness of low strength surficial soil

Cone penetrometer tests

- In situ soil strength
- Thickness of low strength surficial soils

Laboratory tests

- Physical properties
- Compaction and CBR data
- Suitability of soils for use as road subgrade, subbase or base

Existing data

- Suitability of soils for use as road subgrade, subbbase, or base
- Behavior of compacted soils

EXCAVATABILITY AND STABILITY

Borings

- Subsurface soil types
- Presence of cobbles and boulders
- In situ density of subsurface soils
- Stability of vertical walls

Trenches and test pits

- Subsurface soil types
- Subsurface soil density and cementation
- Stability of vertical walls
- Thickness of low strength surficial soils
- Presence of cobbles and boulders

Laboratory tests

- Physical properties
- Engineering properties

Geologic mapping

Distribution of soil types

Seismic refaction surveys

- Excavatability

re no electrical resistivity measurements made in Dry Lake Valley

3

FIELD TECHNIQUES VERIFICATION STUDIES NEVADA-UTAH	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	TABLE 1-1

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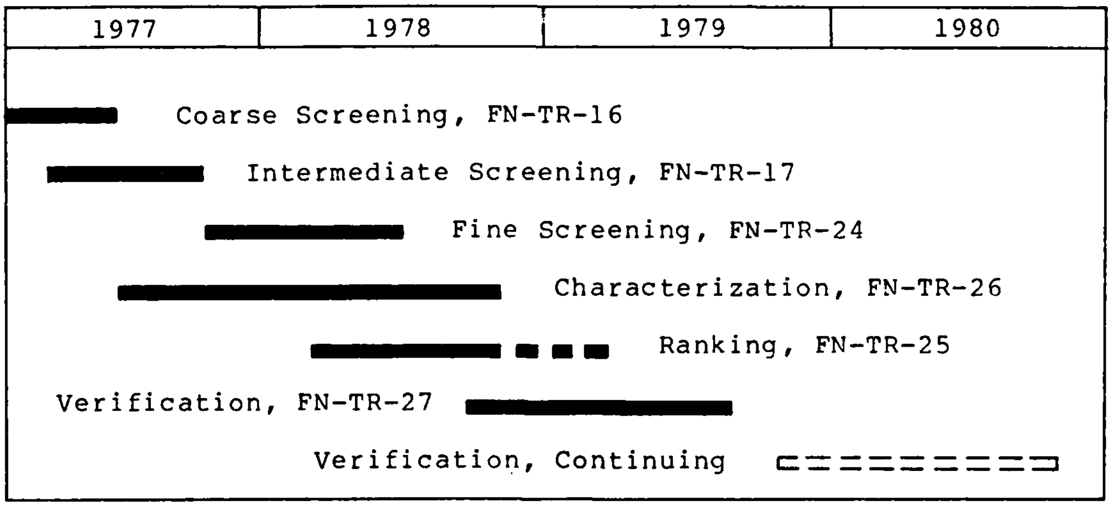

Reveille-Railroad, and Big Smoky). The results of the studies were summarized in report FN-TR-27, Volumes IA and IB. The geotechnical data for each valley were presented in separate volumes, numbered II to VIII, respectively. Beginning with Dry Lake Valley, a separate two-volume report will be issued for each valley studied. They will be numbered in the series, FN-TR-27-xx-I, or II, for the Nevada-Utah region. The "xx" will be replaced by an abbreviation assigned to identify the valley. Volume I of these reports will contain a synthesis of the investigation and Volume II will be a compilation of the geotechnical data. Figure 1-1 shows the valleys for which verification reports are presently available and Drawing 1-1 shows the configuration of useable area as of 27 February 1980.

1.2 VERIFICATION OBJECTIVES

The Verification studies have two major objectives:

1. Verify and refine suitable area boundaries for horizontal and vertical shelter basing modes.

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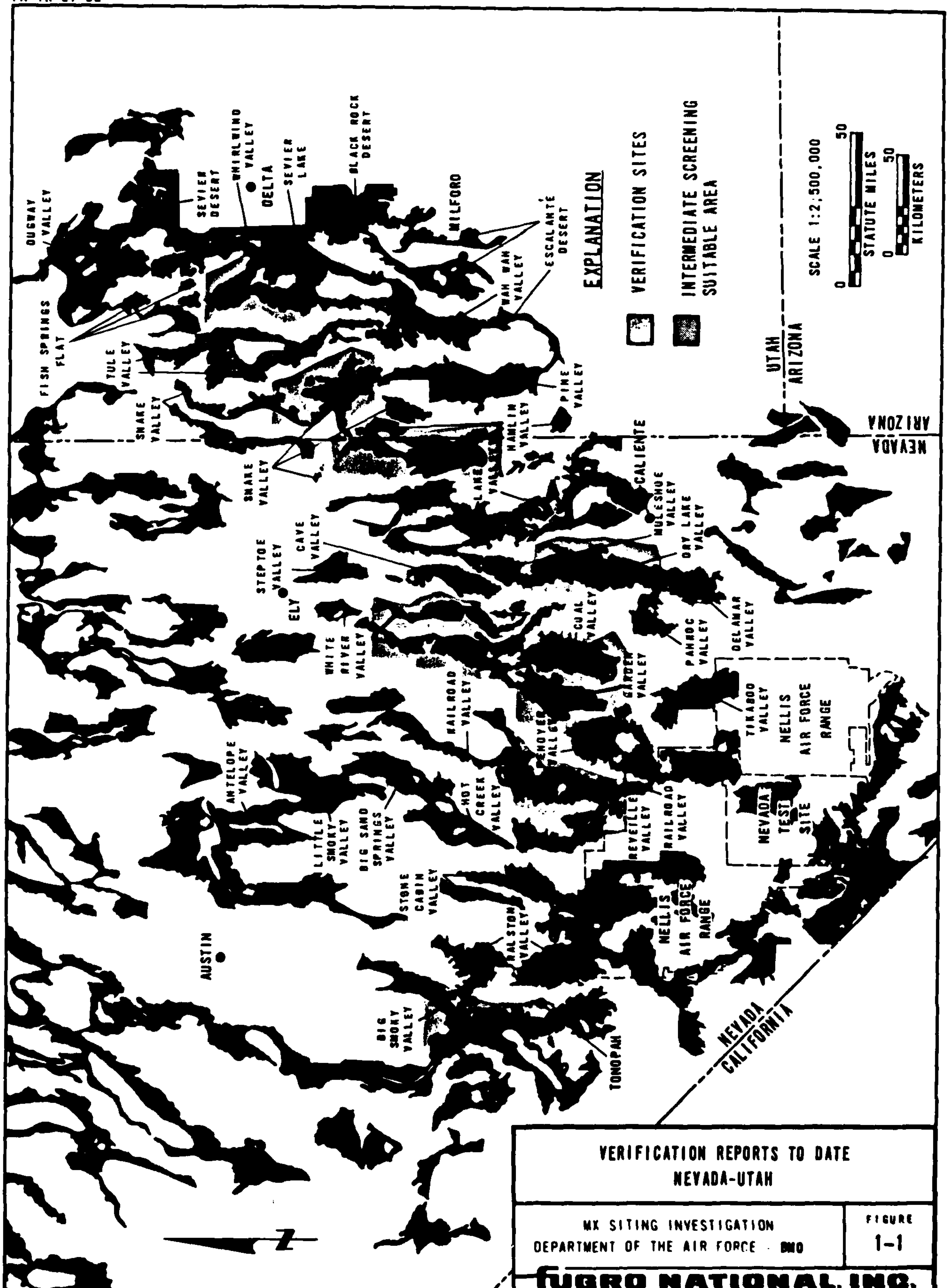

VERIFICATION REPORTS TO DATE
NEVADA-UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE 1-1

FUGRO NATIONAL, INC.

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2. Provide preliminary physical and engineering characteristics of the soils.

1.3 SCOPE OF STUDY

The original field work was started on 28 June 1977 and continued until 25 July 1977. The supplemental activities started on 20 October 1979 and ended on 2 December 1979.

Table 1-2 lists the types and number of field activities that were performed in Dry Lake Valley. The techniques of investigation are described in the appendix.

Permission for access was arranged through the Ely and Las Vegas, Nevada, district offices of the Bureau of Land Management (BLM). At BLM's request, all field activities were performed along existing roads or trails to minimize site disturbance. Archeological and environmental surveys were performed at each proposed activity location. Activity locations were changed in those few instances where a potential environmental or archeological disturbance was identified.

1.4 DISCUSSION OF ANALYSIS TECHNIQUES

1.4.1 Determination of Suitable Area

The number of field activities performed during the Verification Program is small relative to the area being studied. The reader should be aware of the limitations of the investigations and must recognize that there may be additional revisions regarding the suitability of areas as the studies continue.

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geologic mapping stations	60
Shallow refraction	17
Down Hole Velocity	2
Deep Refraction	2

ENGINEERING-LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	155
Specific gravity	15
Sieve analysis	238
Hydrometer	97
Atterberg limits	127
Consolidation	4
Unconfined compression	12
Triaxial compression	9
Direct shear	4
Compaction	14
CBR	10
Chemical analysis	13

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
1	450 (137)
5	300 (91)
8	100 (31)
3	50 (15)
1	25 (8)
NUMBER OF TRENCHES	**NOMINAL DEPTH FEET (METERS)**
7	18 (5)
11	14 (4)
NUMBER OF TEST PITS	**NOMINAL DEPTH FEET (METERS)**
25	5 (2)
4	3 (1)
NUMBER OF CPTs	**RANGE OF DEPTH FEET (METERS)**
84	2-34(1-10)
TYPE OF ACTIVITY	**NUMBER OF ACTIVITIES**
Surficial soil samples	46

SCOPE OF ACTIVITIES
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
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TABLE 1-2

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Maps showing interpretations of depth to rock and water and terrain conditions are included in section 3.0.

a. Depth to rock: For a verification study, 50- and 150-foot (15- to 46-m) depth to rock contours are estimated and shown on a depth to rock map. The locations of the contours are based on boring and geophysical data in combination with geologic interpretation. The interpretation considers the presence or absence of range-bounding faults, bedding plane attitudes, topographic slopes, evidence of erosional features such as pediments, and the presence or absence of young volcanic rocks.

b. Depth to water: The depth to water map is based on data shown in FNI summary report (1979b), which lists a few wells and borings in which no water was found in the upper 150 feet. Consequently, the depth to ground water has no influence on the final suitable area calculated for Dry Lake Valley.

c. Terrain: During Screening Studies, areas were excluded because of unsuitable terrain. The major exclusion criterion was a maximum permissible grade of ten percent. In many of the areas studied, detailed topographic maps have not been made, and the available maps do not show topographic conditions with sufficient detail to make an accurate evaluation of terrain suitability.

Since the Screening Studies, a set of accurate topographic maps has been prepared for Dry Lake Valley which has permitted reliable estimation of terrain conditions.

The "interpretive" terrain map is based on an evaluation of 1:62,500-scale topographic maps, aerial photographs, field observations, and the distribution of geologic units.

1.4.2 Determination of Basin-Fill Characteristics

In addition to the primary objective of refining suitable area boundaries, a secondary objective was to provide preliminary physical and engineering properties of the basin-fill materials. These data will be used for preliminary engineering design studies, will assist in planning future site-specific studies, and will be used by other MX participants.

The investigations of engineering properties were designed primarily to obtain information needed for construction activities. Particular emphasis has been placed on the surficial soil conditions as related to road construction, a major cost item. Moderate emphasis has been placed on soil conditions in the upper 20 feet (6 m) since this would be the approximate depth of excavation for the horizontal shelter basing mode. Limited data have been obtained from borings drilled to a depth of 160 feet (49 m) (and beyond), which is the depth of interest for the vertical shelter basing mode. The length of the seismic refraction lines was also chosen to obtain information to 150-foot (49-m) depth or beyond.

The geologic map showing the distribution of surficial soils is based on the interpretation of aerial photos and field mapping. Other data used to define soil conditions include surficial soil samples, test pits, trenches, and cone penetrometer tests.

Samples obtained at these activity locations were tested in the laboratory to determine physical and engineering properties. The cone penetrometer tests were used to measure in-situ soil properties.

Data obtained from test pits, trenches, borings, seismic refraction lines, and laboratory tests were used to estimate soil properties to a depth of 20 feet (6 m). Since most test pits were excavated to only 5 feet (1.5 m), the amount of data for greater depths, between 5 and 20 feet (1.5 and 6 m), is limited to that obtained from 18 trenches and 18 borings. Thus, 36 data points are used to represent the total area of basin-fill materials in Dry Lake Valley. Consequently, the range of properties presented in the report may not cover all materials that will be encountered.

The soil parameters between a depth of 20 and 160 feet (6 and 49 m) are based on data obtained from only 17 borings. The spacing between borings ranged from 3 to 8 miles (5 to 13 km), so it is possible that all materials in the valley were not encountered.

2.0 RESULTS AND CONCLUSIONS

2.1 SUITABLE AREA

The results of the suitable area interpretation are shown in Drawing 2-1 and listed in Table 2-1. The excluded areas are based entirely on the depth to rock and terrain criteria (Appendix A2.0) because no significant shallow ground water was found within Dry Lake Valley. The area interpreted to be suitable for deployment in the horizontal shelter basing mode is 315 square miles (816 km^2). The suitable area is reduced to 290 square miles (751 km^2) for the vertical shelter mode.

The total area of basin-fill materials in Dry Lake Valley, excluding rock outcrops, is 400 square miles (1036 km^2). Depth to rock and terrain conditions exclude 21 percent of this area for the horizontal shelter basing mode. The exclusion is increased to 27 percent for the vertical shelter basing mode.

2.2 BASIN-FILL CHARACTERISTICS

This section contains brief descriptions of the soils in the valley. More detailed information is presented in Sections 3.3 and 3.4.

2.2.1 Surficial Soils

Coarse-grained granular soils are the predominant surficial soils, covering approximately 80 to 90 percent of the area. They consist of gravelly, silty, and/or clayey sands and sandy gravels. The soils are generally poorly graded and have variable calcium carbonate cementation. Fine-grained soils cover

VERIFICATION VALLEY	STATE	AREA MI^2 (KM^2)*		
		BEGINNING AREA	SUITABLE AREA	
			HORIZONTAL	VERTICAL
DRY LAKE	NEVADA	400 (1036)	315 (816)	290 (751)

EXCLUSIONS	AREA MI^2 (KM^2)	PERCENT REDUCTION**
<50 FEET (15M) TO ROCK	80 (207)	20
<150 FEET (46M) TO ROCK	105 (272)	26
<50 FEET (15M) TO WATER	0 (0)	0
<150 FEET (46M) TO WATER	0 (0)	0
TERRAIN	5 (13)	1

*BEGINNING AREA COMPOSED OF BASIN-FILL MATERIALS EXCLUDING ALL ROCK OUTCROPS. ALL LARGE SQUARE MILE AREAS ARE ROUNDED OFF TO NEAREST FIVE SQUARE MILE INCREMENT. METRIC CONVERSIONS ARE ROUNDED OFF TO NEAREST ONE SQUARE KILOMETER INCREMENT.

**PERCENT REDUCTIONS, BASED ON BEGINNING AREA, ARE ROUNDED OFF TO NEAREST WHOLE PERCENT. GROUND WATER DATA FROM FUGRO NATIONAL, INC. (1979b).

ESTIMATED SUITABLE AREA
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE 2-1

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from ten to 20 percent of the area. They consist of sandy and clayey silts and sandy and silty clays. They are mainly confined to an active playa in the south central portion of the valley. Their plasticity ranges from none to high.

2.2.2 Subsurface Soils

Soils in the subsurface are also predominantly coarse-grained, consisting of sandy gravels, gravelly sands, silty sands, and clayey sands. Fine-grained soils (silts and clays) probably occur in about ten to 20 percent of the subsurface and are generally restricted to buried playa and lacustrine deposits along the valley axis. Variation in areal extent of playas in the geologic past has resulted in local interfingering of coarse- and fine-grained deposits in the subsurface near playa margins.

The coarse-grained soils are generally dense to very dense below 10 to 15 feet (3.0 to 4.6 m), are poorly graded with coarse to fine sand and/or gravel, exhibit low compressibilities, and possess moderate to high shear strengths. The fine-grained soils exhibit low to high plasticity and low to moderate compressibilities and shear strengths. Variable calcium carbonate cementation exists in the subsurface soils.

2.3 CONSTRUCTION CONSIDERATIONS

Geotechnical factors and conditions pertaining to construction of the MX system in suitable areas are discussed in this section. Both the horizontal shelter and vertical shelter basing modes are considered.

2.3.1 Grading

Mean surficial slopes in the suitable area are approximately two to three percent (range of one to nine percent). About five percent of the suitable area has surface gradients exceeding five percent. Therefore, preconstruction grading will be minimal for most of the valley. More extensive grading will be necessary near the mountain fronts where surface slopes range from five to nine percent.

Detailed layout studies showed that, with 7000 feet (2134 m) between shelters, nine clusters can be placed in Dry Lake Valley. The maximum grade at any shelter location in this layout would be approximately five percent. For 90 percent of the shelters, the grade would be less than three percent.

2.3.2 Roads

The predominant coarse-grained surficial soils will generally provide good subgrade support for roads where they are in a dense state. However, most of these soils are not dense near the surface and therefore exhibit low strength. The subgrade supporting properties of these low strength, coarse-grained soils are inadequate but can be improved by mechanical compaction. They exhibit low strength to an average depth of 2.8 feet (0.9 m). Therefore, compaction to depth of 2 to 3 feet (0.6 to 0.9 m) appears necessary in a majority of the suitable areas, with compaction to greater depth required in approximately 30 percent of the granular soil area. Based on results of laboratory CBR test, compacted granular soils will provide good to very good support for roads.

Fine-grained surficial soils, which have an areal extent of 10 to 20 percent of the suitable area, exhibit low strength to an average depth of 2.6 feet (0.8 m), with a maximum depth of 7.8 feet (2.4 m). Supporting qualities of these soils are inadequate for direct support of the base or subbase course of the road system. Results of laboratory CBR tests indicate that mechanical compaction will not adequately strengthen these fine-grained soils. Therefore, a select granular subbase layer will be required over the compacted fine-grained surficial soils to obtain the required support.

Well-graded gravelly sands and sandy gravels with less than 25 percent fines (passing a No. 200 sieve) can be used for road subbase and base courses. These soils are present both in the surface and subsurface; however, their extent is not known.

Drainage incision depths are generally less than 6 feet (1.8 m) within 85 to 90 percent of the suitable area. In the remainder of the valley, generally around the perimeter, the depth of drainage incision ranges from 3 to 25 feet (0.9 to 7.6 m). Therefore, the overall cost of drainage structures for roads will be low.

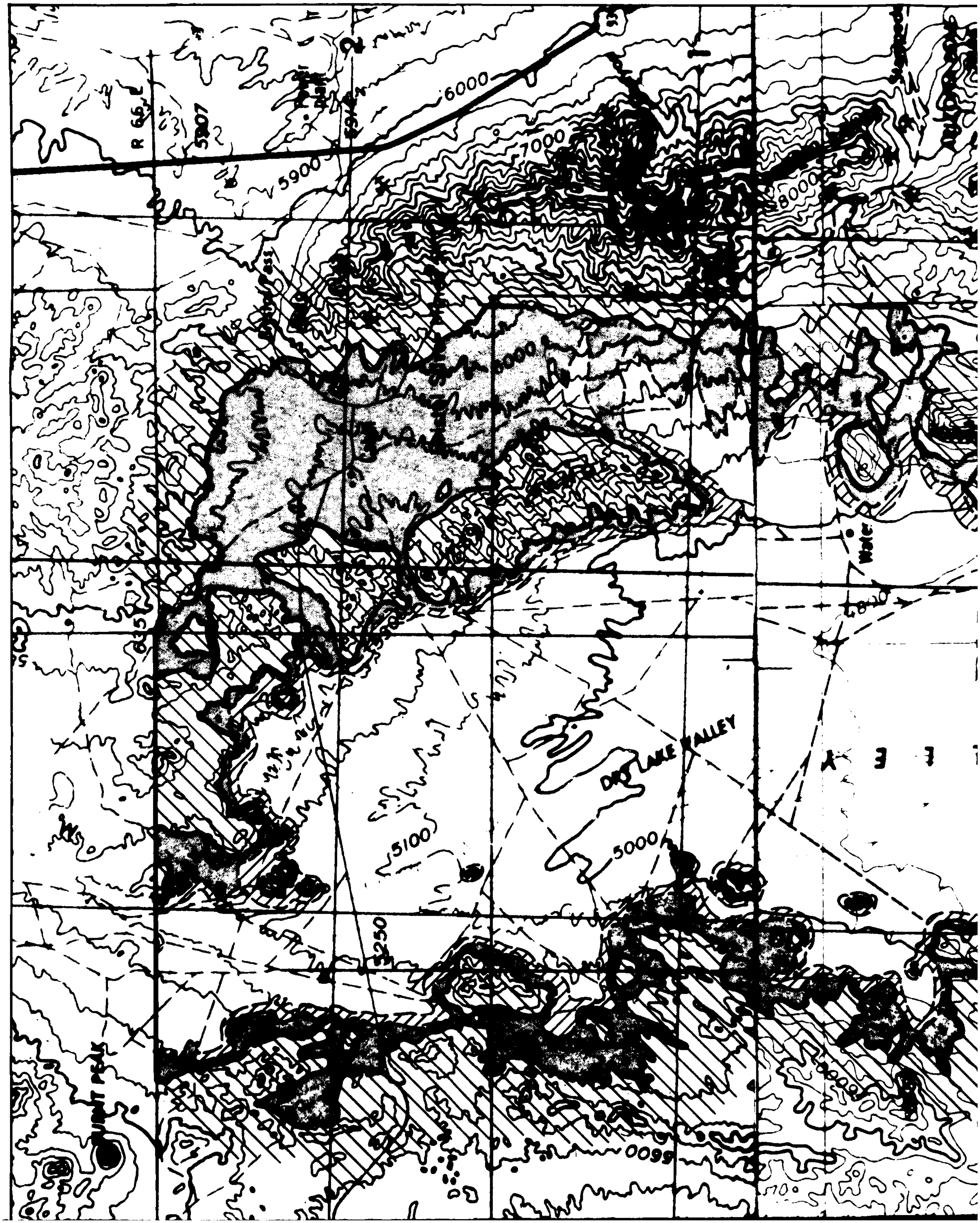
2.3.3 Excavatability and Stability

The soils in the construction zone are generally medium dense to very dense and possess variable calcium carbonate cementation.

Fine-grained soils occur in less than 20 percent of the subsurface.

Horizontal Shelter: Excavation for the horizontal shelter can be done using conventional equipment such as scrapers, backhoes, and dozers. Excavation will be easy in approximately 70 to 80 percent of the area; however, excavation will be moderately difficult in the remaining area due to presence of cobbles, boulders, and strong calcium carbonate cementation in the subsurface. Difficult excavation is generally limited to the areas adjacent to the mountain fronts. Results of the soils engineering investigation indicate that excavations for construction of shelters should be cut back to slopes ranging from $\frac{3}{4}$:1 to $1\frac{1}{2}$:1 (horizontal:vertical) for stability. The wide variation in slope angle is due to variation in density and shear strength which depend on soil composition and degree of cementation. Because of low strength surficial soil, the top 2 to 5 feet (0.6 to 1.5 m) in all excavations will generally have to be cut back to 2:1 slope or flatter.

Vertical Shelter: Relatively low compressional wave velocities in the upper 120 feet (36 m) indicate that large diameter auger drills could be used for vertical shelter excavation. Most excavations will be in granular soils with only intermittent cemented or cohesive soil intervals. Therefore, the vertical walls of these excavations will probably require the use of slurry or other stabilizing techniques.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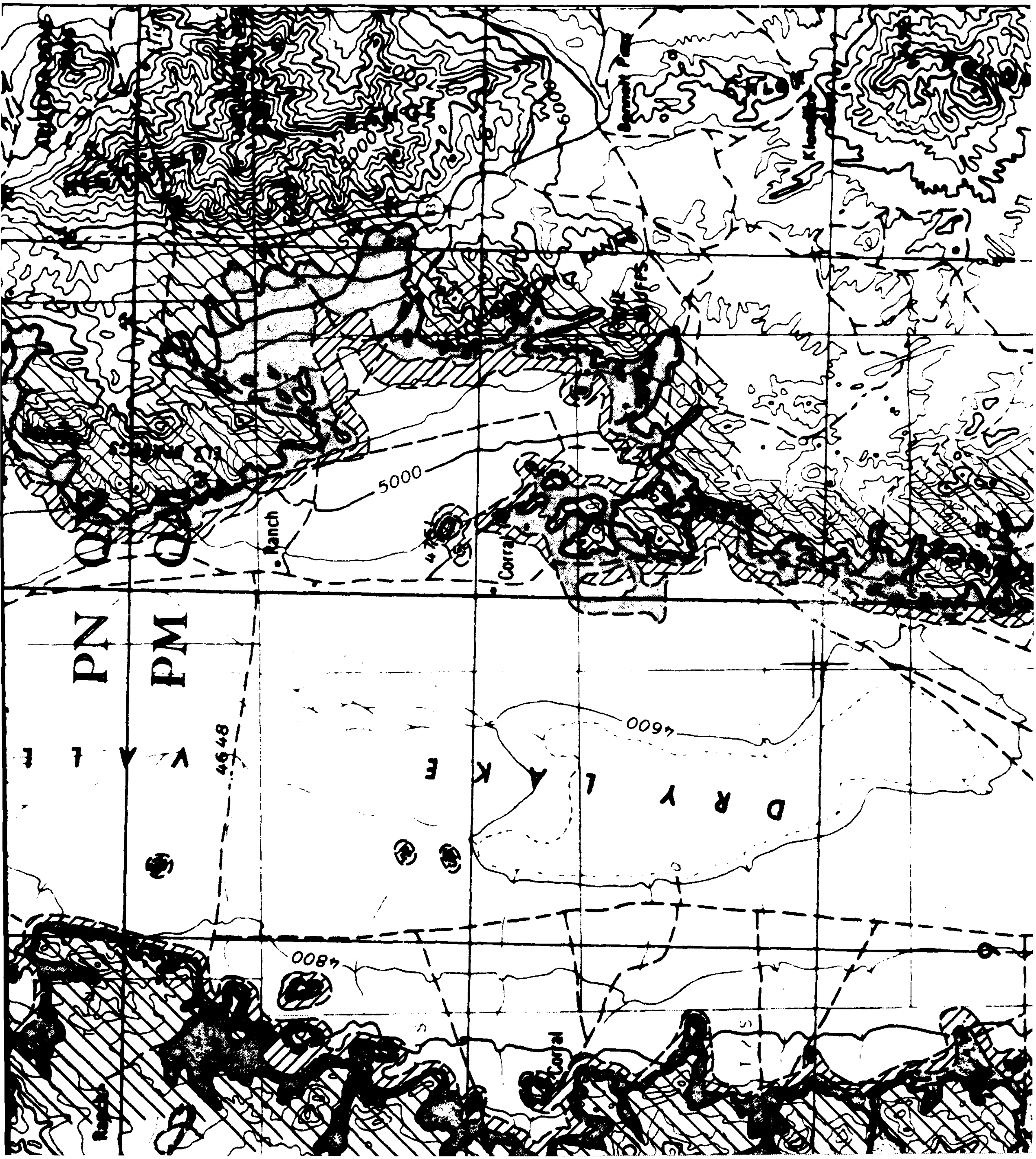

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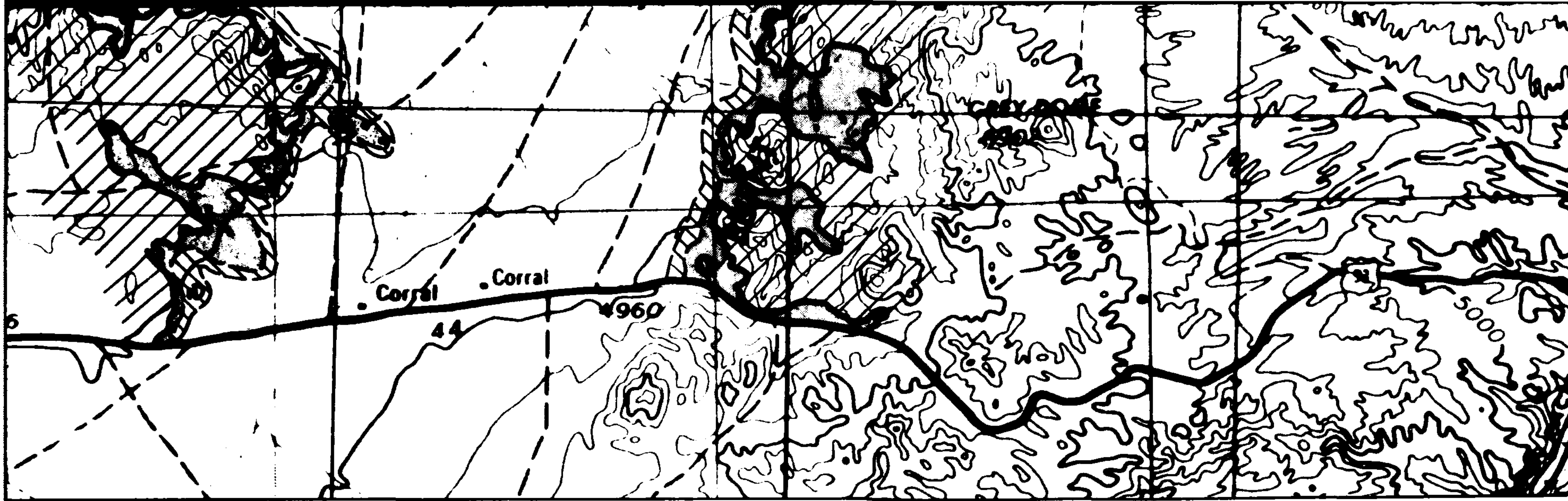

EXPLANATION

Area suitable for horizontal and vertical shelter basing modes. Depth to rock and water greater than 150 feet (46m).

Area suitable for horizontal shelter but, not suitable for vertical shelter. Depth to rock greater than 50 feet (15m) and less than 150 feet (46m).

Area unsuitable for both horizontal and vertical shelter basing modes as determined from application of depth to rock and water, topographic/terrain, and cultural exclusions (see Appendix A-2, Table A2-1 for details of exclusion criteria).

Indicates areas of exposed rock.

Contact between rock and basin-fill (and north and south valley boundaries).

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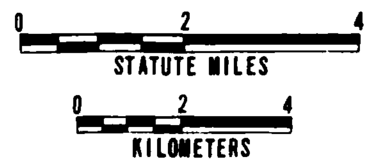

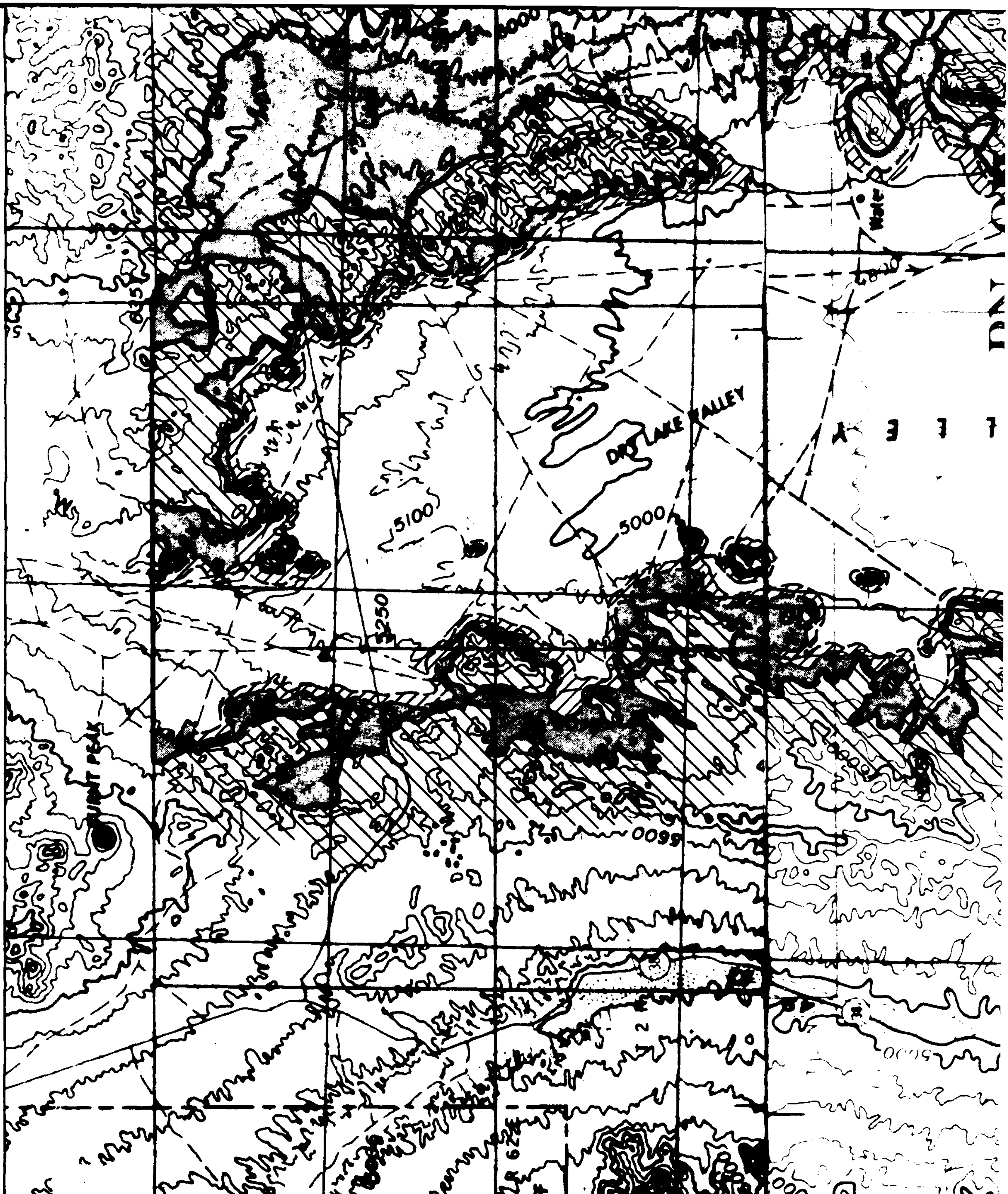

14 MAR 80


NORTH PAHROC RANGE
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Ranch
Corral
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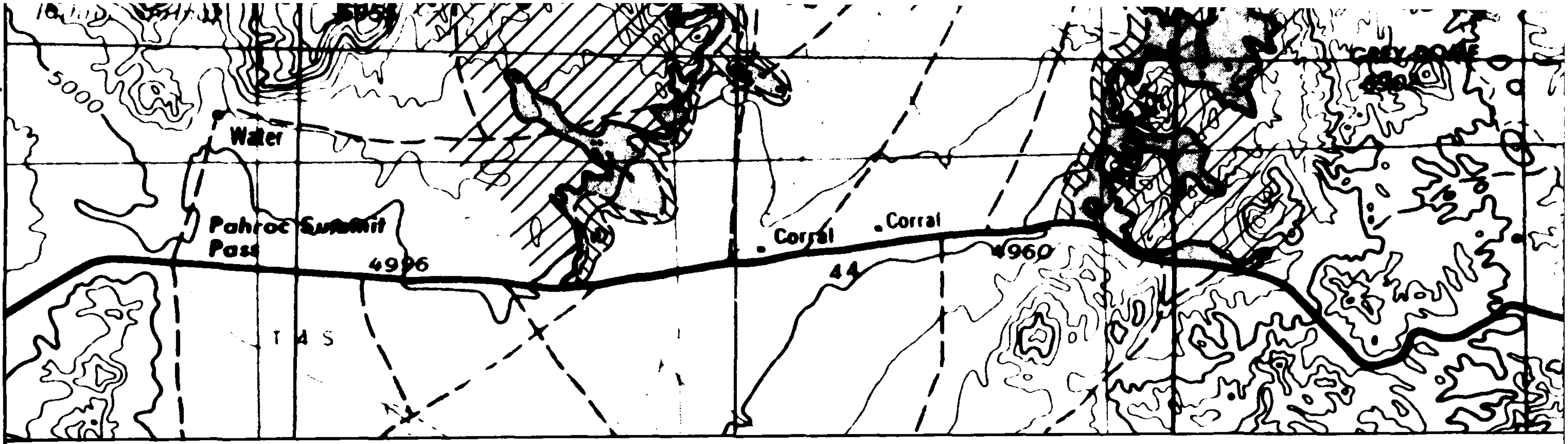

EXPLANATION

- Area suitable for horizontal and vertical shelter basing modes. Depth to rock and water greater than 150 feet (46m).
- Area suitable for horizontal shelter but, not suitable for vertical shelter. Depth to rock greater than 50 feet (15m) and less than 150 feet (46m).
- Area unsuitable for both horizontal and vertical shelter basing modes as determined from application of depth to rock and water, topographic/terrain, and cultural exclusions (see Appendix A-2, Table A2-1 for details of exclusion criteria).
- Indicates areas of exposed rock.
- Contact between rock and basin-fill (and north and south valley boundaries).

SCALE 1:

STATUTE

KILOM

SUITABLE AREA HORIZONTAL AND VERTICAL SHELTER DRY LAKE VALLEY, NEVADA	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	DRAWING 2-1

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6

3.0 GEOTECHNICAL SUMMARY

3.1 GEOGRAPHIC SETTING

Dry Lake Valley is in central Lincoln County, Nevada (Figure 3-1). The valley is bounded on the west and east by the North Pahroc Range and the Burnt Springs, Ely Springs, Highland, and Bristol ranges, respectively. It is bounded on the north by Muleshoe Valley and on the south by Delamar Valley. U.S. Highway 93 forms the southern boundary of the valley and is the only paved road in the vicinity. A network of graded roads and four-wheel-drive trails provide access. The valley is mainly undeveloped desert rangeland, but there are a few corrals and ranch houses. The nearest town is Caliente, Nevada, approximately 15 miles (24 km) east on U.S. Highway 93.

3.2 GEOLOGIC SETTING

3.2.1 Rock Types

Dry Lake Valley is an elongate north-south trending, alluvial basin flanked on the west and east by carbonate and volcanic rocks. The North Pahroc Range consists predominantly of Tertiary ash-flow tuffs with some Paleozoic carbonate rocks. Conversely, the Burnt Springs, Ely Springs, Highland, and Bristol ranges consist primarily of carbonate rocks with minor amounts of Tertiary ash-flow tuffs (Stewart and Carlson, 1978; Tschantz and Pampeyan, 1970).

3.2.2 Structure

The valley exhibits typical basin and range structure: high angle normal faults, oriented north-south, probably border the

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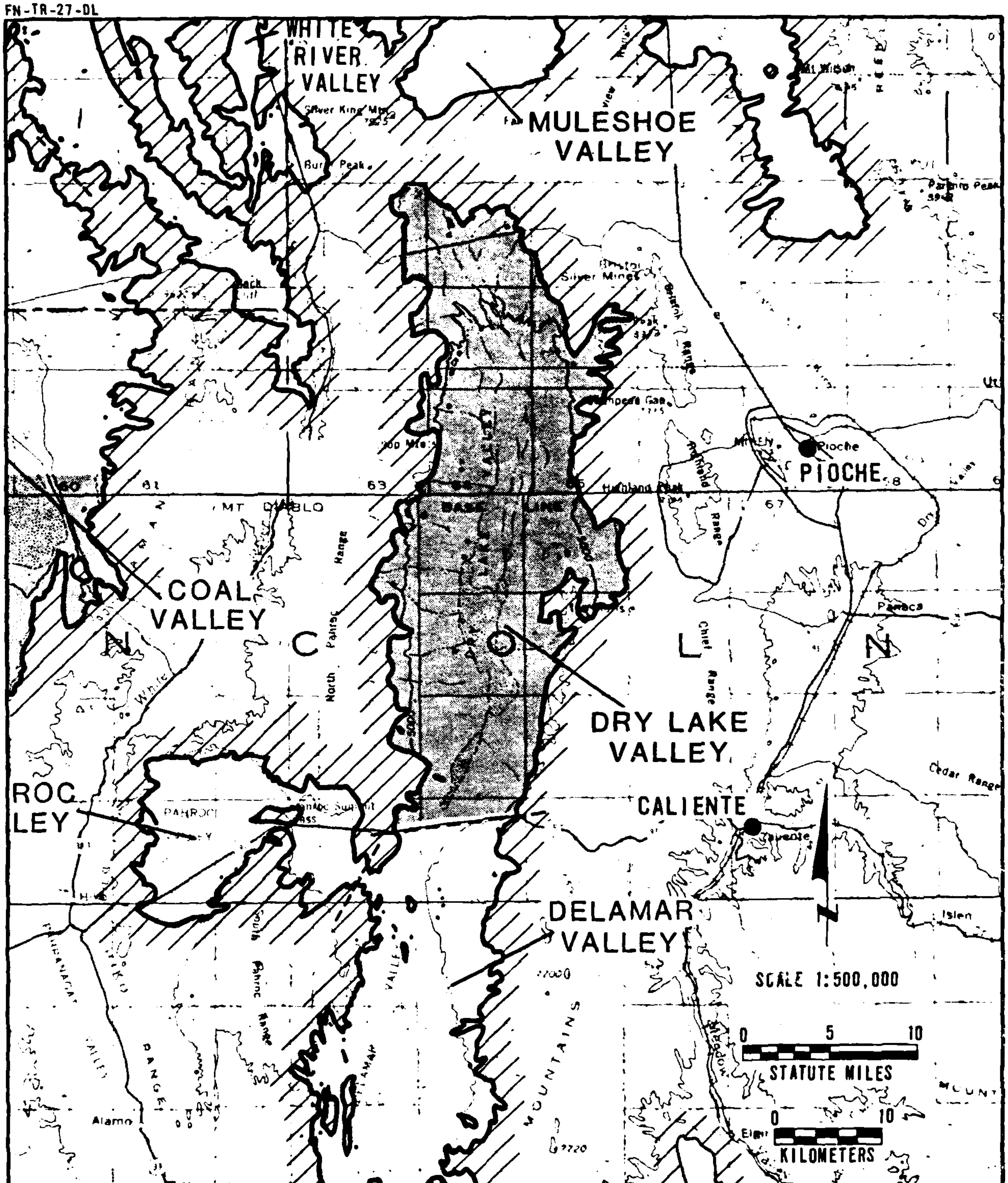

LOCATION MAP
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE 3-1

FUGRO NATIONAL, INC.

14 MAR 80

ranges on either side of the valley. The area between them is faulted downward. Stewart and Carlson (1978) interpret a north-south trending escarpment on the eastern side of the valley to be a fault cutting the surface alluvium. This feature is also mapped by Tschantz and Pampeyan (1970) and Fugro National, Inc. (1978b). Two trenches were dug across the escarpment but neither revealed any offset material (Drawing 3-1, Trenches T-12 and T-13). Several small graben-like features appear to exist between the main trace of the escarpment and adjacent minor traces. Shawe (1965) mentions transverse faults near Dry Lake Valley, occurring at large angles to the major north-south structural trends already discussed. An interpretation of gravity data from Dry Lake Valley also includes transverse faults in the subsurface (FNI, 1980a).

Earth fissures occur in at least three areas just west of the Ely Springs Range (Drawing 3-2). Probably the most well known is an east-west trending one plotted on USGS topographic maps and called "The Crack." The other two fissures are oriented north-south adjacent to the escarpment already discussed. Past (FNI, 1978b) and present investigations (Drawing 3-1, Trench T-11) indicate no fault offset of alluvial material in these areas. These features may be caused by desiccation as the water level dropped in a Pleistocene-aged lake in the valley or by spreading or opening due to tectonic (tensional) stresses.

The interpretation of gravity measurements (FNI, 1980a) in the valley indicates a transverse, strike-slip fault nearly coincident with "The Crack." This subsurface fault was interpreted to explain an apparent shift in the valley axis but is located strikingly near the surface fissure. If this fault interpretation is correct, the strain developed at depth may have caused the surface fissure.

Several other possible faults are indicated on the Surficial Geologic Units Map (Drawing 3-2). These faults are based on air photo interpretation during a regional fault and earthquake study and have not been field verified (FNI, 1980b). They occur in the northeast portion of the valley, along both the west and east sides of the valley.

3.2.3 Surficial Geologic Units

Alluvial fans of younger and intermediate relative age are the predominant surficial geologic units within the valley (Drawing 3-2). They range from sandy gravels near the mountain fronts to sandy silts near the center of the valley. Playa deposits, covering only a small percentage of the valley surface, are generally of great thickness and interfinger with alluvial deposits in the subsurface (FNI, 1978b).

Surficial geologic units mapped consist of the following:

- o Older Alluvial Fan Deposits (A5o) - This Pleistocene unit is the least extensive alluvial unit in the valley. It occurs adjacent to mountain flanks as a gravelly sand with silt and is usually underlain by shallow rock on the west and east sides of the valley. Cementation is weak to moderate; caliche development varies from Stages III to IV. Areal extent is much less than five percent of the valley.

- Intermediate Alluvial Fan Deposits (A5i, - This Pleistocene unit is a more widespread alluvial unit occurring in a fairly narrow band along the base of the ranges on the west and east sides of the valley. That portion of this fan type that exists high on the flanks of the ranges is underlain by shallow rock. The unit occurs as a weak to moderately cemented gravelly sand or sandy gravel with caliche development varying from Stages I to II. Areal extent is about 20 to 30 percent of the valley.

- Younger Alluvial Fan Deposits (A5y) - Holocene young alluvium is the most widespread alluvial unit in the valley. It occurs in the valley bottom adjacent to intermediate alluvial fans but does not occupy the axial portion of the valley. The composition of the fans varies from silty sand to sandy gravel. Cementation varies from none to weak; caliche development varies from none to Stage I. Areal extent is about 40 to 50 percent of the valley.

- Fluvial and Associated Flood Plain Deposits (A1, A2) - Holocene fluvial and associated deposits occur primarily along the central axis of the valley, predominantly in the northern half. Composition varies from silty and clayey sands to silty sands with gravel. Cementation varies from none to moderate; caliche development varies from none to Stage I. Areal extent is about 10 to 20 percent of the valley.

- Lacustrine Deposits (A4, A4o) - This unit designation includes Holocene playa deposits and Quaternary-Tertiary older playa and lacustrine deposits. These units occupy a linear zone in the central and south central portions of the valley. Composition varies from sandy silts and clays to gravelly sand. Cementation varies from none to weak; caliche development varies from none to Stage I. Areal extent of both units combined is about 10 to 20 percent of the valley.

3.3 SURFACE SOILS

Surficial soils of Dry Lake Valley are predominantly coarse-grained. They range from gravels with little fines to sands with appreciable fines. Fine-grained soils (silts and clays) have a limited areal distribution. Soils from the predominant surficial geologic units can be combined into the following three categories based on their physical and engineering characteristics:

1. Silty sands and clayey sands (geologic units A1s, A4os/A4of, A5ys, and A5is);
2. Sandy gravels and gravelly sands (geologic units A1s, A5ys, and A5is); and
3. Silts and clays (geologic units A4f, A4os/A4of, A5ys, and A5is).

3.3.1 Characteristics

A summary of the characteristics of surficial soils, based on field and laboratory test results, is presented in Table 3-1. In addition to the physical properties, road design data, consisting of laboratory compaction and California Bearing Ratio (CBR) test results, thickness of low strength surficial soils, and a qualitative assessment of their suitability for road use are also included in the table. Gradation ranges for the three categories of surficial soils are shown in Figure 3-2. The surficial soils in the top 2 feet (0.6 m) have sporadic, weak calcium carbonate cementation.

Silty sands and clayey sands are the predominant surficial soils, covering approximately 45 to 65 percent of the area. They are widely distributed, being the major component in all areas except alluvial fans very near mountain fronts, alluvial fan deposits associated with small stream channels, and the lacustrine and active playa deposits in the south-central part of the valley. The sands are medium to fine and are poorly graded. They contain appreciable amounts of fines and their

SOIL DESCRIPTION		Silty Sands and Clayey Sands	Sandy Gravels and
USCS SYMBOLS		SM, SC	GP, GM, SM
PREDOMINANT SURFICIAL GEOLOGIC UNITS		Als, A40/A4of, A5ys, A5is	Als, A5ys, A5is
ESTIMATED AREAL EXTENT %		45-65	25-45
PHYSICAL PROPERTIES			
COBBLES 3 - 12 inches (8 - 30 cm) %		0-5	0-10
GRAVEL %		1-28 [18]	13-61
SAND %		34-60 [18]	29-81
SILT AND CLAY %		19-43 [21]	5-38
LIQUID LIMIT		19-32 [3]	NDA
PLASTICITY INDEX		NP-15 [9]	NDA
ROAD DESIGN DATA			
MAXIMUM DRY DENSITY pcf (kg/m³)		108.5-122.4 (1738-1961) [3]	118.0-128.5 (1890-2058)
OPTIMUM MOISTURE CONTENT %		10.3-18.0 [3]	8.5-12.0
CBR AT 90% RELATIVE COMPACTION %		14-21 [3]	14-31
SUITABILITY AS ROAD SUBGRADE (1)		good	good to very good
SUITABILITY AS ROAD SUBBASE OR BASE (1)		fair	fair to good
THICKNESS OF LOW STRENGTH SURFICIAL SOIL (2)	RANGE ft (m)	0.6-11.1 (0.2-3.4) [44]	0.6-6.8 (0.2-2.1)
	AVERAGE ft (m)	3.2 (1.0) [44]	2.1 (0.6)

(1) Suitability is a subjective rating explained in Section A5.0 of the Appendix.

(2) Low strength surficial soil is defined as soil which will perform poorly as a road subgrade at its present consistency; see Table 3-2 for details.

NOTES:
- [ ] - N
- NDA - No ... not

ndy Gravels and Gravelly Sands	Sandy Silts, Clayey Silts· Sandy Clays, Silty Clays and Clays.	
. GM, SM	ML, MH, CL, CH	
s. A5ys, A5is	A4f, A4os/A4of, A5ys, A5is	
-45	10-20	
10	0	
-61 [22]	0-2 [11]	
-81 [22]	2-39 [11]	
-38 [22]	59-98 [12]	
DA	24-74 [12]	
DA	NP-41 [13]	
18 0-128.5 (1890-2058) [3]	96.5-110.8 (1546-1775) [4]	
5-12.0 [3]	19 8-26 0 [4]	
4-31 [2]	3-15 [4]	
ood to very good	poor	
air to good	not suitable	
6-6.8 (0 2-2.1) [22]	0.4-7.8 (0.1-2 4) [18]	
.1 (0.6) [22]	2.6 (0.8) [18]	

ES: • [ ] - Number of tests performed

• NDA - No data available (insufficient data or tests not performed)

2

CHARACTERISTICS OF SURFICIAL SOILS
DRY LAKE VALLEY, NEVADA

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TABLE 3-1

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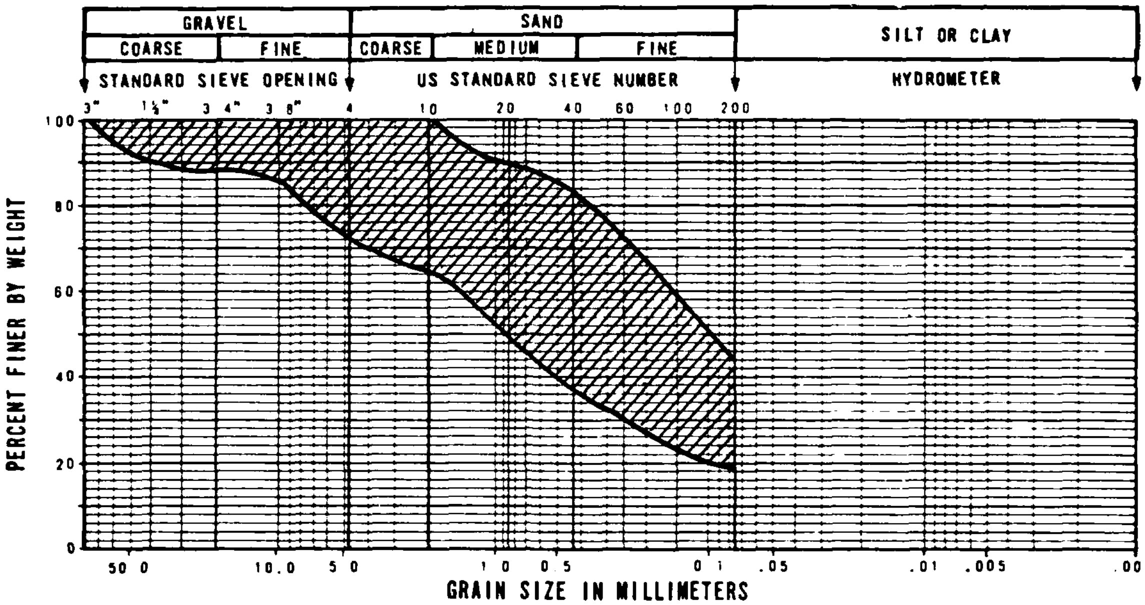
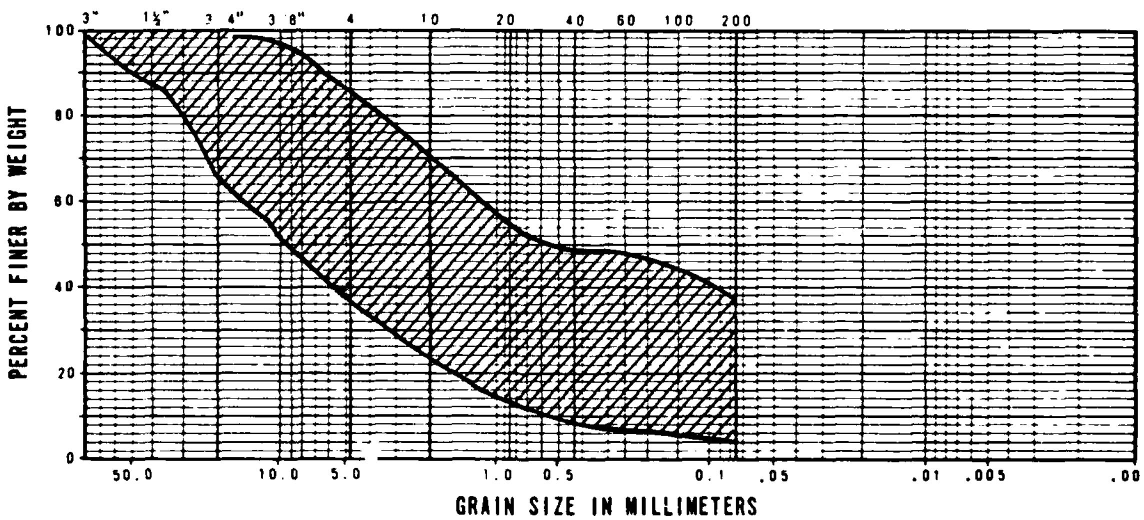
AFV-19



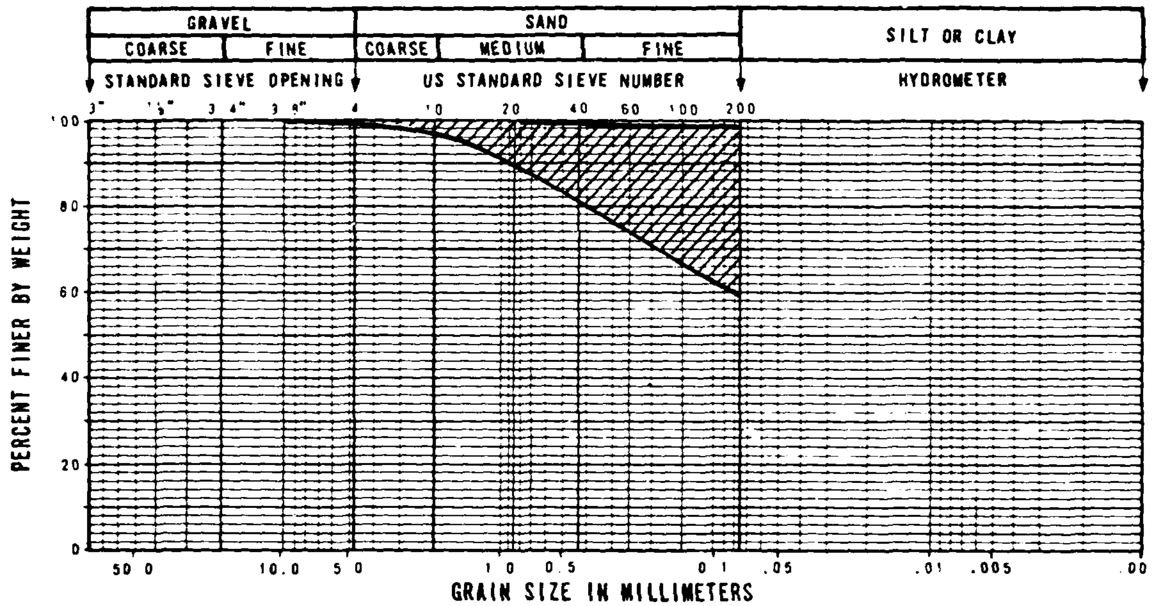
SOIL DESCRIPTION: Silty Sands and Clayey Sands from 0 to 2 feet (0 to 0.6m)



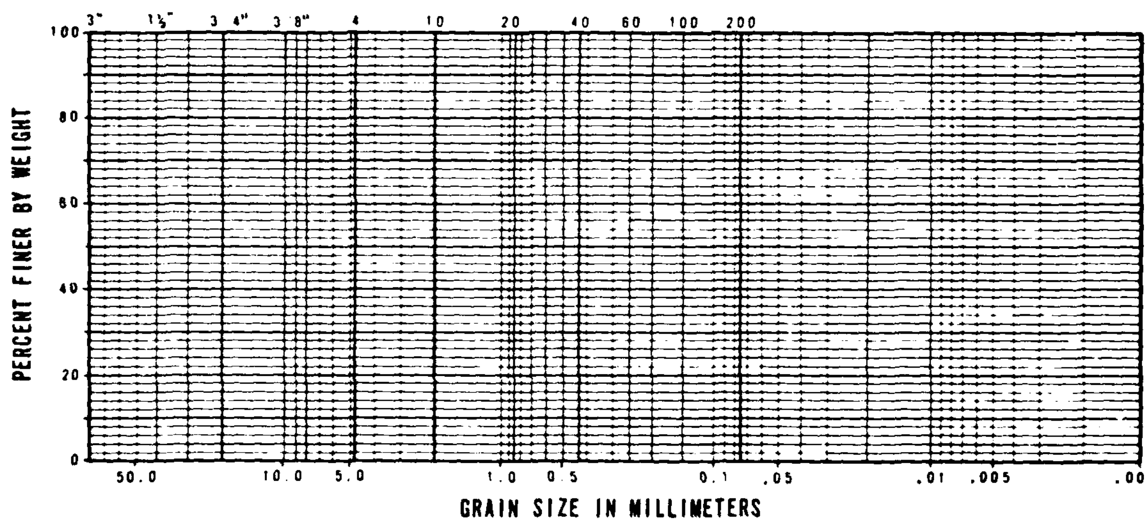
SOIL DESCRIPTION: Sandy Gravels and Gravelly Sands from 0 to 2 feet (0 to 0.6m)

RANGE OF GRADATION OF SURFICIAL SOILS DRY LAKE VALLEY, NEVADA	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	FIGURE 3-2 1 of 2

FUGRO NATIONAL, INC.



SOIL DESCRIPTION: Sandy Silts, Clayey Silts, Sandy Clays, Silty Clays and Clays from 0 to 2 feet (0 to 0.6m)



RANGE OF GRADATION OF SURFICIAL SOILS
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE 3-2
2 of 2

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plasticity ranges from none to slight. The fines content is highest near the playas, decreasing toward the basin margin. Gravel content increases toward the mountain fronts.

Sandy gravels and gravelly sands have an approximate areal distribution of 25 to 45 percent. Gravelly soils are most common in the intermediate age fans along the valley flanks and the young alluvial fans associated with small tributary stream channels. The sands generally extend to the mountain fronts, with increasing gravel content toward the mountain fronts locally grading into gravels. Gravelly sands and sandy gravels have a wide range of particle sizes, are occasionally well graded, and contain traces to appreciable amounts of fines. Cobbles to 12 inches (30 cm) in diameter are occasionally encountered at or near the ground surface in these gravelly deposits.

Silts and clays cover approximately 10 to 20 percent of the valley. They consist of sandy silts, clayey silts, sandy clays, silty clays, and clays and occur predominantly as older lacustrine and active playa deposits in the south-central portion of the valley. Fine-grained soils are also sporadically encountered in both young and intermediate alluvial fans. These soils contain traces to appreciable amounts of sand. Their plasticity ranges from none to high.

3.3.2 Low Strength Surficial Soil

Based on the Cone Penetrometer Test (CPT) results and soil classification, the thickness of low strength surficial soil at each CPT location was estimated and is presented in Table 3-2.

CONE PENETROMETER TEST NUMBER(1)	THICKNESS OF LOW STRENGTH SURFICIAL SOIL(2)		SOIL TYPE(3)
	FEET	METERS	
C-1	2.6	0.8	SM
C-2	1.1	0.3	SM
C-3	0.9	0.3	SM
C-4	2.9	0.9	SM
C-5	3.5	1.1	SM SP-SM
C-6	0.8	0.2	GM
C-7	5.6	1.7	SM SP-SM
C-8	3.1	0.9	SM
C-9	1.0	0.3	SC
C-10	1.0	0.3	SM
C-11	4.7	1.4	SM
C-12	5.3	1.6	SM
C-13	1.1	0.3	SM
C-14	0.7	0.2	SC
C-15	3.2	1.0	SM
C-16	2.6	0.8	SM
C-17	1.2	0.4	SC
C-18	1.2	0.4	SM
C-19	5.7	1.7	SM
C-20	0.7	0.2	GM
C-21	0.7	0.2	SC
C-22	1.9	0.6	SM
C-23	5.9	1.8	SM
C-24	2.8	0.9	SM
C-25	3.2	1.0	SC-SM
C-26	2.0	0.6	ML
C-27	1.3	0.4	ML
C-28	4.0	1.2	ML

CONE PENETROMETER TEST NUMBER(1)	THICKNESS OF LOW STREN SURFICIAL SOIL(2	
	FEET	METERS
C-29	1.0	0.3
C-30	0.8	0.2
C-31	1.4	0.4
C-32	3.9	1.2
C-33	1.0	0.3
C-34	0.5	0.2
C-35	1.1	0.3
C-36	1.8	0.5
C-37	0.9	0.3
C-38	1.2	0.4
C-39	15.2	4.6
C-40	2.3	0.7
C-41	0.8	0.2
C-42	1.8	0.5
C-43	0.5	0.2
C-44	4.0	1.2
C-45	8.2	2.5
C-46	1.1	0.3
C-47	2.6	0.8
C-48	1.0	0.3
C-49	2.3	0.7
C-50	2.0	0.6
C-51	2.8	0.9
C-52	2.1	0.6
C-53	5.9	1.8
C-54	1.2	0.4
C-55	3.0	0.9
C-56	1.3	0.4

(1) For Cone Penetrometer Test locations see Drawing Activity Location Map.

(2) Thickness corresponds to depth below ground surface. Low strength surficial soil is defined as soil which will perform poorly as a road subgrade at its present consistency. Low strength is based on Cone Penetrometer Test results using the following criteria:

Coarse grained soils: $q_c < 120$ tsf (117 kg cm2)
Fine grained soils: $q_c < 80$ tsf (78 kg cm2)

where q_c is cone resistance.

(3) Soil type is based on Unified Soil Classification System; see Section A5.0 in the Appendix for explanation.

NOTES:
- For fine
strength
of the so
- SM GM - i
- NDA - No

...NESS OF LOW STRENGTH SURFICIAL SOIL (2) FEET	METERS	SOIL TYPE (3)
0	0.3	GM
8	0.2	GP
.4	0.4	ML
9	1.2	SM
0	0.3	SM
5	0.2	CL
1	0.3	GW
.8	0.5	GM
9	0.3	GM
.2	0.4	SM
5.2	4.6	SM
2.3	0.7	SM
0.8	0.2	CL
8	0.5	ML
0.5	0.2	ML
4.0	1.2	SM
8.2	2.5	SM
1.1	0.3	SM
2.6	0.8	SW-SM
1.0	0.3	SM
2.3	0.7	SM
2.0	0.6	SM
2.8	0.9	SM
2.1	0.6	SM
5.9	1.8	MH
1.2	0.4	CH
3.0	0.9	SM
3	0.4	SM

CONE PENETROMETER TEST NUMBER (1)	THICKNESS OF LOW STRENGTH SURFICIAL SOIL (2) FEET	METERS	SOIL TYPE (3)
C-57	1.8	0.5	SM
C-58	0.8	0.2	SP
C-59	6.8	2.1	GP-GM
C-60	1.3	0.4	SM
C-61	5.3	1.6	SM CL
C-62	1.8	0.5	ML
C-63	7.8	2.4	CH
C-64	0.4	0.1	CL
C-65	1.3	0.4	SM
C-66	1.7	0.5	CL
C-67	5.0	1.5	SM
C-68	1.1	0.3	SM
C-69	1.1	0.3	SM
C-70	3.8	1.2	SM
C-71	0.8	0.2	ML
C-72	4.4	1.3	CL
C-73	5.3	1.6	CH SM
C-74	2.7	0.8	SM
C-75	6.2	1.9	SM
C-76	0.6	0.2	SM
C-77	0.9	0.3	SW-SM
C-78	5.4	1.6	SM SP
C-79	0.6	0.2	SP-SM
C-80	11.1	3.4	SM
C-81	2.3	0.7	SM
C-82	1.9	0.6	SM
C-83	10.3	3.1	SM
C-84	0.9	0.3	SM

DTES:
- For fine grained soils (ML, CL, MH and CH), thickness of low strength surficial soil will vary depending on moisture content of the soil at time of testing.
- SM GM - indicates SM underlain by GM
- NDA - No data available

2

THICKNESS OF LOW STRENGTH SURFICIAL SOIL
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
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TABLE 3-2

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The range and mean thickness of the low strength surficial soil for the three categories are summarized in Table 3-1. Silty and clayey sands exhibit low strengths to depths ranging from 0.6 to 11.1 feet (0.2 to 3.4 m), with an average of 3.2 feet (1.0 m). Sandy gravels and gravelly sands exhibit low strength to depths ranging from 0.6 to 6.8 feet (0.2 to 2.1 m), with an average of 2.1 feet (0.6 m). The variation in the extent of low strength granular soils is due to variation in the in-situ density and variable calcium carbonate cementation. Silts and clays exhibit low strength to depths ranging from 0.4 to 7.8 feet (0.2 to 2.4 m), with an average of 2.6 feet (0.8 m). The variation in the extent of low strength, fine-grained soils is due to variations in the in-situ density, the amount of fine sand present, and calcium carbonate cementation.

3.4 SUBSURFACE SOILS

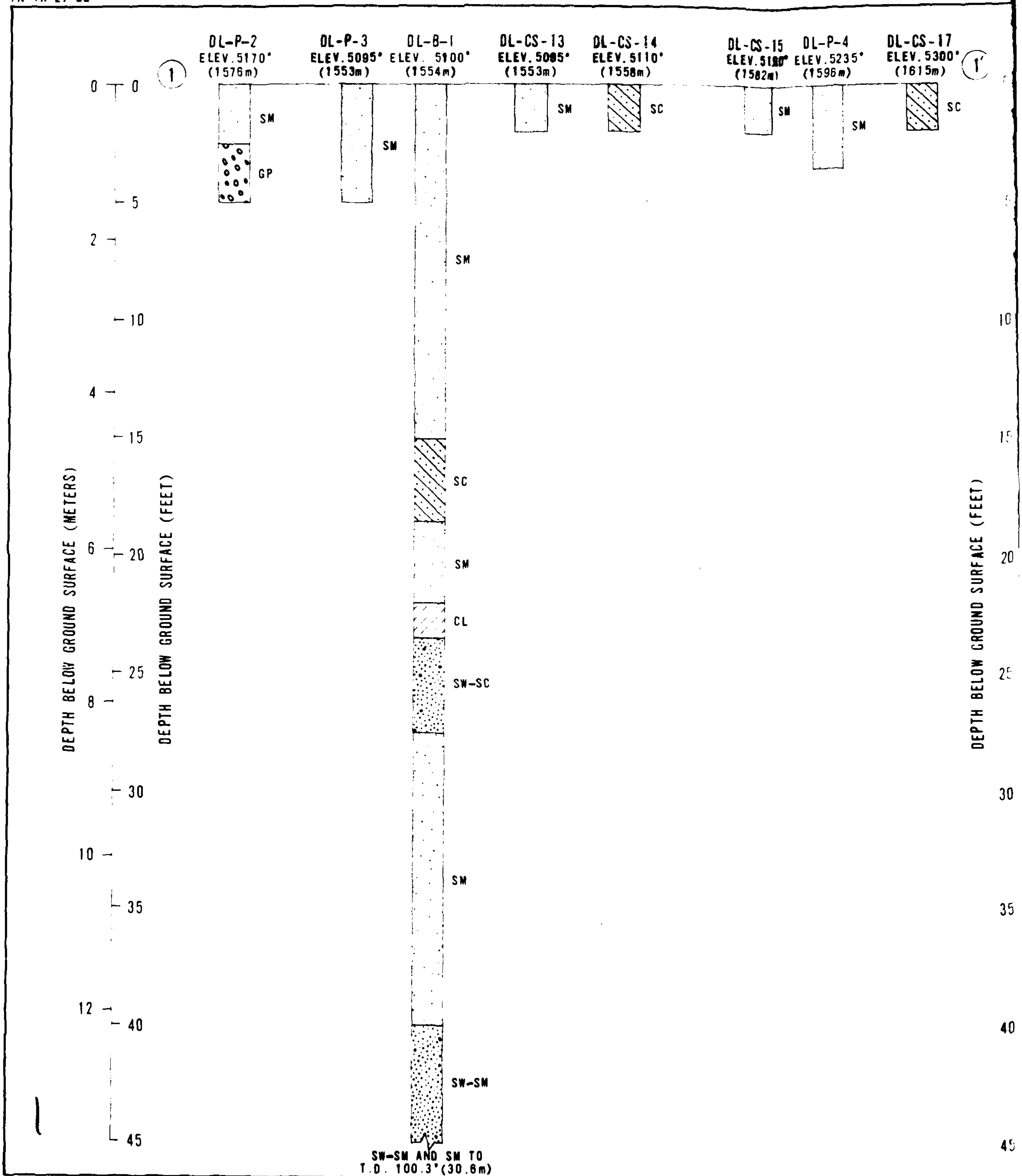
Subsurface soils are predominantly coarse-grained (granular) except in the south-central portion of the valley, where fine-grained soils predominate. The coarse-grained soils consist of sandy gravels, gravelly sands, silty sands, and clayey sands. Subsurface soils within the south-central portion of the valley are predominantly fine-grained and are associated with the active playa deposits. These fine-grained soils consist of sandy silts, clayey silts, silts, silty clays, and clays with plasticity ranging from none to high. At the valley center, these fine-grained soils interfinger with the coarse-grained soils. Fine-grained soils are estimated to compose 10 to 20 percent of the subsurface deposits within the suitable area boundaries. The composition of subsurface soils with depth, as determined from borings, trenches, and test pits, is illustrated in the soil profiles presented in Figures 3-3 through 3-7.

Results of seismic surveys are summarized in Tables 3-3, 3-4, and 3-5. The characteristics of subsurface soils, determined from field and laboratory tests, are presented in Table 3-6. Ranges of gradation of the subsurface soils are shown in Figure 3-8. Coarse-grained subsurface soils are poorly to well graded, contain coarse to fine sands and gravels, and are dense to very dense below 10 to 15 feet (3.0 to 4.6 m). Variable cementation occurs intermittently, but well-developed, continuous cementation is not encountered. These soils exhibit low compressibilities and moderate to high shear strengths.

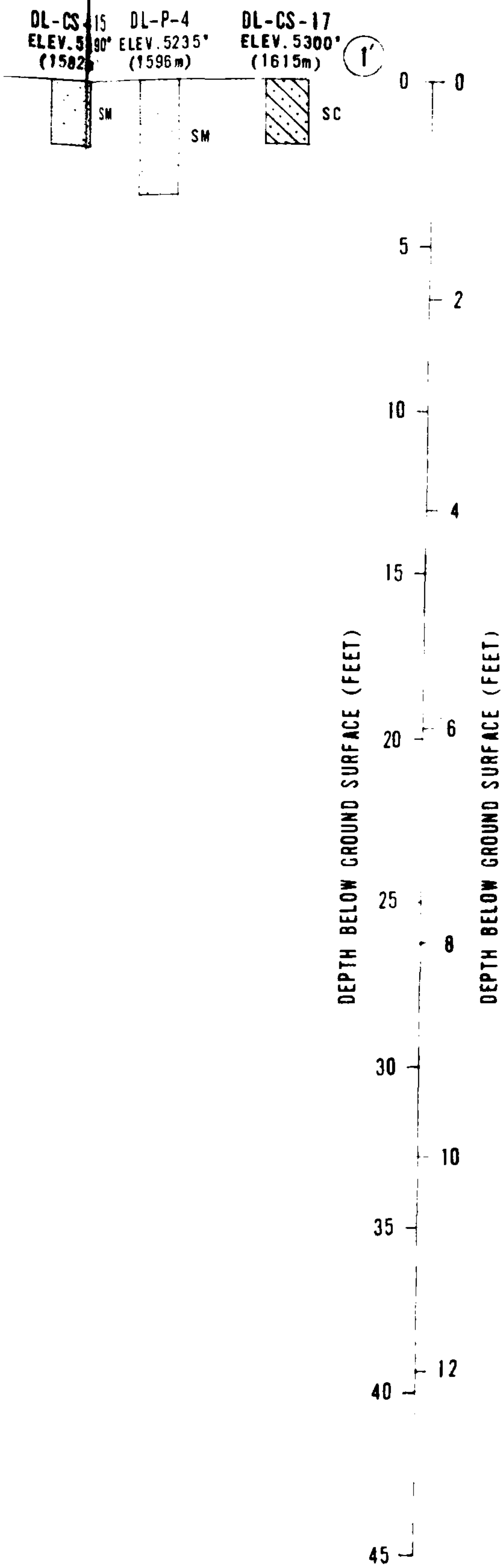
Fine-grained soils (silts and clays) range in consistency from firm to hard and exhibit low to moderate compressibilities and shear strengths. Soil plasticity ranges from none to high, depending in part on the amount of fine sand present. Calcium carbonate cementation varies from weak to moderate, depending on the age of the deposit.

The soils in the construction zone (120 feet; 37 m) have a wide range of seismic compressional wave velocities (960 to > 7000 fps; 293 to > 2135 mps), depending on their composition, consistency, cementation, and moisture content. Seismic compressional wave velocities of the fine-grained soils are substantially lower than those of the coarse-grained soils (see Table 3-6). Compressional wave velocities for deeper materials

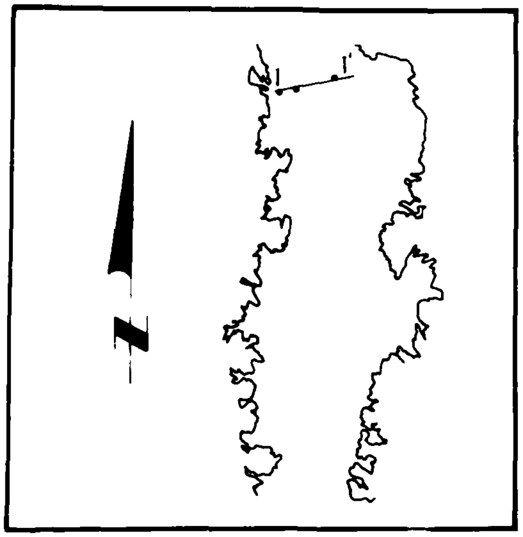
FN-TR-27-CL



14 MAR 80



LOCATION MAP



EXPLANATION

B - Boring
T - Trench
P - Test Pit
CS - Surficial soil sample at Cone Penetrometer Test location

NOTES:

1. Ground surface elevations shown at activity locations are approximate
2. T.D. = Total Depth
3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.

HORIZONTAL SCALE

STATUTE MILES 0 1 2

KILOMETERS 0 1 2 3

2

SOIL PROFILE 1-1'
DRY LAKE VALLEY, NEVADA

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FIGURE 3-3

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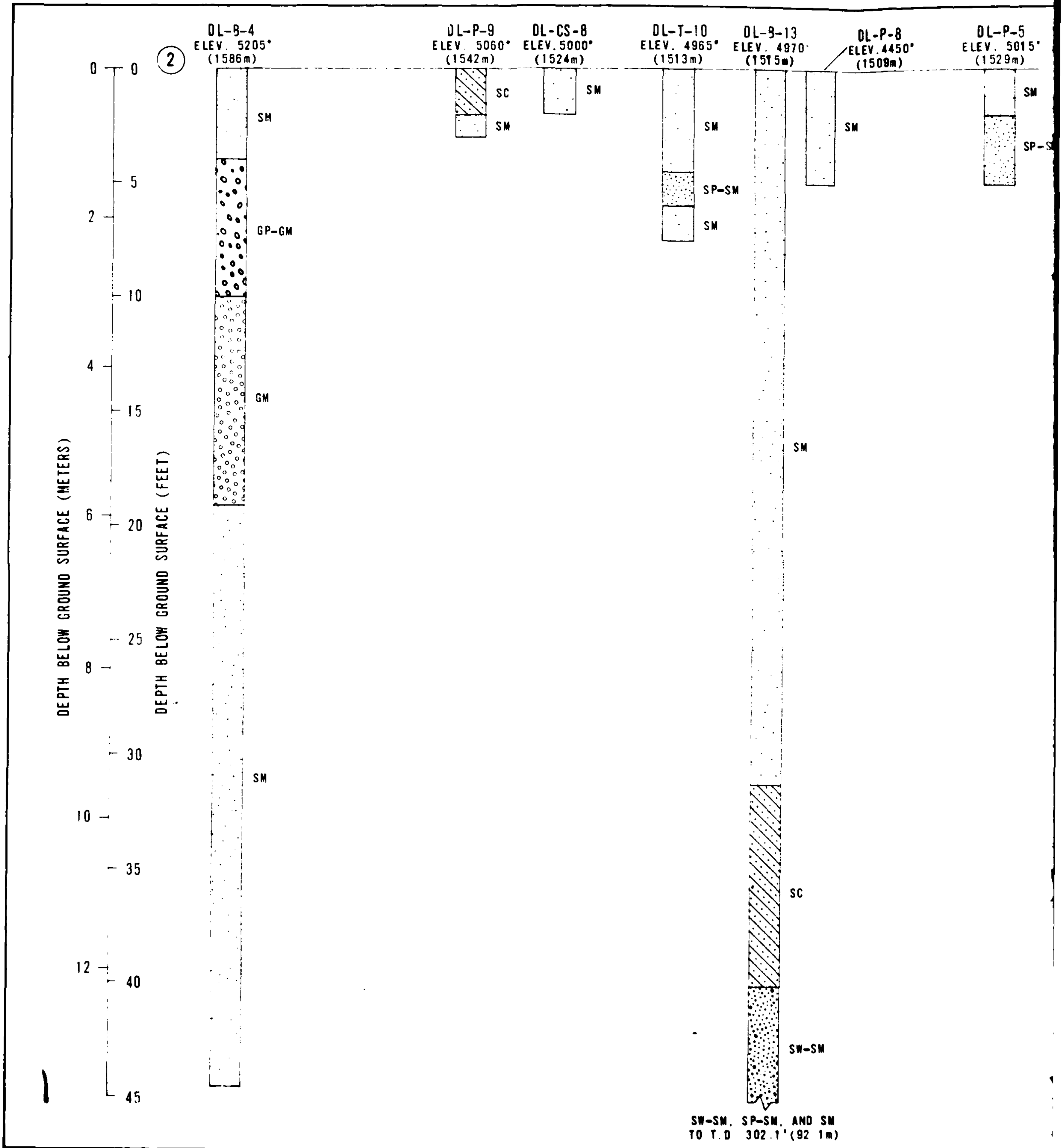
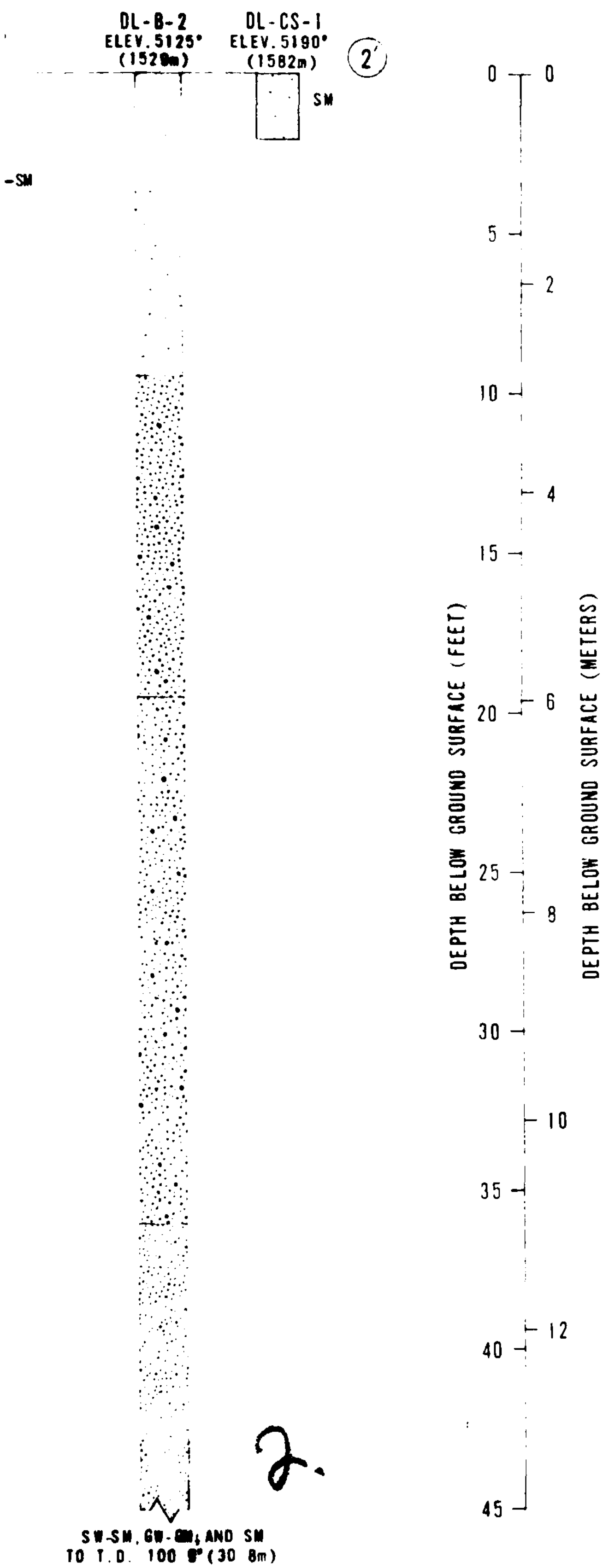
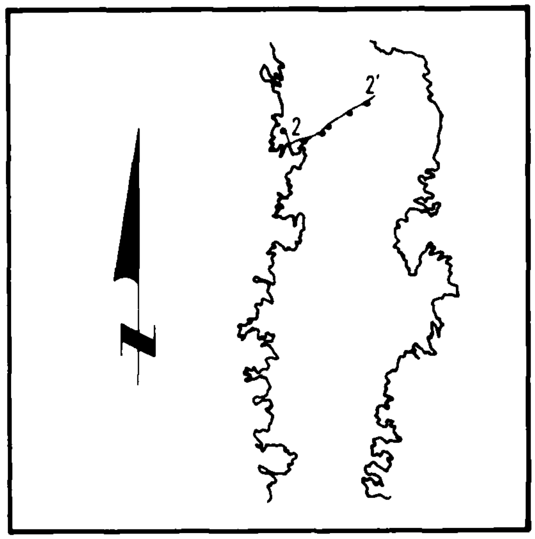


DL-B-4
ELEV. 5205'
(1586m)
DL-P-9
ELEV. 5060'
(1542m)
DL-CS-8
ELEV. 5000'
(1524m)
DL-T-10
ELEV. 4965'
(1513m)
DL-B-13
ELEV. 4970'
(1515m)
DL-P-8
ELEV. 4450'
(1509m)
DL-P-5
ELEV. 5015'
(1529m)
2
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
40
45
SM
GP-GM
GM
SM
SC
SM
SM
SM
SP-SM
SM
SM
SC
SW-SM
SM
SM
SP-S
SW-SM, SP-SM, AND SM
TO T.D 302.1'(92 1m)



LOCATION MAP



EXPLANATION

B – Boring
T – Trench
P – Test Pit
CS – Surficial soil sample at Cone Penetrometer Test location

NOTES:

1. Ground surface elevations shown at activity locations are approximate.
2. T.D. = Total Depth
3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.

HORIZONTAL SCALE

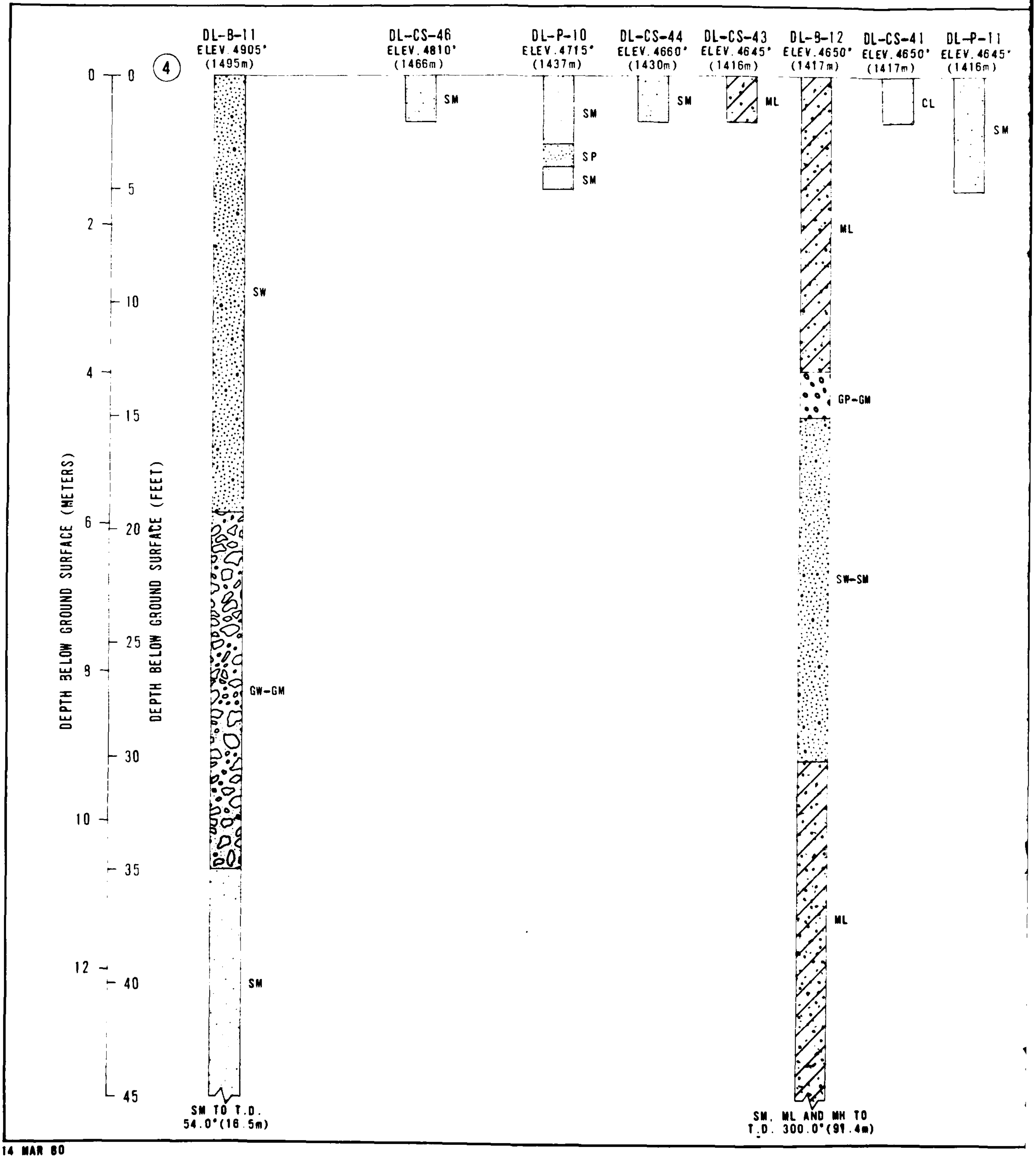
STATUTE MILES 0 1 2
KILOMETERS 0 1 2 3

SOIL PROFILE 2–2'
DRY LAKE VALLEY, NEVADA

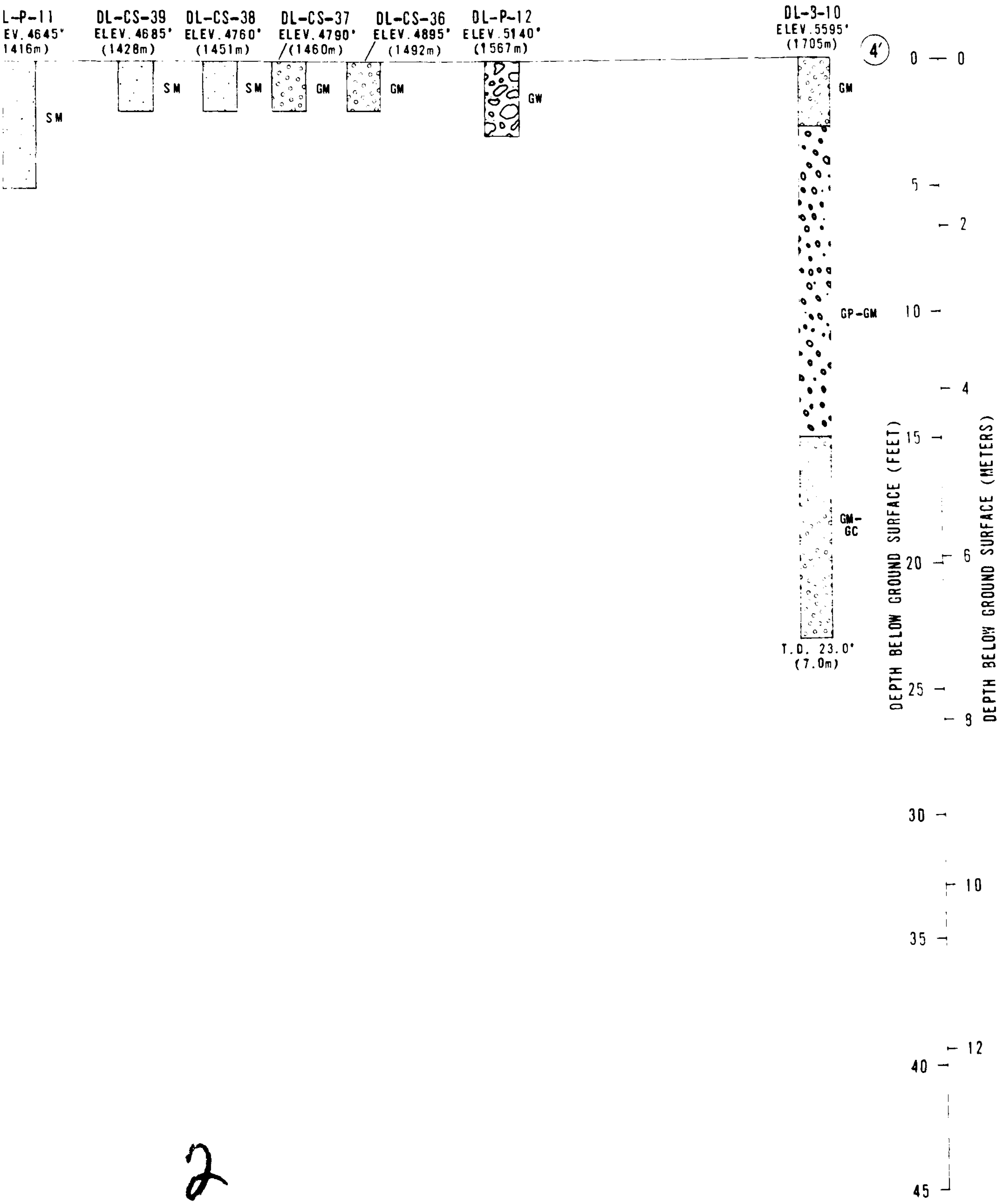
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

FIGURE 3-4

FUGRO NATIONAL, INC.



4
DL-B-11
ELEV. 4905'
(1495m)
DL-CS-46
ELEV. 4810'
(1466m)
DL-P-10
ELEV. 4715'
(1437m)
DL-CS-44
ELEV. 4660'
(1430m)
DL-CS-43
ELEV. 4645'
(1416m)
DL-B-12
ELEV. 4650'
(1417m)
DL-CS-41
ELEV. 4650'
(1417m)
DL-P-11
ELEV. 4645'
(1416m)
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
40
45
SW
GW-GM
SM
SM TO T.D.
54.0'(16.5m)
SM
SM
SP
SM
SM
ML
ML
GP-GM
SW-SM
ML
SM, ML AND MH TO
T.D. 300.0'(91.4m)
CL
SM



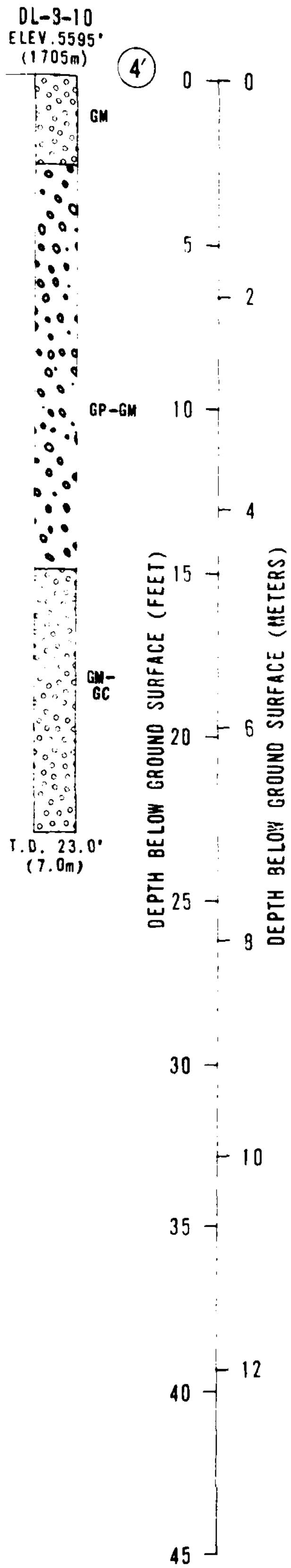
B - Bo
T - Tr
P - Te
CS - Su
Te

NOTES:
1. Ground s
are app
2. T.D. = T
3. Soil ty
Unified
explain

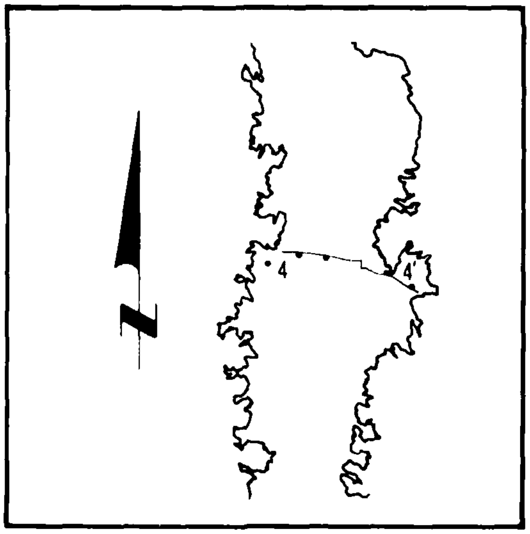
STATUTE

KILOM

2



LOCATION MAP



EXPLANATION

B - Boring
T - Trench
P - Test Pit
CS - Surficial soil sample at Cone Penetrometer Test location

NOTES:

1. Ground surface elevations shown at activity locations are approximate.
2. T.D. = Total Depth
3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.

HORIZONTAL SCALE

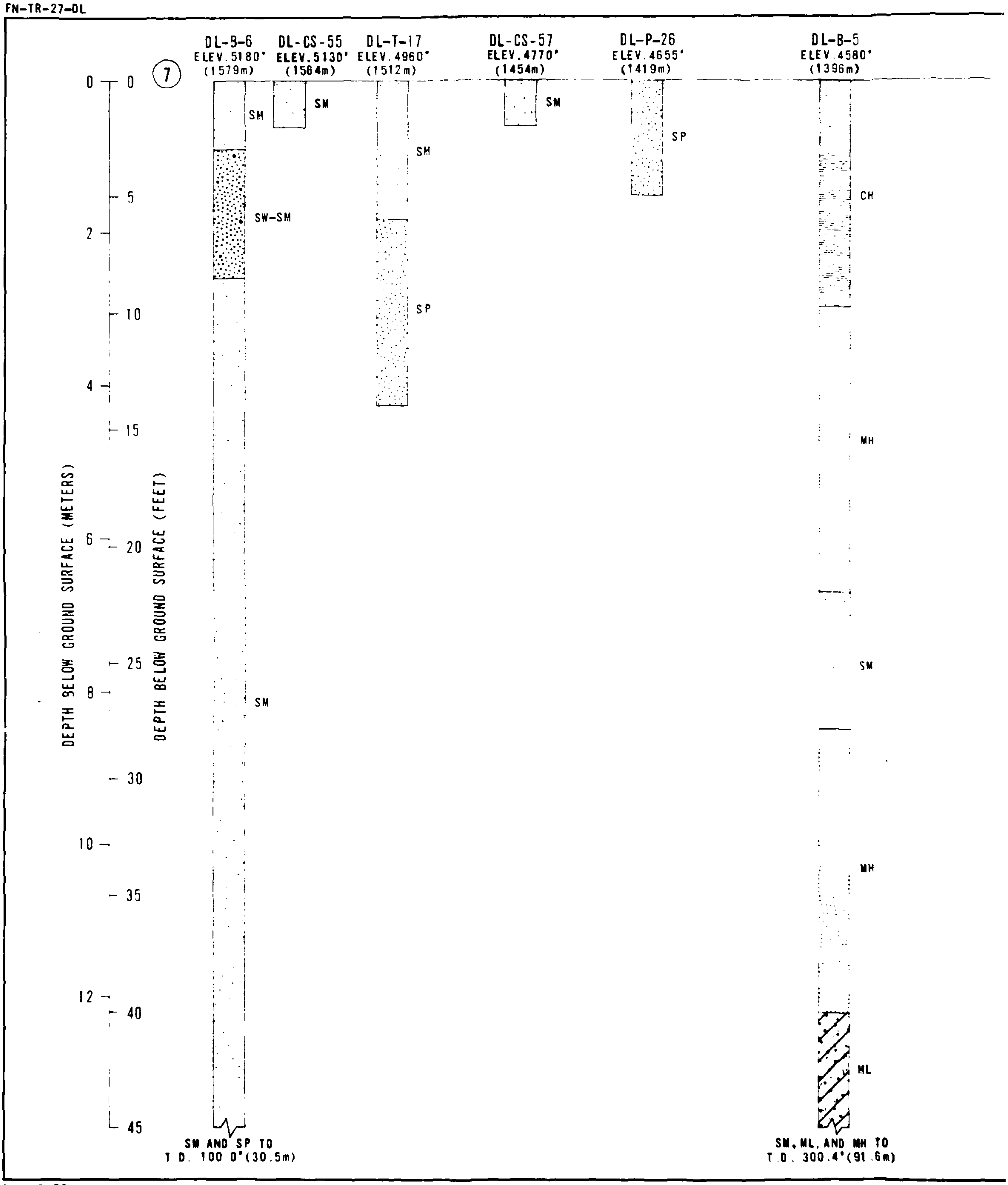
STATUTE MILES 0 1 2

KILOMETERS 0 1 2 3

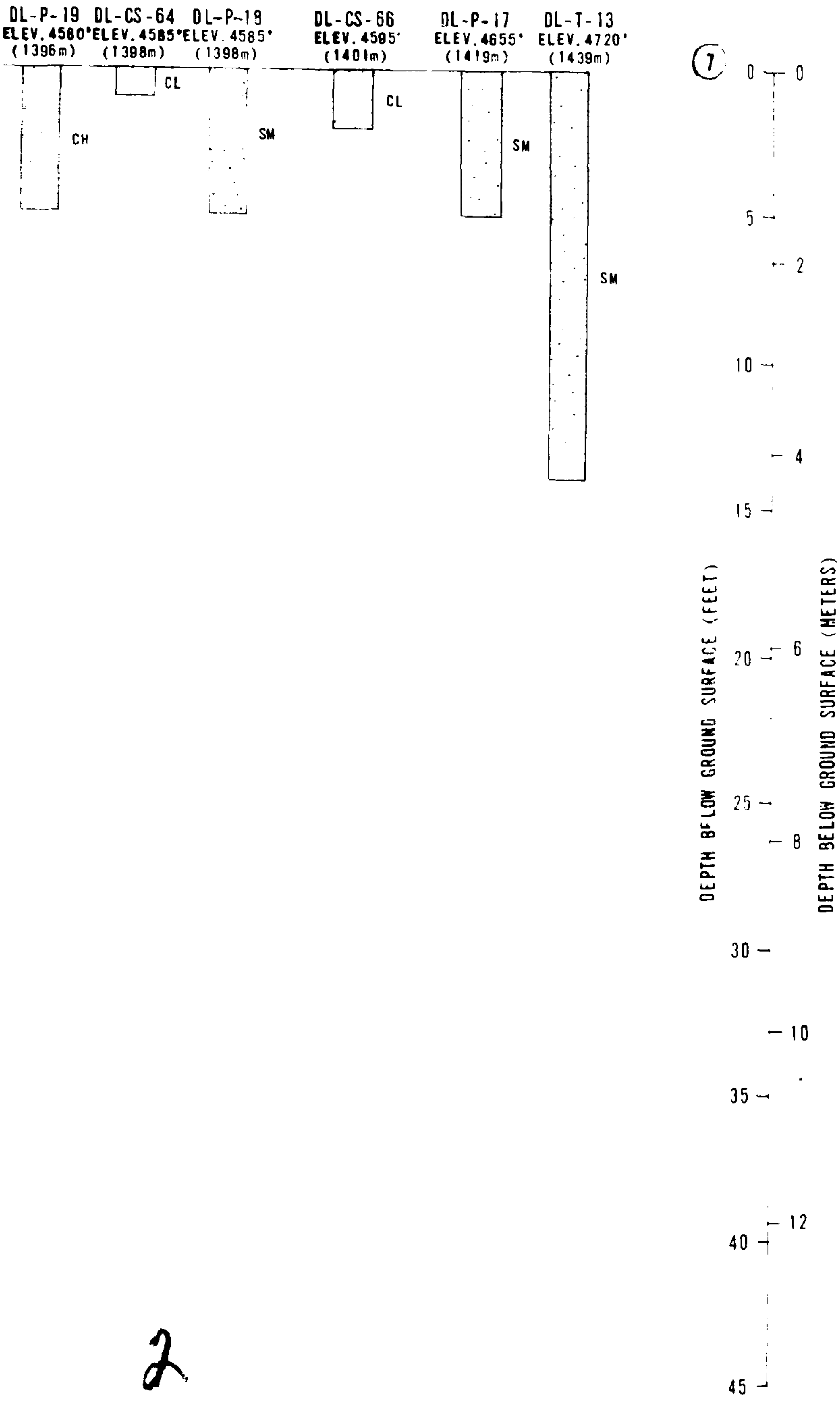
SOIL PROFILE 4-4' DRY LAKE VALLEY, NEVADA	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE BMO	FIGURE 3-5

FUGRO NATIONAL, INC.

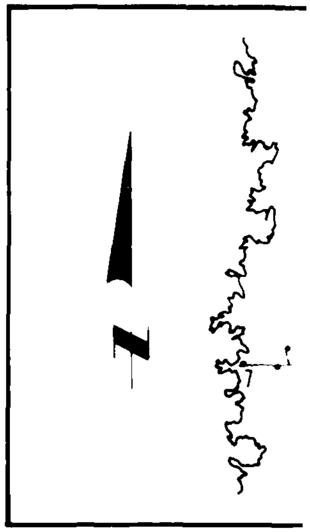
FN-TR-27-DL



14 MAR 80



LOCATION



EXPLANATI

B - Boring
T - Trench
P - Test Pit
CS - Surficial soil sample
Test location

NOTES:

1. Ground surface elevations s
are approximate.
2. T.D. = Total Depth
3. Soil types shown adjacent t
Unified Soil Classification
explained in the appendix.

HOI

STATUTE MILES 0

KILOMETERS 0

SO
DRY L

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FUGRO

2

-T-13
V. 4720'
439m)

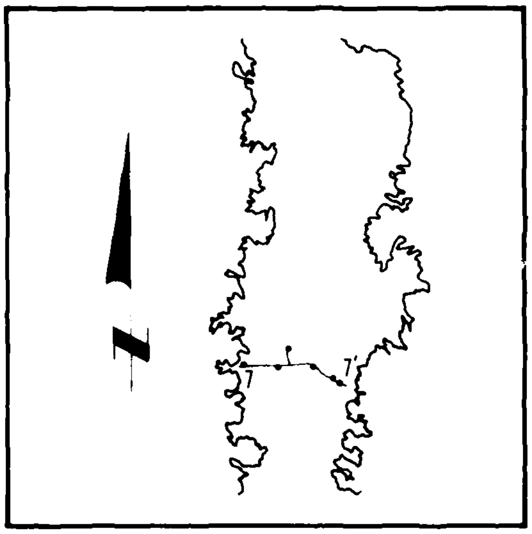
SM

7'

DEPTH BELOW GROUND SURFACE (FEET): 0, 5, 10, 15, 20, 25, 30, 35, 40, 45

DEPTH BELOW GROUND SURFACE (METERS): 0, 2, 4, 6, 8, 10, 12

LOCATION MAP



EXPLANATION

B - Boring
T - Trench
P - Test Pit
CS - Surficial soil sample at Cone Penetrometer Test location

NOTES:

1. Ground surface elevations shown at activity locations are approximate.
2. T.D. = Total Depth
3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.

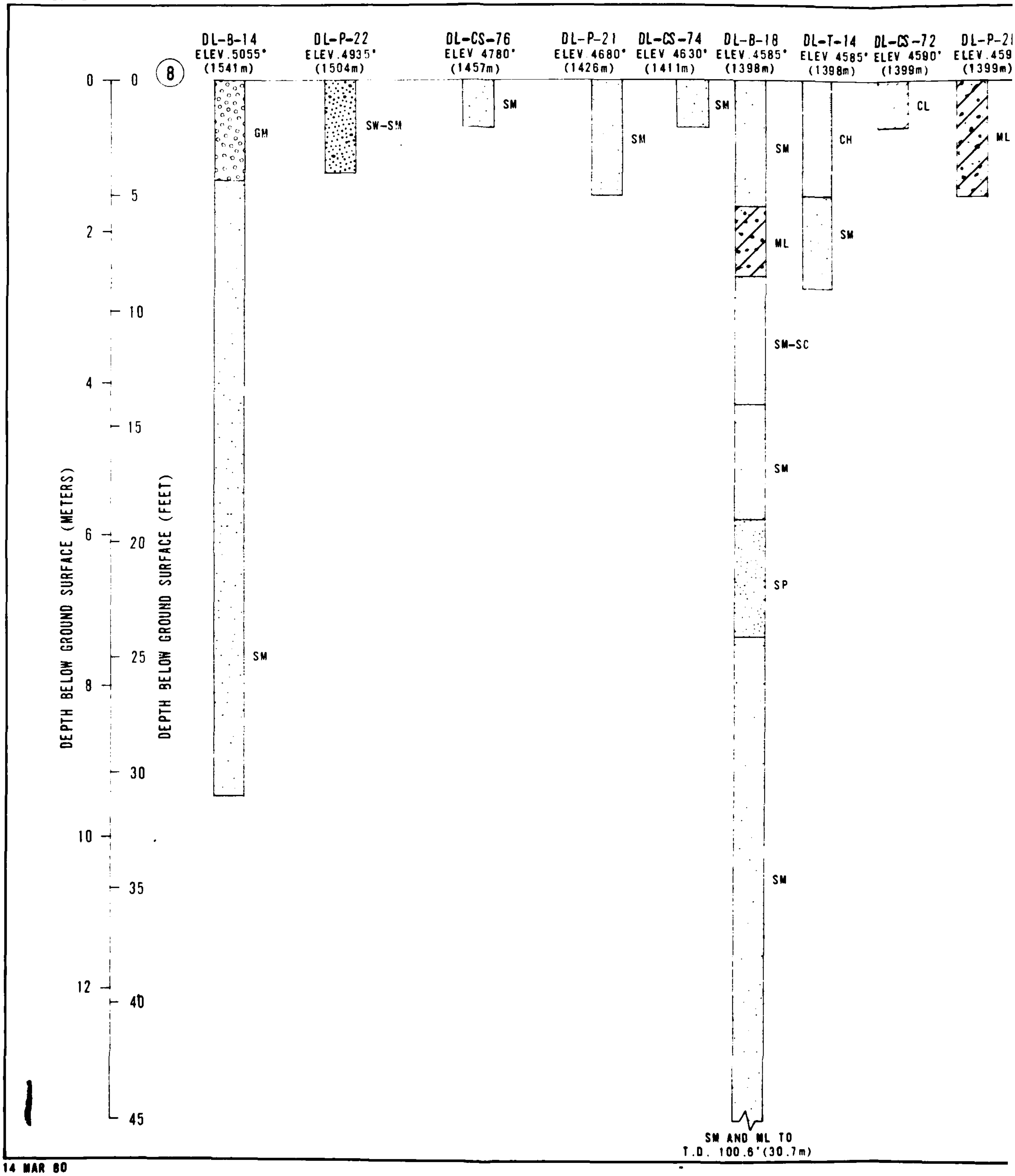
HORIZONTAL SCALE

STATUTE MILES 0 1 2

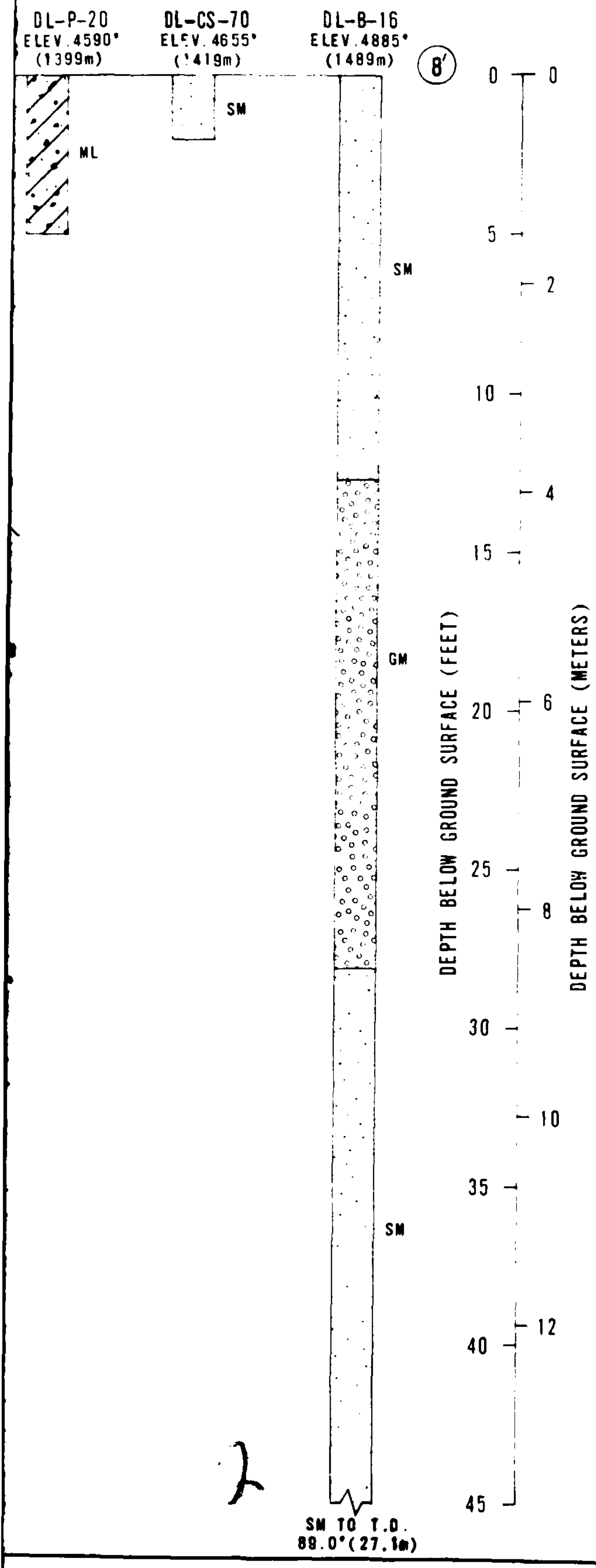
KILOMETERS 0 1 2 3

SOIL PROFILE 7-7' DRY LAKE VALLEY, NEVADA	3
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE BMO	FIGURE 3-6

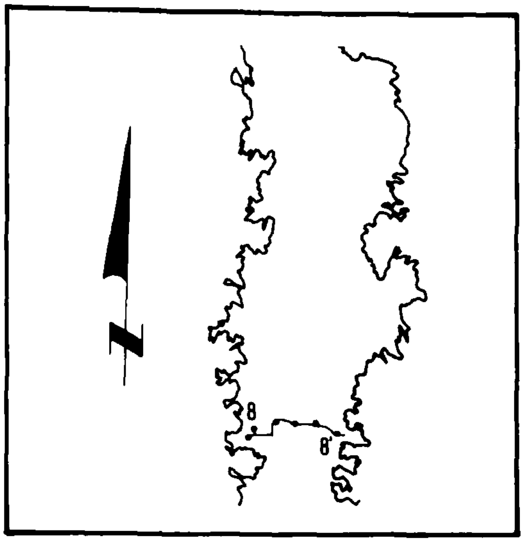
FUGRO NATIONAL, INC.



8
DL-B-14
ELEV.5055'
(1541m)
DL-P-22
ELEV.4935'
(1504m)
DL-CS-76
ELEV 4780'
(1457m)
DL-P-21
ELEV.4680'
(1426m)
DL-CS-74
ELEV 4630'
(1411m)
DL-B-18
ELEV.4585'
(1398m)
DL-T-14
ELEV 4585'
(1398m)
DL-CS-72
ELEV 4590'
(1399m)
DL-P-2
ELEV.459
(1399m)
GM
SM
SW-SM
SM
SM
SM
SM
ML
SM-SC
SM
SP
SM
CH
SM
CL
ML
SM AND ML TO
T.D. 100.6'(30.7m)
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0
2
4
6
8
10
12
0
5
10
15
20
25
30
35
40
45



LOCATION MAP



EXPLANATION

B - Boring
T - Trench
P - Test Pit
CS - Surficial soil sample at Cone Penetrometer Test location

NOTES:

1. Ground surface elevations shown at activity locations are approximate
2. T.D. = Total Depth
3. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.

HORIZONTAL SCALE

STATUTE MILES 0 1 2

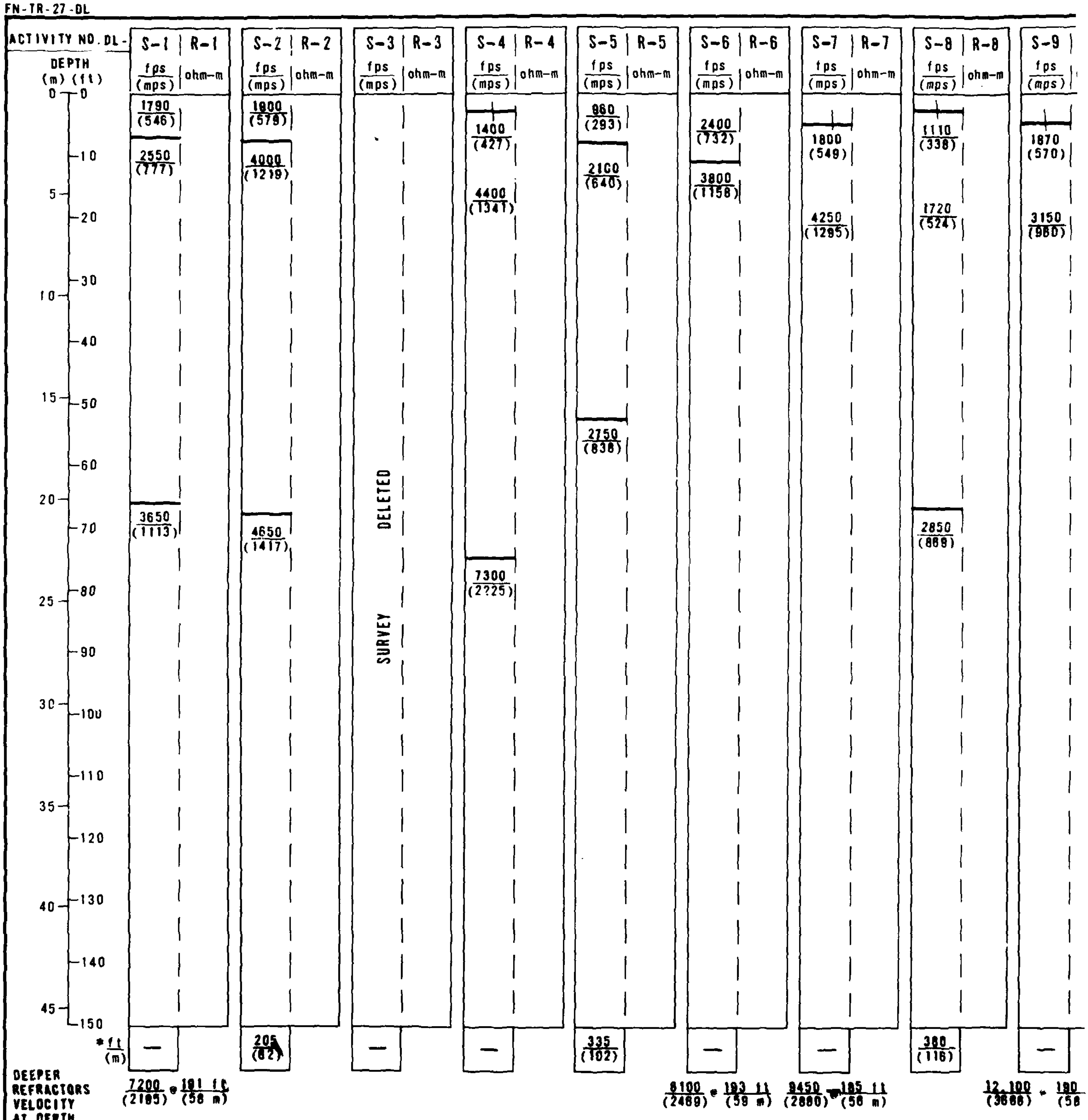
KILOMETERS 0 1 2 3

SOIL PROFILE B-B'
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE 3-7

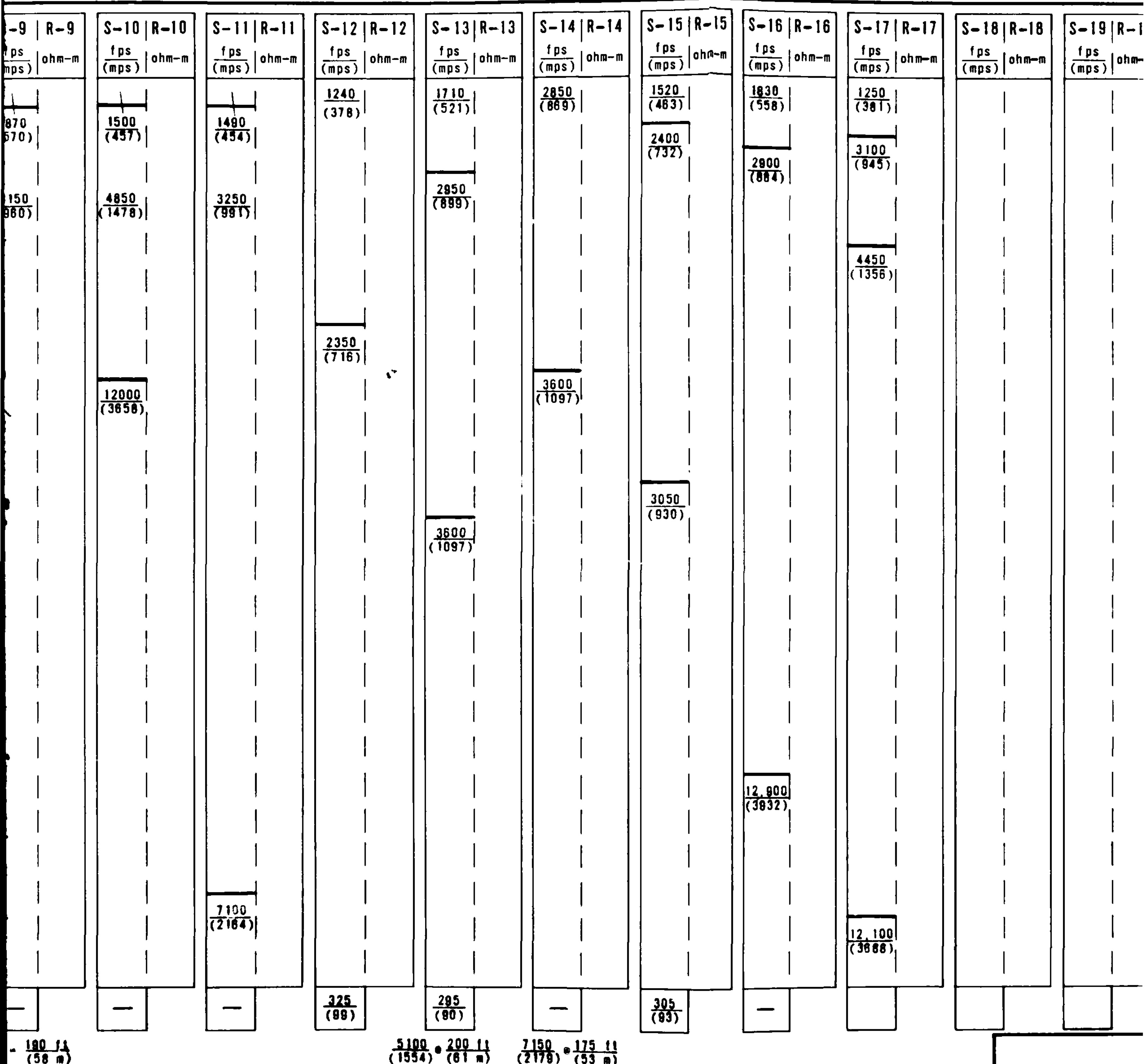
FUGRO NATIONAL, INC.



* Approximate depth above which there is no indication of material with a velocity as great as 7000 fps (2134mps) See Appendix A for an explanation of how this exlusion depth is calculated when the observed velocities are all less than 7000 fps (2134 mps)

NOTE: THERE WERE NO RESISTIVITY SOUNDINGS IN DRY LAKE VALLEY

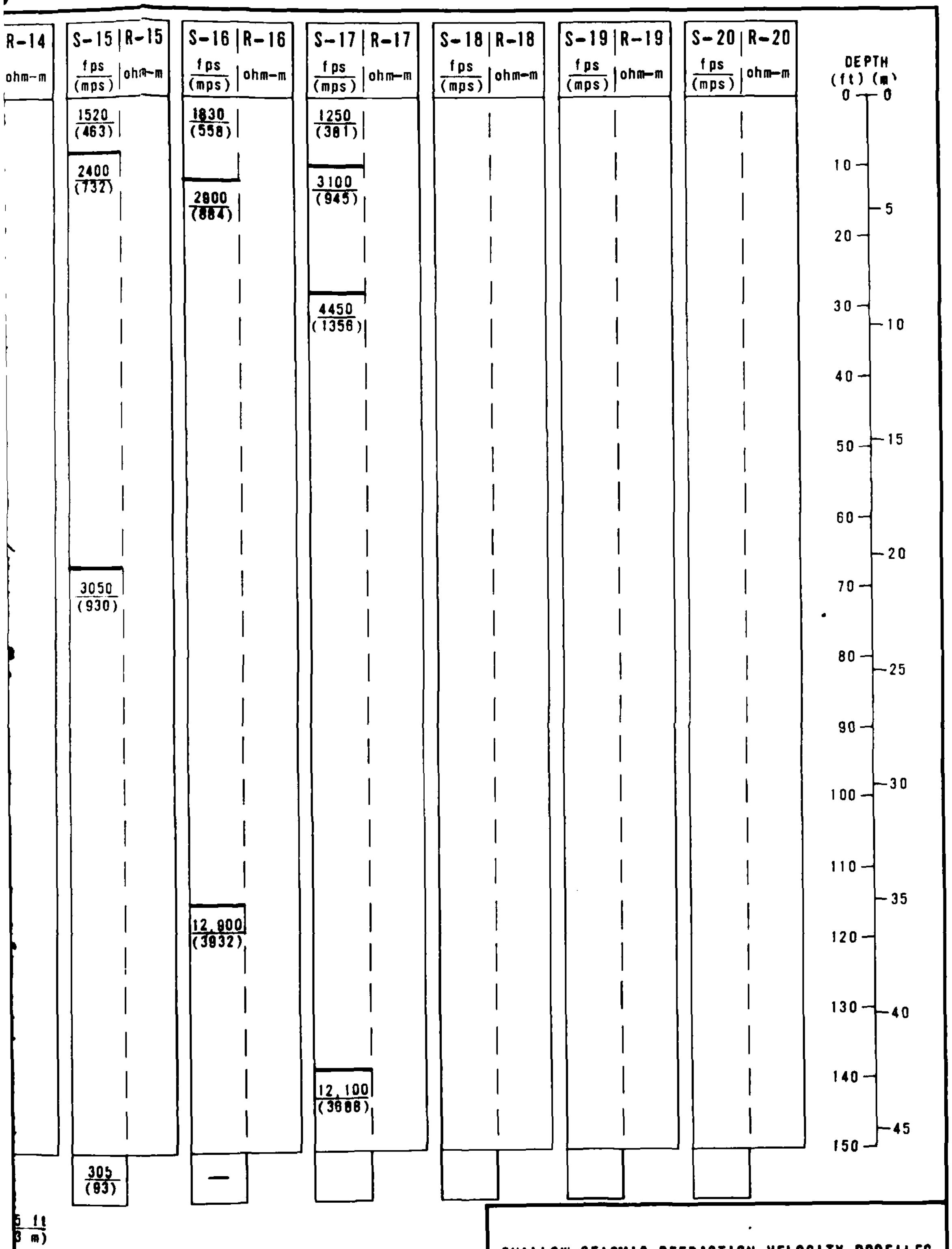
14 MAR 80



SHALLOW SEISMIC
DRY LA

MX SITING
DEPARTMENT OF THE

FUGRO N



SHALLOW SEISMIC REFRACTION VELOCITY PROFILES
DRY LAKE VALLEY, NEVADA

3

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

TABLE 3-3

FUGRO NATIONAL, INC.

AFV-18

VELOCITY LAYER	COMPRESSIONAL WAVE VELOCITY FPS (MPS)	AVERAGE THICKNESS FT (M)	COMMENTS
1	2600 (792)	90 (27)	PINCHES OUT
2	3300-3900 (1006-1189)	150 (46)	-
3	6000-8200 (1829-2499)	500 (152)	DISCONTINUOUS
4	8200-9000 (2499-2743)	1200 (366)	DISCONTINUOUS
5	14,000-16,000 (4267-4877)	UNKNOWN	BASEMENT

LINE DL-DS-1

VELOCITY LAYER	COMPRESSIONAL WAVE VELOCITY FPS (MPS)	AVERAGE THICKNESS FT (M)	COMMENTS
1	2800 (853)	60 (18)	-
2	3900 (1189)	150 (46)	-
3	6600-7400 (2012-2256)	300 (91)	DISCONTINUOUS
4	9000-9300 (2743-2835)	700 (213)	-
5	14,000-16,000 (4267-4877)	UNKNOWN	BASEMENT

LINE DL-DS-2

DEEP SEISMIC REFRACTION VELOCITY PROFILES
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE
3-4

FUGRO NATIONAL, INC.

DOWNHOLE SURVEY NO.	VELOCITY DISTRIBUTION FPS (MPS)				WAVE TYPE
DL-DV-2	2400 (732)	2800 (853)	3760 (1146)		P WAVE
	1400 (427)	1980 (604)	2160 (658)		S WAVE
DL-DV-18	1400 (427)	2050 (625)			P WAVE
	540 (165)	980 (299)	1200 (366)	980 (299)	S WAVE

METERS 0 5 10 15 20 25 30 35 40 45

FEET 0 5 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150

DEPTH INTERVAL

DOWNHOLE SEISMIC VELOCITY PROFILES
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE 3-5

FUGRO NATIONAL, INC.

DEPTH RANGE	2' - 20' (0.6 - 6.0m)			
SOIL DESCRIPTION	Coarse-grained soils		Fine-grained soi
	Sandy Gravels, Gravelly Sands, Silty Sands and Clayey Sands		Sandy Silts, Clayey S Silts, and Clays
USCS SYMBOLS	GW, GP, GM, SW, SP, SM, SC		ML, MH, CH
ESTIMATED EXTENT IN SUBSURFACE %	80-90		10-20
PHYSICAL PROPERTIES			
DRY DENSITY pcf (kg/m^3)	92.9-110.2 (1488-1765)	[10]	69.7-92.0 (1116-1474)
MOISTURE CONTENT %	3.9-14.3	[10]	13.6-31.6
DEGREE OF CEMENTATION	*none to strong*		*moderate*
COBBLES 3 - 12 inches (8 - 30 cm) %	0-10		0
GRAVEL %	0-74	[41]	0-0
SAND %	20-88	[41]	26-47
SILT AND CLAY %	1-42	[43]	53-78
LIQUID LIMIT	17-36	[5]	26-97
PLASTICITY INDEX	NP-12	[16]	NP-60
COMPRESSIONAL WAVE VELOCITY fps (mps)	1240-4850 (378-1478)	[26]	960-2100 (293-640)
SHEAR STRENGTH DATA			
UNCONFINED COMPRESSION S_u - ksf (kN/m^2)	1.6 (77)	[1]	1.2-4.1 (58-196)
TRIAXIAL COMPRESSION c - ksf (kN/m^2), $\phi°$	NDA		NDA
DIRECT SHEAR c - ksf (kN/m^2), $\phi°$	NDA		NDA

NOTES:

- Characteristics of soils between 2 and 20 feet (0.6 and 6.0 meters) are based on results of tests on samples from 18 borings, 8 trenches, and results of 17 seismic refraction surveys.
- Characteristics of soils below 20 feet (6.0 meters) are based on results of tests on samples from 18 borings and results of 17 seismic refraction surveys.

- [ ] - Number o
- NDA - No data ava

.0m)	20' - 160' (6.0 - 49.0m)	
Fine-grained soils	Coarse-grained soils	Fine-grained soils
andy Silts, Clayey Silts, ilts, and Clays	Sandy Gravels, Gravels, Gravelly Sands, Sands, Silty Sands and Clayey Sands	Sandy Silts, Clayey Silts, Silts, Silty Clays, and Clays
., MH, CH	GP GM, SP, SM, SC	ML, MH, CL, CH
-20	80-90	10-20
.7-92.0 (116-1474) [8]	64.3-131.5 (1030-2106) [51]	55.0-101.2 (881-1621) [37]
.6-31.6 [8]	2.8-41.4 [51]	10.6-57.8 [37]
oderate	none to moderate	weak to moderate
	0-10	0
0 [3]	0-98 [74]	0-3 [20]
-47 [3]	1-98 [74]	4-50 [20]
-78 [4]	1-44 [74]	50-96 [22]
-97 [8]	21-49 [4]	28-74 [15]
-60 [9]	NP-12 [32]	NP-28 [19]
0-2100 (93-640) [3]	1240-7300 (378-2225) [26]	1240-2850 (378-869) [6]
2-4.1 (8-196) [2]	3.6-7.5 (173-360) [2]	1.1-4.7 (53-226) [6]
A	C 0.0-1.8 (0-86) ø=33-40 [2]	C=0.0-2.0 (0-96) ø = 29-37 [3]
A	C = 0 ø = 34-35 [3]	NDA

- [ ] - Number of tests performed.
- NDA - No data available (insufficient data or tests not performed.)

2

CHARACTERISTICS OF SUBSURFACE SOILS
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

TABLE 3-6

FUGRO NATIONAL, INC.

AFV-20

DEPTH RANGE	2' - 20' (0.6 - 6.0m)		
SOIL DESCRIPTION	Coarse-grained soils Sandy Gravels, Gravelly Sands, Silty Sands and Clayey Sands		Fine-grained soi Sandy Silts, Clayey S Silts and Clays
USCS SYMBOLS	GW, GP, GM, SW, SP, SM, SC		ML, MH, CH
ESTIMATED EXTENT IN SUBSURFACE %	80-90		10-20
PHYSICAL PROPERTIES			
DRY DENSITY pcf (kg/m³)	92.9-110.2 (1488-1765)	[10]	69.7-92.0 (1116-1474)
MOISTURE CONTENT %	3.9-14.3	[10]	13.6-31.6
DEGREE OF CEMENTATION	none to strong		moderate
COBBLES 3-12 inches (8-30 cm) %	0-10		0
GRAVEL %	0-74	[41]	0-0
SAND %	20-88	[41]	26-47
SILT AND CLAY %	1-42	[43]	53-78
LIQUID LIMIT	17-36	[5]	26-97
PLASTICITY INDEX	NP-12	[16]	NP 60
COMPRESSIONAL WAVE VELOCITY fps (mps)	1240-4850 (378-1478)	[26]	960-2100 (293-640)
SHEAR STRENGTH DATA			
UNCONFINED COMPRESSION S_u - ksf (kN/m²)	1.6 (77)	[1]	1.2-4.1 (58-196)
TRIAXIAL COMPRESSION c - ksf (kN/m²), ø°	NDA		NDA
DIRECT SHEAR c - ksf (kN/m²), ø°	NDA		NDA

NOTES:

- Characteristics of soils between 2 and 20 feet (0.6 and 6.0 meters) are based on results of tests on samples from 18 borings, 8 trenches, and results of 17 seismic refraction surveys.
- Characteristics of soils below 20 feet (6.0 meters) are based on results of tests on samples from 18 borings and results of 17 seismic refraction surveys.

- [ ] - Number o
- NDA - No data av

– 6.0m)	20' – 160' (6.0 – 49.0m)	
Fine-grained soils	Coarse-grained soils	Fine-grained soils
Sandy Silts, Clayey Silts, Silts, and Clays	Sandy Gravels, Gravels, Gravelly Sands, Sands, Silty Sands and Clayey Sands	Sandy Silts, Clayey Silts, Silts, Silty Clays, and Clays
ML, MH, CH	GP GM, SP, SM, SC	ML, MH, CL, CH
10-20	80-90	10-20
69.7-92.0 (1116-1474) [8]	64.3-131.5 (1030-2106) [51]	55.0-101.2 (881-1621) [37]
13.6-31.6 [8]	2.8-41.4 [51]	10.6-57.8 [37]
moderate	none to moderate	weak to moderate
0	0-10	0
0-0 [3]	0-98 [74]	0-3 [20]
26-47 [3]	1-98 [74]	4-50 [20]
53-78 [4]	1-44 [74]	50-96 [22]
26-97 [8]	21-49 [4]	28-74 [15]
NP-60 [9]	NP-12 [32]	NP-28 [19]
960-2100 (293-640) [3]	1240-7300 (378-2225) [26]	1240-2850 (378-869) [6]
1.2-4.1 (58-196) [2]	3.6-7.5 (173-360) [2]	1.1-4.7 (53-226) [6]
NDA	C 0.0-1.8 ø = 33-40 (0-86) [2]	C = 0.0-2.0 ø = 29-37 (0-96) [3]
NDA	C = 0 ø = 34-35 [3]	NDA

- [ ] – Number of tests performed.
- NDA – No data available (insufficient data or tests not performed.)

2

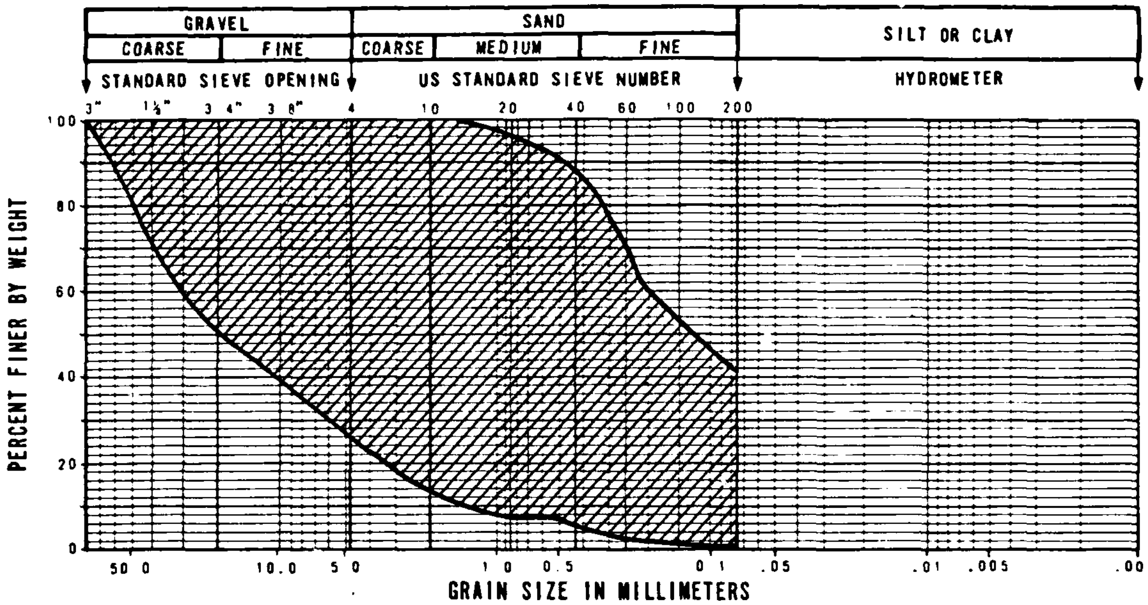
CHARACTERISTICS OF SUBSURFACE SOILS
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

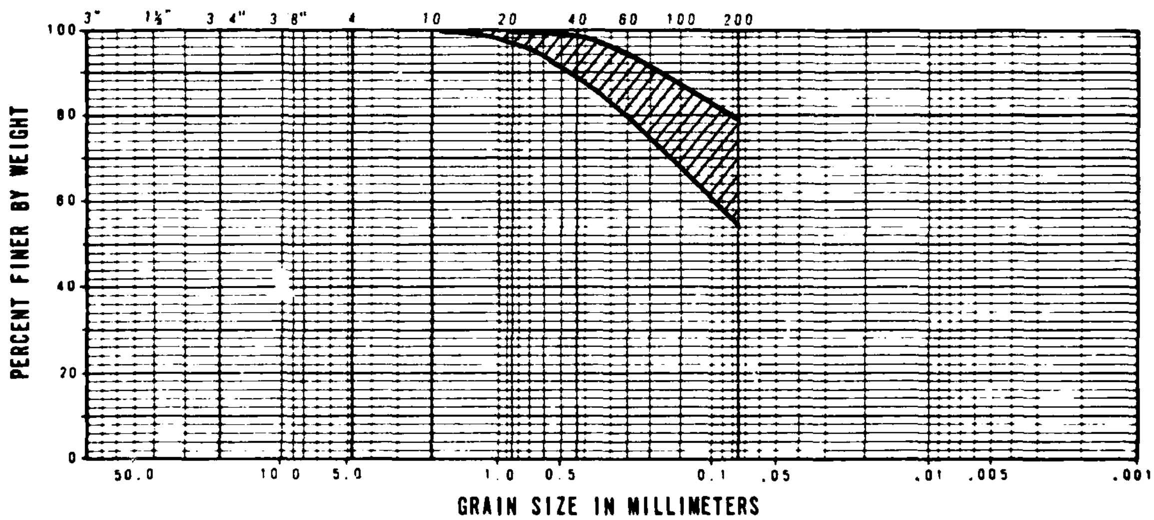
TABLE 3-6

FUGRO NATIONAL, INC.

AFV-20



SOIL DESCRIPTION: Coarse-Grained Soils
from 2 to 20 feet (0.6 to 6.0m)



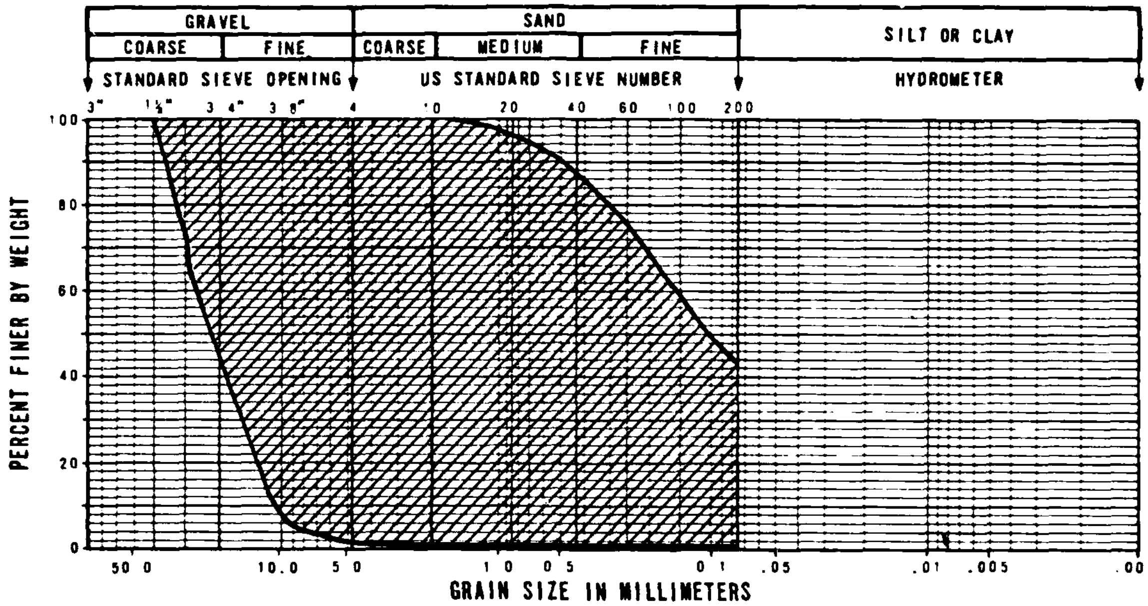
SOIL DESCRIPTION: Fine-Grained Soils
from 2 to 20 feet (0.6 to 6.0m)

RANGE OF GRADATION OF SUBSURFACE SOILS
DRY LAKE VALLEY, NEVADA

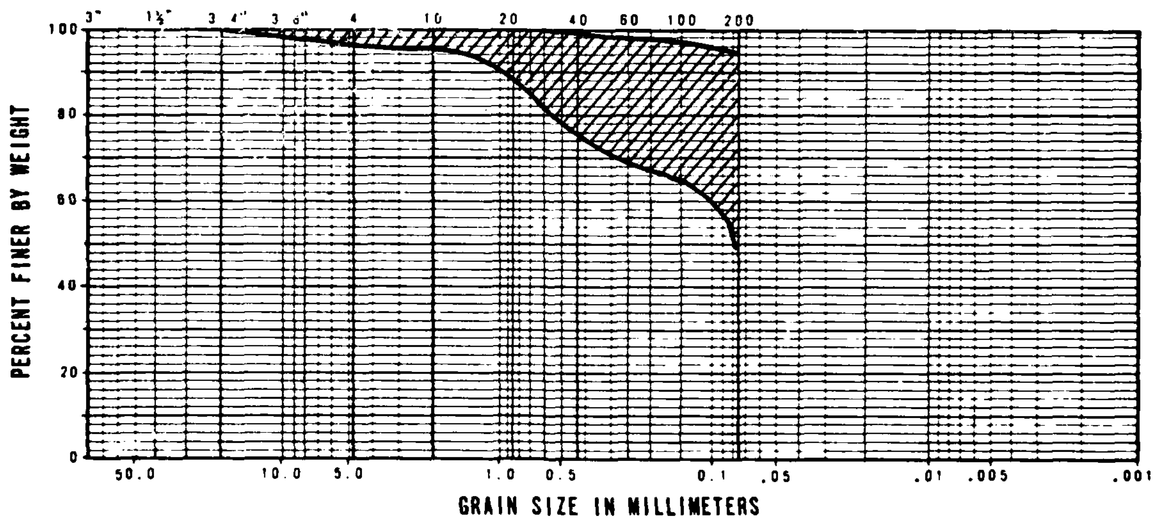
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE 3-8
1 of 2

FUGRO NATIONAL, INC.



SOIL DESCRIPTION: Coarse-Grained Soils
from 20 to 160 feet (6.0 to 49.0m)



SOIL DESCRIPTION: Fine-Grained Soils
from 20 to 160 feet (6.0 to 49.0m)

RANGE OF GRADATION OF SUBSURFACE SOILS DRY LAKE VALLEY, NEVADA	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE - BMO	FIGURE 3-8 2 of 2

FUGRO NATIONAL, INC.

are listed in Table 3-4. The soil types represented by these velocities are unknown.

Seismic shear wave velocities (Table 3-5) of sandy gravels and gravelly sands were measured to range from 1400 fps (427 mps) to 2160 fps (658 mps) between depths of from 0 to 90 feet (0 to 27 m). The shear wave velocities in silty sands and sandy silts were measured to range from 540 fps (165 mps) near the surface to as high as 1200 fps (386 mps) at a depth of approximately 50 feet (15 m).

Results of chemical tests indicate that potential for sulfate attack of soils on concrete will range from "negligible" to "mild."

3.5 DEPTH TO ROCK

Drawing 3-3 shows the approximate configuration of 50- and 150-foot (15- and 46-m) depth to rock contours in Dry Lake Valley. This interpretation is based on limited point data from borings, seismic refraction surveys, site-specific published data, and depths inferred from geologic and geomorphic relationships. Approximately 20 percent of the basin-fill material in the valley is interpreted to be underlain by rock at depths of less than 50 feet. An additional six percent of the valley is interpreted to contain shallow rock between depths of 50 and 150 feet.

The depth to rock interpretation, in most cases, represents subsurface projections of surface rock, tempered by limited confirmatory data from borings and seismic lines. For this reason, contours generally parallel exposed rock in the valley.

Several areas that are interpreted to be underlain by shallow rock exist along the periphery of the valley. In the northeast portion of the valley, west of Bristol Range, intermediate and old alluvial fans are interpreted to be underlain by broad areas of shallow volcanic rock. Many small reentrant canyons are interpreted to contain alluvial fans underlain by shallow rock. Additionally, scattered low-lying volcanic outcrops, extending outward from the mountain ranges, are interpreted to be connected at shallow depths.

Two recently drilled borings in Dry Lake Valley have added to the depth to rock data base (Drawing 3-3). One, Well W3, drilled by the Air Force Weapons Laboratory (AFWL) and Waterways Experiment Station (WES) (1979), penetrated 1000 feet (305 m) of basin-fill material and did not encounter rock. The Water Resources Division of FNI drilled a 1300-foot well (W11) in 1979 for an intermediate aquifer study program and did not encounter rock.

3.6 DEPTH TO WATER

Drawing 3-4 shows the approximate locations of all datum points used to define ground-water conditions in Dry Lake Valley. The sources of these data, in addition to FNI activities, are: USGS, 1978; Eakin, 1963; and AFWL and WES, 1979.

Seven wells, drilled in basin-fill materials, indicate that ground water exists at a depth generally greater than 400 feet (122 m) throughout the central valley. As a consequence of this data, no 50- or 150-foot (15- and 46-m) depth to water contours are shown in Drawing 3-4. Some minor amounts of shallow water occur in some canyon reentrant valleys (FNI, 1979b). Four wells with water at depths less than 150 feet are shown (Drawing 3-4), but they are all located in or directly adjacent to shallow rock/rock areas which were already excluded from the suitable area. Well W3 was drilled by AFWL and WES (1979) for survivability/hardness studies. Water was measured at a depth of 772 (235 m) feet in this well in August 1979. Well W11 was drilled for the FNI intermediate aquifer study. Water was encountered at a depth of 383 feet (117 m) in this boring in January 1980. Additional hydrologic data on Dry Lake Valley is presented in FNI's summary report covering activities of the Water Resources Program in fiscal year 1979 (1979b).

3.7 TERRAIN

Terrain conditions are depicted in Drawing 3-5. In general, terrain categories I through V correspond to alluvial fan or mixed alluvial fan and lacustrine deposits with varying amounts of stream incision. There were no areas interpreted as Category VI terrain (highly variable). Where incision depths are extreme and where topographic slope exceeds 10 percent, the terrain is considered unsuitable and has been excluded (Category VII). Areas with extreme incision generally occur in the northeastern portion of the valley, west of the Bristol Range.

Small areas with topographic slopes exceeding ten percent occur in many of the canyon reentrants around the valley.

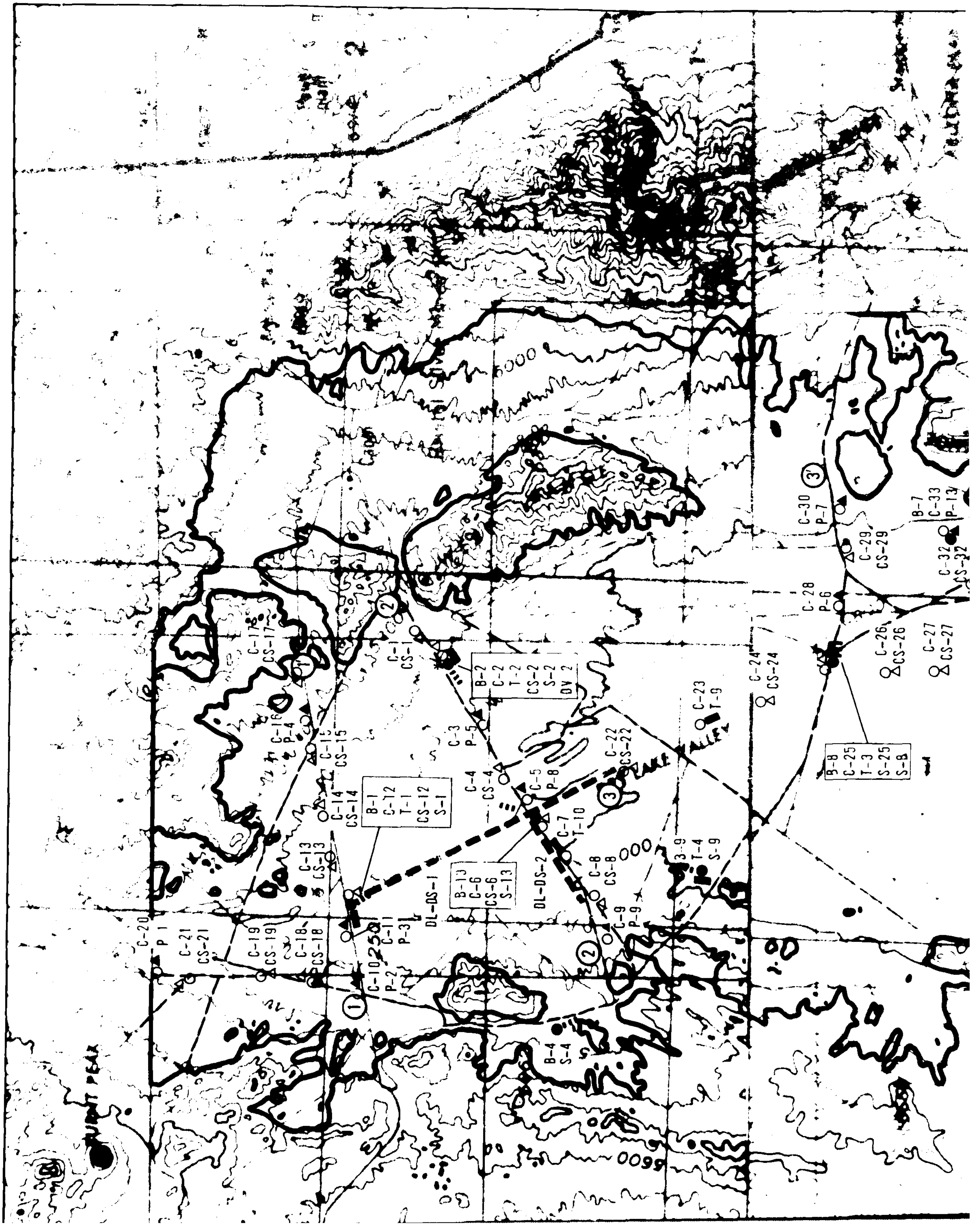
Relief within Dry Lake Valley exceeds 4000 feet (1219 m). Mountain crests bounding the valley generally range in elevation from 7000 feet to 9000 feet (2134 to 2743 m). Highland Peak on the east, at an elevation of 9395 feet (2864 m), is the highest point. The playa in the southern portion of the valley is the lowest point, at an elevation of less than 4600 feet (1402 m). Dry Lake Valley is separated from Delamar Valley to the south by a low, broad alluvial drainage divide.

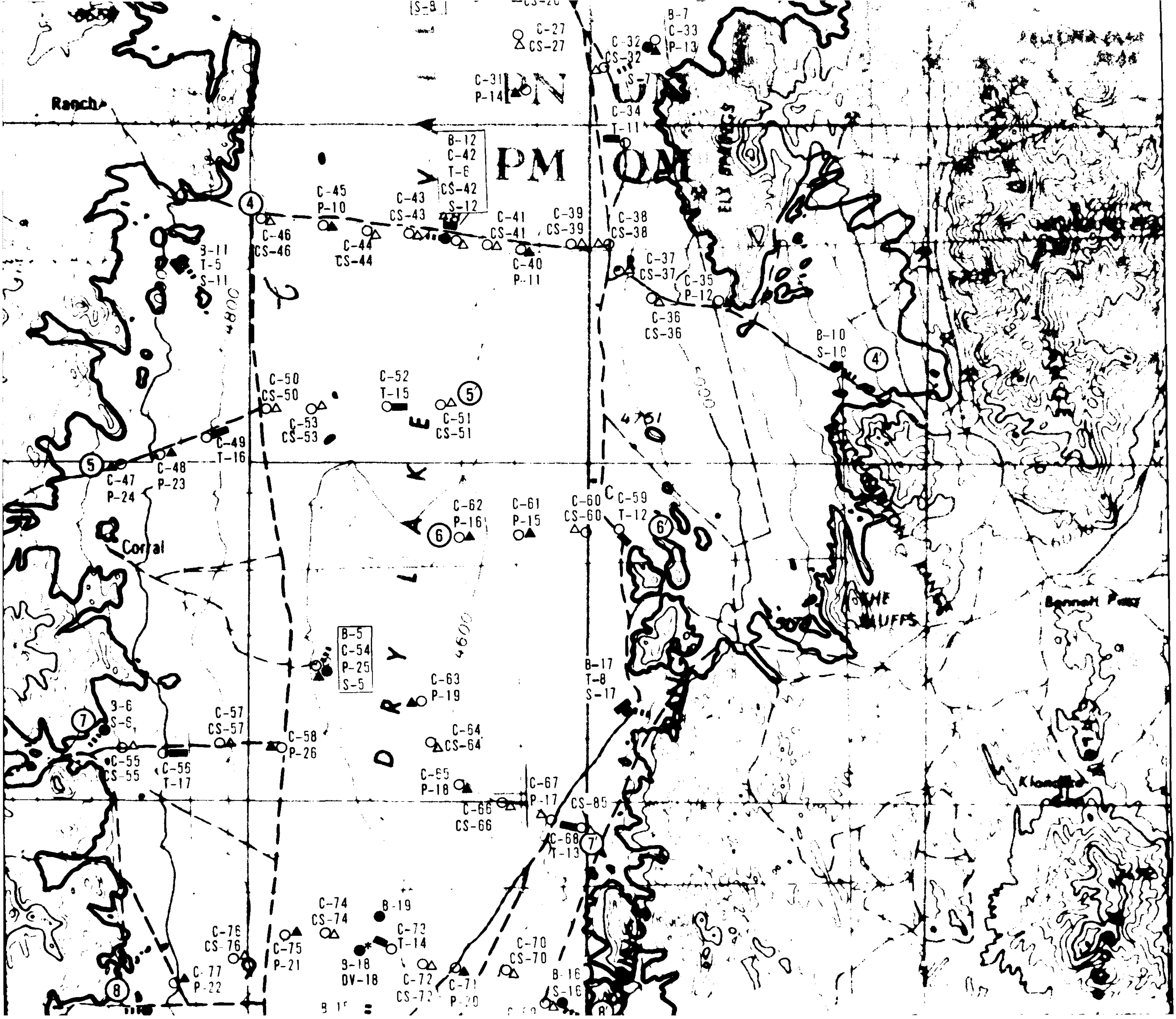
Intermediate and older alluvial fans near mountain fronts (terrain categories II through IV) exhibit incision depths generally ranging from 6 to 15 feet (1.8 to 4.6 m) with variable incision spacing. Surface slopes on intermediate alluvial fans vary from one to nine percent, with a mean value of four percent.

Older fluvial deposits have relief varying from 3 to 5 feet (0.9 to 1.5 m) near the central playa to upwards of 30 feet (9.1 m) in the northern portion of the valley.

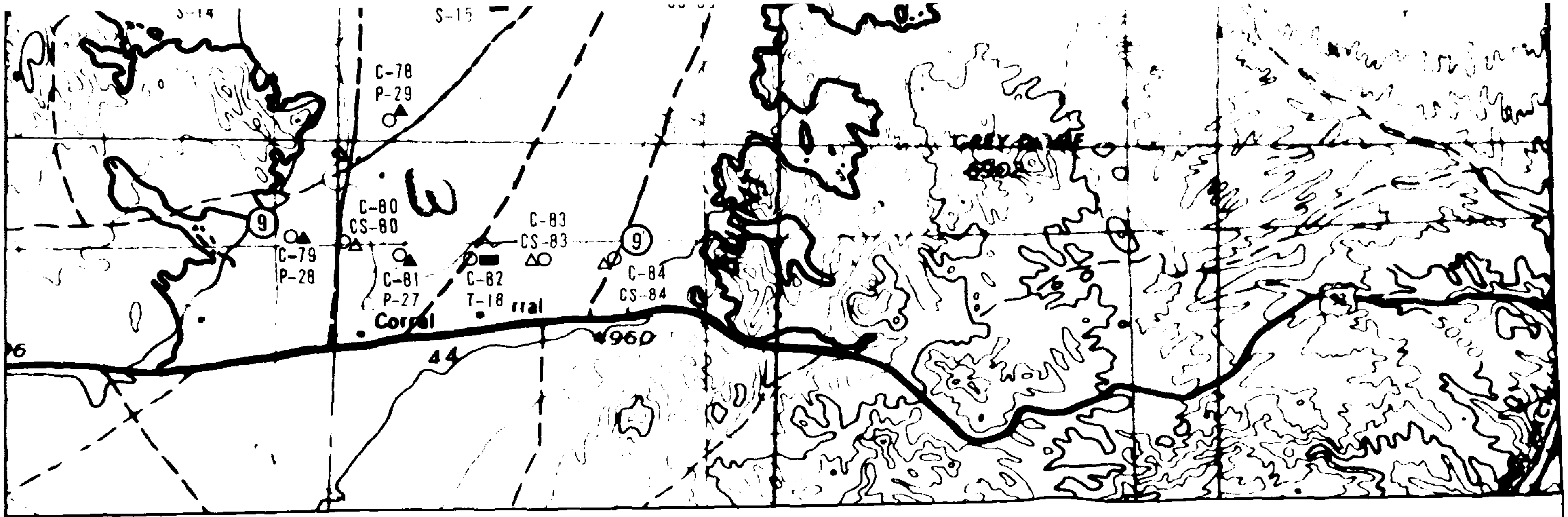
Playa and lacustrine deposits have relief from 0 to 3 feet (0 to 0.9 m). Within these deposits, areas of vegetation are found where the relief is greatest.

Young alluvial fans (generally terrain categories I through III) have incisions ranging from 0 to 6 feet (0 to 1.8 m), with a mean of approximately 3 feet (0.9 m).


LAKE VALLEY
5000
5600
DL-DS-1
DL-DS-2
B-1
C-12
T-1
CS-12
S-1
B-2
C-2
T-2
CS-2
S-2
DV 2
B-8
C-25
T-3
S-25
S-8
B-7
C-33
P-13
B-4
S-4
C-1
CS-1
C-3
P-5
C-4
CS-4
C-5
P-8
C-7
T-10
C-8
CS-8
C-9
P-9
C-10
P-2
C-11
P-3
C-13
CS-13
C-14
CS-14
C-15
CS-15
C-16
P-4
C-17
CS-17
C-18
CS-18
C-19
CS-19
C-20
P 1
C-21
CS-21
C-22
CS-22
C-23
T-9
C-24
CS-24
C-26
CS-26
C-27
CS-27
C-28
P-6
C-29
CS-29
C-30
P-7
C-32
CS-32
T-4
S-9



Ranch
Corral
ELK SPRINGS
PM
DRY LAKE
B-7
C-33
P-13
C-32
CS-32
C-27
CS-27
C-31
P-14
C-34
T-11
B-12
C-42
T-6
CS-42
S-12
C-45
P-10
C-43
CS-43
C-46
CS-46
C-44
CS-44
C-41
CS-41
C-39
CS-39
C-40
P-11
C-38
CS-38
C-37
CS-37
C-35
P-12
C-36
CS-36
B-10
S-10
B-11
T-5
S-11
C-50
CS-50
C-53
CS-53
C-52
T-15
C-51
CS-51
C-49
T-16
C-48
P-23
C-47
P-24
C-62
P-16
C-61
P-15
C-60
CS-60
C-59
T-12
B-5
C-54
P-25
S-5
C-63
P-19
B-17
T-8
S-17
C-57
CS-57
C-58
P-26
C-64
CS-64
C-55
CS-55
C-56
T-17
C-65
P-18
C-67
P-17
CS-85
C-66
CS-66
C-68
T-13
C-74
CS-74
B-19
C-73
T-14
C-76
CS-76
C-75
P-21
C-70
CS-70
C-77
P-22
DV-18
C-72
CS-72
B-16
S-16
4800
4600
5000
4751



EXPLANATION

- ● B-1 BORING
- ○ C-1 CONE PENETROMETER TEST (CPT)
- △ CS-1 SURFACE SAMPLE AT CPT LOCATION
- ▬ T-1 TRENCH
- ▲ P-1 TEST PIT
- S-1 SEISMIC REFRACTION LINE
- R-1 ELECTRICAL RESISTIVITY LINE
- * DV-1 DOWNHOLE VELOCITY SURVEY
- DL-DS-1 DEEP SEISMIC REFRACTION LINE
- (1)---(1') ACTIVITY LINE

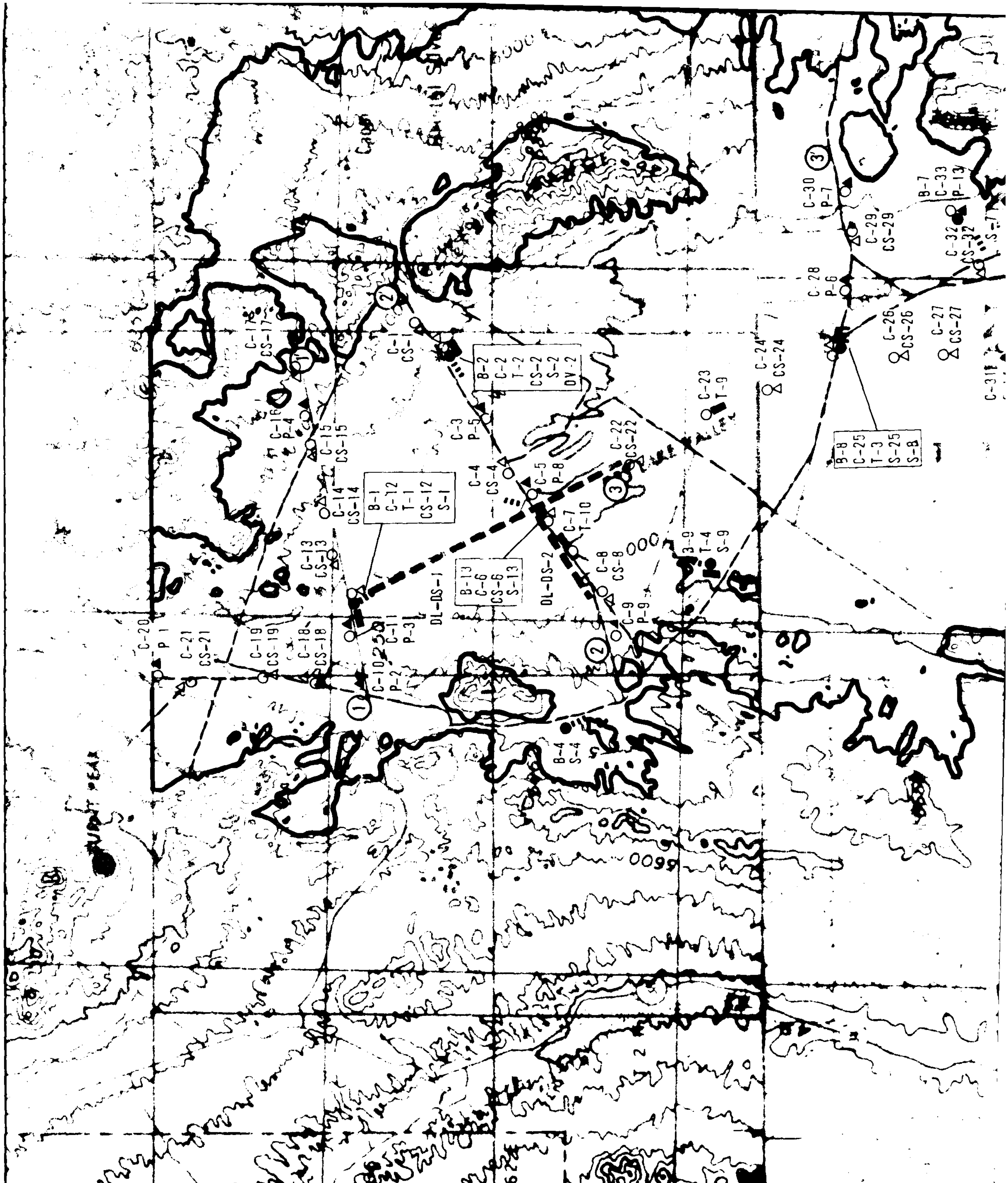
NOTE Where multiple activities were performed at the same location, the correct location is designated by either (1) the boring symbol or (2) the CPT symbol, if no boring was drilled

N

SCALE 1:125,000

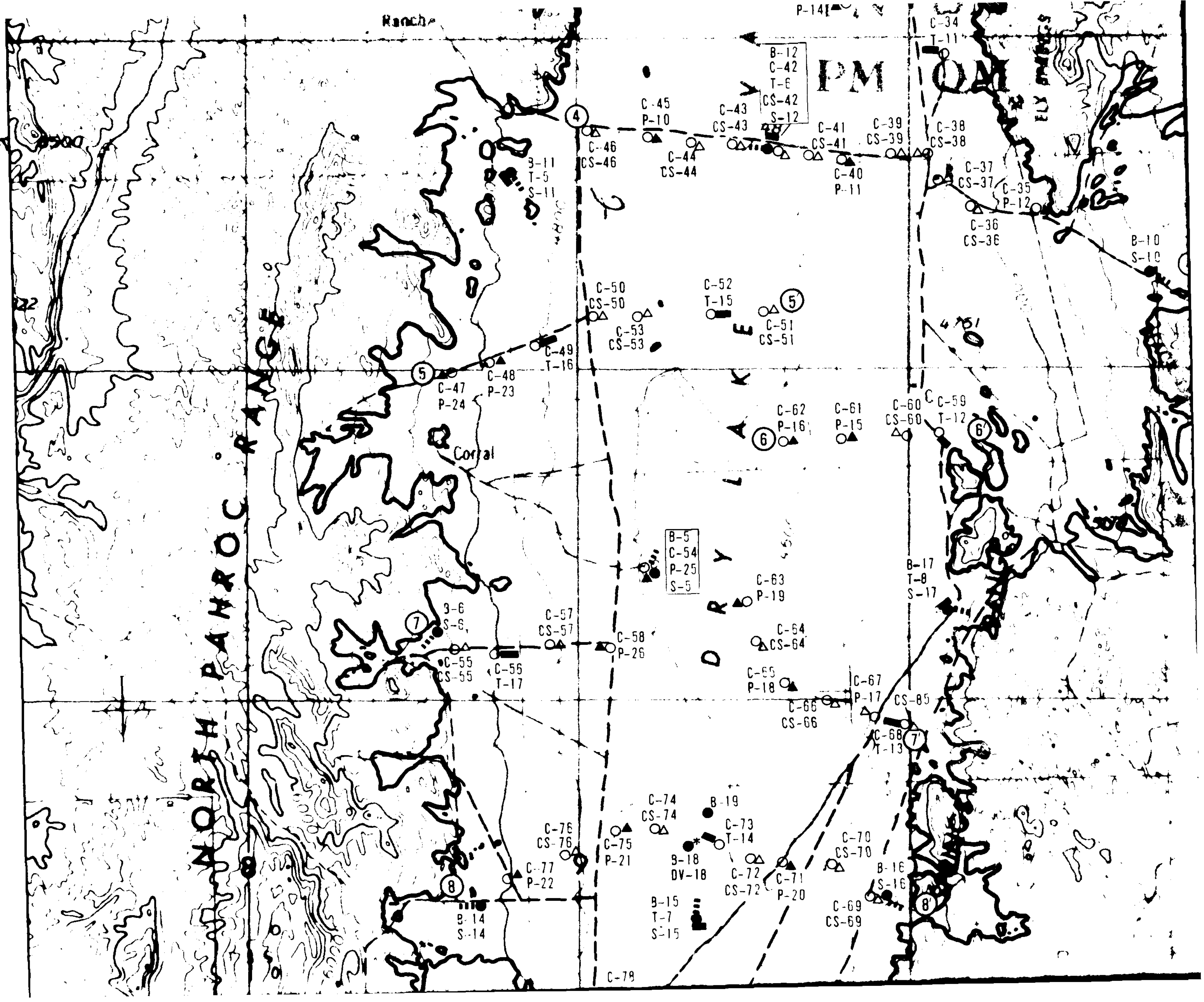
0 2 4
STATUTE MILES

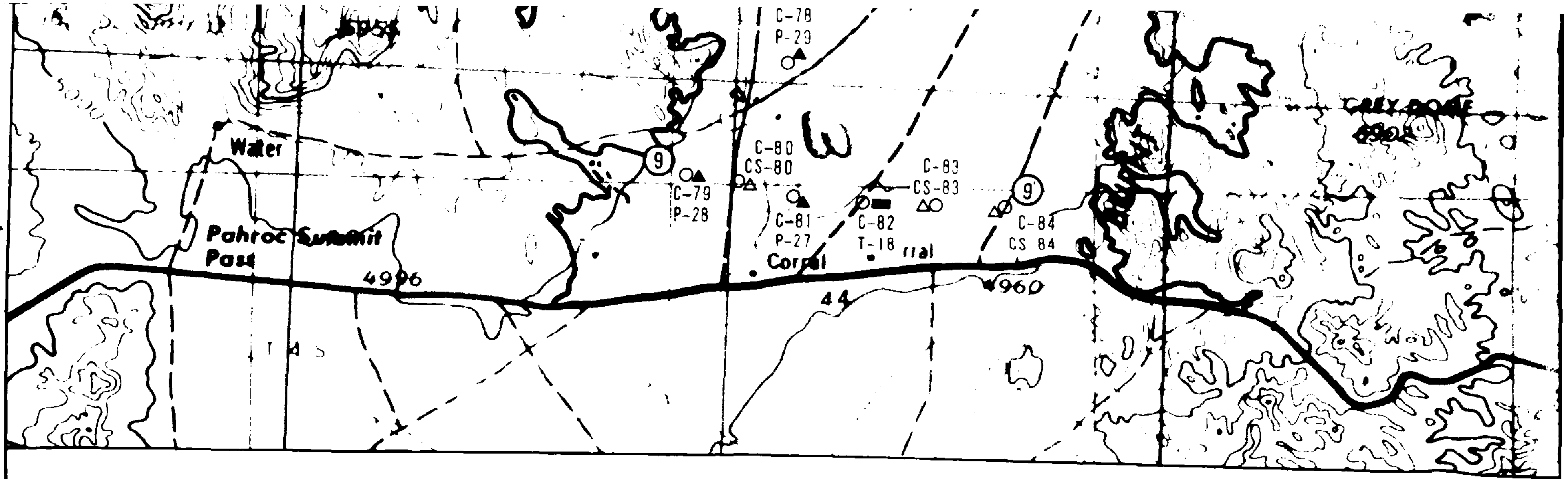
0 2 4
KILOMETERS



C-20
P-1
C-21
CS-21
C-19
CS-19
C-18
CS-18
C-10
P-2
C-11
P-3
C-13
CS-13
B-1
C-12
T-1
CS-12
S-1
C-14
CS-14
C-15
CS-15
C-16
P-4
C-17
CS-17
C-1
CS-1
B-2
C-2
T-2
CS-2
S-2
DV-2
C-3
P-5
C-4
CS-4
C-5
P-8
C-7
T-10
DL-DS-1
B-13
C-6
CS-6
S-13
DL-DS-2
C-8
CS-8
C-9
P-9
B-4
S-4
C-22
CS-22
C-23
T-9
B-9
T-4
S-9
C-24
CS-24
B-8
C-25
T-3
S-25
S-8
C-26
CS-26
C-27
CS-27
C-28
P-6
C-29
CS-29
C-30
P-7
B-7
C-33
P-13
C-32
CS-32
6000
6600

14 MAR 80


NORTH PAHROC RANGE
DRY LAKE
PM
Ranche
Corral
B-12 C-42 T-6 CS-42 S-12
C-45 P-10
C-43 CS-43
C-41 CS-41
C-39 CS-39
C-38 CS-38
C-34 T-11
C-46 CS-46
C-44 CS-44
C-40 P-11
C-37 CS-37
C-35 P-12
C-36 CS-36
B-10 S-10
B-11 T-5 S-11
C-50 CS-50
C-52 T-15
C-51 CS-51
C-53 CS-53
C-49 T-16
C-48 P-23
C-47 P-24
C-62 P-16
C-61 P-15
C-60 CS-60
C-59 T-12
B-5 C-54 P-25 S-5
C-63 P-19
B-17 T-8 S-17
C-57 CS-57
C-58 P-26
C-64 CS-64
B-6 S-6
C-55 CS-55
C-56 T-17
C-65 P-18
C-67 P-17
C-66 CS-66
CS-85
C-68 T-13
C-74 CS-74
B-19
C-73 T-14
C-76 CS-76
C-75 P-21
B-18 DV-18
C-72 CS-72
C-71 P-20
C-70 CS-70
B-16 S-16
C-77 P-22
B-14 S-14
B-15 T-7 S-15
C-69 CS-69
C-78



EXPLANATION

●	B-1	BORING
○	C-1	CONE PENETROMETER TEST (CPT)
△	CS-1	SURFACE SAMPLE AT CPT LOCATION
▬	T-1	TRENCH
▲	P-1	TEST PIT
▪▪▪▪▪	S-1 / R-1	SEISMIC REFRACTION LINE / ELECTRICAL RESISTIVITY LINE
*	DV-1	DOWNHOLE VELOCITY SURVEY
▬ ▬ ▬	DL-DS-1	DEEP SEISMIC REFRACTION LINE
(1)- - - -(1')		ACTIVITY LINE

NOTE Where multiple activities were performed at the same location, the correct location is designated by either (1) the boring symbol or (2) the CPT symbol, if no boring was drilled.

SCALE

0

STAT

0

KI

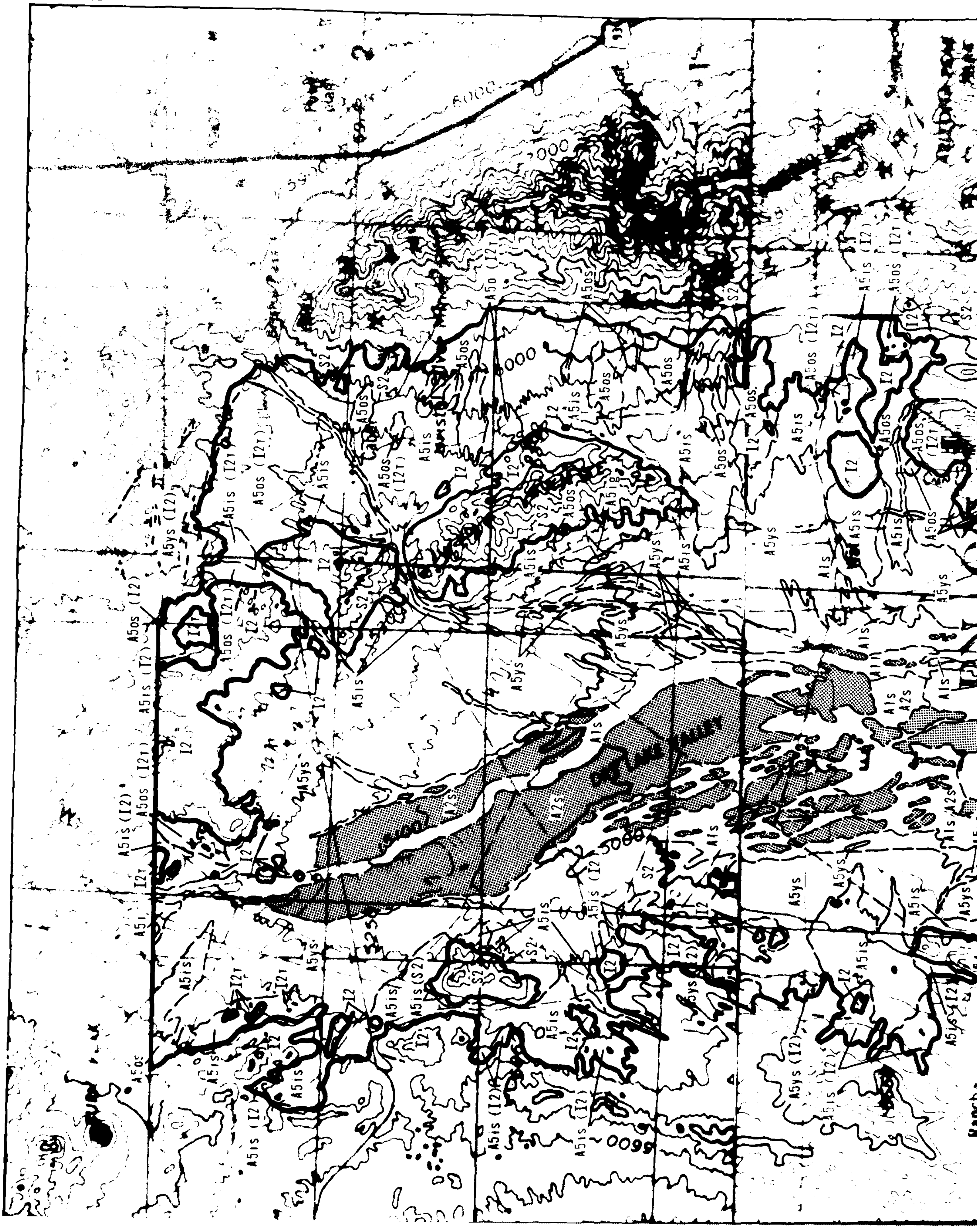
ACTIVITY LOCATIONS
DRY LAKE VALLEY, NEVADA

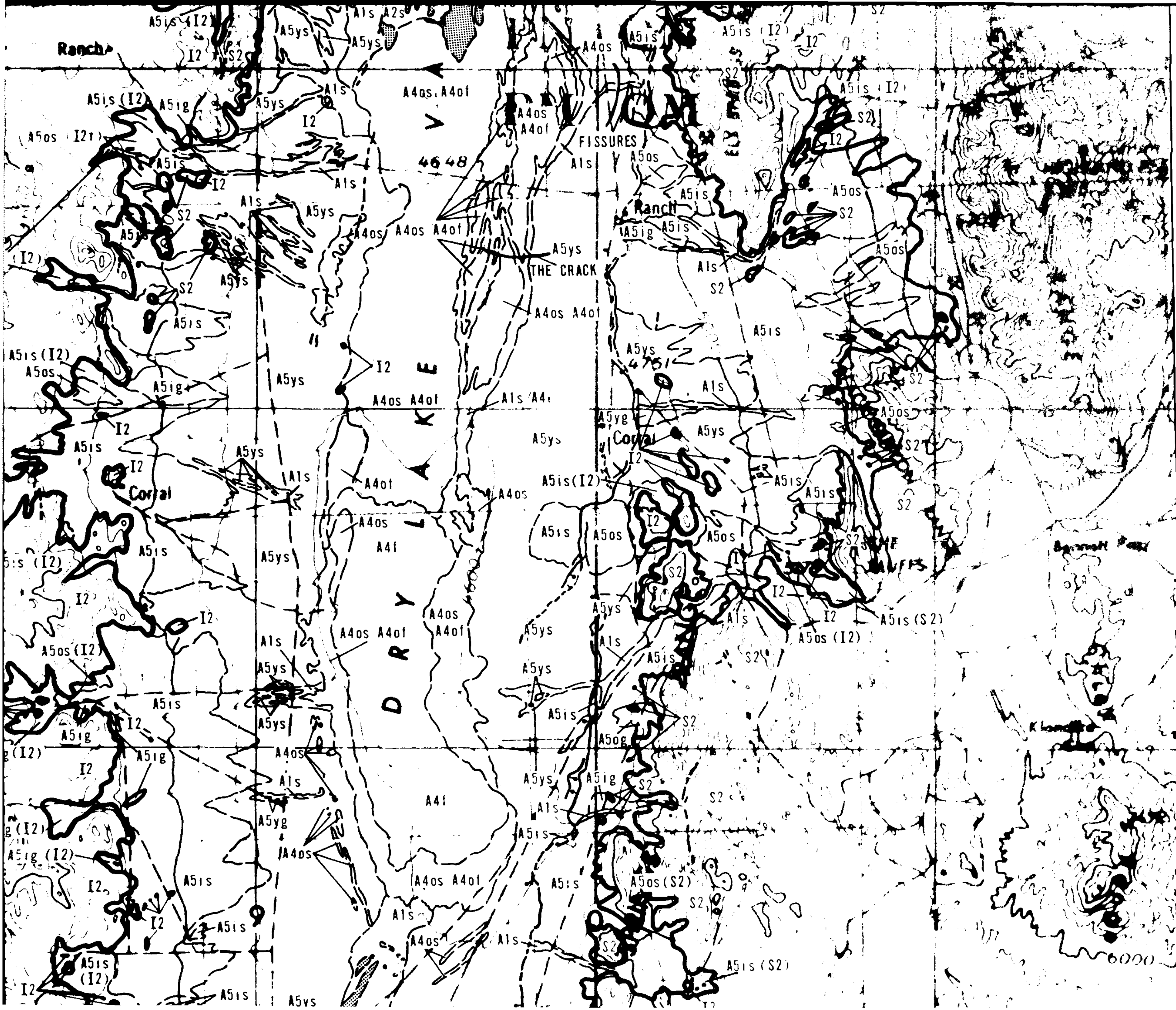
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMD

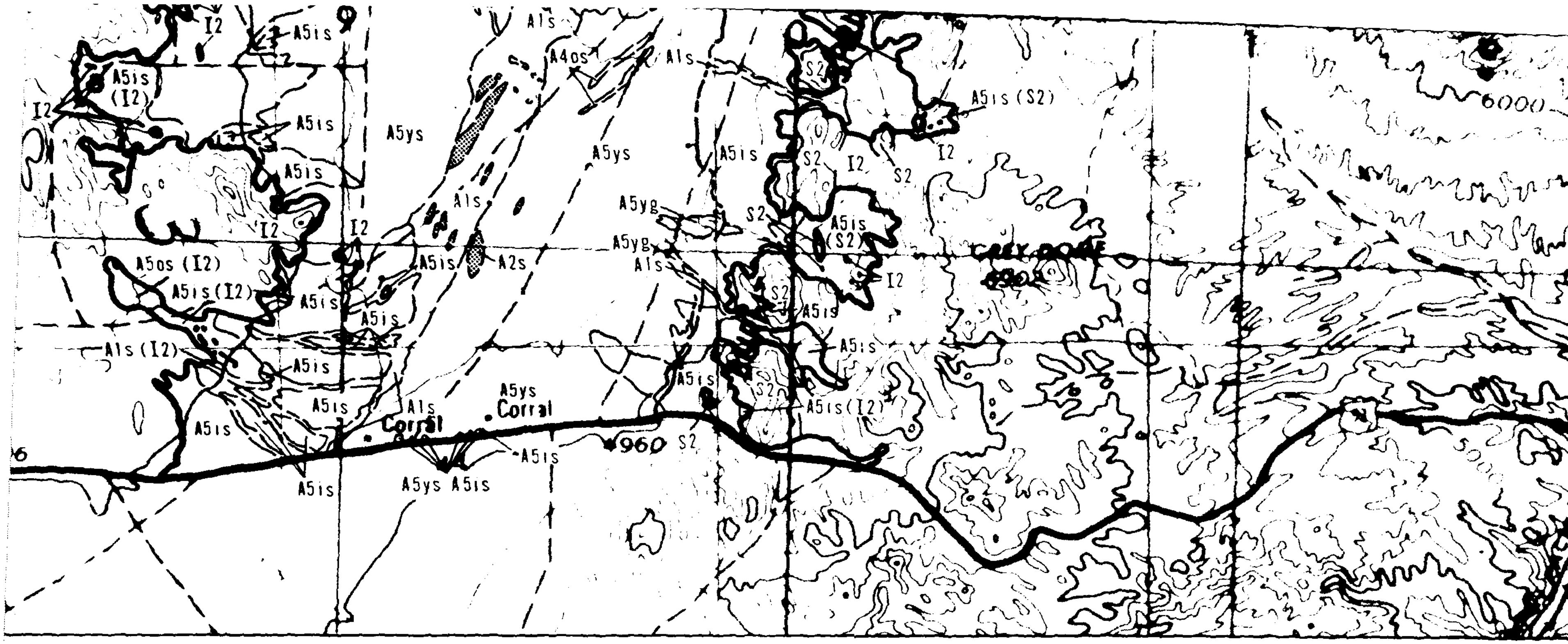
DRAWING
3-1

FUGRO NATIONAL, INC.

6


A5os
A5is
A5ys
I2
S2
A1s
A2s
DRY LAKE VALLEY


Ranch
THE CRACK
FISSURES
4648
4751
D R Y L A K E
Ranch
Corral
Corral
6000
A1s
A2s
A4os
A4of
A4f
A5ys
A5yg
A5is
A5ig
A5os
A5og
A5is (I2)
A5os (I2)
A5is (S2)
A5os (S2)
I2
S2



EXPLANATION

SURFICIAL BASIN-FILL DEPOSITS

A1f / A1s	Younger Fluvial Deposits – Modern stream channel and flood plain deposits of A1f, sandy silt (ML) and A1s, silty sand (SM).
I2s	Older Fluvial Deposits – Older stream channel and flood-plain deposits in terraces composed of silty and clayey sand (SM).
A4f	Younger Playa Deposits – Active playa deposits of A4f, silt (ML) and clay (CL)
A4of / A4os	Older Playa and Lacustrine Deposits – Inactive playa and older lake bed deposits of A4of, sandy or clayey silt (ML), and A4os, silty sand and gravelly sand (SM, SP)
A5ys / A5yg	Younger Alluvial Fan Deposits - Active younger alluvial fan deposits of A5ys, weakly cemented silty sand and gravelly sand (SM SP) and A5yg, weakly cemented sandy gravel (GM)
A5is	Intermediate Alluvial Fan Deposits Inactive intermediate-age alluvial fan deposits of A5is weakly to moderately cemented silty sand and gravelly sand (SM, SP), and A5ig, weakly to

Inactive intermediate-age alluvial fan deposits of A5is ... silty sand and gravelly sand (SM, SP), and A5ig, weakly to ... gravel (GM GP).

... Deposits - Older, highly eroded alluvial fan deposits of A5os, moderately ... sand and gravelly sand (SM,SP).

ROCK UNITS

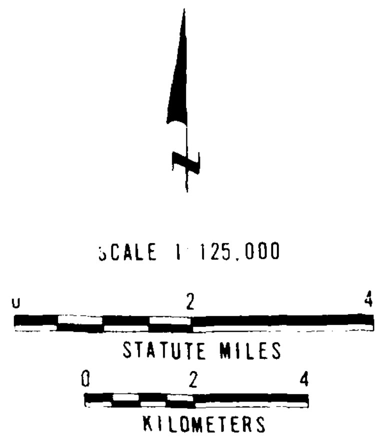
I. ... latite dacite andesite volcanic rock,(I2t) Tertiary, and (I2) undifferentiated.

... S

S ... Limestone and dolomite with some interbedded shale and chert.

A4os A4ot Combination of geologic unit symbols indicates a mixture of either surficial basin-fill or rock units inseparable at map scale.

A5os (I2t) Parenthetic unit underlies surface unit at shallow depth.



SYMBOLS

Contact between rock and basin-fill, (and north and south valley boundaries).

Contact between surficial basin-fill or rock units

Faults, trace of surface rupture, ball on downthrown side, dashed where approximately located.

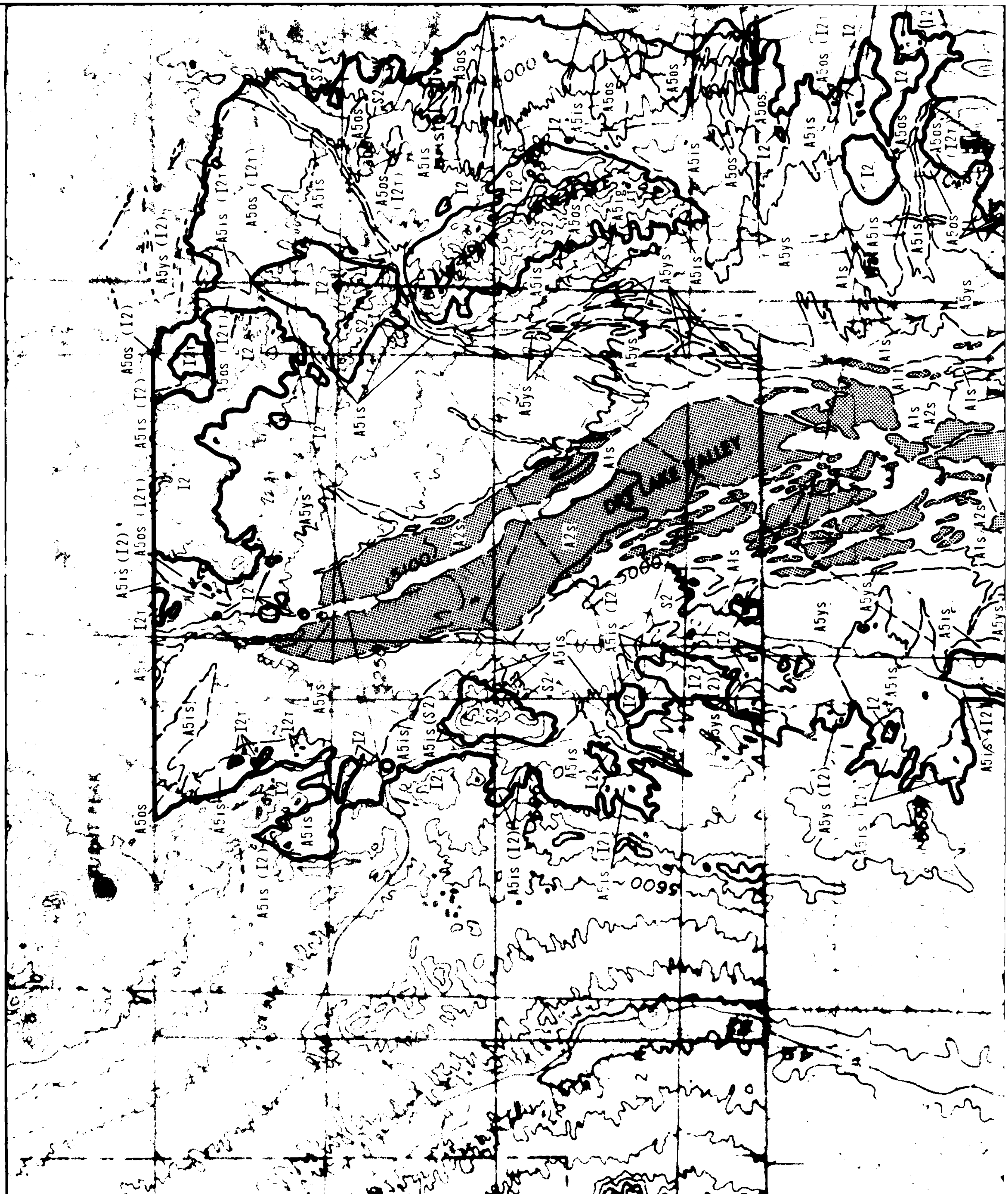
Possible fault, preliminarily located from aerial photographs for fault and earthquake study.

NOTES:

1. Surficial basin-fill units pertain only to the upper several feet of soil. Due to variability of surficial deposits and scale of map presentation, unit descriptions refer to the predominent soil types. Varying amounts of other soil types can be expected within each geologic unit.

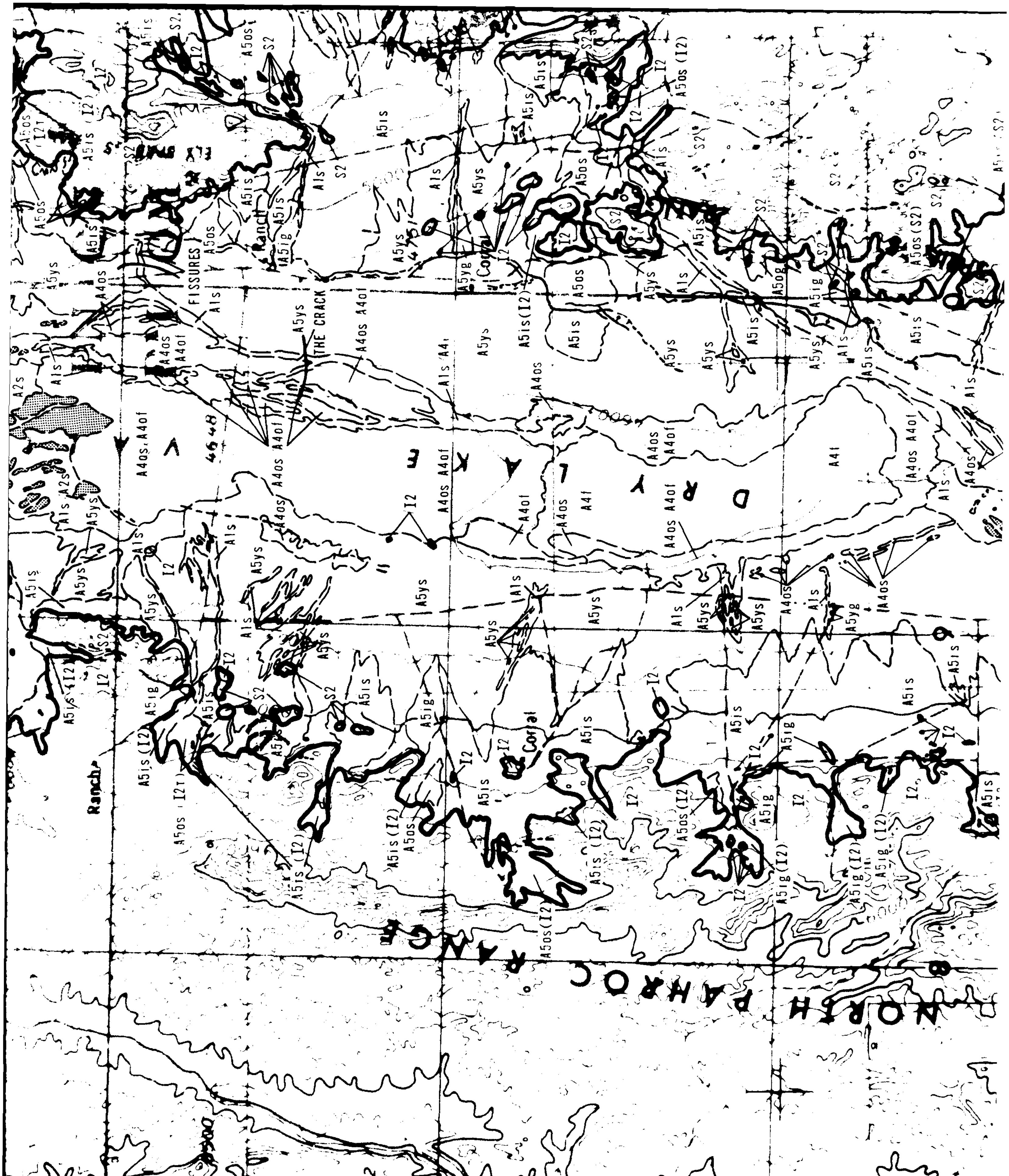
2. The distribution of geologic data stations is presented in Volume II Drawing II-1. A tabulation of all station data and generalized description of all geologic units is included in Volume II Section I.

3. Geology in areas exposed rock from: Fugro National Inc. (1977, 1978) unpublished data, Tschantz and Pampeyan (1970), and Stewart and Carlson (1978).

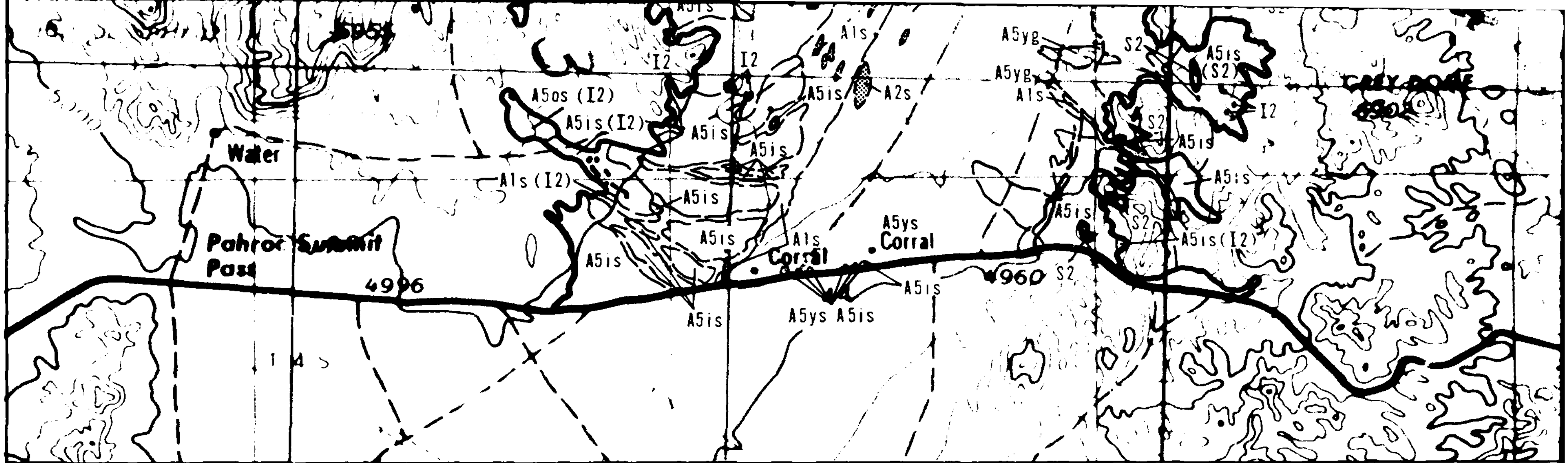


A5os
A5is
A5ys
I2
S2
A1s
A2s
A5os (I2)
A5is (I2)
A5ys (I2)
A5is (S2)
5000
5600

14 MAR 80



DRY LAKE
NORTH PAHROC RANGE
THE CRACK
FISSURES
Corral
Corral
Ranch
Ranch



EXPLANATION

SURFICIAL BASIN-FILL DEPOSITS

A1f / A1s	Younger Fluvial Deposits – Modern stream channel and flood-plain deposits of **A1f**, sandy silt (**ML**) and **A1s**, silty sand (**SM**).
A2s	Older Fluvial Deposits – Older stream channel and flood-plain deposits in terraces composed of silty and clayey sand (SM).
A4f	Younger Playa Deposits – Active playa deposits of **A4f**, silt (**ML**) and clay (CL)
A4of / A4os	Older Playa and Lacustrine Deposits – Inactive playa and older lake bed deposits of **A4of**, sandy or clayey silt (**ML**), and **A4os**, silty sand and gravelly sand (SM, SP)
A5ys / A5yg	Younger Alluvial Fan Deposits – Active younger alluvial fan deposits of A5ys, weakly cemented silty sand and gravelly sand (SM, SP) and A5yg, weakly cemented sandy gravel (GM)
A5is / A5ig	Intermediate Alluvial Fan Deposits – Inactive intermediate-age alluvial fan deposits of A5is weakly to moderately cemented *silty sand and gravelly sand (SM, SP), and A5ig, weakly to* moderately cemented sandy gravel (GM GP).
A5os	Older Alluvial Fan Deposits – Older, highly eroded alluvial fan deposits of A5os, moderately cemented silty sand and gravelly sand (**SM**, **SP**).

ROCK UNITS

Igneous (I)

ROCK UNITS

Igneous (I)

I2t / I2	Rhyolite, latite, dacite, andesite volcanic rock, (I2t) Tertiary, and (I2) undifferentiated.

Sedimentary (S)

S2	*Limestone and dolomite with some interbedded shale and chert.*

A4os A4ot Combination of geologic unit symbols indicates a mixture of either surficial basin-fill or rock units inseparable at map scale.

A5os (I2t) Parenthetic unit underlies surface unit at shallow depth.

SYMBOLS

Contact between rock and basin-fill, (and north and south valley boundaries).

Contact between surficial basin-fill or rock units

Faults, trace of surface rupture, ball on downthrown side, dashed where approximately located.

Possible fault, preliminarily located from aerial photographs for fault and earthquake study.

NOTES:

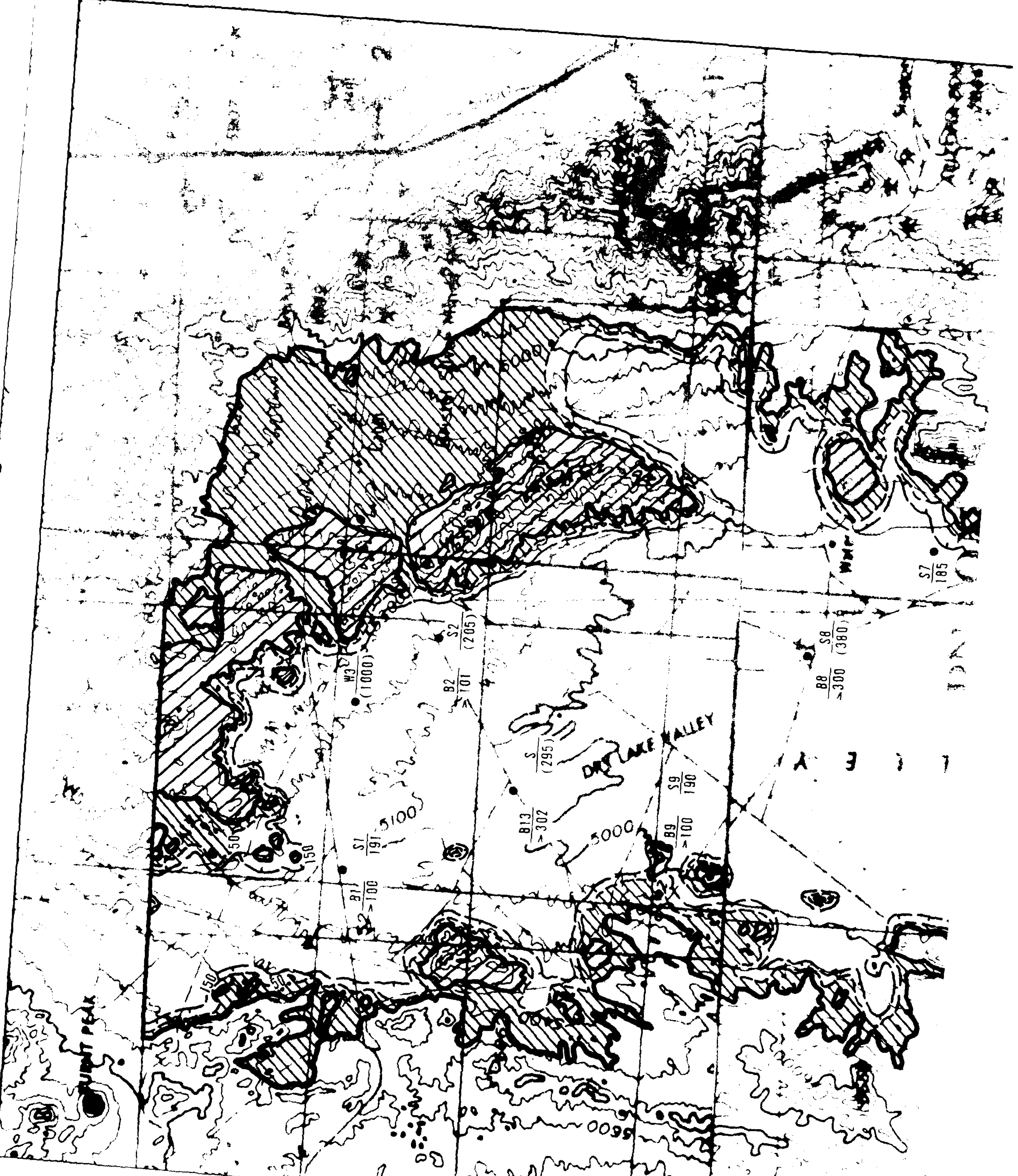
1. Surficial basin-fill units pertain only to the upper several feet of soil. Due to variability of surficial deposits and scale of map presentation, unit descriptions refer to the predominant soil types. Varying amounts of other soil types can be expected within each geologic unit.
2. The distribution of geologic data stations is presented in Volume II Drawing II-1. A tabulation of all station data and generalized description of all geologic units is included in Volume II Section I.
3. Geology in areas exposed rock from: Fugro National Inc. (1977, 1978) unpublished data. Tschantz and Pampeyan (1970), and Stewart and Carlson (1978).

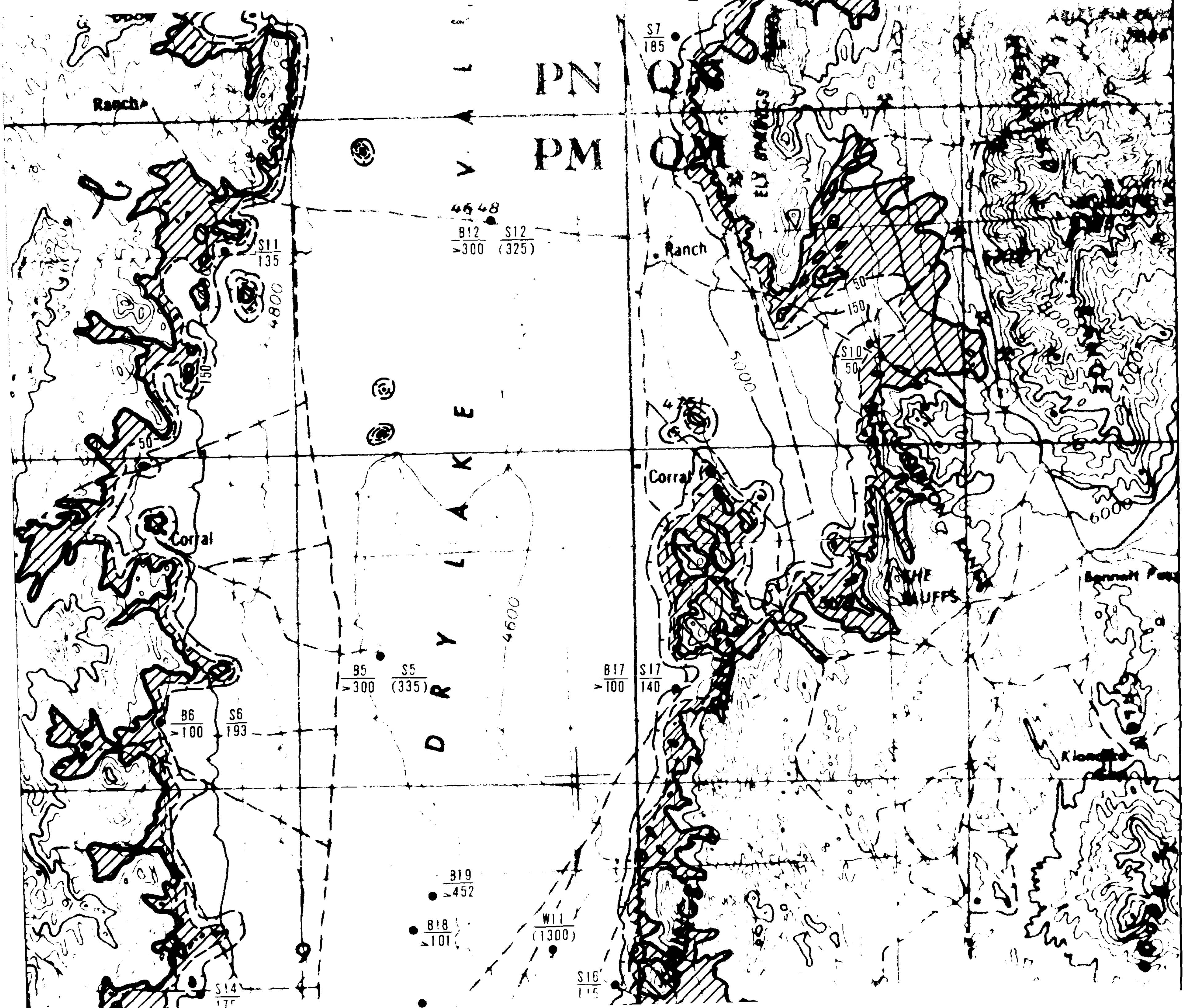
SURFICIAL GEOLOGIC UNITS
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE   BMO

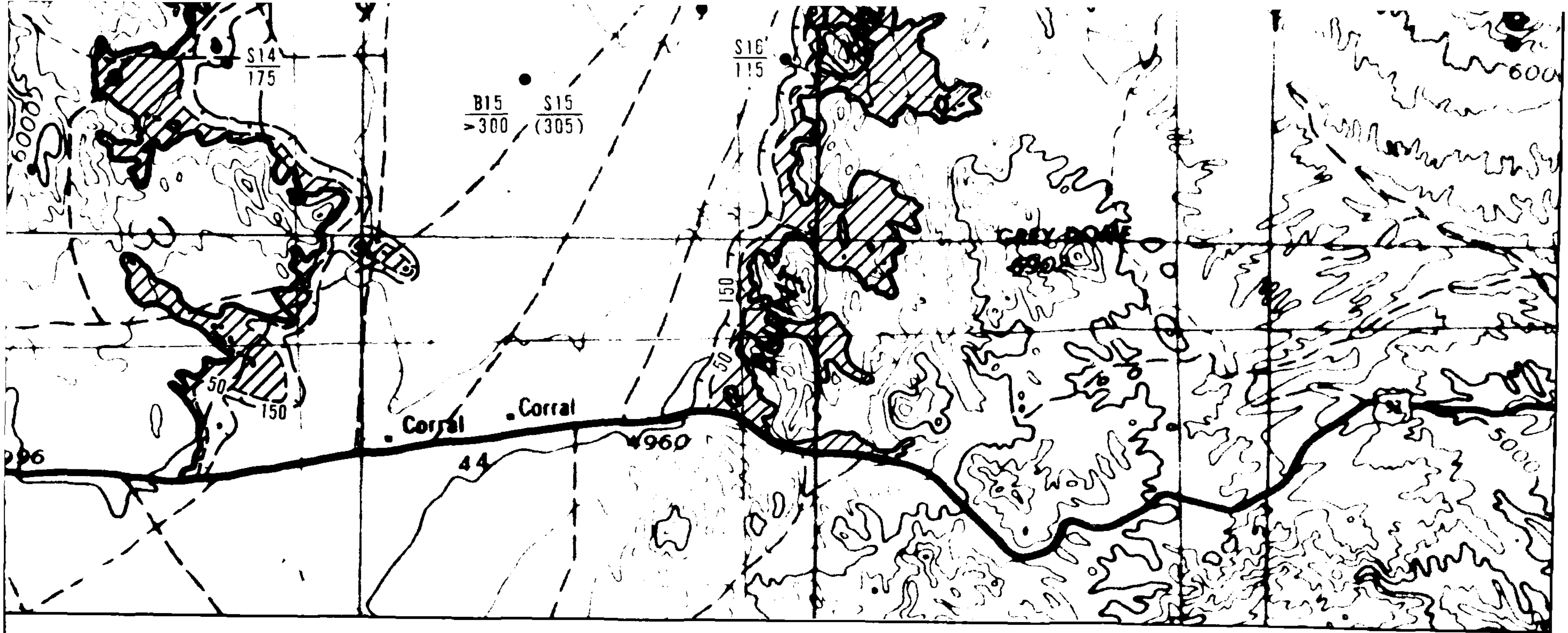
DRAWING 3-2

FUGRO NATIONAL, INC.

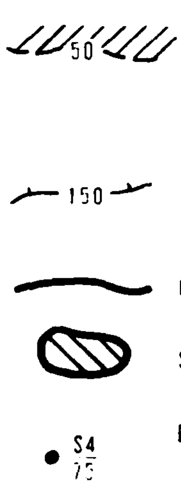

DRY LAKE VALLEY
S7
185
S8
(380)
B8
>300
S9
190
B9
>100
B13
>302
S
(295)
B2
>101
S2
(205)
W3
(1000)
S1
191
B1
>100
5100
5000
5600
5000
150
50



PN
PM
Ranch
Corral
Ranch
Corral
DRY LAKE
4648
B12
>300
S12
(325)
S11
135
4800
150
50
B5
>300
S5
(335)
4600
B6
>100
S6
193
B19
>452
B18
>101
W11
(1300)
S14
S7
185
5000
S10
50
150
50
6000
8000
B17
>100
S17
140
S16



EXPLANATION



Contour indicates rock at a depth of approximately 50 feet (15m) – shading indicates rock less than 50 feet (15m)

Contour indicates rock at a depth of approximately 150 feet (46m) – hachuring indicates rock less than 150 feet (46m)

Contact between rock and basin-fill (and north and south valley boundaries).

Shading indicates areas of isolated exposed rock.

Data Source – Fugro boring (B), seismic refraction line (S), electrical resistivity sounding (R); or water well (W), Volume II, Table 2-1.

Depth to rock (feet) or when in parentheses depth

N

SCALE 1:125,000

0 2 4
STATUTE MILES

0 2 4
KILOMETERS

EXPLANATION

50 — Contour indicates rock at a depth of approximately 50 feet (15m) – shading indicates rock less than 50 feet (15m)

150 — Contour indicates rock at a depth of approximately 150 feet (46m) – hachuring indicates rock less than 150 feet (46m).

Contact between rock and basin-fill (and north and south valley boundaries).

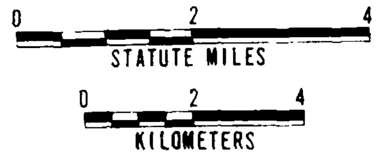
Shading indicates areas of isolated exposed rock.

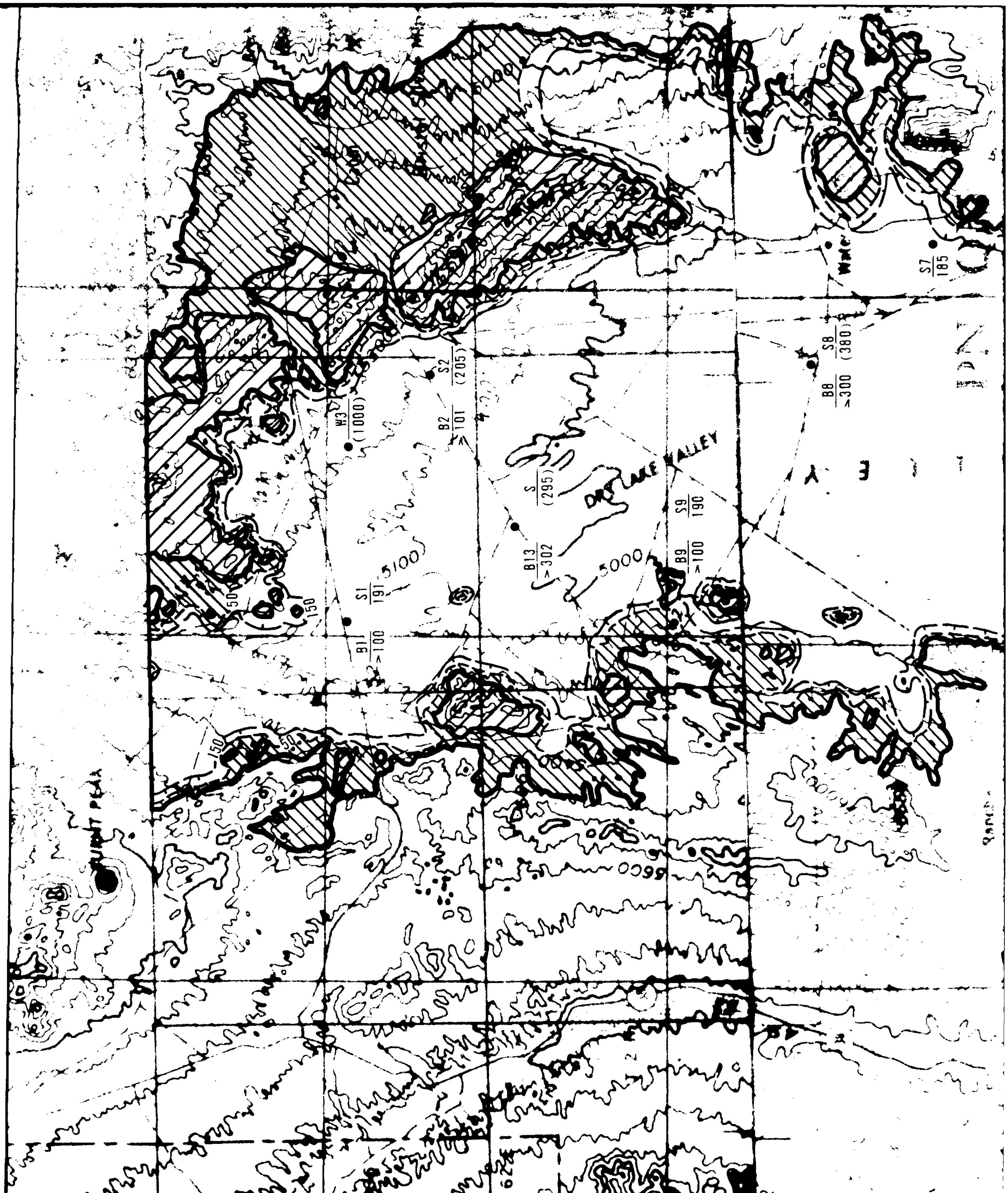
● $\frac{S4}{75}$ — Data Source – Fugro boring (B), seismic refraction line (S); electrical resistivity sounding (R); or water well (W); Volume II, Table 2-1.

Depth to rock (feet) or, when in parentheses, depth above which rock does not occur (feet).

NOTE. The contours are based on geologic interpretations and the limited data points shown on the map. Some changes in contour locations can be expected as additional data are obtained.

SCALE 1:125,000

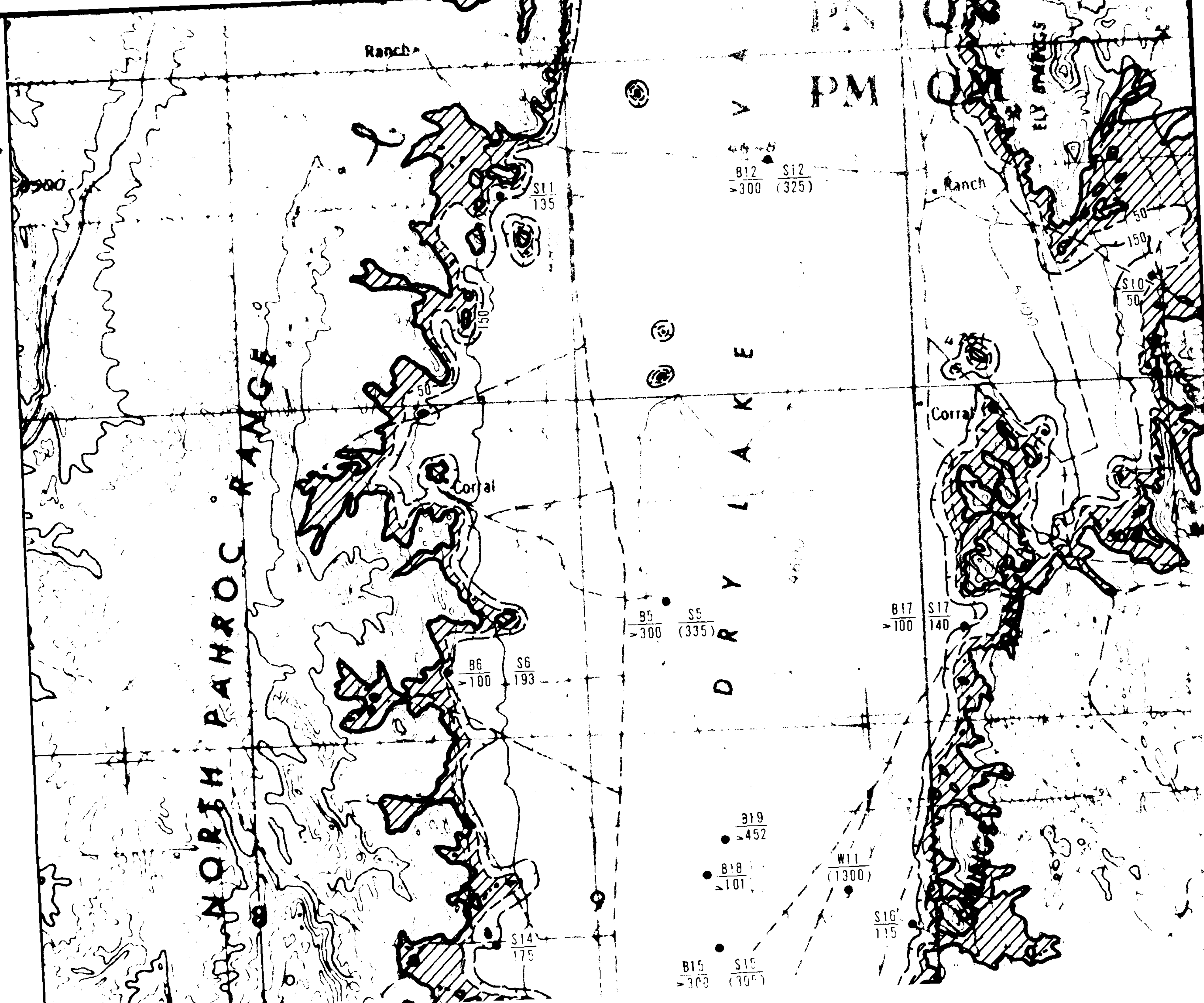



DRY LAKE VALLEY
W3
(1000)
S2
(205)
B2
>101
S
(295)
B13
>302
S9
190
B9
>100
S1
191
B1
>100
B8
>300
S8
(380)
S7
185
5100
5000
150
50

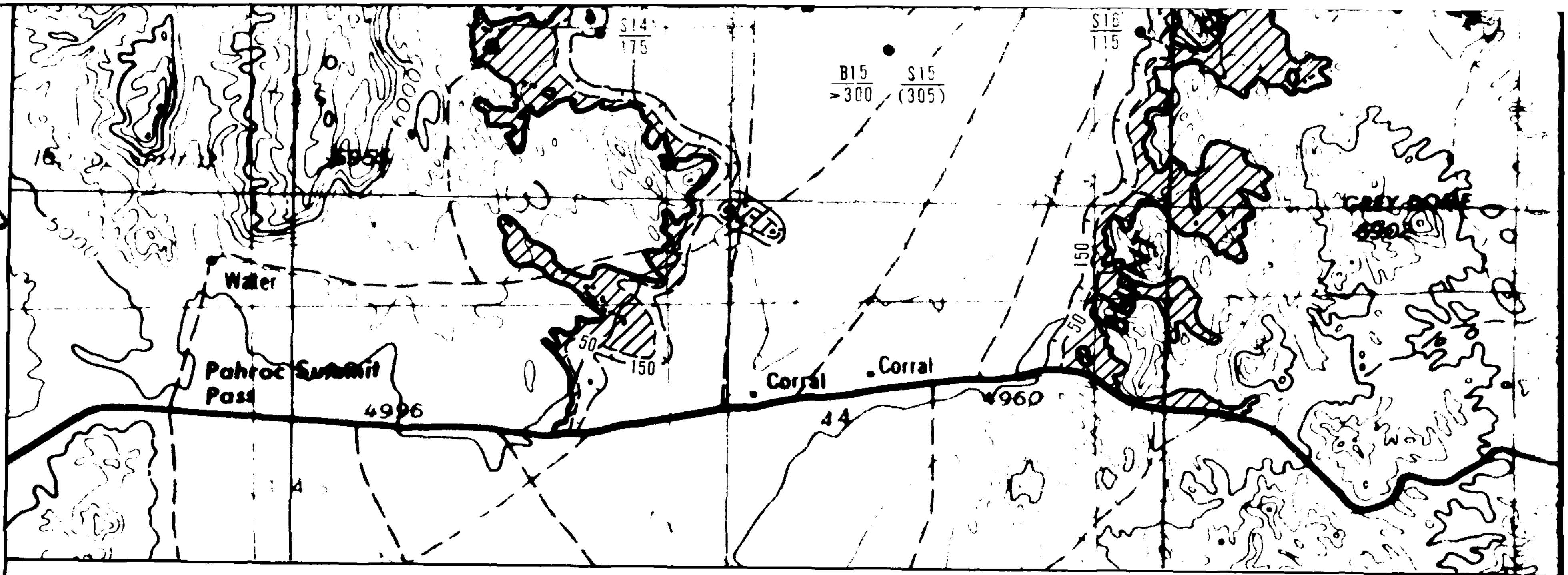
14 MAR 80

5

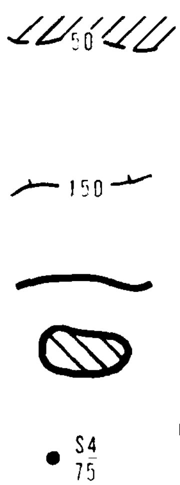
6



Ranch
Ranch
ELY SPRINGS
PM
V
D R Y L A K E
NORTH PAHROC RANGE
Corral
Corral
S11 135
B12 >300
S12 (325)
S10 50
150
50
B5 >300
S5 (335)
B17 >100
S17 140
B6 >100
S6 193
B19 >452
B18 >101
W11 (1300)
S16 115
S14 175



EXPLANATION



Contour indicates rock at a depth of approximately 50 feet (15m) - shading indicates rock less than 50 feet (15m)

Contour indicates rock at a depth of approximately 150 feet (46m) - hachuring indicates rock less than 150 feet (46m)

Contact between rock and basin-fill (and north and south valley boundaries).

Shading indicates areas of isolated exposed rock.

Data Source - Fugro boring (B), seismic refraction line (S) electrical resistivity sounding (R); or water well (W), Volume II, Table 2-1.

Depth to rock (feet) or when in parentheses depth above which rock does not occur (feet).

SCA
STA
0
0
K

DEPT
DRY LAKE

MX SITING INVES
DEPARTMENT OF THE AIR

FUGRO NA

EXPLANATION

50 — Contour indicates rock at a depth of approximately 50 feet (15m) - shading indicates rock less than 50 feet (15m)

150 — Contour indicates rock at a depth of approximately 150 feet (46m) - hachuring indicates rock less than 150 feet (46m).

Contact between rock and basin-fill (and north and south valley boundaries).

Shading indicates areas of isolated exposed rock.

S4/75 — Data Source - Fugro boring (B), seismic refraction line (S), electrical resistivity sounding (R); or water well (W), Volume II, Table 2-1.

Depth to rock (feet) or, when in parentheses, depth above which rock does not occur (feet)

NOTE. The contours are based on geologic interpretations and the limited data points shown on the map. Some changes in contour locations can be expected as additional data are obtained

4

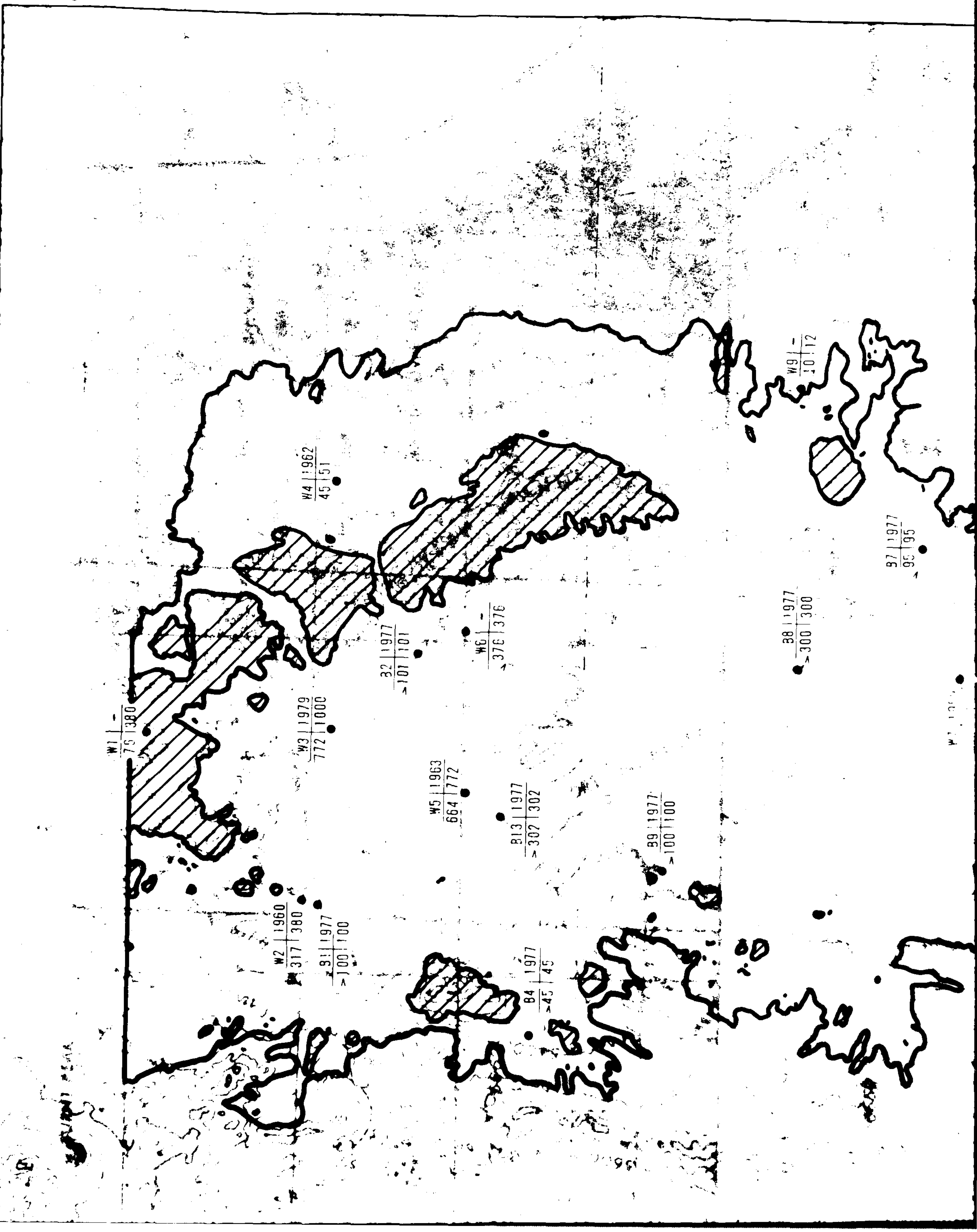
DEPTH TO ROCK
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

DRAWING 3-3

FUGRO NATIONAL, INC.

8


W1 | –
75 | 380
W3 | 1979
772 | 1000
W4 | 1962
45 | 51
32 | 1977
>101 | 101
W6 | –
376 | 376
W5 | 1963
664 | 772
B13 | 1977
>302 | 302
B9 | 1977
>100 | 100
38 | 1977
>300 | 300
B7 | 1977
95 | 95
W9 | –
10 | 12
W2 | 1960
317 | 380
B1 | 1977
>100 | 100
B4 | 1977
>45 | 45

AD-A112 850 FUGRO NATIONAL INC LONG BEACH CA F/G 8/13
MX SITING INVESTIGATION GEOTECHNICAL EVALUATION. VERIFICATION S--ETC(U)
MAR 80 F04704-80-C-0006
UNCLASSIFIED FN-TR-27-DL-1 NL

2 of 2
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END
DATE
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4 82
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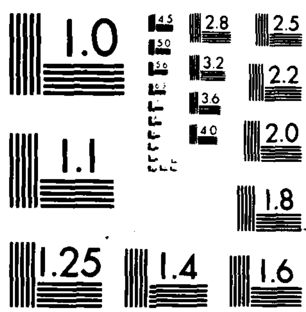
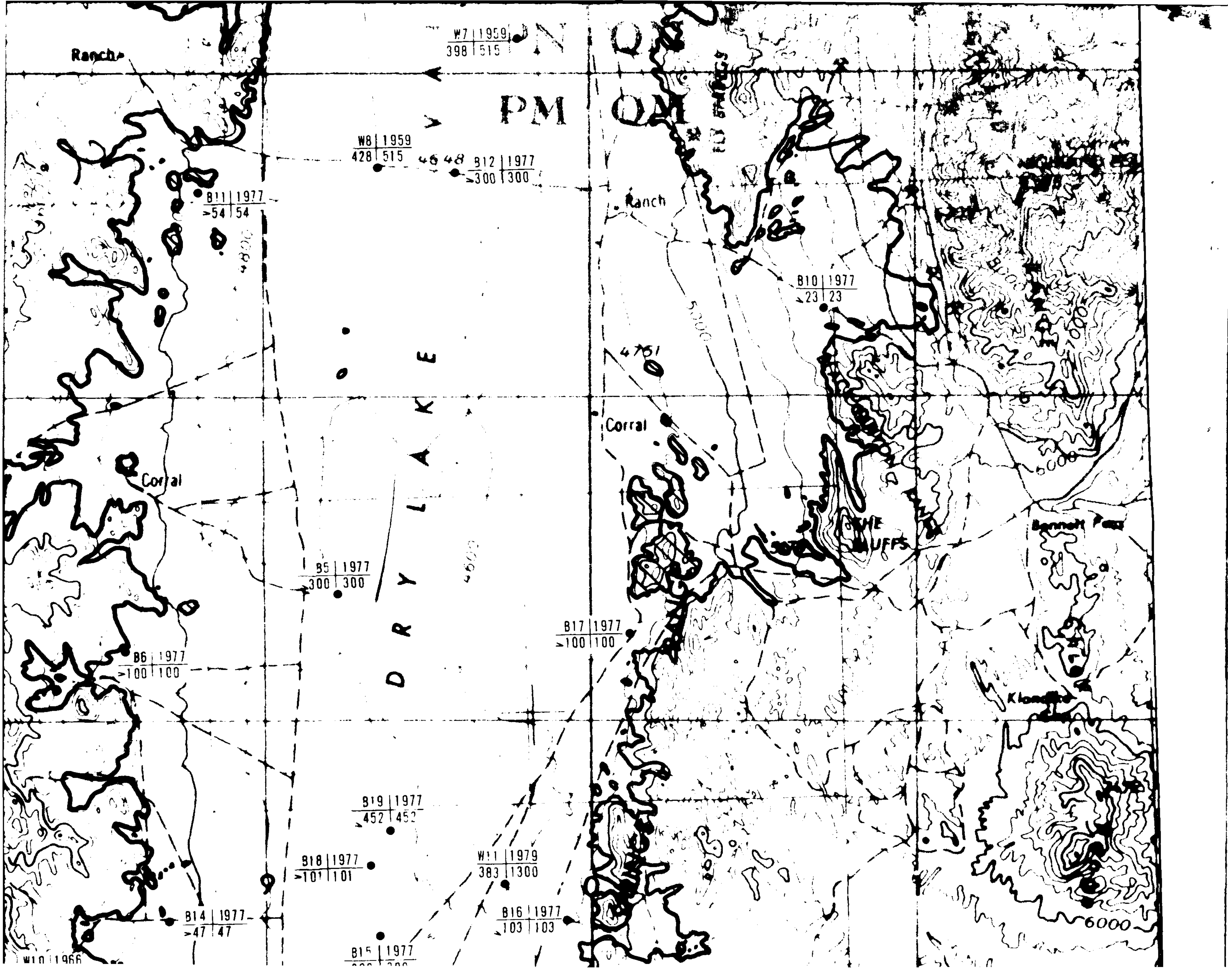
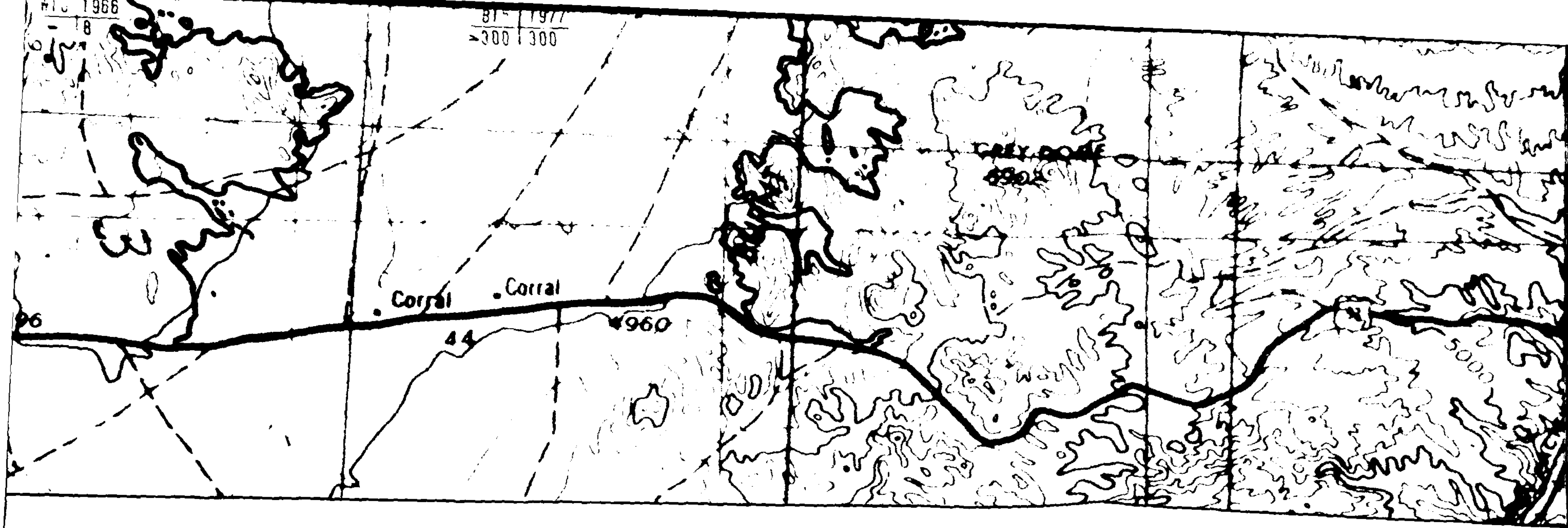


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



Ranch
W7 | 1959
398 | 515
N
Q
PM
QM
W8 | 1959
428 | 515
4848
B12 | 1977
>300 | 300
B11 | 1977
>54 | 54
4800
Ranch
B10 | 1977
>23 | 23
4751
Corral
Corral
6000
Bennett Pass
THE BLUFFS
DRY LAKE
B5 | 1977
300 | 300
4600
B17 | 1977
>100 | 100
B6 | 1977
>100 | 100
Klondike
B19 | 1977
452 | 452
B18 | 1977
>101 | 101
W11 | 1979
383 | 1300
B16 | 1977
>103 | 103
B14 | 1977
>47 | 47
6000
B15 | 1977
W10 | 1966



EXPLANATION

Absence of contours indicates ground water occurs at depths greater than 150 feet. Fugro National, Inc. borings, and assorted wells indicate depth to ground water generally in excess of 400 feet throughout most of the valley (see Volume I, Section 3.0)

Contact between rock and basin-fill (and north and south valley boundaries).

Shading indicates areas of isolated exposed rock.

● W2 | 1977 / 75 | 700

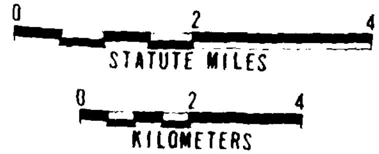
Data Source – Fugro boring (B), seismic refraction line (S), electrical resistivity sounding (R), or water well (W); see Volume II, Table 2-1.

Year of water level measurement

Depth to water (feet)

Depth of well (feet)

SCALE 1:125,000



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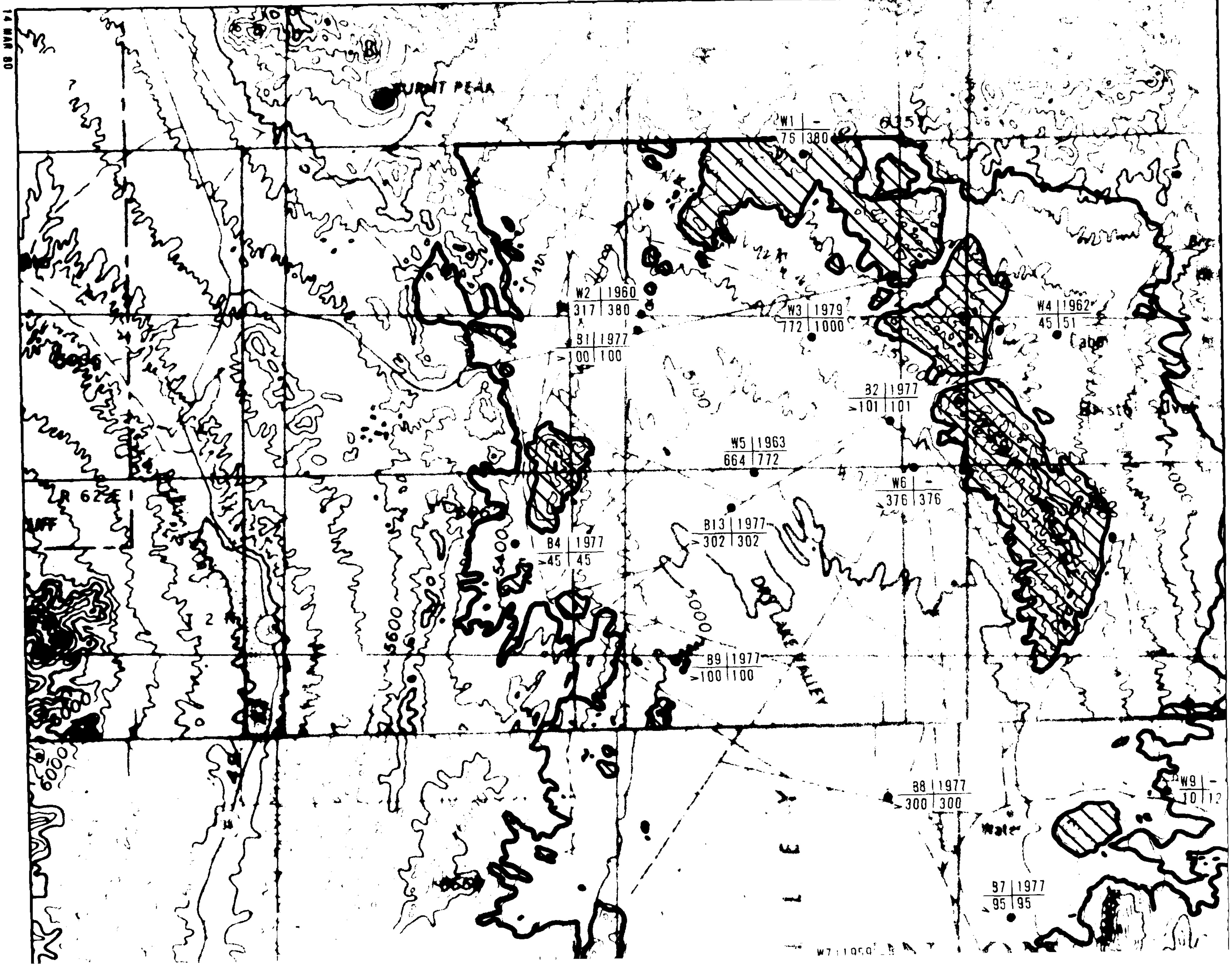
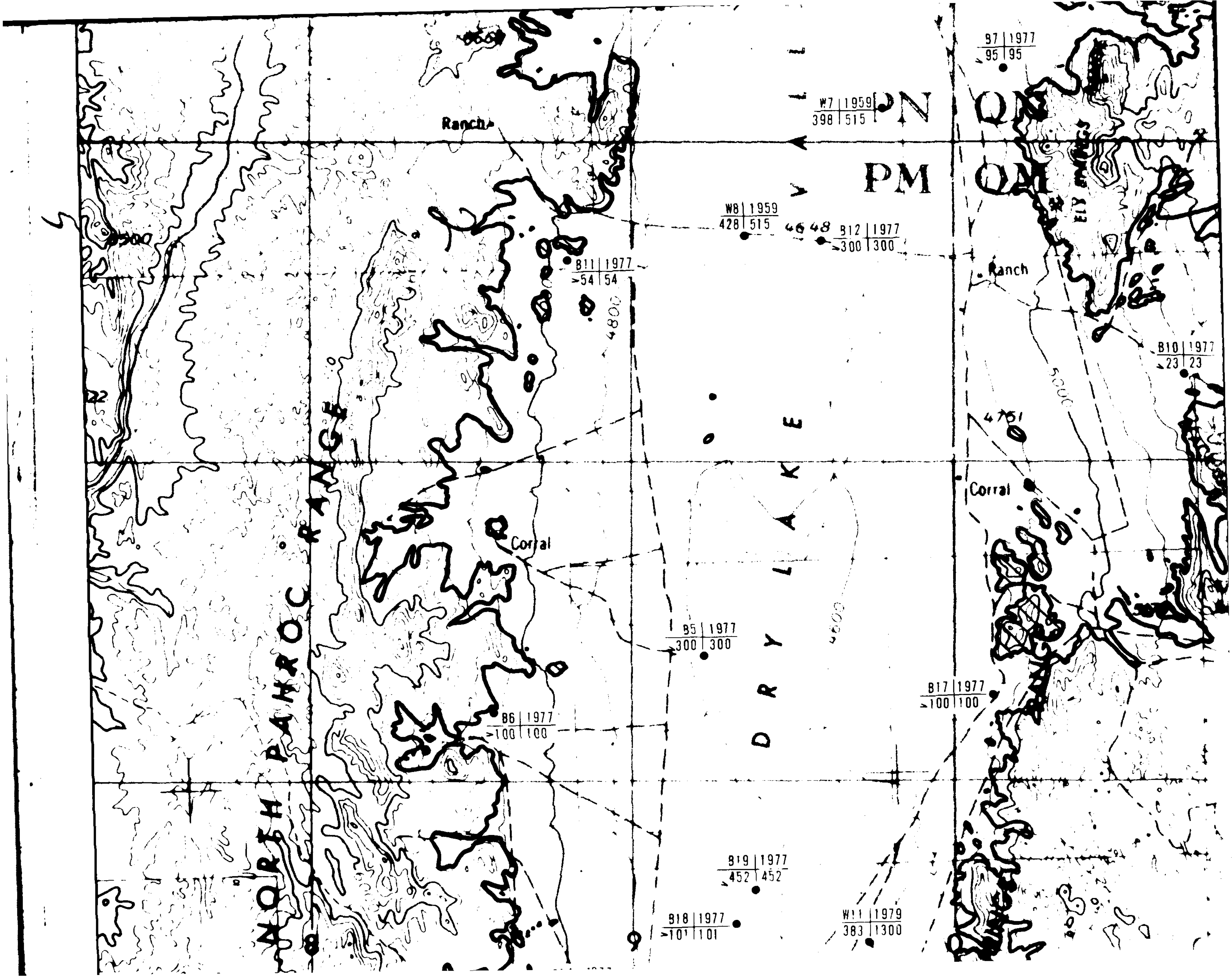
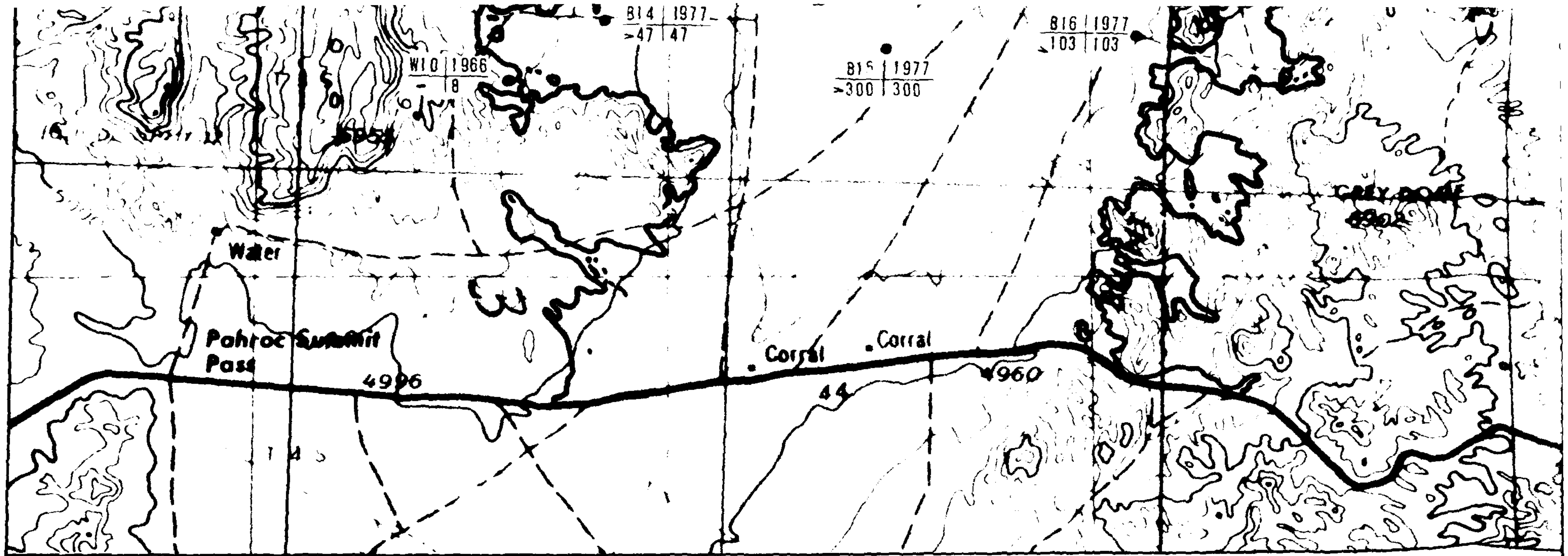


14 MAR 80
BURNT PEAK
W1 | –
75 | 380
W2 | 1960
317 | 380
B1 | 1977
>100 | 100
W3 | 1979
772 | 1000
W4 | 1962
45 | 51
B2 | 1977
>101 | 101
W5 | 1963
664 | 772
W6 | –
376 | 376
B13 | 1977
>302 | 302
B4 | 1977
>45 | 45
B9 | 1977
>100 | 100
B8 | 1977
>300 | 300
W9 | –
10 | 12
B7 | 1977
95 | 95
DRY LAKE VALLEY
5000
5400
5600
6000
R 62 E



NORTH PAHROC RANGE
DRY LAKE
Ranch
Ranch
Corral
Corral
PM
QAl
QN
N
W7 1959 398 515
W8 1959 428 515
B12 1977 >300 300
B11 1977 >54 54
B10 1977 >23 23
B7 1977 95 95
B5 1977 300 300
B6 1977 >100 100
B17 1977 >100 100
B19 1977 452 452
B18 1977 >101 101
W11 1979 383 1300
4648
4751
4800
4800
5000



EXPLANATION

Absence of contours indicates ground water occurs at depths greater than 150 feet. Fugro National, Inc. borings, and assorted wells indicate depth to ground water generally in excess of 400 feet throughout most of the valley (see Volume I, Section 3.0).

Contact between rock and basin-fill (and north and south valley boundaries).

Shading indicates areas of isolated exposed rock.

W2 | 1977
75 | 700

Data Source - Fugro boring (B), seismic refraction line (S), electrical resistivity sounding (R), or water well (W); see Volume II, Table 2-1.

Year of water level measurement

Depth to water (feet)

Depth of well (feet)

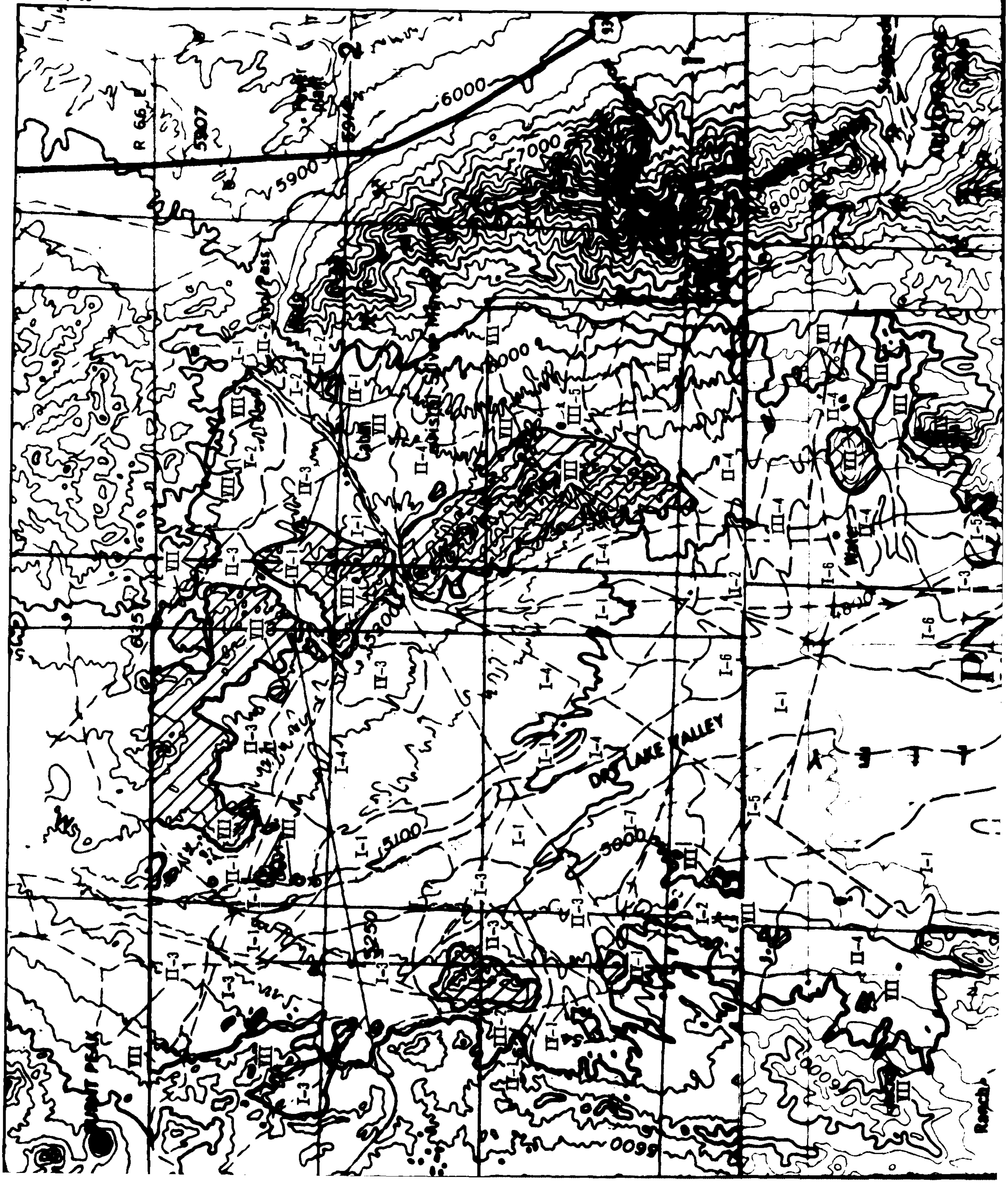
DEPTH TO WATER
DRY LAKE VALLEY, NEVADA

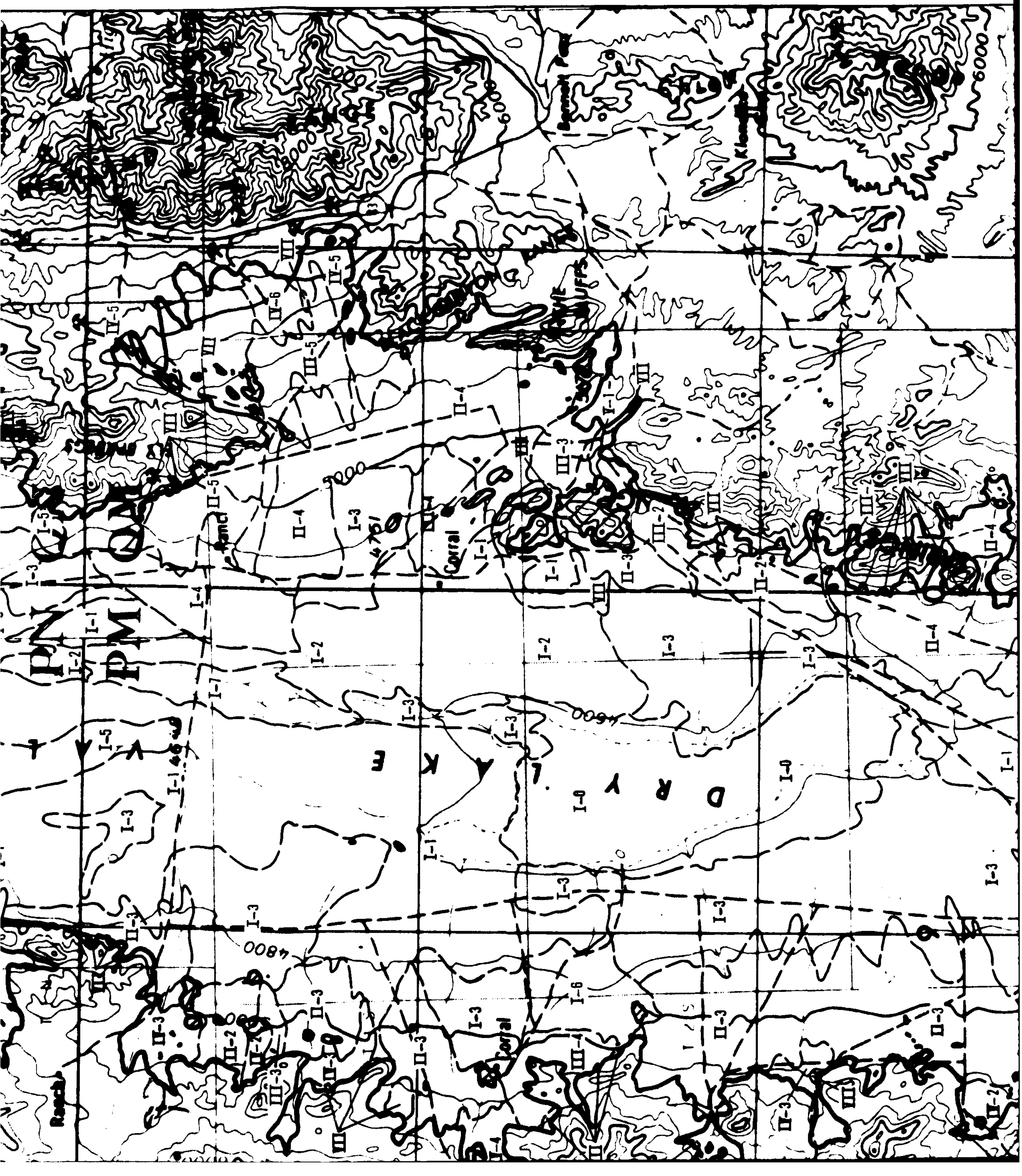
MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

DRAWING 3-4

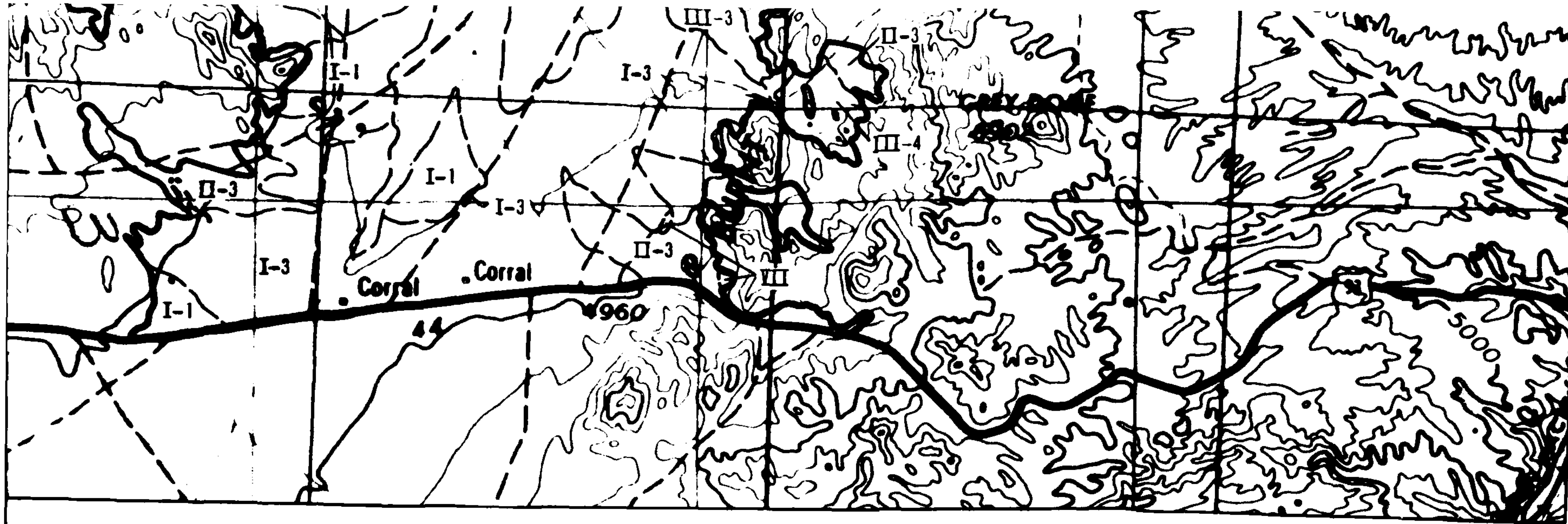
FUGRO NATIONAL, INC.

FN-TR-27-DL





Corral
4800
4600
6000
Ranch



EXPLANATION

Terrain Category (see table below) —— III - 3 —— Drainage spacing, i.e. the maximum number of drainages of the corresponding category occurring in a random traverse of one statute mile (1.6km).

TERRAIN CATEGORY	DRAINAGE DEPTH DESCRIPTION
I	Less than 3 feet (1m)
II	3-6 feet (1-2m)
III	6-10 feet (2-3m)
IV	10-15 feet (3-5m)
V	Greater than 15 feet (5m)
VI	Complex, highly variable terrain not defined by drainage incision (e.g. dunal or hummocky terrains).
VII	Unsuitable terrain

Contact between terrain categories.

Contact between rock and basin-fill (and north and south valley boundaries).

Shading indicates areas of isolated exposed rock

SCALE 1:125,000

0 2 4 STATUTE MILES

0 2 4 KILOMETERS

Terrain Category — — — III - 3 — — — — Drainage spacing. i.e. the maximum number of drainages of the corresponding category occurring in a random traverse of one statute mile (1.6km).
(see table below)

TERRAIN CATEGORY	DRAINAGE DEPTH DESCRIPTION
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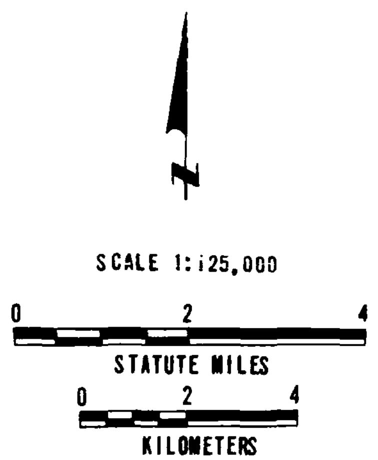
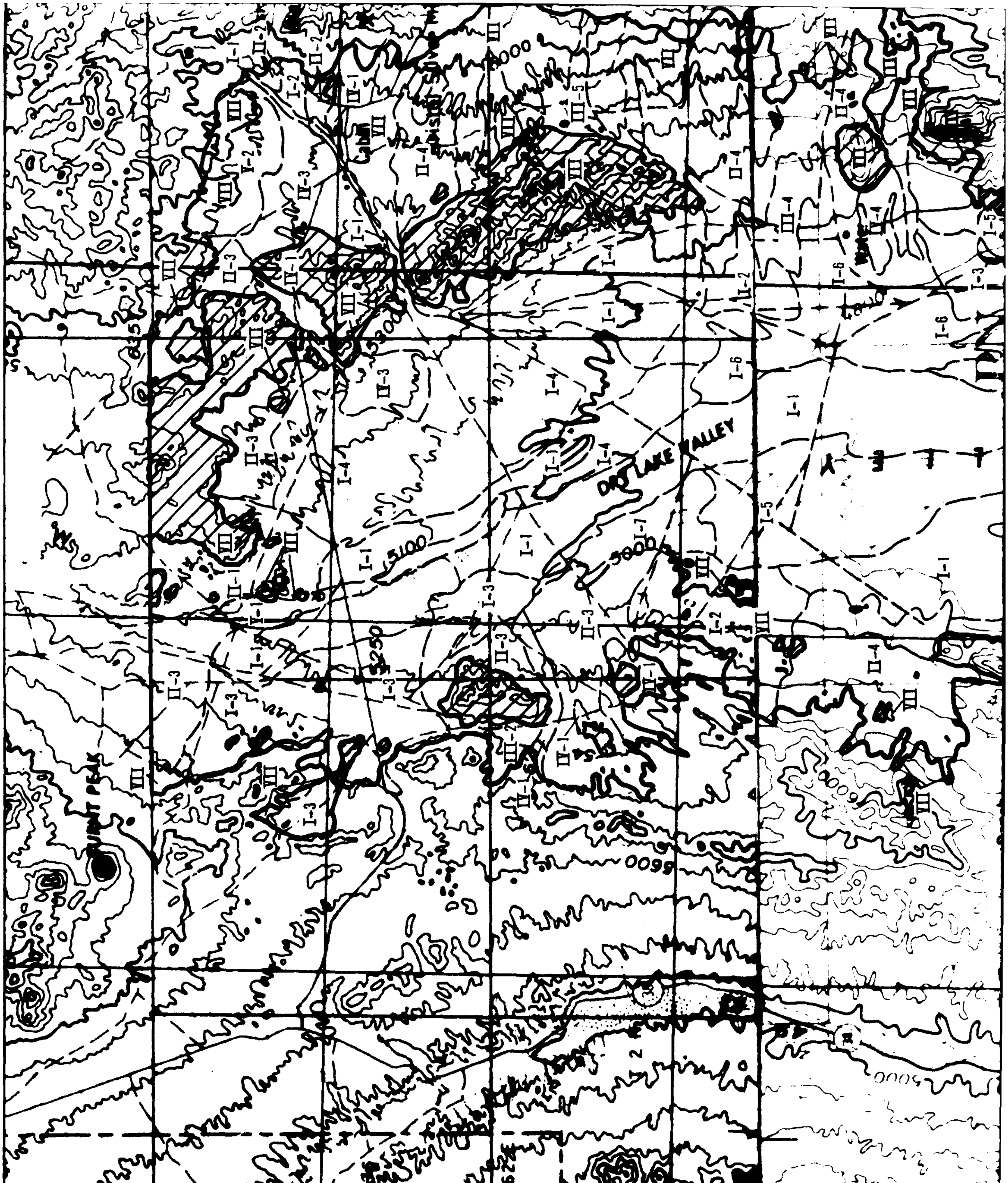
Contact between rock and basin-fill (and north and south valley boundaries).

Shading indicates areas of isolated exposed rock.

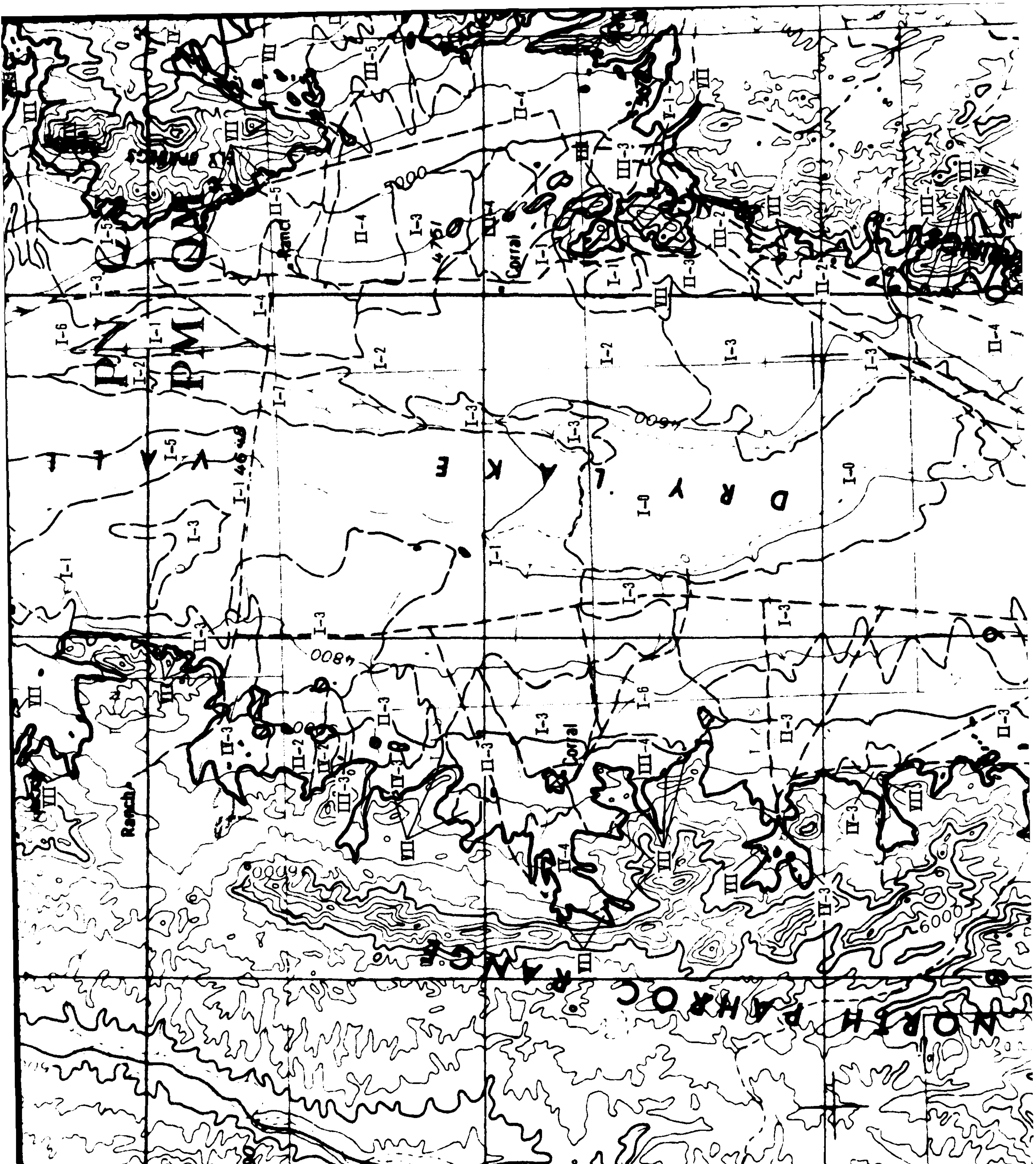
NOTE: Data used in constructing this map are from: (1) field observations, (2) 1:62,500 USGS topographic maps, and (3) 1:60,000 and 1:25,000 aerial photographs. Due to scale of presentation and variability of terrain conditions, this map is generalized.

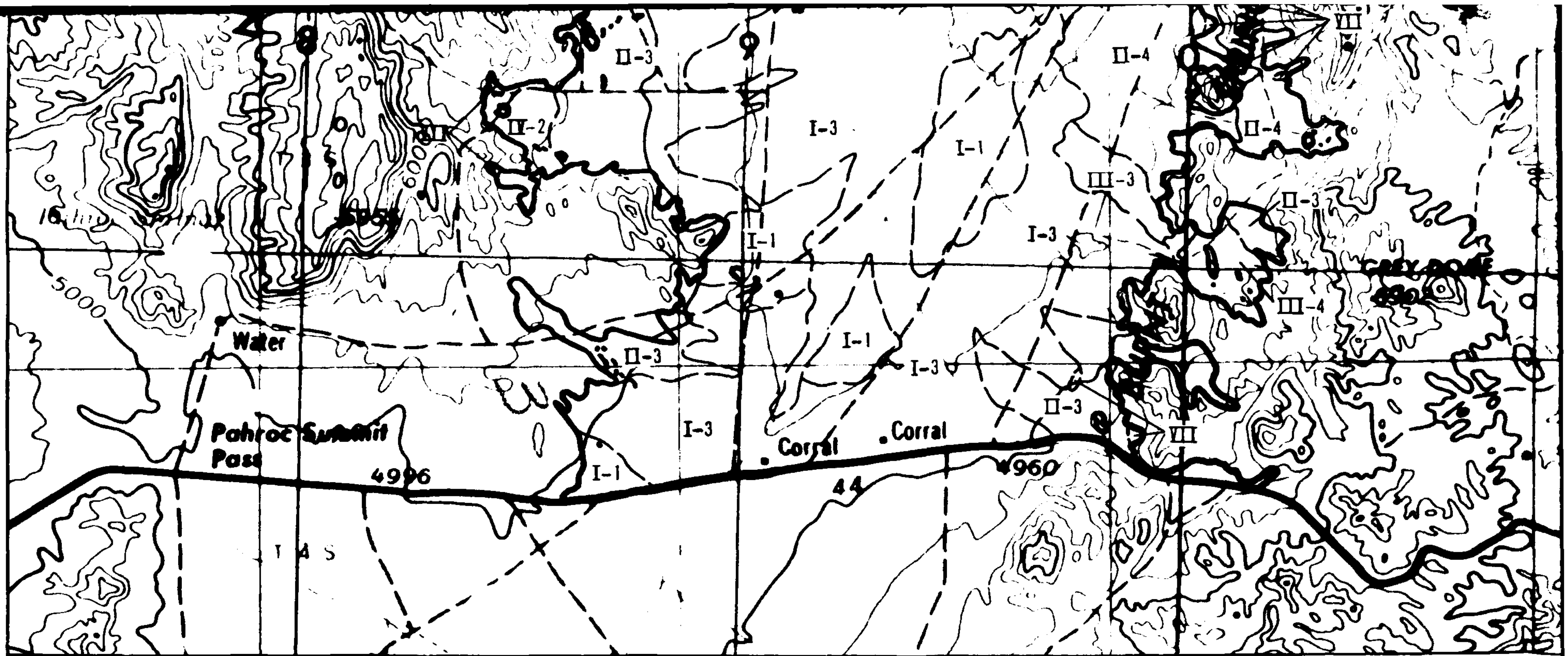
4





14 MAR 80


DRY LAKE
VALLEY
NORTH PAHROC RANGE
Corral
Ranch
4800
6000



EXPLANATION

Terrain Category (see table below) —— III - 3 —— Drainage spacing, i.e. the maximum number of drainages of the corresponding category occurring in a random traverse of one statute mile (1.6km).

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IV	10-15 feet (3-5m)
V	Greater than 15 feet (5m)
VI	Complex, highly variable terrain not defined by drainage incision (e.g. dunal or hummocky terrains).

Terrain Category — III - 3 — Drainage spacing, i.e. the maximum number of drainages of the corresponding category occurring in a random traverse of one statute mile (1.6km).
(see table below)

TERRAIN CATEGORY	DRAINAGE DEPTH DESCRIPTION
I	Less than 3 feet (1m)
II	3-6 feet (1-2m)
III	6-10 feet (2-3m)
IV	10-15 feet (3-5m)
V	Greater than 15 feet (5m)
VI	Complex, highly variable terrain not defined by drainage incision (e.g. *dunal or hummocky terrains*).
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Contact between terrain categories.

Contact between rock and basin-fill (and north and south valley boundaries).

Shading indicates areas of isolated exposed rock.

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4

TERRAIN
DRY LAKE VALLEY, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

DRAWING
3-5

FUGRO NATIONAL, INC.

BIBLIOGRAPHY

BIBLIOGRAPHY

Air Force Weapons Laboratory and Waterways Experiment Station, 1979, Survivability and hardness studies in Dry Lake Valley, Nevada: unpublished data.

Eakin, T. E., 1963, Ground-water appraisal of Dry Lake and Delamar valleys, Nevada: Nevada Dept. of Conservation and Natural Resources, Ground-Water Resources Reconnaissance Series Report 16, 26 p.

Fugro National, Inc., 1977a, MX siting investigation conterminous United States, Volume I Coarse Screening: Cons. Report for SAMSO, v. I, 30 p., Appendices (FN-TR-16).

__________, 1977b, MX siting investigation geotechnical evaluation conterminous United States, Volume II Intermediate Screening: Cons. Report for SAMSO, v. II, 175 p., Appendices (FN-TR-17).

__________, 1978a, MX siting investigation conterminous United States, v. III Fine Screening: Cons. Report for SAMSO, v. III, 51 p., Appendices (FN-TR-24).

__________, 1978b, MX siting investigation geotechnical summary prime characterization sites, Great Basin candidate siting province report: Cons. Report for SAMSO, 71 p., Appendices (FN-TR-26e).

__________, 1979a, MX siting investigation geotechnical evaluation, geotechnical ranking of seven candidate siting regions report: Cons. Report for SAMSO, 61 p., Appendices (FN-TR-25).

__________, 1979b, MX siting investigation geotechnical summary for the water resources program fiscal year 1979: Cons. Report for BMO, 54 p., Appendices.

__________, 1980a, MX siting investigation gravity survey - Dry Lake Valley: Cons. Report for BMO, 17 p., Appendices (FN-TR-33-DL).

__________, 1980b, MX siting investigation fault and earthquake study: Cons. Report for BMO (in progress), (FN-TR-36-I).

Nevada State Engineers Office, 1959-1967, Assorted well logs and reports to the State Engineer of Nevada.

Shawe, D. R., 1965, Strike-slip control of basin-range structure indicated by historical faults in western Nevada: Geological Soc. of Amer. Bull. v. 76, p. 1361-1378.

BIBLIOGRAPHY (cont.)

Stewart, J. H., and Carlson, J. E., 1978, Geologic map of Nevada: Nevada Bureau of Mines and Geology, 1:500,000.

Tschanz, C. M., and Pampeyan, E. H., 1970, Geology and mineral resources of Lincoln County, Nevada: Nevada Bureau of Mines Bull. 73, 188 p.

United States Geological Survey, 1978, Well data from Nye, Lincoln, Esmeralda, and White Pine counties: Unpublished computer print out from USGS Water Resources Division.

APPENDIX

TABLE OF CONTENTS

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LIST OF APPENDIX FIGURES

A1.0 GLOSSARY OF TERMS

ACTIVE FAULT - A fault which has had surface displacement within Holocene time (about the last 11,000 years).

ACTIVITY NUMBER - A designation composed of the valley abbreviation followed by the activity type and a unique number; may also be used to designate a particular location in a valley.

ALLUVIAL FAN DEPOSITS - Alluvium deposited by a stream or other body of running water as a sorted or semisorted sediment in the form of a cone or fan at the base of a mountain slope.

ALLUVIUM - A general term for unconsolidated clay, silt, sand, gravel, and boulders deposited during relatively recent geologic time by a stream or other body of running water as a sorted or semisorted sediment in the bed of a stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

ANOMALY - 1) A deviation from uniformity in physical properties; especially a deviation from uniformity in physical properties of exploration interest. 2) A portion of a geophysical survey which is different in appearance from the survey in general.

AQUIFER - A permeable saturated zone below the earth's surface capable of conducting and yielding water as to a well.

ARRIVAL - An event; the appearance of seismic energy on a seismic record; a lineup of coherent energy signifying the arrival of a new wave train.

ATTERBERG LIMITS - A general term applied to the various tests used to determine the various states of consistency of fine-grained soils. The four states of consistency are solid, semisolid, plastic, and liquid.

Liquid limit (LL) - The water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil (ASTM D423-66).

Plastic limit (PL) - The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil (ASTM D424-59).

Plasticity index (PI) - Numerical difference between the liquid limit and the plastic limit indicating the range of moisture content through which a soil-water mixture is plastic.

BASIN-FILL MATERIAL/BASIN-FILL DEPOSITS - Heterogenous detrital material deposited in a sedimentary basin.

BASE LEVEL - The theoretical limit or lowest level toward which erosion constantly progresses; the level at which neither erosion or deposition takes place.

BEDROCK - A general term for the rock, usually solid, that underlies soil or other unconsolidated, surficial material.

BORING - A method of subsurface exploration whereby an open hole is formed in the ground through which soil-sampling or rock-drilling may be conducted.

BOUGUER ANOMALY - The residual value obtained after latitude, elevation, and terrain corrections have been applied to gravity data.

BOULDER - A rock fragment, usually rounded by weathering and abrasion with an average diameter of 12 inches (305 mm) or more.

BULK SAMPLE - A disturbed soil sample (bag sample) obtained from cuttings brought to the ground surface by a drill rig auger or obtained from the walls of a trench excavation.

c - Cohesion (Shear strength of a soil not related to interparticle friction).

CALCAREOUS - Containing calcium carbonate; presence of calcium carbonate is commonly identified on the basis of reaction with dilute hydrochloric acid.

CALICHE - Gravel, sand, or other material cemented principally by calcium carbonate.

CALIFORNIA BEARING RATIO (CBR) - Is the ratio (in percent) of the resistance to penetration developed by a subgrade soil to that developed by a specimen of standard crushed rock base material (ASTM D1883-73). During the CBR test, the load is applied on the circular penetration piston (3 inches^2 base area; 19 cm^2) which is penetrated into the the soil sample at a constant penetration rate of 0.05 inch/ minute (1.2 mm/min). The bearing ratio reported for the soil is normally the one at 0.1 inch (2.5 mm) penetration.

CLAY - Fine-grained soil (passes No. 200 sieve; 0.074 mm) that can be made to exhibit plasticity within a range of water contents and that exhibits considerable strength when air dry.

CLAY SIZE - That portion of the soil finer than 0.002 mm.

CLOSED BASIN - A catchment area draining to some depression or lake within its area, from which water escapes only by evaporation.

COARSE-GRAINED (or granular) - A term which applies to a soil of which more than one-half of the soil particles, by weight, are larger than 0.074 mm in diameter (No. 200 U.S. sieve size).

COARSER-GRAINED - A term applied to alluvial fan deposits which are predominantly composed of material (cobble) larger than 3 inches (76 mm) in diameter.

COBBLE - A rock fragment, usually rounded or subrounded with an average diameter between 3 and 12 inches (76 and 305 mm).

COMPACTION TEST - A type of test to determine the relationship between the moisture content and density of a soil sample which is prepared in compacted layers at various water contents (ASTM D1557-70).

COMPRESSIBILITY-Property of a soil pertaining to its susceptibility to decrease in volume when subjected to load.

COMPRESSIONAL WAVE -An elastic body wave in which particle motion is in the direction of propagation; the type of seismic wave assumed in conventional seismic exploration. Also called P-wave, dilatational wave, and longitudinal wave.

CONDUCTIVITY - The ability of a material to conduct electrical current. In isotropic material, conductivity is the reciprocal of resistivity. Units are mhos per meter.

CONE PENETROMETER TEST - A method of evaluating the in-situ engineering properties of soil by measuring the penetration resistance developed during the steady slow penetration of a cone (60° apex angle, 10-cm^2 projected area) into soil.

Cone resistance or end bearing resistance, q_c - The resistance to penetration developed by the cone, equal to the vertical force applied to the cone divided by its horizontally projected area.

Friction resistance, f_s - The resistance to penetraton developed by the friction sleeve, equal to the vertical force applied to the sleeve divided by its surface area. This resistance consists of the sum of friction and adhesion.

Friction ratio, f_R - The ratio of friction resistance to cone resistance, f_s/q_c, expressed in percent.

CONSISTENCY - The relative ease with which a soil can be deformed.

CONSOLIDATION TEST - A type of test to determine the compressibility of a soil sample. The sample is enclosed in the consolidometer which is then placed in the loading device. The load is applied in increments at certain time intervals and the change in thickness is recorded.

CORE SAMPLE - A cylindrical sample obtained with a rotating core barrel with a cutting bit at its lower end. Core samples are obtained from indurated deposits and in rock.

DEGREE OF SATURATION - Ratio of volume of water in soil to total volume of voids.

DETECTOR - See GEOPHONE.

DIRECT SHEAR TEST - A type of test to measure the shear strength of a soil sample where the sample is forced to fail on a predetermined plane.

DISSECTION/DISSECTED (alluvial fans) - The cutting of stream channels into the surface of an alluvial fan by the movement (or flow) of water.

DRY UNIT WEIGHT/DRY DENSITY - Weight per unit volume of the solid particles in a soil mass.

ELECTRICAL CONDUCTIVITY - Ability of a material to conduct electrical current.

ELECTRICAL RESISTIVITY - Property of a material which resists flow of electrical current.

EOLIAN - A term applied to materials which are deposited by wind.

EPHEMERAL (stream) - A stream in which water flow is discontinuous and of short duration.

EXTERNAL DRAINAGE - Stream drainage system whose downgradient flow is unrestricted by any topographic impediments.

EXTRUSIVE (rock) - Igneous rock that has been ejected onto the earth's surface (e.g., lava, basalt, rhyolite, andesite; detrital material, volcanic tuff, pumice).

FAULT - A plane or zone of rock fracture along which there has been displacement.

FAULT BLOCK MOUNTAINS - Mountains that are formed by normal faulting in which the surface crust is divided into structural, partially to entirely fault-bounded blocks of different elevations.

FINE-GRAINED - A term which applies to a soil of which more than one-half of the soil particles, by weight, are smaller than 0.074 mm in diameter (passing the No. 200 U.S. size sieve).

FINER-GRAINED - A term applied to alluvial fan deposits, which are composed predominantly of material less than 3 inches (76 mm).

FLUVIAL DEPOSITS - Material produced by river action; generally loose, moderately well-graded sands and gravel.

FORMATION - A mappable assemblage of rocks characterized by some degree of homogeneity or distinctiveness.

FUGRO DRIVE SAMPLE - A 2.50-inch-(6.4-cm) diameter soil sample obtained from a drill hole with a Fugro drive sampler. The Fugro drive sampler is a ring-lined barrel sampler containing 12 one-inch-(2.54-cm) long brass sample rings. The sampler is advanced into the soil using a drop hammer.

GEOMORPHOLOGY - The study, classification, description, nature, origin, and development of present landforms and their relationships to underlying structures, and of the history of geologic changes as recorded by these surface features.

GEOPHONE - The instrument used to transform seismic energy into electrical voltage; a seismometer, jug, or pickup.

GRABEN - An elongated crustal block that has been downthrown along faults relative to the rocks on either side.

GRAIN-SIZE ANALYSIS (GRADATION) - A type of test to determine the distribution of soil particle sizes in a given soil sample. The distribution of particle sizes larger than 0.074 mm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 0.074 mm is determined by a sedimentation process, using a hydrometer.

GRANULAR - See Coarse-Grained.

GRAVEL - Particles of rock that pass a 3-in. (76.2 mm) sieve and are retained on a No. 4 (4.75 mm sieve).

GRAVITY - The force of attraction between bodies because of their mass. Usually measured as the acceleration of gravity.

GYPSIFEROUS - Containing gypsum, a mineral consisting mostly of sulfate of calcium.

HORST - An elongated crustal block that has been uplifted along faults relative to the rocks on either side.

INTERIOR DRAINAGE - Stream drainage system that flows into a closed topographic low (basin).

INTRUSIVE (rock) - A rock formed by the process of emplacement of magma (liquid rock) in preexisting rock, (e.g., granite, granodiorite, quartz monzonite).

LACUSTRINE DEPOSITS - Materials deposited in a lake environment.

LARAMIDE OROGENY - A time of deformation extending from late Cretaceous (about 100 million years ago) to the end of the Paleocene (about 50 million years ago) which accounted for much present Basin and Range structure.

LINE - A linear array of observation points, such as a seismic line.

LIQUID LIMIT - See ATTERBERG LIMITS.

LOW STRENGTH SURFICIAL SOIL - Soil which will perform poorly as a road subgrade, at its present consistency, when used dirctly beneath a road section.

MOISTURE CONTENT - The ratio, expressed as a percentage, of the weight of water contained in a soil sample to the ovendry weight of the sample.

NEOTECTONICS - The study of the recent structural history of the earth's crust, usually during the late Tertiary and the Quaternary periods.

N VALUE - Penetration resistance, described as the number of blows required to drive the standard split-spoon sampler for the second and third 6 inches (0.15 m) with a 140-pound (63.5-kg) hammer falling 30 inches (0.76 m) (ASTM D1586-67).

OPTIMUM MOISTURE CONTENT - Moisture content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort.

P-WAVE - See Compressional Wave.

PATINA - A dark coating or thin outer layer produced on the surface of a rock or other material by weathering after long exposure (e.g., desert varnish).

PAVEMENT/DESERT PAVEMENT - When loose material containing pebble-sized or larger rocks is exposed to rainfall and wind action, the finer dust and sand are blown or washed away and the pebbles gradually accumulate on the surface, forming a mosaic which protects the underlying finer material from wind attack. Pavement can also develop in finer-grained materials. In this case, the armored surface is formed by dissolution and cementation of the grains involved.

PERMEABLE - The ability of liquid to pass through soil and/or rock material.

pH - An index of the acidity or alkalinity of a soil in terms of the logarithm of the reciprocal of the hydrogen ion concentration.

PHI (Ø) - Angle of internal friction.

PIEZOMETRIC SURFACE - An imaginary surface representing the static head of ground water and defined by the level to which water will rise in a well.

PITCHER TUBE SAMPLE - An undisturbed, 2.87-inch-(73-mm) diameter soil sample obtained from a drill hole with a Pitcher tube sampler. The primary components of this sampler are an outer rotating core barrel with a bit and an inner stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending upon the hardness of the material being penetrated.

PLASTIC LIMIT - See ATTERBERG LIMITS.

PLASTICITY INDEX - See ATTERBERG LIMITS.

PLAYA/PLAYA DEPOSITS - A term used in the southwest U.S. for a dried-up, flat-floored area composed of thin, evenly stratified sheets of clay, silt, or fine sand, and representing the lowest part of a shallow, completely closed or undrained, desert lake basin in which water accumulates and is quickly evaporated, usually leaving deposits of soluble salts.

POORLY GRADED - A descriptive term applied to a coarse-grained soil if it consists predominantly of one particle size (uniformly graded) or has a wide range of sizes with some intermediate sizes obviously missing (gap-graded).

RANGE-BOUNDED FAULT - Usually a normal fault in which one side has moved up relative to the other and which separates the mountain front from the valley.

RELATIVE AGE - The relationship in age (oldest to youngest) between geologic units without specific regard to number of years.

RESISTIVITY (True, Intrinsic) - The property of a material which resists the flow of electric current. The ratio of electric-field intensity to current density.

ROCK UNITS - Distinct rock masses with different characteristics (e.g., igneous, metamorphic, sedimentary).

ROTARY WASH DRILLING - A boring technique in which advancement of the hole through overburden is accomplished by rotation of a heavy string of rods while continuous downward pressure is maintained through the rods on a bit at the bottom of the hole. Water or drilling mud is forced down the rods to the bit, and the return flow brings the cuttings to the surface.

S-WAVE - See Shear Wave.

SAND - Soil passing through No. 4 (4.75 mm) sieve and retained on No. 200 (0.075 mm) sieve.

SAND DUNE - A low ridge or hill consisting of loose sand deposited by the wind, found in various desert and coastal regions and generally where there is abundant surface sand.

SEISMIC - Having to do with elastic waves. Energy may be transmitted through the body of an elastic solid as P-waves (compressional waves) or S-waves (shear waves).

SEISMIC LINE - A linear array of travel time observation points (geophones). In this study, each line contains 24 geophone positions.

SEISMIC REFRACTION DATA: deep/shallow - Data derived from a type of seismic shooting based on the measurement of seismic energy as a function of time after the shot and of distance from the shot, by determining the arrival times of seismic waves which have traveled nearly parallel to the bedding in high-velocity layers, in order to map the depth to such layers.

SEISMOGRAM - A seismic record.

SEISMOMETER - See Geophone.

SHEAR STRENGTH - The maximum resistance of a soil to shearing (tangential) stresses.

SHEAR WAVE - A body wave in which the particle motion is perpendicular to the direction of propagation. Also called <u>S-Wave</u> or <u>transverse wave</u>.

SHEET FLOW - A process in which stormborne water spreads as a thin, continuous veneer (sheet) over a large area.

SHEET SAND - A blanket deposit of sand which accumulates in shallow depressions or against rock outcrops, but does not have characteristic dune form.

SHOT - Any source of seismic energy; e.g., the detonation of an explosive.

SHOT POINT - The location of any source of seismic energy; e.g., the location where an explosive charge is detonated in one hole or in a pattern of holes to generate seismic energy. Abbreviated SP.

SILT - Fine-grained soil passing the No. 200 sieve (0.074 mm) that is nonplastic or very slightly plastic and that exhibits little or no strength when air-dried.

SILT SIZE - That portion of the soil finer than 0.02 mm and coarser than 0.002 mm.

SITE - Location of some specific activity or reference point. The term should always be modified to a precise meaning or be clearly understood from the context of the discussion.

SPECIFIC GRAVITY - The ratio of the weight in air of a given volume of soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

SPLIT-SPOON SAMPLE - A disturbed sample obtained with a split-spoon sampler with an outside diameter of 2.0 inches (5.1 cm). The sample consists of a split barrel which is driven into the soil using a drop hammer.

SPREAD - The layout of geophone groups from which data from a single shot are recorded simultaneously. Spreads containing 24 geophones have been used in Fugro's seismic refraction surveys.

STREAM CHANNEL DEPOSITS - See Fluvial Deposits.

STREAM TERRACE DEPOSITS - Stream channel deposits no longer part of an active stream system, generally loose, moderately well graded sand and gravel.

SULFATE ATTACK - The process during which sulfates, salts of sulfuric acid, contained in ground water cause dissolution and damage to concrete.

SURFICIAL DEPOSIT - Unconsolidated residual and alluvial deposits occurring on or near the earth's surface.

TEST PIT - An excavation made to depths of about 5 feet (1.5 m) by a backhoe. A test pit permits visual examination of undisturbed material in place.

TRENCH - An excavation by a backhoe to depths of about 15 feet (4.5 m). A trench permits visual examination of soil in place and evaluaton of excavation wall stability.

TRIAXIAL COMPRESSION TEST - A type of test to measure the shear strength of an undisturbed soil sample (ASTM D2850-70). To conduct the test, a cylindrical specimen of soil is surrounded by a fluid in a pressure chamber and subjected to an isotropic pressure. An additional compressive load is then applied, directed along the axis of the specimen called the axial load.

Consolidated-drained (CD) Test - A triaxial compression test in which the soil was first consolidated under an all-around confining stress (test chamber pressure) and was then compressed (and hence sheared) by increasing the vertical stress. Drained indicates that excess pore water pressures generated by strains are permitted to dissipate by the free movement of pore water during consolidation and compression.

Consolidated-undrained (CU) Test - A triaxial compression test in which essentially complete consolidation under the confining (chamber) pressure is followed by a shear at constant water content.

UNCONFINED COMPRESSION - A type of test to measure the compressive strength of an undisturbed sample (ASTM D2166-66). Unconfined compressive strength is defined as the load per unit area at which an unconfined prismatic or cylindrical specimen of soil will fail in a simple compression test.

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) - A system which determines soil classification for engineering purposes on the basis of grain-size distribution and Atterberg limits.

VALLEY FILL - See Basin-Fill Material/Basin-Fill Deposits.

VELOCITY - Refers to the propagation rate of a seismic wave without implying any direction. Velocity is a property of the medium and not a vector quantity when used in this sense.

VELOCITY LAYER - A layer of rock or soil with a homogenous seismic velocity.

VELOCITY PROFILE - A cross section showing the distribution of material seismic velocities as a function of depth.

WASH SAMPLE - A sample obtained by screening the returned drilling fluid during rotary wash drilling to obtain lithologic information between samples.

WATER TABLE - The upper surface of an unconfined body of water at which the pressure is equal to the atmospheric pressure.

WELL GRADED - A soil is identified as well graded if it has a wide range in grain size and substantial amounts of most intermediate sizes.

Definitions were derived from the following references:

American Society for Testing and Materials, 1976, Annual book of ASTM standards, Part 19: Philadelphia, American Soc. for Testing and Materials, 484 p.

Gary, M., McAfee, R., Jr., Wolf, C. L., eds., 1972, Glossary of geology: Washington, D.C., American Geol. Institute, 805 p.

Merriam, G., and Merriam, C., 1977, Webster's new collegiate dictionary: Springfield, Mass., G. and C. Merriam Co., 1536 p.

Sheriff, R. E., 1973, Encyclopedic dictionary of exploration geophysics: Tulsa, Oklahoma, Soc. of Exploration Geophysicists, 266 p.

A2.0 EXCLUSION CRITERIA

Table A2-1 lists the exclusion criteria applied during Verification Studies. Many of the criteria have not changed significantly since Coarse Screening Studies. Most geotechnical criteria have been modified to accomodate the basing mode requirements of the horizontal and vertical shelter concepts as well as increasing levels of study detail.

CRITERIA		DEFINITION AND COMMENTS
SURFACE ROCK AND ROCK OCCURRING WITHIN 50 FEET (15m) AND 150 FEET (46m) OF THE GROUND SURFACE		Rock is defined as any earth material which is not rippable by conventional excavation methods. Where available, seismic P-wave velocities were evaluated in the determination of rock conditions.
SURFACE WATER AND GROUND WATER OCCURRING WITHIN 50 FEET (15m) AND 150 FEET (46m) OF THE GROUND SURFACE		Surface water includes all significant lakes, reservoirs, swamps, and major perennial streams. Water which would be encountered in a 50-foot and 150-foot excavation was considered in the application of this criterion. Depths to ground water resulting from deeper confined aquifers were not considered.
TERRAIN	Percent Grade	Areas having surface gradients exceeding 10 percent or a preponderance of slopes exceeding 10 percent as determined from maps at scales of 1:125 000, 1:62 500, and 1:24,000 and by field observation.
	Drainage	Areas having drainage densities averaging at least two 10-foot deep drainages per 1000 feet (measured parallel to contours, as determined from maps at scales of 1:24,000 or in the field).
CULTURAL	Quantity Distance:	Eighteen nautical mile exclusion arcs from cities having populations (1970) of 25,000 or more.
		Three nautical mile exclusion arcs from cities having populations (1970) of between 5,000 and 25,000.
	Land Use:	All significant federal and state forests, parks, monuments, and recreation areas.
		All significant federal and wildlife refuges, grasslands, ranges, preserves and management areas.
		Indian reservations.
	Economic:	High potential economic resource areas including oil and gas fields, strippable coal, oil shale, uranium deposits, and known geothermal resource areas (KGRA) of sufficient density so as to prohibit use as a siting area.
		Industrial complexes such as active mining areas, tank farms and pipeline complexes of sufficient density so as to prohibit use as a siting area.

EXCLUSION CRITERIA
VERIFICATION STUDIES, NEVADA-UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - SAMSO

TABLE A2-1

FUGRO NATIONAL, INC.

A3.0 ENGINEERING GEOLOGIC PROCEDURES

The principal objectives of the field geology investigation were to:

1. Delineate surficial extent of soil types and geologic units;
2. Assess terrain conditions; and
3. Make observations helpful in defining depth to rock and water.

Aerial photographs (1:60,000 black and white; 1:25,000 color) served as the base on which all mapping was done. Field activities were directed toward checking the photogeologic mapping.

Field checking consisted chiefly of collecting data about surficial soils at selected locations in order to refine contacts and define engineering characteristics of photogeologic units. At each location, observations of grain size distribution, color, clast lithology, surface soil development, and a variety of engineering parameters were recorded (see Volume II,Geotechnical Data). Observations were made in existing excavations (borrow pits, road cuts, stream cuts) or in hand-dug test pits. Extrapolation of this data to determine surficial extent was accomplished by geologic reconnaissance over existing roads.

Of the parameters listed, grain size is the most important for engineering purposes and for this reason is included in the geologic unit designation. However, grain size is not readily mapped on aerial photos, and much of the field work involved determination of the extent of surficial deposits of a particular grain-size category (gravel, sand, or fine-grained).

Terrain data were also taken at geologic field stations. Drainage width and depth were estimated and predominant surface slope was measured. Slopes were measured over a distance of 100 to 150 feet (31 to 46 m) with an Abney hand level. For additional data, depths of major drainages encountered during geologic reconnaissance between stations were recorded on the aerial photographs.

In order to help refine depth to rock interpretations, observations were concentrated along the basin margin to identify areas of shallow rock. Observations regarding depth to water were restricted to measurements in existing wells and borings.

A4.0 GEOPHYSICAL PROCEDURES

A4.1 SEISMIC REFRACTION SURVEYS

A4.1.1 Instruments

Field explorations were performed with a 24-channel SIE Model RS-44 seismic refraction system which consisted of 24 amplifiers coupled with a dry-write, galvanometer-type recording oscillograph. Seismic energy was detected by Mark Products Model L-10 geophones with natural frequency of 4.5 Hz. Geophones were fitted with short spikes to provide good coupling with the ground. Cables with two takeout intervals were used to transmit the detected seismic signal from the geophones to the amplifiers. Time of shot was transmitted from shotpoint to recording system via an FM radio link.

The degree of gain was set on the amplifiers by the instrument operators and was limited by the background noise at the time of the shot. The amplifiers are capable of maximum gain of 1.1 million. The oscillograph placed timing lines on the seismograms at 0.01-second intervals. The timing lines form the basis for measuring the time required for the energy to travel from the shot to each geophone.

A4.1.2 Field Procedures

"Shallow" seismic refraction lines consisted of a single spread of 24 geophones with 25 feet between geophones. Five shots were made into each spread. Shot points were located 300 feet and 10 feet from both ends of the spread and at the center of the spread. The recording system was located at the center of the spread.

"Deep" seismic refraction lines consisted of two or more spreads of 24 geophones each. The interval between geophones was 200 feet. Where spreads joined, they were overlapped by one geophone interval. In addition to shots at the end of each spread, shots were made at from one to three offset locations. The offset distances ranged from 1200 to 22,000 feet. Each time a shot was detonated, recordings were made along two adjoining spreads with two 24-trace recording systems.

The explosive used was a nitro-carbo-nitrate slurry marketed by Atlas powder company under the registered trade name "Aquaflo". Charge sizes ranged from as small as one pound on the "shallow" seismic lines to as large as 7080 pounds for the longest offset shots on the "deep" seismic lines. The charges were detonated using seismograph grade electric blasting caps.

Relative elevations of geophones and shotpoints within a line were measured with a transit or level.

A4.1.3 Data Reduction

The travel times for compressional waves from the shots to the geophones were obtained from the seismograms by visual inspection. These times were plotted at their respective horizontal distances and best fit lines were drawn through the points to obtain apparent velocities for materials below the seismic line.

A combination of delay time and ray tracing methods was used in a computer program to obtain depth to refracting horizons from the time-distance information.

A4.2 DOWNHOLE SEISMIC VELOCITY SURVEYS

A4.2.1 Instruments

Downhole seismic velocity recordings were made using a SIE Model RS-44 amplifier system and Model R6A oscillographic recorder. The system is capable of recording up to 24 channels of data on 6-inch (15.2-cm) wide photo-sensitive, direct write recording paper. Full width timing lines are impressed on the record at ten millisecond intervals.

Mark Products Model L-10-3D-SWC downhole geophone assembly was used to detect the seismic wave arrivals in the boring. The assembly contains three mutually perpendicular geophones with natural frequency of 4.5 Hz. It is equipped with a leaf spring which maintains contact with the boring (casing) wall.

The record format included six signal traces and a "time break" trace. The amplified output of each of the three geophones was displayed at two different gain settings. The time break trace recorded the instant an electrical circuit was completed as the energy was generated. The "switch" in the circuit was formed by contact between a sledge hammer and a metallic surface which was being struck.

A4.2.2 Field Procedures

Downhole seismic travel times were obtained by mechanically generating energy at the surface and recording the arrival of the energy in a nearby boring. The horizontal separation between the boring and the point of energy generation was approximately 20 feet (6 m). The boring was cased with 3-inch (7.6-cm) diameter PVC pipe. The casing was grouted into the hole.

To begin the downhole observations, the geophone assembly was placed at a depth of 10 feet (3 m). Then seismograms (records) were obtained. Energy for the first record was generated by a sledge hammer blow downward on a metal plate lying flat on the ground. This blow generated a relatively strong compressional wave.

Energy for the second record was generated by a horizontal sledge hammer blow on a vertical metal end plate at one end of a wooden beam lying flat on the ground. The beam was oriented perpendicular to a line extending from its center to the boring.

It was coupled to the ground by having the wheels of a vehicle parked on it. A horizontal blow of this type produces shear wave energy, and relatively small compressional wave energy.

Energy for the third record was generated by striking a horizontal blow against the metal end plate at the other end of the wooden beam in order to produce shear waves with oscillatory polarity opposite to that generated for the second record.

After these three records were obtained, the geophone assembly was lowered ten feet (3 m) into the hole and three more records were obtained in the above pattern. This procedure was repeated until the bottom of the boring was reached.

A4.2.3 Data Reduction

The records were analyzed to determine the travel time between the impact and the arrival of the seismic waves at the geophone assembly. The compressional waves usually appear as a rather obvious excursion of the traces from their rest position. Except when the geophones are at shallow depths, this arrival is normally observed most readily on the traces representing the vertical geophone. The records obtained from the vertical hammer blows are the primary source of compressional wave travel time data.

The arrival of the shear wave usually occurs while the traces are still oscillating in the "wake" of the earlier arriving compressional wave. The shear wave typically causes an increase in amplitude on the trace and a lengthening of the recorded period, but the instant it arrives may be partially obscured by the compressional wave "noise". Since the shear wave is a polarized wave, the traces from the horizontal geophones on two records made with oppositely polarized energy (blows on opposite ends of the beam) are compared to note the point of phase reversal in order to assist the shear wave identification.

The wave travel times are reduced according to the ratio of the depth of the geophone in the boring and slant distance between the impact point and geophone. These reduced times are plotted on a graph of travel time versus depth. The velocity profile is interpreted by fitting straight line segments through the points. The velocity in a particular zone is indicated by the inverse slope of the line segment through that zone (slope defined as Δtime/Δdepth).

A5.0 ENGINEERING PROCEDURES

Soil engineering activities consisted of the following:

1. Field activities:
   - o Borings
   - o Trenches
   - o Test Pits
   - o Surficial Samples
   - o Cone Penetrometer Tests
2. Office activities:
   - o Laboratory Tests
   - o Data Analyses and Interpretations

The procedures used in the various activities are described in the following sections.

A5.1 BORINGS

A5.1.1 Drilling Techniques

The borings were drilled at designated locations using either the Becker Percussion method or rotary techniques. Specifics of these two drilling methods are discussed in the following paragraphs.

a. Becker Percussion Method: With the Becker Method, a double wall drive pipe was driven by a diesel powered pile hammer, while air was forced down the annulus of the drive pipe. The air continuously lifted the material cut by the drive bit to the surface through the center of the double wall pipe. When refusal to driving was encountered, a hydraulic rotary attachment swung into position and conventional rotary methods were used to advance the boring with the drive pipe serving as the overburden casing. Borings drilled by the truck-mounted Becker Percussion rig were nominally 5 1/2 inches (140 mm) in diameter, and ranged in depth from 25 to 100 feet (8 to 30 m).

b. Rotary Method: The borings drilled by rotary techniques used a truck-mounted Failing 1500 drill rig with hydraulic pulldown. These borings were nominally 4 7/8 inches (124 mm) in diameter. A bentonite-water slurry or compressed air was used to return soil cuttings to the surface. A tricone drill bit was used for coarse-grained soils and a drag bit for drilling in fine-grained soils. Depths drilled ranged from 100 to 450 feet (30 to 137 m).

A5.1.2 Method of Sampling

A5.1.2.1 Sampling Intervals

Soil samples were obtained at the following nominal depths as listed for each drilling method as well as at depths of change in soil type.

a. Becker Percussion Method:

0' to 20' (0.0 to 6.1 m) - Bulk or Drive - samples at 5' intervals
20' to 100' (6.1 to 30.5 m) - Bulk - samples at 10' intervals

b. Rotary Method:

0' to 30' (0.0 to 9.1 m) - Split Spoon or Pitcher - samples at 5' intervals
30' to 100' (9.1 to 30.5 m) - Split Spoon or Pitcher - samples at 10' intervals
100' to 300' (30.5 to 91.4 m) - Pitcher or drive - samples at 25' intervals
300' to 450' (91.4 to 137.2 m) - Pitcher - samples at 50' intervals

A5.1.2.2 Sampling Techniques

a. Fugro Drive Samples: Fugro drive samplers were used to obtain relatively undisturbed soil samples. The Fugro drive sampler is a ring-lined barrel sampler with an outside diameter of 3.0 inches (76.2 mm) and inside diameter of 2.50 inches (63.5 mm). It contains 12 individual 1-inch- (25.4-mm) long rings and is attached to a 12-inch- (30-cm) long waste barrel. The sampler was advanced using a downhole hammer weighing 400 pounds (181 kg) with a drop of 15 inches (38.1 cm).

The number of blows required to advance the sampler for a 6-inch (15-cm) interval were recorded. Samples obtained were retained in the rings, placed in plastic bags with manually twisted top ends and sealed in plastic sample containers. Each sample was identified with a label indicating job number, boring number, sample number, depth range, Unified Soil Classification Symbol (USCS), and date. Ring samples were placed in foam-lined steel boxes.

b. Pitcher Samples: The Pitcher sampler was used to obtain undisturbed soil samples. The primary components of this sampler are an outer rotating core barrel with a bit and an inner, stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending on the hardness of the material penetrated. The average inside diameter of the sampling tubes used was 2.87 inches (73 mm). Before placing the Pitcher tube in the outer barrel, the tube was inspected for sharpness and protrusions.

The Pitcher sampler was then lowered to the bottom of the boring and the thin-walled sampling tube advanced into the soil ahead of the rotating cutting bit by the weight of the drill rods and hydraulic pulldown. The thin-walled sampling tube was retracted into the core barrel and the sampler was brought to the surface. After removal of the sampling tube from the core barrel, the length of the recovered soil sample was measured and recorded. Before preparing and sealing the tube, the drilling fluid in the Pitcher tube was removed. Cap plugs were taped in place on the top and bottom of the Pitcher tube and sealed with wax. When Pitcher samples could not be retrieved without disturbance, they were clearly marked as "disturbed." Each sealed Pitcher tube was labeled as explained under "Fugro Drive Samples" and then placed vertically in foam-lined wooden boxes.

c. Bulk Samples: Bulk samples were obtained from Becker Percussion drilling method by circulating the material discharged at the surface through a cyclone to reduce discharge velocity. The material was then sampled, placed in plastic bags and labeled as explained previously.

Bulk samples from rotary drilling were obtained by screening the returning drilling fluid to obtain wash samples or collecting soil cuttings returned by compressed air. Recovered samples were placed in plastic bags and labeled as previously explained.

d. Split-Spoon Samples: Split-spoon samplers were used to obtain disturbed, but representative soil samples. The split-spoon sampler consists of a barrel shoe, a split barrel or tube, a solid sleeve, and a sampler head. The inside diameter of the sampler shoe is 1.375 inches (35 mm) and the length is about 18 inches (45.7 cm). Sampling with the split barrel sampler is accomplished by driving the sampler into the ground with a 140-pound (63.6-kg) hammer dropped 30 inches (76 cm). The number of blows required to drive the sampler a distance of 12 inches (30.4 cm) was recorded as the Standard Penetration Resistance (N value). The disturbed samples obtained from the split-spoon sampler were placed in plastic bags and labeled as explained previously.

A5.1.3 Logging

All soils were classified in the field by the procedures outlined in Section A5.4, "Field Visual Soil Classification," of this Appendix. Rock encountered in the borings was described according to classifications given in Travis (1955) and Folk (1974). The following general information was entered on the boring logs at the time of drilling: boring number; project name, number, and location; name of drilling company and driller; name of logger and date logged; and method of drilling and sampling, drill bit type and size, driving weight and average drop as applicable. As drilling progressed, the soil samples recovered were visually classified as outlined in Section A5.4, "Field Visual Soil Classification," and the description was entered on the logs. Section A5.4 also discusses other pertinent data and observations made, which were entered on the boring logs, during drilling.

A5.1.4 Sample Storage and Transportation

Samples were handled with care, drive spoon sample containers being placed in foam-lined steel boxes, while Pitcher samples were transported in foam-lined wooden boxes. Particular care was exercised by drivers while traversing rough terrain so as not to cause any disturbance to the undisturbed samples. Whenever ambient air temperatures fell below 32°F, all samples were stored in heated rooms during the field work and transported to Fugro National's Long Beach laboratory in heated cabins in back of pickup trucks.

A5.2 TRENCHES, TEST PITS, AND SURFICIAL SAMPLES

A5.2.1 Excavation Equipment

In 1977 the trenches, test pits, and surficial samples were excavated using a rubber tire-mounted Case 780 backhoe with a maximum depth capability of 18 feet (5.5 m). In 1979 a Case 580C with a maximum depth capability of 14 feet (4.2 m) ·as used.

A5.2.2 Method of Excavation

Unless caving occurred during the process of excavation, the trench width was nominally 2 to 3 feet (0.6 to 0.9 m). Trench depths were typically 14 to 18 feet (4.2 to 5.5 m) and lengths ranged from 12 to 60 feet (3.6 to 18.3 m). Test pits were nominally 2 feet (0.6 m) wide, 5 feet (1.5 m) deep, and ranged from 5 to 10 feet (1.5 to 3.0 m) in length. Surficial sample excavations were typically 2 feet (0.6 m) wide, 2 feet (0.6 m) deep, and about 3 to 5 feet (0.9 to 1.5 m) long. The trench and test pit walls were vertical. However, where surface materials were unstable, the trench walls were sloped back to a safe angle to prevent sloughing during the completion of excavation and logging. The excavated material was deposited on one side at least 4 feet (1.2 m) from the edge of the trenches in order to minimize stress loads at the edges. The excavations were backfilled with the excavated material and the ground surface was restored to a condition as conformable with the surrounding terrain as practical.

A5.2.3 Sampling

The following sampling procedures were generally followed for all trenches, test pits, and surficial samples.

- o Representative bulk soil samples (large or small) were obtained in the top 2 feet (0.6 m). If the soil type changed in the top 2 feet, bulk samples of both the soil types were obtained. In addition, bulk samples of all soil types encountered at different depths in the excavation were obtained. For each soil type in the top 2 to 3 feet (0.6 to 0.9 m), two large bulk samples (weighing about 50 pounds each; 11.4 kg) were taken. Bulk samples from other depths were limited to one bag. When soils from two locations were similar, only a small bag sample weighing about 2 pounds (1 kg) was taken from the second location.

- All large bulk samples were placed first in plastic bags and then in cloth bags. The small bulk samples were placed in small plastic bags. All sample bags of soil were tied tightly at the top to prevent spillage and tagged with the following information: project number; trench, test pit, or surficial sample number; bulk sample number; depth range in feet; Unified Soil Classification symbol; and date. The samples were transported to the field office for storage and then to Fugro National's Long Beach office in pickup trucks.

A5.2.4 Logging

The procedures for field visual classification of soil and rock encountered from the trenches, test pits, and surficial samples were basically the same as the procedures for logging of borings (Section A5.1.3). For excavations shallower than 4 feet (1.2 m) technicians entered the excavations and logged them. Logging of the excavations deeper than 4 feet (1.2 m) was accomplished from the surface and by observing the backhoe bucket contents. Most trench walls were photographed prior to backfilling.

Each field trench, test pit, and surficial sample log included trench, test pit, or surficial sample number; project name, number and location; name of excavator; type of excavation equipment; name of logger; and date logged. As excavations proceeded, the soil types encountered were visually classified and described as outlined in Section A5.4, "Field Visual Soil Classification." Section A5.4 also discusses other pertinent data and observations made which were entered on the logs during excavation.

A5.3 CONE PENETROMETER TESTS

A5.3.1 Equipment

The equipment consisted of a truck-mounted [17.5 tons (15,877 kg) gross weight] electronic cone penetrometer equipped with a 15-ton (13,608 kg) fiction cone (cone end resistance capacity of 15 tons (13,608 kg) and 4-1/2-ton (4082 kg) limit on the friction sleeve). All operating controls, recorder, cables, and ancillary equipment were housed in the specially designed vehicle which was completely self-contained. The penetrometer, the key element of the system, contained the necessary load cells and cable connections. One end of the unit was threaded to receive the first sounding rod. When carrying out the tests, hollow rods with an outside diameter of 1.42 inches (3.6 cm) and a length of 3.3 feet (1.0 m) were used to push down the cone.

The hydraulic thrust system was mounted over the center of gravity of the truck, permitting use of the full 17.5-ton truck weight as load reaction.

The cone had an apex angle of 60° and a base area of 2.3 in^2 (15 cm^2. The resistance to penetration was measured by a built-in load cell in the tip and was relayed to the surface recorder via cables in the sounding rods. The friction sleeve, having an area of 205 cm^2, was fitted above the cone base. The local friction was measured by load cells mounted in the friction sleeve and recorded in the same manner as the end resistance. The end resistance and friction resistance were recorded on a strip chart.

A5.3.2 Test Method

Tests were performed in accordance with ASTM D3441-75T, "Tentative Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil." Basically, the test was conducted by positioning the electronic cone penetrometer truck over the designated area for testing, setting the outriggers on the ground surface, checking the level of the rig, then pushing the cone into the ground at a rate of 0.79 in/s (2 cm/s) until refusal (defined as the capacity of the cone, friction sleeve, or hydraulics system) or the desired depth of penetration was reached.

A5.4 FIELD VISUAL SOIL CLASSIFICATION

A5.4.1 General

All field logging of soils was performed in accordance with the procedures outlined in this section. Soil samples were visually classified in the field in general accordance with the procedures of ASTM D 2488-69, Description of Soils (Visual-Manual Procedure). The ASTM procedure is based on the Unified Soil Classification System (see Table A5-1). It describes several visual and/or manual methods which can be used in the field to estimate the USCS soil group for each sample. The following section details several of the guidelines used in the field for describing soils, drilling and excavating conditions, and unusual conditions encountered.

A5.4.2 Soil Description

Soil descriptions entered on the logs of borings, trenches, test pits, and surficial samples generally included those listed below.

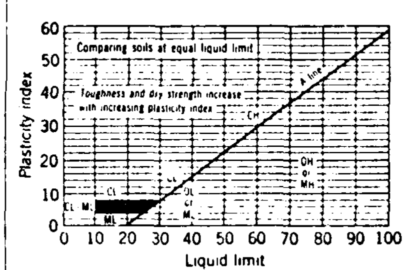
Coarse-Grained Soils	Fine-Grained Soils
USCS Name and Symbol	USCS Name and Symbol
Color	Color

Major divisions		Fraction	Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)	Group Symbols[a]	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria	
Coarse-grained soils More than half of material is *larger* than No. 200 sieve size[b] (The No. 200 sieve size is about the smallest particle visible to naked eye)	Gravels More than half of coarse fraction is larger than No. 4 sieve size (For visual classification, the ¼ in. size may be used as equivalent to the No. 4 sieve size)	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel, maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information, and symbols in parentheses	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing	*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for *GW*	
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)	*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics	Atterberg limits below "A" line, or *PI* less than 4	Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line, with *PI* greater than 7	
	Sands More than half of coarse fraction is smaller than No. 4 sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	*SW*	Well graded sands, gravelly sands, little or no fines	Example: *Silty sand*, gravelly; about 20% hard, angular gravel particles ½-in. maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing	*SP*	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for *SW*	
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)	*SM*	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line or *PI* less than 5	Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*SC*	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits below "A" line with *PI* greater than 7	

Laboratory classification (coarse-grained soils): Use grain size curve in identifying the fractions as given under field identification. Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP*; More than 12% *GM, GC, SM, SC*; 5% to 12% *Borderline* cases requiring use of dual symbols

Identification Procedures on Fraction Smaller than No. 40 Sieve Size

Major divisions		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)	Group Symbols[a]	Typical Names	Information Required for Describing Soils
Fine-grained soils More than half of material is *smaller* than No. 200 sieve size	Silts and clays liquid limit less than 50	None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses
		Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
		Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions
	Silts and clays liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	
		High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (*ML*)
		Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity	
Highly Organic Soils		Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils	



Plasticity chart
for laboratory classification of fine grained soils

From Wagner, 1957.
[a] *Boundary classifications.* Soils possessing characteristics of two groups are designated by combinations of group symbols. For example *GW-GC*, well graded gravel-sand mixture with clay binder.
[b] All sieve sizes on this chart are U.S. standard.

Field Identification Procedure for Fine Grained Soils or Fractions

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

Dilatancy (Reaction to shaking):
After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.
Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.
Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics):
After removing particles larger than No. 40 sieve size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.
High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit):
After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eight inch in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.
After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.
The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.
Highly organic clays have a very weak and spongy feel at the plastic limit.

UNIFIED SOIL CLASSIFICATION SYSTEM

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE
A5-1

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Coarse-Grained Soils	Fine-Grained Soils
Range in Particle Size	Consistency
Gradation (well, poorly)	Moisture Content
Density	Plasticity
Moisture Content	Reaction to HCl
Particle Shape	
Reaction to HCl	

Some additional descriptions or information recorded for both coarse- and fine-grained soils included: degree of cementation, secondary material, cobbles and boulders, and depth of change in soil type.

Definitions of some of the terms and criteria used to describe soils and conditions encountered during the investigations follow.

a. USCS Name and Symbol: Derived from Table A5-1, the Unified Soil Classification System. The soils were first designated as coarse- or fine-grained.

Coarse-grained soils are those in which more than half (by weight) of the particles are visible to the naked eye. In making this estimate, particles coarser than 3 in. (76 mm) in diameter were excluded. Fine-grained soils are those in which more than half (by weight) of the particles are so fine that they cannot be seen by the naked eye. The distinction between coarse- and fine-grained can also be made by sieve analysis with the number 200 sieve (.074 mm) size particle considered to be the smallest size visible to the naked eye. In some instances, the field technicians describing the soils used a number 200 sieve to estimate the amount of fine-grained particles. The coarse-grained soils are further divided into sands and gravels by estimating the percentage of the coarse fraction larger than the number 4 sieve (about 1/4 inch or 5 mm). Each coarse-grained soil is then qualified as silty, clayey, poorly graded, or well graded as discussed under plasticity and gradation.

Fine-grained soils were identified in the field as clays or silts with appropriate adjectives (clayey silt, silty clay, etc.) based on the results of dry strength, dilatancy, and plastic thread tests (see ASTM D 2488-69 for details of these tests).

Dual USCS symbols and adjectives were used to describe soils exhibiting characteristics of more than one USCS group.

b. Color: Color descriptions were recorded using the following terms with abbreviations in parentheses.

White (w)	Green (gn)
Yellow (y)	Blue (bl)
Orange (o)	Gray (gr)
Red (r)	Black (blk)
Brown (br)	

Color combinations as well as modifiers such as light (lt) and dark (dk) were used.

c. Range in Particle Size: For coarse-grained soils (sands and gravels), the size range of the particles visible to the naked eye was estimated as fine, medium, coarse, or a combined range (fine to medium).

d. Gradation: Well graded indicates a coarse-grained soil which has a wide range in grain size and substantial amounts of most intermediate particle sizes. A coarse-grained soil was identified as poorly graded if it consisted predominantly of one size (uniformly graded) or had a wide range of sizes with some intermediate sizes obviously missing (gap-graded).

e. Density or Consistency: The density or consistency of the in-place soil was estimated based on the number of blows required to advance the Fugro drive or split-spoon sampler, the drilling rate (difficulty) and/or hydraulic pulldown needed to drill, visual observations of the soil in the trench or test pit walls, ease (or difficulty) of excavation of trench or test pit, or trench or test pit wall stability. For fine-grained soils, the field guides to shear strength presented below were also used to estimate consistency.

- o Coarse-grained soils - GW, GP, GM, GC, SW, SP, SM, SC (gravels and sands)

Consistency	N-Value (ASTM D 1586-67), Blows/Foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	>50

- o Fine-grained Soils - ML, MH, CL, CH (Silts and Clays)

Consistency	Shear Strength (ksf)	Field Guide
Very Soft	<0.25	Sample with height equal to twice the diameter, sags under own weight
Soft	0.25-0.50	Can be squeezed between thumb and forefinger

Consistency	Shear Strength (ksf)	Field Guide
Firm	0.50-1.00	Can be molded easily with fingers
Stiff	1.00-2.00	Can be imprinted with slight pressure from fingers
Very Stiff	2.00-4.00	Can be imprinted with considerable pressure from fingers
Hard	Over 4.00	Cannot be imprinted by fingers

f. Moisture Content: The following guidelines were used in the field for describing the moisture in the soil samples:

Dry : No feel of moisture
Slightly Moist: Much less than normal moisture
Moist : Normal moisture for soil
Very Moist : Much greater than normal moisture
Wet : At or near saturation

g. Particle Shape: Coarse-grained soils

Angular : Particles have sharp edges and relatively plane sides with unpolished surfaces

Subangular: Particles are similar to angular but have somewhat rounded edges

Subrounded: Particles exhibit nearly plane sides but have well-rounded corners and edges

Rounded : Particles have smoothly curved sides and no edges

h. Reaction to HCl: As an aid for identifying cementation, some soil samples were tested in the field for their reaction to dilute hydrochloric acid. The intensity of the HCl reaction was described as none, weak, or strong.

i. Degree of Cementation: Based on the intensity of the HCl reaction and observation, the degree of cementation of a soil layer was described as weak to strong. Also, the following stages of development of caliche (cemented) profile were indicated where applicable.

Stage	Gravelly Soils	Nongravelly Soils
I	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II	Continuous pebble coatings, some interpebble fillings	Few to abundant nodules, flakes, filaments

(cont.)

Stage	Gravelly Soils	Nongravelly Soils
III	Many interpebble fillings	Many nodules and internodular fillings
IV	Laminar horizon overlying plugged horizon	Increasing carbonate impregnation

j. Secondary Material: Example - Sand with trace to some silt

Trace	5-12%	(by dry weight)
Little	13-20%	(by dry weight)
Some	>20%	(by dry weight)

k. Cobbles and Boulders: A cobble is a rock fragment, usually rounded or subrounded, with an average diameter between 3 and 12 inches (76 and 305 mm). A boulder is a rock fragment, usually rounded by weathering or abrasion, with an average diameter of 12 inches (305 mm) or more. The presence of cobbles and/or boulders was identified by noting the sudden change in drilling difficulty or cuttings in borings or by visual observation in excavations. An estimate of the size, range, and percentage of cobbles and/or boulders in the strata was recorded on the logs.

l. Depth of Change in Soil Type: During drilling of borings, the depth of changes in soil type was determined by observing samples, drilling rates, changes in color or consistency of drilling fluid, and relating these to depth marks on the drilling rods. In excavations, strata thicknesses were measured with a tape. All soil type interfaces were recorded on the logs by a horizontal line at the approximate depth mark.

In addition to the observations recorded relating to soil descriptions, remarks concerning drilling difficulty, loss of drilling fluid in the boring, water levels encountered, trench wall stability, ease of excavation, and other unusual conditions were recorded on the logs.

A5.5 LABORATORY TESTS

Laboratory tests were performed on selected representative undisturbed and bulk samples. All laboratory tests (except chemical tests) were performed in Fugro National's Long Beach laboratory. The chemical tests were conducted by Pomeroy, Johnson, and Bailey Laboratories of Pasadena, California and Smith-Emery Company of Los Angeles, California. All tests were performed in general accordance with the American Society for Testing and Materials (ASTM) procedures. The types of tests performed and their ASTM designations are summarized as follows.

Type of Test	ASTM Designation
Unit Weight	D 2937-71
Moisture Content	D 2216-71
Particle-Size Analysis	D 422-63
Liquid Limit	D 423-66
Plastic Limit	D 424-59
Triaxial Compression	D 2850-70
Unconfined Compression	D 2166-66
Direct Shear	D 3080-72
Consolidation	D 2435-70
Compaction	D 1557-70
California Bearing Ratio (CBR)	D 1883-73
Specific Gravity	D 854-58
Water Soluble Sodium	D 1428-64
Water Soluble Chloride	D 512-67
Water Soluble Sulfate	D 516-68
Water Soluble Calcium	D 511-72
Calcium Carbonate	D 1126-67
Test for Alkalinity (pH)	D 1067-70

A5.6 DATA ANALYSIS AND INTERPRETATION

A5.6.1 Preparation of Final Logs and Laboratory and Field Test Summary Sheets

The field logs of all borings, trenches, test pits, and surficial sample excavations were prepared by systematically combining the information given on the field logs with the laboratory test results. The resultant logs include generally the following information: description of soil types encountered; sample types of intervals, lithology (graphic soil column); estimates of soil density or consistency; depth locations of changes in soil types; remarks concerning trench wall stability; drilling difficulty, cementation, and cobbles and boulders encountered; and the total depth of exploration. Laboratory test results presented in the logs include dry density and moisture content; percent of gravel, sand, and fines; and liquid limit and plasticity index. Also, miscellaneous information such as surface elevation, surficial geologic unit, date of activity, equipment used, and dimensions of the activity are shown on the log.

Laboratory data were summarized in tables. All samples which were tested in the laboratory were listed. Results of sieve analyses, hydrometer, Atterberg limits, in-situ dry strength and moisture content tests, and calculated degree of saturation and void ratio were entered on the tables. Test summary sheets for triaxial compression, unconfined compression, direct shear, consolidation, chemical, CBR, and compaction tests were prepared separately.

The Cone Penetrometer Test results consist of continuous plots of cone resistance, friction sleeve resistance, and friction ratio versus depth from ground surface. Beside the plot is shown a soil column with USCS soil types encountered at the test location. Other information presented on the log includes surface elevation and surficial geologic unit.

Volume II titled "Geotechnical Data" presents the following finalized basic engineering data.

Boring Logs	Section II - 4.0
Trench and Test Pit Logs	Section II - 5.0
Surficial Sample Logs	Section II - 6.0
Laboratory Test Results	Section II - 7.0
Cone Penetrometer Test Results	Section II - 8.0

A5.6.2 Soil Characteristics

A5.6.2.1 General

The soil characteristics are discussed in two parts, surface soils and subsurface soils. The following three tables were prepared and are presented in Sections 3.3 and 3.4 of the report.

1. Characteristics of Surficial Soils;
2. Thickness of Low Strength Surficial Soils; and
3. Characteristics of Subsurface Soils.

The following sections, A5.6.2.2 and A5.6.2.3, explain the data analyses and interpretation used in preparing the above tables.

A5.6.2.2 Surface Soils

In order to define the characteristics of the surficial soils, data from trenches, test pits, borings, surficial soil samples, cone penetrometer tests, and surficial geologic maps were reviewed in conjunction with the laboratory test results. The soils were then grouped into three categories of soils with similar general characteristics. These categories, their descriptions, and associated characteristics were tabulated. This table (Characteristics of Surficial Soils, Table 3-1) includes soil descriptions by the Unified Soil Classification System, predominant surficial geologic units, the estimated areal extent (percent) of each category, important physical properties summarized from laboratory test results, and certain road design related data.

The important physical properties summarized include the estimated cobbles content, grain-size analyses, and Atterberg limits. Ranges for these properties were determined from the field logs and laboratory test results. These ranges are useful for categorizing soils, evaluating construction techniques, and providing data for preliminary engineering evaluations and for use by other MX participants.

Road design data presented in Table 3-1 were developed from field and laboratory tests and consist of three distinct groups:

1. Laboratory test results;
2. Suitability of soils for road use; and
3. Low strength surficial soil.

These road design related data were considered important because roads (interconnecting and secondary) constitute a major portion of the geotechically related costs for the vertical shelter basing mode. The following paragraphs briefly discuss the development of road design data.

a. Laboratory Test Results: These include ranges of maximum dry density, optimum moisture content (ASTM D 1557-70) and CBR (ASTM D 1883-73) at 90 percent relative compaction for each soil category. The maximum dry density and optimum moisture content are important quality control parameters during roadway construction. California Bearing Ratio is the ratio of the resistance to penetration developed by a subgrade soil to that developed by a specimen of standard crushed-rock base material and is the basis for many empirical road design methods used in this country.

b. Suitability of Soils for Road Use: Included in this group is suitability of soils for use as road subgrade, subbase, or base. Parameters used to make these qualitative assessments were characteristics related to CBR, frost susceptibility, drainage, and volume change potential. The following guidelines were used in estimating the suitability of soils for road use.

1. Suitability as a road subgrade.

Very Good - soils which can be compacted with little effort to high CBR values (CBR >30), exhibit low frost susceptibility, fair to good drainage, and low volume change potential.

Good - soils which can be compacted with some effort to moderate CBR values (CBR 15-30), exhibit moderate frost susceptibility, fair drainage, and medium volume change potential.

Fair - soils which can be compacted with considerable effort to moderate CBR values (CBR 15-30), exhibit moderate to high frost susceptibility, fair to poor drainage, and medium volume change potential.

Poor - soils which require considerable effort for compaction to even low CBR values (CBR <15), exhibit high frost susceptibility, poor drainage, or high volume change potential. These soils should generally be removed and replaced with better quality material.

2. Suitability as road subbase or base.

Good	- soils which exhibit negligible frost susceptibility, good drainage, and negligible volume change potential.
Fair	- soils which require some treatment or processing to upgrade for use.
Poor	- soils which would require relatively extensive processing or soil stabilization to upgrade for use.
Not Suitable	- soils which cannot be modified to give adequate roadway support.

The parameters used in the aforementioned suitability ratings are discussed in the following paragraphs.

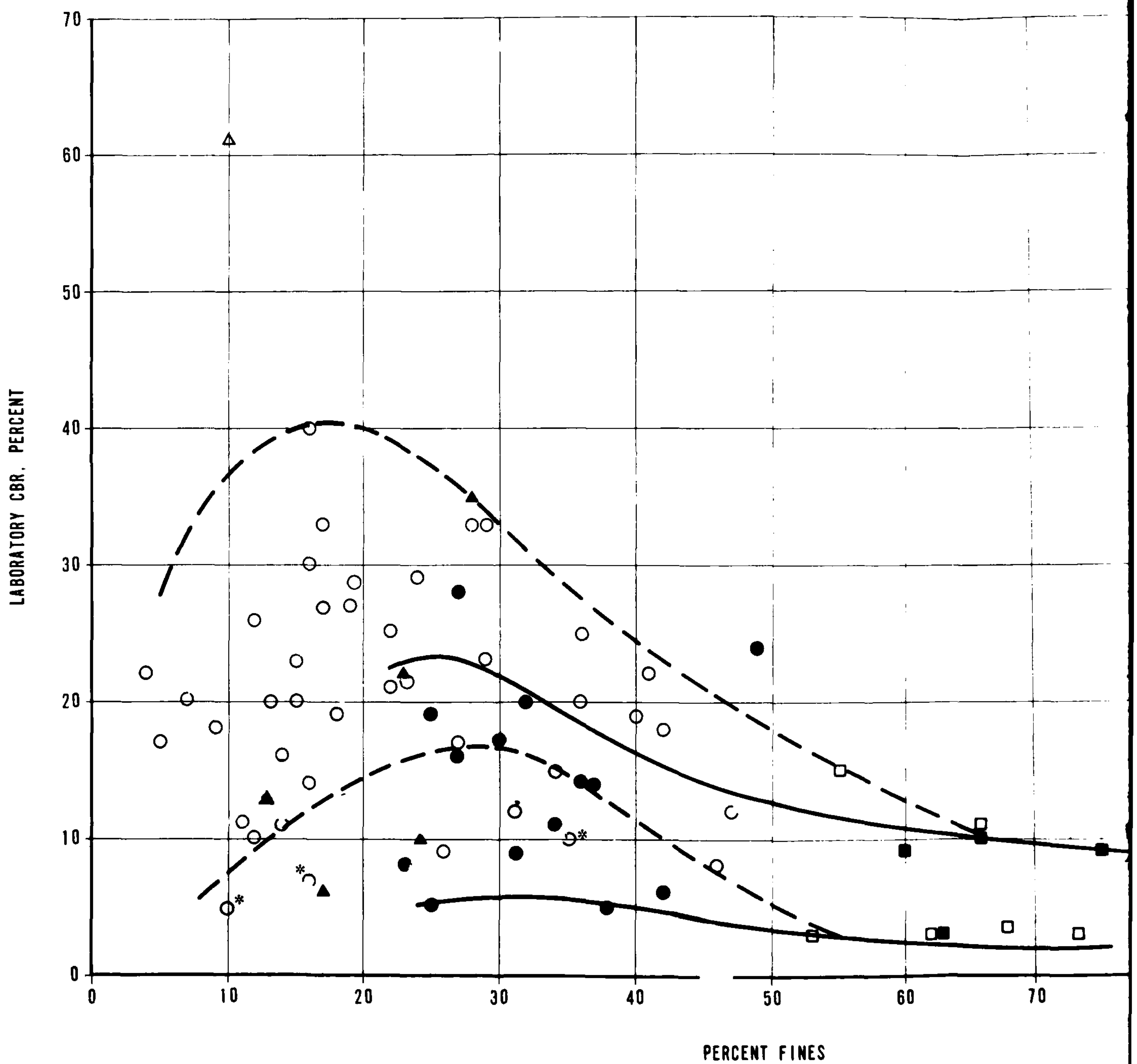
i. CBR Characteristics: California Bearing Ratio, which is commonly used for road design, is dependent on soil type. During previous verification studies, a limited number of CBR tests were performed on several soil types which were representative of the surficial soils in the various Verification Sites. Based on these test results, a relationship between CBR and percent fines (percent passing through No. 200 sieve) was established and is shown in Figure A5-1. Envelopes for clays and granular soils with plastic fines and silts and granular soils with nonplastic fines are shown in the figure. This plot was used to estimate the range of laboratory CBR values for the various surficial soil categories.

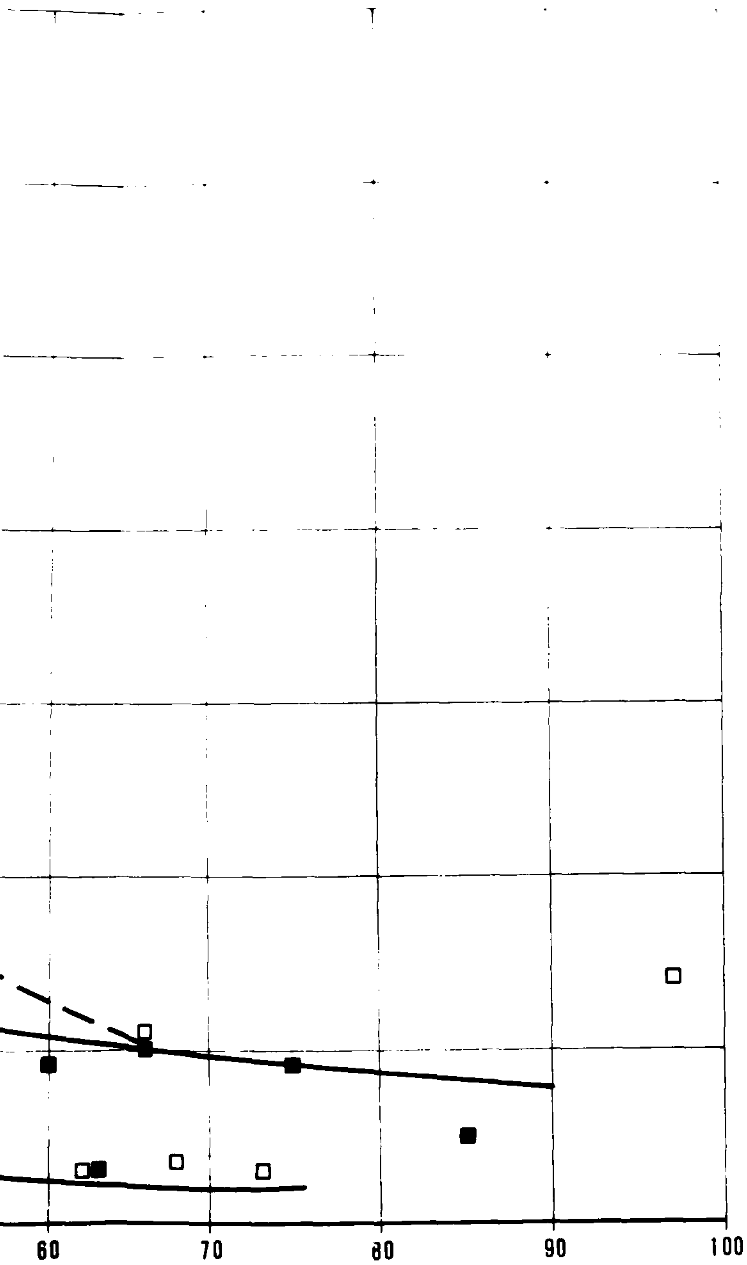
ii. Other Characteristics: These characteristics pertain to frost susceptibility, drainage, and volume change potential. They were estimated based on the physical properties of the soils, results of consolidation tests (for volume change potential), published literature, and our experience. Following are the definitions of these characteristics.

1. Frost susceptibility is defined as potential for detrimental ice segregation upon freezing or loss of strength upon thawing.

Low	- negligible to little potential
Moderate	- some potential
High	- considerable potential

2. Drainage characteristics pertain to internal movement of water through soil.


70
60
50
40
30
20
10
0
LABORATORY CBR, PERCENT
0
10
20
30
40
50
60
70
PERCENT FINES



EXPLANATION

- △ Gravels with nonplastic fines (GM, GW, GP, GP-GM, GW-GM)
- ▲ Gravels with plastic fines (GC, GC-GM)
- ○ Sands with nonplastic fines (SP, SW, SM, SP-SM, SW-SM)
- ● Sands with plastic fines (SC, SC-SM)
- □ Silts (ML)
- ■ Clays (CL, CH, CL-ML)
- – – – – Envelope for silts and granular soils with nonplastic fines
- ——— Envelope for clays and granular soils with plastic fines

NOTES:

1. Fines correspond to soil passing through No. 200 (0.074mm opening) sieve.
2. California Bearing Ratio at 90 relative compaction.
3. Soil types (GM, SC) are based on Unified Soil Classification System.
4. * *Uniform fine or fine to medium sand.*

2

PLOT OF LABORATORY CBR
VERSUS PERCENTAGE FINES
VERIFICATION VALLEYS, NEVADA-UTAH

MX SITING INVESTIGATION
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FIGURE
A5-1

FUGRO NATIONAL, INC.

Good - materials which drain rapidly and do not tend to plug with fines

Fair - natural internal drainage is fairly rapid but there is some tendency for plugging of voids with fines

Poor - internal drainage is somewhat slow and plugging with fines can often occur

Practically Impervious - materials which exhibit almost no natural internal drainage

3. Volume change potential corresponds to soil swelling or shrinkage due to change in moisture content.

Low - 0 to 2 percent volume change
Medium - 2 to 4 percent volume change
High - > 4 percent volume change

c. Low Strength Surficial Soil: Included in this group is extent of low strength surficial soil. The roads for the MX system will be built on existing ground surface with minimum cut and fill. Therefore, the costs of roads depend on the consistency (or strength) of the surficial soil. In order to evaluate the strength of the surficial soils, cone penetrometer test results were used.

Low strength surficial soil is defined as soil which will perform poorly (failure of subgrade) as a road subgrade at its present consistency when used directly beneath a road section. In order to define "low strength" using CPT results, the following four approaches were pursued. These approaches are subjective and qualitative and are based on our experience as well as published literature.

i. Field visual observations: During logging of the borings, the excavation of trenches, test pits, and obtaining surficial soil samples, consistency or compactness of the surficial soils was described qualitatively. A detailed comparison of the CPT results (cone end resistance) and the consistency of the soils was done for different soil types. Using engineering judgement, an upper limit cone resistance was established which encompassed a majority of the soils likely to perform poorly as road subgrades.

ii. Standard Penetration Test (SPT): SPT is very widely used and accepted in geotechnical engineering practice in this country. A study of available literature revealed that the ratio of cone resistance (q_c, tsf) to Standard Penetration Resistance (N, blows per foot) has a certain range for different soil types. In previous verification studies, limited field SPTs were performed in Reveille-Railroad and Big Smoky sites. Ratios of q_c/N were computed for these tests and were found to be comparable to those reported in literature for similar soil types. Using the relationships applicable to the soils present in the Verification sites, an upper limit of cone resistance, equivalent to midrange of "medium dense" category, was established for defining the "low strength" of surficial soils.

iii. In-Situ Dry Density: A comparison was made between in-situ dry densities determined from Fugro Drive and Pitcher samples obtained from soil borings and CPT results at the same locations and depths. From this comparison, it was observed that identifiable trends do exist between cone resistance values and soil densities. An upper limit of cone resistance equivalent to midrange of "medium dense" category was established for defining the "low strength" of surficial soils.

iv. Field CBR Tests: During previous verification studies, field CBR tests were performed in Reveille-Railroad and Big Smoky sites. The procedures for conducting the CBR tests were as described in the U.S. Army Corps of Engineers' Technical Manual (TM' 5-30, pp. 2 - 86 to 2 - 96. The test results were compared to Cone Penetrometer Tests performed at the same location. A plot of average field CBR and average cone resistance was prepared and is presented in Figure A5-2. The plot shows the results of the tests in sands only, since tests in gravel and fine-grained soils were very few. Although there is considerable scatter, majority of the data points fall in a band which is shown in Figure A5-2. From this plot, a range of CPT resistance corresponding to low field CBR values (indicating low strength surficial soils) was established.

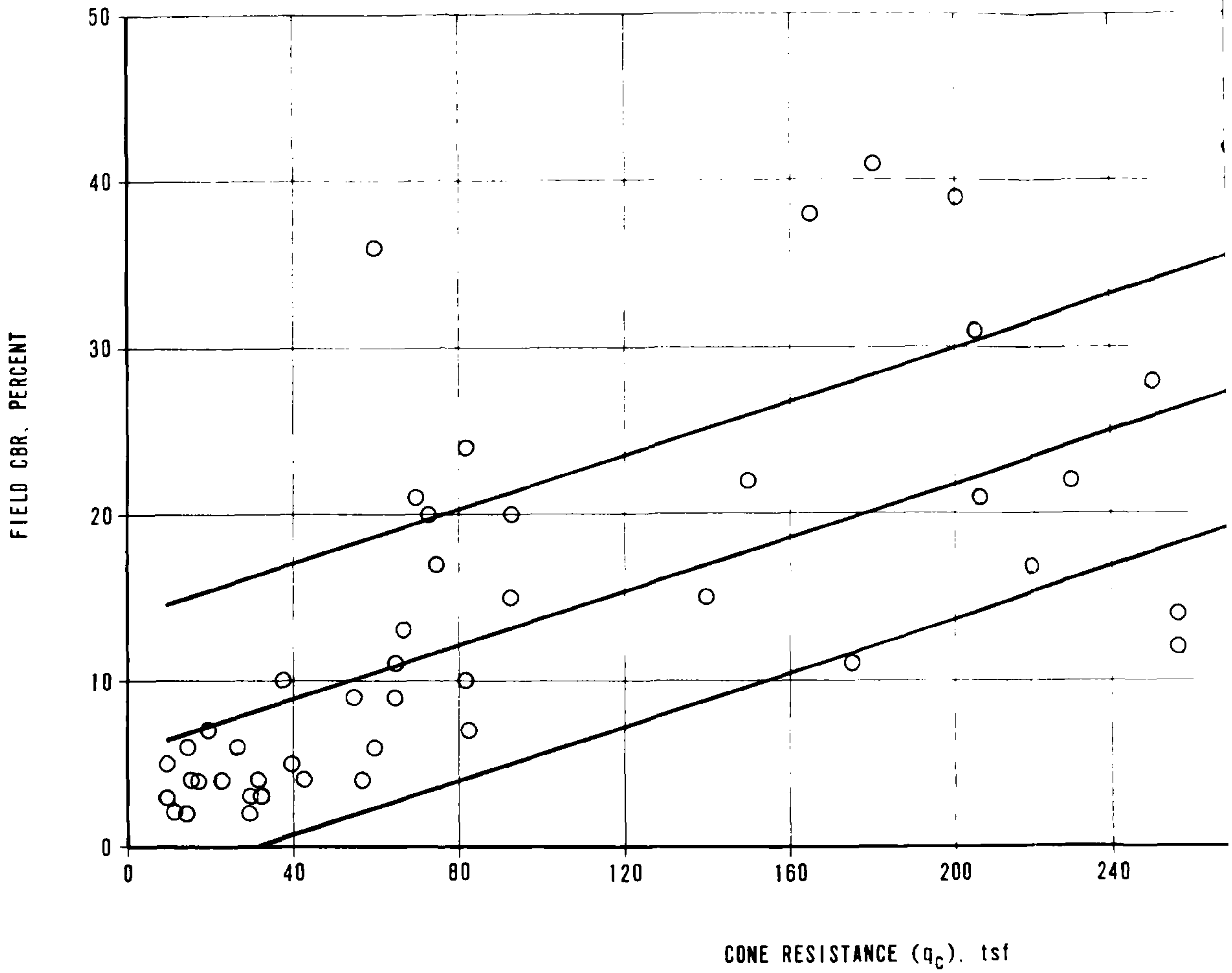
As a result of the preceding four approaches, the following criteria for defining low strength surficial soil were established:

q_c <120 tsf (117 kg/cm^2) for coarse-grained soils
q_c < 80 tsf (78 kg/cm^2) for fine-grained soils

These criteria are preliminary at this stage and may be revised as more data become available from future verification studies. The criteria were used to determine the extent of low strength surficial soil at each CPT location. The results are tabulated the table titled "Thickness of Low Strength Surficial Soil."

A5.6.2.3 Subsurface Soils

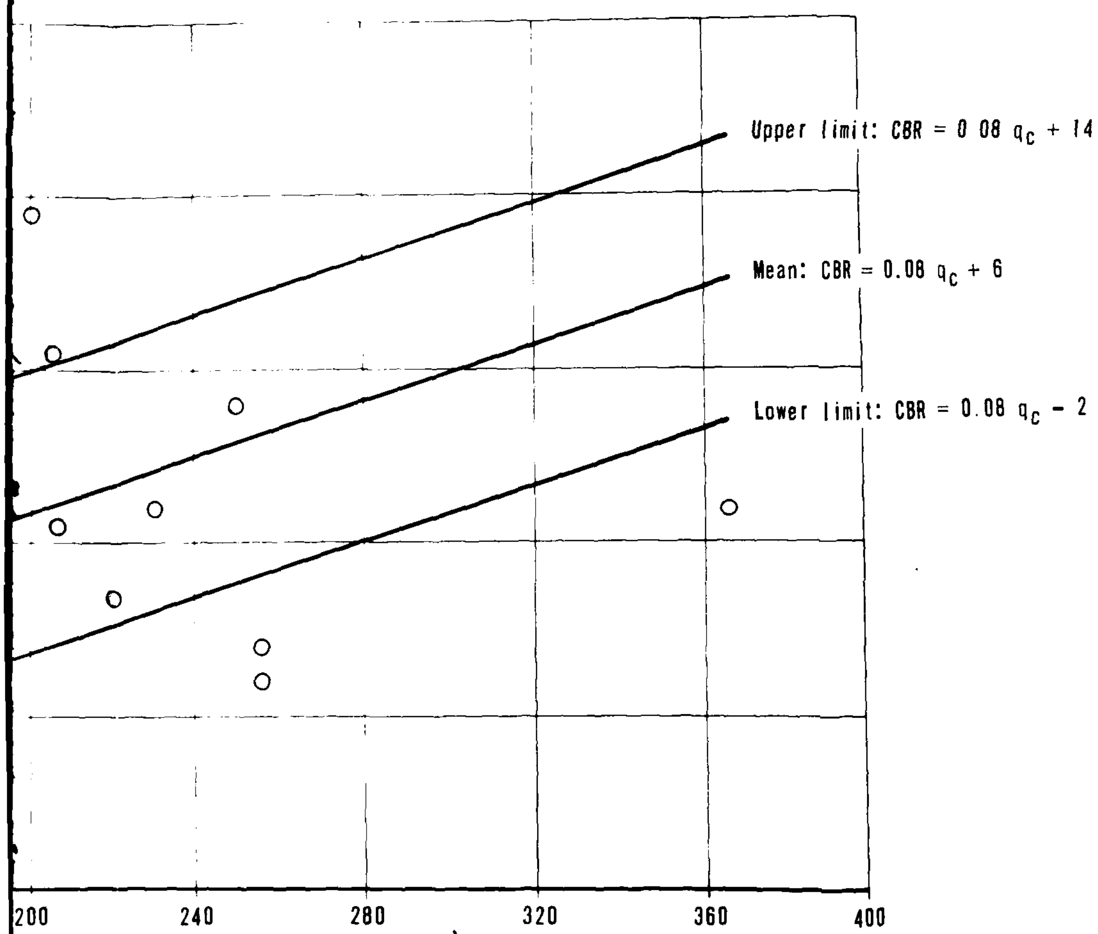
Characteristics of the subsurface soils were developed using data from seismic refraction surveys, borings, trenches, test pits, and laboratory tests.



NOTES: 1. Data are for sands tested in Big Smoky and Reveille-Railroad Verification Sites.

2. Equations shown are based on statistical analysis using standard error of estimate method.

3. Band between the upper and lower limits includes 74% of all the data points.



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RELATIONSHIP BETWEEN FIELD CBR
AND CPT CONE RESISTANCE
VERIFICATION VALLEYS, NEVADA-UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE
A5-2

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The soils were divided into coarse-grained and fine-grained soils in two ranges of depth, 0 to 20 feet and 20 to 160 feet (0 to 6 m and 6 to 49 m). Physical and engineering properties of the soils were then tabulated as "Characteristics of Subsurface Soils" (Table 3-6) based on laboratory test results on representative samples. The table includes soil descriptions, Unified Soil Classification System symbols, the estimated subsurface extent of each soil group, comments on the degree of cementation, estimated cobbles content, and ranges of values from the following laboratory tests: dry density, moisture content, grain-size distribution, liquid limit, plasticity index, unconfined compression, triaxial compression, and direct shear.

The excavatability and stability of excavation walls of a horizontal or a vertical shelter were evaluated from the subsurface data using seismic velocities, soil types, shear strength, presence of cobbles and boulders, and cementation. Problems encountered during trench and test pit excavations and drilling of borings were also considered in the evaluation.

END

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