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# YUCCA MOUNTAIN PROJECT
# STUDY PLAN APPROVAL FORM

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Study Plan Number 8.3.1.14.2

Study Plan Title Studies to Provide Soil and Rock Properties of Locations of Surface and Subsurface Access Facilities

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PDR WASTE
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# STUDY PLANS
## FOR
# INVESTIGATION 8.3.1.14.2

## STUDIES TO PROVIDE SOIL AND ROCK PROPERTIES OF POTENTIAL LOCATIONS OF SURFACE AND SUBSURFACE ACCESS FACILITIES

8.3.1.14.2.1: EXPLORATION PROGRAM STUDY

8.3.1.14.2.2: LABORATORY TESTS AND MATERIAL PROPERTY MEASUREMENT STUDY

8.3.1.14.2.3: FIELD TESTS AND CHARACTERIZATION MEASUREMENTS STUDY

REV. 0

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DEPARTMENT OF THE INTERIOR
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## PREFACE

This investigation plan describes site characterization studies and activities performed to evaluate soil and rock properties required for siting and designing the Exploratory Studies Facility (ESF), including surface structures and subsurface access structures. Work related to the potential repository is not a part of this study plan except as ESF features become part of the repository; that work will be detailed in a separate study plan.

Sections 1, 4 and 5, which show the study in the context of the total site characterization program, are drawn principally from the Site Characterization Plan (SCP) and related Yucca Mountain Project documents. Section 2 discusses the rationale and describes the selected methods for the tests and analyses, and presents greater detail of the plans than those described in the SCP. Constraints on the studies are covered in section 3.

## ABSTRACT

This study plan describes the site-characterization studies and activities for the evaluation of soil and rock properties that will influence or will be influenced by the construction of the Exploratory Studies Facility (ESF) and subsurface access structures at Yucca Mountain. Basic data on the surface characteristics including topography and soil and bedrock properties will be obtained by reviewing existing site information in concert with laboratory analyses and field tests. Results from this study will be used as soil-rock parameter input for the resolution of design Issue 4.4 (preclosure design and technical feasibility: SCP section 8.3.2.5).

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# INVESTIGATION 8.3.1.14.2: STUDIES TO PROVIDE SOIL AND ROCK PROPERTIES OF POTENTIAL LOCATIONS OF SURFACE AND SUBSURFACE ACCESS FACILITIES

## Exploratory Studies Facility and Subsurface Access

Investigation 8.3.1.14.2 consists of three studies:

- 8.3.1.14.2.1: Exploration program study
- 8.3.1.14.2.2: Laboratory tests and material property measurement study
- 8.3.1.14.2.3: Field tests and characterization measurements study

The studies are part of the surface characteristics program (figure A-1); and comprise one of a series of related investigations that gather and synthesize information needed to assess surface characteristics at Yucca Mountain.

# 1. PURPOSE AND OBJECTIVES OF INVESTIGATION

## 1.1 Purpose of this investigation

The characterization of soil and rock properties is required for surface and subsurface design and performance studies. Specifically, information on soil and rock properties, as well as topographic data are needed to site and design the Exploratory Studies Facility (ESF) surface and subsurface access facilities (i.e. surface buildings and roads, ramps, and shaft). This work will also provide hydraulic-related soil information. These data will contribute to evaluating erosion potential and infiltration runoff characteristics so that site drainage and erosion control systems can be designed for the ESF surface facilities. Work related to the potential repository is not a part of this study plan and will be addressed in a separate document.

Direct application of the soil and rock characterization to surface structures will provide the necessary data to design foundations and retaining walls, evaluate the soil/structure interaction (response) due to earthquake loading, and evaluate potential slope stability conditions. Foundation designs will be necessary for various structures, including buildings, shaft collars, shaft headframes, hoist foundations, and ramp portals.

The foundation design will determine what type, size, and configuration of foundation is most compatible with the soil or rock conditions, expected loads, function of structure, and design requirements. A determination of the allowable soil or rock bearing load or pressure will be a key factor in the foundation design analyses.

After the buildings, foundation, and superstructure have been designed for static-loading conditions, the soil or rock-structure interaction will be evaluated for earthquake loading conditions. Under these loading conditions, the height and stiffness of the superstructure will also contribute in the soil-structure response.

Characterization of the soil and rock conditions will also be needed for evaluating slope stability. Slope stability will be evaluated for the main pad, road or rail-line cuts, ramp portal entrances, and cuts or natural slopes near a surface facility.

Rock properties will be required for siting and designing the ramps and shafts. Siting the ramp portals and determining the optimum ramp alignment is interdependent since the siting or alignment of one is contingent on the other. This interdependence also applies to the siting of the shafts and shaft collars. Data will be used for designing both the ramps and shafts and evaluating their support or reinforcement requirements.

## 1.2 Objectives of the Investigation

The objectives of this investigation are to characterize the soil and rock conditions that will influence or be influenced by the construction of the ESF surface and subsurface access facilities. Soil and rock characteristics will provide design data and necessary geotechnical information to help locate and design the surface and subsurface access facilities, evaluate subsurface access support or reinforcement requirements, conduct foundation design analyses, and if necessary, evaluate soil-structure interactions and potential slope instability.

## 1.3 Regulatory Rationale and Justification

The Exploratory Studies Facility (ESF) is one aspect of the site characterization process which will provide data for a number of suitability analyses. A characterization facility is required by 10 CFR Part 60 for the conduct of in situ testing at depth. This testing must be completed prior to license application for authorization to construct a repository. The information acquired by this study plan is required to design an ESF.

In situ testing is required to establish and confirm geologic conditions relevant to the demonstration of the adequacy of the site, in accordance with the requirements of 10 CFR Part 60.

The functional requirements of the Exploratory Studies Facility are as follows:

1. Support in situ site characterization for the Mined Geologic Disposal System and provide testing facilities for in situ site characterization as required by DOE/OGR milestones and the Site Characterization Plan.

2. Provide a facility whose permanent items can be incorporated into the potential repository and which can be used to support phase I repository construction. Those items, listed below, are the ESF permanent systems, structures, and components that could be designed, procured, and constructed to be incorporated into the potential repository. The permanent items must be designed to have a maintainable life and quality as specified for the potential repository.

a. Underground Opening(s) - space created by mining and drilling, including those zones within the rock altered by that process.

b. Shaft and Ramp Liner(s) - all components placed between the inside limits of the shaft or ramp and the accessible extent of the underground opening.

c. Ground Support - any means used to reinforce rock and/or control the movement of rock except for removable or replaceable hardware.

3. Provide a suitable location for in situ site characterization.

4. Provide equipment and facilities for ensuring a safe, healthful, and productive working environment.

5. Provide the facilities to alert on-site personnel of possibly dangerous situations.

6. Provide design and construction methods that will demonstrate licensability and constructability for the candidate repository.

A tentative ESF configuration has been formulated and is shown in diagrammatic form in Figure 1-1. To complete the design and construction of the ESF the Architect-Engineer (A/E) must have certain soil and rock data on which the design of foundations, structures and openings can be based. The soil/rock data gathering will be in three parts: (1) site reconnaissance, (2) Preliminary, and (3) Detailed exploration. This data gathering, testing, and reporting will be in accordance with the second and third (Part 2) editions of the Bureau of Reclamation Earth Manual, American Society for Testing and Materials (ASTM), other applicable codes/standards, and good engineering practice/judgement.

The information gathered in accordance with this study plan will also be used to support the license application if the potential repository site is selected for licensing. The information gathered will primarily be used to support the requirements of 10 CFR 60.21(F)(3) which calls for a "description and analysis of the design and performance requirements for structures, systems, and components of the geologic repository which are important to safety. This analysis shall consider--(i) The margins of safety under normal conditions and under conditions that may result from anticipated operational occurrences, including those of natural origin..." Analyses would

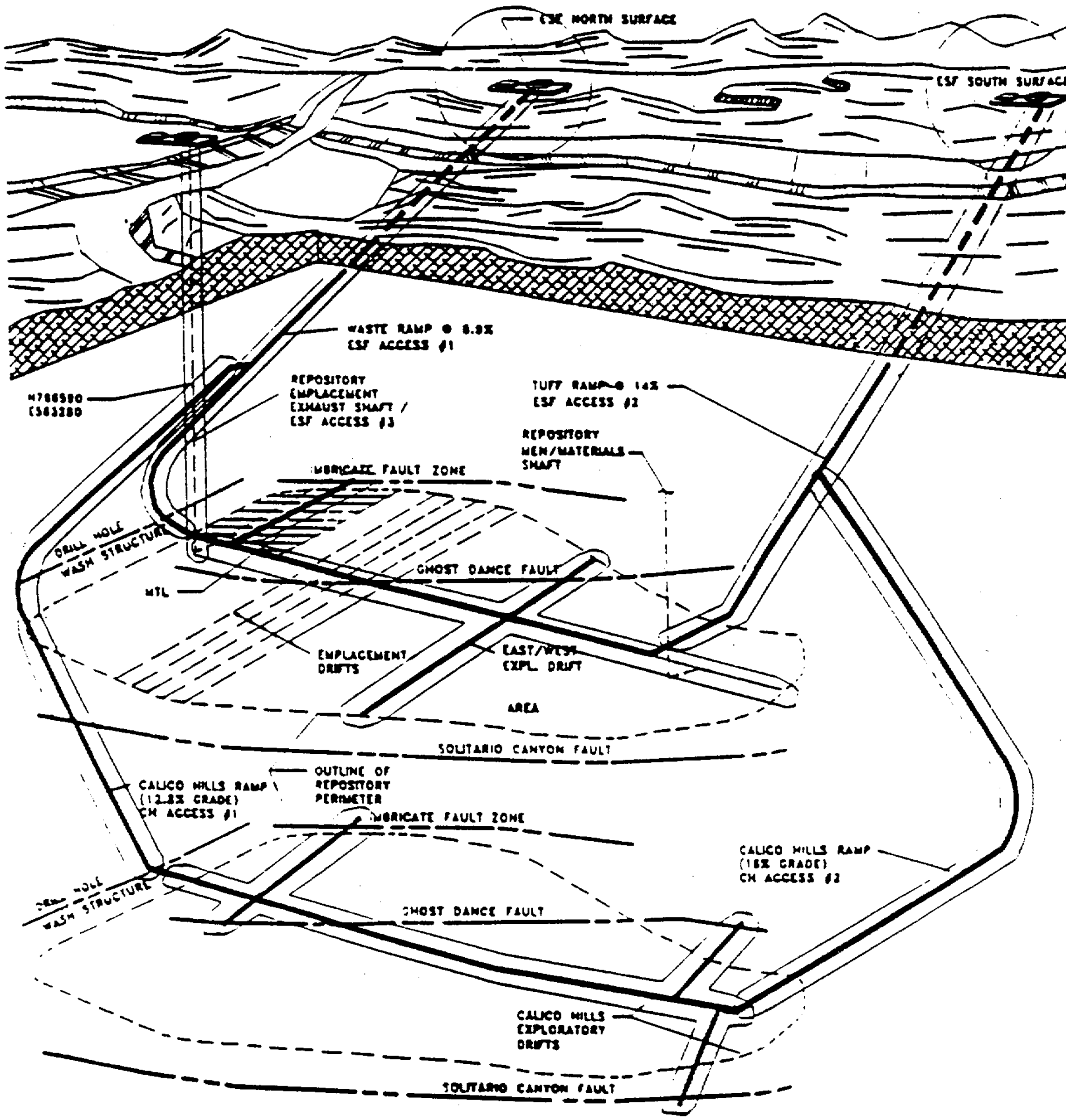


Figure 1-1 - Schematic layout of the Exploratory Studies Facility. The facility is designed such that the ramps and drifts can be incorporated into the design of a potential repository.

also be included for those parts of the ESF system that may be included in the potential repository (e.g. ramps).

Data for the ESF surface facility applies only to the relatively temporary structures designed to support testing and not to the potential repository. The information gathered under this study plan for repository access (portals, ramps, and collars) may also be used to demonstrate compliance with the repository design criteria. General criteria to be met include 10 CFR 60.131(b), which states that "the structures, systems, and components important to safety shall be designed so that natural phenomena and environmental conditions anticipated at the potential geologic repository operations area will not interfere with necessary safety functions." Additional design criteria for the surface facilities include 10 CFR 60.132(a), which states that "surface facilities (i.e. repository surface facilities) in the geologic repository operations area shall be designed to allow safe handling and storage of wastes at the geologic repository operations area, whether these wastes are on the surface before emplacement or as a result of retrieval from the underground facility." Additional design criteria for the underground facility (including those parts of the ESF that may be included in the potential repository) include 10 CFR 60.133(e), which states that "(1) Openings in the underground facility shall be designed so that operations can be carried out safely and the retrievability option maintained. (2) Openings in the underground facility shall be designed to reduce the potential for deleterious rock movement or fracturing of overlying or surrounding rock."

# 2. DESCRIPTION OF STUDIES

## 2.1 Exploration Program Study

The objectives of this study are to conduct exploration activities to characterize soil and rock conditions that will influence or be influenced by the construction of the ESF surface and subsurface access (ramp and shaft) facilities (see Appendix A). The exploration program will consist of three activities: (1) site reconnaissance, (2) preliminary exploration, and (3) detailed exploration. Data obtained from the site reconnaissance activity will primarily be used in Title I design for the ESF, but may also be used at the start of Title II design. Data obtained from the Preliminary and Detailed Exploration activities will be used in Title II design of the ESF. Some of the exploration data gained from the ESF exploration activities may also be used in the potential repository exploration phase.

This study will evaluate existing data and determine what additional and appropriate information will be needed to adequately address all design issues and characterization programs requesting data from this investigation (see Figure A-1 and Table 8.3.1.14-1 in Appendix A). On the basis of these data needs, and the expected soil and rock conditions at the site, an exploration program will be implemented using such methods as drilling, test pit excavation, sampling, and geophysical investigations. The selection of the appropriate methods depend on the specific requirements of each data need and the soil and rock conditions encountered. The types of materials anticipated at the site do not lend themselves well to typical sampling techniques. Nevertheless, it is important to appropriately assess parameters for design. An economical and effective technique is to use approximate methods and conservative assumptions when designing "non-critical", lightly- and moderately-loaded structures.

Quality status determination of the study activities will be made separately, according to AP-6.17Q, "Determination of the Importance of Items and Activities", which implements NUREG-1318, "Technical Position on Items and Activities in the High-Level Waste Geologic Repository Program Subject to Quality Assurance Requirements". The results of that determination will be contained in the Q-List, Quality Activities List and Non-Selection Record, which will be controlled documents.

QA grading packages for the activities of this study plan will be prepared separately, according to AP-5 2.8Q "Quality Assurance Grading".

## 2.1.1 Site Reconnaissance Activity

### 2.1.1.1 Objectives

The objectives of the Site Reconnaissance (8.3.1.14.2.1.1) activity are to review existing site information and conduct field reconnaissance to establish the Preliminary and Detailed Exploration Programs including subsurface drilling, test pits, trenching, and geophysical investigations. Data from this activity will contribute to the development of the geotechnical parameters in the SCP's Table 8.3.1.14-1 (see Appendix A) and to the resolution of Design Issue 4.4 (Section 8.3.2.5, SCP). Design parameters for ESF Title I design will be obtained from this activity.

The following data are required to fulfill the objectives of this activity:

1. Existing topographic, soil, and geologic maps.

2. Existing subsurface drilling, trenching, and geophysical information.

3. Existing geologic and geotechnical reports.

4. Aerial photographs.

5. On site visual reconnaissance.

Some preliminary site reconnaissance and data-gathering activities have been completed in the Midway Valley-Yucca Mountain area. Four test pits were excavated in the alluvium at potential surface repository facility sites. These sites are located along the western edge of Midway Valley and the eastern edge of Yucca Mountain as illustrated in Appendix C, Figure C-1. Site 3 corresponds to the reference conceptual site for the surface facilities. These exploratory activities were conducted to evaluate the conditions of the natural alluvial soils that are expected to support the foundations of the potential surface facility sites. Data collected from these activities include densities, moisture content, specific gravity, gradation analysis, and moisture-dry density compaction relationships (Ho et al., 1986). Selected results from the Ho et al., 1986 report are presented in Appendix B. Results from these previous data gathering activities are included with estimated values for other parameters in Table 8.3.1.14-1 of the SCP (see Appendix A).

Boreholes have also been drilled in the Midway Valley-Exile Hill area as illustrated in Figures C-1 and C-2, in Appendix C. These boreholes were used to better define the geologic stratigraphy and structure of the preferred reference conceptual site for potential repository surface facilities (Figures C-2 through C-7) and to obtain preliminary physical property and wave velocity data from the alluvium and Tiva Canyon cap rock. Figures C-2 and C-6 show locations where geologic cross sections have been developed across Midway Valley. The north geologic cross section, illustrated in Figure C-3, goes through the preferred reference conceptual site for the potential repository surface facilities and is in the vicinity of a proposed ESF north ramp portal. A proposed ESF south ramp portal will be in the vicinity of the geologic cross section illustrated in Figures C-6 and C-7.

Geologic data from these boreholes, plus seismic reflection and refraction surface survey data from the same area, were used to determine that the wedge angle between the alluvium and bedrock was low and the seismic impedance contrast between the alluvium and Tiva Canyon cap rock was small. Both of these characteristics are important from the standpoint of evaluating potential seismic-induced ground motion. Neither the small wedge angle between the alluvium and bedrock nor the low seismic impedance contrast between the alluvium and bedrock would significantly amplify incoming seismic-induced ground motion (Neal, 1986).

Surface seismic and resistivity/geoelectric geophysical surveys have been performed in the Midway Valley area for the purpose of evaluating geologic structure, stratigraphic correlation between boreholes, and assessment of soil and rock engineering dynamic properties. Previous efforts to identify faults in Midway Valley using resistivity/geoelectric surveys were inconclusive and seismic reflection and refraction surveys produced no reliable data (Gibson et al., 1991 draft document). The application of geophysical methods for correlating stratigraphy between boreholes, and assessing soil and rock engineering dynamic properties is addressed in Neal (1986).

Subsurface geotechnical data such as unconfined compressive strength, rock mass classification, geologic stratigraphy and structure, discontinuity or fracture characterization, and in situ stress, will be required to site and design the ramps and shafts. Preliminary estimates of these data needs have already been obtained from the previous exploration boreholes, laboratory and field tests, geologic mapping, and geophysical surveys.

The geologic and thermal/mechanical stratigraphy and structure for the Yucca Mountain area can be seen in Appendix D. Figure D-1 in Appendix D provides a location map for the geologic cross sections shown on Figures D-2 and D-3. Figure D-1 also shows the location of selected drill holes in the vicinity of Yucca Mountain. Locations for thermal/mechanical unit cross sections, faults, and some drill holes are presented in Figure D-4 (Ortiz, et al., 1985). The thermal/mechanical unit cross sections are presented in Figures D-5 through D-8. A comparison between thermal/mechanical unit stratigraphy and geologic stratigraphy is illustrated in Figure D-9. The lithologic equivalent for each thermal/mechanical unit is also identified in Figure D-9. This lithologic characteristic is what gives each unit its thermal/mechanical identity or characteristic.

Existing geophysical data will be evaluated for its application in siting the shafts and ramps. Previous geophysical work in the northern part of Yucca Mountain consists of seismic refraction and reflection and dipole-dipole resistivity/induced polarization as described in the DOE, 1990, "Technical Assessment Review (TAR) Review Record Memorandum - Geologic and Geophysical

Evidence Pertaining to Structural Geology in the Vicinity of the Proposed Exploratory Shaft", and Gibson et al., 1991. In the southern part of Yucca Mountain, the existing geophysical data consists of unpublished low-resolution seismic refraction and dipole-dipole resistivity/induced polarization.

Due to the large amount of other existing geotechnical data that may be used in siting and design such as unconfined compressive strength, rock mass classification, fracture characterization, and in situ stress, this material will not be presented in this document but only referenced. The "The Yucca Mountain Site Characterization Project Reference Information Base" (RIB) is the project database for presenting this type of geotechnical data and all references pertinent to the data.

2.1.1.2 General Approach for Test Activity and Rationale for Test Selection

This activity will collect and evaluate existing geotechnical and aerial photographic information which is relevant to the siting, design, and performance of the ESF surface facilities and subsurface access facilities. These potential facilities will include ramps and shafts with their portals and collars. Surface structures or facilities will include buildings, roads, bridges, and flood protection structures (e.g., embankments, channels, and culverts). The existing geotechnical and aerial photographic information will be used in conjunction with an on-site visual reconnaissance and the preliminary ESF location and specifications to develop an appropriate program of drilling, trenching, and geophysical surveys.

The previously described Site Reconnaissance information will be used to develop a Preliminary Exploration program. This plan will identify the type and number of tests, and type, number, location, spacing, and depth of subsurface borings, test pits, and trenches used to develop data in the Preliminary Exploration phase. This Site Reconnaissance information will also be used to help identify the method and location of recommended geophysical surveys in the Geophysical Field Measurements Activity. Recommendations for subsurface boring location, spacing, depth, and geophysical survey methods will be developed from the Site Reconnaissance information and the methods and procedures presented in the following section.

2.1.1.3 Methods and Technical Procedures

The Preliminary and Detailed Exploration program plans will be developed by analyzing and interpreting existing geotechnical and aerial photographic information, and the results of the Site Reconnaissance. Exploration requirements describing the type, location, spacing, and depth of subsurface borings, test pits, trenches, and geophysical surveys will be developed considering recommendations provided in the references listed in the following table:

| Method | Technical Procedure | | |
|---|---|---|---|
| | Number or Author | Title | Date |
| Site reconnaissance and evaluation of existing data (maps, photos, existing reports) | U.S. Navy NAVFAC DM-7 | Design manual - Soil mechanics, foundations, and earth structures | [a] |
| Site reconnaissance and evaluation of existing data (maps photos, existing reports) | U.S. Army EM 1110-1 | Geotechnical investi- gations | 1984 |
| Concepts of soils Mechanics | U.S. Dept. of Interior (USBR) | Earth Manual 2nd Ed. | 1985 |
| Requirements and Procedures for the Collection of Geologic Data | U.S. Dept. of Interior (USBR) | Laboratory and Field Procedures for Soils Engineering | 1988 |
| Requirements and Procedures for the Collection of Geologic Data | U.S. Dept. of Interior (USBR) | Engineering Geology Field Manual | Apr 88 |
| Highway Exploration and Data Collection | FHWA-DF-88-003, Chptr.6 | Federal lands Highway Project Development and Design Manual, Vol. 1, USDOT | 1988 |

[a] Current version of document or procedure will be used.

Other technical procedures may be used that are comparable to the procedures listed above. In general, procedures used will be the U.S. Bureau of Reclamation procedures presented in the Earth Manual, Part 2, 1990. These procedures are comparable with, and in some cases more inclusive than the technical procedures listed above.

### 2.1.2 Preliminary and Detailed Exploration Activity

#### 2.1.2.1 Objectives

The primary objective of the Preliminary and Detailed Exploration (8.3.1.14.2.1.2) Program is to obtain sufficient subsurface data to design the ESF surface and subsurface access facilities. This data will contribute to Title II design for the ESF. The depth, thickness, and areal extent of the major soil and rock strata influencing or influenced by the construction of the surface facilities will be established in appropriate detail. The depth and thickness of geologic strata and thermal/mechanical units that will be intersected by the ramps and shafts will be determined. The geologic strata and thermal/mechanical units beneath any potential shaft will be reasonably established from a shaft exploration hole. The ramps will intersect rock units that have been offset due to faulting. As a result of these offsets, the geologic units intersected will be determined from existing geologic data and additional drilling. In addition, disturbed and undisturbed (if possible) samples will be obtained for laboratory testing to provide a basic knowledge of the engineering properties of the various strata.

The exploration activities will be performed in phases. These phases will consist of Site Reconnaissance (8.3.1.14.2.1.1) and Preliminary and Detailed Exploration (8.3.1.14.2.1.2) Activities. The objective of the reconnaissance exploration phase will be to obtain a rough interpretive cross-section of the soil and rock stratigraphy and structure of the area. Development of the Site Reconnaissance will consist of evaluating previously gathered soil and rock characteristics data and geologic data in combination with limited field exploration. A general overview of this data is presented in Appendices B, C, and D. The combination of previously accomplished work and the Site Reconnaissance will contribute to development of the second or, Preliminary Exploration phase. This phase will be performed to provide detail to the soil and rock stratigraphy and structure. The third or Detailed Exploration phase will better define areas lacking necessary detail and any anomalous conditions that were identified during the preliminary exploration activities. Sampling will be performed in each of these phases, however, more undisturbed (if possible) sampling may be required in the Detailed Exploration phase.

The following data will be used to fulfill the objectives of this study:

1. Depth, thickness, and areal extent of all major soil and rock strata that will be within the zone of stress influence of surface facility loads or that may influence the soil-structure interaction response of the surface facilities under dynamic loading conditions.

2. Depth and thickness of all major rock strata that will be intersected by the ramps and shafts.

3. Identification of significant geologic structures.

4. Representative disturbed and undisturbed samples (undisturbed sampling will be very difficult in a nonsaturated cohesionless soil with cobbles).

5. Identification and classification of soil and rock types encountered.

The method(s) used will be determined by actual field and material conditions. Preliminary determination of physical, mechanical, and dynamic properties may be developed from empirical methods such as material classifications, relative density, blow count or penetration resistance, Schmidt impact hammer and/or point-load data, geophysical surveys, and borehole logging.

#### 2.1.2.2 General Approach for Test Activities and Rationale for Selection

Field methods such as sounding, test pits, trenching, drilling, and discontinuity characterization mapping will be used in conjunction with geophysical methods to characterize the depth, thickness, areal extent, and structure of soil and rock that will be within the zone of stress influence of surface facility loads or that may influence the soil-structure interaction response of the surface facilities under dynamic loading conditions. These same methods may also be used to identify significant geologic structures, such as faults, in the vicinity of critical surface facilities. However, test pits and trenching are the most reliable method for identifying faults in alluvium.

Field techniques for characterizing the depth and thickness of the geologic strata and structure intersected by the potential ramps and shafts, consist of drilling, geophysical logging, and surface geologic mapping. Geologic mapping will include existing mapping and site-specific geotechnical and seismotechtonic mapping. Surface geophysical methods will not be used along the ramp alignments or shaft locations due to inadequate resolution as shown by previous applications of these geophysical exploration techniques at Yucca Mountain.

Disturbed and undisturbed samples (if possible) of the soil and rock will be obtained from the test pit, trenching, and boring activities for identification, classification, and laboratory testing of physical, mechanical, and dynamic properties. Previous work (Ho et al., 1986) at the site has shown that undisturbed sampling of the unsaturated and cohesionless silty gravels or poorly graded gravels with cobbles will probably be impossible. The gravelly and cobbly colluvium and alluvium at the site precludes the standard SPT, CPT, and undisturbed sampling. Much of the useful data will come from in place densities and soil classification combined with laboratory testing data. The anticipated low loads indicate that empirical estimates of bearing capacity combined with conservative design loads are appropriate. All excavations will be located in areas that will provide required data but will not affect the structure foundation, or the excavations will be backfilled as a controlled fill.

The type of boring method used will be determined by the expected uses of the holes and conditions encountered. Double- or triple-tube diamond core drilling methods will be used in rock. Augers or rotary drilling will be used in the soil. Due to the cohesionless nature of the soil, hollow stem augers, casing, or Odex drilling methods will probably be required for maintaining borehole stability. Most shallow, surface exploration will be by test pit because of high reliability, access, and data requirements.

Selecting the number, location, depth, and type of exploration soundings, test pits, trenches, or borings will depend on the type of structure being designed, the type of soil or rock conditions present, and whether the exploration activity is in the preliminary or detailed phase. In this activity the total number of exploration soundings, test pits, trenches, or borings will be identified for each type of surface or subsurface facility. This total number will include both preliminary and detailed exploration soundings, test pits, trenches, or borings. Generally the number of preliminary soundings, test pits, trenches, or borings will be approximately 40 to 60 percent of the total. As previously described, the preliminary exploration activities will provide a general or rough estimate of the soil and rock stratigraphy and structure. The results from the preliminary exploration program will determine if further detailed exploration is needed to better define the soil and rock stratigraphy and structure or if further explorations will be necessary to investigate any anomalous conditions discovered by earlier exploration.

Low-load structures on alluvium larger than 50 ft minimum dimension, will typically require a minimum of four explorations at the corners, plus possibly intermediate explorations at the interior foundations (U.S. Navy NAVFAC DM-7, 1984, and Fang, 1990). These explorations may consist of either soundings, test pits, trenches, borings, or combinations of these methods. If the soil is significantly heterogeneous areally and the structure is large, then possibly more detailed exploration will be required. Structures smaller than 50 ft maximum dimension, may require only one to three soundings and test pits, trenches, or borings. The exploration requirements will be dependent on the type of soil, its homogeneity, and the importance of the structure. Very small, low-load, non critical structures may not require subsurface exploration.

Sounding is not planned except as a contingency. If sounding is necessary, the appropriate method in the anticipated materials is the Becker Hammer. If this method is used, a prototype testing and site-specific calibration program will be necessary.

Structures on rock will generally require fewer boreholes and no test pits or trenches, unless faults are suspected and the rock is rippable. High-load structures on rock may require borings at a maximum of 100 ft spacing or where changes in rock conditions are suspected. Low-load, non-critical structures will not require borings unless located on slopes.

Shaft collars will require a minimum of one borehole. If conditions are questionable, or if alluvium overlies bedrock, more boreholes may be appropriate. Ramp portals and ramps will require boreholes to explore the general stratigraphy, structure, and specific features along the alignments. One or two boreholes will be required in the areas of the planned cut slopes above the ramp portals. If geologic conditions are unfavorable or complex, more boreholes will be required in these areas to evaluate slope stability. Exploration along the cuts leading into the ramp portal areas will also be required. If the proposed ramp portal excavations begin in soil before encountering rock, trenches on the alignment of the ramps may be used to establish rock line and help determine the location of the ramp portals. These trenches will continue into rock if practical. Another shorter trench or cleaned strip will be located perpendicular to the ramp in the proposed cut above the ramp portal. These trenches will be excavated in the portal area to bedrock, and possibly into bedrock, and will be mapped to identify rock type, rock quality, and characterize discontinuities (fractures, joints, and faults). Detail line mapping of rock exposures (natural or man made) will provide data for evaluating slope stability in the area of the ramp portals.

For roads and asphaltic or concrete pads, exploration data from nearby structures will be used as much as possible, and supplemental test pits, trenches, or borings may be spaced at approximately 200-foot intervals. If subsurface conditions are heterogeneous, exploration spacing will be decreased. Conversely, if subsurface conditions are found to be very uniform, then the spacings for the test pits, trenches, or borings may be extended to 400 or 500 ft.

Potential borrow areas will be evaluated using test pits or trenches. Large bucket augers or helical augers may be used for excavation depths beyond the limits of test pits or trenches. Explorations will be spaced appropriately for the material uses, types, and continuity required (Earth Manual, 2nd. ed.)

Exploration depths for soundings, test pits, trenches, and borings will be dependent on the type and dimensions of the structure, magnitude of loads, and type of soil or rock conditions encountered. As a general rule the exploration will extend below the foundation elevation to a depth where the increase in vertical stress for combined foundations is less than 10% of the effective overburden stress. Exploration will extend through all unsuitable foundation material, such as unconsolidated fill, soft, fine-grained soils, and loose, coarse-grained soils, to reach hard or compact materials of suitable bearing capacity. If bedrock is encountered by drilling, the exploration will extend at least 20 feet into bedrock.

Slope stability exploration will extend to an elevation below active or potential failure surfaces or to a depth for which failure is unlikely because of the geometry or material of the cross section.

Sampling requirements will depend on design needs considering the soil conditions encountered and the testing program required to adequately address these needs. Since most of the soil is cohesionless, only disturbed samples will be obtained. These samples will be from test pits, trenches, or boreholes. If fine-grained materials are encountered (not likely), representative samples from boreholes will be obtained using Standard Penetration Test (split-spoon) samplers (USBR E-21, 1974 or ASTM D-1586), auger or drill cuttings, or direct sampling. If cohesive soils are encountered, then some undisturbed samples may be taken using either double-tube soil samplers, thin-wall drive samplers, or fixed-piston samplers (USBR 7105, 1990). Soil samples will be taken every five feet and at every change in material. Rock will normally be cored continuously using a double or triple tube sampler (ASTM D-2113).

All trenches, test pits, and borehole locations will be surveyed and photographed. Significant geologic outcrops and structural features will also be located, mapped and photographed. Locations will be referenced to the Nevada Central State Plane Coordinates and elevations will be surveyed within 0.1 feet.

Preliminary evaluations of the physical, mechanical, and dynamic soil and rock properties of the site will be developed from empirical methods related to material classifications, in situ densities, blow count (if practical), Schmidt impact hammer data, point load tests, and geophysical surveys and borehole logging. Methods such as the Standard Penetration Test (SPT) (ASTM D-1586) and the Dutch cone penetration resistance (ASTM D-3441) are alternative sounding methods that may be used to estimate the physical or mechanical properties of soil if significant deposits of fine-grained materials are encountered. Established empirical relationships will be used to correlate the soil classification, relative density, and blow count or penetration resistance data to Young's modulus, or friction angle. The use of sounding methods such as the SPT blow count or the Dutch cone penetration resistance in coarse gravels is not practical. If fine-grained soil conditions are encountered, then the SPT blow count method or the Dutch cone penetration resistance method can be used.

The exploration program for the subsurface access ramps and shafts will consist of drilling from the surface. Only one borehole will be required for each shaft. The hole will be cored the full depth of the potential shaft on the shaft axis. The material surrounding the hole will subsequently be removed by shaft construction and therefore will not compromise the repository. Ramps will require drilling along the proposed alignment of the ramp offset from the alinement a minimum of 30 feet from the excavation limit. The number of these boreholes will depend on the complexity of the stratigraphy and structure. Anticipated locations consist of one vertical hole at the top of the portal cut (with clearing of rock surface for fracture data), at least one hole in each major structural block, and angle holes to evaluate the larger faults. At least one hole will be located to define the lower end of the ramps. Other boreholes will be inclined and/or located to intersect significant faults or strata which may produce stability problems. These boreholes will be cored most of their entire length to better define the stratigraphy and fault displacement along the proposed ESF ramp alignments (Memorandum, August 15, 1991).

Geophysical density logs will be obtained from each of these ESF ramp boreholes to develop a correlation between the density logs and the densities measured in the laboratory from the core. These same correlations will also be made between density logs performed in the ESF boreholes and the densities measured from the core of these boreholes. Due to the need to perform wireline density logs, boreholes will be drilled or cored with diameters not less than 3 inches and not greater than 8 inches so that the density logging method or other geophysical logging methods can effectively be performed with standard industry geophysical logging tools.

Preliminary field estimates of the mechanical rock properties may be used. The point load test (Broch and Franklin, 1972) can be used on rock core to estimate unconfined compressive strength and also provide contributing data for designing the tunnel boring machine cutters. The Schmidt impact hammer can be used on rock core or surface outcrops to estimate unconfined compressive strength (ISRM, 1981). These are both fast, inexpensive, but not definitive methods. The tests provide a means for quickly estimating the unconfined strength of the rock as preliminary data for design purposes and for adjusting the ongoing exploration program if the results of the preliminary field tests are significantly different than expected. Unconfined compressive strength values from these tests will be either verified or corrected using the results of laboratory unconfined strength testing of rock core.

Surface and borehole geophysical methods may be used to evaluate the dynamic and physical properties of the subsurface strata and correlated with the laboratory densities. The results of these correlations can be used for estimating densities in boreholes where no coring is performed or no in situ densities taken from test pits or trenches. Other wireline borehole geophysical methods may be used to evaluate the degree of fracturing in rock. Down-hole video can be oriented and correlated with fractures found in the rock core if the borehole is cored. However, due to the unsaturated conditions of the soil and rock, other important engineering parameters, such as wave velocities, can not be determined using wireline borehole geophysical methods.

Seismic geophysical methods such as seismic refraction, cross-hole seismic, and up/down hole seismic may be used for determining the compressive and shear wave velocities of the subsurface strata. The wave velocities can then be used to evaluate the dynamic elastic parameters of the soil and rock. These field parameters are expected to be more indicative of in situ conditions than the same parameters measured in the laboratory. Further detailed discussions of the geophysical field activities will be presented in Section 2.3.3 (Geophysical Field Measurement Activities).

### 2.1.2.3 Methods and Technical Procedures

The following lists methods to obtain the data required to fulfill the objectives of this activity. Selecting the most appropriate method depends on the soil and rock conditions encountered and the data or parameters required. Material such as caliche, if adequately cemented (not likely), will be treated either as a rock or soil depending on the degree of cementation.

1. Test pits, trenching, and drilling.
2. Sounding (probing) subsurface strata.
3. Geophysical surface surveys.
4. Geophysical borehole methods.
5. Surface and subsurface sampling.

The previously described methods with their corresponding technical procedures are listed in the following table:

| Method | Technical Procedure | | |
|---|---|---|---|
| | Number or Author | Title | Date |
| Sounding, sampling classification, drilling, trenching, and geophysical surveys for soils | U. S. Navy NAVFAC DM-7 | Design manual - Soil mechanics, foundations, and earth structures | [a] |

| | | | |
|---|---|---|---|
| Sounding, drilling, trenching, geophysical surveys and borehole logging and sampling | M. J. Hvorslev | Subsurface exploration and sampling of soils for civil engineering purposes | Nov 49 |
| Sampling for soils | U. S. Army EM 1110-2 1907 | Soil sampling | 31 Mar 72 |
| Dynamic sounding (blow count) in soils | ASTM D-1586-67 | Penetration test and split-barrel sampling of soils | [a] |
| Static sounding-penetration resistance in soils (Dutch cone test) | ASTM D-3441-79 | Deep, quasi-static, cone and friction-cone penetration tests of soil | [a] |
| Mechanical properties of rock-(indirect) | ISRM Doc. 5, Part 3 | Suggested method for determination of the Schmidt Rebound Hardness | [a] |
| Geophysical borehole logging | ISRM Parts 1-11 | Suggested methods of geophysical logging of boreholes | [a] |
| Soil classification | ASTM D-2488-69 | Description of soils (visual-manual procedure) | [a] |
| Concepts of soils Mechanics and Procedures | U.S. Dept. of Interior (USBR) | Earth Manual 2nd and 3rd Ed. | 1985 & 1990 |

[a] Current version of document or procedure will be used

Other technical procedures that are comparable to the procedures listed above may be used. An example is the U.S. Bureau of Reclamation procedures presented in the Earth Manual, Part 2, 1990. These procedures are comparable with, and in some cases more inclusive than the technical procedures listed above.

2.2 Laboratory Tests and Material Property Measurement Study

The objectives of this program are to conduct laboratory tests and material property measurements on representative samples of soil, rock and aggregate. The gravels and cobbles of this site preclude undisturbed sampling, therefore, for tests requiring undisturbed samples, remolded samples will be used in testing. These tests and measurements are intended to determine physical, mechanical, and dynamic properties. Additional tests and measurements will be conducted on soils to determine index properties and moisture-density compaction curves for potential fill material. Geotechnical information from this study will contribute to the development of the geotechnical design parameters presented in the SCP's Table 8.3.1.14-1 (see Appendix A), which in turn will be used to address Design Issue 4.4 (Section 8.3.2.5, SCP) and provide geotechnical engineering design parameters to Title II design.

Determination of the quality status for the activities of this study will be made separately, according to AP-6.17Q, "Determination of the Importance of Items and Activities", which implements NUREG-1318, "Technical Position on Items and Activities in the High-Level Waste Geologic Repository Program Subject to Quality Assurance Requirements". The results of that determination will be contained in the Q-List, Quality Activities List and Non-Selection Record, which will be controlled documents.

QA grading packages for the activities of this study plan will be prepared separately, according to AP-5 2.8Q "Quality Assurance Grading" controlled document.

### 2.2.1 Physical Property and Index Laboratory Test Activity

#### 2.2.1.1 Objectives

The objective of this activity is to measure the soil or rock weight and volume components using physical property tests. Soils can be further characterized by index tests such as gradation analysis and Atterberg limits testing. The physical and index property test results are used to classify soils and rocks, to group soils and rocks in major strata, and to extrapolate results from a restricted number of mechanical and dynamic properties tests to determine properties of other similar materials. Empirical methods can also be used to relate the physical properties and soil or rock classifications to engineering parameters.

The following soil, rock, and aggregate parameters will be collected, and/or evaluated, to fulfill the objectives of this activity:

1. Soil parameters

   a. Density

   b. Specific gravity

   c. Moisture content

   d. Soil classification

      i. Gradation analysis

      ii. Atterberg limits (this parameter will only be determined if cohesive soils are encountered)

   e. Moisture-density compaction curves for potential fill material

   f. Relative density (cohesionless soils)

2. Rock parameters

   a. Density

   b. Moisture content

   c. Porosity

   d. Specific gravity

3. Aggregate Durability and Soundness

   a. Sodium sulfate soundness test

   b. Los Angeles abrasion test

   c. Petrographic analysis of aggregate

Current estimates of most of the above parameters are presented in the SCP's Table 8.3.1.14-1 (see Appendix A).

2.2.1.2 General Approach for Test Activity and Rationale for Test Selection

A sufficient number of samples will be tested so that the variations in physical and index properties throughout the proposed ESF surface and ESF ramp and shaft alignments will be adequately characterized. Laboratory physical property tests will be performed on soil and rock samples taken every five feet in depth and at every noticeable change in material where soil or rock characteristics may change. These laboratory tests for soil will include density, specific gravity, moisture content, gradation analysis, Atterberg limits (for cohesive soils only), and relative density (cohesionless soils). Physical property laboratory tests for rock will include density, moisture content, and specific gravity.

The laboratory soil tests can be conducted on disturbed samples except for the density and porosity tests. These two soil tests will require undisturbed samples. Because of the difficulty in obtaining an undisturbed sample from a dry cohesionless soil with cobbles, soil densities will generally be determined in situ using field density test methods. Empirical correlations with sounding methods are a contingency method. These methods will be discussed in further detail in Section 2.3 (Field Tests and Characterization Measurements).

Soil compaction tests will be performed on at least two samples for each type of potential fill material. Because of the very coarse nature of the soil, the Standard Proctor or Modified Proctor compaction methods may not be appropriate to develop the moisture-dry density compaction curve relationships of the soil. For gravelly soils, up to 3-in. maximum size, the U.S.B.R. E-38 procedure will be used to develop compaction curves.

Tests to evaluate the durability of aggregate will be performed on at least two samples from each potential aggregate source. These tests will include the sodium sulfate soundness test, the Los Angeles abrasion test (USBR, Concrete Manual, 1981), and petrographic examination. Potential aggregate sources may include existing sources as well as alluvial material or crushed rock from site areas that will be eventually excavated during the development of the ESF.

### 2.2.1.3 Methods and Technical Procedures

Standard soil, rock, and aggregate test and classification procedures will be used for this activity. A list of test and classification methods follows:

| Method | Technical Procedure: Number or Author | Technical Procedure: Title | Technical Procedure: Date |
|---|---|---|---|
| Sample preparation for soils | USBR 5205-86 | Preparing soil samples by splitting or quartering | b |
| Sample preparation for soils | ASTM D421-58 | Dry preparation of soil samples for particle-size analysis and determination of soil constants | b |
| Moisture content for soil and rock | ASTM D2216-80 | Laboratory determination of water (moisture) content of soil, rock, and soil-aggregate mixtures | b |
| Density of soil | ASTM D2937-83 | Density of soil in place by the drive-cylinder | b |
| Specific gravity for soil: | | | |
| Materials smaller than number 4 sieve | ASTM D854-83 | Specific gravity of soils | b |
| Materials larger than number 4 sieve | ASTM C127 | Test method for specific gravity and absorption of coarse aggregate | b |
| Soil Classification: | | | |
| | USBR 5000 | Determining Unified Soil Classification (Lab method) | b |
| | ASTM D2487-83 | Classification of soils for engineering purposes | b |
| Atterberg limit: [a] | | | |
| Liquid and plastic limits | ASTM D4318-83 | Liquid limit, plastic limit, and plastic index of soils | b |

| | | | |
|---|---|---|---|
| Shrinkage limit | ASTM D427-83 | Shrinkage factors of soils | b |
| Soil Gradation: | | | |
| Sieve analysis | ASTM D422-63 | Particle-size analysis of soils | b |
| Hydrometer analysis | ASTM D422-63 | Particle-size analysis of soils | b |
| Compaction moisture-density relationships: | | | |
| Standard Proctor | ASTM D698-78 | Moisture-density relations of soils and soil-aggregate mixtures using 5.5-lb. hammer and 12-in. drop | b |
| Modified Proctor | ASTM D1557-78 | Moisture-density relations of soils and soil-aggregate mixtures using 10-lb hammer and 18-in. drop | b |
| U.S.B.R. Compaction Test (gravelly soils--3 in. maximum size) | USBR 5517 | Compaction test for soil containing gravel | b |
| Relative density | ASTM D4254-83 | Minimum index density of soils and calculation of relative density | b |
| Porosity/density of rock | ISRM Doc. 6 Part 1, No. 2-5 | Suggested method of porosity/density determination | b |
| Moisture content for rock | ISRM Doc. 6 Part 1, No. 1 | Suggested method for determination of water content | b |
| Aggregate Durability: | | | |
| | Designation 19 (USBR Concrete Manual) | Soundness of Aggregate (Sodium Sulfate Method) | 1981 |

| | | | |
|---|---|---|---|
| 1981 | Designation 21 (USBR Concrete Manual) | Abrasion of Coarse Aggregate by use of the Los Angeles Machine | |
| 1981 | Designation 7 (USBR Concrete Manual) | Petrographic Examination of Aggregates | |
| Specific gravity for rock | ISRM Doc. 6 Part 1, No. 4 | Suggested method for porosity/density determination | b |

[a] Atterberg limits will be required only if cohesive soils are encountered.

[b] Current version of document or procedure will be used.

The Principal Investigator will have the option of using other technical procedures that are comparable to the procedures listed above. An example is the U.S. Bureau of Reclamation procedures from the Earth Manual, Part 2, 1990. These procedures are comparable with, and in some cases more inclusive than the technical procedures listed above.

### 2.2.2 Mechanical and Dynamic Laboratory Property Test Activity

#### 2.2.2.1 Objectives

The objective of this activity is to measure in the laboratory the static and dynamic deformation and strength characteristics of soil and rock samples obtained from the exploratory program. The results of this testing will be used to evaluate bearing capacity, earth pressures, shear strength parameters, slope stability, settlement and swelling potentials, and the dynamic characteristics of the soil and rock. This geotechnical information will be used for locating and designing buildings, foundations, retaining walls, ramp portals, shaft collars, fills, roads, and slopes. Results from this activity will be the major contributor for developing the geotechnical design parameters presented in Table 8.3.1.14-1 of the SCP (see Appendix A).

The following data and parameters will be collected, and/or evaluated, to fulfill the objectives of this activity.

1. Required static load derived parameters

   a. Mohr-Coulomb strength criteria parameters for soils (cohesion and angle of friction). The type of strength testing will depend on the type of soil, stress history, new stress state, and rate of loading.

   b. Peak and residual failure envelopes for rocks.

   c. Young's modulus.

   d. Poisson's ratio.

   e. Shear modulus.

   f. Rock discontinuity shear strength parameters in terms of cohesion and friction angle.

2. Contingent static load derived parameters.

   a. Collapse potential (for relatively dry, low-density soils).

   b. Coefficient of consolidation (for saturated, clayey soils).

   c. Compression and swell index (for saturated, clayey soils).

   d. Other failure criteria parameters such as Drucker-Prager or Hoek and Brown.

   e. Deformation modulus of soils in terms of stress-strain characteristics and confinement stress conditions.

   f. Bulk modulus and constrained modulus of soils.

3. Required dynamic load derived parameters.

   a. Compressive wave velocities.

   b. Shear wave velocities.

4. Contingent dynamic load derived parameters.

   a. Strength and stress-deformation characteristics of soil under dynamic load conditions evaluated as a function of stress rates, confinement stress, initial static stress level, magnitude of pulsating stress, number of stress cycles, and frequency of loading.

   b. Dynamic shear modulus as a function of strain and confinement stress.

   c. Damping as a function of strain.

   d. Shear wave velocities as a function of strain.

   e. Liquefaction parameters--cyclic shearing stress ratio, cyclic deformation, and pore-pressure response (applicable for soils with perched-water tables near the surface).

The need for any contingent parameters will be determined by the soil or rock conditions encountered, the function or design requirements of the surface facilities, the types of foundations selected, and the type or sophistication of the analyses that are selected for the design or performance studies. On the basis of the known site conditions and the design presented in the SCP-CDR (SNL, 1987), these contingent parameters are not presently required. The contingent parameters will be characterized if unexpected soil and rock conditions are encountered, or if more sophisticated constitutive models are required or used in the soil or rock-structure interaction numerical codes.

Estimated values and some measured values for most of the previously described data and parameters are presented in the SCP's Table 8.3.1.14-1 (see Appendix A).

### 2.2.2.2 General Approach for Test Activity and Rationale for Test selection

Standard mechanical and dynamic laboratory tests for geotechnical engineering practice will be performed. Testing will be conducted on undisturbed or recompacted samples taken from soil and rock strata that will influence or are influenced by ESF surface facility construction. Selection of sample location, depth, and type of test will be determined by the surface structure function, loads (static or dynamic), and foundation depths and widths. As a general rule 3 to 5 mechanical tests will be performed on soil and rock samples at every noticeable change in strata where soil or rock characteristics change.

Test conditions will approximate actual field conditions as closely as is practicable. For example, the range of confining pressures for triaxial tests will span the anticipated in-place confining pressures. The upper confining pressures may be considerably higher than in-place pressures in order to affect rock with strengths of 20,000 psi or more. Moisture conditions will also be as close to in-place moisture conditions as is practical with drained or undrained tests as is appropriate. Sample sizes will be as large as is appropriate, NQ or HQ for rock and up to 9.5 inches in diameter for gravelly soil samples. Strain rates will also be controlled to provide results as close to in-place conditions as is practical.

Dynamic tests will only be performed on samples from beneath potential structures important to safety, such as the ramp portals and shaft collars. Testing will also be conducted on all soils to be used for engineered fills. These soils will be compacted to the appropriate dry density and moisture content before conducting laboratory tests to determine their mechanical and dynamic properties.

Laboratory test methods used to measure the strength and deformability parameters of representative soil samples or potential borrow material will rely primarily on the triaxial compression test method, however, the direct shear test method may be used as an alternative. Triaxial test results are considered more reliable due to certain limitations of the direct shear test. The direct shear test is a simpler, more economical test but is limited in that the failure plane is predetermined by the test method and not by the soil properties, and the distribution of the shear stresses and displacements along the failure plane are non-uniform.

A minimum of three (preferably four or five) triaxial tests or direct shear tests will be performed on each soil condition encountered or each potential borrow material considered. The triaxial and direct shear tests will be performed over the range of confinement or normal stresses that may be expected.

Since the soil conditions are expected to be cohesionless, undisturbed sampling will probably be impractical. Therefore, mechanical property tests will be performed in the laboratory on recompacted samples. These samples will be recompacted to the densities and moisture contents measured in situ, even though the disturbance and then recompaction of the soil will not result in the same soil fabric as found in place. This change in fabric can impact the soil's mechanical properties, however, the effects on a cohesionless soil are expected to be minimal. Sample sizes will be increased to reduce size effects, e.g. 9.5 by 22-inch specimens will be used to reduce size effects. Caliche-cemented materials will be treated as rock or soil depending on the degree of cementation. Caliche soils treated as soils will lose in situ fabric during sampling and test results will be conservative.

Borrow materials that are being evaluated for use as engineered fills will be prepared by compacting the material using USBR 5515, "Procedure for Performing Laboratory Compaction of Soils Containing Gravel". The selection of the compaction method and the percentage of the maximum density and moisture content at which the potential borrow material will be compacted, depends on the type of borrow material used and the projected use of the material.

Since soil samples tested in the laboratory will probably be recompacted representative samples, other laboratory and field methods will be used to help estimate or confirm the laboratory test results. These methods will estimate the in situ soil strength (cohesion and angle of friction) and deformability (Young's modulus) using empirical correlations with soil classification, and relative density. The relative density method is described in Section 2.3 (Field Tests and Characterization Measurements Study). The soil classification method is described in Section 2.2.1 (Physical Property and Index Laboratory Test Activity).

Since the soil is expected to be cohesionless, the immediate settlement characteristics of the soil beneath the footings will be determined by laboratory consolidation tests (USBR 5700) on recompacted samples. If collapsable soils are encountered, recompacted samples will not be used. These data combined with conservative designs and low loads should be adequate.

The strength and deformability of intact rock core will be determined in the laboratory from the results of triaxial compression tests, unconfined compression tests, and Brazilian or direct tensile tests in areas of particularly high loads such as steep cuts or underground excavations. The strength of fractured or jointed rock core will be determined using the triaxial compression test. The results of these tests will be plotted in the form of peak and residual strength envelopes from which the strength parameters (cohesion and angle of friction) can be determined for both the intact and fractured or jointed core. These strength parameters can be used to evaluate the allowable foundation bearing pressure of the rock (Goodman, 1980).

The direct shear testing method will be used in the laboratory to measure the mechanical properties of rock discontinuities. These tests will be performed on samples taken from areas that may have potential slope instability such as the cutslope above the ramp portal and any other cuts which have the potential for slope instability. Enough samples will be tested to develop peak and residual failure envelopes from such locations. The tests will at a minimum determine the strength parameters (cohesion and friction angle) of the discontinuity. Test results will be used in the stability evaluation of the rock slopes and will contribute to the evaluation of the allowable bearing pressure for a foundation, especially for foundations on sloping topography.

Core taken from the boreholes along the alignment of the ramps or from the exploratory borehole for the shaft, will be tested in unconfined compression and possibly triaxial compression. Mechanical parameters such as strength, Young's modulus, and Poisson's ratio can be obtained from the unconfined compression test. Core will be examined petrographically for deleterious minerals including quartz which has a significant impact on bit wear. Core will also be reserved for proprietary testing by equipment manufacturers. Sampling and testing of core from the boreholes along the ramp alignment will, as a minimum, occur where the borehole intersects the ramp. If inspection and/or early testing indicates additional testing is necessary, core will be tested from other stratigraphic horizons or geologic structures.

The velocity and damping characteristics of elastic waves through soil and rock can be determined in the laboratory using resonant methods. High- and low-frequency ultrasonic pulse techniques can also be used for rock. The resulting velocities from these tests can then be used to determine the elastic deformation parameters of the soil or rock. However, since these tests will only measure the dynamic characteristics of intact rock and not the fractured or jointed rock mass, these tests will only be used as alternative tests to validate the elastic deformation and damping parameters derived from field geophysical seismic methods.

Determination of the dynamic compression and shear moduli depends primarily on field geophysical seismic methods such as, down-hole, cross-hole, and surface refraction measurement techniques. Using these techniques, the maximum dynamic shear modulus (low-strain) can be obtained. The nonlinearity of soil can be considered by reducing the shear modulus with strain based on correlations developed by Seed et al. (1984). The relationship developed by Seed et al. (1984) can also be used to determine the maximum shear modulus of soil as a function of a density related factor, $K^2$, obtainable from the field measured shear wave velocities, and the mean effective confining stress. The Seed et al. (1984) report also provides a correlation with dynamic shear modulus or shear wave velocities and Standard Penetration Test blow count data. A method for reducing the shear modulus of rock as a function of strain is addressed by Schnabel et al., (1971).

The determination of the strength and stress-deformation characteristics of soils under dynamic load conditions evaluated as a function of stress level, magnitude of pulsating stress, number of stress cycles, and frequency of loading can only be determined in the laboratory using a cyclic loaded triaxial compression test. However, because of the difficulty in obtaining undisturbed samples of the coarse cohesionless soils and the potential unreliability of testing recompacted samples under dynamic loading conditions, the cyclic loaded triaxial compression test will not be conducted if sufficient confidence can be acquired in the previously described field and empirical methods for determining the dynamic mechanical characteristics of the soil. Certain conditions may develop that will either require or produce more of a need for cyclic loaded triaxial test data. These conditions would include a lack of confidence in the previously described field and empirical methods, therefore requiring the cyclic loaded triaxial test as a means of confirming or validating the parameters developed from the field and empirical methods. In addition, this test would potentially provide the design engineer with more information to better assess the dynamic characteristics of the soil. The need and validity of the cyclic loaded triaxial test may increase if other soil conditions are encountered such as saturated soils or finer grained soils. Other conditions that may require the implementation of cyclic loaded triaxial test methods are the use of more sophisticated constitutive models in the soil structure interaction numerical codes.

### 2.2.2.3 Methods and Technical Procedures

Standard testing procedures will be used. A list of possible test methods are given in the following table. The selection of the most appropriate method will depend on the soil or rock conditions that are encountered in the exploration activities and the type or sophistication of the analyses that are selected or required for design or performance studies. These considerations were described in the previous section.

| Method | Technical Procedure Number or Author | Technical Procedure Title | Date |
|---|---|---|---|
| Drained triaxial strength of granular soils[b] | USBR 5755 | Performing consolidated -drained triaxial shear testing of soils | c |
| Unconfined compression testing for cohesive soils[a] | ASTM 2166-66 | Unconfined compressive strength of cohesive soils | c |
| Triaxial compression testing for soils[a] | ASTM D2850-82 | Unconsolidated, undrained compressive strength of cohesive soils in triaxial compression | c |
| Direct-shear strength for soils[a] | ASTM D3080-72 | Direct shear test of soils under consolidated drained conditions | c |
| Compressibility-swell test for soils[a] | ASTM D2435-80 | One-dimensional consolidation properties of soils | c |
| Resonant column test for soil[b] | ASTM D4015-81 | Modulus and damping of soils by the resonant-column method | c |
| High-frequency ultrasonic pulse for rock[b] | ISRM, Doc. 4, pp. 108-109 | Suggested methods for determining sound velocity | c |
| Low-frequency ultrasonic pulse technique for rock[b] | ISRM, Doc. 4, pp. 109-110 | Suggested methods for determining sound velocity | c |
| Resonant method test for rock[b] | ISRM, Doc. 4, p. 110 | Suggested method for determining sound velocity | c |

| | | | |
|---|---|---|---|
| Unconfined compressive strength of rock core | ASTM D2938 | Suggested method for determination of the uniaxial compressive strength of rock materials | c |
| Unconfined compressive deformability of rock core | ISRM Part 2 | Suggested methods for determining deformability of rock materials in uniaxial compression | c |
| Triaxial compressive strength of rock core | ISRM, Doc. 7 | Suggested methods for determining the strength of rock materials in triaxial compression | c |
| Triaxial compressive strength and deformability of rock core | ASTM D2664 | Triaxial compressive strength of undrained rock core specimens without pore pressure measurements | c |
| Indirect tensile strength of rock discontinuities | ISRM, Doc. 8, Part 2 | Suggested method for determining indirect tensile strength by the Brazil test | c |
| Direct shear strength of rock discontinuities | ISRM, Doc. 1, Part 2 | Suggested method for laboratory determination of direct shear strength | c |

[a] The need for these test methods is contingent on encountering cohesive soils. Based on known site conditions, cohesive soils are not expected.

[b] Alternative test method.

[c] Current version of document or procedure will be used.

The Principal Investigator will have the option of using other technical procedures that are comparable to the procedures listed above. An example would be the U.S. Bureau of Reclamation procedures in the Earth Manual, Part 2, 1990. These procedures are comparable with, and in some cases more inclusive than the technical procedures listed above.

## 2.3 Field Tests and Characterization Measurements Study

The objective of this program is to conduct field tests and characterization measurements. These field tests are intended to determine the in situ physical, mechanical, and dynamic properties of the soil and rock. Characterization measurements will be conducted on the rock for the purpose of classifying the rock and quantitatively describing the rock structure (discontinuities). Geophysical field measurements will help develop a three-dimensional velocity structure of the subsurface soil and rock strata in addition to determining their dynamic properties. Geotechnical information from this study will contribute to the development of the geotechnical design parameters presented in the SCP's Table 8.3.1.14-1 (see Appendix A), which in turn will be used to address Design Issue 4.4 (Section 8.3.2.5, SCP) and provide geotechnical engineering design parameters to Title II design.

Determination of the quality status for the activities of this study will be made separately, according to AP-6.17Q, "Determination of the Importance of Items and Activities", which implements NUREG-1318, "Technical Position on Items and Activities in the High-Level Waste Geologic Repository Program Subject to Quality Assurance Requirements". The results of that determination will be contained in the Q-List, Quality Activities List and Non-Selection Record, which will be controlled documents.

QA grading packages for the activities of this study plan will be prepared separately, according to AP-5 2.8Q "Quality Assurance Grading" controlled document.

### 2.3.1 Physical Property Field Tests and Characterization Measurements Activity

#### 2.3.1.1 Objectives

The objectives of this activity are to classify and describe the soil and rock conditions in the field and to determine their physical properties. The results of these tests and measurements will be used to develop preliminary estimates of the engineering characteristics of the soils and rocks. In addition, these properties and measurements will aid in the grouping of soils and rocks into stratigraphic units and the extrapolation of results from a restricted number of mechanical and dynamic properties tests to zones of soil and rock with similar material properties.

The data and parameters that will be collected and/or evaluated to fulfill the objectives of this activity are as follows:

1. Soil

   a. Density

   b. Relative density (from standard penetration blow count data on cohesionless soils)

2. Rocks

   a. Rock mass classification

      i. Q-Norwegian Geotechnical Institute (NGI) Tunneling Quality Index

      ii. RMR--rock mass rating from South African Council for Scientific and Industrial Research (CSIR) Geomechanics Classification

   b. Rock structure (discontinuities)

      i. Description of faults

         (a) Location
         (b) Orientation
         (c) Thickness
         (d) Type of infilling
         (e) Moisture and seepage conditions
         (f) Waviness and roughness

      ii. Description of joints

         (a) Number of joint sets
         (b) Spacing of joints for each set
         (c) Orientation of each joint set
         (d) Type of infilling, if any
         (e) Moisture and seepage conditions
         (f) Waviness and roughness
         (g) Continuity
         (h) Persistence
         (i) Wall strength
         (j) Block size
         (k) Drill core (total rock recovery, discontinuity frequency, and rock quality designation (RQD))

Estimated values and some measured values for the previously described data and parameters are presented in the SCP's Table 8.3.1.14-1 (see Appendix A).

2.3.1.2 General Approach for Test Activity and Rationale for Test Selection

Standard geotechnical engineering field tests and characterization activities will be conducted. A representative number of these tests and characterization activities will be conducted throughout the ESF surface and subsurface access facility sites.

In-place soil density can be determined by any one of the four different methods presented in Section 3.3.1.3 (Methods and Technical Procedures). The sand-cone method is the most commonly used method for measuring density in the field, however, if the soil does not have enough cohesion to maintain a free standing hole then the nuclear method or the drive-cylinder method may provide more suitable methods for measuring density. If the soil is very gravelly, then U.S.B.R. "Field Density Procedure Test", E-24, will be used. These measurements will be taken in test pits, trenches, and any cut areas. Soil density measurements will be taken every five feet and at any changes in material.

Rock mass classification data will be developed from rock core and outcrops using two methods. The first method is called the tunneling quality index (Q) method and was developed by the Norwegian Geotechnical Institute, while the second method is referred to as the rock mass rating (RMR) method and was developed by the South African Council for Scientific and Industrial Research. This rock mass classification data will be used to evaluate the stability and required support or reinforcement for subsurface excavations. Rock core from the boreholes for the shaft and the ramp will be classified to assist in evaluating subsurface excavation stability and providing the designers with data necessary to estimate support or reinforcement requirements.

Preliminary estimates of rock mass strength and deformation characteristics can be developed from rock mass classification data (Hoek and Brown, 1980). This classification data and estimates of rock mass strength and deformation characteristics can contribute to the siting and design of surface facilities such as the ramp portals and shaft collars. This includes using the rock mass strength to evaluate bearing capacity, stability and support requirements of the portal, and slope stability for highly fractured rock where failure may be through the rock mass and not along discrete discontinuities.

Rock mass discontinuities will be quantitatively described using methods recommended by the International Society for Rock Mechanics Commission on Standardization of Laboratory and Field Tests. These data will be used in conjunction with the rock mass classification data to evaluate the stability of any potentially hazardous rock slopes and to contribute to a better understanding of the engineering characteristics of the rock mass. The quantitative description of discontinuities can be performed on rock core and outcrops.

### 2.3.1.3 Methods and Technical Procedures

Standard testing procedures will be used by this activity. The selection of the most appropriate method for measuring soil density in the field will depend on the soil conditions that are encountered during the exploration activities. A list of the possible test methods follows:

| Method | Technical Procedure | | |
|---|---|---|---|
| | Number or Author | Title | Date |
| Density of soil in place | ASTM D2937-83 | Density of soil in place by the drive-cylinder method | [a] |
| | ASTM D1556-82 | Density of soil in place by the sand-cone method | [a] |
| | ASTM D2167-66 | Density of soil in place by the rubber-balloon method | [a] |
| | ASTM D2922-81 | Density of soil and soil-aggregate in place by nuclear methods (shallow depth) | [a] |
| Density of soil in place | U.S.B.R. E-24 | Field density procedure test | 1980 |
| Dynamic sounding (blow count) in soils | ASTM D1586-67 | Penetration test and split-barrel sampling of soils | [a] |

| | | | |
|---|---|---|---|
| Static sounding-penetration resistance in soils (Dutch cone test) | ASTM D3441-79 | Deep, quasi-static, cone and friction-cone penetration tests of soil | [a] |
| Quantitative description of rock mass discontinuities | ISRM, Part 1, No. 1-11 | Suggested methods for the quantitative description of discontinuities in rock masses | [a] |
| Rock mass classification, rock mass rating (RMR) | Bieniawski, Z. T. | Rock mass classification in rock engineering | 1976 |
| Rock mass classification, tunneling quality (Q) | Barton, Lien, and Lunde | Engineering classification of rock masses for the design of tunnel support | 1974 |

[a] Current version of document or procedure will be used.

Other technical procedures that are comparable to the procedures listed above may be used. An example is the U.S. Bureau of Reclamation procedures presented in the Earth Manual, Part 2, 1990. These procedures are comparable with, and in some cases more inclusive than the technical procedures listed above.

2.3.2 Mechanical Property Field Test Activity

2.3.2.1 Objectives

The objective of this activity is to measure the deformation and strength characteristics of in situ soil and rock. The results of this testing will be used to evaluate bearing capacity, earth pressures, settlement and swelling potentials, slope stability, and the dynamic response of soil and rock for the design of foundations, retaining walls, fills, roads, and slopes.

The data and parameters to be collected and/or evaluated to fulfill the objective of this activity are listed as follows:

1. Required parameters for soil (these parameters will be developed from empirical relationships using the following possible data: in place density, relative density and soil classification or gradation).

   a. Indirect estimates of Mohr-Coulomb shear strength parameters.

b. Indirect estimates of stiffness or Young's modulus for use in evaluating immediate settlement (compression).

2. Contingent parameters for soil.

a. Plate load bearing pressure versus settlement (this will be applicable if spread footings are considered in the design).

b. Modulus of subgrade reaction from plate load test (static or dynamic).

c. Pile load versus settlement (presently piles are not considered in the SCP-CDR (SNL, 1987).

d. Sounding (Only if fine-grained materials are encountered)

3. Required parameters for rock (these parameters will be developed from empirical relationships using rock mass classification data).

a. Indirect estimates of strength.

b. Indirect estimates of stiffness or Young's modulus.

4. Contingent parameters for rock.

a. Plate load bearing pressure vs. settlement (on the surface or down a borehole).

b. In situ direct shear test to measure the peak and residual shear strength of rock discontinuities.

The need for any contingent parameters will be determined by the soil or rock conditions encountered, the function or design requirements of the ESF surface facilities, the types of foundations selected, and the type or sophistication of the analyses that are selected for the design or performance studies. On the basis of the known site conditions and the primary conceptual designs presently considered in the "ESF Alternatives Study Task No. 4", these contingent parameters are not presently required. The contingent parameters will be obtained if unexpected soil and rock conditions are encountered, or if more sophisticated constitutive models are required or used in the soil or rock-structure interaction numerical codes.

2.3.2.2 General Approach for Test Activity and Rationale for Test Selection

Standard geotechnical field tests will be conducted on soil and rock that will influence or be influenced by construction at the ESF. Preliminary field testing may also be performed on rock core taken from the exploration boreholes for the subsurface shafts and ramps. The type of test, location of test, and depth of test depend on factors such as surface facility function, loads, type and depth of footings, and subsurface soil or rock conditions. Material such as caliche will be treated as either soil or rock depending on degree of cementation.

The primary methods used to measure soil strength (cohesion and angle of friction) and stiffness (Young's modulus) are indirect methods using in situ penetration tests. The two most common methods are the Standard Penetration Test and the Dutch Cone Test. Both of these in situ methods are penetration resistance methods. The Standard Penetration Test applies an impact load and the Dutch Cone applying a continuous load. Unfortunately these methods are ineffective in gravelly soils. Since the soil conditions expected at the site are expected to be cohesionless, coarse-grained, and gravelly, these penetration test methods will not be effective in measuring the strength and stiffness of the site soil. Required parameters will be estimated from in place density, relative density, and gradations. As a contingency, the Becker Hammer penetration resistance method can be used for sounding and correlated with SPT blow counts and engineering soil properties (Harder and Seed, 1986, and Fang, 1990). The contingency conditions that would require a soil/rock-structure interaction analysis, which in turn would require shear modulus, Poisson's ratio, and damping parameters, are discussed in Section 2.3.3.2.

Preliminary estimates of rock mass strength and deformability will be made from empirical relationships with rock mass classification data. Hoek and Brown (1980) have attempted to relate Q and RMR rock mass classification values to failure criteria parameters they developed, which in turn can be related to Mohr-Coulomb failure criteria parameters. Rock mass deformation modulus was also empirically related to rock mass classification values by Bieniawski (1978).

The rock mass classification data can be obtained on rock core and outcrops from areas where potential surface structures are planned. This classification data and estimates of rock mass strength and deformation characteristics can contribute to the siting and design of surface facilities such as the ramp portals and shaft collars. This would include using the rock mass strength to evaluate bearing capacity, stability and support requirements of the portal, and slope stability for highly fractured rock where failure may be through the rock mass and not along discrete discontinuities.

Other alternative field tests for soil and rock include plate load test (static and dynamic), pile load test, and in situ direct shear test of rock discontinuities. However, for anticipated soil or rock conditions and the type of structures and foundations being designed, these alternative tests are not expected to be necessary.

2.3.2.3 Methods and Technical Procedures

The testing procedures that will be used for this activity are standard. The selection of the most appropriate methods will depend on the soil conditions that are encountered in the exploration activities. A list of possible test methods follows:

| | Technical Procedure | | |
|---|---|---|---|
| Method | Number or Author | Title | Date |
| Dynamic sounding (blow count) in soils | ASTM D1586-67 | Penetration test and split-barrel sampling of soils | [b] |
| Plate load settlement in soils or rock (use only if spread footings are considered in the design) | ASTM D1194 | Standard test method for bearing capacity of soil for static load on spread footings | [b] |
| Pile load settlement in soils (pile foundations are presently not considered in the SCP-CDR)[a] | ASTM D1143-81 | Standard method of testing piles under static axial compressive load | [b] |

| | | | |
|---|---|---|---|
| Plate load settlement in rock (use only if spread footings are considered in the design) | ISRM, Part 2, | Suggested method for field deformability determination using a plate test down a borehole | b |
| In situ direct shear strength of rock discontinuity (use only if very unfavorable structure is encountered) | ISRM, Doc. 1, Part 1 | Suggested method for in situ determination of direct shear strength | b |

[b] Current version of document or procedure will be used.

Other technical procedures that are comparable to the procedures listed above may be used. An example is the U.S. Bureau of Reclamation procedures in the Earth Manual, Part 2, 1990. These procedures are comparable with, and in some cases more inclusive than the technical procedures listed above.

2.3.3 Geophysical Field Measurement Activity

2.3.3.1 Objectives

The primary objectives of this activity are to obtain measurements of the compressional and shear wave velocities, and to determine the velocity structure in the area of the ESF surface facilities. Other possible objectives of this activity will include profiling the alluvium-bedrock contact and identifying the location of possible faults through the alluvium in the vicinity of these structures. This information will be used to assist in the geologic interpretation of the site area, and will contribute to the development of the geotechnical parameters in the SCP's Table 8.3.1.14-1 (see Appendix A) and to the resolution of Design Issue 4.4 (Section 8.3.2.5, SCP).

2.3.3.2 General Approach for Test Activity and Rationale for Test Selection

As discussed previously, the existing geophysical information in the area of the surface facilities and subsurface ramps and shaft will be evaluated with respect to the location and extent of the proposed facilities. Additional geophysical work would be planned or attempted, based on this evaluation. This additional work would probably include the following:

1. One or more seismic lines will be performed along the axis of proposed portal approaches. Other surface facilities important to safety will also have one or more seismic lines performed at their proposed locations. The primary purpose of these lines will be to measure compressional and shear wave velocities of the alluvial materials and the bedrock, and to determine the seismic structure in the vicinity of the proposed portal and approach. A secondary purpose will be to profile the alluvium/bedrock contact and/or identify possible faults. A sledgehammer or small explosive charges will be used to supply the seismic energy. Previous work by Gibson, et al (in press) indicates that the usefulness of geophysical methods at this site is questionable. The work described above may not meet all objectives.

2. In addition, one or more of the boreholes drilled for each of the surface facilities important to safety will be logged for seismic velocities. A down-hole survey utilizing wall-locking geophones will be performed with a sledgehammer or small explosive charges at ground surface, if such geophones are effective in the borehole. Otherwise, an up-hole survey with geophones at the ground surface and small explosive charges down hole, will be used. If the up- or down-hole methods are ineffective and do not provide enough resolution, then a cross-hole method may be attempted. Density logs can also be performed in these holes and correlated with density measurements in the laboratory and field.

The in situ velocity and velocity structure data resulting from these geophysical methods will be used to identify subsurface strata and structure and to calculate the dynamic deformation modulus and Poisson's ratio of the subsurface strata.

Either pseudo-static or more sophisticated soil/rock-structure interaction methods will be used as design tools to consider dynamic loading conditions. The pseudo-static methodology will be sufficient for designing most of the surface and subsurface structures. Since most structures important to safety ,such as the ramp portal, will be embedded in rock, the need for using soil/rock-structure interaction methods of analysis in design are not expected to be necessary. The ramp portal is not expected to be vulnerable because it is embedded in rock; however, the cut slope above the ramp portal will be vulnerable to dynamic loading. Due to the importance to safety, the slope stability analysis methodology will at a minimum consider the dynamic loading conditions as pseudo-static and possibly a numerical modeling approach considering dynamic loading conditions may be appropriate for the conditions encountered.

2.3.3.3 Methods and Technical Procedures

Appropriate standard seismic equipment, data acquisition, and interpretation techniques will be used to perform this work. There are no standardized methods for these techniques, but they are described in the literature.

## 3. CONSTRAINTS ON THE STUDY

The selection of test methods for this investigation was unaffected by possible impacts on the potential repository site except in the selection of the drilling medium and techniques for drill holes along the ramp alignments. If water as a drilling fluid potentially effects other testing, air will be used and drilling techniques will be adjusted accordingly. The type of drilling medium should not effect the sample suitability, quantities, or locations. Exploration for the surface facilities will be shallow and typically consist of test pits and/or auger holes; these will not impact the potential repository site or other tests.

Because all planned tests are standard tests, precision and accuracy of measurements are described in the procedures controlling tests or calibration of equipment. The designs for which the data are being collected are standard practice and standard tests will provide the appropriate precision and accuracy. Where these factors are not clearly defined, they will comply with industry standard practice.

Samples and in situ measurements will be collected at the locations of the structures and should be representative of actual conditions. The selection of test excavation locations and backfilling methods must not compromise the structure foundations.

## 4. APPLICATION OF RESULTS

This section describes how the information obtained in the present study will be used in other site characterization studies. The description is summarized from information detailed in Chapter 8 of the SCP. Related discussions in section 1.2 consider the uses of information from the study in the context of issue resolution and performance goals.

The main application of the results from this soil and rock investigation is to provide the necessary geotechnical information for the design of the ESF surface facilities and subsurface access facilities. The most direct application of the soil and rock characterization activities will be to provide the necessary data to design surface structures, foundations and retaining walls, evaluate the soil-structure interaction (response) due to earthquake loading conditions, and evaluate any potential slope instability conditions. Foundation designs will be necessary for various types of structures, including buildings, shaft collars, shaft headframes, hoist foundations, and ramp portals. Rock characterization data will be used for siting and designing the subsurface ramps and shafts.

Data will be submitted in the form of reports consisting of mapping and testing results, including test pit logs, gradation analyses, geologic maps and cross-sections, testing results, and text describing and discussing findings with conclusions. All data collected will be submitted in accordance with Project procedures. All data, including data supporting test results, will be submitted for final analysis and analytical studies by the design entities.

## 4.1 Resolution of Design and Performance Issues

The data obtained from this investigation will be primarily used in the resolution of Design Issue 4.4 (Preclosure Design and Technical Feasibility). Design Issue 4.4 (SCP 8.3.1.14-2) addresses whether construction, operation, closure, and decommissioning technologies are adequate to resolve performance issues.

The information derived from this investigation will also be used to support the following issues, site characterization investigations, and potential repository design and performance assessment information needs:

| Information need, issue, or investigation | Description |
|---|---|
| 1.11 | Establish characteristics and configurations of the repository and repository engineered barriers (Section 8.3.2.2) |
| 2.3.1 | Determination of credible accidents applicable to the repository (Section 8.3.5.5.1) |

4.2.1 Site and performance information needed for design (Section 8.3.2.4.1)

4.4.1 Site and performance assessment information needed for design, technical feasibility (Section 8.3.2.5.1)

8.3.1.4.3 Development of three-dimensional models of rock characteristics

8.3.1.15.1 Spatial distribution of thermal and mechanical properties

8.3.1.17.3 Potential vibratory ground motion at the site from natural or manmade seismic sources

4.2 Interfaces with Other Site Characterization Plans

Considerable information is required to conduct an assessment of the risk categories identified in SCP Sections 8.3.5.1 and 8.3.5.1.1. This information includes physical property values, design descriptions and objectives, and analytical tools. The resolution strategies for performance Issues 2.1 through 2.3 provide a comprehensive and systematic process for determining the required information needs. As shown in SCP Sections 8.3.5.3 through 8.3.5.5, most of this information is associated with the design of engineered systems and does not require site characterization, environmental monitoring, or socioeconomic monitoring activities. Instead, the goals and expected ranges for this design-related information will be developed as an integral part of the normal design and safety assessment processes. For information to be obtained from site characterization or from the collection of environmental and socioeconomic data, the parameters measured and the methods of satisfying the information needs are contained in study plans appropriate for the discipline or subject area of interest.

The general analytical strategies and approaches for assessing preclosure radiological safety are described in SCP Sections 8.3.5.1.3 and 8.3.5.1.4. The analytical approaches fall within two broad categories: (1) the assessment of radiological risks and releases from accidents and (2) the assessment of radiological risks releases from routine operations. These two general safety assessment analyses may also be applicable to the other risk categories.

As previously described in Section 2.1.1.2, some of the siting and reconnaissance activities for the ESF ramps and ramp portals will be performed under Study Plan activity 8.3.1.4.2.2.4, "Geologic Mapping of the Exploratory Shaft and Drifts". Other Study Plans will also require coordination and interfacing with this Investigation including Study Plan 8.3.1.17.4.2, "Location and Recency of Faulting near Prospective Surface Facilities", and Study Plan 8.3.1.17.2.1, "Faulting Potential at the Repository". The location, extent, and objectives of these seismic surveys must be coordinated with Study Plan 8.3.1.17.2.1 and Study Plan Activity 8.3.1.14.2.3.3, "Geophysical Field Measurement Activity". Data from Study Plan Activity 8.3.1.14.2.3.3 will be used to support Study Plan 8.3.1.17.2.1. Coordination will also be required between Study Plan 8.3.1.17.4.2 and Study Plan Activity 8.3.1.14.2.1.2, "Preliminary and Detailed Exploration Activity", to optimize trench locations so that the objectives of both studies are met and data from each study can be used to supplement the other.

## 5. SCHEDULES AND MILESTONES

The surface and subsurface access soil/rock characterizations investigation includes three studies and seven associated activities. No further studies or activities are planned for the soils/rocks investigation at this time. The schedule for this investigation is presented in Table 5-1 and Figure 5-1. Table 5-1 includes a brief description of each study and the major events associated with these studies and activities. A major event, for purposes of these schedules, may represent the initiation or completion of an activity, completion or submittal of a report to the DOE, an important data feed, or a decision point. The date of completion and duration of events are also presented in Table 5-1. Figure 5-1 diagrams the principal milestones for this study and scheduling ties to other studies. This information is taken from the most current and complete schedule information available.

Table 5-1 and Figure 5-1 provide the temporal relationships of major elements of the activities.

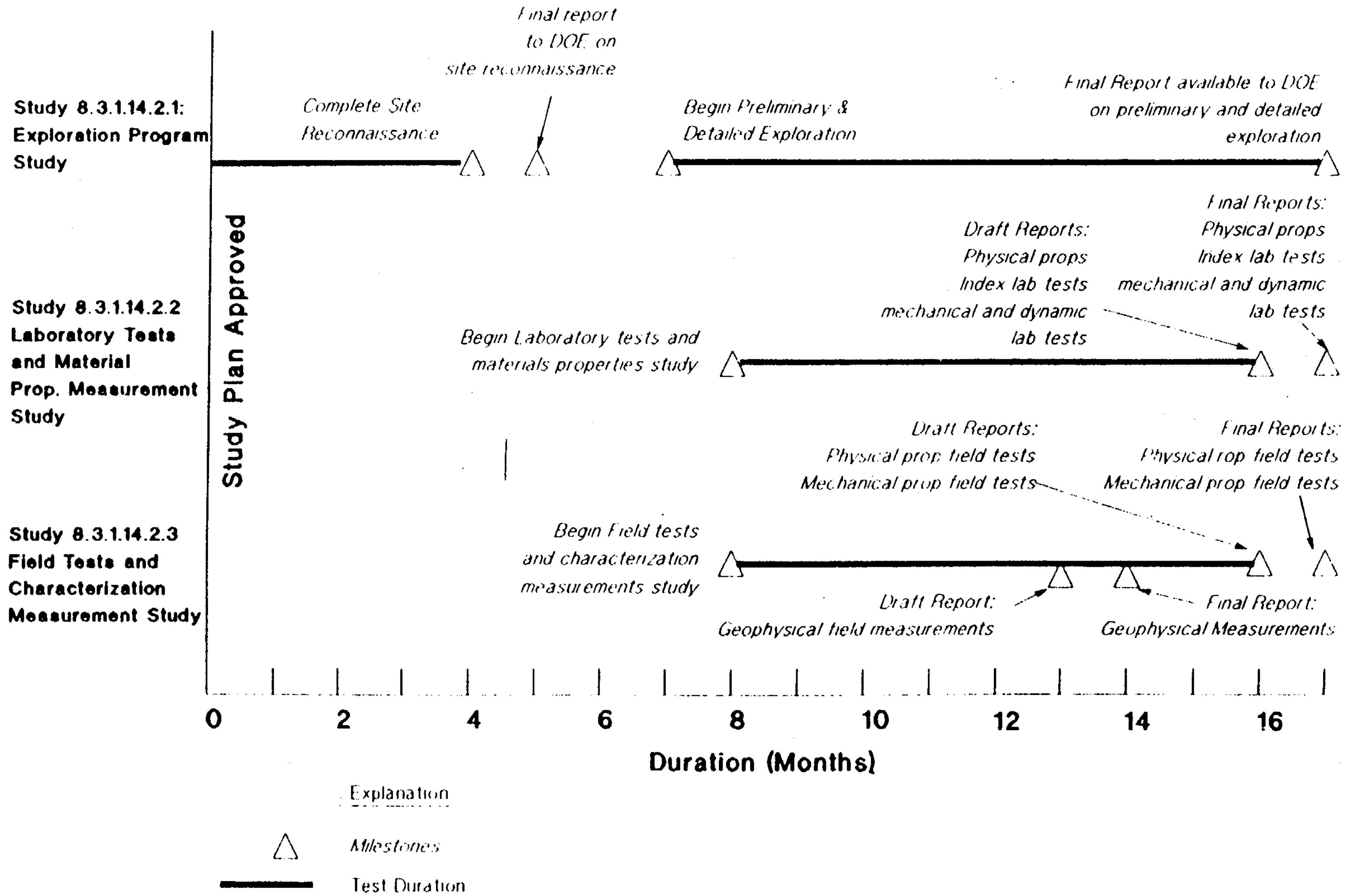


Figure 5-1. Schedule for Studies 8.3.1.14.2.1, 8.3.1.14.2.2, and 8.3.1.14.2.3

Table 5-1 Major events and projected duration until completion for studies in the ESF soil and rock properties investigation (page 1 of 3)

| Study description | Event description | Duration* |
|---|---|---|
| Study Plan approved | | (1) |
| Exploration program study | | |
| Reconnaissance (Non-site disturbing) | Begin site reconnaissance | (1) |
| | Complete site reconnaissance | (4) |
| | Final report available to the U. S. Department of Energy (DOE) on the results of site reconnaissance; (input to ESF Title I design) | (5) |
| Preliminary and Detailed Exploration (Site disturbing) | Begin preliminary and detailed exploration program. Final report available to DOE on the results of site reconnaissance | (7) |
| | Final report available to DOE on the results of preliminary and detailed exploration; (input to ESF Title II design) | (17) |
| Laboratory tests and material properties study | Draft report available to DOE on the results of physical properties and index laboratory testing | (16) |

* Duration in months for completion of event after initiation of Study

Table 5-1 Major events and projected duration till completion for studies in the ESF soil and rock properties investigation (page 2 of 3)

| Study description | Event description | Duration* |
|---|---|---|
| | Draft report available to DOE on the results of mechanical and dynamic laboratory property testing | (16) |
| | Final of updated report on physical properties and index laboratory testing available to DOE | (17) |
| | Final of updated report on mechanical and dynamic laboratory property testing available to DOE | (17) |
| Field tests and characterization measurements study | Draft report available to DOE on the results of physical property field tests | (16) |
| | Draft report available to DOE on the results of mechanical properties field tests | (16) |
| | Draft report available to DOE on geophysical field measurements | (13) |

* Duration in months for completion of event after initiation of Study

Table 5-1 Major events and projected duration till completion for studies in the ESF soil and rock properties investigation (page 3 of 3)

| Study description | Event description | Duration* |
|---|---|---|
| | Final of updated report on the results of physical property field tests available to DOE | (17) |
| | Final of updated report on the results of mechanical properties field tests available to DOE | (17) |
| | Final report on geophysical field measurements available to DOE | (14) |

* Duration in months for completion of event after initiation of Study

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## APPENDIX A

FIGURE A-1. LOGIC DIAGRAM SHOWING RELATION OF STUDIES 8.3.1.14.2.12.3 TO THE SURFACE CHARACTERISTICS PROGRAM, PERFORMANCE AND DESIGN ISSUES, AND OTHER ACTIVITIES

TABLE 8.3.1.14-1. FROM THE SCP (PERFORMANCE ALLOCATION FOR SITE SURFACE CHARACTERIZATION PARAMETERS AND THE CORRESPONDING PERFORMANCE OR DESIGN PARAMETERS AND ISSUES THEY SUPPORT)

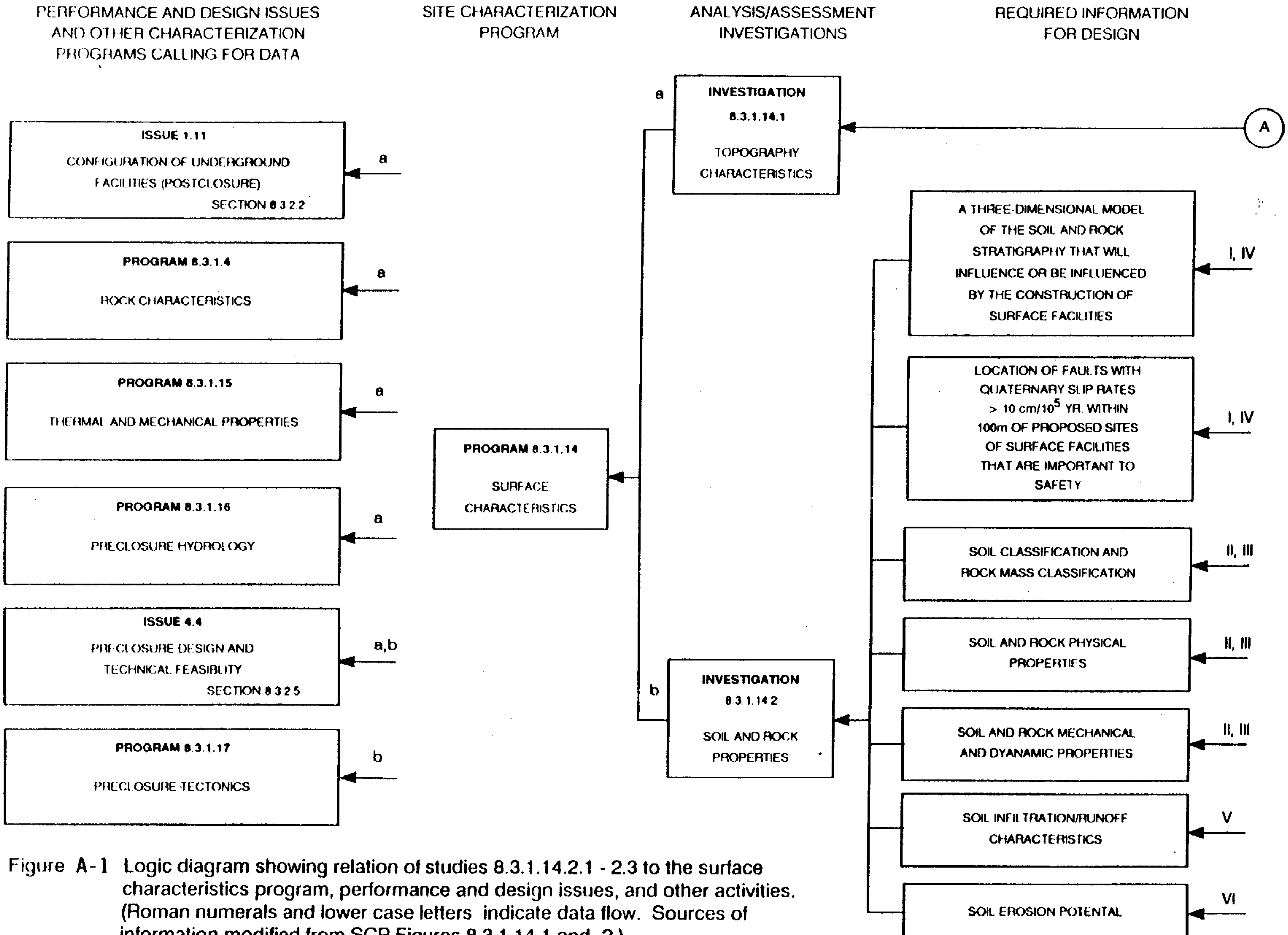


Figure A-1 Logic diagram showing relation of studies 8.3.1.14.2.1 - 2.3 to the surface characteristics program, performance and design issues, and other activities. (Roman numerals and lower case letters indicate data flow. Sources of information modified from SCP Figures 8.3.1.14-1 and -2.)

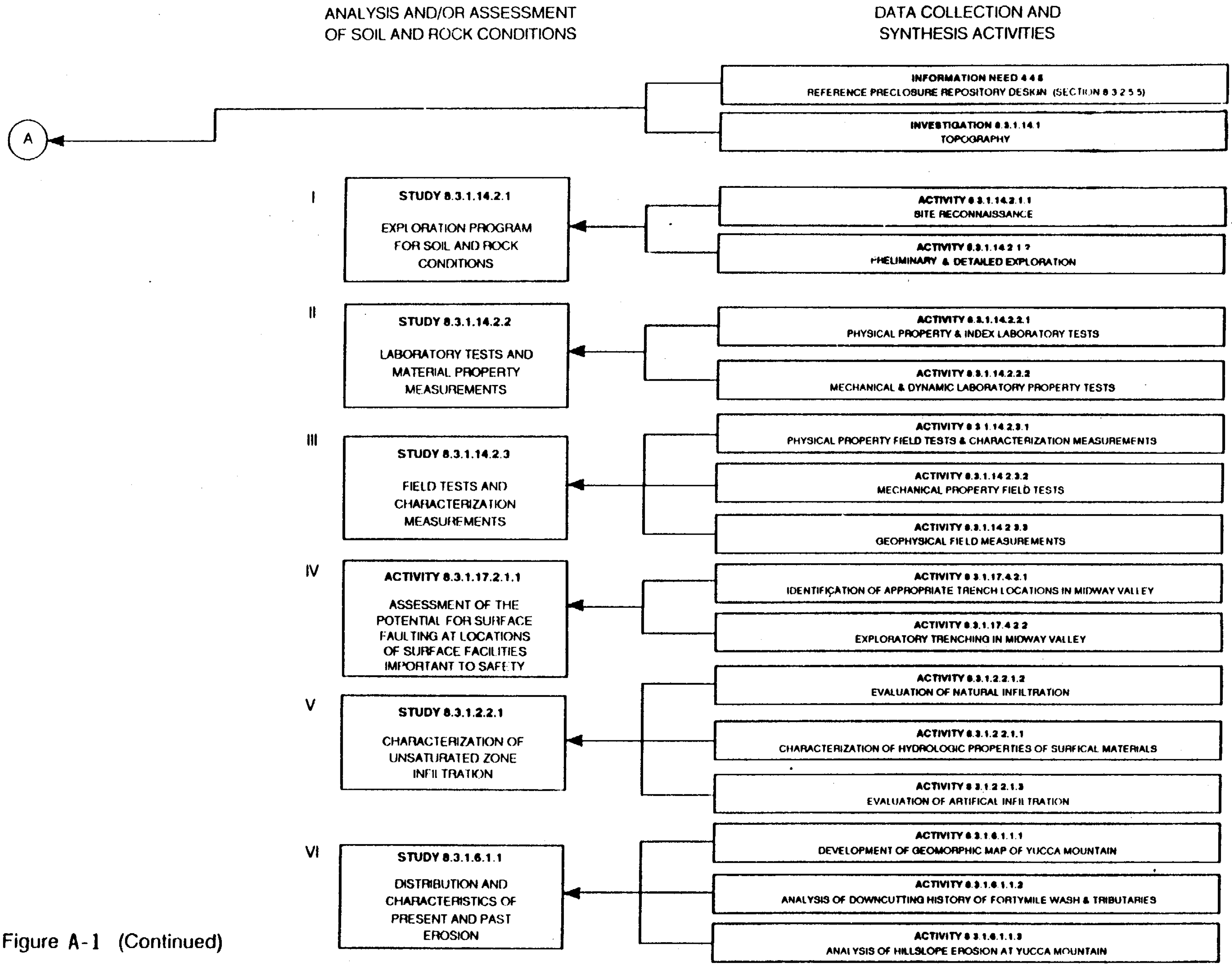


Figure A-1 (Continued)

Table 8.3.1.14-1. Performance allocation for site surface characterization parameters and the corresponding performance or design parameters and issues they support[a] (page 1 of 12)

| Issue or program | SCP section | Performance or design parameters[b] | Characterization parameters (key column) | Current estimate | Current confidence | Needed confidence | Study or activity providing data |
|---|---|---|---|---|---|---|---|
| | | | GEOMETRICAL PARAMETERS | | | | |
| 1.11<br>4.4<br><br><br>8.3.1.4<br>8.3.1.15<br>8.3.1.16 | 8.3.2.2.1<br>8.3.2.2.3<br>8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7<br>8.3.1.4.3<br>8.3.1.15.3<br>8.3.1.16.1 | Surface topography at facility locations (1-m contour interval) | Surface topography at facility locations (1-m contour interval) | 20-ft contour interval topographic map (see Figure 4-3 of the SCP-CDR (SNL, 1987)) | Medium | Medium | No further studies are planned. Topographical measurements have been made and topographic maps are forthcoming |
| 4.4 | 8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7 | Allowable foundation bearing capacity in soil | | | | | |
| | | Allowable foundation bearing capacity in rock | | | | | |
| | | Active and passive soil pressures on a wall | | | | | |
| | | Active and passive rock pressures on a wall | | | | | |
| | | Factor of safety of slope (soil) | | | | | |
| | | Factor of safety of slope (rock) | | | | | |
| 4.4<br><br><br>8.3.1.16 | 8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7<br>8.3.1.16.1 | Surface topography of access routes (2-m contour intervals) | Surface topography of access routes (2-m contour intervals) | 20-ft contour interval topographic map (see Figures 4-2 and 4-3 of the SCP-CDR (SNL, 1987)) | Medium | Medium | No further studies are planned. Topographical measurements have been made and topographic maps are forthcoming |

Table 8.3.1.14-1. Performance allocation for site surface characterization parameters and the corresponding performance or design parameters and issues they support[a] (page 2 of 12)

| Issue or program | SCP section | Performance or design parameters[b] | Characterization parameters (key column) | Current estimate | Current confidence | Needed confidence | Study or activity providing data |
|---|---|---|---|---|---|---|---|
| | | **GEOMETRICAL PARAMETERS (continued)** | | | | | |
| 4.4 | 8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7 | Factor of safety of slope (soil) | | | | | |
| | | Factor of safety of slope (rock) | | | | | |
| | | **SOIL PARAMETERS** | | | | | |
| | | Allowable foundation bearing capacity in soil | Alluvial stratigraphy<br>Layering<br>Thickness<br>Geometry | General stratigraphic description: Top 0.1 to 0.7 m is loose fine-grained sandy soil overlying approximately 2 m of material that is partly to wholly cemented with calcite (caliche). Below the caliche layer is an 10 to 50 m thick layer of dense sandy gravel alluvial material which overlies the ashflow tuff bedrock (Section 6.3.2.1.2) | Low | Medium | 8.3.1.14.2.1.1,<br>8.3.1.14.2.1.2,<br>8.3.1.14.2.1.3,<br>8.3.1.14.3.3 |
| | | Active and passive soil pressure on a wall | | | | | |
| | | Factor of safety of slope (soil) | | | | | |
| 4.4 | 8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7 | Soil-structure interaction for foundation[c] | | | | | |
| 8.3.1.17 | 8.3.1.17.3 | Soil-structure interaction for retaining wall[e] | | | | | |
| 4.4 | 8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7 | Magnitude of time dependent settlement in soils below earthfills[d] | | | | | |
| | | Magnitude of swell in subgrade soils[d] | | | | | |
| | | Magnitude of soil collapse[d] | | | | | |
| | | Soil liquefaction potential[d] | | | | | |
| | | Identification of any fault within 100 m of facilities important to safety (FITS) with greater than 1 chance in 100 of producing more than 5 cm of surface displacement in 100 yr | Alluvial faulting (the study for this characterization parameter is developed in Section 8.3.1.17.4.2 (preclosure tectonics))<br>Location<br>Orientation | See Section 8.3.1.17.4.2 in preclosure tectonics | Low | High | See Study 8.3.1.17.4.2 (Location and recency of faulting near prospective surface facilities) |

Table 8.3.1.14-1. Performance allocation for site surface characterization parameters and the corresponding performance or design parameters and issues they support[a] (page 3 of 12)

| Issue or program | SCP section | Performance or design parameters[1] | Characterization parameters (key column) | Current estimate | Current confidence | Needed confidence | Study or activity providing data |
|---|---|---|---|---|---|---|---|
| | | | SOIL PARAMETERS (continued) | | | | |
| | | Allowable foundation bearing capacity in soil | Soil classification vs depth | | | | |
| | | Active and passive soil pressure on a wall | Soil gradation | GP GM[e] | Low | Medium | 8.3.1.14.2.2.1 |
| | | Factor of safety of slope (soil) | Atterberg limits[d] | From preliminary investigations, no cohesive soils have been found | Low | Medium | |
| | | Soil structure interaction for foundation[b] | | | | | |
| | | Soil structure interaction for retaining wall[b] | | | | | |
| | | Magnitude of time dependent settlement in soils below earthfills[d] | | | | | |
| | | Magnitude of swell in subgrade soils[d] | | | | | |
| | | Magnitude of soil collapse[d] | | | | | |
| | | Soil liquefaction potential[d] | | | | | |
| | | Allowable foundation bearing capacity in soil | Physical properties vs depth | | | | 8.3.1.14.2.2.1, 8.3.1.14.2.3.1 |
| | | Active and passive soil pressure on a wall | In situ density | 101-112 pcf | Low | Medium | |
| | | | Relative density | Not available | Low | Medium | |
| | | | Moisture content | 7-26 | Low | Medium | |
| | | Factor of safety of slope (soil) | Percent saturation | 47-36 | Low | Medium | |
| | | | Specific gravity | 2.43 | Low | Medium | |
| | | Soil structure interaction for foundation[c] | | | | | |
| | | Soil structure interaction for retaining wall[c] | | | | | |
| | | Magnitude of time dependent settlement in soils below earthfills[f] | | | | | |

Table 8.3.1.14-1. Performance allocation for site surface characterization parameters and the corresponding performance or design parameters and issues they support[a] (page 4 of 12)

| Issue or program | SCP section | Performance or design parameters[b] | Characterization parameters (key column) | Current estimate | Current confidence | Needed confidence | Study or activity providing data |
|---|---|---|---|---|---|---|---|
| | | | SOIL PARAMETERS (continued) | | | | |
| | | Magnitude of swell in subgrade soils[d] | | | | | |
| | | Magnitude of soil collapse[d] | | | | | |
| | | Soil liquefaction potential[d] | | | | | |
| | | Allowable foundation bearing capacity in soil | Compaction characteristics | | | | |
| | | Active and passive soil pressure on a wall<br>Magnitude of soil collapse[d] | Compaction curves for potential fill material including maximum dry density ($\gamma_d$) and optimum water content | $\gamma_d$ (max) = 108-114 pcf<br>Optimum water content = 12-15% | Low<br>Low | Medium<br>Medium | 8.3.1.14.2.2.1 |
| | | | Mechanical and dynamic properties vs. depth for undisturbed and recompacted soils | | | | |
| 4.4<br>8.3.1.17 | 8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7<br>8.3.1.17.3 | Allowable foundation bearing capacity in soil<br>Soil structure interaction for foundation[e] | Young's modulus (static and dynamic) | 10,000-20,000 psi (static) (Ho et al., 1986)<br>192,000 psi (dynamic calculated from Vp) | Low | Medium | 8.3.1.14.2.2.2,<br>8.3.1.14.3.2,<br>8.3.1.14.2.3.1 |
| | | Soil structure interaction for retaining wall[c]<br>Soil liquefaction potential[d] | Poisson's ratio (static and dynamic) | 0.3-0.35 (static) (Ho et al., 1986)<br>0.286 (dynamic) (Neal, 1986) | Low | Medium | 8.3.1.14.2.2.2,<br>8.3.1.14.2.3.1 |

Table 8.3.1.14-1. Performance allocation for site surface characterization parameters and the corresponding performance or design parameters and issues they support[a] (page 5 of 12)

| Issue or program | SCP section | Performance or design parameters[b] | Characterization parameters (key column) | Current estimate | Current confidence | Needed confidence | Study or activity providing data |
|---|---|---|---|---|---|---|---|
| | | | SOIL PARAMETERS (continued) | | | | |
| | | Soil structure interaction for foundation[c]<br>Soil-structure interaction for retaining wall[e]<br>Soil liquefaction potential[d] | Compressive wave velocity (Vp) and shear wave velocity (Vs) (these parameters will be used to calculate the dynamic elastic characterization parameters: Young's modulus, shear modulus, and Poisson's ratio). | Vp = 3,300 ft/sec (Neal, 1986)<br>Vs = 1,800 ft/sec (Neal, 1986) | Medium | High | 8.3.1.14.2.3.1 |
| | | | Shear modulus (static and dynamic) | 3,700-7,700 psi (static-calculated)<br>74,100 psi (dynamic-calculated from Vs) | Low | Medium | 8.3.1.14.2.3.3 |
| | | | Damping | Not available | Low | Medium | 8.3.1.14.2.3.3 |
| 4.4 | 8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7 | Allowable foundation bearing capacity in soil<br>Active and passive soil pressure on a wall<br>Factor of safety of slope (soil)<br>Soil-structure interaction for foundation[c]<br>Soil structure interaction for retaining wall[e] | Mohr-Coulomb strength parameters in terms of cohesion (c) and angle of friction (φ) | c = 500 psf (cemented)<br>φ = 33 to 37° | Low | High | 8.3.1.14.2.2.2 |
| | | Allowable foundation bearing capacity in soil | Plate load bearing pressure vs settlement | Not available | Low | Medium | |

Table 8.3.1.14-1. Performance allocation for site surface characterization parameters and the corresponding performance or design parameters and issues they support[a] (page 6 of 12)

| Issue or program | SCP section | Performance or design parameters[b] | Characterization parameters (key column) | Current estimate | Current confidence | Needed confidence | Study or activity providing data |
|---|---|---|---|---|---|---|---|
| | | | CONTINGENT SOIL PARAMETERS | | | | |
| | | | The following characterization parameters are contingent parameters (see footnote d) | | | | |
| 4.4 | 8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7 | Soil structure interaction for foundation[e] | Other strength parameters such as Drucker-Prager, etc. (if required)[d] | Not available | Low | Medium | 8.3.1.14.2.2.2 |
| 8.3.1.17 | 8.3.1.17.3 | Soil structure interaction | Bulk modulus and constrained modulus[d] | Not available | Low | Medium | 8.3.1.14.2.2.2 |
| | | Soil liquefaction potential[d] | Strength and stress-deformation characteristics under dynamic load conditions evaluated as a function of stress rate, confinement stress, initial static stress level, magnitude of pulsating stress, number of stress cycles, and frequency of loading[d] | Not available | Low | Medium | 8.3.1.14.2.2.2 |
| | | | Dynamic shear modulus as a function of strain and confinement stress[d] | Not available | Low | High | 8.3.1.14.2.2.2, 8.3.1.14.2.3.3 |
| | | | Damping as a function of strain[d] | Not available | Low | High | 8.3.1.14.2.2.2, 8.3.1.14.2.3.3 |
| | | | Shear wave velocities as a function of strain[d] | Not available | Low | High | 8.3.1.14.2.2.2, 8.3.1.14.2.3.3 |
| | | | Deformation modulus in terms of stress-strain characteristics and confinement stress conditions[d] | Not available | Low | High | 8.3.1.14.2.2.2 |

Table 8.3.1.14-1. Performance allocation for site surface characterization parameters and the corresponding performance or design parameters and issues they support[a] (page 7 of 12)

| Issue or program | SCP section | Performance or design parameters[b] | Characterization parameters (key column) | Current estimate | Current confidence | Needed confidence | Study or activity providing data |
|---|---|---|---|---|---|---|---|
| | | | CONTINGENT SOIL PARAMETERS (continued) | | | | |
| 4.4 | 8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7 | Soil liquefaction potential[d] | Liquefaction parameters, cyclic shearing stress ratio, cyclic deformation, and pore-pressure response (this information will not be needed if there are no perched water bodies near the ground surface)[d] | Not available | Low | Medium | 8.3.1.14.2.2.2 |
| | | Allowable foundation bearing capacity in soil<br><br>Soil-structure interaction for foundation[c]<br><br>Soil-structure interaction for retaining wall[c] | Modulus of subgrade reaction from plate load test (static and dynamic)[d] | 200-300 pci | Low | Medium | 8.3.1.14.2.3.2 |
| | | Allowable foundation bearing capacity in soil<br><br>Magnitude and rate of time dependent settlement below earthfills[d] | Compression and swell index (for saturated clayey soils if they are encountered) | Not available | Low | Medium | 8.3.1.14.2.2.2 |
| | | Magnitude of swell in subgrade soils below roads[d] | Coefficient of consolidation (for saturated clayey soils if they are encountered)[d] | Not available | Low | Medium | 8.3.1.14.2.2.2 |
| | | Allowable foundation bearing capacity in soil<br><br>Magnitude of soil collapse below surface facilities (foundations, earthfills, and roads) due to saturation and/or loading[d] | Collapse potential (for relative dry low density soils)[d] | Not available | Low | Medium | 8.3.1.14.2.2.2 |

Table 8.3.1.14-1. Performance allocation for site surface characterization parameters and the corresponding performance or design parameters and issues they support[a] (page 8 of 12)

| Issue or program | SCP section | Performance or design parameters[b] | Characterization parameters (key column) | Current estimate | Current confidence | Needed confidence | Study or activity providing data |
|---|---|---|---|---|---|---|---|
| | | | OTHER SOIL PARAMETERS | | | | |
| | | Favorable hydraulic induced soil erosion characteristics | Erosion potential | <13 m/100 yr of scour around bridge piers<br><5 m/100 yr of bed erosion<br><1 m/100 yr of sheet erosion | Low | Medium | 8.3.1.6.1.1.2,<br>8.3.1.6.1.1.3 |
| | | Favorable infiltration/runoff ratio | Infiltration/runoff ratio | See Section 8.3.1.12 (meteorology) and 8.3.1.2 (geohydrology) | Low | Medium to high | See Section 8.3.1.12 (meteorology) and 8.3.1.2 (geohydrology) |
| | | | ROCK PARAMETERS | | | | |
| 4.4<br><br><br>8.3.1.17 | 8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7<br>8.3.1.17.3 | Allowable foundation bearing capacity in rock<br>Active and passive rock pressure on a wall<br>Factor of safety of slope (rock)<br>Rock-structure interaction for foundation[e]<br>Rock-structure interaction for retaining wall[e] | Rock stratigraphy<br>Rock type<br>Layering<br>Thickness<br>Geometry | See Figure 6-6 in the SCP and Figures 5 and 7 in Neal (1986) | Low | Medium | 8.3.1.14.2.1.1,<br>8.3.1.14.2.1.2,<br>8.3.1.14.2.1.3,<br>8.3.1.14.2.3.3 |
| 4.4 | 8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7 | Allowable foundation bearing capacity in rock<br>Active and passive rock pressure on a wall<br>Factor of safety of slope (rock) | Rock structure<br>Quantitative description of faults<br>Location<br>Orientation<br>Aperture<br>Type of infilling<br>Moisture and/or seepage conditions<br>Waviness and roughness | Not available | Low | High | 8.3.1.14.2.1.2,<br>8.3.1.14.2.1.3,<br>8.3.1.14.2.3.1 |

Table 8.3.1.14-1. Performance allocation for site surface characterization parameters and the corresponding performance or design parameters and issues they support[a] (page 9 of 12)

| Issue or program | SCP section | Performance or design parameters[b] | Characterization parameters (key column) | Current estimate | Current confidence | Needed confidence | Study or activity providing data |
|---|---|---|---|---|---|---|---|
| | | | ROCK PARAMETERS (continued) | | | | |
| | | | Quantitative description of joints<br>Number of joint sets<br>Spacing of joints for each set<br>Orientation of each joint set<br>Type of infilling if any<br>Moisture and/or seepage conditions<br>Waviness and roughness<br>Persistence<br>Drill core (total core recovery, discontinuity, frequency, and rock quality designation (RQD)) | Not available | | | |
| | | Allowable foundation bearing capacity in rock<br>Active and passive rock pressure on a wall<br>Rock-structure interaction for foundation[e]<br>Rock-structure interaction for retaining wall[e] | Rock mass classification<br>Rock mass rating (RMR)[f]<br>Tunneling quality index (Q)[f] | Not available | Low | Medium | 8.3.1.14.2.3.1 |
| | | Allowable foundation bearing capacity in rock<br>Active and passive rock pressure on a wall<br>Factor of safety of slope (rock)<br>Rock structure interaction for foundation[c]<br>Rock-structure interaction for retaining wall[e] | Physical properties vs. depth | | | | |
| | | | Density (dry) | 2.23 gm/cc or 139 lb/ft³ | Low | Medium | 8.3.1.14.2.2.1 |
| | | | Percent saturation | 67% ± 23% | Low | Medium | |
| | | | Porosity | 11% ± 4% | Low | Medium | |
| | | | Specific gravity | 2.51 ± 0.04 | Low | Medium | |
| | | | Mechanical and dynamic properties | | | | |

Table 8.3.1.14-1. Performance allocation for site surface characterization parameters and the corresponding performance or design parameters and issues they support[a] (page 10 of 12)

| Issue or program | SCP section | Performance or design parameters[b] | Characterization parameters (key column) | Current estimate | Current confidence | Needed confidence | Study or activity providing data |
|---|---|---|---|---|---|---|---|
| | | **ROCK PARAMETERS (continued)** | | | | | |
| | | Allowable foundation bearing capacity in rock<br>Rock-structure interaction for foundation[c]<br><br>Magnitude of soil collapse below surface facilities[d] | Plate load bearing pressure vs. settlement | Not available | Low | Medium | 8.3.1.14.2.3.2 |
| | | Allowable foundation bearing capacity in rock<br>Factor of safety of slope (rock)<br>Rock-structure interaction for foundation[c]<br>Rock-structure interaction for retaining wall[c] | Peak and residual failure envelopes derived from uniaxial and triaxial compression tests | c (peak) = 26.0 ±10.13 MPa (range)<br>ϕ (peak) = 44.7° ±0.20° (range)<br>Tensile strength = 9.3 MPa<br>Unconfined compressive strength = 120 ± 82 MPa (range) | Low | High | 8.3.1.14.2.2.2 |
| | | Allowable foundation bearing capacity in rock<br>Active and passive rock pressure on a wall<br>Factor of safety of slope (rock) | Discontinuity shear strength in terms of c and ϕ | c = 0.1 MPa < 0.1 (range)<br>ϕ = 28.4 (range 11.3° - 38.7° | Medium | High | 8.3.1.14.2.2.2 |
| 4.4<br><br><br>8.3.1.17 | 8.3.2.5.1<br>8.3.2.5.5<br>8.3.2.5.7<br>8.3.1.17.3 | Allowable foundation bearing capacity in rock<br><br>Rock-structure interaction for foundation[c] | Young's modulus (static and dynamic | 20.0 GPa ± 5.55 (range) - static rock mass (SCP, Chapter 6)<br>2.94 GPa (calculated from in situ Vp) | Low | Medium | 8.3.1.14.2.2.2,<br>8.3.1.14.2.3.2,<br>8.3.1.14.2.3.3 |
| | | Rock-structure interaction for retaining wall[c] | Poisson's ratio | 0.24 (laboratory-static) (SCP, Chapter 6)<br>0.319 (in situ calculated from Vp and Vs) (Neal, 1986) | Low | Medium | 8.3.1.14.2.2.2,<br>8.3.1.14.2.3.3 |
| | | Rock-structure interaction for foundation[c]<br>Rock-structure interaction for retaining wall[c] | Shear modulus (static and dynamic) | 8.1 GPa ± 2.2 (range) - static rock mass<br>1.1 GPa (calculated from in situ Vs) | Low | Medium | 8.3.1.14.2.2.2,<br>8.3.1.14.2.3.3 |

Table 8.3.1.14-1. Performance allocation for site surface characterization parameters and the corresponding performance or design parameters and issues they support[a] (page 11 of 12)

| Issue or program | SCP section | Performance or design parameters[b] | Characterization parameters (key column) | Current estimate | Current confidence | Needed confidence | Study or activity providing data |
|---|---|---|---|---|---|---|---|
| | | | **ROCK PARAMETERS (continued)** | | | | |
| | | Rock-structure interaction for foundation[c]<br>Rock-structure interaction for retaining wall[e] | Compressive wave velocities vs depth | Vp = 7,500 - 9,000 ft/sec (laboratory) (Neal, 1986) | Low | High | 8.3.1.14.2.2.2,<br>8.3.1.14.2.3.3 |
| | | | | Vp = 4,500 ft/sec (in situ) (Neal, 1986) | Low | High | |
| | | | Shear wave velocities vs depth (the compressive and shear wave velocities will be used to calculate the dynamic elastic characterization parameters: Young's modulus, shear modulus, and Poisson's ratio) | Vs = 4,390 - 5,790 ft/sec (laboratory-calculated) | Low | High | 8.3.1.14.2.2.2,<br>8.3.1.14.2.3.3 |
| | | | | Vs = 2,320 ft/sec (in situ calculated) | Low | High | |
| | | | Damping vs depth | Not available | Low | High | 8.3.1.14.2.2.2,<br>8.3.1.14.2.3.3 |
| | | | **CONTINGENT ROCK PARAMETERS** | | | | |
| | | | The following characterization parameters are contingent parameters (see footnote (d)) | | | | |
| | | Rock-structure interaction for foundation[e]<br>Rock-structure interaction for retaining wall[c] | Shear wave velocities as a function of strain[d] | Not available | Low | High | 8.3.1.14.2.2.2,<br>8.3.1.14.2.3.3 |
| | | | Dynamic shear modulus as a function of strain[d] | Not available | Low | High | 8.3.1.14.2.2.2,<br>8.3.1.14.2.3.3 |
| | | | Damping as a function of strain[d] | Not available | Low | High | 8.3.1.14.2.2.2,<br>8.3.1.14.2.3.3 |

Table 8.3.1.14-1. Performance allocation for site surface characterization parameters and the corresponding performance or design parameters and issues they support[a] (page 12 of 12)

Footnotes

[a]This table is organized around column 4, characterization parameters, as the "key" column. The parameter listed in this column "feeds" characterization data to the design and performance parameters listed in column 3, performance or design parameters. Conversely, the resolution of the performance or design issues listed in column 3 requires data input from the characterization parameter specified in column 4 (key column).

[b]See Table 8.3.2.5-1 for complete description of performance and design parameter.

[c]If the alluvium or rock adjacent to the foundation has shear velocities greater than 3,500 ft/sec, then a soil structure interaction analysis will probably not be necessary.

[d]The need for these design and performance parameters or characterization parameters are contingent on the soil and rock conditions encountered, function or design requirements of the surface facilities, types of foundations selected, and the sophistication or type of analyses used in the design or performance studies. However, based on the sites preliminary surface soil and rock data and the type of foundations which are recommended in the SCP-CDR (SNL, 1987), the paramters are currently not needed.

[e]GP - poorly graded gravel. GM - silty gravel.

[f]RMR - rock mass rating from CSIR (South African Council for Scientific and Industrial Research) Geomechanics Classification. Q - NGI (Norwegian Geotechnical Institute) tunneling quality index.

# APPENDIX B

## SELECTED GEOTECHNICAL RESULTS FROM THE HO ET AL., 1986, REPORT

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

By

D. M. Ho, R. L. Sayre, and C. L. Wu
of
Bechtel National, Inc.
P.O. Box 3965
San Francisco, CA 94119

For

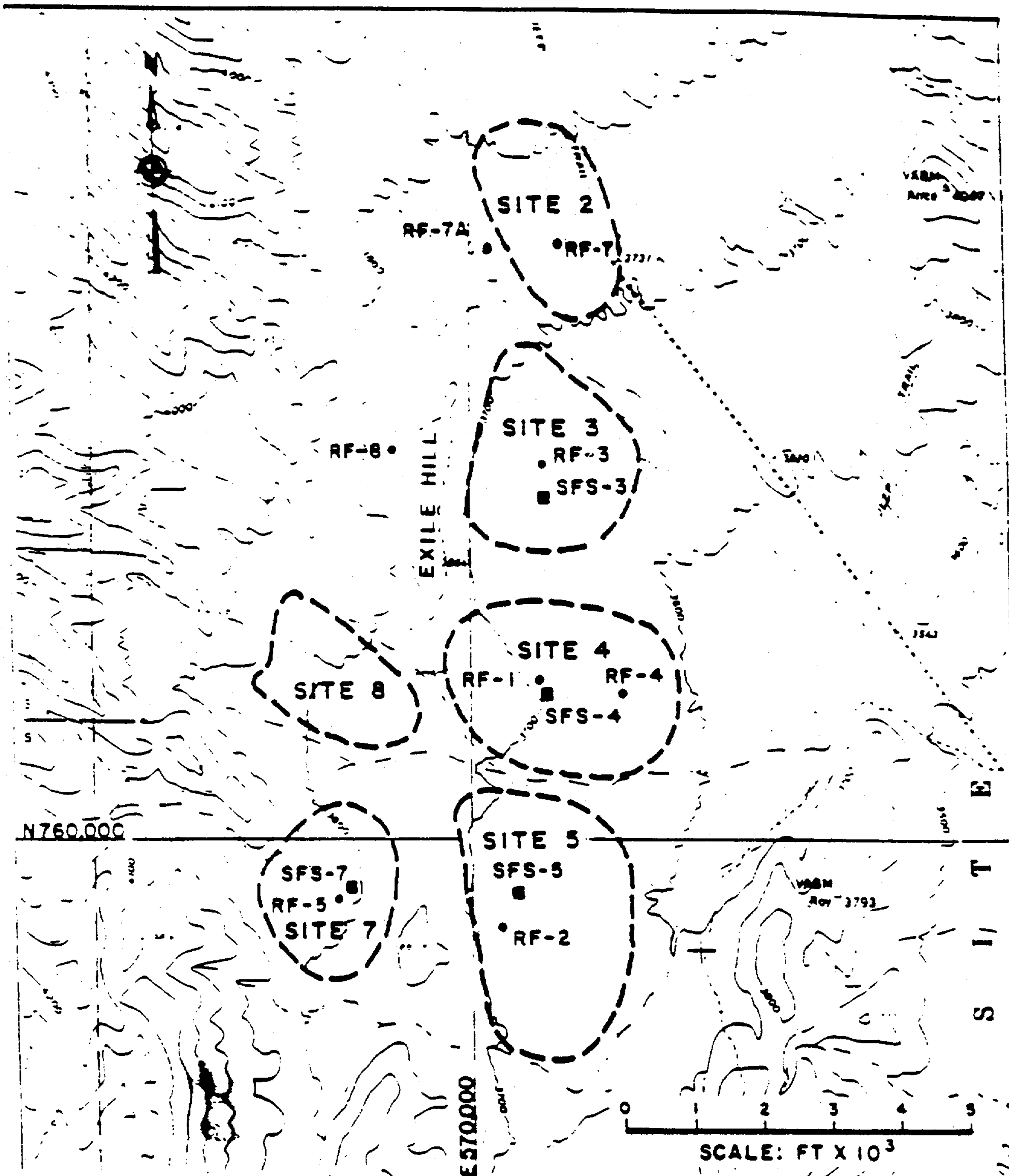
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185

Under Sandia Contract: 21-6932

Sandia Contract Monitor
C. V. Subramanian

## ABSTRACT

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




KEY

■ SFS TEST PITS

• RF BORINGS

(SOURCE OF DATA: SNL)

TUFF REPOSITORY SURFACE FACILITIES

LOCATION OF TEST PITS

16039 FIGURE 1

# 4.0 RESULTS

## 4.1 Geologic Logs of Test Pits

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

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

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

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

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

## 4.2 Results of Field and Laboratory Testing

### 4.2.1 Field Test Results

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

### 4.2.2 Laboratory Test Results

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

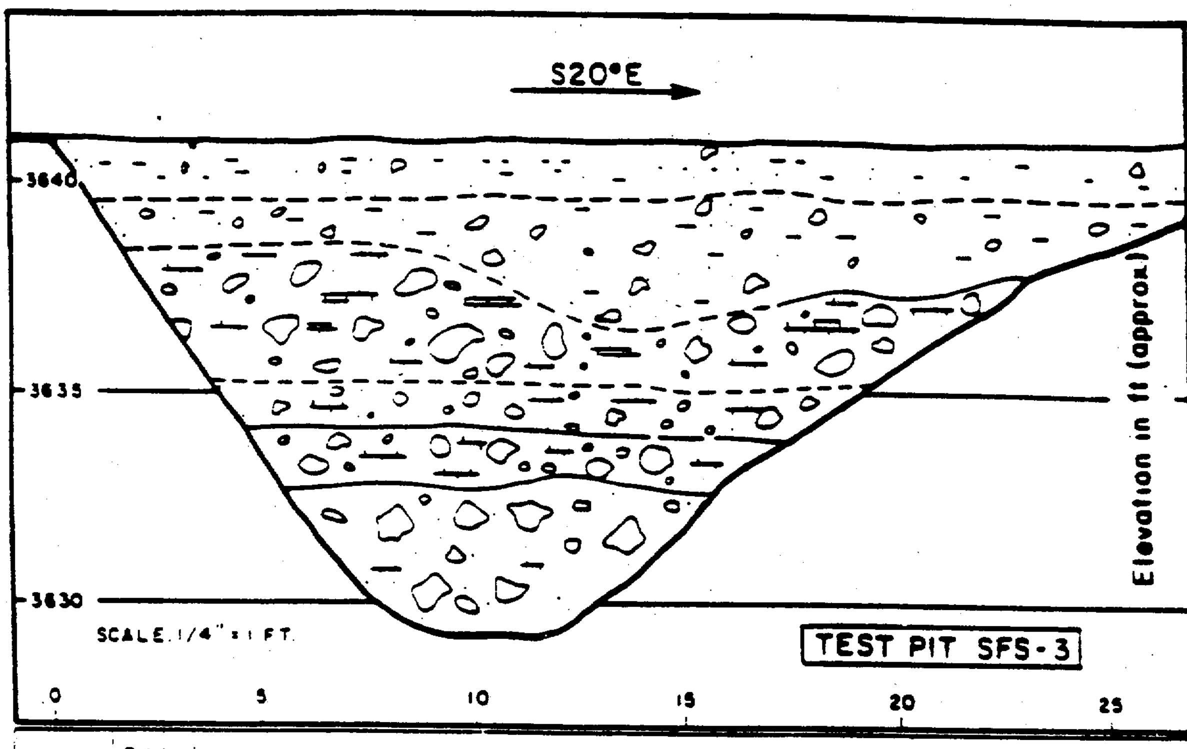
# TEST PIT LOG

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

Ground El.: 3641  Location: N [illegible], [illegible]50

Depth of Pit: 12 FT  E [illegible], 941

Date Excavated: [illegible] 2/84  Method of Excavation: BANTAM 4-26 BACKHOE




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

**FIGURE 2**

**GEOLOGIC LOGS OF TEST PITS**

**SHEET 1 OF 4** | **TEST PIT SFS-3**

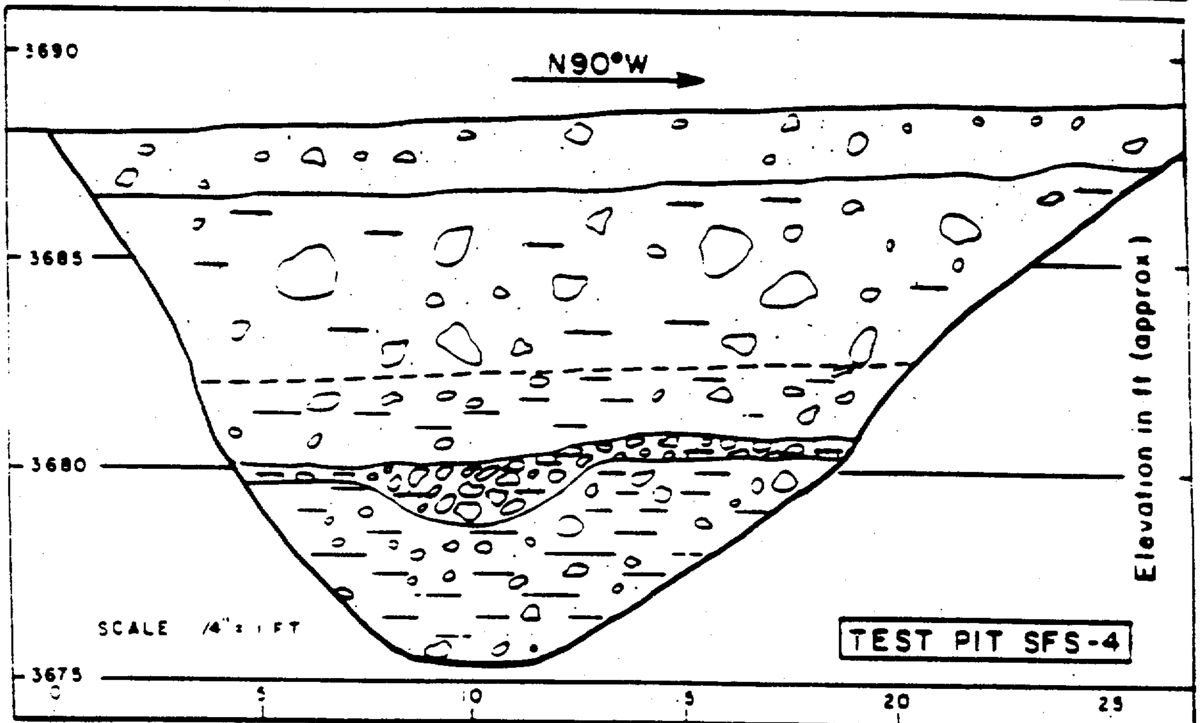
# TEST PIT LOG

Project: TUFF REPOSITORY-SURF. FACILITIES  Job No: [illegible]  **TEST PIT NO.** [illegible]

Ground E.: 3688 FT  Location: N 762,190

Depth of Pit: 13 FT  E 570,390

Date Excavated: 5 1.84  Method of Excavation: BANTAM [illegible] BACKHOE




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

**FIGURE 2**

**GEOLOGIC LOGS OF TEST PITS**

**SHEET 2 OF 4** | **TEST PIT SFS-4**

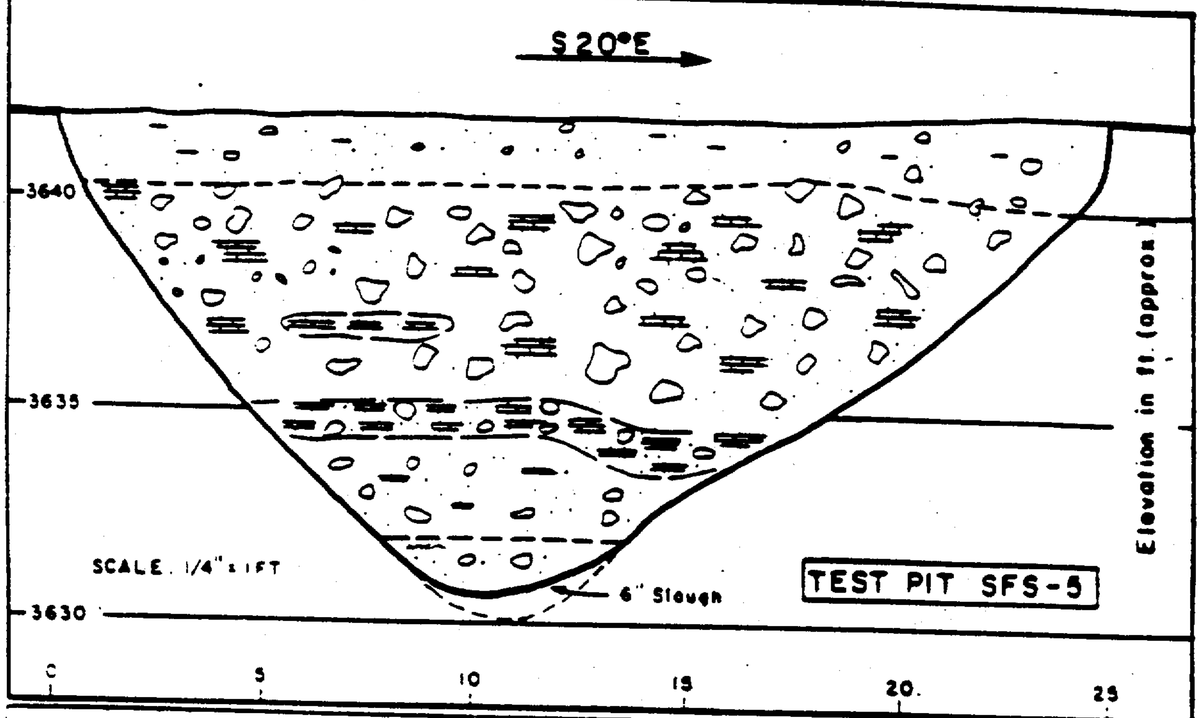
# TEST PIT LOG

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

Ground El.: 3642 FT — Location: N 759,[illegible]38

Depth of Pit: 12 FT — E 570,[illegible]98

Date Excavated: [illegible] — Method of Excavation: [illegible] BACKHOE




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

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

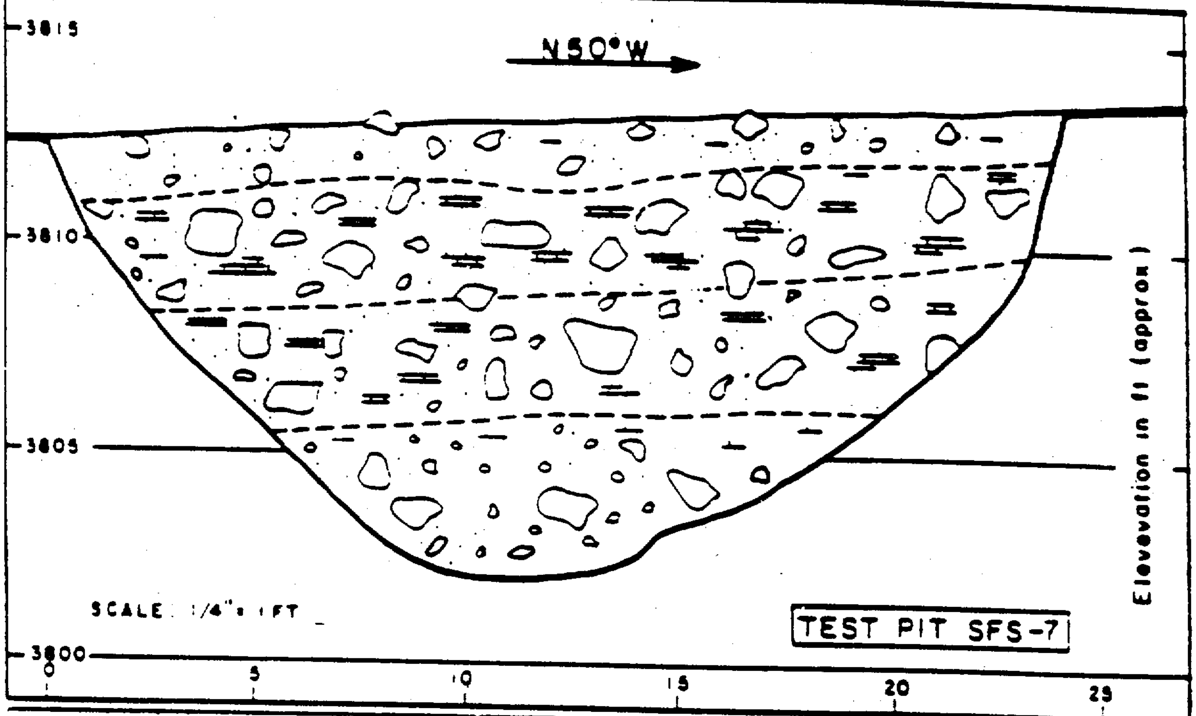
**FIGURE 2**

**GEOLOGIC LOGS OF TEST PITS**

**SHEET 3 OF 4** | **TEST PIT SFS-5**

# TEST PIT LOG

Project [illegible] REPOSITORY [illegible] Job No [illegible] **TEST PIT NO.** SFS-7
Ground El. 3813 FT Location [illegible]
Depth of Pit [illegible] [illegible]
Date Excavated [illegible]/3/84 Method of Excavation BANTAM [illegible]-26 BACKHOE




| Depth Feet | Sample Type and Number | Symbol | Description | Remarks |
|---|---|---|---|---|
| 0-1.5 | | | SAND, grayish-brown, fine-grained, silty, with gravel, cobbles and boulders (topsoil). | A and B horizons |
| 1.5-7 | B-1 | | GRAVEL, tan to light brown, with numerous angular volcanic cobbles and boulders to 24" dia. in matrix of medium to fine sand; very dense, well cemented with caliche, boulders break apart during excavation; bedding indistinct, bottom [illegible]t indistinct. White caliche very promin[illegible] 1-1/2-4ft. | K horizon, 1.5-6ft. SC, ND tests not feasible due to cementation and large rocks |
| 7-11 | B-2 B-3 | | [illegible]L, light gray-brown, with cobbles and boulders as above; medium to coarse sandy matrix, little fines; dense; uncemented except cemented fine gravel in top 1 ft (depth 7-8ft); bedding indistinct. | |

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

**FIGURE 2**

**GEOLOGIC LOGS OF TEST PITS**

**SHEET 4 OF 4 | TEST PIT SFS-7**

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

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

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

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

where

$G$ = average specific gravity of soil solids

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

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

$A$ = average absorption, percent

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

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

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

TABLE 2

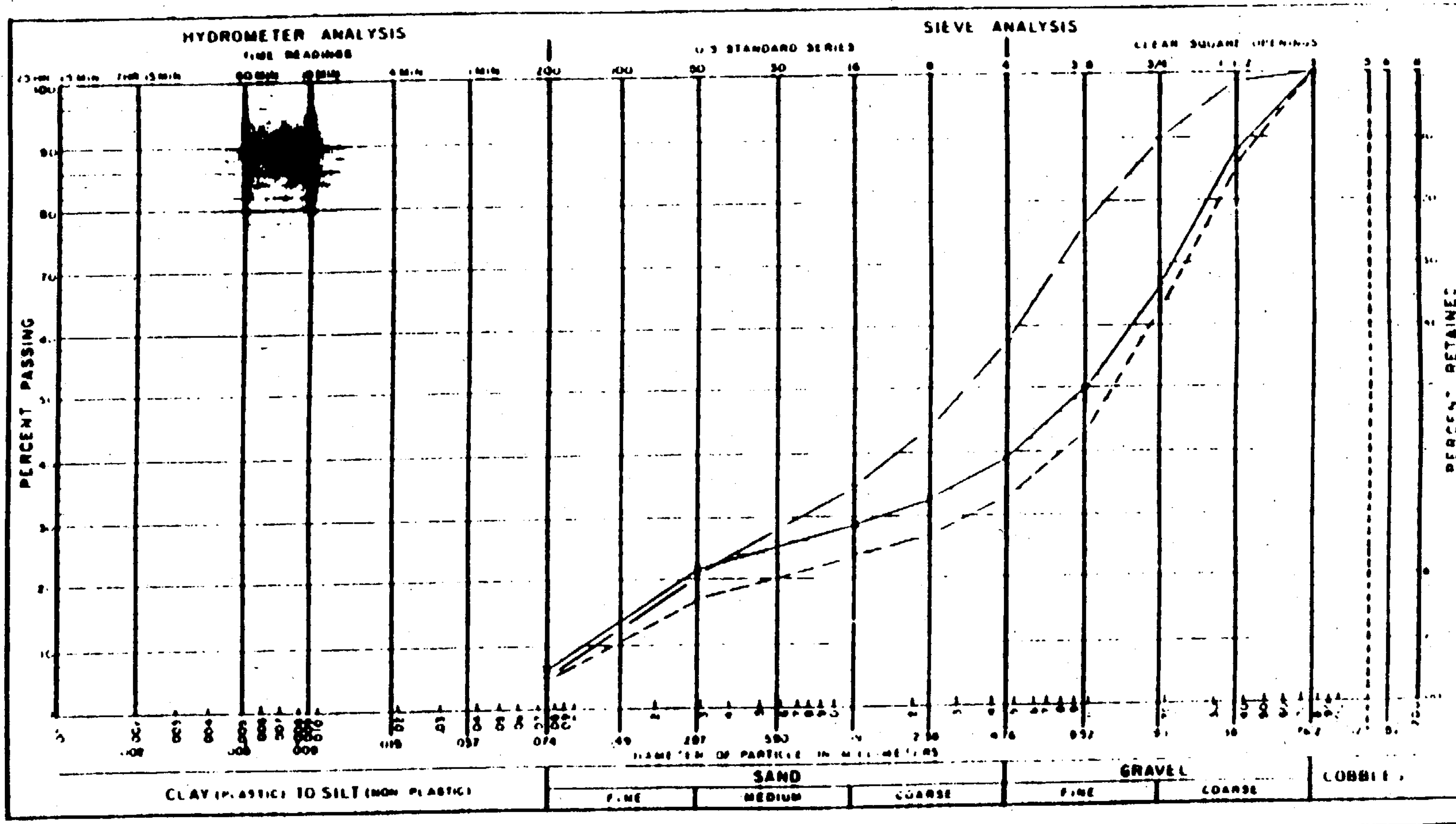
Summary of In-Place Density Tests

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

Notes:

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

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




SFS-3

4.5'-5.5'
8'
12'

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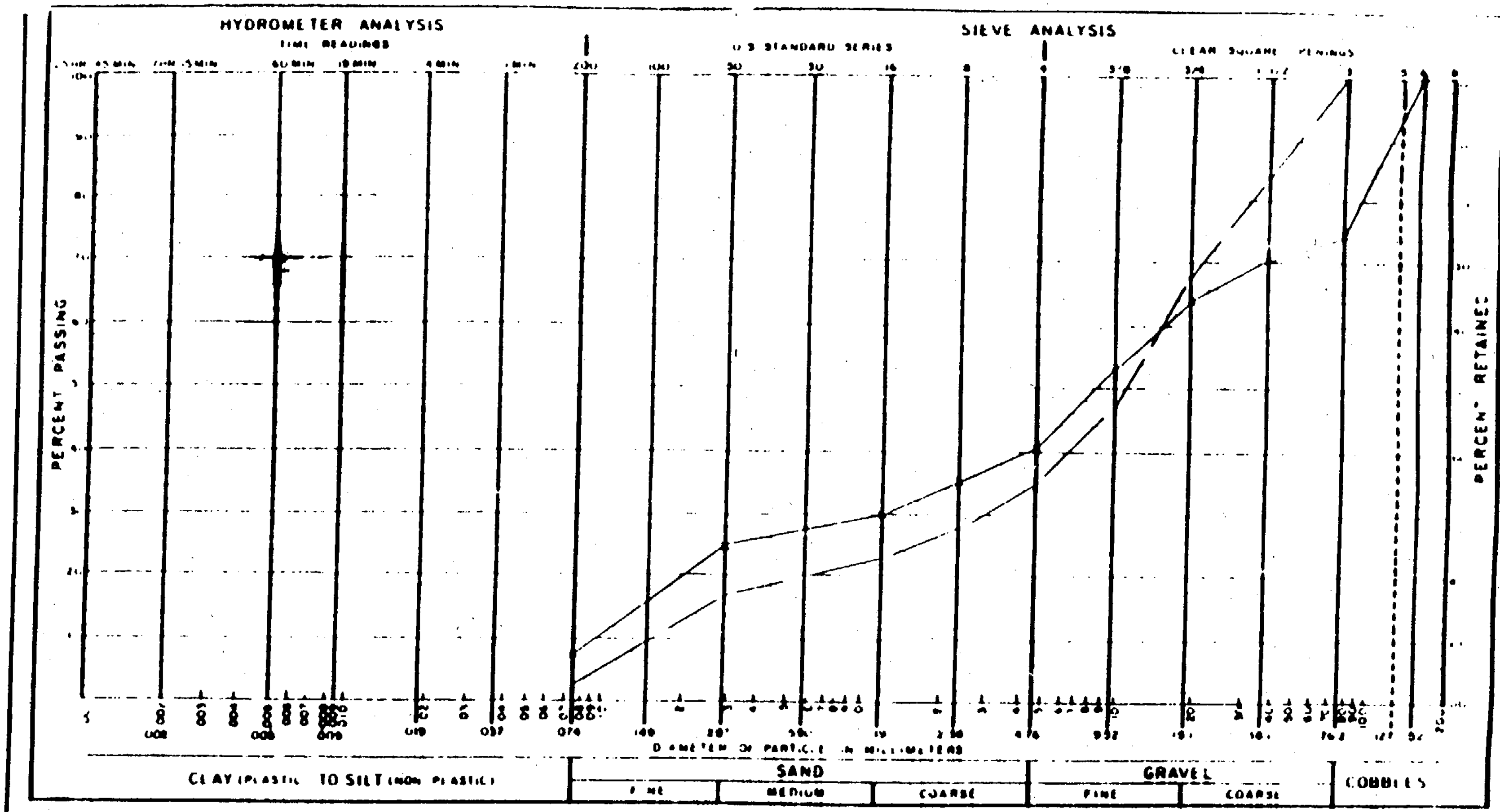
TUFF REPOSITORY SURFACE FACILITIES

**GRADATION CURVES OF SITE SOILS TEST PIT SFS 3**

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

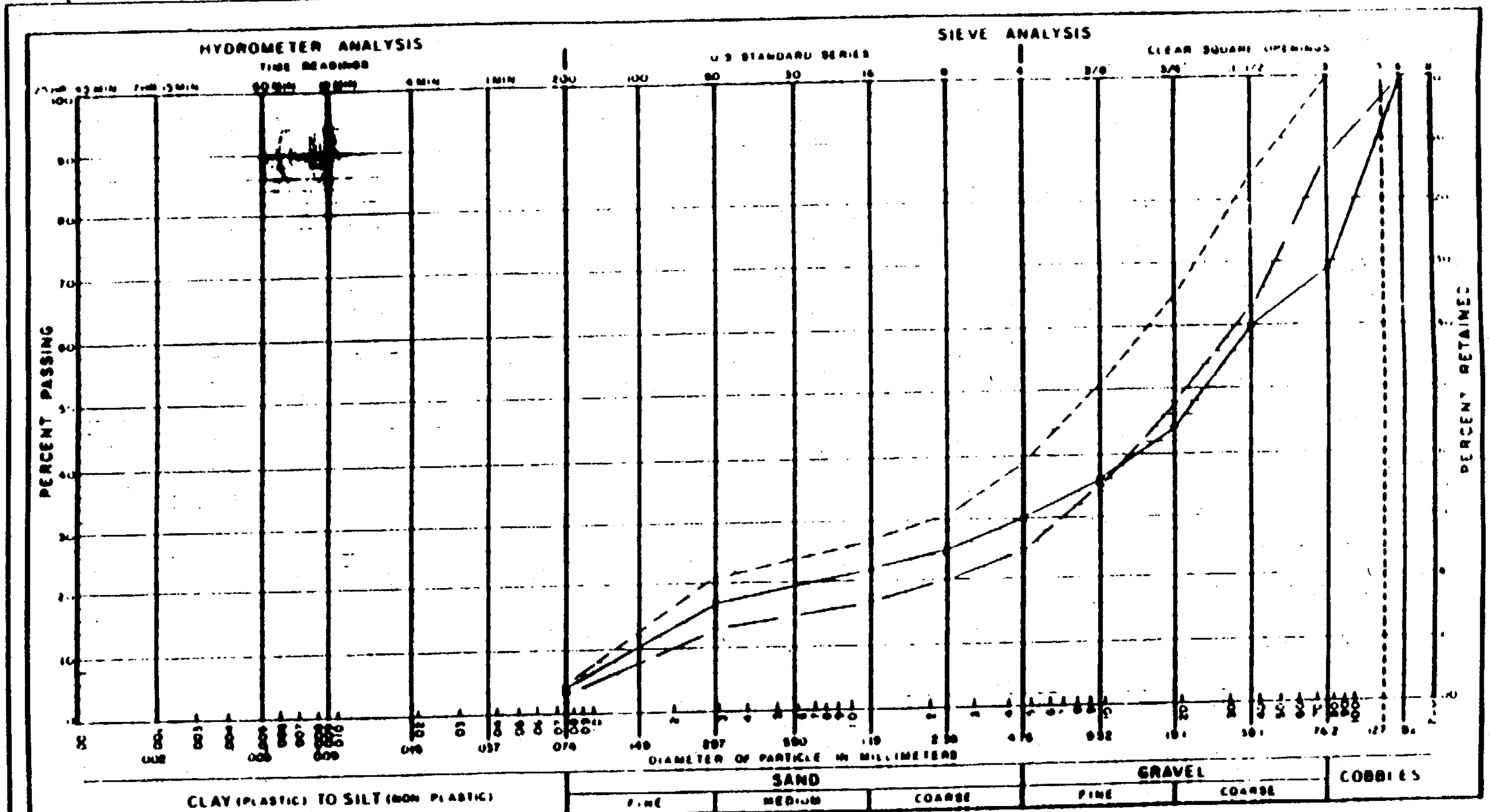



**BECHTEL**
SAN FRANCISCO

TUFF REPOSITORY SURFACE FACILITIES

**GRADATION CURVES OF SITE SOILS TEST PIT SFS 4**

| JOB No. | DRAWING No. | REV. |
|---|---|---|
| 16039 | FIGURE 3b | |




SFS-5

x———x 2'- 4'
— — — 6'
- - - - 12'

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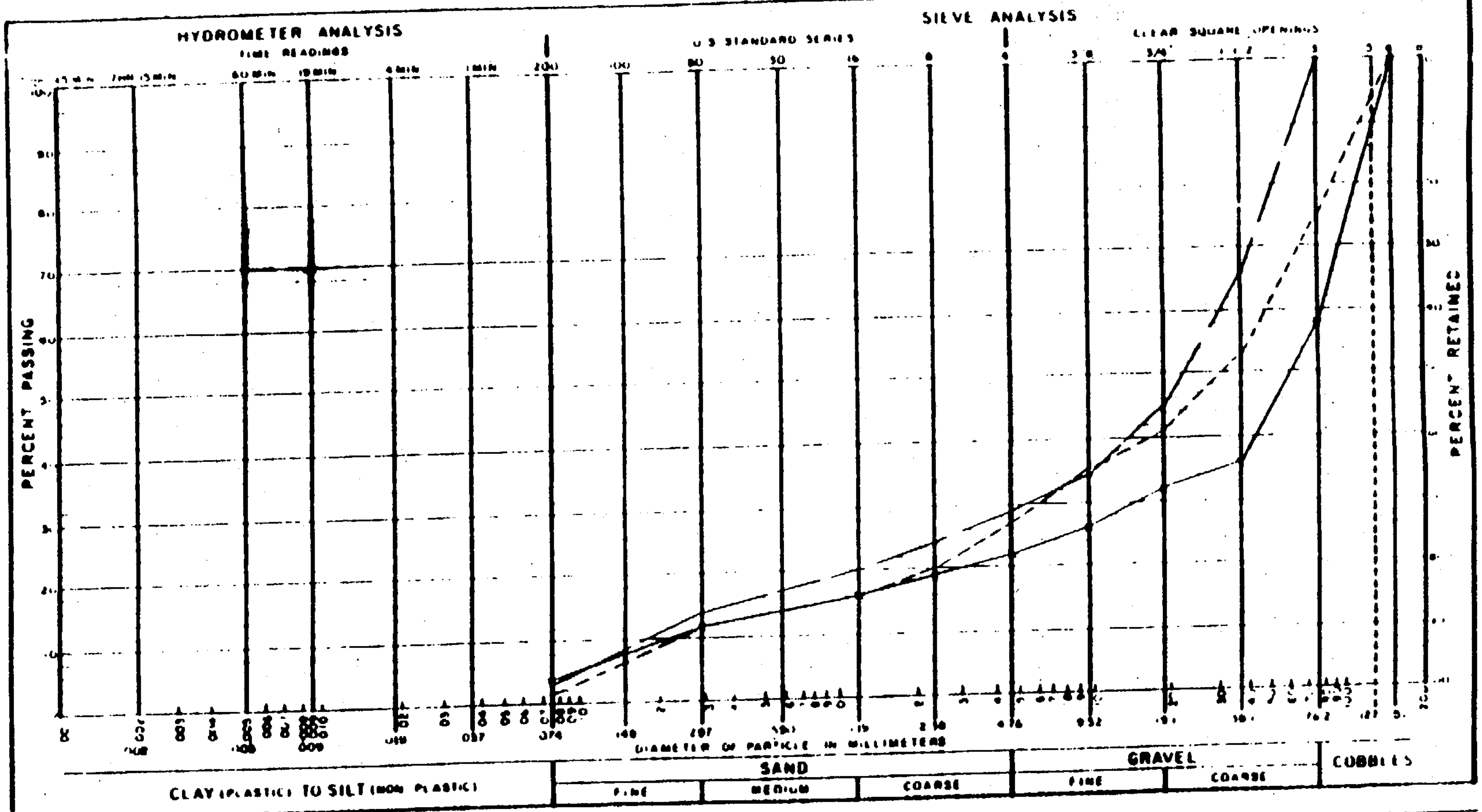
**GRADATION CURVES OF SITE SOILS TEST PIT SFS 5**

| JOB No. | DRAWING No. | REV |
|---|---|---|
| 18039 | FIGURE 3c | |




SFS-7

3'
7'
11'

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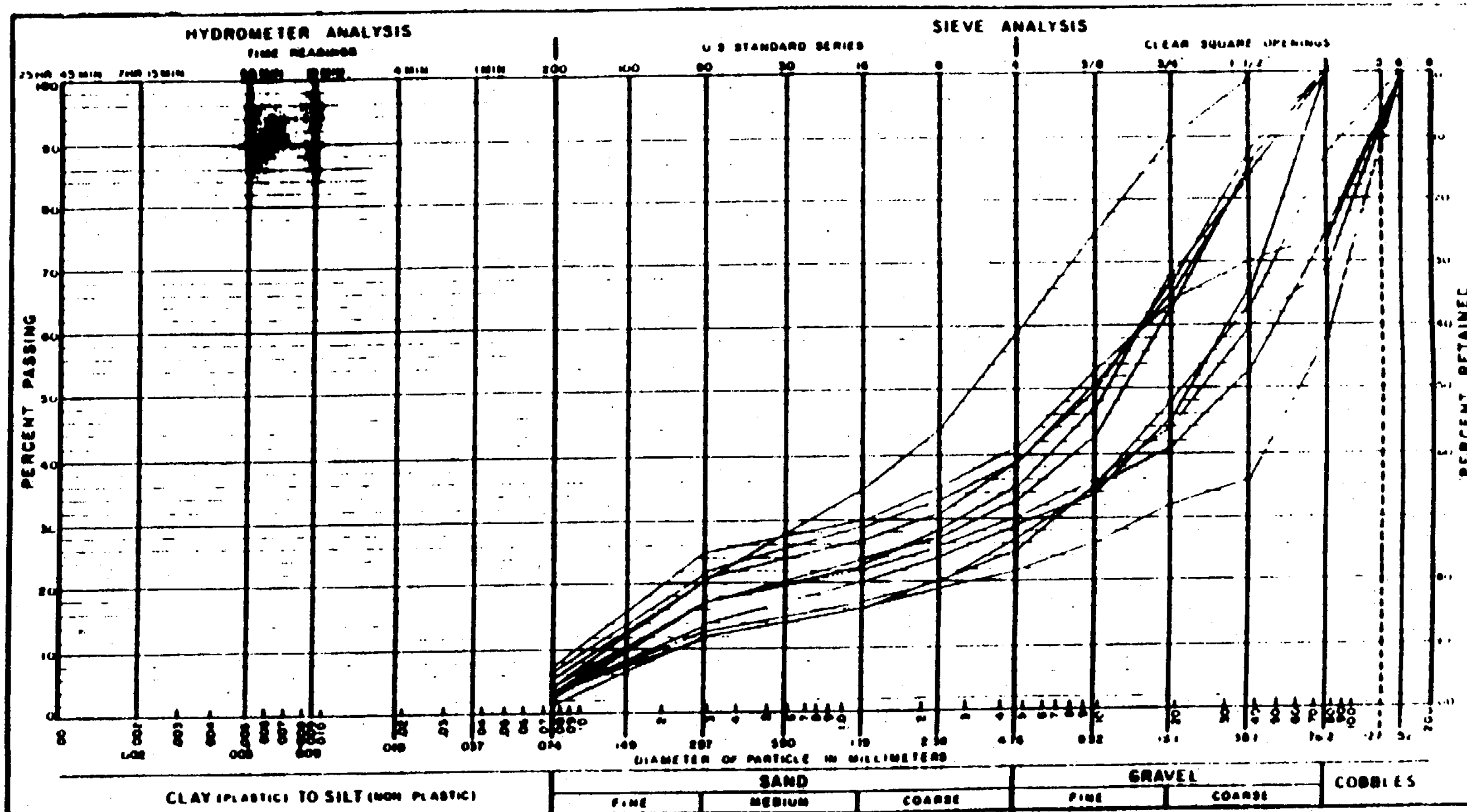
**GRADATION CURVES OF SITE SOILS TEST PIT SFS 7**

| JOB No. | DRAWING No. | REV |
|---|---|---|
| 16039 | FIGURE 34 | |

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TUFF REPOSITORY SURFACE FACILITIES

**GRADATION CURVES OF SITE SOILS SUMMARY**

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

TABLE 3

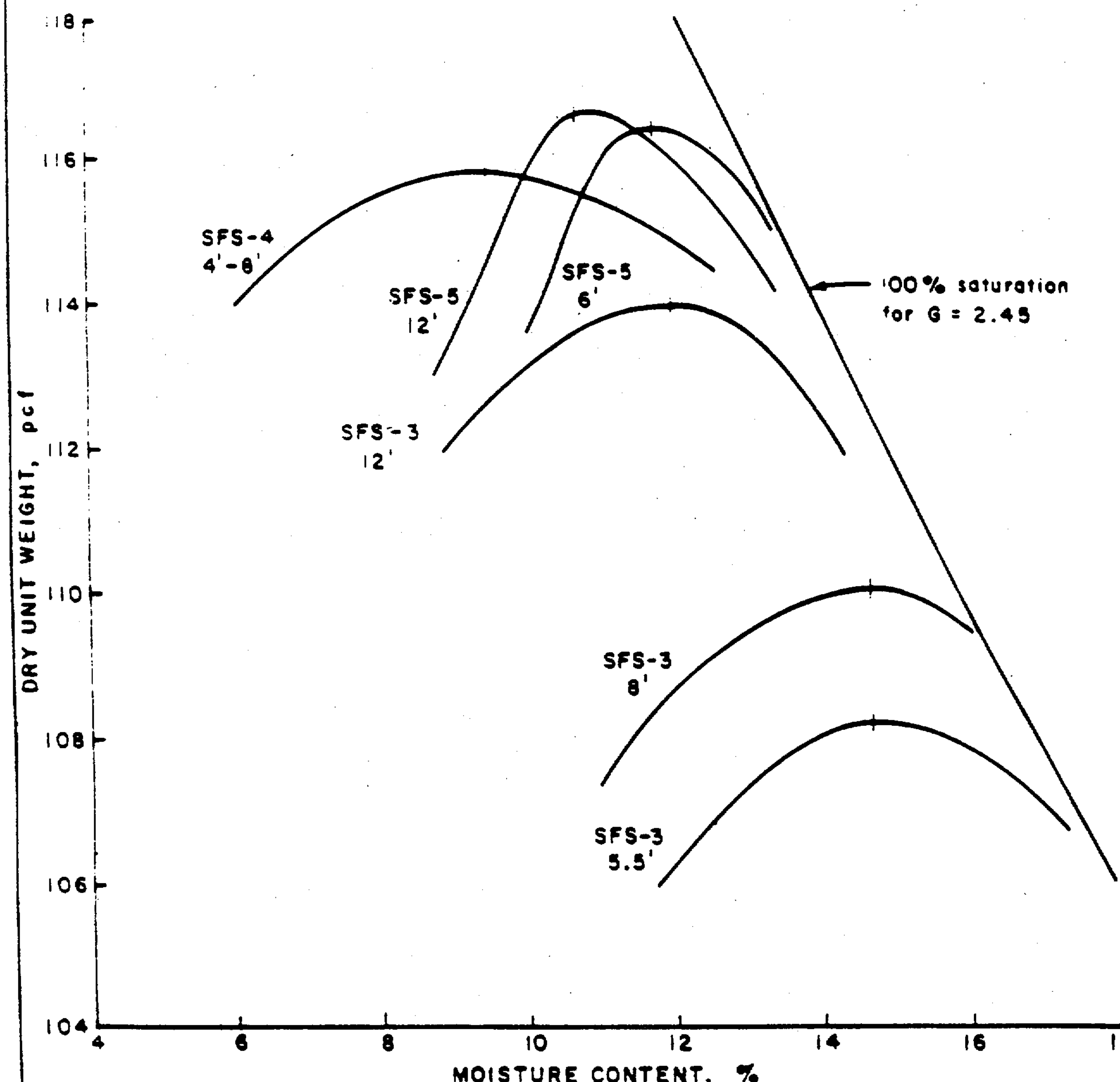
Summary of Soil Index Properties

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

Notes:

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

(2) The values in parentheses represents the average.

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TUFF REPOSITORY SURFACE FACILITIES

**COMPACTION CURVES OF SITE SOILS**

| | |
|---|---|
| 16039 | FIGURE 4 |

TABLE 4

Comparison of In Place and Laboratory Density Test Results

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

Notes:

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

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

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

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

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

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

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

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

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

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

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

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

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

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

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

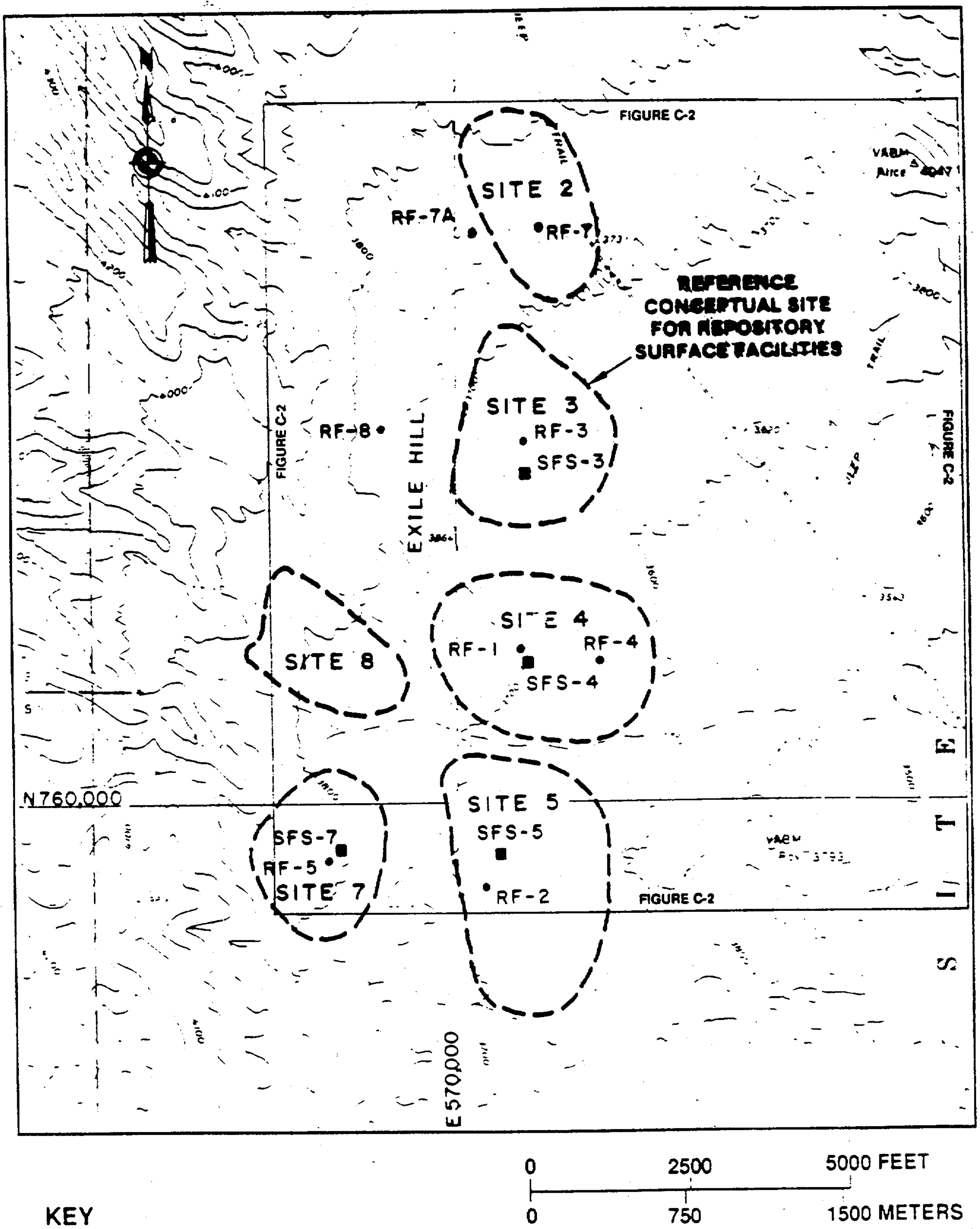
7. Permanent slopes in cut should not be steeper than 1.5 horizontal to 1 vertical where the soil deposits are cemented and 2 horizontal to 1 vertical where the cementation is absent. Fill slopes should be 2 horizontal to 1 vertical.

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

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

# APPENDIX C

## DRILL HOLE AND TEST PIT LOCATIONS AND GEOLOGIC STRATIGRAPHIC AND STRUCTURAL CROSS SECTIONS IN MIDWAY VALLEY




**KEY**

■ SFS TEST PITS

● RF BORINGS

FIGURE C-1 LOCATION OF SURFACE TEST PITS IN ALLUVIUM. MODIFIED FROM HO ET AL. (1986)

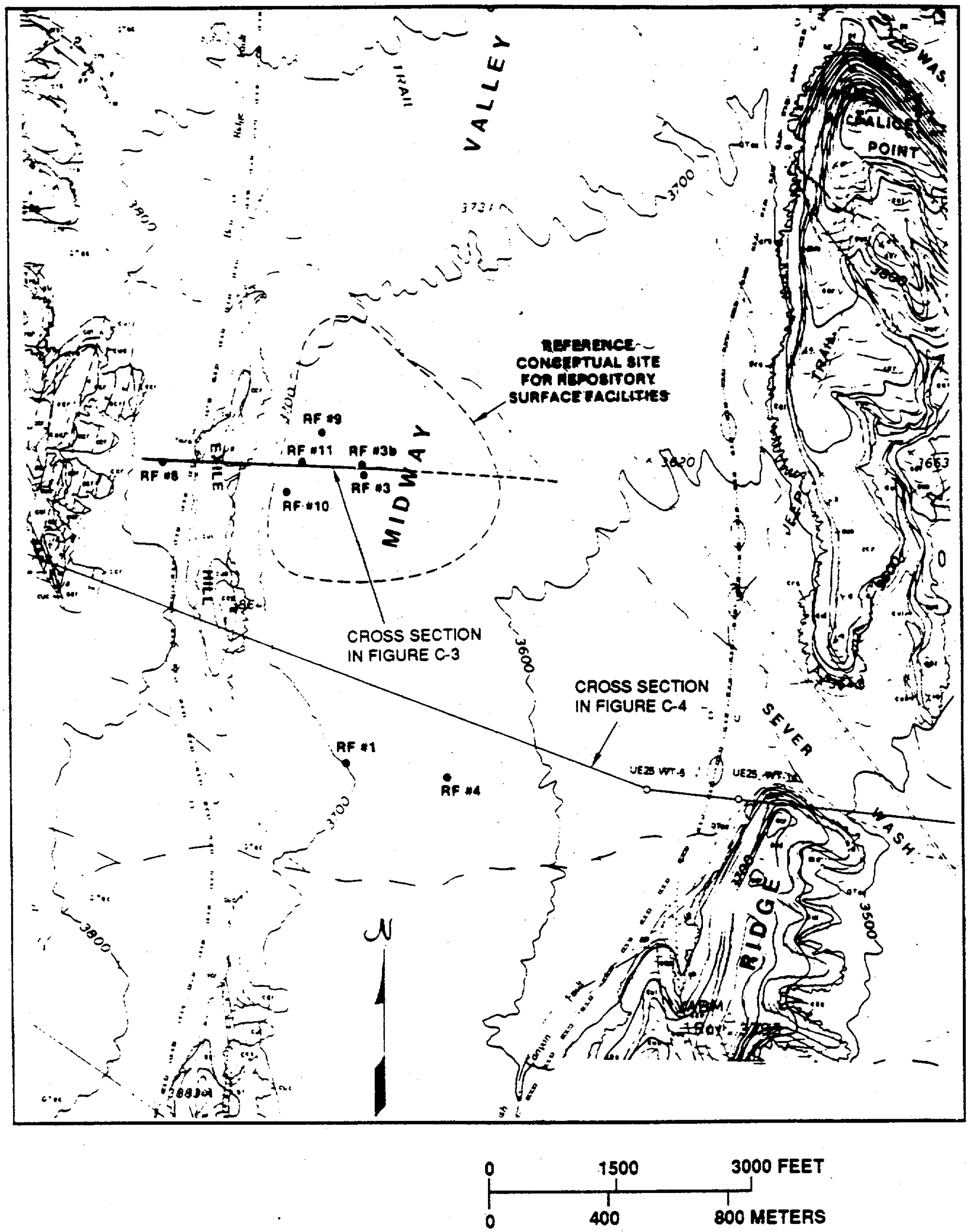



FIGURE C-2 M⁚⁻ OF THE SURFACE GEOLOGY AND FAULTS IN THE VICINITY OF E.._E HILL. (UNIT DEFINITIONS ARE GIVEN ON FIGURES C-3 AND C-4).

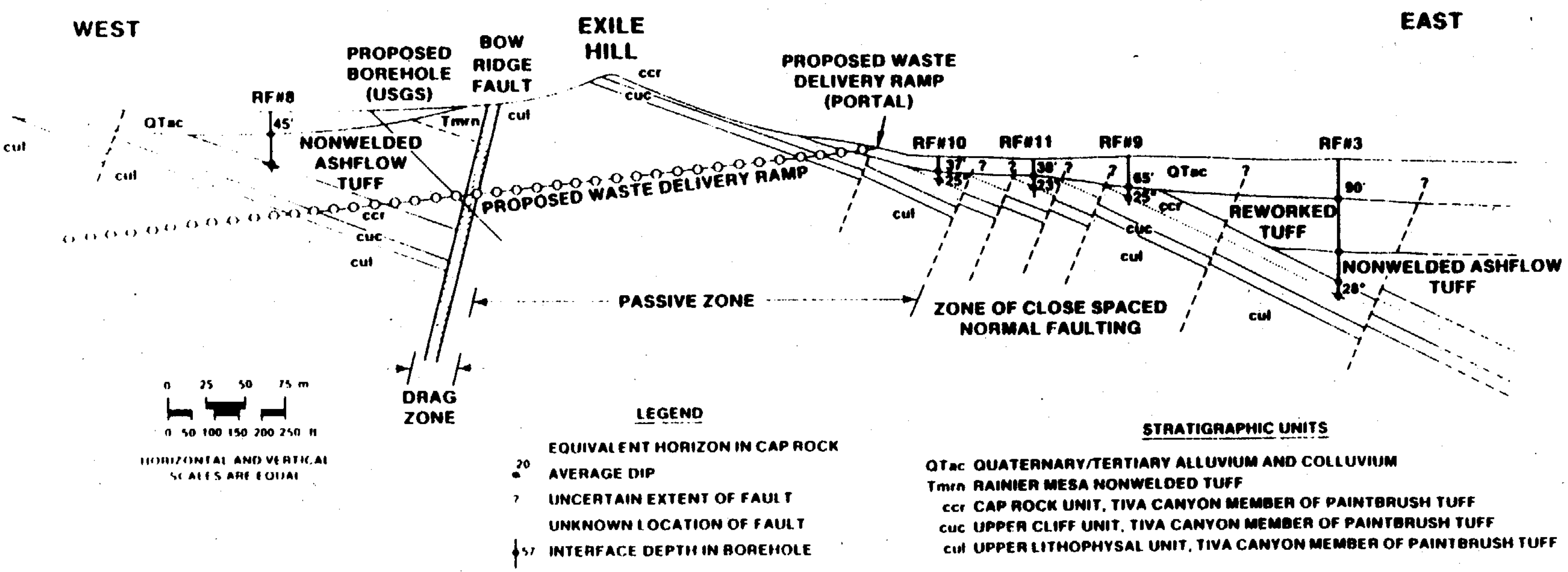
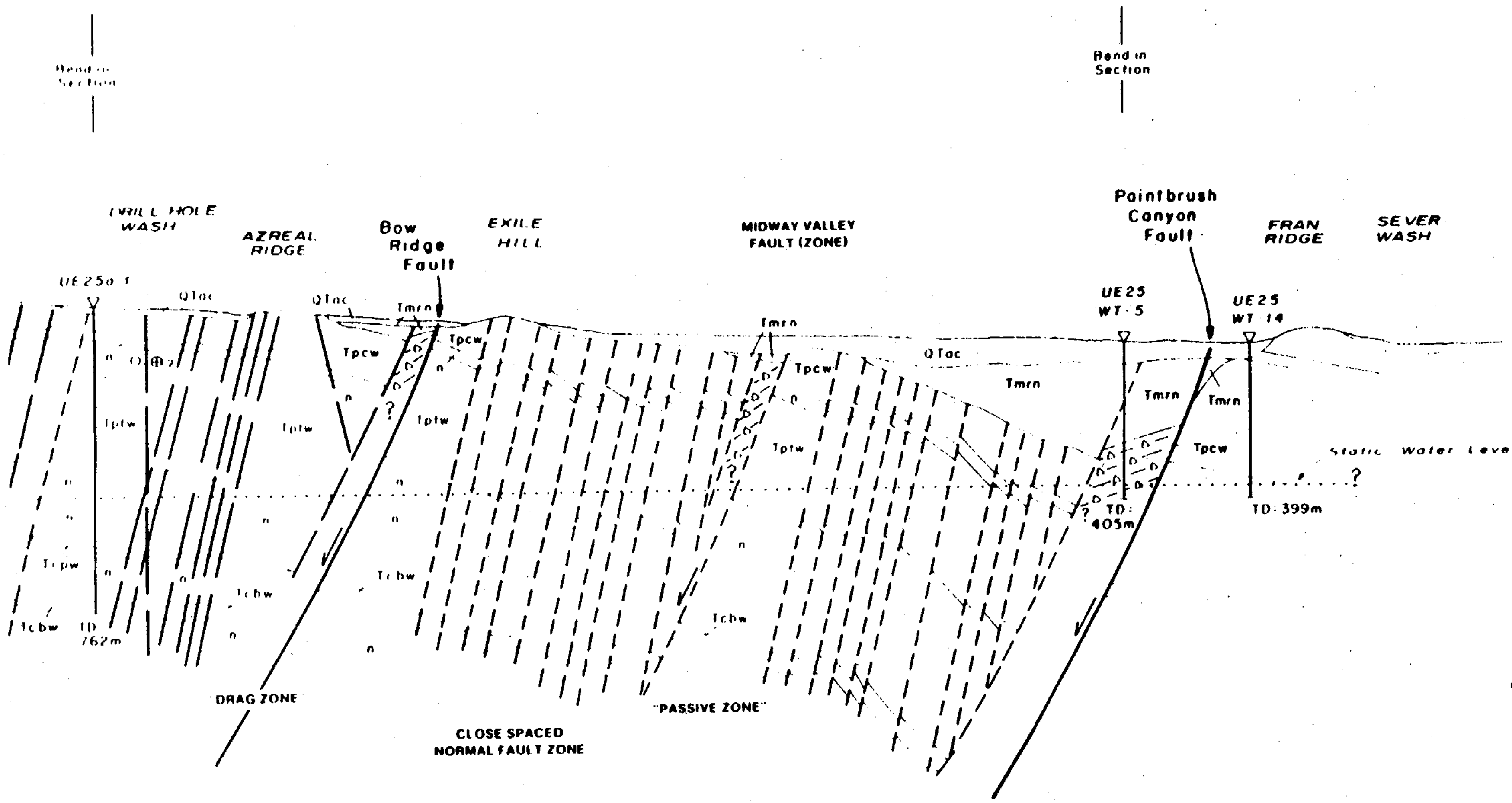



**FIGURE C-3 CROSS SECTION OF THE GEOLOGIC STRUCTURE THROUGH EXILE HILL AND THE REFERENCE CONCEPTUAL SITE BASED ON SURFACE MAPPING AND BOREHOLE DATA (SEE FIGURE C-2 FOR THE LOCATION OF THE SECTION) GEOLOGIC CROSS SECTION FROM NEAL (1986).**




| | |
|---|---|
| QTac | QUATERNARY/TERTIARY ALLUVIUM AND COLLUVIUM |
| Tmrn | RAINIER MESA MEMBER OF TIMBER MOUNTAIN TUFF, NONWELDED |
| Tpcw | TIVA CANYON MEMBER OF PAINTBRUSH TUFF, WELDED |
| n | NONWELDED TUFF |
| Tptw | TOPOPAH SPRING MEMBER OF PAINTBRUSH TUFF, WELDED |
| Tcbw | BULLFROG MEMBER OF CRATER FLAT TUFF, WELDED |
| TD | TOTAL DEPTH |

FIGURE C-4 CONCEPTUAL CROSS SECTION OF THE GEOLOGIC STRUCTURE SOUTH OF THE REFERENCE CONCEPTUAL SITE FOR REPOSITORY SURFACE FACILITIES (SEE FIGURE C-2 FOR THE LOCATION OF THE SECTION) MODIFIED FROM SCOTT AND BONK (1984)

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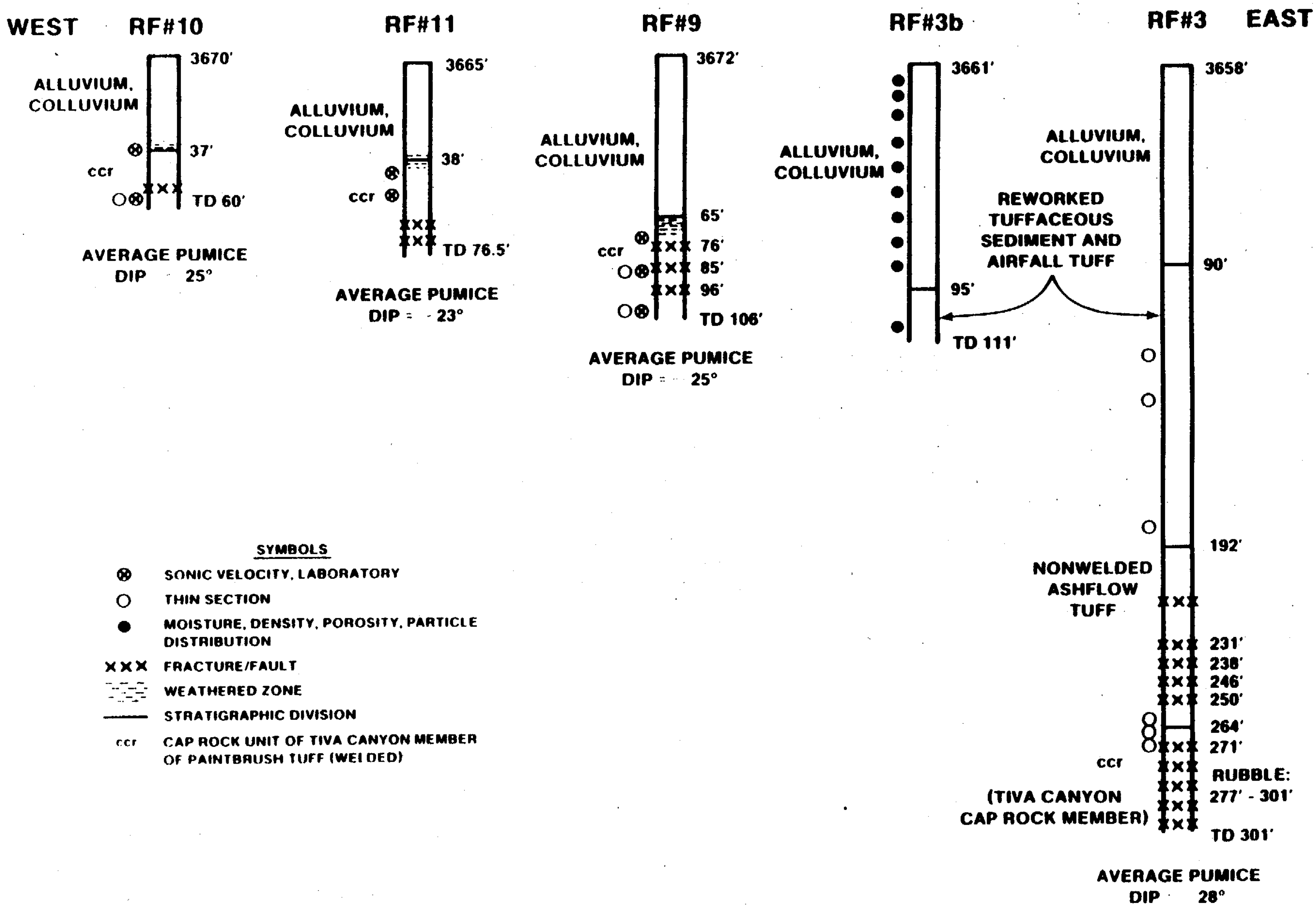



FIGURE C-5. SUMMARY OF BOREHOLES UE 25 RF #10, 11, 9,3B AND 3 SHOWING MAJOR STRATIGRAPHIC UNITS AND FEATURES (SEE FIGURE C-2 FOR THE LOCATIONS OF THE BOREHOLES) TO CONVERT FEET TO METERS MULTIPLY BY 3048 MODIFIED FROM SCOTT AND BONK (1984)

TUFREHP.125./5-20-91

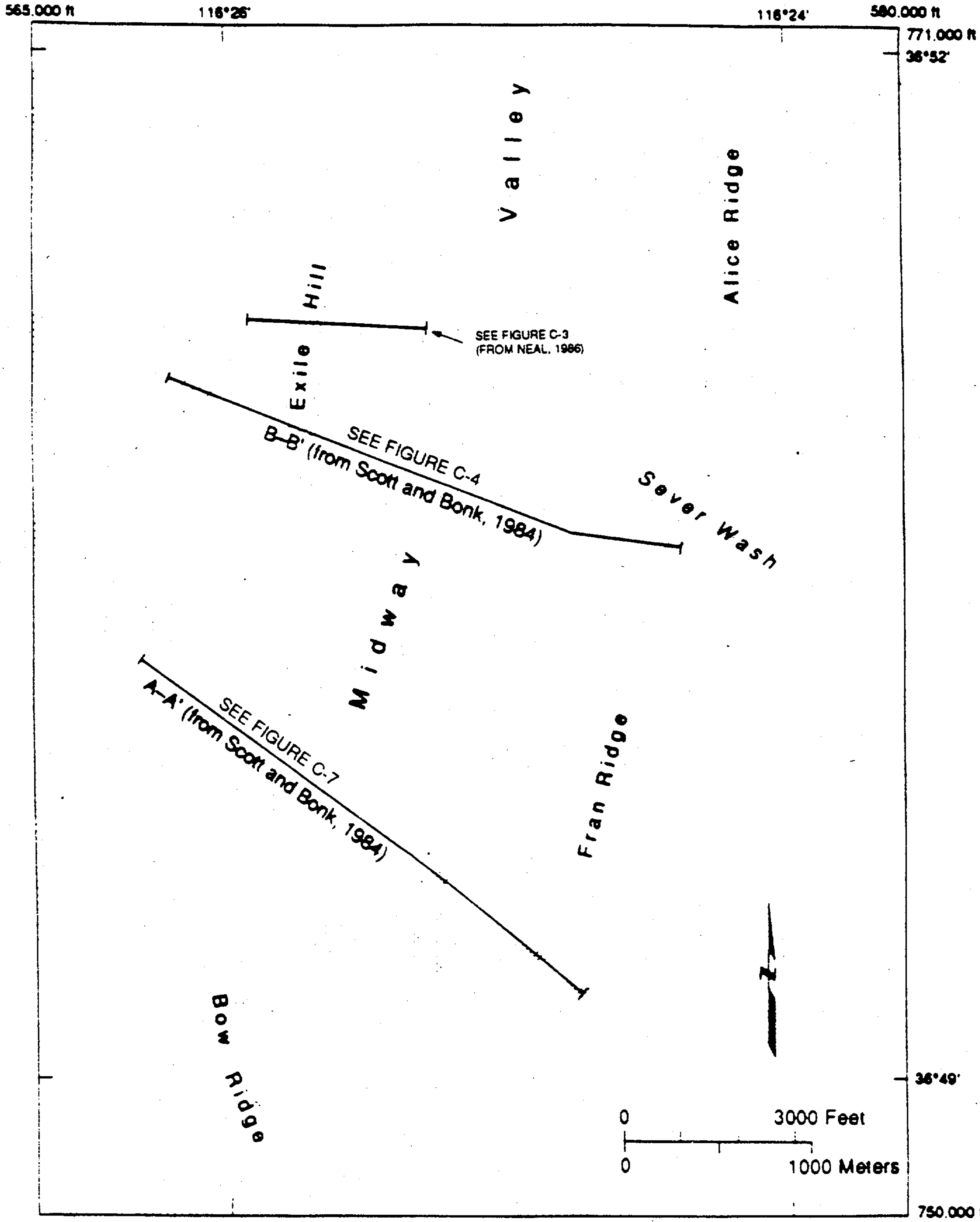
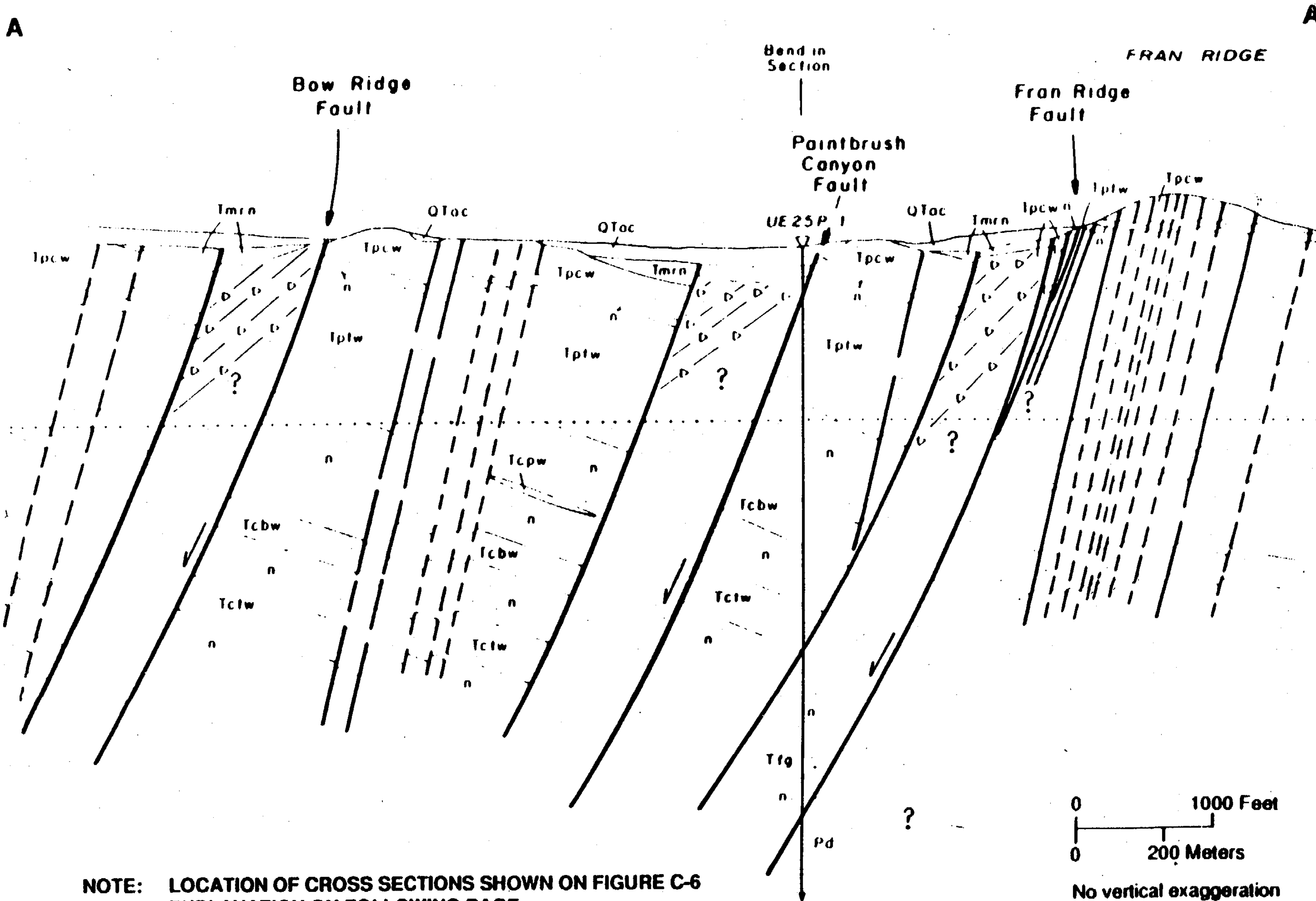



FIGURE C-6 LOCATIONS OF CROSS SECTION SHOWN IN FIGURES C-3, C-4, AND C-7 INDICATE THE LOCATION OF TERTIARY SILICIC VOLCANIC ROCKS. UNSCREENED AREAS INDICATE THE LOCATION OF TERTIARY TO QUATERNARY ALLUVIAL, FLUVIAL, AND EOLIAN SEDIMENTS.

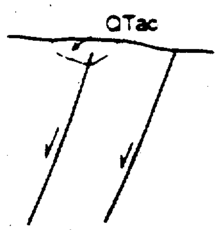



NOTE: LOCATION OF CROSS SECTIONS SHOWN ON FIGURE C-6
EXPLANATION ON FOLLOWING PAGE.

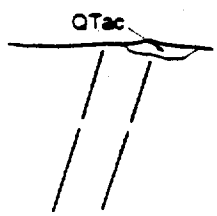
FIGURE C-7. PART OF GEOLOGIC CROSS SECTION A-A' FROM SCOTT AND BONK (1984)

## EXPLANATION

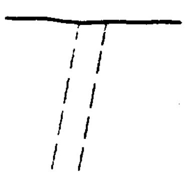
? Contact: queried where inferred



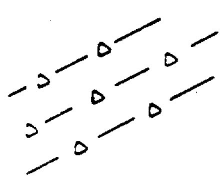

Fault with major dip-slip displacement, position known or concealed at surface: arrows show direction of relative displacement. Average dip of fault planes at surface is 70° and subsurface drill hole data suggest a decrease to about 60° below 1 km depth. Some faults cut older QTac but do not cut younger Quaternary deposits shown by partial penetration of fault through QTac to surface




Faults with minor dip-slip displacements, positions known or concealed at surface; no evidence to suggest a decrease in dip with depth; average dip is 76° at surface and in drill holes

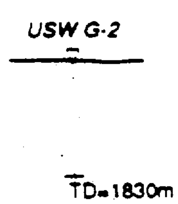


Unmapped and inferred faults of small displacement required by geometric constraints in surface exposures and drill holes



Zone of west-dipping strata containing abundant breccia and faults too complex to draw individually; stratigraphic units shown only near surface

Static water level; queried where extended beyond drill hole data control; measured prior to December 1983




Drill hole showing total depth

### Physical-Property Stratigraphic Units

| | |
|---|---|
| QTac | Alluvium and colluvium (Quaternary and Tertiary) |
| Tmrw/Tmrn | Rainier Mesa Member of Timber Mountain tuff, w - welded, n - nonwelded |
| n | Nonwelded tuff |
| Tpcw | Tiva Canyon Member of Paintbrush tuff, welded |
| n | Nonwelded tuff |
| Tptw | Tonopah Spring Member of Paintbrush tuff, welded |
| n | Nonwelded tuff |
| Tcpw | Prow Pass Member of Crater Flat tuff, welded |
| n | Nonwelded tuff |
| Tcbw | Bullfrog Member of Crater Flat tuff, welded |
| n | Nonwelded tuff |
| Tctw | Tram Member of Crater Flat tuff, welded |
| Tfg | Fanglomerate |
| Pd | Paleozoic dolomite (Devonian) |

Source: Scott and Bonk (1984)

FIGURE C-7 CONTINUED.

# APPENDIX D

## GEOLOGIC AND THERMAL/MECHANICAL STRATIGRAPHIC AND STRUCTURAL CROSS SECTIONS AND DRILL HOLE LOCATIONS FOR YUCCA MOUNTAIN

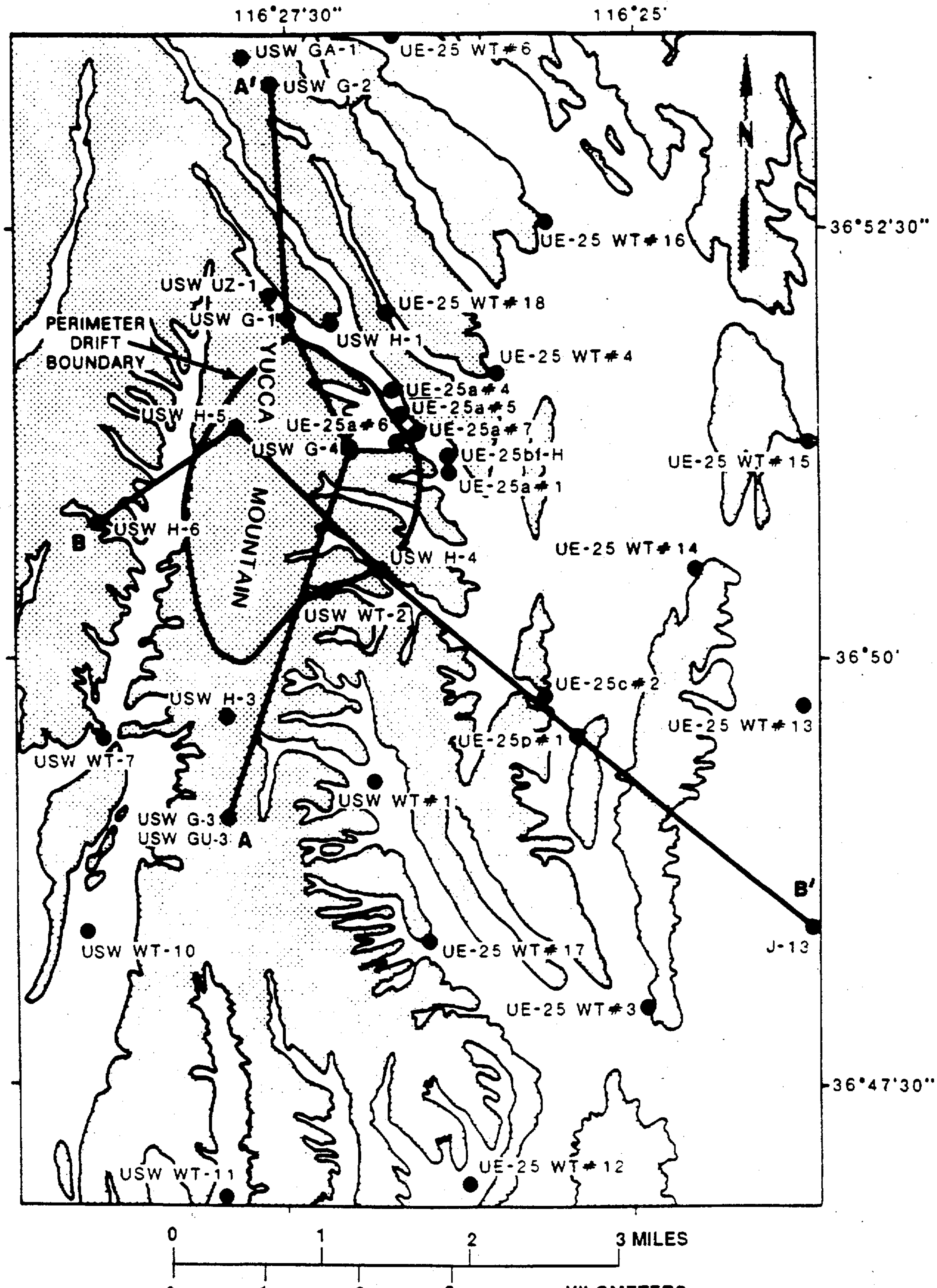



FIGURE D-1 INDEX MAP SHOWING THE LOCATIONS OF SELECTED DRILLHOLES IN THE VICINITY OF YUCCA MOUNTAIN AND THE LOCATIONS OF CROSS SECTIONS SHOWN ON FIGURES D-2 AND D-3. MODIFIED FROM USGS (1984).

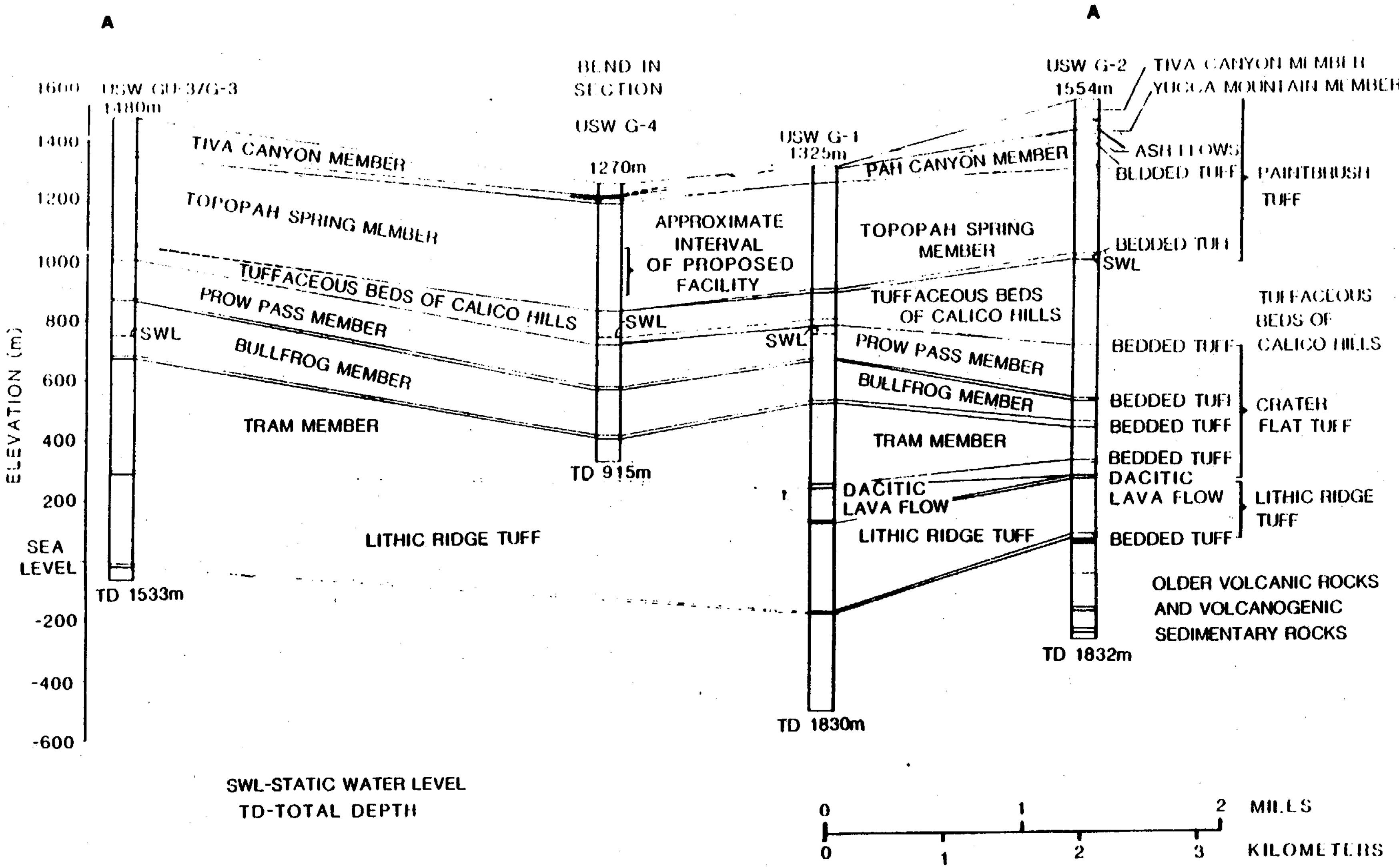



**FIGURE D-2. NORTH-SOUTH STRATIGRAPHIC CORRELATION BETWEEN SELECTED DRILLHOLES AT YUCCA MOUNTAIN. MODIFIED FROM USGS (1984)**

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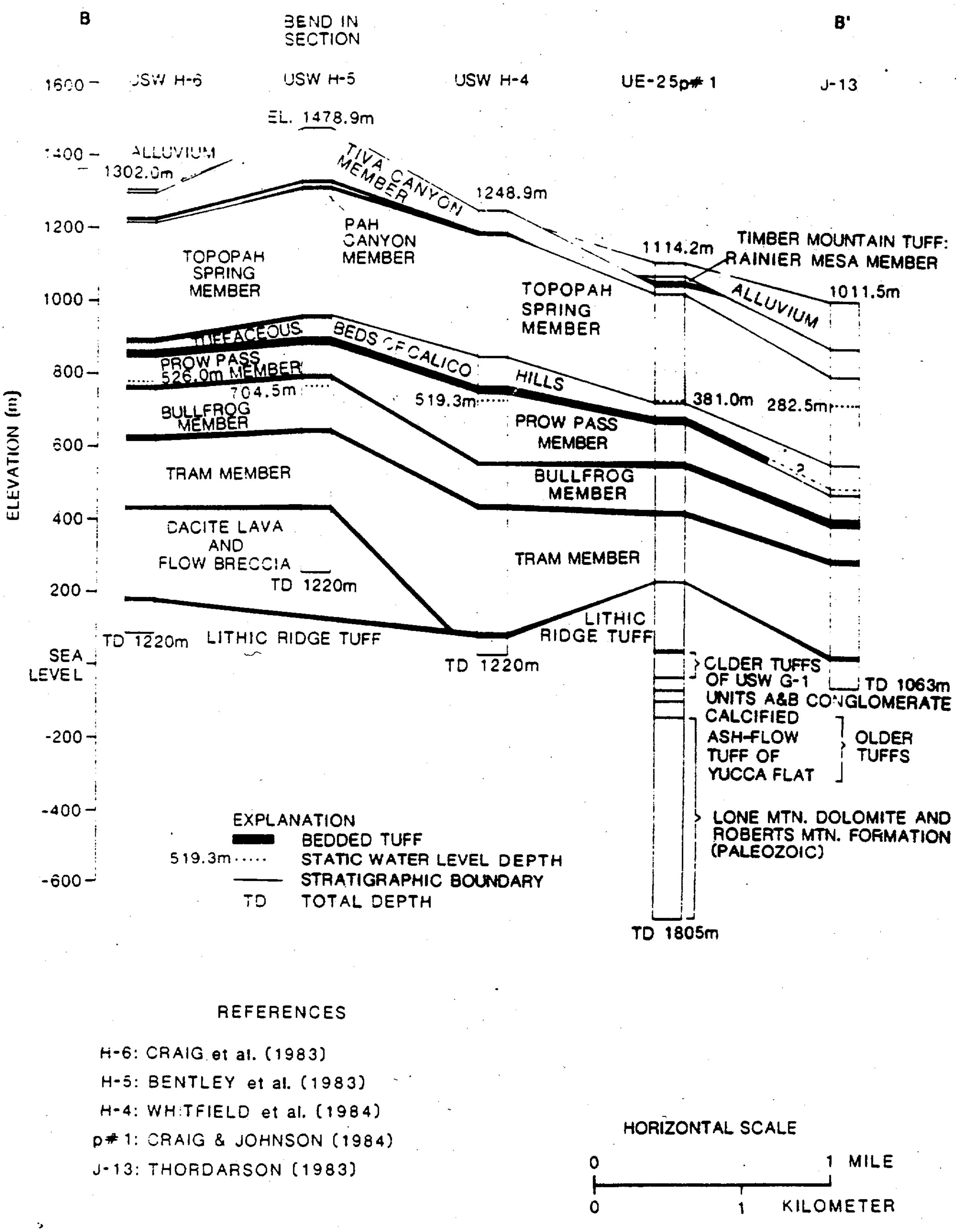


REFERENCES

H-6: CRAIG et al. (1983)
H-5: BENTLEY et al. (1983)
H-4: WHITFIELD et al. (1984)
p# 1: CRAIG & JOHNSON (1984)
J-13: THORDARSON (1983)

**FIGURE D-3 EAST-WEST STRATIGRAPHIC CORRELATION BETWEEN SELECTED DRILLHOLES AT YUCCA MOUNTS**

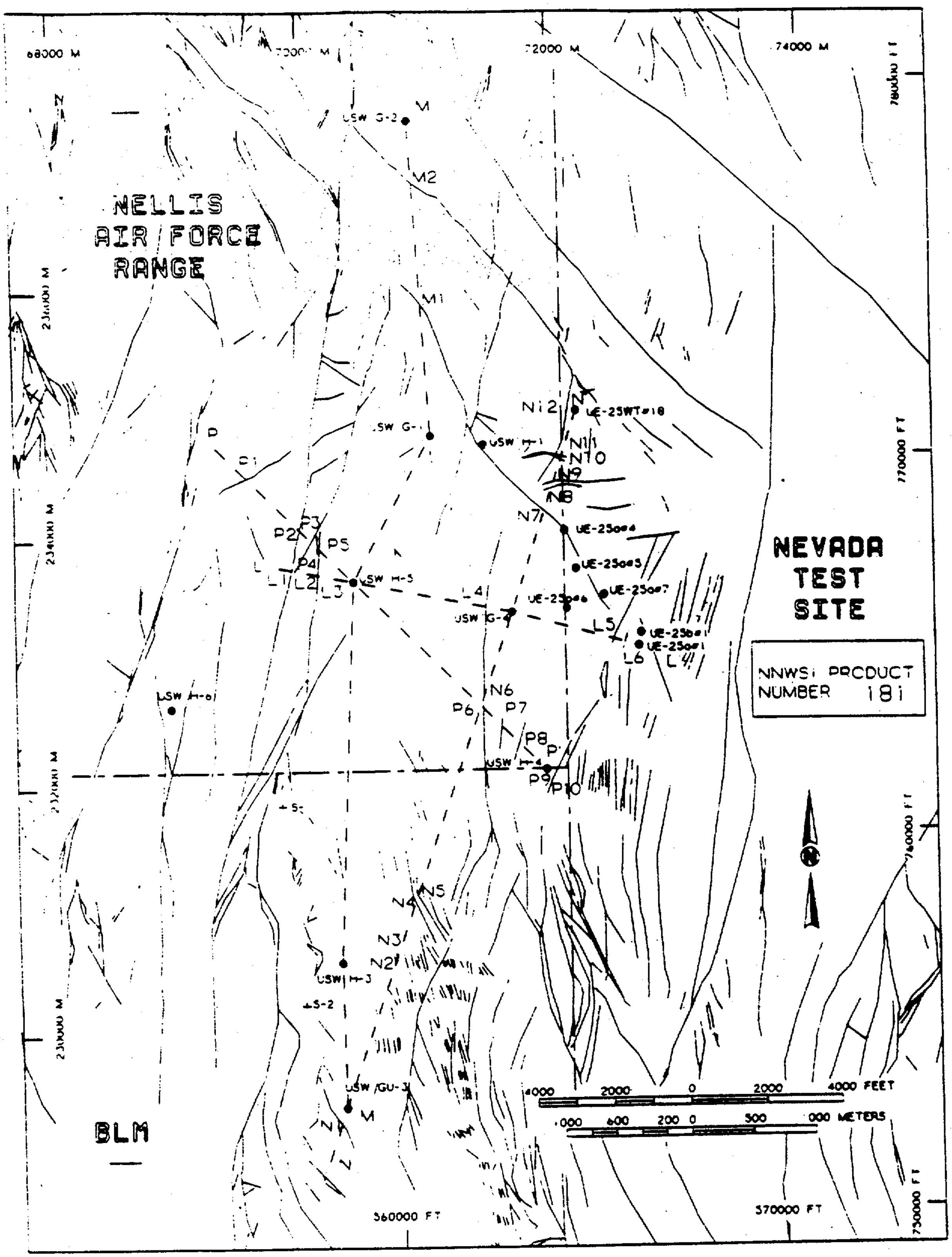


FIGURE D-4 LOCATION OF FAULTS, DRILL HOLES, AND CROSS SECTIONS.

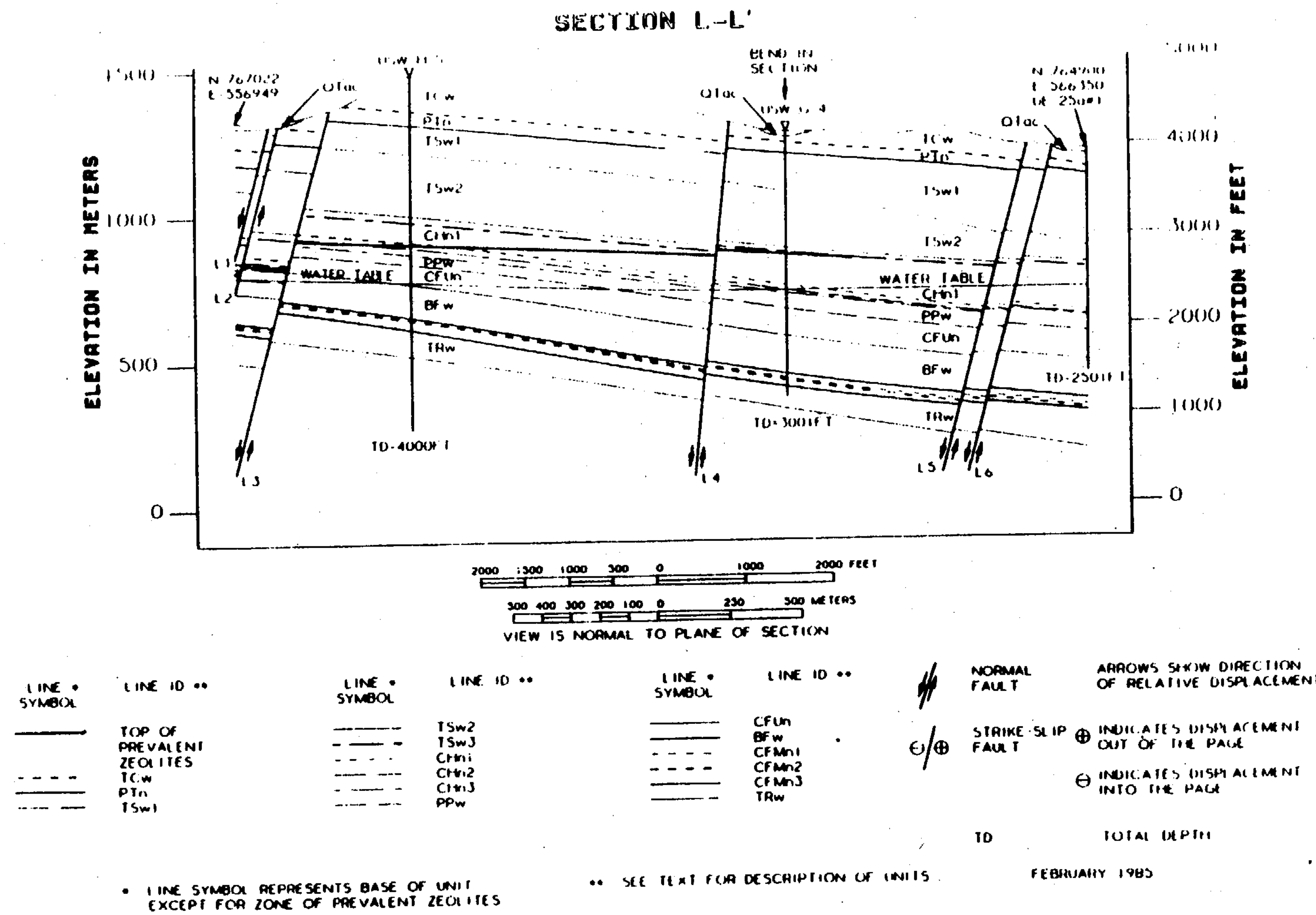


**FIGURE D-5. CROSS SECTION L-L'. (SEE FIGURE D-4 FOR LOCATION OF CROSS SECTION AND FIGURE D-9 FOR DESCRIPTION OF UNIT DESIGNATORS.) MODIFIED FROM ORTIZ et.al., 1985.**

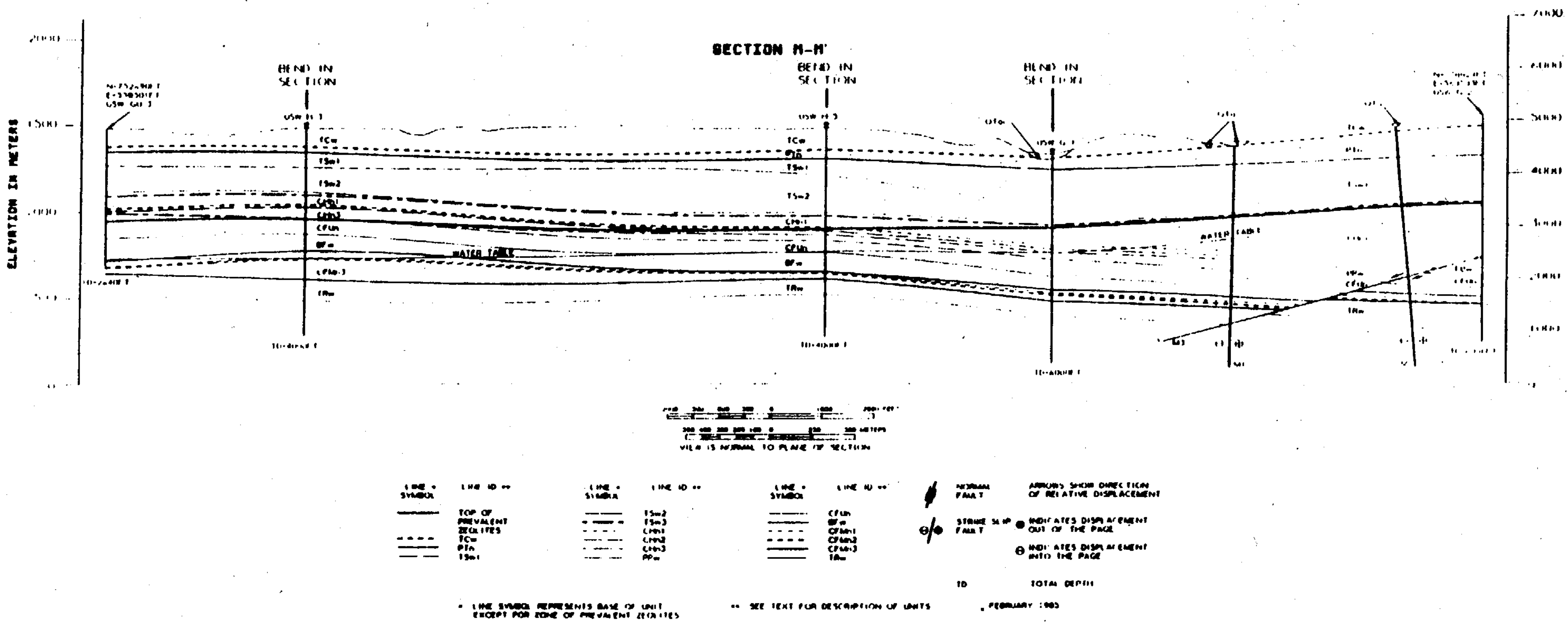


FIGURE D-6. CROSS SECTION M-M'. (SEE FIGURE D-4 FOR LOCATION OF CROSS SECTION AND FIGURE D-9 FOR DESCRIPTION OF UNIT DESIGNATORS.) MODIFIED FROM ORTIZ et. al., 1985

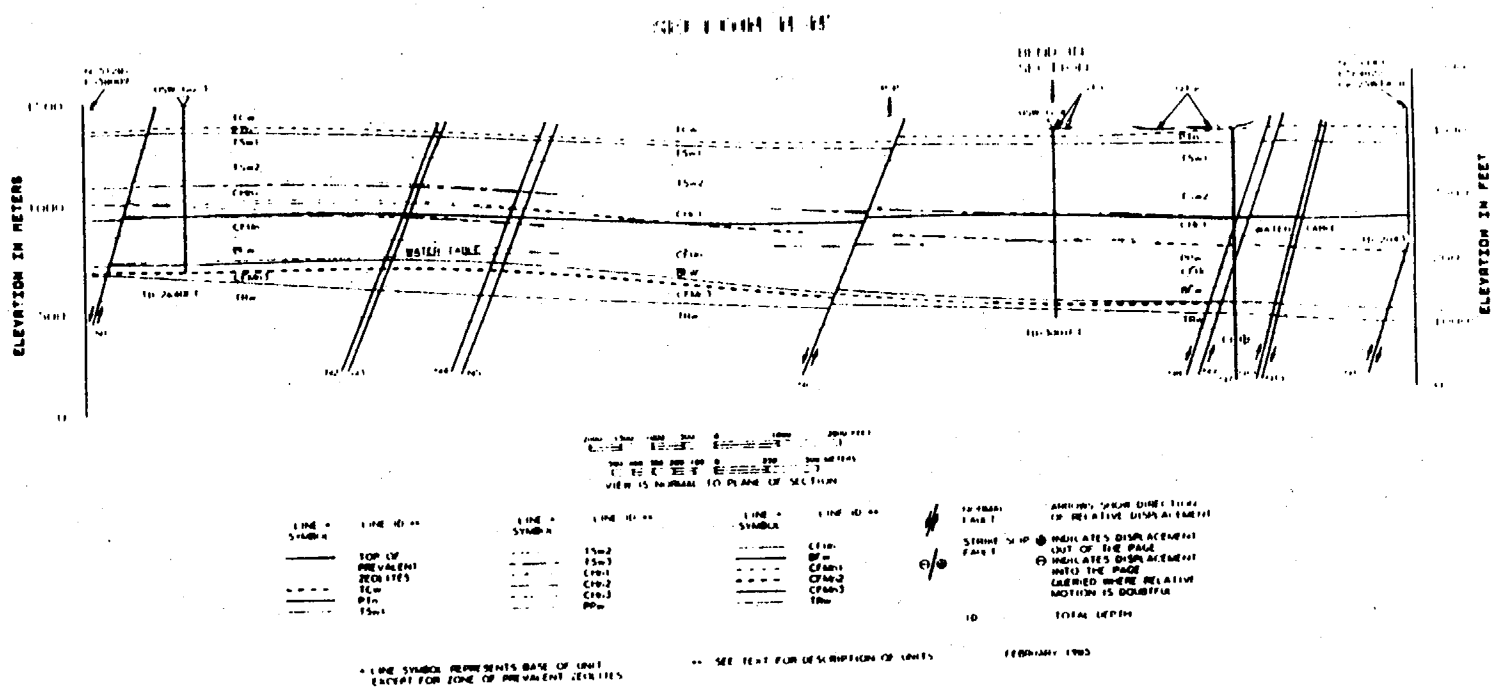


FIGURE D-7. CROSS SECTION N-N'. (SEE FIGURE D-4 FOR LOCATION OF CROSS SECTION AND FIGURE D-9 FOR DESCRIPTION OF UNIT DESIGNATORE.) MODIFIED FROM ORTIZ et.al., 1985

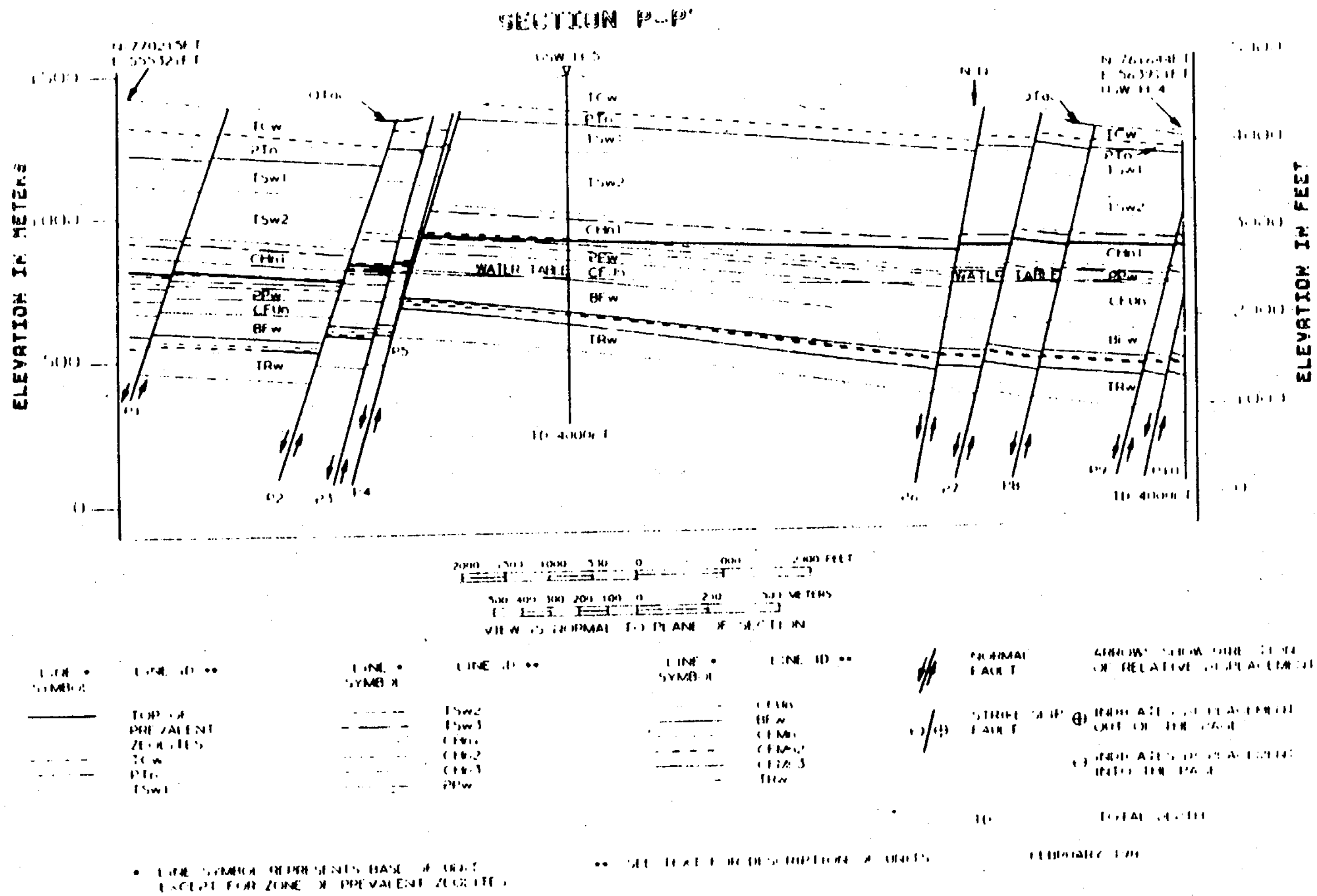


FIGURE D-8. CROSS SECTION P-P'. (SEE FIGURED-4 FOR LOCATION OF CROSS SECTION AND FIGURE D-9 FOR DESCRIPTION OF UNIT DESIGNATORS.) MODIFIED FROM ORTIZ et.al., 1985.

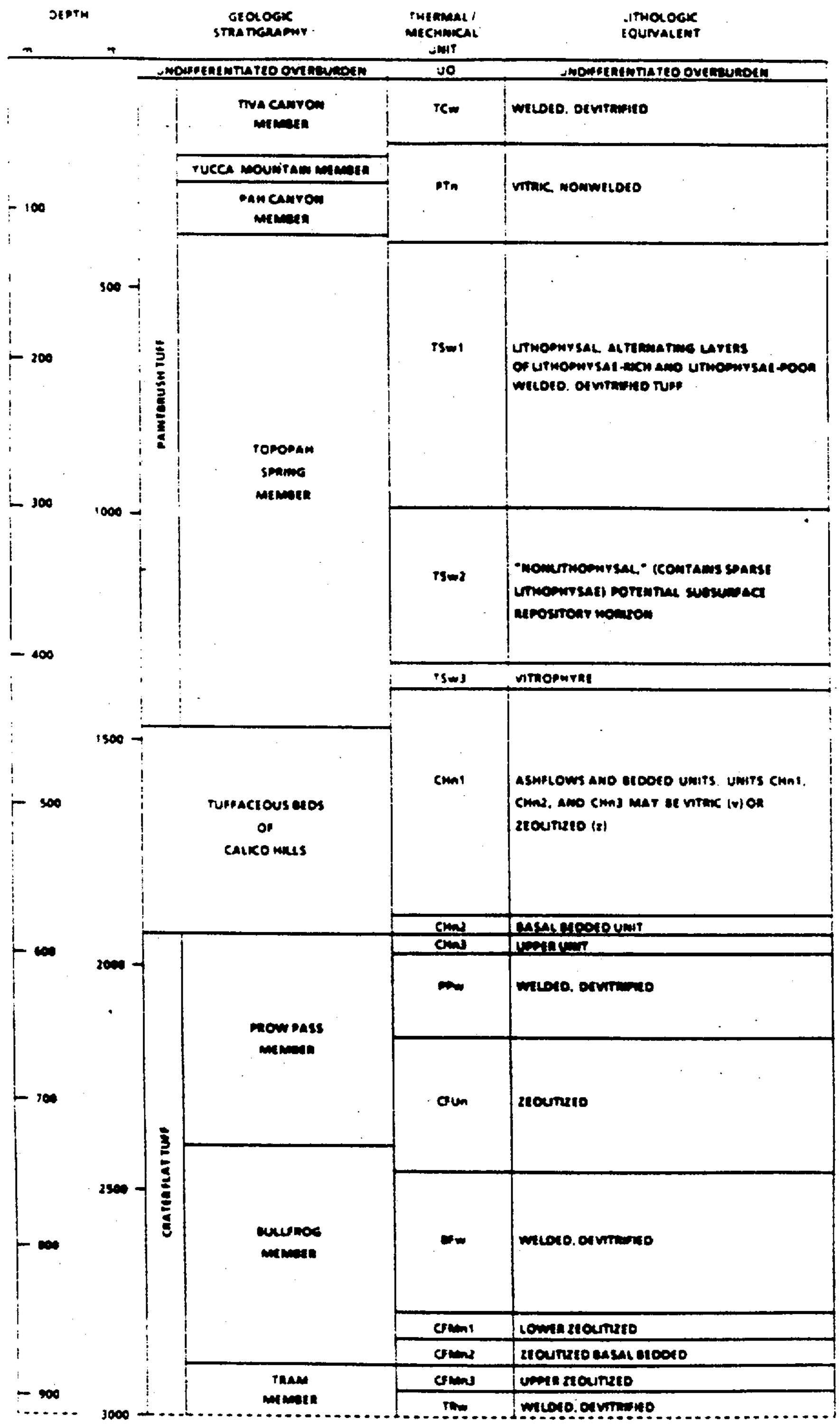


**FIGURE D-9** COMPARISON BETWEEN THE THERMAL/MECHANICAL STRATIGRAPHY AND THE GEOLOGIC STRATIGRAPHY. MODIFIED FROM YUCCA MOUNTAIN PROJECT, RIB, 1989.