FN-TR-44

MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

PRELIMINARY GEOTECHNICAL INVESTIGATION
PROPOSED OPERATIONAL BASE SITE
MILFORD, UTAH

VOLUME I - SYNTHESIS

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FOREWORD

This report was prepared for the Department of the Air Force, Ballistic Missile Office (BMO), in compliance with Contract No. F04704-80-C-0006, CDRL Item 004A6. It contains a preliminary geotechnical evaluation of the proposed Operational Base (OB) site near Milford, Utah. The operational base will support the MX Land Mobile Advanced ICBM System in Nevada and Utah. This report presents geological, geophysical, and soils engineering data as well as recommendations regarding site suitability, preliminary conclusions regarding foundations for various facilities, construction considerations, and aggregate resources.

Concurrent with the study reported herein, one other proposed operational base site in Utah (Beryl) and one in Nevada (Coyote Spring Valley) have been investigated for the same purpose. A report on the Beryl site will be issued at a later date; the report for the Coyote Spring site was issued on 23 December 1980. Other studies in progress for the same three operational base sites are water resources, environmental and mineral surveys, and topographic mapping. The results of these studies will be presented in separate reports.

Volume I of this report is a synthesis of the data obtained during the study. Volume II is a detailed compilation of the data generated and used in this investigation.

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EXECUTIVE SUMMARY

Preliminary geotechnical investigations were completed at two potential sites for the proposed Milford, Utah, Operational Base (OB). One site, referred to as Option 1, is located approximately 30 miles (48 km) southwest of Milford (5 miles [8 km] north of Lund). The other site, Option 2, is located 12 miles (19 km) southwest of Milford. Results of the investigations are as follows:

1. Depth to Rock - Rock is found at the surface in portions of the isolated, northwestern extension of the Operational Base Test and Training Site (OBTS) of Option 1; the isolated, northern extension of the OBTS of Option 2; and the Base Housing (BH) of Option 2. Depth to rock is interpreted to be less than 50 feet (15 m) at the BH of Option 2 and greater than 50 feet (15 m) below the Main Operational Base (MOB) locations of Options 1 and 2. Depth to rock is expected to be less than 150 feet (46 m) below the Designated Assembly Area (DAA) of Option 2 and greater than 150 (46 m) below the DAA of Option 1.

2. Depth to Water - Shallow water (less than 50 feet [15 m] below the ground surface) is anticipated below portions of the DAA, MOB, and OBTS of Option 1 and the DAA and MOB of Option 2. Depth to water below all other activity centers is interpreted to be greater than 100 feet (30 m).

3. Terrain - Adverse terrain determined from incision depths, spacing, and slope criteria is present in portions of the OBTS of both Options 1 and 2 and the BH of Option 2. Areas with surface gradients exceeding five and 10 percent generally occur along the mountain fronts and rock outliers on the western side of the study area.

4. Flooding and Ponding - The potential for major flooding is relatively low in the general OB site areas. Flooding would be limited to the major incisions in young- and intermediate-age alluvial fans. Ponding may occur in low lying areas of older lacustrine and younger playa deposits. It appears that conventional flood control methods would be effective in controlling any flood hazard. The extent and precise locations of potential flooding and ponding should be determined in subsequent studies.

5. Faults - Active and potentially active faults trend toward and through the site areas. The fault traces and projections of the traces should be avoided with appropriate set-back for locating structures. Historic seismicity in the site areas has been low; however, earthquakes of magnitudes of 7.5 have been recorded regionally. The potential for fault rupture and earthquake hazards should be evaluated in future studies.

6. Subsidence - A ground fracture most likely associated with subsidence due to ground-water withdrawal occurs within 2 miles (3 km) of the proposed activity centers of Option 2. No fractures were observed within the proposed activity centers for either Option 1 or Option 2. The potential for renewed breakage along existing ground fractures and the likelihood of new ground fractures should be evaluated in future studies.

7. Sand Dunes - Sand dunes and sheet sand deposits occur throughout the proposed site areas. Presently, these deposits are mostly stable. The potential for reactivation of the sand dunes from surface disruptions related to site construction should be evaluated in future studies.

8. Rockfalls - The potential for rockfalls is limited to the western margin of the study area near the mountain fronts and rock outliers. Potential rockfalls should be considered for construction of the OBTS and BH of both Options 1 and 2.

9. Foundations - The subsoil conditions are quite complex. The soils in the activity center areas consist of medium dense to dense granular soils (sand and gravel) and firm to very stiff fine-grained soils (silt and clay). The silt and clay are more compressible than the granular soils.

   o In the areas underlain mainly by the granular soils, shallow spread or continuous footings can be used to support the structures.

   o In areas underlain by both granular and fine-grained soils, a combination of shallow footings and pier or pile foundations will be necessary depending on the relative thicknesses of the soil strata, load on columns, and tolerable differential settlements. Detailed geotechnical investigations will be required to determine the most cost-effective type of foundation.

10. Roads and Runway - Most of the roads will be on sandy alluvial fan deposits which will provide good support as a subgrade. Some roads will be constructed on silt and clay soils (lacustrine deposits) which will provide poor to fair

support as a subgrade. The runway for Option 1 will be constructed on sandy alluvial deposits. The Option 2 runway will be constructed on both eolian sand with good subgrade support and silt and clay soils of the lake deposits with poor to fair support properties.

11. Slope Stability - Natural slopes are in stable condition. Temporary excavations can be cut with slopes between 1/2:1 (horizontal:vertical) in the well-cemented materials and clays to 1 1/2:1 in the cleaner sandy materials.

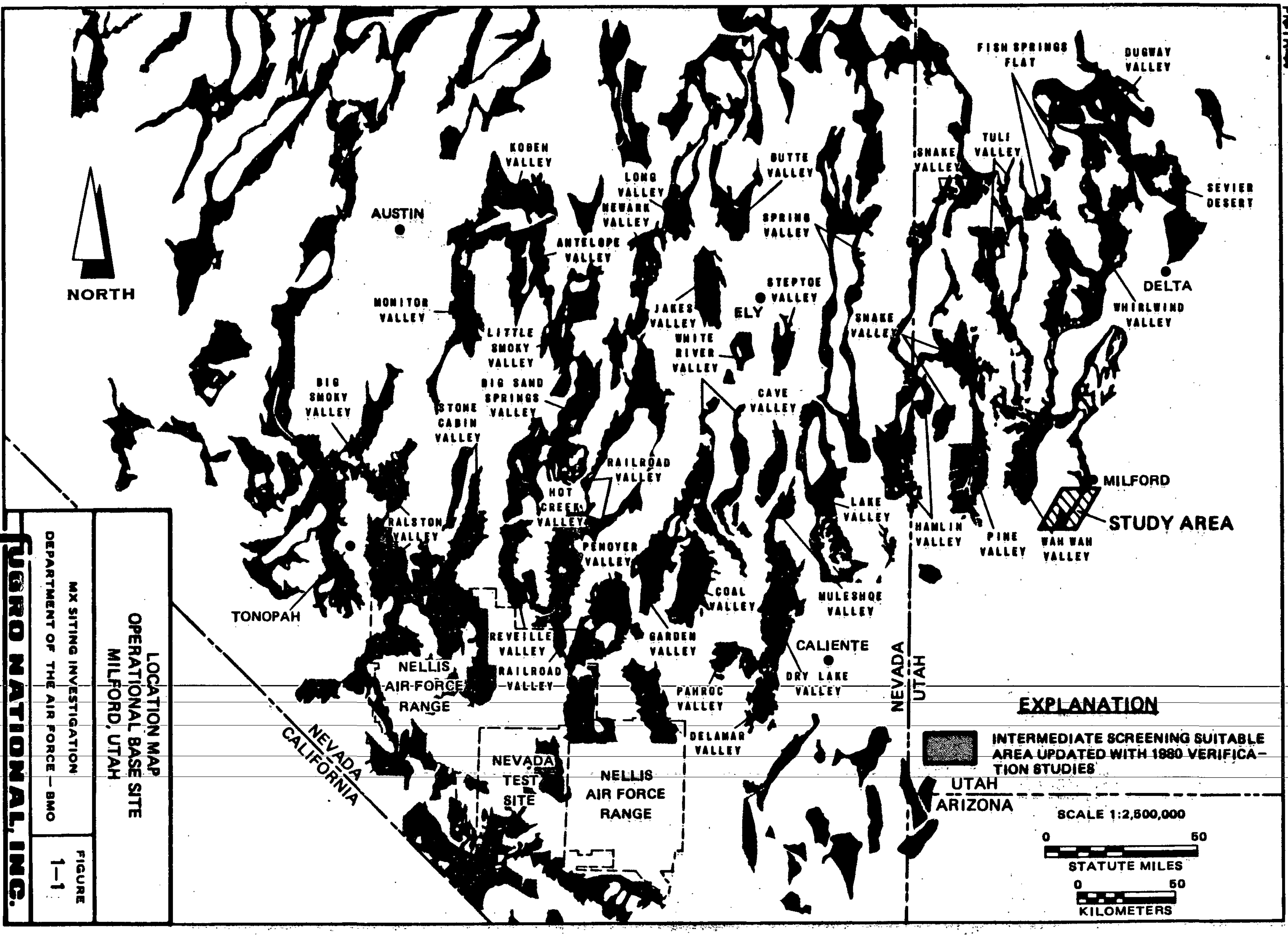
12. Construction Considerations - Conventional equipment can be used for excavation and compaction in the top 5 feet (1.5 m). However, in areas where Stage III caliche or surface rock exists, ripping and/or blasting may be necessary for excavation. Sulfate attack of lake sediments on concrete will have to be taken into consideration in design of concrete elements exposed to the soil. The silty sand of the alluvial fan deposits and the sandy silt of the lake deposits are considered to be severely frost susceptible. Frost action in the finer grained soils, gravels with a significant amount of fines, and the cleaner sands will be moderate. Frost attack should be considered for the design of the roads, runways, and foundations.

1.0 INTRODUCTION

This report presents the results of a preliminary geotechnical evaluation of two potential locations for the proposed Operational Base (OB) site near Milford, Utah (Figure 1-1). The purpose of this study was to assess the geological, geophysical, and soils engineering data and to present recommendations regarding site suitability, foundations for various facilities, construction considerations, and aggregate resources.

Our previous report, "Operational Base Site, Escalante Desert, Milford Area, Utah," submitted 10 March 1980, included discussions on water supply, land ownership, existing and proposed transportation systems, and terrain and geotechnical conditions. No field work was conducted for that initial study. Four conceptual layouts were presented in the 1980 report for the three major activity centers; i.e., the Main Operational Base (MOB), the Designated Assembly Area (DAA), and the Operational Base Test and Training Site (OBTS). Subsequently, there have been a series of meetings and discussions concerning the location of activity centers within the siting areas.

For the present site-specific investigation, the preferred conceptual layouts (as described in Section 2.0) were developed by a working group on operational base siting composed of personnel from SAC, AFRCE, BMO, Fugro National, TRW, Martin Marietta, COE, and the Ralph M. Parsons Company. The geotechnical siting criteria and exclusions which formed a baseline for the present



LOCATION MAP
OPERATIONAL BASE SITE
MILFORD, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE — BMO

FIGURE
1-1

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study are derived from the document entitled "Siting Criteria for MX Operating Bases, 10 November 1980."

The present report is more detailed than our prior report and is the result of a thorough review of available geotechnical data and preliminary field studies within the proposed site areas. This report contains two volumes; Volume I is a synthesis of the data with conclusions and recommendations, and Volume II is a compilation of the data. This report is intended to be utilized by the architect and engineer for the preliminary layout of facilities within the various activity centers and for preliminary foundation design considerations.

The objectives of this study have been to:

- Identify the geologic units,
- Determine the subsurface conditions and estimate depths to rock and water,
- Characterize the basin-fill deposits and describe the physical and engineering properties of the subsoils in the activity center areas,
- Identify adverse terrain conditions,
- Identify geologic hazards including flooding and ponding, faults and seismicity, subsidence, sand dunes, and rockfalls,
- Develop preliminary foundation design recommendations in the activity center areas and general construction considerations, and
- Identify potential aggregate sources.

2.0 SITING CRITERIA AND ASSUMPTIONS FOR OPERATIONAL BASE STRUCTURES

Conceptually, two options (1 and 2) have been proposed for the Milford OB, each consisting of the same four main activity centers (Figure 2-1). The names and approximate areas of the activity centers are as follows:

Activity Center	Approximate Area acres (hectares)
Main Operational Base (MOB)	1800 (700)
Designated Assembly Area (DAA)	1800 (700)
Operational Base Test and Training Site (OBTS)	2200 (900)
Base Housing (BH)	2700 (1100)

The proposed layouts of these centers at the Milford site were developed by the operational base working group on 20 August 1980.

2.1 SITING CRITERIA

The operational base layout for the proposed Milford site generally follows the criteria set out in the draft BMO document "MX Siting Criteria for MX Operating Bases, 10 November 1980." In this document, guidelines for siting and exclusion are also provided. Excerpts from those guidelines relevant to the present geotechnical investigation are presented below.

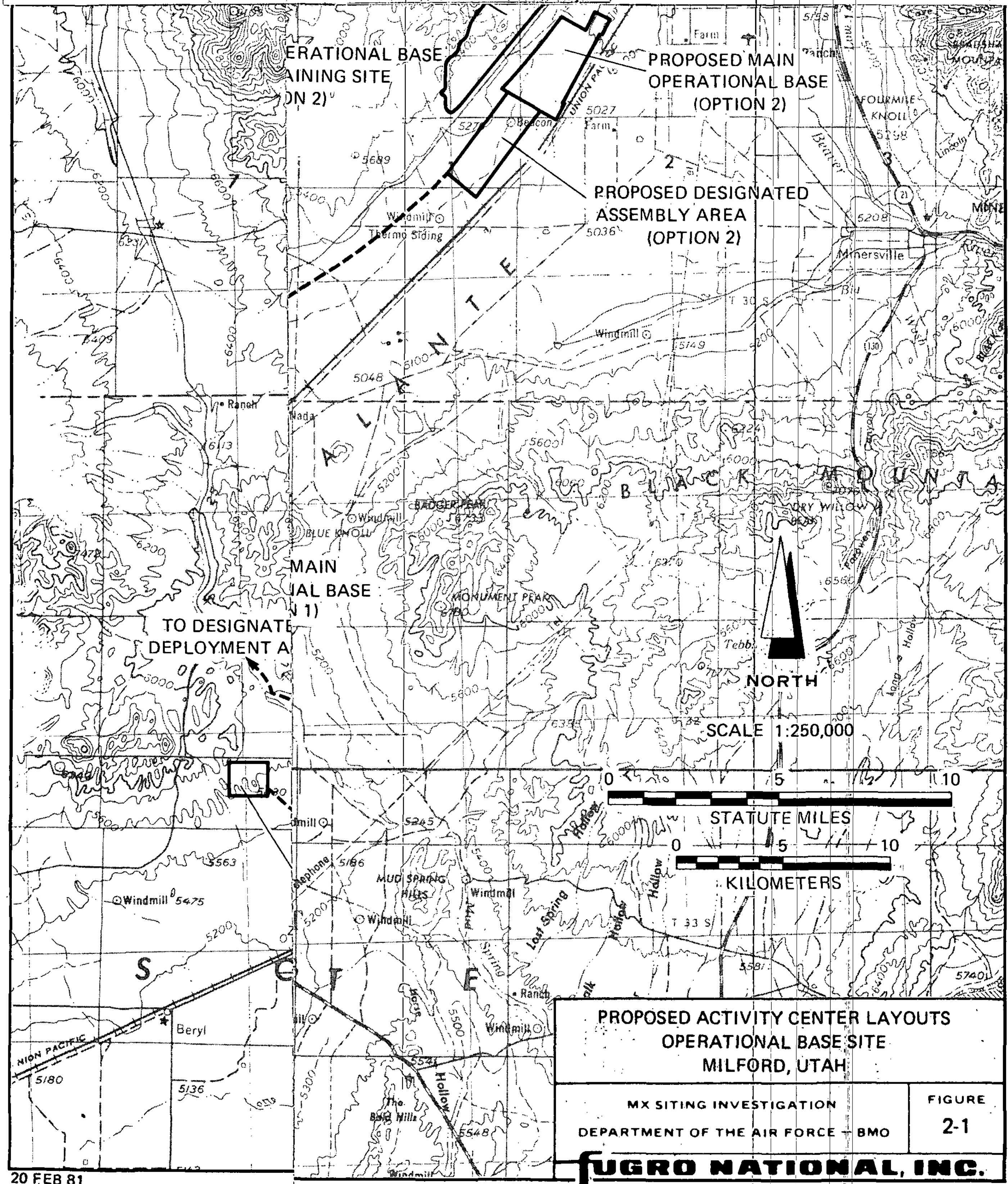
Desirable Geotechnical Features

o Suitable soil for building and landscaping; and

o Avoid active and potentially active fault zones.

Geotechnical Exclusions

o Areas having rock and water within 50 feet (15 m) of the surface except base technical and housing areas;



PROPOSED ACTIVITY CENTER LAYOUTS
OPERATIONAL BASE SITE
MILFORD, UTAH

MX SITING INVESTIGATION

DEPARTMENT OF THE AIR FORCE — BMO

FIGURE

2-1

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- o Surface grade of areas (for DAA/OBTS/Training and Airfield) having
  - Nominal surface grade of greater than five percent;
  - Local grade greater than 10 percent measured over a 1000-foot (305-m) length;
  - More than two 10-foot (3-m) deep drainage crossings per 1000 feet (305 m); and
- o Areas of surface water including all significant lakes, reservoirs, swamps, perennial drainages, and playas subject to flooding.

2.2 ASSUMPTIONS FOR OPERATIONAL BASE STRUCTURES

Proposed structures and the estimated column loads, identified in each activity center, are listed below. For discussion purposes, the estimated column loads are categorized into light (less than 50 kips [23 tonnes]), medium (50 to 200 kips [23 to 91 tonnes]), and high (greater than 200 kips [91 tonnes]).

Structures in MOB	Estimated Column Load High (H), Medium (M), or Light (L)
Office (office space for 800 personnel, computer center, and dining space for 1000 people)	M
Shop	L
Communication Tower	H
Fuel Tank	not applicable
Storage Silo	H
Warehouse	L to M
Fire Station	L
Vehicles Maintenance Facility	L
Airport Facility	M
Runway (12,000 feet [3658 m] long)	not applicable
Marshalling Yard	not applicable

Structures in DAA	
Missile Assembly Building (150-ton bridge crane) (136-tonne)	H
Heavy Vehicles Assembly Facility (15-ton bridge crane) (14-tonne)	M

Launcher Assembly Building	M
Launcher Integration Building	M
Stage Storage Area (earth covered structure, 10-ton overhead crane) (9-tonne)	M
Weapon Storage Area	M
Missile Storage Area	M
Warehouse	L to M
Office	L
Laboratory (electronic equipment)	L
Shop	L

Structures in OBTS

Cluster Maintenance Facility Storage	M
Office	L
Laboratory	L
Shop	L

Structures in BH

Residential Houses	L
Apartments	L
Community Center	M
Hospital	M
Recreation Center	M
School	M

These assumptions regarding column loads were used in planning the geotechnical investigations described herein. Additionally, they are the basis for the discussion of Foundation Considerations in Section 6.2.

All the structures except the Missile Assembly Building (MAB) have been assumed to have the lowest floor level at final grade. Only the deeper part of the MAB will have lowest floor level at 50 feet (15 m) below grade.

3.0 SCOPE

The scope of the study consisted of the following:

- Review of existing data;
- Field investigations by geologists, geophysicists, and engineers;
- Laboratory testing on selected samples recovered from the borings, trenches, and test pits; and
- Analyses of the results of the field and laboratory investigations and the subsequent discussions, conclusions, and recommendations.

3.1 REVIEW OF EXISTING DATA

Prior to the geotechnical field activities, existing data were reviewed. The existing data included the results of the previous investigation by Fugro National, Inc. (report dated 10 March 1980, FN-TR-35), other published literature, land-status conditions, and results of geologic investigations in the general vicinity of the sites published by the Nevada Bureau of Mines and the U.S. Geological Survey.

3.2 FIELD INVESTIGATION

The field investigation performed in November 1980 consisted of geologic mapping, exploratory borings, trenches, test pits, cone penetrometer tests, and geophysical (seismic refraction and electrical resistivity) surveys. The different techniques used in the field investigation are outlined in Table 3-1. Detailed procedures for geologic, geophysical, and engineering activities are included in Sections A2.0, A3.0, and A4.0 of Appendix A, respectively. Table 3-2 lists the types and numbers of the field activities performed.

soils. Following the field and laboratory investigations, detailed analyses will be necessary to determine the most suitable and cost-effective foundation type for the various structures considering the type of structure, loading, and its tolerance to settlement.

It is also recommended that plate loading tests and load tests for piers and piles be performed to evaluate their capacities and determine the most cost-effective type of foundation.

7.6 AGGREGATE RESOURCES

A detailed aggregate study should be performed to delineate the most promising aggregate sources and to determine their chemical and physical characteristics. The study should consist of:

- Field geologic mapping;
- Excavation of test pits; and
- Obtaining samples for laboratory testing.

The field work should be planned so that the lateral and vertical extent of the potential aggregate sources can be determined. To determine the quality of the aggregate, we recommend the following tests:

- Sieve analysis, Los Angeles abrasion, soundness, potential reactivity, specific gravity, and absorption.

In addition, we recommend that trial mixes of concrete using these aggregates be made to determine the concrete strength and related properties.

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A1.0 GLOSSARY OF TERMS

ACTIVE FAULT - A fault which has had surface displacement within Holocene time (about the last 12,000 years).

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

AGGREGATE - Granular material such as sand, gravel, crushed stone, and iron-blast furnace slag used for constructional purposes.

ALLOWABLE BEARING PRESSURE - The maximum foundation pressure to the soil which will not induce structural damage to the super-structure. The net allowable bearing pressure is the allowable bearing pressure less the original overburden pressure.

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

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

ARTESIAN - A general term for referring to ground water confined under hydrostatic pressure.

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

Liquid Limit (LL) - The water content corresponding to an arbitrary limit between the liquid and plastic states of consistency of a soil (ASTM D 423-66).

Plastic Limit (PL) - The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil (ASTM D 424-59).

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

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

BEDROCK - A general term for the rock, usually solid, that underlies soil or other unconsolidated surficial material. The term is also used here to include the rock composing the local mountain ranges.

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

BOULDER - A detached rock mass having a diameter greater than 10 inches (256 mm), being somewhat rounded or otherwise distinctively shaped by abrasion in the course of transport.

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

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

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

CALICHE - In general, secondary calcium carbonate cementation of unconsolidated materials occurring in arid and semiarid areas.

CALIFORNIA BEARING RATIO (CBR) - The ratio (in percent) of the resistance to penetration developed by a subgrade soil to that developed by a specimen of standard crushed rock-base material (ASTM D 1883-73). During the CBR test, the load is applied on the circular penetration piston (3 in^2 base area) (19 cm^2) which is penetrated into the the soil sample at a constant penetration rate of 0.05 inch/minute (1.2 mm/min). The bearing ratio reported for the soil is normally the one at 0.1-inch (2.5-mm) penetration.

CENOZOIC - An era of geologic time from the beginning of the Tertiary period (about 65 million years ago) to the present.

CLAST - An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering (disintegration) of a larger rock mass.

CLAST SUPPORTED GRAVEL - Gravel in which the support is provided by clast-to-clast contact instead of by an interstitial matrix.

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

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

CLOSED BASIN - A catchment area draining to some depression or lake within its area from which water escapes by evaporation or infiltration into the subsurface.

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

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

COBBLE - A rock fragment, larger than a pebble and smaller than a boulder, having a diameter between 3 and 10 inches (64 and 256 mm), being somewhat rounded or otherwise modified by abrasion in the course of transport.

COMPACTION TEST - A type of test to determine the relationship between the moisture content and density of a soil sample which is prepared in compacted layers at various water contents (ASTM D 1557-70).

COMPRESSIBILITY - Property of a soil pertaining to its susceptibility to decrease in volume when subjected to load. See M_v for definition of coefficient of volume compressibility.

CONE PENETROMETER TEST - A method of evaluating the in-situ engineering properties of soil by measuring the penetration resistance developed during the steady slow penetration of a cone (60^o apex angle, 15-cm^2 projected area) into soil.

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

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

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

CONGLOMERATE - A coarse-grained clastic sedimentary rock composed of fragments larger than 2 mm in diameter. The consolidated equivalent of a gravel.

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

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

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

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

DISSECTION/DISSECTED - The cutting of stream channels into soil units by the movement (or flow) of water.

DOLOMITE - A carbonate sedimentary rock composed of more than 50 percent magnesium carbonate.

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

EPHEMERAL STREAM - A stream or reach of a stream that flows briefly only in direct response to precipitation in the immediate locality and whose channel is at all times above the water table.

FAULT - A fracture or a zone of fractures along which there has been displacement of the sides relative to one another parallel to the fracture.

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

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

FLOODPLAIN DEPOSITS - Sediment deposited by river water that was spread out over a floodplain.

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

FOOTING - (Spread, combined, continuous, or strip) - If various parts of the structure are supported individually, the individual supports are known as spread footings, and the foundation is called a footing foundation. A footing that supports a single column is called an individual footing; one that supports a group of columns is a combined footing; and one that supports a wall is a continuous footing.

FUGRO DRIVE SAMPLE - A 2.50-inch-(6.4-cm) diameter soil sample obtained from a drill hole with a Fugro drive sampler. The Fugro drive sampler is a ring-lined barrel sampler containing 12 1-inch- (2.54-cm) long brass sample rings. The sampler is advanced into the soil using a drop hammer.

GEODETIC LEVELING - Leveling at a high order of accuracy, usually extended over large areas to furnish accurate vertical control for surveying and mapping operations.

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

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

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

HUMMOCKY - A term used to describe a land surface containing abundant rounded or conical knolls, mounds, or dunes.

JOINTS - Surfaces of fracture or parting in a rock, without displacement.

LACUSTRINE DEPOSITS - Materials deposited in a lake environment.

LIMESTONE - A sedimentary rock consisting chiefly of calcium carbonate.

LINEAMENT - A linear topographic feature of regional extent that is believed to reflect crustal structure.

LIQUID LIMIT - See ATTERBERG LIMITS.

MATRIX - The finer-grained material filling the interstices between the larger particles of a sediment or sedimentary rock.

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

M_V - Coefficient of Volume Compressibility (the compression of a soil, per unit of original thickness, due to a unit increase of pressure).

N VALUE - Penetration resistance, described as the number of blows required to drive the standard split-spoon sampler for the second and third of three 6-inch (0.15-m) increments with a 140-pound (63.5-kg) hammer falling 30 inches (0.76 m) (ASTM D 1586-67).

NET ALLOWABLE BEARING PRESSURE - See ALLOWABLE BEARING PRESSURE.

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

PALEOZOIC - An era of geologic time from about 570 to about 225 million years ago.

PEBBLE - A rock fragment larger than a granule and smaller than a cobble, having a diameter in the range of 1/6 to 2.5 inches (4 to 64 mm), being somewhat rounded or otherwise modified by abrasion in the course of transport.

PIER - An underground structural member that serves the same purpose as a footing, namely, to transmit a load to a stratum capable of supporting it without danger of failure or excessive settlement. In contrast to a footing, however, the ratio of the depth of foundation to the base width of piers is usually greater than 4, whereas for footings this ratio is commonly less than unity.

PILE - A structural member with a small cross-sectional areas as compared to its length used to transfer foundation loads through a soil layer which is too weak or compressible to provide adequate support and into a more suitable material at a greater depth.

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

PLASTIC LIMIT - See ATTERBERG LIMITS.

PLASTICITY INDEX - See ATTERBERG LIMITS.

PLEISTOCENE - A division of geologic time (epoch) within the Quaternary period (1.8 to 0.1 million years).

PLIOCENE - A division of geologic time (epoch) within the late Tertiary period (5 to 1.8 million years).

POTENTIALLY ACTIVE FAULT - A fault which has not moved during the Holocene epoch (0 to 12,000 years) but which shows geologic evidence of recurrent movement during the Pleistocene epoch (12,000 years to 1.8 million years) and remains favorably oriented to the present tectonic stress regime such that it has a potential for movement in the future.

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

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

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

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

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

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

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

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

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

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

SETTLEMENT - The subsidence of a structure, caused by compression or movement of the soil below the foundation.

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

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

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

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

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

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

STREAM CHANNEL DEPOSITS - See Fluvial Deposits.

SUBGRADE - A layer of earth or rock that is graded to receive the foundation of an engineered structure.

SUBSIDENCE - The sudden sinking or gradual downward settling of the earth's surface with little or no horizontal motion.

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

TALUS - Rock fragments of any size or shape derived from and lying at the base of a steep rocky slope.

TECTONICS - Related to regional structural features.

TERTIARY - A division of geologic time (period) within the Cenozoic era (65 to approximately 2 million years).

TEST PIT - An excavation made to depths of about 10 feet (3 m) by a backhoe. A test pit permits visual examination of undisturbed material in place.

TRENCH - An excavation by a backhoe to depths of about 14 feet (4.3 m). A trench permits visual examination of soil in place and evaluaton of excavation wall stability.

TRIAXIAL COMPRESSION TEST - A type of test to measure the shear strength of an undisturbed soil sample (ASTM D 2850-70). To conduct the test, a cylindrical specimen of soil is surrounded by a fluid in a pressure chamber and subjected to an isotropic pressure; an additional compressive load is then applied, directed along the axis of the specimen, called the axial load.

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

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

UNCONFINED COMPRESSION - A type of test to measure the compressive strength of an undisturbed sample (ASTM D 2166-66). Unconfined compressive strength is defined as the load per unit area at which an unconfined prismatic or cylindrical specimen of soil will fail in a simple compression test.

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

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

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

Definitions were derived from the following references:

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

Bates, J.A., R.L. Bates, 1980, Glossary of Geology: American Geological Institute - 2nd Edition.

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

Merriam, G., and Merriam, C., 1977, Webster's New Collegiate Dictionary: Springfield, Mass., G. and C. Merriam Co., 1536 p.

Sheriff, R. E., 1973, Encyclopedic Dictionary of Exploration Geophysics: Tulsa, Oklahoma, Society of Exploration Geophysicists, 266 p.

Terzaghi, K., and Peck, R.B., 1967, Soil Mechanics in Engineering Practice: 2nd Edition, New York, Wiley, 729p.

A2.0 ENGINEERING GEOLOGIC PROCEDURES

The geotechnical evaluation of the potential operational base area in Milford, Utah, was conducted in two major phases, 1) a literature study, data search, and aerial photograph analysis followed by 2) extensive field mapping and field verification of site conditions.

A2.1 REVIEW OF EXISTING DATA

The literature study and data search included a review of all pertinent geological and related literature in the region surrounding the site and discussions with state and county highway and U.S. Weather Bureau personnel to assess potential geologic hazards such as flooding.

Photogeologic analysis was done primarily on color stereo photographs at a scale of 1:25,000. Black and white aerial photographs at a scale of 1:60,000 were used to complement interpretation of data.

A2.2 GEOLOGIC RECONNAISSANCE

The primary objective of the geotechnical field program was to verify and document site conditions and potential hazards. Geologic stations were established at selected locations throughout the site area. The information collected at each station included some or all of the following, depending on local conditions:

- Detailed geologic descriptions of outcrops, with emphasis on soil types, bedding characteristics, cementation, etc.; and

- Description of surface conditions, including slope gradient, ground cracking, vegetation, evidence for flooding, "hardness" of surface, etc.

Observations from outcrops were supplemented by observations of existing excavations (borrow pits and road cuts) and hand-dug test pits. Data obtained from engineering backhoe trenches, test pits, and hydrologic and engineering borings were incorporated in our geotechnical analysis of the site area.

Geologic mapping was done on 1:25,000-scale color aerial photos with plastic overlays. Data were compiled into four maps and four cross sections. The maps consist of a geologic map, terrain map, depth-to-water map, and geologic hazards map. Data from the aerial photo overlays were transferred directly to 1:24,000 (geologic and terrain) and 1:62,500 (depth to water and geologic hazards) topographic base maps.

The data presented on the terrain map are based on aerial photo and topographic map interpretations combined with representative field measurements. The depth-to-water map is an interpretation based on widely spaced control points (wells) and regional hydrogeologic conditions. Our assessment of the flood and ponding hazards, as presented on the geologic hazards map (Drawing 5-4) is based on aerial photo analysis of existing drainage conditions and limited field observations.

A3.0 GEOPHYSICAL PROCEDURES

A3.1 SEISMIC REFRACTION SURVEYS

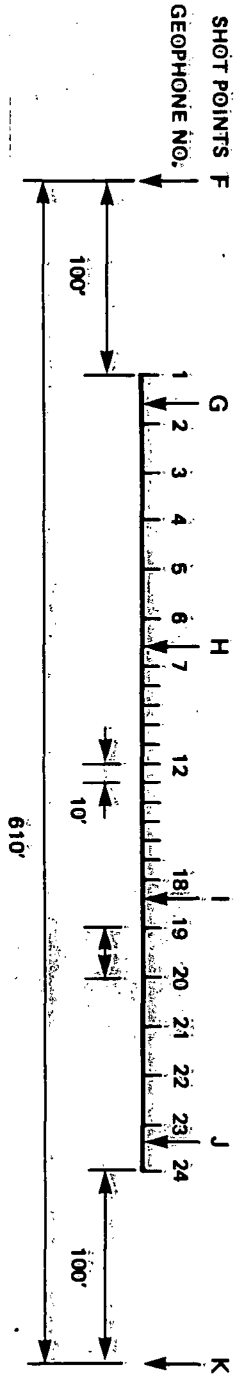
A3.1.1 Instruments

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

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

A3.1.2 Field Procedures

Each seismic refraction line consisted of a single spread of 24 geophones with a distance of 410 feet (125 m) between end points (Figure A3-1). Geophone spacing provided six intervals of 25 feet (7.6 m) at both ends of the line and 11 central intervals of 10 feet (3 m). Six shots were made per spread at



SPREAD CONFIGURATION
SEISMIC REFRACTION LINE
OPERATIONAL BASE SITE
MILFORD, UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE — BMO	FIGURE A3-1

FUGRO NATIONAL, INC.

locations 65 feet (20 m), 190 (58 m) and 305 feet (93 m) left and right of the spread center. The recording system was located between geophones 12 and 13.

The explosive used was "Kinestik" which was transported to the site as two nonexplosive components, a powder and a liquid. The components were mixed in the field to make an explosive compound. Charges ranged in size from one-third to five pounds and were buried from 1 to 5 feet (0.3 to 1.5 m) deep. Charges were detonated using Reynold's exploding bridge wire (EBW) detonators instead of conventional electric blasting caps. Use of EBWs provides maximum safety against accidental detonation and extremely accurate "time breaks" (instant of detonation). Relative elevations of geophones and shotpoints were obtained by level or transit where lines had more than 2 or 3 feet (0.6 to 0.9 m) of relief.

A3.1.3 Data Reduction

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

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

A3.2 ELECTRICAL RESISTIVITY SURVEYS

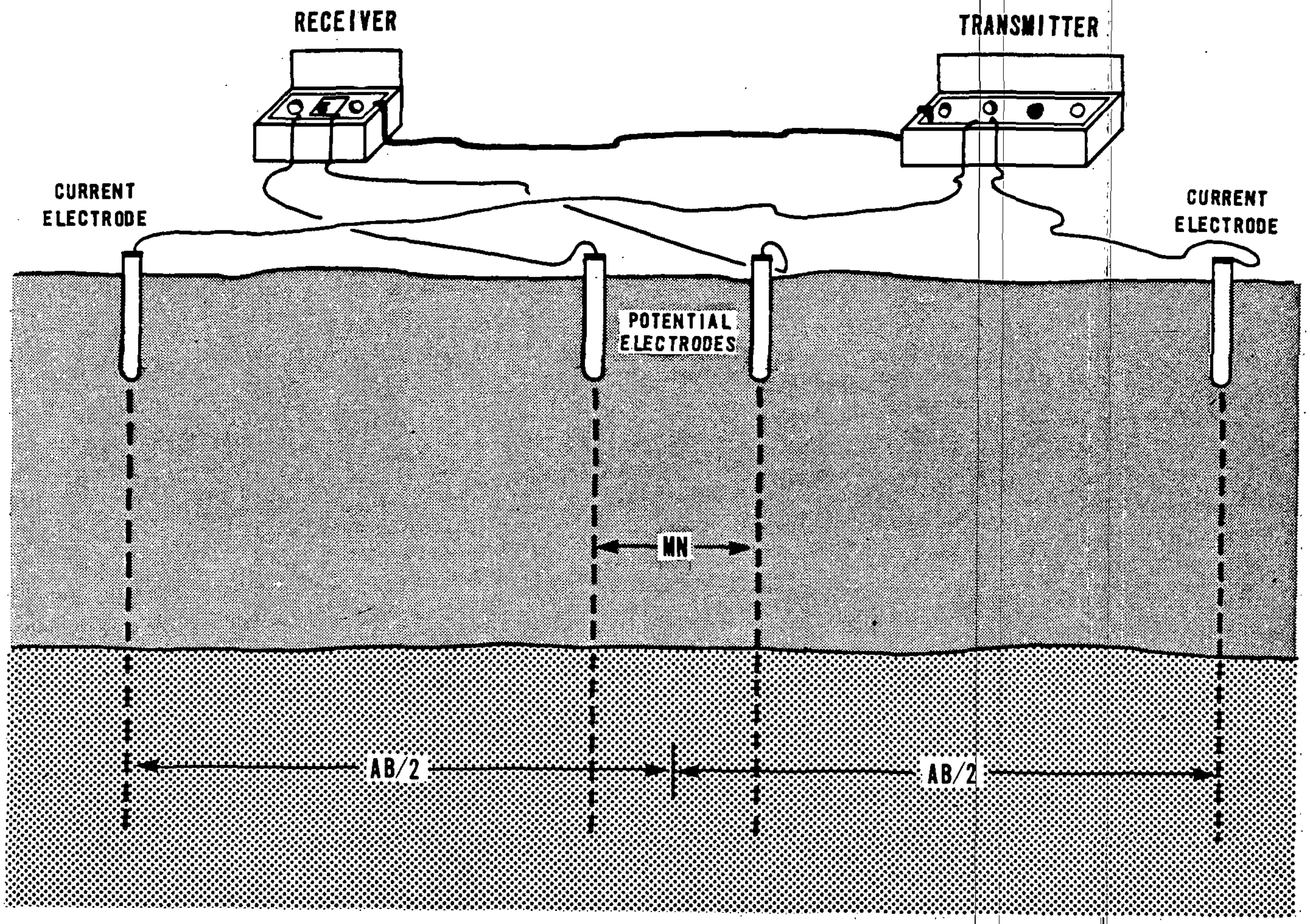
A3.2.1 Instruments

Electrical resistivity measurements were made with a Bison Instrument model 2350B resistivity meter which provides current to the earth through two electrodes and measures the potential (voltage) drop across two other electrodes.

A3.2.2 Field Procedures

Electrical resistivity soundings were made using the Schlumberger electrode arrangement. Soundings are made by successive resistivity measurements which obtain information from deeper and deeper materials. The depth of penetration of the electrical current is increased by increasing the distance between the current electrodes. The arrangement of electrodes in the Schlumberger method is shown in Figure A3-2. The four electrodes are in a line with the two current electrodes on the ends. The distance between the current electrodes (AB) is always five or more times greater than the distance between the potential electrodes (MN).

The initial readings are made with MN equal to 5 feet (1.5 m) and AB equal to 30 feet (9 m). Successive readings were made with AB at 40, 50, 60, 80, 100, 120, 140, 160, 180, 200, 240, 300, 360, 400, 500, and 600 feet (12, 15, 18, 24, 30, 37, 43, 49, 55, 61, 73, 91, 110, 122, 152, and 183 m). MN spacing is sometimes increased one or two times as AB is expanded. This increase is required when the signal drops to a level below the meter's sensitivity. The potential drop is greater between



SCHLUMBERGER ARRAY ELECTRICAL RESISTIVITY SOUNDINGS
OPERATIONAL BASE SITE
MILFORD, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE
A3-2

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more widely spaced electrodes (MN), so increasing MN increases the signal. When it becomes necessary to increase MN, the spacing of AB is reduced to the spacing of the previous reading. MN is then increased and a measurement is made. This provides two resistivity measurements at the same AB spacing but with different MN spacings.

A3.2.3 Data Reduction

Each apparent resistivity value is plotted versus one-half the current electrode spacing (AB/2) used to obtain it. Log-log graph paper is used to form the coordinates for the graph. A smooth curve is drawn through the points. This sounding curve forms the basis for interpreting the resistivity layering at the sounding location.

A computer program that does iterative "curve-matching" is used to develop a layer model that has a theoretical resistivity curve that is similar to the field curve. Input to the program is generated by digitizing the field curve with an electronic digitizer.

A4.0 ENGINEERING PROCEDURES

Soil engineering activities consisted of the following:

- o Field activities;
  - Borings;
  - Trenches;
  - Test Pits; and
  - Cone Penetrometer Tests;

- o Office activities;
  - Laboratory Tests; and
  - Data Analyses.

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

A4.1 BORINGS

A4.1.1 Drilling Techniques

The borings were drilled at designated locations using a truck-mounted Failing 1500 drilling rig with hydraulic pulldown and rotary wash techniques. Borings were nominally 4-7/8 inches (124 mm) in diameter and drilling fluid (typically a bentonite-water slurry) was used to stabilize the hole. A tricone drill bit was used for coarse-grained soils and a drag bit for drilling in fine-grained soils. Nominal maximum depth drilled was 160 feet (49 m). Rock was encountered in boring MD-B-5 and was cored for 3 feet (0.9 m) before terminating the boring.

A4.1.2 Method of Sampling

A4.1.2.1 Sampling Intervals

Soil samples were obtained at the following nominal depths as well as at depths of change in soil type.

0' to 2'	(0-0.6 m)	- Drive sample
2.5' to 5'	(0.8 - 1.5 m)	- Pitcher or drive

6' to 8' (1.8 - 2.4 m) - Pitcher or drive

10' to 50' (3.0 - 15.2 m) - Pitcher or drive - samples at 5' intervals, starting at a depth of 10'

50' to 100' (15.2 - 30.5 m) - Pitcher or drive - samples at 10' intervals

100' to 160' (30.5 - 48.0) - Pitcher or drive - samples at 15' intervals

A4.1.2.2 Sampling Techniques

a. Fugro Drive Samples: Fugro drive samplers were used to obtain relatively undisturbed soil samples. The Fugro drive sampler is a ring-lined barrel sampler with an outside diameter of 3.0 inches (76.2 mm) and inside diameter of 2.50 inches (63.5 mm). It contains 12 individual 1-inch- (25.4-mm) long rings and is attached to a 12-inch- (30-cm) long waste barrel. The sampler was advanced using a downhole hammer weighing 335 pounds (76 kg) with a drop of 18 inches (46 cm).

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

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

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

c. Wash Samples: Wash samples (cuttings) were obtained by screening the returning drilling fluid during the drilling operations to obtain lithologic information between samples. Recovered wash samples were placed in plastic bags and labeled as explained previously.

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

A4.1.3 Logging

All soils were classified in the field by the procedures outlined in Section A4.4, "Field Visual Soil Classification," of this Appendix. The following general information was entered on the boring logs at the time of drilling: boring number; project name, number, and location; name of drilling company and driller; name of logger and date logged; method of drilling and sampling, drill bit type and size; driving weight; and average drop as applicable. As drilling progressed, the soil samples recovered were visually classified as outlined in Section A4.4, "Field Visual Soil Classification," and the description was entered on the logs. Section A4.4 also discusses other pertinent data and observations made, which were entered on the boring logs during drilling.

A4.1.4 Sample Storage and Transportation

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

A4.1.5 Ground-Water Observation Wells

At designated locations, the completed boring was cased with a 2-inch-diameter (51-mm) polyvinyl-chloride (PVC) pipe to the bottom of the boring. This PVC pipe was slotted in the bottom 20 feet (6 m). After installation of the pipe, it was flushed until clear water came out. After equilibrium was reached, the water level was measured periodically in the observation wells and recorded.

A4.2 TRENCHES AND TEST PITS

A.4.2.1 Excavation Equipment

The trenches and test pits were excavated using a rubber-tire-mounted Case 580 C backhoe with a maximum depth capability of 15 feet (5 m).

A4.2.2 Method of Excavation

Unless caving occurred during the process of excavation, the trench width was nominally 2 feet (0.6 m). Trench depths were typically 14 feet (4.2 m) and lengths ranged from 12 to 20 feet (3.6 to 6.1 m). Test pits were nominally 2 feet (0.6 m) wide, 10 feet (3.0 m) deep, and ranged from 5 to 10 feet (1.5 to 3.0 m) in length. The trench and test pit walls were vertical. However, where surface materials were unstable, the trench walls were sloped back to a safe angle to prevent sloughing during the completion of excavation and logging. The excavated material was deposited on one side at least 4 feet (1.2 m) from the edge of the trenches in order to minimize stress loads at the edges. The excavations were backfilled with the excavated material and the ground surface was restored to a condition as conformable with the surrounding terrain as was practical.

A4.2.3 Sampling

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

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

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

A4.2.4 Logging

The procedures for field visual classification of soil encountered from the trenches and test pits were basically the same as the procedures for logging of borings (Section A4.1.3). For excavations shallower than 4 feet (1.2 m), technicians entered the excavations and logged them. Logging of the excavations deeper than 4 feet (1.2 m) was accomplished from the surface and by observing the backhoe bucket contents. All trench walls were photographed prior to backfilling.

Each field trench and test pit log included trench or test pit number; project name, number, and location; name of excavator; type of excavation equipment; name of logger; and date logged. As excavations proceeded, the soil types encountered were visually classified and described as outlined in Section A4.4, "Field Visual Soil Classification." Section A4.4 also discusses other pertinent data and observations made which were entered on the logs during excavation.

A4.3 CONE PENETROMETER TESTS

A4.3.1 Equipment

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

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

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

A4.3.2 Test Method

Tests were performed in accordance with ASTM D 3441-75T, "Tentative Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil." Basically, the test was conducted by positioning the electronic cone penetrometer truck over the designated area for testing, setting the outriggers on the ground surface, checking the level of the rig, then pushing the cone into the ground at a rate of 0.79 inch/sec (2 cm/sec) until refusal (defined as the capacity of the cone, friction sleeve, or hydraulics system) or the desired depth of penetration was reached.

A4.4 FIELD VISUAL SOIL CLASSIFICATION

A4.4.1 General

All field logging of soils was performed in accordance with the procedures outlined in this section. Soil samples were visually classified in the field in general accordance with the procedures of ASTM D 2488-69, Description of Soils (Visual-Manual Procedure). The ASTM procedure is based on the Unified Soil Classification System (Table A4-1). It describes several visual and/or manual methods which can be used in the field to estimate the USCS soil group for each sample. The following section details several of the guidelines used in the field for describing soils, drilling and excavating conditions, and unusual conditions encountered.

A4.4.2 Soil Description

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

Coarse-Grained Soils

USCS Name and Symbol
Color
Range in Particle Size
Gradation (well, poorly)
Density
Moisture Content
Particle Shape
Reaction to HCl

Fine-Grained Soils

USCS Name and Symbol
Color
Consistency
Moisture Content
Plasticity
Reaction to HCl

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

Following are definitions of some of the terms and criteria used to describe soils and conditions encountered during the investigations.

a. USCS Name and Symbol: This was derived from Table A4-1, the Unified Soil Classification System. The soils were first designated as coarse- or fine-grained.

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

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

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

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

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

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

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

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

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

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

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

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

Consistency	Shear Strength (ksf)	Field Guide
Very Soft	<0.25	Sample with height equal to twice the diameter, sags under own weight
Soft	0.25-0.50	Can be squeezed between thumb and forefinger
Firm	0.50-1.00	Can be molded easily with fingers
Stiff	1.00-2.00	Can be imprinted with slight pressure from fingers
Very Stiff	2.00-4.00	Can be imprinted with considerable pressure from fingers
Hard	Over 4.00	Cannot be imprinted by fingers

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

Dry : No feel of moisture

Slightly Moist: Much less than normal moisture

Moist : Normal moisture for soil

Very Moist : Much greater than normal moisture

Wet : At or near saturation

g. Particle Shape: Coarse-grained soils

Angular :	Particles have sharp edges and relatively plane sides with unpolished surfaces
Subangular:	Particles are similar to angular but have somewhat rounded edges
Subrounded:	Particles exhibit nearly plane sides but have well-rounded corners and edges
Rounded :	Particles have smoothly curved sides and no edges

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

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

Stage	Gravelly Soils	Nongravelly Soils
I	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II	Continuous pebble coatings, some interpebble fillings	Few to abundant nodules, flakes, filaments
III	Many interpebble fillings	Many nodules and internodular fillings
IV	Laminar horizon overlying plugged horizon	Increasing carbonate impregnation

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

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

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

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

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

A4.5 LABORATORY TESTS

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

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

A4.6 DATA REDUCTION

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

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

The Cone Penetrometer Test results consist of continuous plots of cone resistance, friction sleeve resistance, and friction ratio versus depth from ground surface. Beside the plot is shown a soil column with USCS soil types encountered at the test location.

GEOLOGY AND GEOPHYSICS

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geologic mapping stations	163
Shallow refraction	12
Electrical resistivity	12

ENGINEERING - LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	298
Specific gravity	5
Sieve analysis	165
Hydrometer	14
Atterberg limits	67
Consolidation	10
Unconfined compression	20
Triaxial compression	7
Direct shear	83
Compaction	11
CBR	11
Chemical analysis	14

ENGINEERING

NUMBER OF BORINGS	NOMINAL DEPTH FEET (METERS)
3	160 (49)
7	100 (30)
7	50 (15)

NUMBER OF TRENCHES	NOMINAL DEPTH FEET (METERS)
32	14 (4)

NUMBER OF TEST PITS	NOMINAL DEPTH FEET (METERS)
54	10 (3)

NUMBER OF CONE PENETROMETER TESTS	NOMINAL DEPTH FEET (METERS)
70	33 (10)
17	SAME AS NEAREST BORING

SCOPE OF ACTIVITIES
OPERATIONAL BASE SITE
MILFORD, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE — BMO

TABLE
3-2

FUGRO NATIONAL, INC.

Permits for access were arranged through the District Office of the Bureau of Land Management (BLM). At BLM's request, all field activities were performed along existing roads or trails to minimize site disturbance. Archaeological and environmental surveys were performed at each proposed activity location. Activity locations were changed in those few instances where a potential environmental or archaeological disturbance was identified. Brief descriptions of each type of of activity follow.

3.2.1 Geologic Mapping

The primary objectives of the field geologic mapping were to identify any geologic hazards or adverse conditions not identified in previous studies and to delineate and define soil and rock formations. Color aerial photographs (1:25,000 scale) were used as a mapping base. The field data were subsequently transferred to 1:24,000-scale topographic maps.

3.2.2 Borings

Rotary wash techniques were used to drill borings to depths ranging from approximately 50 to 160 feet (15 to 49 m) below the existing ground surface. Both undisturbed and representative soil samples were taken at various depths for laboratory testing.

3.2.3 Trenches and Test Pits

Trenches and test pits were excavated at selected locations to determine characteristics of the shallow subsurface soils. Bulk samples were taken for laboratory testing.

3.2.4 Cone Penetrometer Tests (CPTs)

Cone penetrometer tests were performed to supplement borings to obtain continuous soil information and to estimate in-situ soil properties.

3.2.5 Seismic Refraction Surveys

Twelve shallow seismic refraction surveys were conducted to determine the depth and configuration of subsurface velocity layers.

3.2.6 Electrical Resistivity Surveys

Twelve resistivity surveys were performed to provide data on the electrical properties of the subsurface soils.

3.3 LABORATORY TESTING

Laboratory testing was performed on representative soil samples to determine the engineering properties of surface and subsurface soils. The testing program included soil classification, moisture/density, Atterberg limits, compaction, California Bearing Ratio (CBR), triaxial shear, unconfined compression, direct shear, and consolidation tests. In addition, chemical tests were performed on representative samples from various soil layers. Testing procedures, which are in general compliance with the American Society of Testing Materials (ASTM) standards, are discussed in Section A4.0 of Appendix A. The number of tests performed is summarized in Table 3-2.

3.4 ANALYSES, CONCLUSIONS, AND RECOMMENDATIONS

Following the field and laboratory investigations, analyses were made of all the collected data. These included studies of land status in the study area, cultural conditions, depths to shallow rock and water, locations of faults and lineaments, and types and properties of surface and subsurface soils. Following the analyses, conclusions and recommendations were developed regarding site suitability; potential geotechnical hazards such as flooding and ponding, faults and seismicity, subsidence, sand dunes, and rockfall; stability of natural and cut slopes; location of potential aggregate sources; types of foundations for the various structures and their allowable bearing pressures; and construction considerations.

4.0 GEOGRAPHIC AND CULTURAL CONDITIONS

4.1 LOCATION

The Milford OB site is located in southwestern Utah along the northwestern margin of the Escalante Desert. The Milford OB site is divided into two areas; Option 1 is located in the southern portion of the study area, and Option 2 lies in the northern portion of the study area. The largest nearby communities are Milford, Minersville, and Cedar City. Milford is located approximately 33 miles (53 km) and 12 miles (19 km) northeast of Options 1 and 2, respectively. Minersville is located approximately 30 miles (48 km) northeast of Option 1 and 18 miles (29 km) east and southeast of Option 2. Cedar City lies approximately 37 miles (59 km) and 45 miles (74 km) southeast of Options 1 and 2, respectively. Cedar City is the largest town with a 1980 census population of 10,881 (Iron County clerk, 1981); Milford and Minersville have populations of 1350 and 500, respectively (Beaver County clerk, 1981).

Escalante Desert is a northeasterly trending valley extending from Modena in the south to Black Rock in the north; a total length of approximately 90 miles (144 km). Escalante Desert is approximately 40 miles (64 km) across at its widest point.

In the site area, Escalante Desert is bounded on the western margin by mountain ranges (Drawing 4-1). These mountain ranges, from north to south, include the Star Range, the Shauntie Hill, the Blue Mountains, the Wah Wah Mountains, and the Needle Range. The maximum elevation in the study area is 7594 feet (2330 m) on Blue Peak Mountain; the minimum elevation is 4982 feet (1528 m) on the valley floor south of Milford.

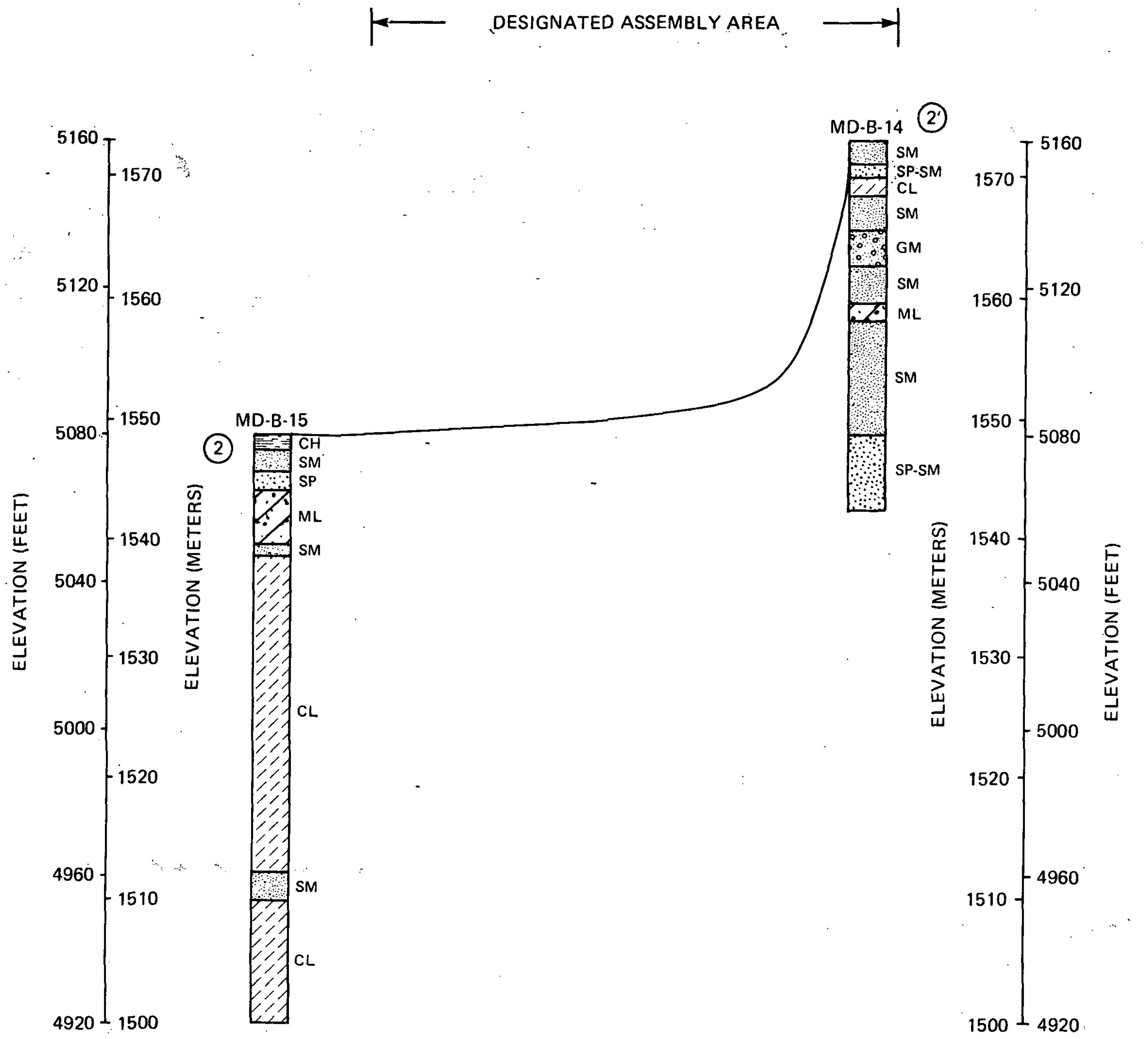
4.2 CULTURAL FEATURES

The main highways in the vicinity of the proposed Milford OB site are state highways 21, 19, 130, and 56. State Highway 21, east of the study area, runs east-west through Milford and Minersville. State Highway 19 trends northwest from Cedar City to Lund (at the southern portion of the study area), a distance of 33 miles (52.8 km). State Highway 130, east of the study area, is a north-south route connecting Minersville to Cedar City, a distance of 35 miles (56 km). State Highway 56, south of the study area, traverses the southern portion of Escalante Desert east-west from Cedar City to Panaca, Nevada. A well-maintained dirt road runs west from Minersville into the proposed site areas.

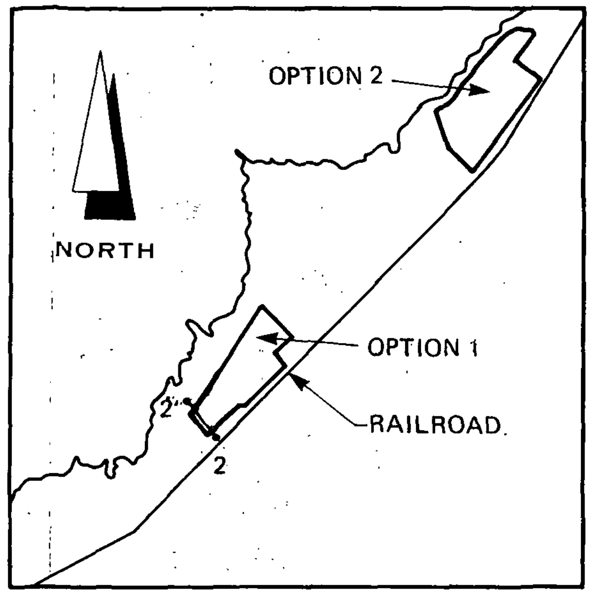
The Union Pacific Railroad traverses Escalante Desert and is essentially the eastern boundary of the site areas. Train stops, from north to south, along the Union Pacific Railroad in the study area include Thermo Siding, Latimer, Lund, Zane, and Beryl. Two Intermountain Power Project (IPP) power lines (500 kilovolts direct power) are proposed to parallel the Union Pacific Railroad between Milford and Lund and would bisect the proposed Milford OB site areas (Drawing 4-1).

4.3 LAND STATUS

The study area, like the rest of Escalante Desert, consists generally of state and private property (Drawing 4-1). The chief land use in the area is ranching. Less than half of the area consists of public lands administered by the BLM from their Cedar City District Office. Much of the public land contains grazing rights. Within the limited BLM lands, there exist two applications for land withdrawal which would change the present land status. The first is a state exchange application for 5290 acres (2141 hectares) along Wah Wah Wash and westward to the Wah Wah Mountains. This land, once acquired by the State of Utah, would be sold or leased to the Alumet Company for the purpose of developing a large alunite mining operation. The mining plan calls for a 20-mile rail spur, a 75-megawatt power plant, a processing plant, and a water-well system. The estimated annual water usage for the Alumet operation within the Milford area would be 32 acre-feet. If the land exchange is approved, it is not known when the Alumet Company might begin operation.



LOCATION MAP



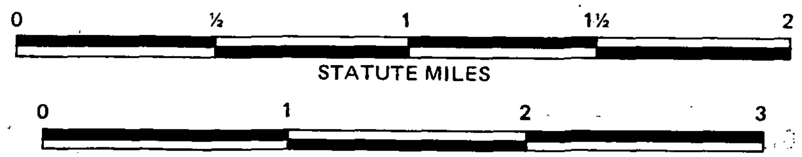
EXPLANATION

B - Boring
T - Trench
P - Test Pit

NOTES:

1. Ground surface elevations shown at activity locations are approximate
2. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.
3. * - indicates that only the predominant soil type is shown and that relatively thin, interbedded layers of one or more other soil types are also present.
4. Datum is mean sea level.

HORIZONTAL SCALE



VERTICAL EXAGGERATION IS 66X

SOIL SECTION 2-2' - OPTION 1
OPERATIONAL BASE SITE
MILFORD, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE – BMO

FIGURE 6-2

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- Sands (SP, SW, SM, SC): The sands consist of poorly to well-graded gravelly sand, silty sand, and clayey sand ranging in particle size from fine to coarse. The sands are in a medium dense to dense condition. Fines in the sands range from nonplastic to slightly plastic. The degree of cementation ranges from none to Stage III. The shear strength of the sand ranges from moderate to high, and the compressibility ranges from very low to moderate. The shear strength and compressibility characteristics of the sands are presented in Table 6-2.
- Silts and Clays (ML, MH, CL, CH): The fine grained soils consist of sandy silt, silt, silty clay, and clay. They range from firm to stiff in consistency and are nonplastic to highly plastic. The degree of cementation ranges from none to Stage III. The shear strength of the silts and clays ranges from moderate to high. The compressibility ranges from very low to moderate. The highly plastic materials may exhibit some shrinkage or swelling behavior when subjected to moisture changes. The shear strength and compressibility characteristics of the silts and clays are presented in Table 6-2.

6.2.1.2 Option 2

The surficial soils at this site vary from sandy gravel to silty clay. The western two-thirds of the MOB and the entire DAA, OBTS, and BH areas are typically covered by sandy gravel and sand. These soils are loose to depths ranging from 1 to 5 feet (0.3 to 1.5 m). The eastern one-third of the MOB is covered by surficial soils consisting typically of sandy clay and silty clay. These soils are generally of a firm consistency to depths ranging from 2 to 5 feet (0.6 to 1.5 m).

The surficial soils are underlain by interbedded layers of gravel, sand, silt, and clay of the alluvial fan and lake deposits. Two soil sections showing typical subsoil conditions are presented in Figures 6-3 and 6-4. The geotechnical properties of these subsurface soils follow.

SOIL DESCRIPTION			SAND	SILT AND CLAY
			Gravelly SAND, Silty SAND, and Clayey SAND	Sandy SILT, SILT, Silty CLAY, and CLAY
USCS SYMBOLS			SP, SW, SM, SC	ML, MH, CL, CH
SHEAR STRENGTH DATA				
UNCONFINED COMPRESSION Su-ksf(kN/m^2)			0.1 - 4.2 (4.8 - 201.6) [6]	1.0 - 5.3 (48.0 - 254.4) [7]
TRIAXIAL COMPRESSION c-ksf(kN/m^2), ø°			NDA	0.3-1.2, 16°-38° (14.4-57.5) [3]
DIRECT SHEAR	NATURAL MOISTURE CONTENT 4.9% to 19.0%	c-ksf(kN/m^2)	0.1-1.9 (4.8-91.0) [12]	1.6 (76.6) [2]
		ø°	30°-46° [12]	37°-41° [2]
	SOAKED MOISTURE CONTENT 15.7% to 25.7%	c-ksf(kN/m^2)	0.1-1.1 (4.8-52.7) [6]	0.2-1.2 (9.6-57.5) [2]
		ø°	33°-50° [6]	34°-46° [2]
CONSOLIDATION	NATURAL MOISTURE CONTENT 10.4% to 26.3%	m_v $ft^2/k(m^2/MN)$	0.0015-0.0029 (0.0313-0.0606) [1]	0.0009-0.0041 (0.0190-0.0856) [5]
	SOAKED MOISTURE CONTENT 14.3% to 24.5%	m_v $ft^2/k(m^2/MN)$	0.0020-0.0052 (0.0418-0.1090) [1]	0.0007-0.0052 (0.0146-0.1090) [4]

NOTES: [ ] - NUMBER OF TESTS PERFORMED
NDA - NO DATA AVAILABLE (INSUFFICIENT DATA)

CHARACTERISTICS OF SUBSURFACE SOILS
OPTION 1
OPERATIONAL BASE SITE
MILFORD, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE — BMO

TABLE
6-2

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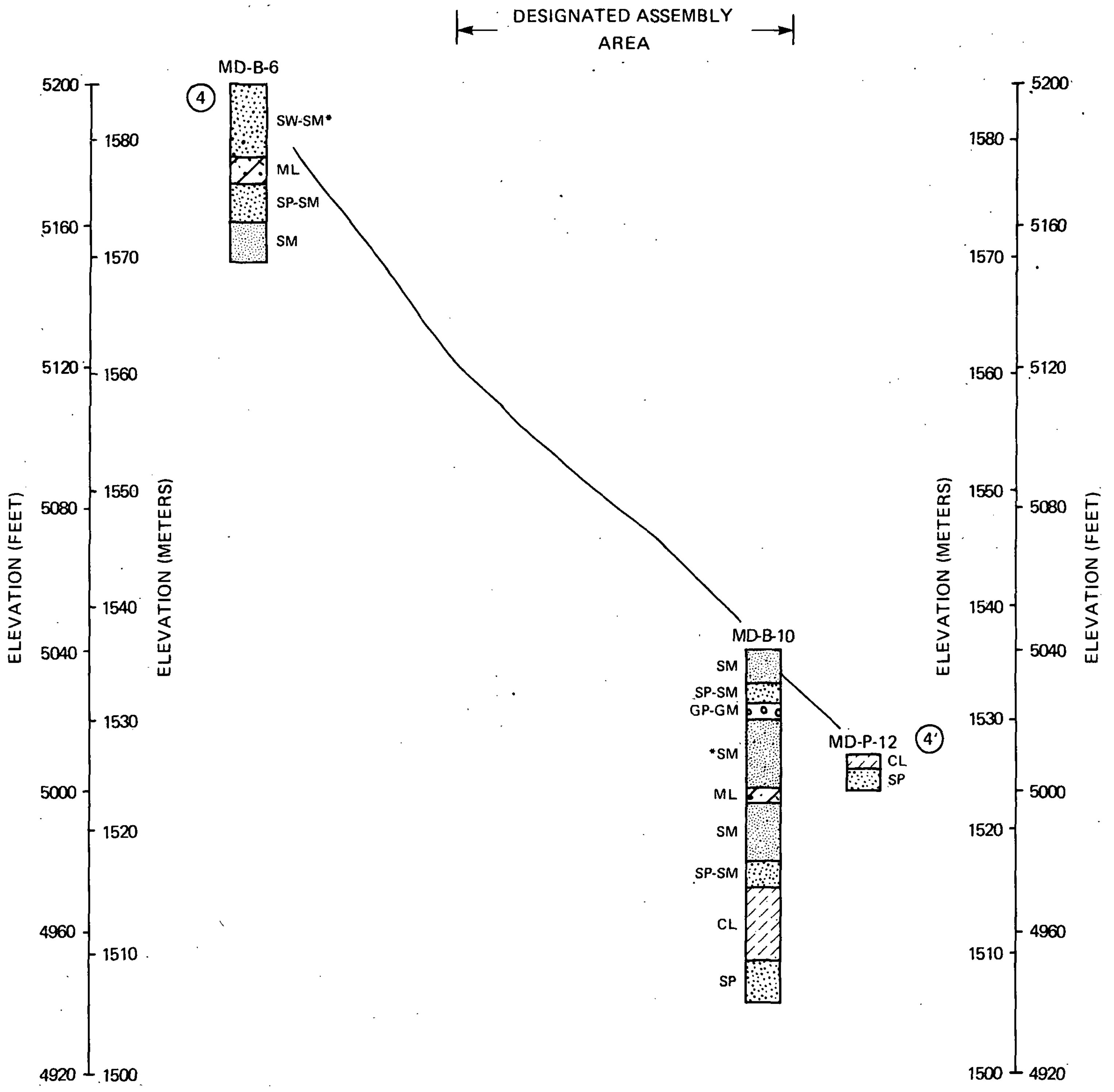
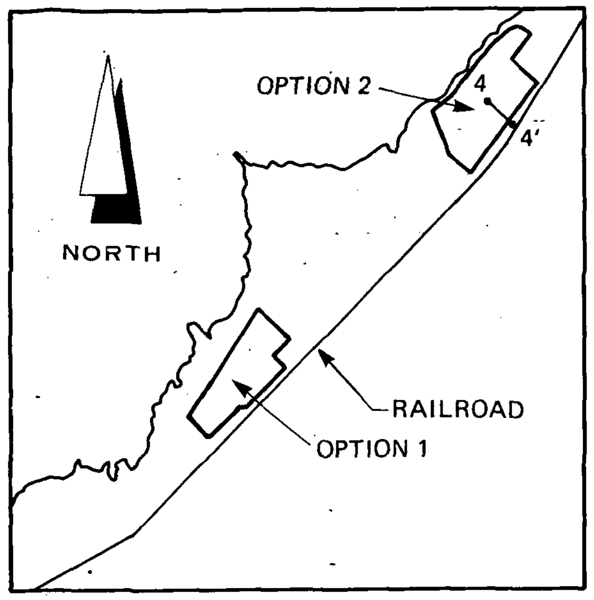


LOCATION MAP



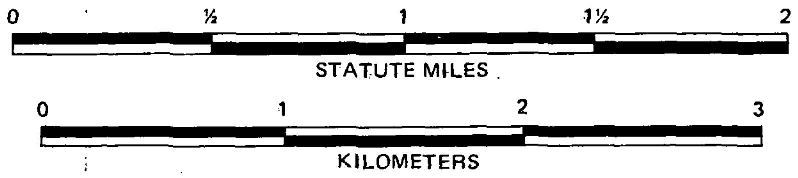
EXPLANATION

B - Boring
T - Trench
P - Test Pit

NOTES:

1. Ground surface elevations shown at activity locations are approximate
2. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.
3. * - indicates that only the predominant soil type is shown and that relatively thin, interbedded layers of one or more other soil types are also present.
4. Datum is mean sea level.

HORIZONTAL SCALE



VERTICAL EXAGGERATION IS 66X

SOIL SECTION 4-4' -OPTION 2
OPERATIONAL BASE SITE
MILFORD, UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE — BMO	FIGURE 6-4

FUGRO NATIONAL, INC.

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- Gravels (GP, GW, GM, GC): The gravels consist of poorly to well-graded sandy gravel, silty gravel, and clayey gravel ranging in particle size from fine to coarse. The density of the gravels ranges from medium dense to dense and they are predominantly matrix-supported by sand. The degree of cementation ranges from none to Stage I. The results of the cone penetrometer tests indicate that the gravels have a moderately high to high shear strength.

- Sands (SP, SW, SM, SC): The sands consist of poorly to well-graded gravelly sand, silty sand, and clayey sand. They range in particle size from fine to coarse, and the fines in the sands are nonplastic to slightly plastic. The sands are loose to dense, and the degree of cementation ranges from none to Stage III. The shear strength of the sands ranges from moderate to high, and the compressibility ranges from very low to moderate. The shear strength and compressibility characteristics of the sands are presented in Table 6-3.

- Silts and Clays (ML, MH, CL, CH): These consist of sandy silt, silt, silty clay, and clay. They range from firm to hard in consistency and are nonplastic to highly plastic. The degree of cementation of the silts and clays ranges from none to Stage III. The shear strength of the silt and clay ranges from moderate to high. The compressibility ranges from very low to moderate. The highly plastic materials may exhibit some shrinkage or swelling behavior when subjected to moisture content changes. The shear strength and compressibility characteristics of the silts and clays are presented in Table 6-3.

6.2.2 Foundation Recommendations

To provide preliminary foundation recommendations for the various facilities in the proposed operational base, all the structures are grouped into three categories according to their anticipated column loads. These loads are as follows:

o Structures with light column loads (less than 50 kips [22.7 tonnes])	- Structures with one or two stories
o Structures with medium column loads (50 to 200 kips [22.7 to 90.7 tonnes])	- Structures with more than two stories, or light structures with large spans between columns
o Structures with heavy column loads (greater than 200 kips [90.7 tonnes])	- All structures with more than two stories, warehouses, and other heavy structures

SOIL DESCRIPTION			SAND	SILT AND CLAY
			Gravelly SAND, Silty SAND, and Clayey SAND	Sandy SILT, SILT, Silty CLAY, and CLAY
USCS SYMBOLS			SP, SW, SM, SC	ML, MH, CL, CH
SHEAR STRENGTH DATA				
UNCONFINED COMPRESSION Su-ksf(kN/m^2)			0.2 - 3.0 (9.6 - 144.0) [5]	1.4 - 1.6 (67.2 - 76.8) [2]
TRIAXIAL COMPRESSION c-ksf(kN/m^2), ϕ°			0.5 34° (23.9) [1]	1.0 - 1.3, 15°- 30° (47.9 - 62.2) [2]
DIRECT SHEAR	NATURAL MOISTURE CONTENT 10.1% to 22.5%	c-ksf(kN/m^2)	0.2 - 1.4 (9.6 - 67.0) [6]	NDA
		ϕ°	33°- 49° [6]	NDA
	SOAKED MOISTURE CONTENT 22.4% to 26.2%	c-ksf(kN/m^2)	0.0 - 1.0 (0.0 - 47.9) [3]	NDA
		ϕ°	37°- 49° [3]	NDA
CONSOLIDATION	NATURAL MOISTURE CONTENT 17.1% to 30.2%	m_v $ft^2/k(m^2/MN)$	0.0012 - 0.0028 (0.0251 - 0.0585) [1]	0.0012 - 0.0100 (0.0251 - 0.2090) [3]
	SOAKED MOISTURE CONTENT 16.3% to 29.5%	m_v $ft^2/k(m^2/MN)$	0.0010 - 0.0027 (0.0209 - 0.0564) [1]	0.0009 - 0.0053 (0.0188 - 0.1107) [3]

NOTES: [ ] - NUMBER OF TESTS PERFORMED
NDA - NO DATA AVAILABLE (INSUFFICIENT DATA)

CHARACTERISTICS OF SUBSURFACE SOILS
OPTION 2
OPERATIONAL BASE SITE
MILFORD, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE — BMO

TABLE
6-3

FUGRO NATIONAL, INC.

The typical subsurface conditions in the areas of Option 1 and Option 2, as revealed by the borings, trenches, and test pits, are shown in soil sections (Figures 6-1, 6-2, 6-3, and 6-4).

Based on the interpretation of the field activities and laboratory test results, the subsurface conditions can be represented by three generalized strata (see Figure 6-5) described in descending order from the ground surface as follows:

- Stratum A: This stratum consists mostly of loose to medium-dense sand and/or firm to stiff silt and clay of medium to high compressibility. The thickness of this stratum ranges between zero and 20 feet (0.0 and 6.1 m).
- Stratum B: Soils in this stratum are predominantly medium dense to dense sand and/or gravel with high shear strength and low compressibility. The thickness of this stratum ranges from 7 to greater than 100 feet (2.1 m to >30.5 m).
- Stratum C: This stratum contains fine-grained lacustrine deposits of silt and clay. Some lenses and/or layers of sand are also present in some randomly distributed zones. Most of the silts and clays have consistencies of firm to hard with compressibilities ranging from low to medium and are slightly over-consolidated. The thickness of these deposits is believed to be greater than 300 feet (91.5 m) as discussed in Section 5.0.

Since Strata A and B have very dissimilar types of soils and their thicknesses vary considerably, foundation types for the structures also will vary. To simplify foundation recommendations, four typical soil profiles are considered (Figure 6-5).

Profile I : Stratum A of loose to medium-dense sand having a thickness of less than 2 feet (0.6 m) underlain by Stratum B having a thickness ranging from 40 to 100 feet (12.2 to 30.5 m).

Profile II : Stratum A of loose to medium-dense sand having a thickness ranging from 2 to 10 feet (0.6 to 3.1 m) underlain by Stratum B having a thickness ranging from 7 to 40 feet (2.1 to 12.2 m).

5.0 GEOTECHNICAL CONDITIONS

5.1 REGIONAL GEOLOGIC SETTING

The proposed OB site lies within the eastern portion of the Great Basin subdivision of the Basin and Range Physiographic Province. The Great Basin, which includes Nevada and portions of Utah, Oregon, Idaho, California, and Arizona, is characterized by north-south trending mountains separated by broad desert valleys which generally contain thick accumulations of basin-fill deposits. Relief between valleys and adjoining mountains is generally less than 5000 feet (1500 m). Typically, the valleys are closed basins with internal drainage. During Pleistocene time, many of these basins were occupied by extensive lakes produced by climatic adjustments during glacial periods. The eastern portion of the study area lies within the southern part of the Bonneville Basin, the section of the Great Basin that once contained Lake Bonneville, the largest of the Pleistocene lakes. Locally, the proposed OB site includes the alluvial slopes and valley bottom along the northwestern side of Escalante Desert, Utah.

5.2 SITE GEOLOGIC UNITS

The two proposed options (1 and 2) for the Milford OB site are primarily underlain by Quaternary (about 2 million years to present) sedimentary deposits ranging from older lake sediments and alluvial deposits to recent unconsolidated alluvial fan and stream channel deposits. Drawing 5-1, Geologic Map, shows the surficial distribution of the geologic units.

The mountain ranges along the western boundary of the proposed site areas are composed of Tertiary intrusive and volcanic rocks and pre-Cenozoic sedimentary and metamorphic rocks (individual bedrock units are not delineated on the geologic map, but are briefly discussed in Section 5.2.1). The following sections discuss the bedrock and basin-fill deposits from oldest to youngest in geologic age; from Pre-Cenozoic and Tertiary bedrock through the Quaternary alluvial fan, lacustrine (Pleistocene lake), and modern channel deposits.

5.2.1 Bedrock Undifferentiated (Bu)

The pre-Cenozoic bedrock units in the mountain ranges along the western boundary of the proposed site areas are composed of limestone, dolomite, quartzite, sandstone, and siltstone, with minor amounts of shale, chert, and conglomerate. Regionally, the bedding in the pre-Cenozoic bedrock strikes northerly and dips easterly. However, local variations to this regional trend are common due to belts of strong folding and complex structures.

Tertiary igneous rocks are also found in the mountain ranges along the western boundary of the proposed site areas and as isolated knobs and knolls east of the main mountain fronts. Regionally, the bedding in the Tertiary extrusive rocks generally strikes northeasterly and dips southeasterly. Complex structures and faults cutting the Tertiary extrusive rocks cause local variations in the bedding orientation.

5.2.2 Intermediate-Age Alluvial Fan Deposits (A5i)

Intermediate-age alluvial fan deposits compose about 50 percent of the study areas. These deposits consist predominantly of fine- to medium-grained, reddish-brown sand and pebbly sand with gravel lenses. The sand is generally medium dense to dense, massive to poorly bedded, and contains about 10 to 30 percent fines. The gravel lenses appear to range from less than a foot to greater than 10 feet (3 m) in thickness. Clasts within the gravel lenses consist predominantly of subangular to subrounded particles of limestone, volcanic rocks, and quartzite.

The upper 12 to 18 inches (30 to 46 cm) of most of the A5i deposits predominantly consist of reddish-brown, medium-dense silty sand with trace pebbles and cobbles. A Stage II caliche horizon averaging 2 feet (0.6 m) thick typically occurs below the sandy silt.

5.2.3 Pleistocene Lacustrine Deposits (A4of)

Approximately two percent of the study area is underlain by Pleistocene lacustrine deposits. These deposits generally consist of gray and brown, laminated, very stiff clay and well-bedded, fine- to medium-grained, medium dense sand. Most of the deposits are overlain by about 2 to 3 inches (5 to 8 cm) of loose active stream and/or eolian silty sand and silt. An incipient caliche horizon is located between 1 foot (0.3 m) and 4 feet (1 m) below ground surface in the lacustrine sediments. The incipient caliche is soft and easy to excavate. Although no gravel deposits were observed in the pits or trenches, boring data indicate that gravel deposits are interbedded with the lacustrine clay and sand.

5.2.4 Young-Age Alluvial Fan Deposits (A5y)

Young-age alluvial fan deposits compose about 20 percent of the area mapped. They consist mainly of red-brown sands, pebbly sands, and varying amounts of red-brown silty sand and pink-brown gravels. The sand and pebbly sand are generally medium dense and are massive to poorly bedded. They contain about 35 percent fines. The red-brown silty sand is generally massive and loose to medium dense. The gravels occur as lenses that range from 1 foot (30 cm) to greater than 10 feet (3 m) thick. Clasts within the gravel lenses are predominantly subangular to subrounded pebbles and cobbles of limestone, volcanic rocks, and quartzite. Typically, these clasts are partially coated with caliche and are very hard. The gravel lenses range from clast to matrix supported with fines averaging 25 percent in the matrix. Moderately dense, coarse sand lenses occasionally occur within the gravel lenses. The upper 10 inches (25 cm) of most of the A5y deposits consist of reddish-brown, medium-dense silty sand to clay with trace pebbles and cobbles. A Stage II caliche horizon averaging 3 feet (0.9 m) thick occurs immediately below the upper 10 inches (25 cm) in most of the excavations.

5.2.5 Eolian Deposits (A3)

Approximately five percent of the proposed site areas is covered by eolian deposits consisting of dunes (A3d) and sheet sand (A3s).

The largest dune fields are located northeast of Thermo, in the immediate vicinity of Hot Springs (Drawing 5-1), northeast of Latimer, and east of Zane (Drawing 5-1). Smaller dune fields occur east of Fishers Wash and north of Lund. The dunes are typically stable and have an outer layer (less than 2 inches [5 cm] thick) of moderately loose, fine to medium sand overlying moderately loose to moderately dense clayey sand and silty sand. The dunes are generally elongate in a north-easterly direction and have an average height of 3 feet (0.9 m), with an observed maximum height of 15 feet (4.6 m). Small desert shrubs (average height of 2 feet [0.6 m]) are usually found growing on the dunes.

The most widespread deposits of sheet sand occur west of Hot Springs, east of Zane, and east of Fourmile Wash (Drawing 5-1). Sheet sand deposits also occur southwest of Latimer. The sheet sands are loose, fine to medium sand occurring as thin deposits (generally not more than a few inches thick) in widespread patches throughout the proposed site areas.

5.2.6 Young Playa Deposits (A4)

Young playa deposits occur at Lund Flats less than 1 mile (1.6 km) north of Lund (Drawing 5-1). They generally consist of brown and red silty clays. The clay is generally stiff and appears to be laminated. A soft Stage I caliche horizon occurs about 5 inches (10 cm) below the surface of the playa.

5.2.7 Young Fluvial Deposits (A1)

Young fluvial deposits consist of recent stream channel and floodplain deposits such as those in Moscow Wash (Drawing 5-1) and Fishers Wash (Drawing 5-1). The near-surface deposits within these washes consist predominantly of very loose, uncemented sand, silty sand, and gravel. The gravel is generally comprised of subangular to subround pebbles and cobbles of limestone, dolomite, quartzite, and siliceous volcanic rocks. The clasts are usually unweathered, have partial to complete caliche coatings, and are very hard.

The fluvial deposits range from loose to medium dense. They are commonly lenticular and vary in composition and consistency both laterally and vertically.

5.2.8 Pleistocene Lacustrine - Young Fluvial Deposits (Mixed Unit - A4o/A1 and A1/A4o)

Pleistocene lake deposits intermixed with young fluvial deposits in varying proportions compose about 10 percent of the study area. A portion of these young fluvial deposits consist of reworked Pleistocene lake sediments. The deposits are predominantly greenish-brown and gray sandy and clayey silt with lenses of loose- to medium-dense sand. The silt is generally medium dense and moderately well-bedded.

5.3 SUBSURFACE CONDITIONS

5.3.1 Thickness of the Basin-Fill Deposits

The following discussion presents the estimated thicknesses of the basin-fill deposits interpreted from literature data, boring logs, and the results of geologic field mapping.

- Intermediate-Age Alluvial Deposits (A5i) - These deposits are probably thickest near the valley margin. Data indicate that within the site areas the thickness of A5i deposits ranges from a maximum of about 100 feet (30 m) near the mountain front to very thin toward the central portion of the valley.

- Pleistocene Lake Sediments (A4o) - Similar lake deposits in other parts of the Lake Bonneville basin are known to be greater than 230 feet (70 m) thick (Morrison, 1966). The A4o deposits at the site are approximately 145 feet (44 m) thick and probably approach thicknesses around 230 feet (70 m) as interpreted in the literature.

- Young Alluvial Fan Deposits (A5y) - This unit appears to consist of a relatively thin veneer a few feet thick overlying the older basin-fill units. Field data suggest this unit does not exceed 20 feet (6 m) thick near the valley margins and is probably less than 10 feet (3 m) thick away from the mountain front.

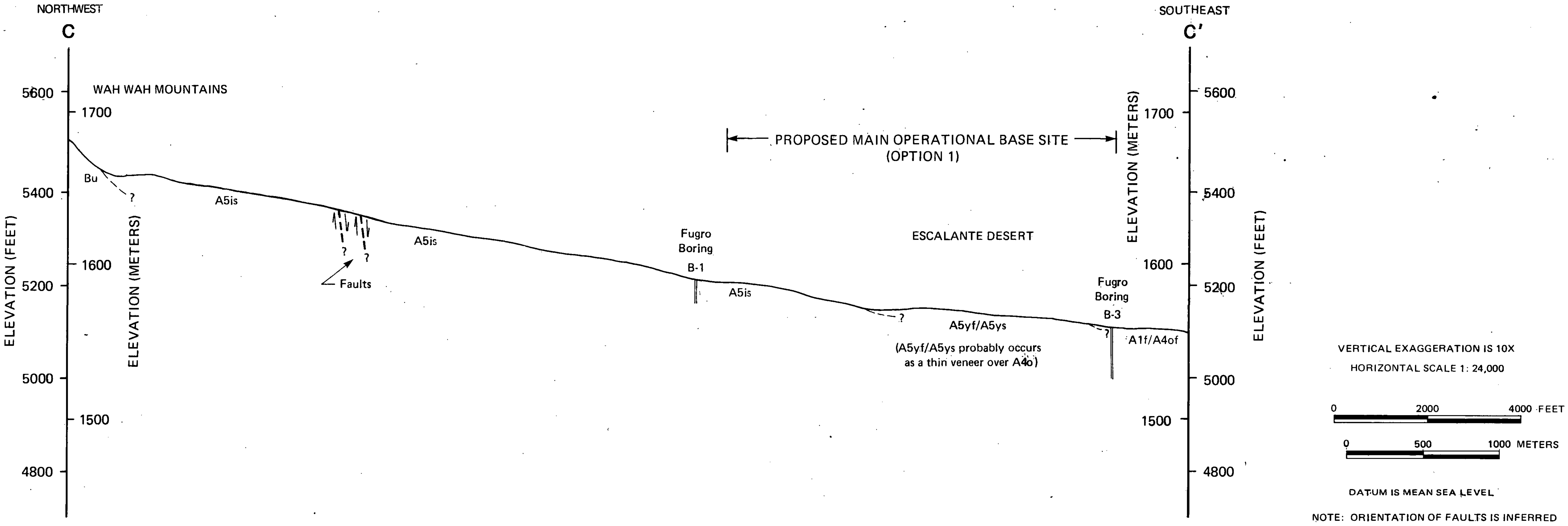
- Eolian Deposits (A3d and A3s) - Sand dunes (A3d) range from about 1 foot (0.3 m) to a maximum of about 15 feet (5 m) in height, with an average height of about 3 feet (0.9 m). Sheet sands (A3s) within the site areas range from a few inches to about 1 foot (0.3 m) thick.

- Mixed Pleistocene Lake and Young Fluvial Deposits (A4o/A1) - Although the thickness of these units is variable, it generally ranges from 20 to 30 feet (6 m to 9 m) thick and is thickest toward the central portion of the valley.

Although data obtained from borings, trenches, and pits are not conclusive with regard to the depth to the undisturbed Pleistocene lake sediments, analysis of the data indicates that the depth to undisturbed Pleistocene lake sediments (mostly stiff clay) below the area identified as Option 2 and in the southeasterly portion of Option 1 is about 30 feet (9 m).

5.3.2 Subsurface Soils

Four cross sections illustrating typical subsoil conditions at the operational base site are shown in Figures 5-1, 5-2, 5-3,



VERTICAL EXAGGERATION IS 10X

HORIZONTAL SCALE 1: 24,000

DATUM IS MEAN SEA LEVEL

NOTE: ORIENTATION OF FAULTS IS INFERRED

NOTE: SEE DRAWING 5-1 (SHEET 2) FOR CROSS SECTION LOCATIONS AND IDENTIFICATION OF GEOLOGIC UNITS.

CROSS - SECTION C-C'
OPERATIONAL BASE SITE
OPTION 1
MILFORD, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE — BMO

FIGURE
5-3

FUGRO NATIONAL, INC.

SOIL DESCRIPTION	GRAVEL	SAND	SILT AND CLAY
	Sandy GRAVEL, Silty GRAVEL, Clayey GRAVEL	Gravelly SAND, Silty SAND, Clayey SAND	Sandy SILT, SILT, Silty CLAY, CLAY
USCS SYMBOLS	GP, GW, GM, GC	SP, SW, SM, SC	ML, MH, CL, CH
DRY DENSITY pcf (kg/m^3)	95.8-128.3 (1535-2055) [9]	79.3-135.6 (1270-2172) [227]	57.3-114.7 (918-1837) [62]
MOISTURE CONTENT %	2.9-13.6 [9]	4.3-38.7 [228]	5.8-37.5 [62]
DEGREE OF CEMENTATION	NONE TO STAGE I	NONE TO STAGE III	NONE TO STAGE III
COBBLES 3 - 12 INCHES (8 - 30 cm) %	0-25	0-10	0
GRAVEL %	45-74 [13]	0-44 [82]	0-8 [24]
SAND %	18-49 [13]	33-94 [82]	1-46 [24]
SILT AND CLAY %	2-19 [13]	2-50 [82]	52-99 [24]
LIQUID LIMIT	NDA	22-36 [8]	26-79 [22]
PLASTICITY INDEX	NP [1]	NP-13 [24]	NP-44 [25]
COMPRESSIONAL WAVE VELOCITY fps (mps)	1110-2550 (339-777)	1110-6150 (339-1875)	1830-5400 (558-1646)

NOTES: [ ] - NUMBER OF TESTS PERFORMED
NDA - NO DATA AVAILABLE (INSUFFICIENT DATA)
NP - NON PLASTIC

PHYSICAL PROPERTIES OF SUBSOILS
OPERATIONAL BASE SITE
MILFORD, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE — BMO

TABLE
5-1

FUGRO NATIONAL, INC.

The moisture contents range from 5.8 to 37.5 percent. The plasticity of the fines varies from nonplastic to highly plastic. The degree of cementation in the silts and clays ranges from none to Stage III.

5.3.3 Depth to Rock

Boring and seismic refraction data, field mapping, and the geologic literature suggest that shallow bedrock will most likely be encountered in the proximity of the mountain fronts and isolated bedrock outcrops. Generally depth to rock will increase away from these outcrops. However, published well logs and a Fugro boring indicate that the buried bedrock surface is irregular and does not show a consistent pattern with regard to distance from outcrops. Therefore, distance from outcrops can, at best, be used as a general guide for depth-to-rock estimates.

5.3.4 Depth to Water

Data obtained from published literature, Fugro National, Inc. borings and observation wells, and water-level measurements performed on existing wells were used to construct the Depth to Water Map (Drawing 5-2). The depth to water contours shown on the map are based on interpretations from widely spaced data points (wells). Because of the small number and wide spacing of data points, the depth to water will likely vary at some locations from depths indicated on the map. The data discussed here and presented in Drawing 5-2 are strictly intended for preliminary identification of areas of potential construction problems due to shallow water. A more-detailed report assessing the water resources of the study area is underway and is expected to be published in May 1981.

In general, depth to water increases to the northwest toward the mountain front. Immediately along the mountain front, the depth to water is probably greater than 300 feet (91 m). In the vicinity of Lund Flats and Hot Springs, the water probably lies within 10 feet (3 m) of the surface (Drawing 5-2).

5.4 TERRAIN AND DRAINAGE

Terrain conditions in the proposed site areas are characterized by level to gently sloping surfaces with relatively shallow incisions (Drawing 5-3). Incision depths range from less than 1 foot (0.3 m) to greater than 100 feet (30 m). Surface slopes within the basin-fill deposits range from greater than 10 percent near the mountain front to nearly flat in the central portion of the valley. Sand dune areas are characterized as "hummocky" topography.

Areas along the mountain front underlain by A5i and A5y deposits are characterized by moderately steep slopes (five percent or greater) and incisions with an average depth of 4 feet (1.2 m). Divides between incisions are gently rolling to smooth. Away from the mountain front, areas underlain by A4o, A5i, and A5y deposits are characterized by gently sloping (less than three percent) to near level surfaces with an average incision depth of less than 3 feet (0.9 m). Divides between incisions are relatively smooth and the incisions generally have gently sloping banks.

The study area is characterized by an axial, or basin centered drainage located in the Escalante Desert. This axial drainage is flanked by numerous tributaries which partially dissect the valley-fill sediments. In general, surface water drains northeasterly through Escalante Desert except for local areas between Latimer and Lund where surface water drains southerly or becomes ponded. To the northeast, the axial drainage intersects the Beaver River near Milford Flats. The Beaver River then drains northerly out of Escalante Desert and through Sevier Desert until it eventually intersects the Sevier River and terminates at Sevier Lake.

5.5 GEOLOGIC HAZARDS

Geologic hazards discussed in the following sections include flooding and ponding, faults and seismic conditions, subsidence, sand dunes and sheet sands, and rockfalls (Drawing 5-4).

5.5.1 Flooding and Ponding

Evaluation of the flooding and ponding potential for the proposed study area consisted of aerial photograph analysis and limited field observations. No hydrographic studies or calculations were performed.

The aerial photograph analysis consisted of reviewing the drainage patterns to determine the stream channels which appear to be most recently active (would contain water during a rainstorm) and to determine areas which appear subject to ponding based on surface conditions. The field observations were aimed at determining the most active channels based on surficial characteristics. Some field observations were made during a heavy rainstorm and areas of ponding and excessive surface runoff were noted.

Most of the larger channels in the study area occur in the intermediate- and younger-age alluvial fan deposits, and contain linear accumulations of cobbles and boulders. Floodplain deposits generally occur along the margins of active channels. These data suggest that the larger drainages are most likely to experience flooding. A5y surfaces and associated shallow channels will likely experience sheet flooding during periods of heavy rainfall. Generally, areas underlain by A4o deposits are less likely to experience high velocity flooding but are probably susceptible to ponding.

Areas of potential flooding and ponding are shown in the Geologic Hazards Map (Drawing 5-4). Based on observations made during a heavy rainstorm, it appears that portions of the areas occupied by A4o and A4 deposits are subject to ponding as a direct result of precipitation.

5.5.2 Faults and Seismicity

Several faults, generally striking northeasterly, have been mapped on the aerial photographs within the proposed site areas (Drawing 5-1). Most of these offset late Quaternary basin-fill deposits (less than 700,000 years old) and therefore should be regarded as potentially active. In some instances, faults also offset basin-fill deposits of Lake Bonneville age (12,000 years old) or younger; these faults should be regarded as active.

The only active or potentially active faults shown on previously published geologic maps of the study area are several northeasterly and east-west trending faults in the vicinity of Thermo and Hot Springs (Drawing 5-1). In this area, aerial photographs show several scarps that appear to offset a mixed geologic unit of young fluvial deposits and old lacustrine (Bonneville age) deposits (A1/A4o). Hot springs emanate from two northerly striking faults within this system.

Several other faults were mapped during this study. These generally strike northeasterly and appear to cut intermediate- and young-age alluvial fan deposits. One of the more prominent northeasterly striking faults is located northwest of Lund. The surface expression of this fault consists of a pronounced southeasterly facing scarp that averages approximately 27 feet (8 m) in height; in young alluvial deposits, the scarp is only about 1 foot (0.3 m) high. This fault is fairly continuous from southeast of Zane to northwest of Lund Flats, a distance of about 12 miles (19 km) (Drawing 5-1). Similar faults extend northeasterly from Lyman Well to near the Beaver/Iron County line, a distance of about 6 miles (10 km).

In addition to these faults, several north and northeasterly trending lineaments were mapped on the aerial photographs in the proposed site areas and are shown on the geologic map (Drawing 5-1). The lineaments are expressed by linear vegetation concentrations and tonal changes on aerial photographs. Field observations indicate that at least some of the lineaments are probably not faults. Those lineaments observable in the field appear to consist of shallow troughs, some of which contain erosional sinks which may be the result of tensional fracturing that may have occurred due to ground-water withdrawal.

The historic seismicity of the region (Drawing 5-5) includes a few clusters of earthquake epicenters within the study area. Most of these events are small (4.0 magnitude or less). One magnitude 5.0 event occurred within the area about 16 miles (26 km) northwest of Lund.

The Intermountain Seismic Belt is located about 30 miles (48 km) east of the study area. The zone is a northeast trending belt of intense seismic activity that extends from north central Arizona through Utah, eastern Idaho, western Wyoming, and northwestern Montana. An important concern is a system of Quaternary faults that coincides with portions of the Intermountain Seismic Belt and extends from the Grand Canyon region in Arizona to the western edge of the Wasatch Mountains in Idaho. In the Cedar City region, the system of faults is about 50 miles (80 km) wide. The major faults in this system are the Hurricane fault, located about 30 miles (48 km) south of the site areas, and the Wasatch fault, located about 90 miles (144 km) (Anderson and Miller, 1979) north of the site areas. Although there have been no known historic surface fault ruptures within this fault system (since settlement by Mormon pioneers), there is evidence of repeated Holocene displacements on the Wasatch fault (Sevan and others, 1980) and of very late Pleistocene displacement on the Hurricane fault (Hamblin and Best, 1970).

5.5.3 Subsidence

According to Mower and Cordova (1973), fracturing and subsidence of the land surface in the Milford area have occurred as a result of ground-water withdrawal. Mining of ground water in the Milford area has led to local ground-water level declines of as much as 30 feet (10 m) (between 1950 and 1972). The area of maximum ground-water level decline is about 5 miles (8 km) east of the Option 2 (northerly) OB site. A ground fracture, assumed to be associated with subsidence due to ground-water withdrawal, is located approximately 2 miles (3 km) east of the Option 2 site area.

5.5.4 Sand Dunes

Several sand dune fields occur in the site area (Drawing 5-1). The average height of the dunes is about 3 feet (1 m) with a maximum of about 15 feet (5 m).

A comparison of sand dune locations based on 1953 aerial photographs versus 1978 aerial photographs shows that most of the dunes and sheet sands are relatively stable. However, longitudinal dunes east of Zane have migrated northeasterly at a rate of about 50 to 60 feet (15 to 18 m) per year.

5.5.5 Rockfall

The potential for rockfall hazards is greatest along the western boundary of the study area due to the steep relief along the mountain front. However, evidence of any major rockfalls or slide-related phenomenon was not observed. No anomalously large boulders, rock fragments, or rockfall talus accumulations were observed along the mountain front. However, as previously discussed in Sections 5.2.1 and 5.2.2, large near-vertical joints and easterly dipping out-of-slope beds occur along the mountain fronts immediately west of the site areas.

6.0 DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

6.1 SITE SUITABILITY

Site conditions including depths to rock and water, terrain, geologic units, flooding and ponding, faults, and rockfall are summarized in Table 6-1.

6.1.1 Depth to Rock

Boring and seismic refraction data, field mapping, and the geologic literature suggest that rock does not occur within 150 feet (45 m) of the surface below the proposed DAA of Option 1 and does not occur within 50 feet (15 m) below the proposed MOB of Option 1. Rock is found at the surface in the isolated northwestern portion and below 50 feet (15 m) in the southern portion of the OBTS of Option 1. Published well logs indicate that rock occurs at 75 feet (23 m) below the surface within the Option 1 proposed BH and interpretations suggest that rock may be encountered at less than 50 feet (15 m) in the southwest portion of the BH of Option 1.

Outcrops of volcanic rock occur in the isolated northern portion of the OBTS of Option 2. Rock probably occurs within 50 feet (15 m) of the surface in areas of the southern portion of the OBTS of Option 2. The depth to rock probably increases toward the southern end of the OBTS. Fugro boring B (O)-5, located approximately 3500 feet (1067 m) northwest of the DAA of Option 2, penetrated volcanic rock at 88 feet (27 m). Because of the irregular upper surface of these rocks, there is a possibility that rock occurs less than 150 feet (46 m) below the northwestern portion of the proposed DAA of Option 2. Numerous bedrock outcrops are present within the Option 2 BH area. However, subsurface data indicate that except for these outcrops, most of the BH area of Option 2 can be expected to have rock at depths greater than 50 feet (15 m). Regional relationships, such as distance to bedrock and attitude of the nearest rock outcrops, indicate that rock will not be encountered within 50 feet (15 m) of the surface in the proposed MOB of Option 2.

6.1.2 Depth to Water

The BH and part of the OBTS of Option 1 are located in areas where the depth to water is estimated to be greater than 100 feet (30 m) (Drawing 5-2). The isolated, northwestern portion of the OBTS of Option 1 (Township 32S, Range 16W, Sections 26 and 27) is interpreted to have minimum depths to water of less than 20 feet (6 m). At the MOB site of Option 1, depth to water is expected to be as deep as 150 feet (46 m) on the northwestern corner and less than 30 feet (9 m) at the southern corner. Similarly, depth to water at the DAA site of Option 1 is probably greater than 150 feet (46 m) at the northern corner but less than 10 feet (3 m) at the southernmost corner.

Base housing and the OBTS of Option 2 are located in areas where the depth to water is interpreted to be greater than 100 feet (30 m) and probably greater than 150 feet (46 m). Depth to water below the proposed MOB site of Option 2 is less than 50 feet (15 m) for most of the eastern two thirds of the area

and approaches depths as deep as 100 feet (30 m) on the west side. The proposed DAA of Option 2 is interpreted to have depths to water between 100 and 150 feet (30 m and 46 m) on the western half and less than 30 feet (9 m) at the northeasternmost corner.

6.1.3 Terrain

Terrain conditions (Drawing 5-3) for each proposed activity center are summarized in Table 6-1. A small portion of the study area has been delineated as adverse terrain based on the incision depth and drainage-spacing criteria. Areas with surface gradients that exceed five percent and 10 percent generally occur along the western margin of the proposed site areas and are delineated on the terrain map (Drawing 5-3). Areas with local surface gradients of less than five percent slope are also indicated on the terrain map with arrows pointing in the downslope direction. Three of the proposed activity center locations include area categorized as adverse terrain: the isolated, northwestern portion of the OBTS of Option 1; the isolated, northern portion of the OBTS of Option 2; and the northern margin and areas around rock outliers of the BH of Option 2.

6.1.4 Geologic Hazards

Discussions and conclusions pertaining to flooding and ponding of water, faults and seismic conditions, subsidence, sand dunes, and rockfall, are presented in the following paragraphs.

6.1.4.1 Flooding and Ponding

Major flooding within the study area would be confined to the incised floodplains occurring in young-age alluvial fans and the major incisions of intermediate-age alluvial fans. Flooding on the A5y fans would occur as either stream or sheet floods. Stream floods would occur when water and detrital material emerge from the mountain canyons but do not overflow existing channels. The water would remain confined to definite channels on the fan surface. The linear concentrations of cobbles and boulders in several A5yg channels suggest that considerable amounts of water flow down these channels during periods of heavy rainfall. Sheet floods are likely to occur when exceedingly large amounts of water and detritus emerge from a mountain canyon and overflow existing channels or spill out of the incision mouth spreading out over broad areas of the fan surface. Flooding in areas underlain by intermediate-age alluvial fan deposits would primarily be restricted to the incisions within these units.

Considerable amounts of runoff should be expected in areas of the A5y fan drainages. Ponding should be expected in the low-lying areas which contain older lacustrine deposits or young playa deposits (Drawing 5-4).

Stream and sheet-flooding areas are present in the south central portion of the DAA of Option 1 and in the north central and eastern portions of the MOB of Option 1. Small areas in the northwestern, southern, and east central portions of the BH of

Option 2 are also subject to stream and sheet flooding. Areas of potential ponding occur in the southern portion of the DAA of Option 1 and in the eastern corner of the MOB of Option 1. Most of the eastern portion of the MOB of Option 2 is also an area of potential ponding.

A potential method to protect the roads and facilities from flooding would be diversion dikes. An alternative method would be to elevate the roads and to use elevated building pads.

6.1.4.2 Faults and Seismicity

Several of the faults in the study area appear to have displaced basin-fill deposits as young as 12,000 years old. For this level of investigation, these faults should be regarded as active. Other faults noted in the study area displace late Quaternary deposits; these should be considered potentially active.

Northeasterly trending faults project into the northern corner of the DAA of Option 1. A northeasterly trending fault occurs in the central portion of the DAA of Option 2. Several north-south trending faults occur in the northern part of BH of Option 2. For subsequent engineering planning, fault traces and lineaments, or their projections across the site areas, should be avoided with regard to locating structures. If these faults are found by more-detailed investigations to be active (e.g., having moved in the last 10,000 to 12,000 years), appropriate seismic design criteria such as setback from the fault traces and design for potential ground shaking from a near source should be considered.

Assuming the northeasterly striking fault northwest of Lund (Section 5.5.2) is continuous with the northeasterly trending fault between Lyman Well and the Beaver/Iron County line and represents one continuous fault zone, the combined length would be about 19 miles (31 km) (Drawing 5-1). A 1-foot (0.3-m) scarp has been observed in Holocene deposits along this fault. Faultlength/earthquake-magnitude and fault-offset/magnitude relationships (Slemmons, 1977) suggest such a fault could generate about a 6.5 magnitude earthquake (this is a crude estimate based on the data available and should be subject to the verifying studies described in Section 7.0). This fault system probably represents the major earthquake hazard in the immediate site areas. Ground motions from earthquakes located so near to a site cannot be accurately predicted. Published attenuation relationships (Housner, 1965; Schnabel and Seed, 1973; and Donovan, 1973) and ground motions recorded during recent earthquakes suggest that peak accelerations on the order of 1/2 g can be expected at the site from a large earthquake on the nearby fault.

Although the Quaternary fault system discussed in Section 5.5.2, which includes the Wasatch and Hurricane faults, has no known historic fault ruptures, the high rate of earthquake activity in the region (Smith and Sbar, 1974) suggests that faults in the system have a potential for generating earthquakes. Maximum earthquakes along the Wasatch fault zone have been estimated at about 7.5 magnitude (Swan and others, 1980). The length of the Hurricane fault zone (160 miles [255 km]) suggests that earthquakes with magnitudes on the order of 7.5 are possible on that fault too.

6.1.4.3 Subsidence

Areas of maximum subsidence will likely occur where water-level declines are the greatest. If rates of ground-water withdrawal from the basin-fill sediments continue to exceed recharge, continued land subsidence will likely result. Continued subsidence may be accompanied by new earth fissures and/or enlargement of existing fissures.

The extent and amount of subsidence in the site areas is not accurately known. However, as previously discussed in Section 5.5.3, a single ground fracture has been mapped in the study area that is in an area of known declining ground-water levels. This fracture may be the result of land subsidence due to ground-water withdrawal. The ground fracture is located about 2 miles (3 km) east of the proposed MOB of Option 2 and about 23 miles (37 km) northeast of the MOB of Option 1. Because of the fracture's proximity to the Option 2 activity centers and its location in an area of known declining ground-water levels, the potential for future earth cracking due to subsidence should be a design consideration in the Option 2 site area.

6.1.4.4 Sand Dunes

As previously discussed in Section 5.5.4, sand dunes occur in many portions of the proposed site areas. At present, the eolian deposits in the immediate vicinity of the proposed site areas appear stable. If the dunes do become mobile, it is likely they would move in a northeasterly direction due to prevailing wind directions. Renewed sand dune mobility results from disturbance of the stabilized surface. Studies in the Great Basin (Melhorn and Trexler, 1977) have documented reactivated sand dune migrations from renewed attempts to cultivate large expanses of stable basin-fill deposits.

Sand dunes are present in the proposed MOB and DAA of Option 2 and in the southern portion of the Option 1 DAA. Preserving the existing vegetation and increasing the vegetative cover in the site areas are possible methods for decreasing the potential for sand dune mobility and for stabilization of new dunes.

Another possible method of protecting structures and facilities from sand dune migration would be by the use of "deflection barriers" such as those presently being used in the area to protect portions of the Union Pacific Railroad.

6.1.4.5 Rockfall

The potential for rockfall hazards appears to be greatest along the western margin of Escalante Desert due to the high relief along the steep mountain front. As previously discussed in Section 5.5.5 of this report, large near vertical joints and easterly-dipping beds occur along the mountain front. The joints are generally less than a foot wide and are several tens of feet long. OBTS and BH of both Options 1 and 2 are the only activity centers located near the base of the mountains and are therefore in areas of potential rockfall. During seismic events, the potential exists for rock fragments to break along joints or bedding planes and fall to the base of the mountain front.

6.2 FOUNDATION CONSIDERATIONS

Geotechnical properties of the subsurface soils in the activity centers for both Options 1 and 2 and foundation recommendations for the structures are discussed in this section.

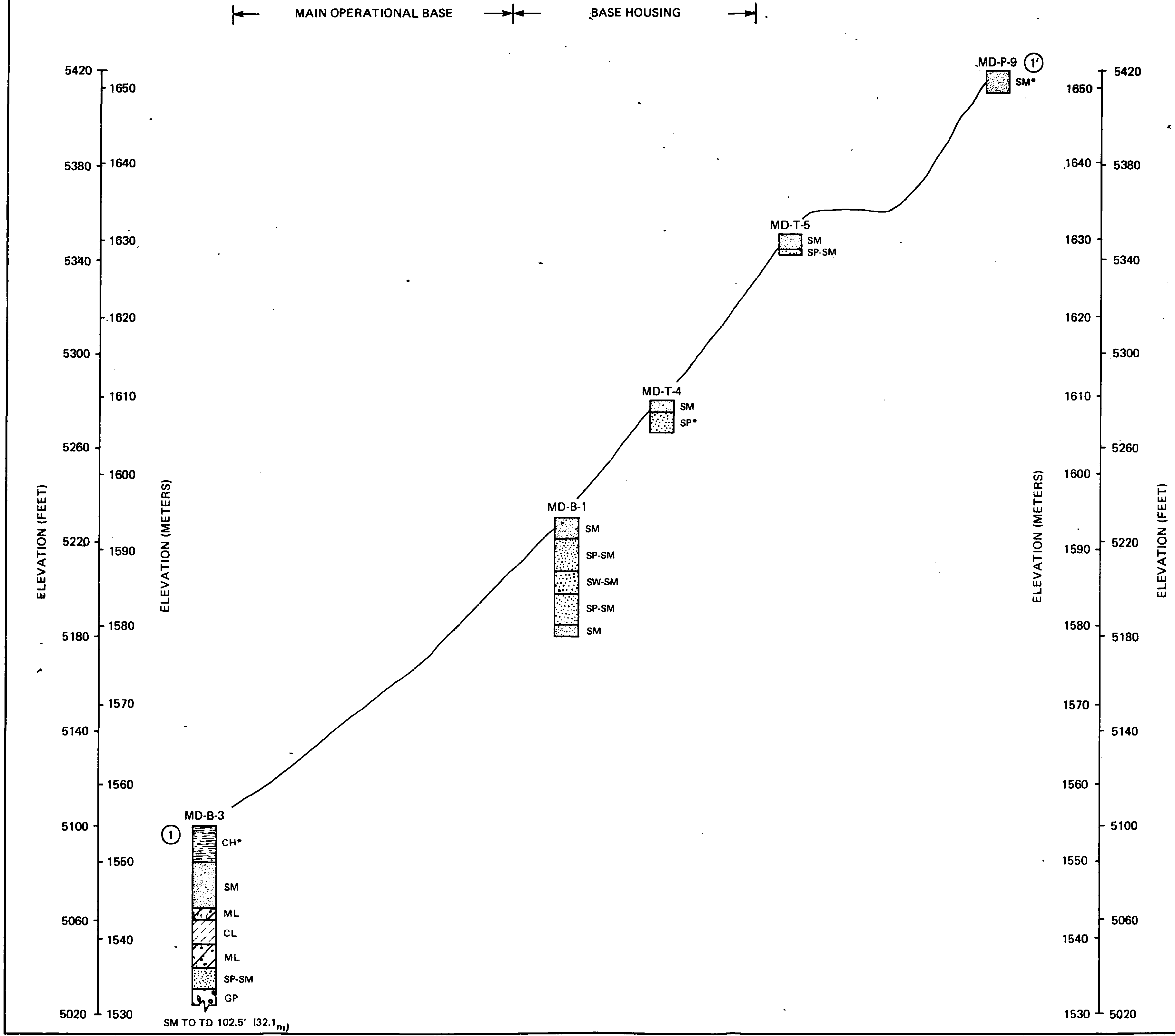
6.2.1 Geotechnical Properties of Subsurface Soils

6.2.1.1 Option 1

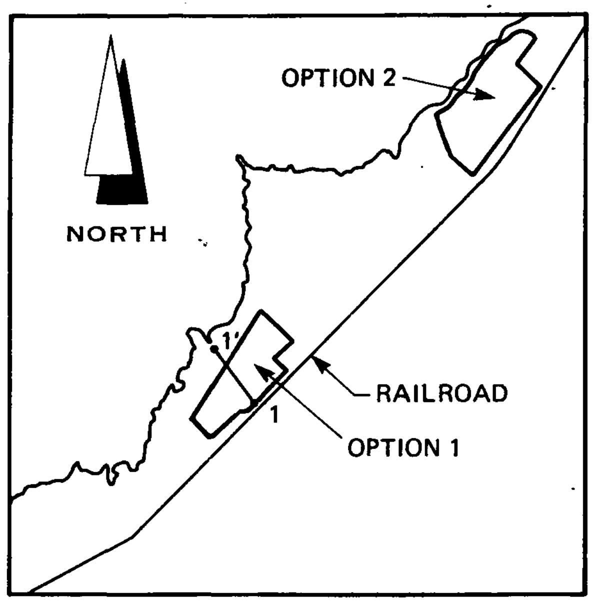
The surficial soils at this site vary from sand to silty clay. Their consistency ranges from loose to firm to depths ranging from 1 to 5 feet (0.3 to 1.5 m). The southeastern corner of the MOB is typically covered by firm silty clay to depths of 2 to 5 feet (0.6 to 1.5 m).

The surficial soils are underlain mainly by alluvial fan gravel and sand. In the southeastern corners of both the MOB and DAA, the surficial soils are underlain by interbedded layers of gravel, sand, silt, and clay of the alluvial fan and lake deposits. Two soil sections showing typical subsoil conditions are presented in Figures 6-1 and 6-2. The geotechnical properties of these subsurface soils are described as follows:

- o <u>Gravels (GP, GW, GM)</u>: The gravels consist of poorly to well-graded sandy gravel and silty gravel ranging in particle size from fine to coarse. The gravels are generally in a dense condition and are predominantly matrix-supported by sand. The results of the cone penetrometer tests indicate that they have a moderately high to high shear strength.



LOCATION MAP



EXPLANATION

B - Boring
T - Trench
P - Test Pit

NOTES:

1. Ground surface elevations shown at activity locations are approximate
2. Soil types shown adjacent to soil column are based on Unified Soil Classification System (USCS) and are explained in the appendix.
3. * - indicates that only the predominant soil type is shown and that relatively thin, interbedded layers of one or more other soil types are also present.
4. Datum is mean sea level.

HORIZONTAL SCALE

VERTICAL EXAGGERATION IS 66X

SOIL SECTION 1-1' - OPTION 1
OPERATIONAL BASE SITE
MILFORD, UTAH

MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE — BMO	FIGURE 6-1

FUGRO NATIONAL, INC.

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Profile III: Stratum A of mostly silt and clay having a thickness ranging from 2 to 10 feet (0.6 to 3.1 m) underlain by Stratum B having a thickness ranging from 40 to 100 feet (12.2 to 30.5 m).

Profile IV: Stratum A of mostly silt and clay having a thickness ranging from 2 to 20 feet (0.6 to 6.2 m) underlain by Stratum B having a thickness ranging from 7 to 40 feet (2.1 to 12.2 m).

These typical soil profiles are shown in Figure 6-5. The areas of the various activity centers, for the two options of the operational base site, underlain by soils with the different soil profiles are also indicated in Figure 6-5. The foundation recommendations for areas with each profile are discussed in the following sections.

6.2.2.1 Areas with Soil Profile I

Areas underlain by soils with Profile I are as follows (see Figure 6-5):

Option 1:
- The western quarter of the MOB
- The northern one-third of the DAA
- The entire OBTS (except the isolated area)
- The northern two-thirds of the BH areas

Option 2:
- The most northwesterly one-fifth of the MOB
- Most of the northwesterly quarter of the DAA
- The entire OBTS (except the isolated area)
- The entire BH (except in areas with rock outcrops and shallow rock)

Since Stratum A is only 2 feet (0.6 m) thick, all structures could be founded on the underlying Stratum B. Shallow spread, combined, or continuous footings will be appropriate for the foundations of most buildings having the lowest floors at grade. The minimum foundation depth should be 2 to 3 feet (0.6 to

0.9 m) below final grade on the undisturbed medium-dense to dense sand/gravel (Stratum B). This minimum depth is determined from frost-heave consideration which will be discussed later in Section 6.5. The recommended net allowable bearing pressures for the footings are as follows:

Column Load	Minimum Foundation Depth Below Final Grade feet (meters)	Net Allowable Bearing Pressure, q_a ksf (kN/m^2)
Light	2 to 3 (0.6 to 0.9)	2 to 4 (96 to 192)
Medium	3 to 4 (0.9 to 1.2)	3 to 6 (144 to 287)
Heavy	5 (1.5)	4 to 8 (192 to 383)

The selection of bearing values depends on local soil conditions and settlement limitations as governed by the structural design. Where loose sand lenses or layers are at foundation level, the sand should either be densified by conventional compaction methods or the bearing pressures should be appropriately reduced. In the BH area of Option 2 where surface or shallow rock exists, the depths of foundation and bearing pressures should be determined in future investigations.

6.2.2.2 Areas with Profile II

Areas underlain by soils with Profile II are as follows:

Option 1:
- The southern one-third of the MOB
- The southern two-thirds of the DAA

Option 2:
- The southeastern half of the DAA and south one-tenth of the MOB

In these areas, thickness of Stratum A ranges from 2 to 10 feet (0.6 to 3.1 m). However, in most cases, the sand of Stratum A is loose to a maximum depth of 5 feet (1.5 m). This loose sand should be densified before the construction of the foundations. Following this densification, shallow spread, combined, or continuous footings founded in either Stratum A or Stratum B should be appropriate for the foundations of the buildings. The recommended net allowable bearing pressure will be the same as for Soil Profile I except for areas underlain by a thin Stratum B where allowable bearing pressures will be lower. Moreover, where Stratum B is thin, the structures undergo significant settlement due to the underlying compressible Stratum C. Therefore, settlement of Stratum C governs the allowable bearing pressures for medium and heavy column loads underlain by a thin Stratum B. The recommended allowable bearing pressures are as follows:

Column Load	Minimum Foundation Depth Below Final Grade feet (meters)	Net Allowable Bearing Pressure, q_a ksf (kN/m^2)
Light	2 to 3 (0.6 to 0.9)	2 to 4 (96 to 192)
Medium	3 to 4 (0.9 to 1.2)	2.5 to 5 (120 to 239)
Heavy	5 (1.5)	3 to 6 (144 to 287)

Should looser materials exist at greater depths in Stratum A, the allowable bearing pressures should be reduced or the materials be densified.

6.2.2.3 Areas with Soil Profile III

Areas underlain by soils with Profile III are as follows:

Option 1:
- The northern corner of the MOB
- The southern one-third of BH

In these areas, Stratum A consists of silt and clay having a thickness of 2 to 10 feet (0.6 to 3.1 m). In areas where the thickness is less than 5 to 6 feet (1.5 to 1.8 m), shallow spread, combined, or continuous footings founded on Stratum B will be appropriate for the foundations of the buildings. The recommended net allowable bearing pressures will be the same as for areas underlain by Soil Profile I.

In areas where the thickness of Stratum A is more than 5 to 6 feet (1.5 to 1.8m), columns with light to medium loads can be supported by spread, combined or continuous footings founded at a minimum depth of 3 to 6 feet (0.9 to 1.8 m). Footings for columns with heavy loads can be founded in either Stratum A, as indicated below, or on the surface of Stratum B. The recommended net allowable bearing pressures are as follows:

Column Load	Minimum Foundation Depth Below Final Grade feet (meters)	Net Allowable Bearing Pressure, q_a ksf (kN/m^2)
Light	3 to 5 (0.9 to 1.5)	1 to 3 (48 to 144)
Medium	4 to 6 (1.2 to 1.8)	2 to 4 (96 to 191)
Heavy	6 to 10 (1.8 to 3.1)	4 to 8 (191 to 383)

In localized areas, highly plastic soils are present near the ground surface in Stratum A. Seasonal soil moisture changes in these soils, reportedly down to a depth of 10 feet (31. m) (Tomlinson, 1975), may cause ground swelling and shrinking. Under such circumstances, the minimum foundation depth should be increased. To alleviate settlement, it is recommended that footings for heavy column loads be founded on Stratum B. Alternatively, structures with heavy column loads can be supported by drilled piers or end-bearing piles extending at least 3 to 5 feet (1.0 to 1.5 m) into Stratum B.

Cast-in-place concrete piles, steel pipe or H-piles, or precast concrete piles can be used. Allowable loads on the piers or piles depend on type, size, and depth of embedment which can be determined when the surface of Stratum B is located. For preliminary design, the allowable loads developed by a combination of end bearing and frictional resistance on piers and piles can be determined as follows:

End Bearing = 40 to 130 ksf (1900 to 6200 kN/m^2)

Frictional Resistance = (0.2 to 1.0 ksf) x (perimeter of pier or pile in feet) x (length of embedment in feet) or (10 to 50 kN/m^2) x (perimeter of pier or pile in meters) x (length of embedment in meters)

There should be no problem of drilling or driving piles through Stratum A. Generally, casing of the drilled hole for pier foundations would not be necessary.

6.2.2.4 Areas with Profile IV

Areas underlain by soils with Profile IV are as follows:

Option 1: The east corner of the MOB; and

Option 2: The southeastern three-quarters of the MOB.

In these areas, Stratum A consists of 2 to 20 feet (0.6 to 6.1 m) of silt and clay. Two cases can be considered in these areas as follows:

Case 1 - Thickness of Stratum B is 20 to 40 feet (6.1 to 12.2 m).

For this case, foundation recommendations are the same as for those areas underlain by Profile III if Stratum A is less than 10 feet (3.1 m) thick. If Stratum A is thicker than 10 feet, (3.1 m), one of the following modifications may be necessary:

- o Columns with medium load will require pier or pile supported foundations;
- o The minimum foundation depth of the footings will have to be increased; or
- o The allowable bearing pressure of the footings will have to be reduced.

Case 2 - Thickness of Stratum B is from 7 to 20 feet (2.1 to 6.1 m).

Lightly loaded structures can be supported by shallow footing foundations in the silt and clay of Stratum A. The recommended net allowable bearing pressures are as follows:

Column Load	Minimum Foundation Depth Below Final Grade feet (meters)	Net Allowable Bearing Pressure, q_a ksf (kN/m^2)
Light	3 to 5 (0.9 to 1.5)	1 to 3 (48 to 144)

As discussed previously, the minimum depth of the foundation should be increased in localized areas with near-surface highly plastic soils.

Columns with medium and heavy loads may be supported on pier or end bearing pile foundations extending into Stratum B.

These foundations will probably undergo significant settlements due to the underlying, more-compressible Stratum C. If the settlement magnitudes are considered excessive, columns with medium and heavy loads can be alternatively supported by friction piles

(piles supported mainly by frictional resistance between the pile shaft and soils) extending into Stratum C. Cast-in-place concrete piles, steel pipe or H-piles, or precast concrete piles can be used in this case. For preliminary estimates, allowable loads developed by a combination of end bearing and frictional resistance on piers or piles can be estimated by

End Bearing = 6 to 20 ksf (300 to 1000 kN/m^2

Frictional Resistance = (0.5 to 1.0) x (perimeter of pile in feet) x (length of embedment in feet) or (25 to 50 kN/m^2) x (perimeter of pile in meters) x (length of embedment in meters)

Drilling for cast-in-place piles through Strata A and C using conventional equipment should not pose any significant problem. However, drilling in the dense, sometimes cemented sand or gravel in Stratum B may occasionally require some supplementary chiseling. Casing during drilling should generally not be required unless ground water is present. Driven piles are less favorable when Stratum B is thick since hard driving is expected in the variably cemented sand and/or gravel of this stratum.

As an alternative to the pier or pile foundations, the more-compressible soils in Stratum A up to 10 feet (3.1 m) thick can be replaced by compacted granular materials. The depth of this replacement depends on how sensitive the structure is to differential settlement and the depth to Stratum C. Shallow footings can then be constructed in the compacted materials.

6.2.2.5 Foundation for Missile Assembly Building (MAB)

The deeper part of the MAB is a pit that is 50 feet (15.2 m) deep and 80 feet (24.4 m) by 35 feet (10.7 m) in plan with an

8-foot (2.4-m) diameter shaft which extends 80 feet (24.4 m) below the bottom of the pit. The MAB of each option is located in the DAA which is underlain by soils with Profiles I or II. In areas where Profile I is applicable, the pit will be mostly in the medium dense to dense sand of Stratum B. In areas where Profile II is applicable, the pit will also encounter some lake deposits of Stratum C.

Although the foundation load is high, the net bearing pressures on the soils at the bottom of the pit will be small and should not cause bearing or settlement problems.

The sides of the pit excavation may be either sloped or vertical. In the latter case, an adequately designed lateral support system would be necessary. The pressures from the soils, those induced by shallow footings from other parts of the structure, and where applicable water pressure, should be considered for designing the supporting system.

The excavation of the shaft beneath the pit could be accomplished by using a large-diameter earth auger. For lateral support of the hole, methods such as reinforced gunite, shotcrete, or liners could be used.

As discussed in Section 6.1, shallow ground water may be encountered between 10 and 50 feet (3.1 to 15.2 m) in the southern part of DAA in Option 1 and as shallow as 30 feet (9.2 m) in the eastern-most corner of DAA in Option 2. This ground water should be handled satisfactorily during construction by using conventional pumping equipment.

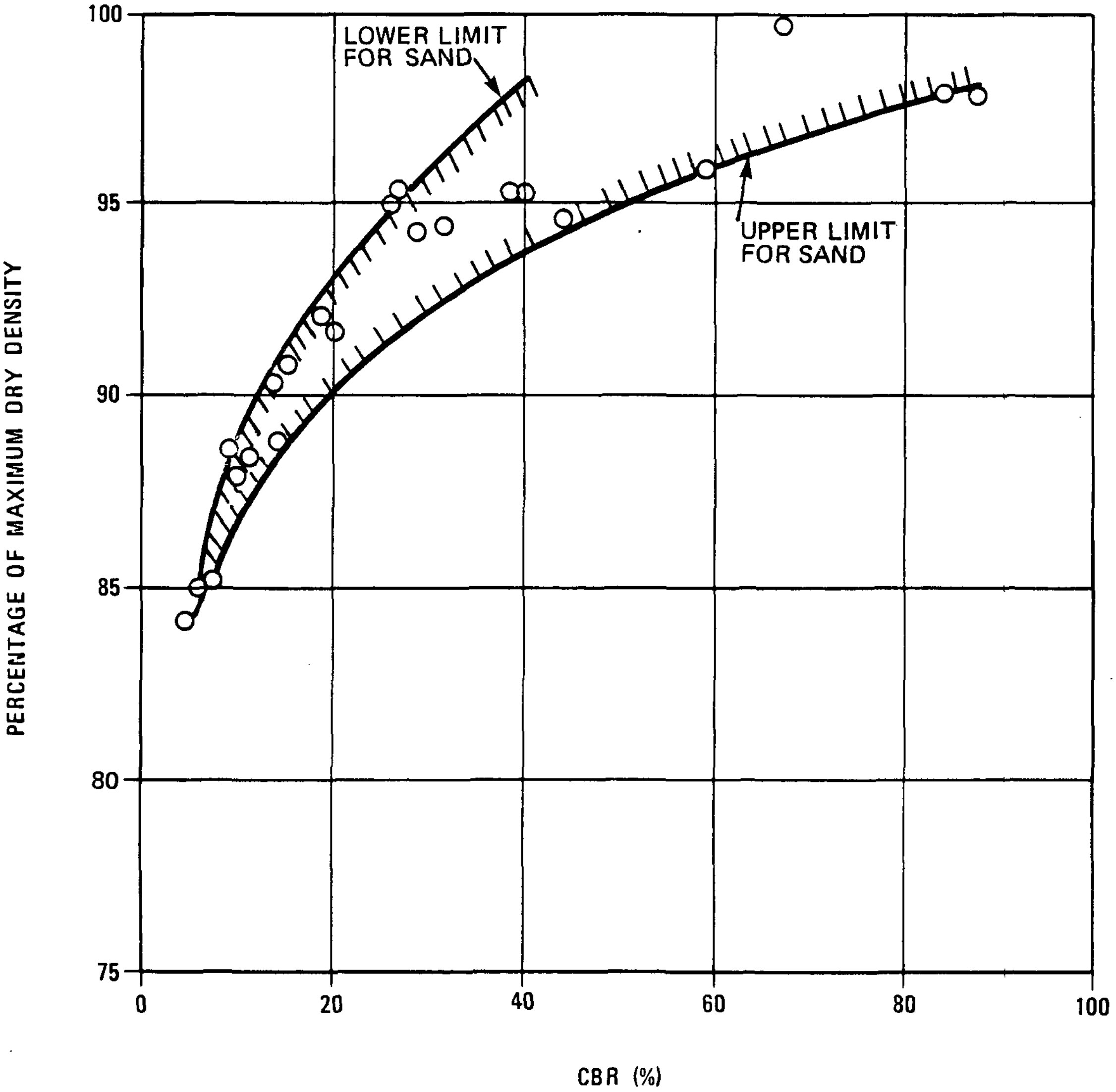
6.3 ROADS AND RUNWAYS

6.3.1 Roads

The present layout shows that most of the roads connecting the major activity centers will be constructed on the alluvial fan deposits consisting of gravelly sand, silty sand and clayey sand. The results of CBR tests on these soils indicate that the sand will provide good support as a subgrade. Figure 6-6 shows the sand has a considerable range of CBR values for a given relative compaction. The reasons for this are the variations in gradation, fines content, and plasticity. Moderate to extensive compactive effort will be required for the subgrade preparation in these soils.

In addition, some of the roads in Option 1 will be constructed on the sandy silt and silty clay of the lake deposits. The results of CBR tests on these soils, ranging from two to 10 at 95 percent relative compaction, indicate that they will provide poor to fair support as a subgrade. Moderate to extensive compactive effort will be required for the subgrade preparation in these soils.

Due to the frost susceptibility of the silty and clayey sand, sandy silt, silt, silty clay, and clay, these soils may require replacement by coarse granular material or modification by the addition of cement, lime, or chemical stabilizing agents to provide a suitable subgrade for the roads.



CBR VALUES FOR SAND
OPERATIONAL BASE SITE
MILFORD, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE — BMO

FIGURE 6-6

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6.3.2 Runways

6.3.2.1 Option 1

As presently proposed (Drawing 5-1), the runway for Option 1 will be constructed on the alluvial fan deposits. As described in the previous Section (6.3.1), these materials will provide good support as a subgrade. However, due to consideration of the frost susceptibility of silty and clayey sands, these soils may require replacement or modification to provide acceptable subgrade support for the runway.

6.3.2.2 Option 2

As presently proposed (Drawing 5-1), approximately 50 percent of the runway for Option 2 will be constructed on the silty and clayey sand of the eolian deposits and the remaining portion on the sandy silt, silt, silty clay, and clay of the lake deposits. The eolian sand should provide good subgrade support while the silts and clays will provide only poor to fair subgrade support. As discussed in Section 6.3.1, these soils may require replacement or modification due to their susceptibility to frost attack.

6.4 SLOPE STABILITY

From our observations, there is no evidence of any landslide or major "hillside mass wasting." All the natural slopes in this proposed OB site area appear to be stable.

Most temporary excavations in the granular alluvial deposits should be stable on slopes between 1/2:1 (horizontal:vertical) in the cemented gravelly materials and 1 1/2:1 in the cleaner sandy deposits. Permanent slopes should be flatter as dictated by local soil conditions.

Slopes for excavations in the fine-grained soils of either the alluvial or the lake deposits will have a wide range because of the variations in the strength of the soils. It is expected temporary cuts can be made at a slope of 1/2:1. Flatter slopes may be required locally in areas of relative weak soils. Permanent slopes will have to be designed based on the results of site-specific investigations.

Significant erosion control has to be provided for most of the slopes except those in the gravelly deposits. Diverting runoff or vegetative cover on the slopes may be necessary.

Drainage must be provided in limited areas in the Option 1 DAA and the Option 2 MOB, where shallow ground water may be present. Pumping from a sump at the bottom of the excavation should, in general, be sufficient for temporary ground-water control.

6.5 CONSTRUCTION CONSIDERATIONS

Construction aspects such as site preparation, excavatability and compactability of the soils, chemical attack, and frost attack are briefly discussed in this section.

- o Site Preparation - As noted in Section 5.5.4, deflation of land in the area is common once the vegetative cover is removed. For this reason, the extent of the stripping operations should be confined only to the areas where it is required for construction. In areas where stripping is required and in areas of undisturbed, nonvegetated windblown sand deposits, new vegetative cover should be provided.

- Slab-on-grade - The thickness of the loose coarse-grained surficial soils ranges from 1 to 5 feet (0.3 to 1.5 m). These soils should be densified before the construction of the slab on grade. The depth of densification will depend on the design load on the floor slab. In areas of fine-grained surficial soils, they should be compacted first and then covered by 6 to 12 inches (15 to 30 m) of compacted granular materials prior to construction of the slab.

- Excavation and Compaction - The seismic velocity of the top 5 feet (1.5 m) of the subsurface soils ranges between 1110 and 2800 fps (338 and 853 mps). Based on the range of the seismic velocities and observations made during the backhoe trench and test pit excavations, conventional equipment could be used for all shallow excavations (less than 5 feet [1.5 m]). However, in areas along the western edge of the BH of Option 2 where Stage III caliche cementation or shallow rock exists, ripping and/or blasting may have to be used for excavation. For most of the shallow excavations, temporary lateral support is not required. However, in localized areas of the northeast corner of the MOB of Option 1 and the southwest portion of the DAA of Option 1, excavations will require relatively flatter cut slopes or temporary lateral support.

  Compactibility of the gravel and sand of the alluvial fan deposits is good. A wide range of compaction equipment would be suitable for compacting these soils. The most efficient type would be vibratory rollers.

  Compactibility of the sandy silt, silt, silty clay, and clay of the lake deposits is poor to fair. Compaction of these soils would be most efficiently performed by static methods such as rubber-tired or sheepsfoot rollers.

- Sulfate Attack on Concrete - Results of chemical tests indicate that the potential for sulfate attack of the soils on concrete will be "negligible" (maximum sulfate content 0.14 percent). Although none were observed, it is possible that gypsiferous materials are present in the lake sediments. Since the high sulfate content of such materials is damaging to concrete, any future studies of this site should include tests for the presence of sulfate in the lake sediments.

- Frost Attack - The gravel or gravelly sand with significant amounts of fines of the alluvial fan deposits and the lean silty clay and clay of the lake deposits are considered to be moderately frost susceptible. Footings in these soils should be founded at least 2 feet (0.6 m) below the final grade. The silty sand of the alluvial fan deposits and the sandy silt and silt of the lake deposits are considered to be severely frost susceptible. Footings in these soils should be founded at least 3 feet (0.9 m) below the final grade.

6.6 AGGREGATE SOURCES

Aggregate materials are commonly derived from both basin-fill and rock sources. High quality rock sources are generally more readily available than high quality basin-fill sources. However, because of the higher cost of developing aggregates from rock sources, it is usually more economical to develop basin-fill sources.

An ideal basin-fill source for concrete aggregate should be composed of well-graded, hard, durable, subangular to subrounded particles. An ideal rock source for concrete aggregate should be easily accessible with favorable bedding and jointing patterns. It should also possess chemical and physical characteristics that, upon mining and crushing-down, produce optimum-sized, equidimensional particles. Physical and chemical properties for basin-fill and rock road-base aggregate sources are similar but less stringent than those for concrete aggregate sources.

The principal source of potentially suitable coarse and fine basin-fill aggregates are the alluvial fan deposits (A5yg and A5ig) that flank the limestone and dolomite carbonate rocks of the Star Range and southern Wah Wah Mountains along the western boundary of the study area. These deposits are typically heterogeneous mixtures of boulders, cobbles, gravel, sand, silt, and clay that grade from coarse grained near the rock/basin-fill contact to fine grained near the valley axis. Limited test data indicate that the fine aggregate fraction of some of these deposits may not be acceptable for concrete.

Stream channel deposits (A1) associated with secondary and primary ephemeral streams may supply additional coarse and fine aggregates. They are heterogeneous mixtures that vary from boulders to silt and clay depending on their location in the valley area. The most durable materials are found along streams which drain the most acceptable rock sources.

Potential sources of suitable crushed rock for the study area are Paleozoic carbonate rocks located along the western margin of the area in the Star Range and southern Wah Wah Mountains. Similar carbonate rocks are present in the southern Mineral Mountains east of the study area.

Other potential sources of crushed rock may be from the Cenozoic granitic rocks of the Star Range and southern Mineral Mountains and Cenozoic basalt/andesitic basalt of the southern Needle Range (southwest) and Black Mountains (east).

In general, sufficient volumes of coarse and fine aggregates required for concrete and road-base construction purposes appear to be available from a variety of basin-fill and rock sources within or nearby the study area. However, these conclusions are based on field observations with limited laboratory test data. An aggregate laboratory testing program (i.e., sieve analysis, Los Angeles abrasion, soundness, potential alkali reactivity, specific gravity, and absorption) is recommended before precise estimates on the quality and quantity of aggregates can be made.

7.0 RECOMMENDATIONS FOR FUTURE STUDIES

Additional detailed studies should be made before final layout and design of the various activity centers in the proposed operational base. Further studies are recommended to better define the hazards due to 1) flooding and ponding, 2) faulting and seismicity, 3) subsidence, and 4) sand dune migration and reactivation. Future studies are also recommended to develop more specific and precise foundation-design criteria for the individual activity centers, and to identify the extent and chemical and physical characteristics of the available aggregate resources. These recommended future studies are discussed in the following sections.

7.1 FLOODING AND PONDING POTENTIAL

An assessment of the potential for flooding and ponding at the activity centers should be made, including the following determinations:

- Volume of storm runoff;
- Peak flood discharge;
- Flow velocities; and
- Maximum probable flood for the predicted lifetime of the facilities.

7.2 FAULTS AND SEISMICITY

We recommend the following detailed seismic risk analysis:

- Seismotectonic setting and its significance;
- Seismic history of the region;
- Local and regional fault relationships;

- Fault parameters (including length, projections, nature of displacement, etc.);
- Activity ratings (ages of last movement);
- Empirical relationships of fault length-scarp height to credible and probable maximum magnitudes;
- Probablistic study for future earthquakes; and
- Seismic design of structures.

We also recommend that trenches be excavated across the major faults and lineaments (Section 5.5.2) that are located in or project through the planned activity centers. These data will aid in determining minimum fault ages, seismic design, and final activity center locations.

7.3 SUBSIDENCE

An assessment of the potential for land subsidence due to ground-water withdrawal is recommended. This study should include:

- Estimates of ground-water recharge and current and future withdrawal requirements;
- Determination of the amount of historic ground-water level decline; and
- Trench and/or bucket auger exploration to visually examine suspected subsidence features that may involve the proposed activity centers.

7.4 SAND DUNES

A detailed study of the migration and potential for reactivation of dunes in the site areas should be made and include the following determinations:

- Rate of migration;

- Prominent regional and local wind directions; and
- Possible relationship between disturbing the ground surface at the proposed activity centers and the potential for dune reactivation.

7.5 FOUNDATION DESIGN

The results of the preliminary foundation investigation have revealed that the subsoil conditions are quite complex at the Milford OB site. The recommendations presented in this report are intended to give an architect/engineering firm general ideas regarding the type of foundations that will need to be considered for the various structures. The data will also be useful in the master planning effort since profiles have been developed to identify the various foundation conditions.

The results of this study indicate that detailed foundation investigations will be required and should be performed after building locations have been determined. It is recommended that the field investigations include borings, trenches, test pits, and cone penetrometer tests. Because of the heterogeneous soil conditions, field activities should be well spaced within actual building sites. During drilling, undisturbed samples should be obtained at closely spaced intervals to determine changes in soil conditions. Cone penetrometer tests spaced between borings will be very helpful in correlating soil conditions from one boring to the next. The foundation studies should also be planned to determine the degree of cementation and the depth-to-ground-water table. An extensive laboratory testing program will be needed to determine the engineering properties of the