FN-TR-38-D
Vol. I

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MX SITING INVESTIGATION WATER RESOURCES PROGRAM SUMMARY FOR DRAFT ENVIRONMENTAL IMPACT STATEMENT

VOLUME I

FUGRO NATIONAL
CONSULTING ENGINEERS AND GEOLOGISTS

MX SITING INVESTIGATION
WATER RESOURCES PROGRAM
SUMMARY FOR DRAFT ENVIRONMENTAL IMPACT STATEMENT

VOLUME I

Prepared for:

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15 May 1980

FOREWORD

This report was prepared for the Department of the Air Force, Ballistic Missile Office (BMO), in compliance with Contract No. F04704-80-C-0006, CDRL Item 004A2. It presents water resources evaluations of selected valleys in the Nevada-Utah siting area based on work that was completed by 1 April 1980. It is submitted at this time so that it can be incorporated into the Draft Environmental Impact Statement.

The water resources program is a continuing program which was started in June 1979 and is expected to continue into 1981. Many of the water resource tasks are still in progress and more comprehensive evaluations will be possible when these tasks are completed.

The report consists of three volumes as follows:

Volume I - Main text providing evaluations of valley and regional ground-water resources in the siting area, assessment of the potential impacts of MX ground-water withdrawals on the local water users, the environment, and the aquifers, and the measures that could be employed to mitigate the impacts.

Volume II - Data volume consisting of basic hydrogeologic data collected during Fugro National, Inc. field hydrologic reconnaissances, drilling and testing programs and from existing data sources.

Volume III - Municipal Water Resources requirements

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

INTRODUCTION

The MX Water Resources program was initiated in June 1979 for the purpose of evaluating the availability of water for both the construction and operational phases of the MX project in the Nevada-Utah siting area. Six valleys representative of typical hydrologic conditions in the siting area were studied during Fiscal Year 1979 (FY 79). The Water Resources program was expanded in FY 80 to include the investigation of the hydrologic conditions in 31 valleys, including the six valleys studied during FY 79. Sixteen of the 31 valleys have been investigated to date and the results are presented in this report.

Field activities have included 19 aquifer (pump) tests, 121 water quality analyses, 218 ground-water level measurements, 40 spring and stream discharge measurements, drilling and testing of two approximately 1000-foot wells in Dry Lake and Delamar valleys, and the drilling of one approximately 1000-foot observation well in White River Valley.

RESULTS AND CONCLUSIONS

Surface water in the MX siting area is quite limited and is considered to be entirely appropriated and utilized. Ground-water from valley-fill aquifers is the most likely source of water for MX construction and is physically obtainable in all the valleys in the siting area. Ground-water withdrawals during construction, however, may exceed the perennial yield in a few valleys depending on construction rates, the location of construction facilities and camps, and the number of clusters in each valley. In several valleys, additional ground-water withdrawals may not be approved by the State Engineer's Office because the valleys are either designated as in Big Smoky, Lake, Penoyer, Ralston, Stone Cabin, and Steptoe valleys in Nevada, or ground-water withdrawals significantly exceed perennial yield as in Sevier Desert, Utah. There are one or more possible alternative sources of construciton water to the valley-fill aquifer that exist in each valley studied. Alternatives are: (1) importation of ground water from a neighboring valley where it is more plentiful, (2) purchase or lease of existing water rights from local water users for the short-term construction period, and (3) development of possible carbonate aquifers.

Water quality was evaluated for the 16 valleys studied according to criteria for drinking water listed in Table C1-1. In general, major areas of Cave, Snake, White River, Hamlin, Little Smoky, Railroad, and Dry Lake valleys contain good quality water except for a few localized areas which contain either poor quality water or that which exceeds the established criteria.

Major areas of Pine, Wah Wah, Whirlwind, Tule, and Big Smoky valleys and Sevier Desert contain poor quality water except for a few localized areas (usually near springs) which contain good water. Fish Springs Flat and Dugway Valley contain water which generally exceeds established criteria. Water quality analyses have not been completed for Delamar Valley.

Generally, water classified as being poor is high (greater than 500 milligrams per liter; mg/l) in Total Dissolved Solids (TDS). In some areas (Whirlwind and Wah Wah valleys, and Sevier Desert), high TDS values are the result of high dissolved chloride concentrations. In localized areas where water exceeds established criteria, high concentrations of either nitrates, chlorides, or total dissolved solids were measured. High concentrations of calcium and magnesium are usually associated with water discharging from or flowing through carbonate rock terrain (Hem, 1970).

The transmissivity values determined from the 19 aquifer tests ranged from 430 to 350,000 gallons per day per foot (gpd/ft; 0.62 to 504 square centimeters per second; cm^2/sec). The broad range of transmissivities suggest that well yields are likely to be quite variable in the siting area. High transmissivity values indicate that the aquifer is efficient and capable of supplying high well yields of approximately 1000 gallons per minute (gpm; 63 liters per second; l/s). Low well yields are anticipated in playa areas and in the central portion of several valleys where the sediments are fine grained and transmissivities are likely to be low. High well yields from valley-fill aquifers were measured or observed in existing or Fugro National wells in Big Smoky, Little Smoky, Railroad, White River, Dry Lake, Snake, and Hamlin valleys. High well yields in other valleys in the siting area may be possible.

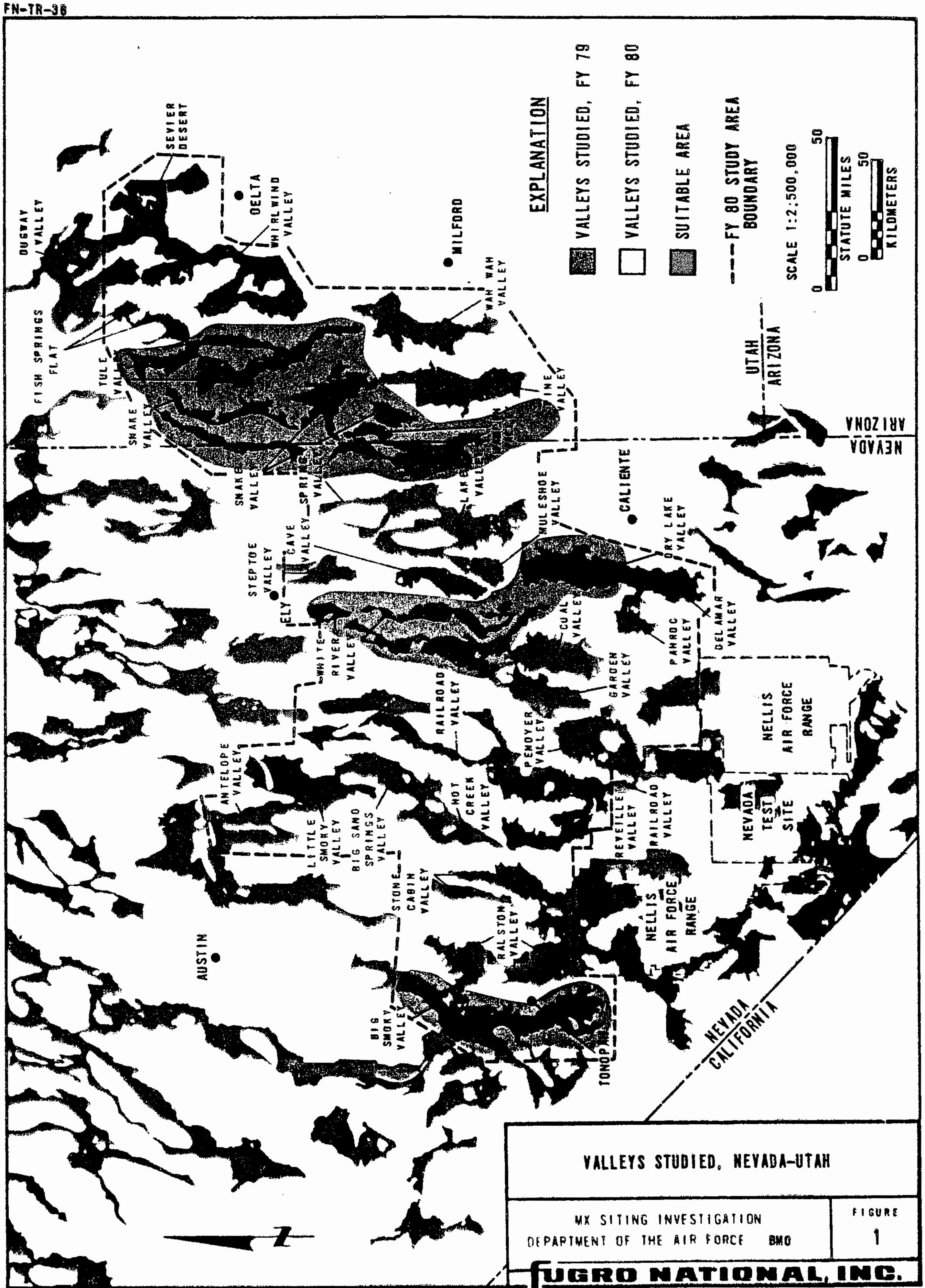
The aquifer test of the intermediate-depth (1000 feet; 305 meters; m) well in Dry Lake Valley resulted in a high well yield of approximately 750 gpm (47 l/s) which converts to approximately 1200 acre-feet per year (acre-ft/yr; 1.5 cubic hectometers per year; hc^3/yr) or nearly half the quantity of water that may be needed for shelter construction in Dry Lake Valley. The aquifer test of the intermediate-depth well in Delamar Valley resulted in a low well yield of about 85 gpm (5.4 l/s) which converts to approximately 140 acre-feet per year (0.2 hm^3/yr) or about six percent of the quantity of water that may be needed for shelter construction. A higher well yield could be developed with greater penetration of the aquifer.

The potential impacts of MX ground-water withdrawals on the local water users, the environment, and the aquifers are expected to be minimal with proper planning and water management. The anticipated drawdown of the ground-water table for a typical valley-fill aquifer in the region, at a pumping rate of 350 gpm (22.1 l/s) for a two-year period and a realistic storage coefficient of 0.1, is projected to range from approximately 25 feet (8 m) near the pumping well to about 1 foot (0.3 m) at a distance of approximately 10,000 feet (3050 m). The numerical model of Snake Valley developed by Fugro National indicates that using the most representative simularion of the valley ground-water conditions, MX withdrawals would likely result in drawdowns at existing water-use locations ranging between 0.1 and 4.3 feet (0.03 and 1.3 m) after five years of pumping. Similar conditions were determined by Fugro National for White River Valley through numerical modeling. The predicted drawdown of the ground-water levels and alteration of spring discharge is negligible assuming a realistic storage coefficient of 0.1 and transmissivities ranging from 5000 to 10,000 gpd/ft (7.2 to 14 cm^2/sec).

Most of the springs in the valleys studied are fed by precipitation and snowmelt or are derived from carboante aquifers that are part of the regional ground-water flow system. MX construction water withdrawals from the valley-fill aquifers are unlikely to have a significant effect on these springs.

The present capacity of municipal water-supply and wastewater-treatment systems and their capacity to expand were investigated as part of the MX Water Resources program. It was determined that significant capital expenditures will have to be made to accomodate water-supply and wastewater-treatment requirements of MX-related population growth. Many of the water-supply systems and wastewater treatment systems do not now meet legal requirement. The wastewater systems can be improved and expanded if funding can be obtained. The water-supply systems are expandable given proper funding, but in some cases, water rights are not available by appropriation and will have to be purchased from existing water users.

Significant impacts of MX construction water withdrawals can generally be avoided in each valley within the siting area through careful well-field design. MX water supply wells can be located a sufficient distance from existing wells and springs to largely avoid interference effects that may significantly lower water levels or alter spring discharge. A system of water-level, spring-discharge, and water-quality monitoring stations could be established and monitored during construction to provide early detection of potential changes in the ground-water system. This information would be input to a numerical model of the ground-water system to project the effects on the local water users and the environment. If significant water level declines or reduced spring dishcarges were detected, the pumping patterns of wells in proximity to the affected area could be adjusted.



VALLEYS STUDIED, NEVADA-UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE BMO

FIGURE
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1.0 INTRODUCTION

1.1 BACKGROUND

This report presents the preliminary findings of the MX Water Resources program for the Nevada-Utah siting area based on studies conducted to 1 April 1979.

The MX Water Resources program was initiated in June 1979 for the purpose of evaluating the availability of water for both the construction and operational phases of the MX project. Six valleys representative of typical hydrologic conditions in the siting area were studied during Fiscal Year 1979 (FY 79) ending 30 September, and a report was submitted to the Ballistic Missile Office on 21 December 1979. Based on the FY 79 studies, it was determined that the Water Resources program should be expanded to include aquifer testing and field investigations in all valleys within the siting area in order to better understand the potential effects of MX ground-water withdrawals on the local water users and the environment and to determine the optimum water supply system for the project. The Water Resources program was expanded during Fiscal Year (FY 80) to include the investigations of the hydrologic conditions in 31 valleys, which includes the six valleys studied during FY 79. Sixteen of the 31 valleys have been investigated to date; the results are presented in this report. Also presented are overview discussions of the hydrologic conditions in the entire siting area. The FY 79 and FY 80 study areas are shown in Figure 1. Explanation of the terms used in the hydrologic discussions is provided in Appendix I1.0, Glossary of Selected Hydrogeolgic Terminology.

1.2 OBJECTIVES

The primary objectives of the overall Water Resources program are to:

- o Determine the effects of MX ground-water withdrawals on the local water users, the environment, and the aquifers. Water withdrawals in some areas may cause the lowering of ground-water levels which could affect existing wells, wildlife refuges, and the discharges of springs where endangered species may reside.
- o Determine the optimum water source and supply system with possible supply alternatives for each valley.
- o Provide the necessary data and documentation in support of the conclusions and recommendations of the Water Resources Program. The regulatory agencies will require thorough documentation prior to granting permits and permission for water development and use.

1.3 SCOPE

The FY 79 and FY 80 Water Resources programs to date have involved the investigation of 16 valleys in the siting area: (1) Big Smoky, (2) Cave, (3) Delamar, (4) Dry Lake, (5) Dugway, (6) Fish Springs Flat, (7) Little Smoky, (8) Pine, (9) Railroad, (10) Sevier Desert, (11) Snake, (12) Hamlin, (13) Tule, 14) Wah Wah, (15) Whirlwind, and (16) White River. The location of the valleys studied and the activities performed in each are shown in Figure 1 and Table 1, repectively. The activities are identified in the text and appendices according to conventional township-range terminology. An example for Nevada is: 12N/40E-13da which means Township 12 north, Range 40 east, Section 13, Subsection da (NE1/4, SE1/4). A slightly different but similar

AREA	ACTIVITY					
	AQUIFER TEST	WATER QUALITY ANALYSIS	TRITIUM ANALYSIS	WATER LEVEL MEASURMENT	DISCHARGE MEASUREMENT	WATER TABLE MONITORING BORING
BIG SMOKY VALLEY	2	5	5	23	2	0
CAVE VALLEY	0	4	0	8	3	0
DRY LAKE/DELAMAR VALLEY	2	4	3	2	3	0
DUGWAY VALLEY	0	1	1	3	1	0
FISH SPRINGS FLAT	0	2	1	10	1	0
LITTLE SMOKY VALLEY	0	4	0	16	4	0
PINE VALLEY	0	5	3	1	1	0
RAILROAD VALLEY	0	7	5	5	11	0
SEVIER DESERT	1	8	0	21	0	0
SNAKE/HAMLIN VALLEY	9	50	49	59	38	2
TULE VALLEY	1	9	11	17	5	1
WAH WAH VALLEY	0	1	1	0	0	0
WHIRLWIND VALLEY	0	2	2	13	2	0
WHITE RIVER VALLEY	4	21	22	55	3	1

FUGRO NATIONAL FIELD ACTIVITIES
NEVADA-UTAH

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TABLE
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system is used for Utah and is also included in the report.

The Water Resources program included the following studies:

- Review of existing pertinent publications and data contained in agency files relating to water availability, local water-use, regional ground-water flow systems, and aquifer characteristics.
- Contacts with various state and federal officials knowledgeable about ground-water conditions in Nevada and Utah.
- Hydrogeologic field studies to identify water uses, measure ground-water levels, collect ground-water samples for chemical analyses, measure spring and well discharges, conduct aquifer tests, and overview general hydrogeologic conditions.
- Drilling and testing of intermediate depth [1000 feet (305 meters), or (m)] observation and test wells in Dry Lake and Delamar valleys, and the drilling of an observation well in White River Valley. Aquifer tests in the Dry Lake and Delamar wells.
- Assess municipal water supplies and waste-water treatment facilities for their capacity to handle increases due to MX population influx. This study included towns within and immediately adjacent to the siting area with emphasis on Tonopah, Ely, Caliente, and Pioche in Nevada and Delta, Milford, and Cedar City in Utah.
- Evaluate basin structure to better understand regional ground-water flow systems.
- Computer numerical modeling of the ground-water system in Snake and White River valleys to assess the effects of MX ground-water withdrawals on the local water users and the environment.
- Industry activity inventory to identify the water requirements of existing and proposed industries in the siting area and how these requirements may interact with MX construction and operational activities. This study is being conducted by the Desert Research Institute for Nevada and the Utah Water Research Laboratory for Utah. Preliminary comments on the methods of investigation and the impacts of industrial water requirements on the MX project in the Utah portion of the siting are presented in this report (Section 3.17). The industrial activity in the Nevada portion of the siting area is under current investigation. The complete study for Nevada and Utah will be submitted to the Ballistic Missile Office the end of June 1980.

- Study of Nevada and Utah water laws and permitting procedures and a water rights inventory. Phase I of the study, concerning water law and the permitting process prepared by the Desert Research Institute, Nevada, was presented to the Ballistic Missile Office and subsequently submitted to the Nevada Division of Water Resources (NDWR) and Utah Division of Water Rights (UDWR) for review and comments. Corrections to the study are currently being made and the final study will be issued before mid-June along with Phase II of the Water Legal Study concerned with a water rights inventory in the MX siting area.

The FY 79 and FY 80 Water Resources field studies included aquifer tests of existing wells, water-level measurements, water sampling for quality analyses, spring and stream discharge measurements, and evaluation of evapotranspiration conditions. Further explanation of these tests and evaluations follow.

- Aquifer tests were conducted in selected wells to determine potential well yields and the aquifer's ability to store and transmit water. This information is needed in designing well fields, in evaluating the optimum yield, and in minimizing well interference effects.

- Ground-water levels were measured in selected wells and drill holes in order to construct potentiometric maps for identifying ground-water migration patterns, identify areas of recharge or discharge, and as an aid in calculating expected pumping lifts for well design.

- Ground-water samples were collected from wells and springs for analyses to characterize the water quality and assess its suitability for construction or drinking purposes and as an aid in identifying ground-water migration patterns and recharge areas. The water quality analyses included field measurements of the water temperature, pH and specific conductance, and laboratory determination of the concentrations of sodium, potassium, calcium, magnesium, sulfate chloride, fluoride, nitrate, silica, carbonate, bicarbonate, and tritium. Unusually high concentrations of tritium are common from the atmospheric nuclear testing that was conducted in the region prior to 1954. Its concentration in water supplies has been used as an indication of relative recharge rates to ground-water systems; however, results obtained during the FY 79 Water Resources program are inconclusive and are not presented here.

- o The relationship between evapotranspiration and depth to ground water was analyzed in Snake, Hamlin, White River, and Tule valleys to determine the amount of water consumed by phreatophytes (plants which obtain water from a shallow saturated zone) and used as an important input parameter to the computer models.

1.4 METHOD OF INVESTIGATION

1.4.1 Existing Data

Collection of existing data has been an ongoing process through all phases of the geotechnical site selection studies conducted by Fugro National. Besides a thorough review of pertinent publications, data have been collected from Federal and State agencies, private consultants, petroleum and mining firms, universities, local officials, and private citizens. All information and data collected have been evaluated and, where applicable, incorporated into this report to supplement field work and original data gathering.

1.4.2 Aquifer Tests

Tests to determine aquifer response to ground-water withdrawals were conducted on existing privately-owned and Bureau of Land Management wells, in addition to wells drilled by Fugro National. Testing was performed on large discharge (over 500 gallons per minute; 31.5 l/s) wells where available; however, smaller discharge capacity stock-water wells were also used. Right-of-entry permission was obtained from well owners prior to any aquifer testing. This permission was generally verbal, but owners were offered a "Hold Harmless" agreement in which Fugro National accepted all liability for personal injury and damage to private equipment during testing.

1.4.3 Water Quality Analyses

Water samples for quality analysis were collected from irrigation wells, operating windmills (stock-water wells), springs, and flowing streams. Irrigation wells were allowed to discharge a minimum of ten minutes before samples were collected. The analyses performed are listed in Section 1.3 above and in the table of Water Quality Criteria (Table C1-1).

During collection, samples for laboratory analysis were separated into bottles of various sizes and were filtered and/or acidified, depending upon the requirement for testing of the particular suite of ions. After collection, all samples were kept chilled until analysis to further inhibit bacterial production that might change the water chemistry. Water chemistry determinations were done by Controls for Environmental Pollution Laboratory in Santa Fe, New Mexico, and the Utah Water Research Laboratory in Logan, Utah.

In addition, certain physical characteristics of the water, i.e., temperature, specific conductance, and pH, were measured in the field at the time of water samples collection and the water also was analyzed for the carbonate and bicarbonate concentrations. At the beginning of each work day in the field, the calibration of the conductivity meter was checked using the meter's internal reference system. During calibration checking, subsequent to field work, a significant deviation in probe readings was observed. This error has since been eliminated, but specific conductance values listed in Appendix C may be spurious. The pH meter was calibrated by checking the meter with a buffer solution of known pH prior to each test. Analyses for carbonate and bicarbonate ions were performed using standard titration methods the same day the water samples were collected by Fugro National personnel.

1.4.4 Ground-Water Level Measurements

The depth to ground water below land surface was measured in existing wells and drill holes when accessible, and in wells and borings drilled by Fugro National. Measurements were made using electric water-level sounders or an electro/piezo recorder. Electric sounders indicate depth of water by deflection of a needle on an ammeter when a circuit is closed by contact of an electrode with the water surface. An electro/piezo recorder was used during aquifer test operations on wells developed by Fugro National. The electro/piezo recorder monitors rapid changes in pressure from pressure transducers which are lowered a known depth below the water-level in a well. Relative pressure changes recorded during testing are adjusted for barometric changes and subsequently converted to feet of water-level change relative to the ground surface.

1.4.5 Discharge Measurements

Various types of instruments were used to measure spring, stream, and flowing well discharge rates. Following is a list of the instruments used and their ranges of application.

Range of discharge (gallons per minute)	Type of Instrument Used
>500	Pygmy-type current meter
1000 - 50	8-inch cutthroat flume
250 - 10	2-inch cutthroat flume
<30	calibrated containers

Current meter and flume measurements were conducted in channel sections that were relatively smooth, straight, and had the least amount of turbulence. Calibrated containers were used to measure the discharge from small wells and from small springs which have been developed by the Bureau of Land Management.

1.4.6 Water-Table Monitoring Borings

Water-table monitoring borings were located at the edge of phreatophytic areas as determined from aerial photographs and by field inspection. These borings were drilled with a Failing 1500 rotary drilling rig to a depth of 5 feet (1.5 m) below the ground-water level or to a depth of 50 feet (15 m) if there was no clear indication of water during drilling. Borings were cased with 2-inch-diameter (5-cm) PVC pipe which was capped at the bottom and perforated at 1-foot (0.3-m) intervals in the bottom 5 feet (1.5 m).

1.4.7 Intermediate Aquifer Drilling Program

1.4.7.1 Site Selection Criteria

The site selection process for intermediate depth (greater than 500 feet; 152 meters) observation and test wells involved considerations of four criteria: (1) valleys having existing high rates of withdrawals of ground water from shallow aquifers indicating possible keen competition for water and the need to identify alternative sources; (2) the lack of comprehensive data; (3) hydrogeologically favorable areas within a valley; and (4) specific sites with acceptable access and other conditions favorable to efficient drilling operation.

The valleys considered were those with existing high rates of ground-water withdrawals from the shallow valley-fill aquifer (e.g., White River and Snake valleys) and with some potential for an intermediate depth aquifer below possible confining materials. Other valleys considered were those with little or no ground-water data (e.g., Dry Lake and Delamar valleys) due to a deep (greater than 300 feet; 91 meters) water table.

Within each valley, favorable hydrogeological areas were considered where a stratigraphic layering of fine-grained deposits (confining) and coarse-grained deposits (aquifer) was expected. These areas were generally near the base of the alluvial fans extending outward into the valley from the mountain fronts. Here, fine-grained playa deposits were expected to interfinger with the coarser-grained fanglomerates. These potential siting areas were refined to include only those areas having little or no existing nearby hydrogeologic data.

The hydrogeologically acceptable sites were further refined so that they were along access roads capable of carrying heavy drilling equipment. In addition, the final sites were chosen as near as possible to a source of water for drilling. The first phase of drilling was conducted in White River, Dry Lake, and

Delamar valleys. The locations of these sites in each valley are shown on Drawings B1-3, B1-4, and B1-16.

1.4.7.2 Drilling Operations

Drilling operation at each site consisted of installing a multiple point observation/exploration well and, if hydrogeologic conditions warranted, a test well. The observation well contained two 2-inch ID piezometers, one of which tapped the shallow and the other tapped the deep valley-fill aquifer. The test well consisted of a 10-inch ID well casing and screen and tapped only the deeper aquifer zones.

Drilling operations began on 20 November 1979 in White River Valley (8N/61E-27dc). The drilling equipment consisted of a Howard Turner combination reverse circulation and air rotary drilling rig. Only the observation well was completed at this site because a lower aquifer was not penetrated within the 1300-foot (396-m) depth capability of the drill rig (well completion data and drilling schedule are presented in Appendix H1-1). After drilling operations were completed in White River Valley, observation and test wells were installed in both Dry Lake and Delamar valleys. These drilling operations were completed 22 March 1980.

1.4.7.3 Aquifer Testing and Monitoring

Aquifer testing and monitoring operations were conducted in the test wells in Dry Lake and Delamar valleys. The aquifer test pumping was done using a deep-well vertical line-shaft turbine pump with a diesel motor for power.

Prior to and during testing, all spring discharges and water levels in wells near the test wells were measured to assess any potential impact incurred during aquifer testing operations. Testing consisted of a short duration step-drawdown test to determine well efficiency and to design the optimum long-term rate of pump discharge. After the water levels recovered following the step-drawdown test, each test well was pumped at constant discharge for ten days. At the completion of pumping, water-level recovery was monitored. Results of these pump tests are presented later in this report in the individual valley discussions (Section 3.3).

1.4.8 Numerical Modeling

Computer-based numerical methods for predicting the response of ground-water systems to increased development has, in recent years, become widely utilized. Numerous programs have been developed and used for evaluating ground-water system (e.g., Pinder, 1970; Prickett and Lonquist, 1973; Pinder and Larson, 1976). The two-dimensional finite-difference model for aquifer simulation developed by Trescott, Pinder and Larson (1976), was selected for the MX Water Resources study for analyzing the ground-water flow system and to assess possible effects of withdrawals. The selection was based on the acceptability of the model, the hydrogeologic conditions, and the data base.

The Trescott, Pinder, Larson model simulates ground-water flow within a valley by solving the flow equation developed by Pinder and Bredehoeft (1968).

$$\frac{\delta}{\delta x}(Txx\frac{\delta h}{\delta x}) + \frac{\delta}{\delta y}(Tyy\frac{\delta h}{\delta y}) = S\frac{\delta h}{\delta y} + W(x, y, t) ,$$

where

Txx, Tyy = The components of the transmissivity tensor along the x and y axes.

h = Hydraulic head.

S = Storage coefficient.

t = Time.

W(x, y, t) = Volumetric flux of recharge or withdrawal per unit surface area of aquifer.

To solve this partial differential equation, a finite-difference approach is used which first subdivides the aquifer into a grid and then approximates the ground-water flow equation solution at the node (center point) of each block in the gird. The model allows the aquifer to be confined, semiconfined, or unconfined, and the grid may have variable spacing. It assumes, however, that aquifer properties within a single grid block are constant.

To apply the model to a given aquifer, a number of input parameters are required. For unconfined aquifers, the recharge and discharge rates, the elevations of the land surface and bottom of the aquifer, the maximum depth and rate of evapotranspiration, the vertical and horizontal hydraulic conductivities, and the storage coefficent are input. For confined or semiconfined aquifers, the specific storage of the confining bed, its thickness and hydraulic conductivity, and the hydraulic head of the water on top of the confining bed must be supplied as well. Other required input parameters include the location and rates of discharge and recharge points on areas. The outputs after processing the model include maps of the predicted drawdown and hydraulic head within the aquifer in response to puming at specified rates. In addition, a mass balance is provided between sources such as water in storage, recharge, and interaquifer leakage and discharges including evapotranspiration, pumpage, and leakage.

1.4.9 Municipal Water-Supply and Wastewater-Treatment Systems and Competing Industrial Activities

The studies of municipal water supply and wastewater treatment and competing industrial activities have been conducted for Furgo National by the Desert Research Institute (DRI) in Nevada and the Utah Water Research Laboratory (UWRL) in Utah. DRI studied the existing systems and expansion capabilities for the 12 communities most likely to be affected by MX-related growth. The analysis is based upon recent water system planning reports by private consultants and state and federal agencies, and supplemented with communication by DRI with community officials, and others.

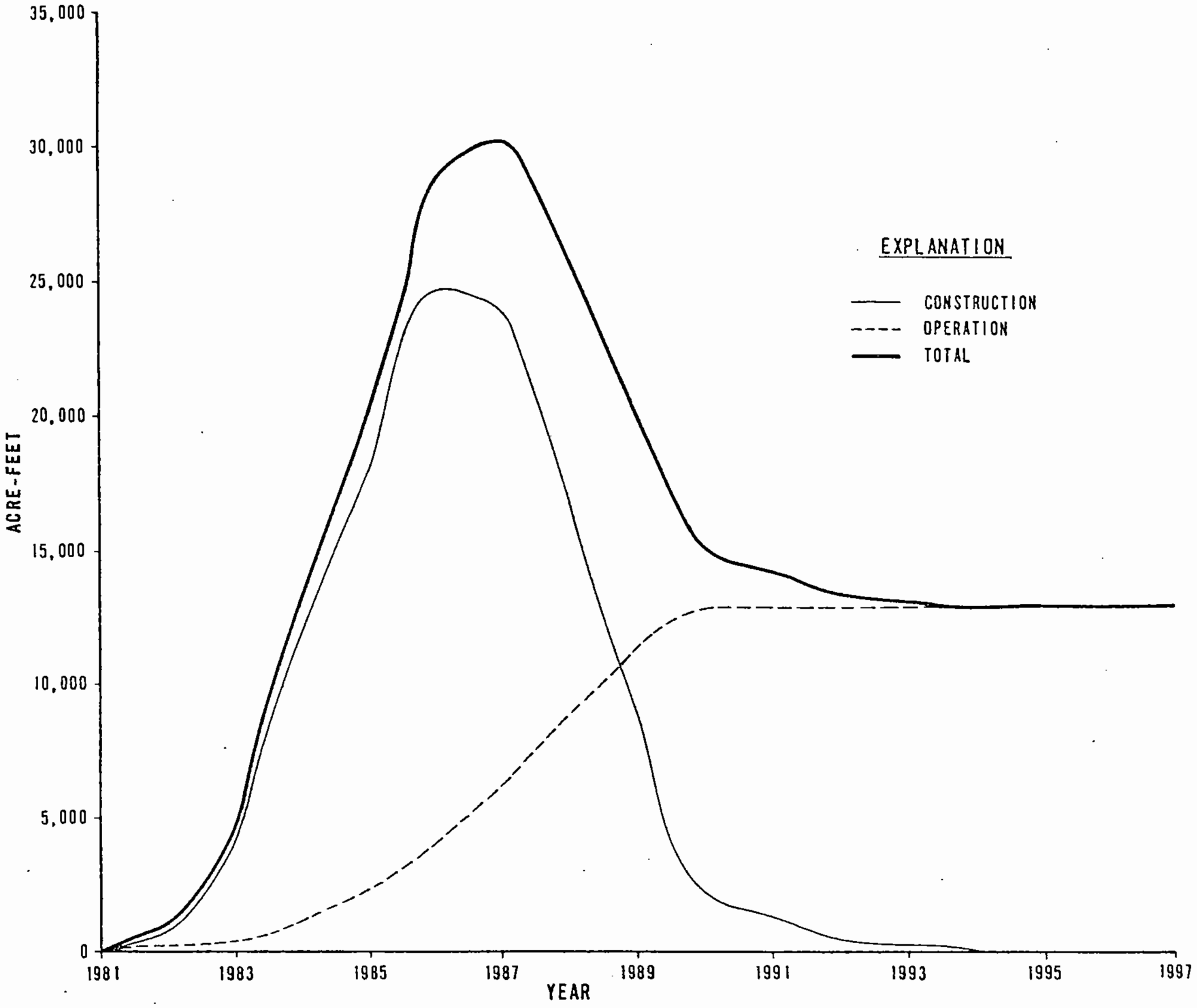
UWRL studied the five populated areas in Utah most likely to be affected. Their report is based on published data from private and government sources and communication with community officials. UWRL also did an industrial activity inventory by contacting state and federal regulatory agencies which have knowledge of planned future industrial activity.

1.5 MX WATER NEEDS

1.5.1 Construction

Figure 2 shows the projected MX water requirements from the start of construction in 1981 through 1997. Construction-water needs as shown in the table are based on estimates provided to Fugro National by the Ballistic Missile Office in the Fall 1979. These estimated requirements are under current evaluation and revision based on different shelter numbers and spacings per cluster. Detailed cluster layouts of the system will not be complete until late 1980. It is anticipated, however, that the amount of water required for construction will be lower than current estimates.

Construction water use will begin in 1981 with an estimated 107 acre-feet (acre-ft; 9.13 hm^3), will peak in 1986 with 24,594 acre-ft (30.32 hm^3) and taper off to zero in 1994 under present use estimates. The peak construction water demand will be distributed among several valleys. Water demand in each valley will be based on the number of clusters in each valley and the rate of construction. Because the water requirements for each cluster and cluster layouts have not been finalized at this time, it is not yet possible to accurately determine water needs on a per-valley basis. However, under current water need estimates, Dry Lake Valley, which has an average quantity of suitable area for cluster layout has an estimated construction water need of about 5000 acre-ft (6.17 hm^3). This assumes a two-year construction period. Therefore, the present average water use in any one valley in any year is not expected to



PROJECTED MX WATER REQUIREMENTS

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FIGURE
2

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exceed about 2500 acre-ft (3.08 hm^3), if cluster construction rates in other valleys are similar to those in Dry Lake Valley.

1.5.2 Operations

Operational water use has been divided into three categories: operating bases, deployment area service centers (DASC), and surveillance/maintenance facilities. The final deployment mode and location has not been established for these operations stations at the time of this report. Several operating base systems are under evaluation at the present time. Currently, the use estimate for a single base system is approximately 13,000 acre-ft (16.0 hm^3). Potential locations for operating bases have been evaluated by Fugro National and presented to the U.S. Air Force, Ballistic Missile Office under separate cover. A two-base system would likely have a higher total water demand but less for each individual base. At the present time, it is anticipated that approximately four DASCs will be required in the siting area. Based on current manpower needs and consumptive-use estimates, it is expected that these bases will probably require less than 100 acre-ft (0.12 hm^3) of ground water per year. Surveillance/maintenance facilities will be small, house only a few personnel and be located adjacent to clusters. Although deployment locations for these facilities have not been finalized, it is anticipated that the operational water-use will be very small.

2.0 REGIONAL HYDROLOGIC SETTING

As shown in Figure 1, most of the valleys in the Nevada-Utah siting area lie within the Great Basin physiographic province. Hydrologically, this province is characterized by an internal drainage system which has no surface outlet to the sea. The only exception to this is the White River drainage system in the south-central portion of the siting area in which surficially-connected valleys drain to the south and into the Colorado River.

Individual valleys within the system are characterized as having either open or closed surface drainage. Hydrologically open surface drainage valleys are defined as those valleys which topographically can drain to other valleys or basins. Hydrologically closed surface drainage valleys are defined as those valleys which retain all of the surface-water runoff originating within the basin.

Streamflow in the Great Basin region varies seasonally in response to both precipitation and temperature. Spring snowmelt contributes the most runoff to nearly all significant streams. Seasonal runoff can begin as early as February or as late as July (depending on location and temperature); however, for most of the region the first significant runoff appears in April or May. Most of the runoff that is available for development is found in the river systems in the eastern and western portions of the region. These rivers are the Bear, Weber, Jordan, Sevier, Humboldt, Truckee, Carson, and Walker. Runoff in the central part of the region is widely scattered in small perennial, intermittent, and ephemeral streams (Price, Eakin, and others, 1974).

In the central desert basins the climate is generally arid. Mean annual precipitation is approximately 8 inches (20.3 cm). Because the area has no drainage to the sea, the streams end in lakes or in sinks, including playas, mudflats, and salt marshes. Very few perennial streams occur in the valleys. Most streams are ephemeral, that is they have streamflow only in direct response to precipitation. As a consequence, very little data has been colleted on streamflow.

The U.S. Geological Survey operates a limited number of gaging stations in the central area. These stations are almost exclusively located in mountain streams or in streams within the upper portions of the drainage basins. Surface runoff from these areas quickly infiltrates into alluvial deposits, and is rarely present in most valley streambeds.

In the subsurface, valleys in the siting area can be divided into three categories; undrained, partially drained, and drained (Eakin, Price and Harrill, 1976). Undrained valleys are hydrologically closed in the subsurface and all recharge in the valley is discharged through evapotranspiration primarily on a discharging playa. Partly drained valleys also contain a discharging playa; however, a portion of the total recharge in these valleys is also discharged through permeable bedrock into the regional ground-water system. In drained valleys, nearly all of the recharge originating within and entering the valley by subsurface or underflow is also discharged by underflow through permeable rocks. These valleys, therfore, may have a dry playa on the surface but no significant amount of surface discharge takes place. The static water level or potentiomentric surface may be at any depth below the ground surface but is in hydrostatic equilibrium with the regional interbasin system.

Within each valley there may be one or several aquifer systems. All of the aquifers discussed above refer to the saturated alluvial aquifers which are of two types, confined and unconfined. Ground water in confined aquifers is under pressure greater than that of the atmosphere and whose upper surface is the bottom of an impermeable bed. Impermeable and semi-impermeable confining beds in the alluvial valley fill in the siting area are commonly fine-grained lake sediments deposited during the Pleistocene time. Many valleys contain more than one confining layer. Unconfined or water table aquifers are defined as having hydrostatic pressure equal to atmospheric pressure. Another type of unconfined aquifer is the perched aquifer. A perched aquifer is separated from the saturated valley-fill sediments by an unsaturated zone. They are usually relatively small in extent and volume and overlay impermeable or semi-impermeable lake deposits which have limited areal extent.

2.1 WATER AVAILABILITY

Surface water in the siting area is quite limited and appears to be entirely appropriated and/or utilized. The published estimates of perennial yield as compared to the current groundwater use estimates for each valley in the siting area are the measure of water availability discussed here. Table 2 summarizes these estimates. The total volume of ground water that may be withdrawn annually from a ground-water basin without causing undesirable results is termed the perennial yield of the basin. Domenico (1972, p. 43) defined the possible undesirable results as a lowering of ground-water levels or a reduction in water quality. Because of the short term MX construction water needs, however, these effects are expected to be temporary as the aquifer will likely replenish itself through normal hydrologic processes.

The Utah Department of Water Resources has not estimated the perennial yields of Utah's ground-water basins. Eakin, Price, and Harrill (1976) did, however, make provisional estimates for the valleys in Utah. Withdrawal rates and basin ground-water level records are available for the Sevier Desert, Utah, for the period from 1968 to 1978. Based upon these figures, the perennial yield of the Sevier Desert was estimated using the Hill method described by Todd (1959). This method, shown in Figure 3 consists of plotting the change in ground-water levels versus the average annual withdrawal. The perennial yield is then estimated to be the annual pumpage which results in no ground-water change.

Based on the estimated construction water requirements of the MX project as discussed in Section 1.5, MX Water Needs, and based

VALLEY NAME	PERENNIAL YIELD (THOUSANDS OF ACRE-FEET PER YEAR)	CURRENT USE (THOUSANDS OF ACRE-FEET PER YEAR)	COMMENTS
1 BIG SMOKY	9	1	DESIGNATED
2 WHITE RIVER	37	26*	
3 HAMLIN	**	**	
4 SNAKE	32, 80	14*	
5 TULE	< 5	0.035	
6 DRY LAKE	3	M	
7 WHIRLWIND	5-25[1]	M	
8 FISH SPRINGS	25-50	M	
9 DUGWAY	5-25[1]	M	
10 ESCALANTE DESERT	25-50	65	OVERDRAFT IN IRRIGATED AREAS
11 SEVIER DESERT	100[1]	39	OVERDRAFT IN IRRIGATED AREAS
12 SPRING	70-100	UNK	
13 FERGUSON DESERT	**	**	
14 PINE	< 5[1]	.005	
15 WAH WAH	< 5	M	
16 TIKABOO	1	M	
17 COAL	6	M	
18 CAVE	2	M	
19 LAKE	17	2*	DESIGNATED
20 DELAMAR	3	M	
21 PAHROC	21	M	
22 REVIELLE	UNK	M	
23 RAILROAD	75	17*	
24 HOT CREEK	6	UNK	
25 BIG SAND SPRING	1	UNK	
26 PENOYER	5	M	DESIGNATED
27 GARDEN	6	M	
28 LITTLE SMOKY	5	UNK	
29 ANTELOPE	4	M	
30 RALSTON	6	UNK	
31 STONE CABIN	2	M	DESIGNATED
32 STONEWALL FLAT	M	M	
33 STEPTOE	70	53	DESIGNATED
34 BLACK ROCK DESERT	***	***	

EXPLANATION

* ESTIMATED BY FUGRO NATIONAL

** INCLUDED IN SNAKE VALLEY

*** INCLUDED IN SEVIER DESERT

M-MINOR, LESS THAN 1000 ACRE FEET PER YEAR

UNK-UNKNOWN

(1) SYSTEM YIELDS ESTIMATES: DEFINED AS THE MAXIMUM AMOUNT OF SURFACE AND GROUND WATER THAT CAN ANNUALLY BE OBTAINED FOR AN INDEFINITE PERIOD OF TIME (EAKIN, PRICE, AND HARRILL 1976)

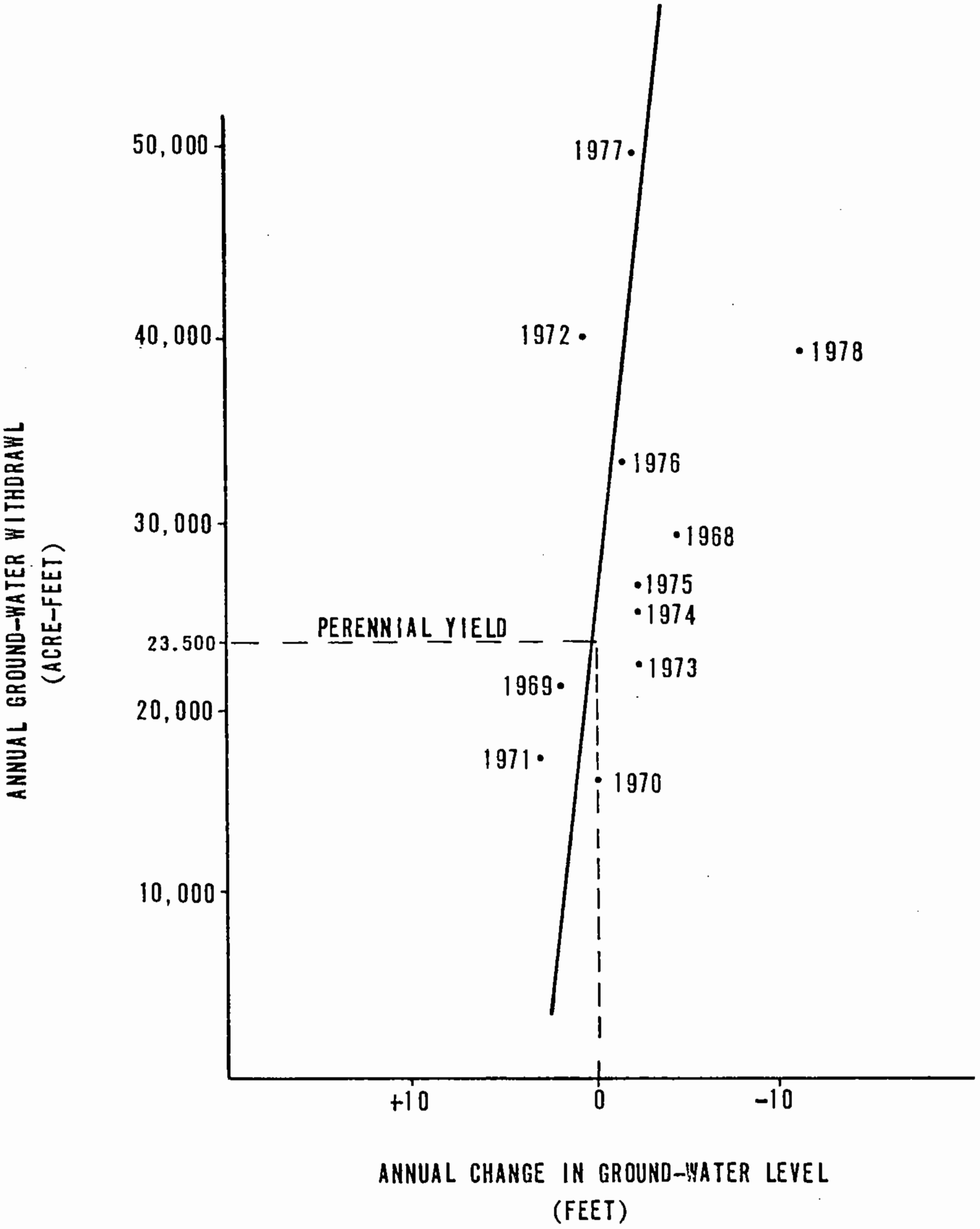
NOTE: PERENNIAL YIELD ESTIMATES ARE FROM VARIOUS STATE AND FEDERAL AGENCIES: WATER RIGHTS HAVE BEEN NEARLY OR TOTALLY APPROPRIATED IN DESIGNATED VALLEYS, EVEN THOUGH CURRENT-USE ESTIMATES MAY BE MUCH LOWER THAN THE ESTIMATED PERENNIAL YIELD.

SUMMARY OF GROUND WATER AVAILABILITY

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE
2

FUGRO NATIONAL, INC.



PERENNIAL YIELD ESTIMATE FOR
THE SEVIER DESERT, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE
3

FUGRO NATIONAL, INC.

on the estimated perennial yield, it appears that ground-water withdrawals may exceed the estimated perennial yield in only a few valleys in the siting area. It is believed, however, that ground water is physically obtainable in all the valleys in the siting area, and that ground-water withdrawal from aquifers in these valleys would be replenished through normal hydrologic processes following construction. In other valleys, the water may not be available because it is designated as in Big Smoky, Lake, Penoyer, Ralston, Stone Cabin, and Steptoe valleys. In some of these valleys, however, it may be possible to purchase or lease existing surface and/or ground-water rights for the approximate two year estimated construction period.

2.2 WATER QUALITY

The quality of the water in the siting area is quite variable as indicated by the valley studies completed by Fugro National and ranges from good to exceeds drinking water criteria as defined in Appendix Cl-1. Generally, water which exceeds established criteria is high in total dissolved solids and chloride. These high concentrations are commonly observed in water from playas. Water with high concentrations of chloride and total dissolved solids may be present in areas where very little ground water flushing has occurred or where ground water has traveled considerable distances from the recharge areas (Freeze and Cherry, 1979). High nitrate concentration may also occur in areas where agriculture and livestock are present (Hem, 1970).

Generally, water classified as being poor is high (<500 mg/l) in Total Dissolved Solids (TDS). In some areas (Whirlwind and Wah Wah valleys, Sevier Desert), high TDS values are the result of high dissolved chloride concentrations. Water from localized areas classified as poor will usually exhibit high concentrations of calcium, magnesium, or fluoride. High concentrations of calcium and magnesium are usually associated with water discharging from or flowing through carbonate terrain (Hem, 1970), whereas, high fluoride concentrations may be associated with water discharging from or flowing through either sedimentary or igneous (probably volcanic) terrain (Hem, 1970). Hydrologic conditions in the valleys studied to date are described in the following individual valley sections.

3.0 GROUND-WATER CONDITIONS IN SELECTED VALLEYS

3.1 BIG SMOKY VALLEY

3.1.1 Physiography and Geology

The study of Big Smoky Valley in Nye and Esmeralda counties was limited to the southern portion of the valley as shown in Figure 1 and Drawings B1-1. The valley has a northerly trend and is about 65 miles (105 km) long and up to about 25 miles (40 km) wide. The area of the valley is about 1600 mi^2 (4144 km^2) of which about 665 mi^2 (1722 km^2) is suitable area for MX deployment. The elevation of the valley floor ranges from 4800 feet (1463 m) in the southern playa to about 5800 feet (1768 m) at the north end. Elevations along the crest of the mountain ranges are from about 5500 to 11,000 feet (1676 to 3353 m).

Alluvial and lacustrine deposits of Tertiary and Quaternary age fill the valley up to thicknesses believed to be from 3000 to 5000 feet (914 to 1524 m) (Rush and Schroer, 1970). The generally coarse-grained alluvial deposits are probably interlayered with the fine-grained lake deposits. Playa deposits occur where there are closed topographic lows such as Alkali Spring Flat and Tonopah Flat. Rocks of the bounding mountain ranges are primarily volcanics of Tertiary age with local areas of clastic and carbonate sedimentary rocks of Paleozoic age. Minor outcrops of granitic igneous rocks occur throughout the mountain ranges.

3.1.2 General Hydrology

Big Smoky Valley has a closed surface and subsurface drainage (Rush and Schroer, 1970) although there is some indirect evidence for subsurface discharge based on differences in potentiometric levels and unbalanced water budgets in Clayton Valley and Tonopah Flat (Rush and Schroer, 1970).

The majority of recharge to the valley-fill aquifer is believed to occur on the fans from infiltration of ephemeral streamflow from the mountain ranges in response to precipitation events. Only a minor rate of recharge is believed to take place through the finer-grained sediments on the valley floor. This is due to the low precipitation, high evaporation, and low infiltration rates of these deposits. The total recharge from precipitation is estimated to be about 12,000 acre-ft/yr (14.8 hm^3/yr) (Rush and Schroer, 1970). Additional recharge takes place by subsurface inflow from Ione Valley, Ralston Valley, and the northern part of Big Smoky Valley. The gradient down the axis of Ione Valley is about 35 feet per mile (7 m/km) and it is 5 ft/mi (0.9 m/km) down the axis from Big Smoky in the north end of the study area as shown in Drawing B1-1. Inflow from Ione and Ralston valleys is estimated to be 2000 acre-ft/yr (2.5 hm^3/yr) (Rush and Schroer, 1970). There is no published estimate of inflow from northern Big Smoky, but based on a narrower width and lower gradient than Ione Valley, an inflow of about 1000 acre-ft/yr (1.2 hm^3/yr) is estimated. Total recharge is therefore about 15,000 acre-ft/yr (18.5 hm^3/yr).

Discharge takes place by evapotranspiration, use by man, springs and possible subsurface outflow. Evapotranspiration is estimated at 6000 acre-ft/yr (7.4 hm^3/yr) (Rush and Schroer, 1970) based on the area of phreatophyte growth. Total use by man is estimated at 1000 acre-ft/yr (1.2 hm^3/yr) (Rush and Schroer, 1970). This estimate includes irrigation, but also includes domestic and municipal use. Numerous springs along the base of the mountain ranges discharge minor quantities of water, primarily from perched alluvial aquifers. The total quantity of dishcarge accounted for is 7000 acre-ft/yr (8.6 hm^3/ yr). The remaining 8000 acre-ft/yr (9.9 hm^3/yr) of recharge is assumed by Rush and Schroer (1970) to leave the valley by subsurface flow to Clayton Valley, south of Tonopah Flat. There is, however, no direct evidence for subsurface outflow. If the assumption of subsurface outflow is inaccurate, the difference between recharge and discharge rates is likely due to errors in estimating evapotranspiration, infiltration, and subsurface inflow.

Rush and Schroer (1970) estimate the perennial yield to be the same as discharge by evapotranspiration or 6000 acre-ft/yr (7.4 hm^3/yr).

Drawing B1-1 shows the potentiometric surface and depth to water in Big Smoky Valley. The potentiometric gradient averages about 30 feet per mile (6 m/km) from north to south down the axis of the valley. Horizontal flow terminates in a closed potentiometric low southwest of the study area in southern Tonopah Flat.

There is another closed potentiometric low in Alkali Flat, in the southern end of the study area, separated from Big Smoky Valley by a ground-water divide south of Highway 6. The closed potentiometric contours indicate that discharge cannot take place by horizontal flow and that either evapotranspiration or deep interbasin flow must account for all the water entering the basin. Depth to water ranges from near the surface in the northeast part of the valley near San Antonio Ranch and in Alkali Springs Flat in the southern part, to about 150 feet (46 m) in the central part of the valley. Depth to water beneath the alluvial fans is generally over 500 feet (152 m).

3.1.3 Aquifer Characteristics

Aquifer (pump) tests of wells 6N/40E-13da and 3N/40E-2dc were conducted in Big Smoky Valley. These wells are 350 and 280 feet (107 and 84 m) deep, respectively. The respective transmissivities were 124,000 and 1400 gallons per day per foot (gpd/ft) (178 and 2.0 cm^2/sec). Aquifers with transmissivities greater than 100,000 gpd/ft are adequate for large well yields (over 1000 gpm (63.1 l/s) capacity). The hydraulic conductivities in the screened intervals of these respective wells are 1700 and 9 gallons per day per square foot (gpd/ft^2) (0.08 and 4.2×10^{-4} cm/sec). These values indicate the presence of gravel or clean well-sorted sand in the vicinity of well 6N/40E-13da in the western portion of the valley and less conductive subsurafce sediments around well 3N/40E-2dc, in the southwest portion of the valley. Neither of the two wells tested had an observation well nearby. Thus, no storage coefficient values were computed.

The results of the aquifer tests suggest that wells 300 feet to 500 feet (91 to 152 m) deep tapping lake sediments of low conductivity should yield less than 100 gpm (6.3 l/s); whereas, wells tapping drainage channels and fans containing sediments of high conductivity could yield more than 1000 gpm (63.1 l/s). These conclusions are based on well data in Big Smoky Valley and hydrogeologic similarities with other valleys, and indicates that with proper well placement, well yields sufficient for MX needs (up to 350 gpm (22.1 l/s) could be attained throughout most of the valley.

3.1.4 Water Quality Limitations

Five ground-water samples were collected for chemical analysis by Fugro National during the field work in Big Smoky Valley, and tested by Controls for Environmental Pollution (CEP). In addition, two samples from the study area were tested by the U.S. Geologic Survey in 1968 (Rush and Schroer, 1970). Of the seven samples, five are from wells, and two are from springs. With the exception of the quality of water from Alkai Flat Hot Spring and well 3N/40E-2dcc, the water quality was within the minimum standards for drinking water which are listed in Table C1-1.

Ground water from Alkali Hot Springs exceeded the criteria for sulfate (494 mg/l) and fluoride (8.2 mg/l) and that from well 3N/40E-2dcc exceeded the criteria for fluoride (1.8 mg/l). Of the five ground-water samples which were of suitable quality for drinking water, three were of good quality (from wells at 7N/40E-35cc, 7N/42E-17cd, and 9N/43E-9bbb), one from well

(6N/40E-13dac) was poor due to magnesium (50 mg/l) and fluoride (0.91 mg/l) and one from Willow Spring (2N/40E-10bba) was poor due to fluoride (0.88 mg/l) and calcium (94 mg/l), . Table C1-2 shows the results of testing and Drawing D1-1 shows the areas of "good," "poor," and "exceeds critieria" for drinking water.

In general, water quality deteriorates toward the playas where horizontal flow terminates and discharge by evapotranspriation takes place. Evapotranspiration tends to concentrate dissolved solids by removing nearly pure water. The high temperature of the water at Alkali Springs (120°F, 49°C) indicates deep circulation of ground water. The high concentrations of flouride, sulfate, and bicarbonate at this location are probably the result of a long flow path and increased solubility due to the high temperature. Discharge from Alkali Springs is probably from a regional flow system, based on the above assumptions.

3.2 CAVE VALLEY

3.2.1 Physiography and Geology

Cave Valley, located in Lincoln and White Pine counties in Nevada (Figure 1), is a relatively small north-south trending valley with an approximate area of 356 mi^2 (922 km^2), of which 137 mi^2 (355 km^2) is suitable area for the deployment of MX. Cave Valley is a southern extension of the Steptoe Valley structural basin. Cave Valley is separated from Steptoe Valley by a low topographic divide. The Egan Range separates Cave Valley from White River Valley to the west and the Schell Creek Range separates Cave Valley from Lake Valley to the east. The

Schell Creek Range trends toward the southwest from latitude 38°30' and closes the south end of the valley by merging with the Egan Range in a low topographic divide.

Elevations in the Egan Range are typically from 7600 to 8600 feet (2315 to 2620 m). The Schell Range has elevations ranging from 7400 to 8600 feet (225 to 2620 m) in the northern and southern part of the range and up to 10,993 feet (3350 m) (Mount Grafton Peak) in the middle. The low point in the valley has an elevation of 5969 feet (1820 m).

The Egan and Schell Creek ranges are composed of 80 percent carbonate rocks and 20 percent of shale and sandstone rocks of Paleozoic age (Kellog, 1960). The central part of the valley is composed primarily of valley-fill materials deposited partly under lacustrine (lake) conditions (Eakin, 1962). The only lacustrine deposits exposed in Cave Valley are the playa deposits occurring in the southern portion at the topographically lowest point of the valley.

In late Pleistocene time a lake occupied the lower part of Cave Valley. Several shore lines were noted at an elevation of about 6100 feet (1860 m). Aerial photographs and topographic maps indicate that the maximum elevation of the lake was not more than about 6100 feet (1860 m). It is also noted that the elevation of the drainage divide between Cave and the adjacent White River Valley is about 6400 feet (1950 m); therefore, it is unlikely that the lake overflowed into White River Valley to the south and southwest (Eakin, 1962).

3.2.2 General Hydrology

Cave Valley is a topographically closed basin, with no surface water inflow or outflow. The principal drainage in the valley lowlands is southward toward the playa. The main drainage channel contains streamflow only during the spring runoff or for short periods after high intensity storms (Eakin, 1962). Eakin estimated the average annual recharge to the ground-water reservoir from precipitation by dividing the valley into five precipitation zones based on elevation. The boundary between the zones of less than 8 inches (20.3 cm) of precipitation and 8 to 12 inches (20.3 to 305 cm) was delineated at the 6000-foot (1829 m) contour; between 8 to 12 inches (20.3 to 30.5 cm) and 12 to 15 inches (30.5 to 38.1 cm) at the 7000-foot (2134 m) contour; between 12 to 15 inches (30.5 to 38.1 cm) and 15 to 20 inches (38.1 to 50.8 cm) at the 8000-foot (2438 m) contour; between 15 to 20 inches (30.5 to 40.8 cm) and more than 20 inches (50.8 cm) at the 9000-foot (2743 m) contour.

The average precipitation used for the respective zones, beginning with the zone of 8 to 12 inches (20.3 to 30.5 cm) of precipitation, is 10 inches (25.4 cm), 13.5 inches (34.3 cm), 17.5 inches (44.4 cm), and 21 inches (53.3 cm).

The recharge estimates, as a percentage of the average precipitation, for each zone are: less than 8 inches (20.3 cm), 0 percent; 8 to 12 inches (20.3 to 30.5 cm), 3 percent; 12 to 15 inches (30.5 to 38.1 cm), 7 percent; 15 to 20 inches (38.1 to

50.8 cm), 15 percent; and more than 20 inches (50.8 cm), 15 percent; and more than 20 inches (50.8 cm), 25 percent. As a result the total recharge of Cave Valley was estimated at 14,000 acre feet per year (Eakin, 1962).

Ground-water discharge from Cave Valley was also estimated to be approximately 14,000 acre-ft/yr (17.3 hm^3/yr) (Eakin, 1962) (State Engineer, Nevada, 1971). Ground-water discharging by evapotranspiration probably does not exceed a few hundred acre-feet a year, and a smaller quantity is discharged by pumping from wells. Most ground-water discharge from the valley is probably by underflow through the underlying carbonate rocks to the west, southwest or south (Eakin, 1962). Fugro National findings confirm that ground-water flow (Drawing B1-2) in Cave Valley has a north to south or southwest direction and that there is a drainage divide between the southern boundary of Cave Valley and White River Valley. Therefore it is likely that ground-water flow from Cave Valley to White River Valley occurs through the underlying carbonates as it has been stated by Eakin, 1962. The quantity of underflow cannot be estimated directly, without additional hydrologic and geologic data.

As shown in Drawing B1-2, the potentiometric surface of the ground water in the valley-fill aquifer slopes down from the north of the valley towards the south. The ground-water table between township 9 and 11 is less than 50 feet (15 m) below land surface due to shallow bedrock underlying the valley-fill deposit (unpublished preliminary bedrock contour map prepared by Fugro National). As shown on the potentiometric map, a semi-perched aquifer exists locally in Townships 8N and 9N, Range 64E. This could be caused by local shallow impervious bedrock, or a hydrologic barrier such as a fault. The geologic conditions in the area where the Egan Range protrudes into Cave Valley suggest the presence of shallow bedrock or possible local faulting.

Water-level measurements made by Fugro National, in March 1980 indicate higher water elevations in four existing wells amounting to 10 to 24 feet (3.5 to 7.3 m) than those reported by Eakin 1962 and the BLM well record 1964. However, well (8N/64E-15 bcb) (Harris well) shows a 14 feet (4.3 m) decline in the ground-water level for the same period of time. Annual average precipitation from 1963 to 1977, measured at three meteorolocial stations (Ely, Ruth and Lund) taken from the climatological data, annual summary (Department of Commerce, NOAA), indicate no substantial departure from the overall average precipitation attributed to the Cave Valley area. Because rises or declines in ground-water levels might be attributable to incorrect early measurements, or to well casing failure; or to other unidentified causes, no explanation for the observed phenomena can be given.

3.2.3 Aquifer Characteristics

The ground-water reservoir of Cave Valley is composed of valley fill divided into two units: older unconsolidated to partly consolidated sedimentary deposits of late Tertiary and

Quaternary age, and unconsolidated clay, silt, sand, and gravel of late Quaternary age (Eakin, 1962).

The unconsolidated sand and gravel deposits of Quaternary age are capable of transmitting ground water freely. However, the finer sand, silt, and clay have low permeability and transmit water slowly.

Because none of the existing wells in Cave Valley could be used for an aquifer test, the transmissivity for the valley fill was estimated by way of comparison with adjacent White River Valley which has similar sedimentary depositional history. In the valley fill of White River Valley transmissivity values of 1420 and 10,300 gpd/ft (4.9 and 36 cm^2/sec) were obtained from wells located at 7N/61E-36cc and 10N/61E-19bc, respectively (Fugro National, Inc., 1979). The low transmissivity value can be representative of the fine sand, silt, and clay sediments of the valley fill in Cave Valley. The higher transmissivity value may be representative of the partly consolidated sand and gravel deposits of the valley fill.

3.2.4 Water Quality Limitations

Six ground-water samples were collected and tested for chemical quality from three springs (9N/64E-16dbd; 7N/64E-33cc; 6N/63E-19da) and three wells (10N/63E-25aca; 8N/64E-4abd; 8N/64E-15bcb). Two of these tests were conducted by the Bureau of Land Management, Ely District. Four samples were collected by Fugro National and analyzed by Controls Environmental Pollution, Inc. The results indicate good quality water for all samples taken north of township 6 with total dissolved solids concentrations ranging from about 130 to about 280 mg/l. Two springs (7N/64E-33cc; 6N/63E-19da), analyzed by the BLM have moderately high bicarbonate concentrations (more than 250 mg/l). This condition is probably due to the solution of carbonate rocks by the ground water.

Cave Valley Spring located at 9N/64E-16bdb also originates from the carbonates but has low bicarbonate concentration (80 mg/l) and low total dissolved solid concentrations (127 mg/l). This is probably due to a short resident time of the ground water with the rocks which suggests that it is related to precipitation and snowmelt. Thus it is not connected to the regional carbonate aquifer. The discharge in Cave Spring ranges from a few hundred gallons per minute to less than 10 gallons per minute. Table C1-3 lists the chemical analysis of the water samples and Drawing D1-2 shows the area of good water quality. As can be seen on the Drawing, all of the valley is estimated to contain ground water of good quality.

3.3 DRY LAKE/DELAMAR VALLEYS

3.3.1 Physiography and Geology

Dry Lake and Delamar valleys are believed to be hydrologically connected through valley-fill aquifers and are treated essentially as the same ground-water basin in the ensuing discussions. The Dry Lake/Delamar drainage basin lies within central Lincoln County in east-central Nevada (Figure 1). The basin is approximately 82 miles (132 km) long and 20 miles (32 km) wide at the widest point, and encompasses an area of 1300 mi^2 (3367 km^2). Of that area, 497 mi^2 (1287 km^2) are suitable for MX siting including 315 mi^2 (815 km^2) in Dry Lake Valley and 182 mi^2 (417 km^2) in Delamar Valley.

The valley-fill deposits are up to 10,000 feet (3 km) thick along the axis of the valleys and thin toward the margins. Based on detailed gravity maps constructed by Fugro National, (FN-TR-33-DL), the volume of valley-fill in Dry Lake Valley is estimated to be 635,000,000 acre-ft (732,955 hm^3). The estimated volume of valley-fill in Delamar Valley is 200,000,000 acre-ft (246,600 hm^3). These substantial potential aquifer volumes provide tremendous storage capacity for ground water.

Mountain crests bounding the valleys range in elevation from about 7000 feet (2134 m) to over 9000 feet (2743 m). Highland Peak, on the east side of Dry Lake Valley, has an elevation of 9395 feet (2864 m), and is the highest point in the basin. The playa, in the extreme south end of Delamar Valley, has an elevation of less than 4400 feet (1341 m) and is the lowest point in the basin. The two valleys are separated by a low, broad alluvial fan that extends across the basin just south of Dry Lake playa.

Dry Lake and Delamar valleys exhibit typical Basin and Range structure, consisting of high angle, north-south trending, normal basement faults that border the Pahroc ranges on the west and the Bristol, Highland, Chief, and Delamar ranges on the east. The area between the ranges is faulted downward. A north-south trending fault on the eastern side of the basin displaces surface alluvium and forms a prominent scarp. Additionally, Shawe (1965) shows east-west trending faults that transect the basin and displace deep valley-fill deposits. This interpretation is supported also by gravity surveys (Fugro Nationa, FN-TR-26E).

The mountains on the western side of the valley are predominantly composed of ash flow tuffs of Tertiary age with some carbonate rocks of Paleozoic age. Conversely, the eastern mountains are composed primarily of carbonate rocks of Paleozoic age with minor amounts of ash flow tuffs of Tertiary age (Stewart and Carlson, 1978).

Coarse-grained alluvial and fine-grained lacustrine deposits make up the majority of sediments in the valleys. Although playa deposits cover only a small percentage of the valley surface, they are thought to be of great thickness and interfinger with alluvial deposits in the subsurface (Fugro National, FN-TR-27). These playa deposits are located in the south-central portions of the valleys. From the central part of the valleys, the grain size and grading of alluvial deposits progressively increase towards the mountains.

3.3.2 General Hydrology

Dry Lake and Delamar valleys form closed surface drainage basins. There are no perennial streams in the valleys, and streamflow only occurs in the mountain ravines and alluvial fans after high-intensity rains and as snowmelt runoff.

Springs in the Dry Lake and Delamar valley area occur in volcanic rocks composed predominantly of tuffs along the basin margins. The springs are recharged by meteoric waters (precipitation and snowmelt) and are not associated with the deep regional carbonate aquifer. They generally have low yields (less than 20 gpm) and are used primarily to supply stock ponds in the area.

The ground-water table in the basin aquifer occurs at considerable depths (Drawings B1-3 and B1-4). In Dry Lake Valley, ground-water levels are about 400 feet (122 m) below ground surface, and in Delamar Valley, levels are generally greater than 800 feet (244 m) below ground surface. Some water wells in the northern and western part of Dry Lake Valley tap perched aquifers with water levels significantly higher than the underlying basin aquifer. Water use in the valleys is limited to a few isolated stock ponds fed by infrequent surface runoff and nearby springs with waters of meteoric origin.

Ground-water recharge to the basin is primarily from precipitation occurring in the mountains along the northwest and east flanks of the valleys (Eakin, 1963). From these areas, ground water moves laterally and downward toward the central part of the valleys as indicated on the ground-water level contour map (Drawing B1-3 and B1-4). Generally, the ground water moves from Dry Lake Valley toward Delamar Valley. An annual (recharge based on a percentage of average annual precipitation) of about 6000 acre-ft (7.4 hm^3) for the valleys has been estimated by

Eakin (1963). Discharge occurs primarily as deep underflow to the south through carbonate rocks. Alluvial ground-water gradients between Dry Lake Valley and Delamar Valley closely resemble the carbonate aquifer gradient between White River Valley and Pahranagat Valley. This suggests that the valley-fill aquifers of the basin and the regional carbonate aquifers are hydraulically connected (Eakin, 1963).

3.3.3 Aquifer Characterisitics

The considerable depth to ground water (Drawing B1-3 and B1-4) has precluded much development in these valleys and, therefore, very little has been published about specific aquifer characteristics. However, all wells in the basin tap valley-fill aquifers with little indication of confinement. Existing wells produce less than 100 acre-ft of water annually for use by livestock. During Furgo National's field investigations in 1979, none of the wells were found to be suitable for aquifer testing because of pumping limitations. In 1980, two intermediate depth test wells (3S/64E-12ca and 6S/63E-12ad) were drilled in Dry Lake/ Delamar valleys (lithologic and geophysical logs are presented in Appendices H1-3 and H1-34). At each site, observation and test wells were constructed.

Aquifer tests in Dry Lake Valley were conducted for ten days at 500 gpm (31.5 l/s) followed by an aquifer recovery test. The maximum well yield during development was approximately 750 gpm (47.3 l/s). Maximum drawdown at the pumping well during the pump test was about 50 feet (15 m). These tests indicated an aquifer transmissivity of about 45,000 gpd/ft (155 cm^2/sec) and a storage coefficient of 3 x 10^{-4}. Because the well only partly penetrated the aquifer, the transmissivity of the total thickness of the aquifer is probably much higher. The unusually low storage coeffiecient in the valley-fill aquifer is probably due to the tremendous thickness of the aquifer.

Aquifer tests in Delamar Valley were conducted for ten days at 85 gpm (5.3 l/s) followed by an aquifer recovery test. Maximum drawdown during the test was 85 feet (26 m). Transmissivity was calculated at 5000 gpd/ft (7 cm^2/sec) with a storage coefficient of 4.0 x 10^{-4}.

Potential well yields in Dry Lake Valley are expected to be high in the unconsolidated valley-fill deposits around the valley periphery. However, a significant portion of the basin is probably composed of fine-grained lacustrine deposits near the central valley areas. These areas probably have relatively low hydraulic conductivities. The extent and depth of the low yield deposits are not fully known. However, there appears to be sufficient water for development of the MX system within the basin.

Because of the great depths to water in Delamar Valley [870 ft (265 m) in test well 6S/63E-12ad], well yields are expected to be less than 100 gpm (6.3 l/s). Well yields may increase slightly away from the central valley axis, but any yield increase due to higher aquifer permeability will probably be offset by the corresponding increase in pumping lift.

3.3.4 Water Quality Limitations

Because there are very few wells in Dry Lake Valley, only four ground-water quality analyses are available. The well and spring sample locations are shown in Drawing D1-3. Four of these samples were collected by Fugro National in 1979 and 1980 and one sample was collected by Carpenter (1915) and reported by Eakin in 1963.

Based on the water quality critieria listed in Appendix C1-1, all of the water analyzed is of good quality and is acceptable for drinking. All ground-water samples contained moderately high bicarbonate levels ranging from 187 to 320 mg/l, which result in hardness levels of about 100 mg/l. Calcium concentrations range from about 40 to 83 mg/l and were generally in the poor range. In addition, the sample collected at 3N/65E-21dbd and analyzed by Carpenter also contained relatively high chloride (110 mg/l) and nitrate (32 mg/l) concentrations.

Ground water in the northern part of Dry Lake Valley is of the calcium-magnesium/chloride-bicarbonate type. As the ground water migrates from the fans toward the central valley area, the concentrations of calcium and chloride increase slightly and sodium concentrations decrease, yielding water of the sodium-calcium/bicarbonate type. The higher calcium and chloride concentrations in the central valley area may be related to the soil chemistry of the playa deposits.

The only ground-water samples for chemical quality testing from Delamar Valley was from the Fugro National test well. However, the analyses were not completed at the time of publication of this report.

3.4 DUGWAY VALLEY

3.4.1 Physiography and Geology

Dugway Valley is located in Tooele and Juab counties in west-central Utah (Figure 1) and has a total area of 890 mi^2 (2300 km^2). Of the total area only 182 mi^2 (471 km^2) are suitable for MX siting.

Dugway Valley trends north-south and is approximately 30 miles (48 km) long and varies in width from 1 to 8 miles (2 to 13 km). The valley is bordered on the west by the Dugway Mountains and the Thomas Range, on the south by the Drum Mountains, and on the east and northeast by Keg Mountain and Slow Elk Hills. The northern boundary of the valley is the Great Salt Lake Desert. Valley floor elevations range from 4480 feet (1365 m) at the north end to 5080 feet (1548 m) in the central-southern portion of the valley. The valley is bounded by peaks on the northwest that reach elevations of nearly 9000 feet (2700 m). Most of the area below about 4600 feet (1400 m) is nearly flat as a result of planation and deposition by ancient Lake Bonneville (Stephens and Sumsion, 1978).

Valley-fill deposits consist mainly of alluvial fan deposits along the margins of the valley which interfinger with lake and playa deposits in and near the center of the valley. These deposits consist mainly of clay, silt, sand, and minor amounts of gravel in the playa area and gravels and sands in the alluvial fans and stream channel deposits. Significant influence from ancient Lake Bonneville is evident with thick lake deposits and well-developed shorelines.

Although the thickest section of valley-fill deposits penetrated by drilling is 1003 feet (306 m), the valley-fill probably reaches a thickness of up to several thousand feet. Volcanic rocks of Tertiary age locally overlie rocks of Paleozoic age in the surrounding mountains.

3.4.2 General Hydrology

It is believed that the ground water in Dugway Valley flows northwestward into the Great Salt Lake Desert and that some deep underflow occurs from the Sevier Desert drainage basin from the south and east (Stephens and Sumsion). Drawing B1-5 which shows the potentiometric ground-water surface supports the theory of the northerly flow of the water. Ground water in the valley moves principally through coarse-grained alluvium deposited by ancient streams (Stephens and Sumsion, 1978). Most of the streams within the valley area are ephemeral. Pismire Wash, the principal drainage in the northern portion of Dugway Valley, extends generally northward from the Thomas Mountains for about 35 miles (56 km) before the channel dissipates into the desert floor southeast of Granite Peak. Flow in Pismire Wash occurs only in direct response to thunderstorms or rapid snowmelt (Stephens and Sumsion, 1978).

Most of the ground water is under confined or partially confined conditions due to the presence of one or more layers of lacustrine silt or clay. In general, ground water moves from recharge areas adjacent to the mountains northward to the Great Salt Lake Desert. In the southern part of the valley, due to the presence of a bedrock divide, the ground water as well as the surface flow moves in a southeasterly direction toward Whirlwind Valley. The hydraulic gradient in the northward flow direction to the Great Salt Lake Desert is variable and is greater than 90 ft/mile (17 m/km) in some areas. According to Stephens and Sumsion (1978) the hydraulic gradient averaged about 40 ft/mile (7.6 m/km) between Sheeprock Mountains and the Great Salt Lake Desert.

Water levels in the alluvium range from very close to the land surface in the northwestern part of the valley to at least 270 feet (82 m) in the center of the valley. Yields of wells in the valley fill are generally greater where the wells penetrate coarse materials, mainly along the valley margins. According to Stephens and Sumsion (1978), reported yields of wells completed in the valley fill range from less than 10 gpm (0.6 l/s) to as much as 400 gpm (25 l/s).

Approximately 12,000 acre-ft (14.8 hm^3) of water per year is recharged to the ground-water system in Dugway Valley; of this less than 5000 acre-ft (6.2 hm^3) is through inflow from outside the valley, the remainder is from precipitation (Stephens and Sumsion, 1978).

3.4.3 Aquifer Characteristics

There have been no aquifer (pump) tests performed in Dugway Valley; therefore, at present, it is not possible to calculate transmissivity and storage coefficient values for the valley-fill or carbonate aquifers. According to Stephens and Sumsion, finer material composed of clay,silt, and fine sand predominate the southwestern part of Dugway Valley and the yields from wells in this portion of the valley are expected to be relatively low. However, closer to the mountains, the valley fill material becomes coarser and well yields are expected to be larger, on the order of 400 gpm (25 l/s).

3.4.4 Water Quality Limitations

Drawing D1-4 shows areas of good and poor quality ground water as well as areas where the ground water exceeds criteria. The majority of the ground water within Dugway Valley exceeds the criteria for suitable drinking water. Appendix C1-1 lists criteria for judging water quality. Laboratory test results for one ground-water sample collected from a well at (C-12-10)35baa tested during the FY 80 field program and for several others tested by the U. S. Geological Survey exceed criteria for domestic use based on chloride (>400 mg/l), calcium (>200 mg/l), and sodium (>250 mg/l) concentrations. Stephens and Sumsion (1978) state that the concentrations of dissolved solids in the ground water from the valley fill range from about 1000 mg/l to 2790 mg/l and range from poor (500 to 1500 mg/l) to exceeds criteria (>1500 mg/l). Some ground-water samples were considered poor on the basis of fluoride and magnesium concentrations

(>1.4 and >150 mg/l, respectively). Ground-water samples taken from the western part of the valley are rich in sodium and potassium chloride as compared to those from the center and eastern parts of the valley. These samples may represent ground water in contact with fine-grained playa deposits with high salt concentrations. In this area ground water may have undergone a ion base-exchange where the calcium and magnesium were exchanged for sodium and potasium ions.

3.5 FISH SPRINGS FLAT

3.5.1 Physiography and Geology

Fish Springs Flat is a north trending basin which is bounded on the west by the Fish Springs Range and on the east by the Thomas Range. It is separated from Whirlwind Valley to the south by a low divide in the Swasey Bottom area, and it opens to the north to the Great Salt Lake Desert. Elevations along the axis of the valley range from about 5100 feet (1554 m) at the drainage divide in the south to about 4300 feet (1310 m) at the northern end of the study area. The peaks in the Fish Springs Range are up to 8523 feet (2598 m) in elevation and those in the Thomas Range are up to 7046 feet (2148 m) in elevation. The watershed area is 590 mi^2 (1530 km^2), of which 117 mi^2 (303 km^2) are suitable area for MX development.

The Fish Springs and Thomas ranges are composed primarily of carbonate rocks with minor exposures of quartzite rocks, both of Paleozoic age. About half of the area of the Thomas Range is overlain by volcanic extrusive rocks of Tertiary age. The lower slopes of the ranges are covered with alluvial fans and colluvium composed of poorly-sorted sands and gravels.

Surficial deposits in the valley are of Quaternary age and include alluvial channel, eolian, and lacustrine deposits. The valley-fill deposits are believed to be composed of mixed, reworked, and interlayered alluvial and lacustrine deposits, including Lake Bonneville sediments. It is also likely that volcanic ash and lava flows are present throughout the valley-fill stratigraphic section, based on their presence in the Thomas Range and in the valley-fill at the Brush-Wellman beryllium mine in southeast Fish Springs Flat.

3.5.2 General Hydrology

Recharge to the valley-fill aquifer from precipitation is believed to take place primarily on the alluvial fans along the margins of the valley. Recharge by infiltration in the central part of the valley is believed to be minor due to low rates of precipitation, high rates of evaporation, and the fine-grained nature of the surficial deposits in that area. Annual precipitation ranges from 6 to 8 inches (15 to 20 cm) on the lower part of the valley floor to 16 to 20 inches (41 to 51 cm) on the peaks of the ranges (Bolke and Sumsion, 1978). Total precipitation over the water-shed is estimated to be 232,000 acre-ft/yr (286 hm^3/yr), of which 4000 acre-ft/yr (5 hm^3/yr) is estimated to recharge the ground-water valley-fill aquifer (Bolke and Sumsion, 1978). Recharge by interbasin flow is estimated at 31,000 acre-ft/yr (38 hm^3/yr), based on the indirect evidence of an unbalanced water budget (Bolke and Sumsion, 1978). The source for this interbasin flow is probably from the valley and ranges to the west of Fish Springs Flat. This is based on differences in ground-water potentiometric surfaces in Fish Springs Flat and those to the west of it. For example, the potentiometric surface in the Fish Springs discharge area is about 4300 feet (1310 m); to the west in Snake Valley it is about 4400 feet (1341 m) at the northern end. Further to the west in Spring Valley, springs discharge at an elevation of 5600 feet (1707 m). Additional evidence of the regional nature of the flow to Fish Springs is the warm temperature of the water, which ranges from 63.5 ° to 141°F (17.5°C to 60.5°C) which indicateds deep circulation. The discharge rate correlates better with regional precipitation trends than with the Fish Springs Flat precipitation record which also indicates regional ground-water flow (Bolke and Sumsion, 1978). The conduit for this interbasin flow is believed to be through fractrue, solution openings and faults in the deep consolidated, rock aquifers. The discharge at Fish Springs is in the valley fill alluvium near the base of the Fish Springs Range and above the inferred location of the valley bounding fault. Bicarbonate concentrations are not unusually high (246 mg/l to 321 mg/l). Therefore, no conclusions have been made about the rock type through which flow is taking place.

Discharge from ground water in Fish Springs Flat is by springs, evapotranspiration, wells, and subsurface outlfow to the Great

Salt Lake Desert. There are no well-defined ares of phreatophyte growth, except for the waterfowl ponds which were built and are maintained by U.S. Department of Wildlife in the Fish Springs National Wildlife Refuge. Discharge from these ponds is accounted for in the spring discharge as explained below. Greasewood and pickleweed are the most abundant phreatophytes in the valley. They occur primarily in scattered growths on the lower margins of the fans, where the depth to water is about 40 feet (12 m) or less and where the salinity of the water does not exceed the plant tolerance (Bolke and Sumsion, 1978). It is likely that a significant amount of discharge by evapotranspiration occurs only where the ground water level is less than about 10 feet (3 m) even though phreatophytes can survive with deeper ground-water conditions. Discharge by phreatophytes is estimated at 8000 acre-ft/yr (9.9 hm^3/yr) (Bolke and Sumsion, 1978). The majority of discharge by springs takes place from the Fish Springs group. About 26,000 acre-ft/yr (32.1 hm^3/yr) discharge from this group of springs and about 600 acre-ft/yr (0.7 hm^3/yr) discharge from the other smaller springs along the base of the Fish Springs Range (Bolke and Sumsion, 1978). The discharge from the Fish Springs group is used in part to maintain a series of artificial ponds for wildlife habitat. Discharge by wells is minor. There are a few stock watering wells and cluinary wells at the Fish Spring Ranger Station, (C-11-14)23, and the Brush-Wellman mine, (C-13-12)5. The total ground-water withdrawal by these users is probably less than 100 acre-ft/yr (0.1 hm^3/yr). Subsurface outflow to the Salt Lake Desert is believed by Bolke and Sumsion (1978) to be insignificant, due to the low gradient (on the order of 3 feet per mile; 0.6 m/km) and the presumed low transmissivity of the valley-fill.

There has been no estimate of the perennial yield, however the 8000 acre-ft/yr (9.9 hm^3/yr) of phreatophyte discharge could possibly be salvaged, assuming no environmental damage would occur. Any outflow to the Great Salt Lake Desert could be salvaged without undesirable results.

Water depths in the main part of the valley are from over 150 feet (46 m) in the south end of the valley and on the upper alluvial fans to near the surface in the central and northern part of the valley. The potentiomentric surface as shown in Drawing B1-6 slopes down from an elevation of 4400 feet (1341 m) at the southern end to 4320 feet (1317 m) in the northern end. The gradient is about 3 feet per mile (0.5 m/km).

3.5.3 Aquifer Characteristics

The valley fill in Fish Springs Flat may be to be up to a few thousand feet thick in its central area, based on its similarity to other valleys. Bolke and Sumsion (1978), however, stated only that the average aquifer thickness is probably greater than 450 feet (137 m). No aquifer tests were conducted in this valley due to the lack of suitable wells, so neither transmissivity nor storage coefficient of the valley-fill aquifer are known. Visual inspection of materials in two excavations one at the Brush-Wellman Mine, (C-13-12)5 and one north of the Fish Springs Ranger Station which contained open-work gravels, indicates that there may be at least some areas with moderate transmissivities which could support well yields of up to a few hundred gpm. However, the stock and culinary wells which are currently in use in the valley yield only 12 to 40 gpm (0.8 to 2.5 l/s). There is no evidence of the presence or absence of continuous confining beds in the valley fill deposits. Fish Springs, however, as well as the other smaller springs along the base of the Fish Springs Range, are apparently discharging from a bedrock aquifer under artesian conditions.

3.5.4 Water Quality Limitations

Two ground-water samples were tested for water quality for Fugro National by the Utah Water Research Laboratory. An additional 13 ground-water samples from 11 sites were tested by the U.S. Geological Survey from 1956 through 1977. Where a source was retested by Fugro National, the U.S. Geological Survey results are not included in Table C1-6. All of the samples exceeded one or more criteria for drinking water (Table C1-1). The water is generally a sodium-chloride type with high total dissolved solids (1700 mg/l to 22,400 mg/l). The springs in the Fish Springs group showed a wide range of temperatures and water qualities, indicating the possibility of different source areas, flow paths, and/or depths of circulation. For example, temperatures ranged form 63.5° to 141°F (17.5° to 60.5°C) and chloride concentrations from 670 mg/l to 12,000 mg/l. Although all samples tested exceeded criteria for drinking as used in this report, these criteria are only a recommendation for potable water quality where no better quality water is readily obtained. Water quality test results are listed in Table C1-6 and areas of "poor" and "exceeds criteria" water quality are shown on Drawing D1-5.

3.6 LITTLE SMOKY VALLEY

3.6.1 Physiography and Geology

Little Smoky Valley encompasses about 585 mi^2 (1515 km^2) and lies in southeast Eureka and northeast Nye counties in central Nevada (Figure 1). This north-trending basin is 44 miles (71 km) long and from 6 to 18 miles (9.6 to 29 km) wide. Of the total area of the valley, 296 mi^2 (767 km^2) is suitable for MX siting.

The valley floor is nearly flat with elevations increasing from 6000 feet (1829 m) at the northern end, near Newark Valley, up to approximately 6500 feet (1981 m) elevation in the existing playa at the southern end of the basin. Fish Creek, Antelope, and Hot Creek Ranges flank the west side of the valley and attain elevation of 9000 feet (2743 m). On the east side, the Pancake Range crests at about 7500 feet (2286 m). The basin is separated from Big Sand Springs Valley to the south and east by a pediment formed of carbonate rocks of Paleozoic age. Total relief in Little Smoky valley is about 3000 feet (about 914 m).

The mountains surrounding Little Smoky Valley are primarily composed of carbonate rocks of Mesozoic and Paleozoic ages. There are also volcanic rocks of Tertiary age which crop out at the southern end of the valley.

Valley-fill deposits consist predominantly of interfingering alluvial and lacustrine (lake) sediments of late Tertiary age. Rush and Everett (1966) suggest that two Pleistocene lakes once existed in Little Smoky Valley. One lake occurred at the south end of the valley where a small playa now exists; the second lake occurred in Fish Creek Valley, within northern Little Smoky Valley.

3.6.2 General Hydrology

The northern part of Little Smoky Valley is considered to have an open system in terms of surface and subsurface drainages. The southernmost part of the valley (Drawing B1-8) is occupied by a playa which is only about 50 feet (15 m) south of the subtle topographic divide. This part of the valley is considered to have a closed surface drainage.

There are no major perennial streams in the valley; however, Fish Creek, which is fed by Fish Creek Springs (Drawing B1-8) flows eastward for about 5 miles (8 km). The discharge of these springs is probably sustained by interbasin flow through the carbonate aquifer. Intermittent streamflow does occur in the valley during high intensity rains and snowmelt runoff.

Drawing B1-8 shows the ground-water potentiometric surface and depth to water in Little Smoky Valley. Ground water occurs at about 6 feet (2 m) below the ground surface in the northern part of the valley. The depth to water increases; however, toward the mountains and the southern portion of the valley. At the extreme southern part of the valley, the depth to water in one well (11N/53E-6cda) near the edge of the playa, is 500 feet (152 m). The playa is probably part of a local perched aquifer as evident by the presence of phreatophytes downstream from the playa. The perched aquifer overlies and is separated from the main aquifer by a thick unsaturated zone.

The ground-water flow direction in the main valley-fill aquifer is generally to the north (Drawing B1-8), and towards Newark Valley. This is in agreement with Eakin (1960). According to Rush and Everett (1966) the flow is mainly to the north because there are more consolidated and less permeable rocks to the south and east of the valley. The hydraulic gradient ranges from 1 foot/ mile to 4 feet/mile (0.2 m/km to 0.8 m/km), depending upon location within the valley. Eakin (1960) estimated that the hydraulic gradient was 4 feet/mile (0.2 m/km).

Ground-water recharge to Little Smoky Valley is primarily from precipitation occurring in the mountains along the west flank of the valley. The average estimated volume of water that falls as precipitation in the valley is about 230,000 acre-ft/yr (284 hm^3/yr), of which about 4000 acre-ft/yr (4.9 hm^3/yr) or 1.7 percent, recharges the valley-fill aquifer (Rush and Everett, 1966). The second source of recharge to the valley-fill aquifer is Fish Creek Springs. This complex of four springs is thought to result from interbasin flow through carbonate rocks from the east in Antelope Valley. The estimated recharge to the valley-fill ground-water system from the springs is 800 acre-feet per year. The third major source of recharge to the valley-fill aquifer are two springs which occur along the western side of the valley at 16N/53E. These springs probably discharge water from the carbonate aquifer similar to Fish Creek Springs. The total contribution to the valley-fill ground-water system from these springs is estimated to be 720 acre-ft/yr (0.9 hm^3/yr) (Rush and Everett, 1966). Spring discharges are negligible on the east side of the valley.

The volume of water stored in the upper 100 feet (30.5 m) of saturated valley-fill is estimated to be 1,600,000 acre-ft (1973 hm^3). This estimate is based on the assumptions that 160,000 acre-ft (64,750 hm^3) represent the surface area of the aquifer with greater than 100 feet (30.5 m) of saturated valley-fill (75 percent of the total acreage underlain by valley fill), and a specific yield of 10 percent (Rush and Everett, 1966).

Water use in Little Smoky Valley is mainly in the north end of the valley, where the depth to water in the valley fill is less than 300 feet (101 m), and along the northwest part of the valley, where there are springs.

Discharge from the valley-fill aquifer occurs primarily through irrigation and stock watering, which is estimated to use 3300 acre-ft/yr (4.1 hm^3/yr) (Rush and Everett, 1966). The phreatophytes in the middle of the valley (13N/53E) are estimated to transpire about 1900 acre-ft/yr (2.3 hm^3/yr), and subsurface outlfow is estimated to be 1000 acre-ft/yr (1.2 hm^3/yr). The subsurface outlfow water moves northward into Newark Valley.

The estimated perennial yield of Little Smoky Valley is 5000 acre-ft (6.1 hm^3) (Rush and Everett, 1966).

3.6.3 Aquifer Characteristics

Few wells have been developed in Little Smoky Valley and most use low-capacity piston pumps which are unsuitable for aquifer testing.

Due to the short growing season, wells that might have been tested were without power at the time of the field investigation. In northern Little Smoky Valley there are several large capacity [1000 gpm (63 l/s)] irrigation wells suitable for aquifer testing. Results of well drillers' aquifer tests at these four wells in 17N/54E-21 show a range of specific capacities from 34 to 82 gpm (2.1 to 5.2 l/s) per foot of drawdown. This would indicate a range in transmissivity of about 60,000 gpd/ft to 160,000 gpd/ft. Such well yields and transmissivities indicate that the aquifer can yield sufficient quantities of ground water for the MX development needs.

3.6.4 Water Quality Limitations

Chemical analyses of ground water in Little Smoky Valley were reviewed for potability using the criteria listed in Table C1-1. Four samples were tested for water quality by Fugro National. Analyses of these samples indicated that the ground water is generally of good quality (Drawing D1-7). A water sample from Pogues Station Spring (15N/54E-11acd), which discharges near the mountains at a slow rate [0.26 gpm (.02 l/s)], was found to have high calcium and sulfate concentrations of, 261 mg/l and 1080 mg/l, respectively; which exceed the established drinking water criteria.

There are no water quality data for the southern end of Little Smoky Valley, where the water is at greater depths and there is little development. The ground water quality could be poor due to former Pleistocene lake and present playa deposits at the surface, which may add salt to the infiltrating water from the surface or other recharge areas.

3.7 PINE VALLEY

3.7.1 Physiography and Geology

Pine Valley is a relatively small valley with a total area of 730 mi^2 (1890 km^2), of which 365 mi^2 (945 km^2) are suitable area for MX deployment. It is a southern extension of the Snake Valley structural basin, and is separated from Snake Valley by a topographic-high south of the Ferguson Desert area. The Wah Wah Mountain Range is an extension of the Confusion Range, and bounds the valley on the east side. The Needle Range bounds the valley on the west. The peaks in the Wah Wah Range are up to about 9000 feet (2740 m) in elevation; in the Needle Range they are up to about 9790 feet (2980 m). The low point in the valley has an elevation of 5097 feet (1554 m).

Both of these mountain ranges are composed primarily of carbonate rocks of Paleozoic age with lesser amounts of quartzites of Paleozoic age. Rocks of Paleozoic age in the Needle Range are capped by volcanic extrusive rocks of Tertiary age. There are minor intrusive rock outcrops in the Wah Wah Range. The central part of the valley is composed primarily of alluvial fans and channel deposits. Playa deposits occur at the topographically lowest point in the valley. Other than these playa deposits, there are no lacustrine deposits exposed in Pine Valley. The lowest surface elevation of the drainage divide between Pine Valley and the Ferguson Desert is 760 feet (230 m) higher than the highest mapped Lake Bonneville deposits. Therefore, there are no extensive fine-grained Lake Bonneville deposits in Pine Valley, although there may be fine grained lacustrine deposits from localized smaller Pleistocene lakes underlying the Quaternary materials. It is possible that volcanic extrusives are also present in the valley fill based on their presence in the Needle Range. The valley fill is estimated to be a few thousand feet thick in the center of the valley. Geophysical work now in progress by Fugro National will enable a better estimate to be made of valley geometry.

3.7.2 General Hydrology

Pine Valley is a topographically closed basin, with no surface inflow or outflow. A well developed stream system leads from the mountains on both sides of the valley into the central playa. All of the surface flow is the result of precipitation within the valley (Stephens, 1976). The maximum rainfall has been estimated at over 20 inches per year (50 cm/yr) on the highest peaks in the Wah Wah Range, and the minimum has been estimated at less than 8 inches per year (20 cm/yr) in the low central part of the valley (Stephens, 1976). The average over the entire basin is estimated at 10.6 inches per year

(26.9 cm/ yr), (Stephens, 1976). The total precipitation over the 730 mi^2 (1890 km^2) area is therefore estimated at 410,000 acre 410,000 acre-ft/yr (506 hm^3/yr). These estimates are not precise because they are based on average precipitation measurements at various altitudes in other parts of Utah, and not on actual measurements in Pine Valley. Total recharge from precipitation is estimated at 21,000 acre-ft/yr (26 hm^3/yr) (Stephens, 1976).

Ground-water discharge is primarily through springs and evapotranspiration, with minor amounts withdrawn from wells. Springs and seepage to stream channels have been estimated to discharge approximately 1590 acre-ft/yr (2 hm^3/yr). The spring discharge is primarily from perched alluvial aquifers in mountain canyons on the valley margins. Evapotranspiration has been estimated at 5500 acre-ft/yr (6.8 hm^3/yr), based on a phreatophyte area of 5500 acres and a consumptive use estimate of one acre-foot per acre per year (0.0003 hm^3 per hectare per year) (Stephens, 1976). According to Stephens (1976), another 3000 acre-ft/yr (3.7 hm^3/yr) is estimated to flow through carbonate rocks under the divide into Wah Wah Valley. This is based on the observation that the carbonate and quartzite rocks in the Wah Wah Range dip to the east and Stephens' belief that bedding is controlling the flow of ground water in this region. There are no direct observations to support this belief. Additional ground-water use by man is estimated to be only 5 acre-ft/yr (0.006 hm^3/yr), mainly by the Desert Range Experiment Station and the Pine Grove Associates wells. Thus, the total discharge accounted for is about 10,000 acre-ft/yr (12 hm^3/yr). The 11,000 acre-ft/yr (14 hm^3/yr) of recharge that is not accounted for in these estimates is assumed to leave the valley by deep interbasin flow through the carbonate rocks of Paleozoic age.

As shown in Drawing B1-9, the potentiometric surface of the ground water in the valley-fill aquifer slopes from the margins of the valley to the center with an average gradient of about 100 feet/mile (20 m/km) on the upper alluvial fans to about 50 ft/ mile (10 m/km) on the lower slopes. This evidence combined with the lack of surface discharge tends to confirm outflow by deep percolation. Ground-water depths are 200 to 400 feet (61 to 122 m) below land surface in the central low part of the valley.

The Utah State Engineer has not made an estimate of perennial yield for Pine Valley, but the system yield has been estimated at less than 5000 acre-ft/yr (6.2 hm^3/yr) by Eakin, Price, and Harrill (1976). The rate of natural discharge through springs and seepage (1590 acre-ft/yr; 2 hm^3/yr) and through evapotranspiration (5500 acre-ft/yr; 6.7 hm^3/yr) could be considered to be the perennial yield. The diffuse nature of this discharge, however, could make it difficult to economically salvage more than a small percentage of it, because water levels would have to be lowered over a large area.

3.7.3 Aquifer Characteristics

No aquifer testing was done as part of the Fugro National field work. However, Pine Grove Associates, a mining concern, has tested two of their wells. The tests are considered to be proprietary information and were given to Fugro National in confidence, and are not reproduced in this report. Public information from the Utah State Engineer on one of the Pine Grove Associates wells indicates a specific capacity of 0.33 gpm/ft (0.68 cm^2/sec). Because this well is 2006 feet (611 m) deep and has a static water level of 375 feet (144 m) it can be expected to produce a few hundred gpm. The well at the Desert Range Experiment Station has a reported specific capacity of 0.8 gpm/ft (1.6 cm^2/sec). However, only 28 feet (8.5 m) of the 649 feet (198 m) total depth is screened. The specific capacity of the total saturated thickness at this well is probably larger. These values of specific capacity indicate that well yields on the order of hundreds of gallons per minute are possible from wells 1000 feet to 2000 feet (305 to 610 m) in depth in the same type of geologic environment as the two wells described above. For maximum yield, wells should be sited so as to penetrate the maximum thickness of valley-fill sediments. It is believed that there is sufficient water in Pine Valley for MX water requirement. It is likely, however, that the wells would need to be widely distributed.

3.7.4 Water Quality Limitations

Eighteen ground water samples for quality analysis were tested from 13 locations, including two ephemeral streams, eight springs, two wells, and one mine adit. Thirteen of these tests were performed by a U.S. Geological Survey laboratory for the Utah Department of Natural Resources. Five samples were collected by Fugro National, Inc., and analyzed by the Utah Water Research Laboratory. All samples tested with the exception of the sample from Mountain Home Spring were within the minimum drinking water standards established for this study which are listed in Table C1-1. Some samples, particularly those from springs along the Needle Range were poor due to high calcium (75 to 226 mg/l) and magnesium (56 to 199 mg/l), these high ionic concentrations were probably from the limestone and dolomite rocks in that range, and soils and alluvium derived from those rocks. The ground-water sample from Mountain Home Spring, (C-26-19)3acc, exceeded drinking water criteria for magnesium (199mg/l). The sample from the well at the Desert Experimental Range was poor due to a high fluoride content (0.84 mg/l). Fluorite mining is conducted in the region. Table C1-9 lists the results of chemical analyses of ground-water samples, and Drawing D1-8 shows areas of good and poor water quality. It is estimated that five percent of the valley contains ground water of good drinking quality, 94 percent contains ground water of poor drinking quality, and one percent contains water that exceeds the water quality criteria used in this report.

3.8 RAILROAD VALLEY

3.8.1 Physiography and Geology

Railroad Valley is a north-trending valley and lies in Nye and White Pine Counties in east-central Nevada (Figure 1). The drainage basin covers 2752 mi^2 (7128 km^2) of which about 975 mi^2 (2530 km^2) are suitable for MX siting. The valley is 110 miles (177 km) long and varies from 15 to 25 miles (24 to 40 km) in width. It is one of the largest topographically-closed basins in Nevada.

The mountains along the east and west sides of the valley range from 7000 to 10,000 feet (2134 to 3048 m) in altitude with Currant Mountain, at 11,531 feet (3515 m), the highest point in the basin. The lowest point in the basin is 4706 feet (1434 m) in elevation on the northern playa. This playa is the remnant of a large lake which existed during the Pleistocene Epoch and had a maximum area of about 430 mi^2 (1114 km^2) according to Van Denburgh and Rush (1974). Additionally, there is a smaller playa in the southern part of the valley at an elevation of 4845 feet (1478 m).

Van Denburgh and Rush (1974) identified the three principal aquifers within the valley as valley-fill deposits, fractured Tertiary volcanics, and fractured carbonates of Paleozoic age. The valley-fill deposits consist of interbedded gravels, sands, silts, and clays with sands and gravels predominating along the valley margins and grading to the silts and clays in the playa areas. The Tertiary volcanics crop out in the mountains to the west and south and underlie the northwestern and southern parts of the valley. The fractured carbonates crop out in the mountains to the east and west and probably underlie the valley-fill aquifer in the northern part of the valley.

3.8.2 General Hydrology

Railroad Valley is a topographically closed basin but Blankennagel and Weir (1973) estimated that about 1000 acre-ft/yr

(1.2 hm^3/yr) of ground water is discharged through the valley-fill and carbonate aquifers to Kawich Valley to the south. Van Denburgh and Rush (1974) noted, however, that this estimate may be too small. Railroad Valley receives about 1200 acre-ft/yr (1.5 hm^3/yr) of surface recharge from Hot Creek Valley via Twin Springs Slough.

Van Denburgh and Rush (1974) estimated the total ground-water recharge to Railroad Valley to be 52,000 acre-ft/yr (64 hm^3/yr) from precipitation and 3000 acre-ft/yr (3.7 hm^3/yr) from subsurface inflow but noted that, due to difficulties in estimating subsurface inflow, this latter estimate could be considerably lower than the actual subsurface recharge. For water budget calculations, Van Denburgh and Rush (1974) did not include surface inflow and, reporting that the estimates of recharge through precipitation and subsurface inflow were probably low, used an assumed total inflow of 75,000 acre-ft/yr (92 hm^3/yr) to Railroad Valley.

Discharge of ground water from Railroad Valley occurs mainly as evapotranspiration with only small discharges reported through subsurface outlfow. Van Denburgh and Rush (1974) estimated the total evapotranspiration to be 80,000 acre-ft/yr (99 hm^3/yr) and estimated that subsurface outflow through the valley-fill or carbonate aquifer totals only 1000 acre-ft/yr (1.2 hm^3/yr). For water budget calculations it was assumed that the discharge from Railroad Valley is 75,000 acre-ft/yr (92 hm^3/yr).

The perennial yield of Railroad Valley was estimated to be 75,000 acre-ft/yr (92 hm^3/yr) by Van Denburgh and Rush (1974). This estimate was based on the assumption that all the losses to evapotranspiration could be recovered and put to a more economic use and that one-half of the subsurface outflow to Kawich Valley could be recovered. In addition, a transitional storage reserve of 4,000,000 acre-ft (4932 hm^3) was estimated to be available in the upper 50 feet (15 m) of saturated sediments.

The potentiometric surface in Railroad Valley is shown in Drawings B1-10 and B1-11. The ground-water level data and interpretation is based upon published water well information and measurements made by Fugro National. As shown, ground water from both ends of the valley moves toward and discharges to a wildlife management area. Numerous flowing wells indicate artesian conditions in the wildlife management area. Table F1-9 lists the flowing well discharge measurements recorded in Railroad Valley. Depths to water vary, but it is estimated that 40 to 50 percent of the valley has ground water at depths of less than 50 feet (15 m). The shallow ground water is in the central portions of the valley and the depth to ground water increases to over 200 feet (61 m) along the valley margins as the land surface elevation increases.

3.8.3 Aquifer Characteristics

No aquifer testing could be performed in Railroad Valley because permission could not be obtained from private well owners. No records of previous aquifer tests that may have been conducted in the area are available. Reports from local well owners, however, indicate that interference between wells is very high in the Currant area. This could reflect high transmissivities in a small local perched aquifer.

The amount of ground water stored in the upper 50 feet (15 m) of saturated sediments in Railroad Valley is vast. Lithologic logs for 76 water wells in Railroad Valley were analyzed and it was found that, in the upper 50 feet of sediments, 29 percent of the sediments were comprised of clay, 3 percent of silt, 23 percent of sand, and 32 percent of gravel. Assumming that the porosities of clay, silt, sand, gravel, and cemented gravel are 40, 35, 30, 30, and 15 percent respectively, the total ground-water in storage in the upper 500 feet of sediments is over 7.4 million acre (9124 hm^3) or 148,000 acre-ft (183 hm^3) per foot of saturated sediments. To determine how much of that stored ground-water is actually recoverable through conventional pumping, specific yield values of 4, 10, 15, 25, and 10 percent were used for clay, silt, sand, gravel, and cemented gravel. Calculations indicate that almost 3.7 million acre-ft (4562 hm^3) could be recovered from storage in the upper 50 feet or 74,000 acre-ft (91 hm^3) per foot of saturated sediments. This calculation compares well with estimates made by Van Denburgh and Rush (1974).

3.8.4 Water Quality Limitations

A total of 66 ground-water quality analyses (Table C1-10) were used in the compilation of the water quality map shown in

Drawings D1-9 and D1-10. Seven of these samples were collected by Fugro National and were analyzed by Controls for Environmental Pollution in Santa Fe, New Mexico. The other 59 analyses were analyzed by the U.S. Geological Survey and reported by Van Denburgh and Rush (1974). The samples were classified as good, poor, or exceeds criteria according to the water quality criteria listed in Table C1-1. A total of five samples were classified as poor and nine samples were classified as exceeding criteria; 52 samples were classified as good. Three samples were classified as poor due to fluoride concentrations between 0.8 and 1.4 mg/l, one sample was poor due to a calcium concentration between 75 and 200 mg/l, and one sample was classified as poor due to a chloride concentration between 250 and 400 mg/l. Five samples exceeded the fluoride criteria (1.4 mg/l), three samples exceeded the criteria for sulfate (400 mg/l), three samples exceeded the chloride criteria (600 mg/l), two samples exceeded the calcium criteria (200 mg/l), and four samples exceeded the criteria for total dissolved solids (1500 mg/l).

Because of the sparsity and distribution of water quality data, only generalizations can be made about the water quality in Railroad. The high fluoride concentrations in the central and southern areas may be due to interactions between ground-water and volcanic rocks.

3.9 SEVIER DESERT

3.9.1 Physiography and Geology

Sevier Desert is a broad, gently southwest-sloping area of approximately 970 mi^2 (1190 km^2) in Juab and Tooele counties. About 460 mi^2 (1190 km^2) is considered suitable area for MX deployment. The area defined as Sevier Desert for this study is actually the north central portion of a larger Sevier Desert studied by Mower and Feltis in 1968. That study defined Sevier Desert as the 3100 mi^2 (830 km^2) area between the Canyon and Tintic Mountains on the east and the House Range on the west, and between Clear Lake and the north end of Sevier Lake on the south and the Sheeprock Mountains on the north. For this study Sevier Desert is the area bounded by the Simpson and Sheeprock Mountains to the north which separates the Sevier Desert from Skull and Rush valleys. Slow Elk Hills, Keg Mountains, and the southern part of Dugway Valley form the western border. The eastern boundary is formed by a line roughly drawn from the Sheeprock Mountains to Sand Mountain. Sevier Desert is bounded to the south by the 50-feet-to-water contour line as shown on Drawing B1-12. The peaks in the Simpson and Sheeprock Mountains are the highest in the Sevier Desert study area with elevations up to 8275 feet (2522 m). The lowest point in the area occurs in the Old River Bed in the northwestern portion of Sevier Desert where the elevation is below 4500 feet (1372 m).

According to Mower and Feltis, 1968, the mountains surrounding the Sevier Desert Basin are composed of igneous, sedimentary, and metamorphic rocks ranging in age from Precambrian to

Tertiary. Consolidated to unconsolidated sedimentary rocks, composed of clay, silt, sand, and gravel, along with volcanic rocks of Tertiary and Quaternary age form the central part of the valley. During the Pleistocene age, Lake Bonneville altered the topography of the basin, building shoreline deposits and cutting terraces and cliffs on the bordering mountains (Mower and Feltis, 1968).

3.9.2 General Hydrology

The Sevier Desert as defined by Mower and Feltis, 1968, is a topographically closed basin on all sides except the south. The Sevier River enters the desert near the midpoint of the eastern boundary and flows southwest toward Sevier Lake in the southwest corner of the desert. The Beaver River enters the desert and empties into Sevier River about 5 miles (8 km) to the north near the midpoint of the southern boundary. Because of irrigation diversions, surface water from these rivers reaches Sevier Lake only during years of heavy rainfall (Mower and Feltis, 1968). These two rivers, the only significant surface flow in the Sevier Desert, are south of the area studied for this report.

The average annual precipitation prior to 1963 ranged from less than 6 inches (15 cm) to about 12 inches (30.5 cm) in the lowlands and from 8 inches (20 cm) to more than 25 inches (63.5 cm) in the mountains (Mower and Feltis, 1968). The average annual precipitation from 1963 to 1978 in the lowlands was 7.4 inches (19 cm) (Climatological Data Annual summary 1963-1977). Most rain falls in short-term, high-intensity summer storms resulting in fast runoff and little penetration of the soil. The most important source of water within the Sevier Desert region is the mountain snowpack which sustains river flow and is the source of recharge to the ground-water reservoir (Mower and Feltis, 1968). According to Mower and Feltis (1968), the main recharge areas are along the north and east edges of the basin.

Estimated recharge of the ground-water reservoir, although quantitatively undetermined, occurs through direct infiltration through the sediments when total precipitation exceeds evapotranspiration. This happens only during years of prolonged, relatively heavy rainfall. In the fifteen-year period from 1949 to 1964 this type of rainfall occurred only twice (Mower and Feltis, 1968). Other sources of ground-water reservoir recharge include seepage from streams and canals, infiltration of irrigation water, flow through fractured consolidated rock, and underflow from Pavant Valley to the east and from Beaver River Valley to the south (Mower and Feltis, 1968).

Ground water in the Sevier Desert is discharged primarily by subsurface outflow, by well pumpage and by evapotranspiration. According to Mower and Feltis, 1968, the amount of subsurface outflow is probably less than 5000 acre-ft/yr (6.2 hm^3/yr).

Mower and Feltis (1968) identified three prinicipal aquifers within the area as valley-fill deposits, fractured volcanics of Tertiary age, and fractured carbonates of Paleozoic age. The valley-fill deposits consist of interbedded silts, clays, and evaporites in the playa area and gravel and sands in the adjacent alluvial fans. Extensive cementation has occurred in the older valley-fill deposits. The fractured volcanic aquifer is comprised of tuffs and lava flows. The carbonate rocks of Paleozoic age crop out in the mountain ranges flanking the valley and are a source of recharge through ground-water underflow toward the younger unconsolidated deposits which form the valley fill.

The water table within the valley-fill aquifer slopes to the southwest as well as away from a hydrologic divide (12S/11W and 10 W) toward the northwest in the suitable MX siting area and toward Dugway Valley. The ground-water gradient for Sevier Desert averages 8 feet per mile (2.4 m per km) from the recharge area in the Sheeprock, Simpson, and Tintic Mountains toward the southwest. The ground-water gradient in the northwest, as it flows through the Old River Bed toward Dugway Valley, is 20 feet per mile (3.8 m per km) (Drawing B1-12). The potentiometric ground-water surface map (Drawing B1-12) prepared by Fugro National provides support to the general pattern of the contours and the flow directions developed by Mower and Feltis, 1968.

Records compiled by the United States Geological Survey (U.S. G.S.) (1978) and ground-water level measurements collected by Fugro National in 1979 and 1980 indicate that the depth to ground water is less than 10 feet (3.04 m) in the Delta area (Drawing B1-12) with several flowing wells reported. Measured depths to water exceed 200 feet (61 m), however, along the valley margins to the northwest where elevations are higher. The Utah Division of Water Resources (UDWR) (1978) reported that a slight rise in ground-water levels occurred between 1977 and 1978, probably due to a period of high precipitation, however, an overall decrease in the ground-water level of about 6 feet (1.83 m) has occurred since 1955. The perennial yield of the Sevier Desert is not known to have been calculated by previous work. Based upon pumping rates and piezometric level declines for the period from 1960 to 1977 compiled by the UDWR (1978) and using the Hill method described by Todd (1959), it is estimated that the perennial yield of the Sevier Desert ground water basin is 23,500 acre-feet per year (Figure 3).

Ground-water utilization in the Sevier Desert averaged 28,000 acre-ft/yr (34.5 hm^3/yr) for the 15 year period from 1963 to 1977 according to the UDWR (1978). Recent ground-water withdrawal has significantly increased, however, reaching about 50,000 acre-ft (61.2 hm^3) in 1977 (UDWR, 1978). Of that amount, about 46,500 acre-ft (57.7 hm^3) were used for irrigation; 2000 acre-feet were extracted for industrial use, and municipal and domestic pumpage consumed an additional 1500 acre-ft (1.8 hm^3).

3.9.3 Aquifer Characteristics

The ground-water reservoir in the Sevier Desert is composed mainly of unconsolidated to partly-consolidated clay, silt, sand, and gravel, deposited under subaerial and lacustrine (Lake Bonneville) conditions, forming a multi-aquifer artesian system that is more than 1000 feet (305 m) thick (Mower and Feltis, 1968). There are two artesian aquifers in the Sevier Desert. The deep and shallow aretesian aquifers, separated by 300 to 500 feet (92 to 152 m) of relatively impermeable clay, silt, and fine sand (UDWR, 1964). Geophysical work now in progress by Fugro National will enable a better estimate to be made of valley geometry.

An aquifer test was performed by Fugro National on well (C-13-7)9cbc (Desert Mountain Well), which is 210 feet (64 m) deep. This test resulted in a transmissivity value of 1500 gpd/ft (5.2 cm^2/sec). This value is much lower than the value of transmissivity of an aquifer located in typical valley-fill deposits, and could be cause by the poor construction of the 35-year-old well tested. It is expected that had the Desert Mountain Well had a longer screened section the transmissivity value would have been greater. The storage coefficient of the aquifer could not be determined because an observation well was not present. Judging from the extensive agricultural development in the Delta area, it is likely that well yields in excess of 1000 gpm (63.0 l/s) could be obtained through proper well placement and design.

3.9.4 Water Quality Limitations

Eight ground-water samples for quality analysis were collected from eight different well locations by Fugro National in March 1980 and analyzed by the Utah Water Research Laboratory. The ground-water samples from wells (C-13-6)26bac; (C-13-6)12bcb;

(C-14-6)9bab; and (C-14-6)9dda show moderately high chloride (456 to 681 mg/l) and sulphate (275 to 531 mg/l) concentrations and wells (C-13-6)26bac; (C-14-6)9bab; (C-14-6)9dda and (C-15-7)18caa show high fluoride concentrations (greater than 1.4 mg/l). These values are categorized as "poor" according to the water quality criteria presented in Table C1-1.

Water quailty exceeds criteria in the sand dune area northwest of Lynndyl (Drawing C1-11). Analyses of samples collected in this area exceeded permissible limits in either sulphate (greater than 600 mg/l), fluoride (greater than 1.4 mg/l), chloride (greater than (600 mg/l), total dissolved solids (greater than 1500 mg/l), or a combination of the above. Ground-water in the Old River Bed is generally of poor quality.

In addition, more than fifty ground-water samples were previously analyzed for chemical quality under the direction of the U.S.G.S. and the Bureau of Land Management (Table C1-11. These tests support the results of the water quality analyses conducted by Fugro National in the portion of the Sevier Desert suitable for MX deployment.

3.10 SNAKE/HAMLIN VALLEYS

3.10.1 Physiography and Geology

Snake and Hamlin valleys, although separted by a narrow divide south of Garrison, Utah, and considered separate valleys by local custom, are parts of the same hydrologic system. They encompass portions of Juab, Millard, Beaver, and Iron counties in

Utah, and White Pine and Lincoln counties in Nevada (Drawings B1-7 and B1-13).

The valleys have a combined length of approximately 135 miles (217 km), a width ranging from 5 to 43 miles (8 to 69 km), and an area of about 3500 mi^2 (9060 km^2). The area judged suitable for MX missile deployment under current criteria is 887 mi^2 (2222 km^2) in both valleys, of which 335 mi^2 (869 km^2) is in Hamlin Valley and 552 mi^2 (1354 km^2) is in Snake Valley. The valleys are bounded on the west by peaks up to 13,063 feet (3982 m) in elevation and on the east by peaks up to 9785 feet (2982 m) in elevation. The valleys extend from the Paradise Mountains in the south to the Great Salt Lake Desert in the north. The valley floor has elevations ranging from 6600 feet (2012 m) in southern end at Hamlin Valley to 4250 feet (1295 m) at the northern end of Snake Valley.

The valley-fill deposits consist mainly of clay, silt, and sand in the lacustrine areas at the center of the valleys and predominantly of gravels and sands in the alluvial fan and stream channel deposits along the mountain fronts. There is significant influence from ancient Lake Bonneville, with well developed shorelines and thick lake deposits occuring in portions of Snake Valley and northern Hamlin Valley. The thickest section of valley-fill sediments penetrated by exploration oil-well drilling is 4200 feet (1280 m) in Snake Valley at (C-20-19) 19dc. Gravity surveys conducted by Fugro National in the Ferguson Desert area indicate that the valley has a maximum thickness of about 3000 feet (914 m) and is bound by faults in this area. These faults are structurally typical for valleys in the Basin and Range. Gravity surveys conducted by Fugro National in Hamlin Valley indicates that vally-fill sediments are about 10,000 feet thick in the area east of the Limestone Hills.

The bounding mountain ranges in Snake and Hamlin valleys are composed of carbonate rocks of Paleozoic age and extrusive rocks of Cretaceous and Tertiary age; intrusive igneous rocks of Tertiary, Jurrasic, and Precambrian age underlie the valley fill deposits (Hood and Rush, 1965).

3.10.2 General Hydrology

Snake and Hamlin valleys appear to form an open system in terms of both ground water and surface water. As indicated by the potentiometric maps (Drawings B1-7 and B1-13), and according to Hood and Rush (1965), both surface and the majority of groundwater flow north into the Great Salt Lake Desert. Ground water occurs under both confined and unconfined conditions in Snake Valley. According to Hood and Rush (1965) the artesian conditions are illustrated by some springs and flowing wells. The potentiometric maps prepared by Fugro National show that the ground-water surface slopes to the north from Hamlin Valley toward Snake Valley at a hydraulic gradient ranging from 40 ft/mi (8 m/km) to less than 14 ft/mi (3 m/km). In Snake Valley, in addition to the underflow from Hamlin Valley, there is recharge from the western side of the valley from the Wheeler Peak area and Spring Valley. The flow continues to the north, however, it also moves to the southeast through the Ferguson Desert area. The majority of the flow, nevertheless, continues northward along the valley until it reaches the Salt Lake Desert. The eastern component of the ground-water flow is significant, and it may ultimately be part of the regional ground-water underflow that moves eastward through the fractured caverneous limestones. Such flow may be part of the underflow that supplements the recharge of the tributary valleys on the eastern side of Snake Valley.

The depth to the potentiomentric surface ranges from several feet above ground level at some flowing wells along the central valley axis to about 50 feet (15 m) below ground level away from the center of the valley and several hundred feet along the margins. The zero depth to water contour follows both sides of the central part of the valley. Considerable quantity of water is lost in this part of the valley by evaporation and evapotranspiration.

The limestone bedrock beneath the valley-fill is also known to contain water and to be highly conductive due to the fractures and solution openings (Hood and Rush, 1965). Characteristics of the intermediate and deep sediments, between 500 feet (152 m) and the bedrock contact, are not well defined.

Hood and Rush (1965) estimated the total ground-water recharge of both Hamlin and Snake valleys at 105,000 acre-ft (129 hm^3) through precipitation and runoff, and another 4000 acre-ft/yr (4.9 hm^3/yr) is recharged through underflow from Spring Valley.

Drawing B1-7 and B1-13 show the recharge component of flow coming from the direction of Spring Valley and the western mountains bounding the valley.

Discharge takes place as evapotranspiration from native plants, soil moisture, irrigated fields, and ponded water, as well as underflow north to the Great Salt Lake Desert and east to the Confusion Range and the Ferguson Desert. According to Hood and Rush (1965) the potential evapotranspiration rate in Snake Valley is 5 feet (1.5 m) per year per acre, where evaporation or transpirations occurs. Based on this estimate, evapotranspiration accounts for about 80,000 acre-ft/yr (98.6 hm^3/yr) and outflow accounts for about 25,000 acre-ft/yr (30.8 hm^3/yr). The phreatophytes, which mainly consists of greasewood and rabbitbrush, occupy the central part along the whole length of Snake Valley. Other ground-water users are spread along the whole valley. Active use of water in Snake Valley area for stockraising and agricultural purposes started early in 1903 (Hood and Rush, 1965). Irrigation is from wells and springs at Callao, the southern part of Garrison, along the road from Garrison to Gandy and at Gandy. Estimated ground-water use for agriculture is about 14,000 acre-ft/yr (17 hm^3/yr). Springs are found in Willow Springs area (T10S/R17W) near Callao, the Old Miller Ranch (T14S/R18W), the Bishop and Knoll Spring areas (T16 and 18S/R18W) and Big Spring (T10S/R70W). According to Hood and Rush (1965), the temperature of water from these springs is 64 to 68°F (18° to 20°C), which is 10 to 20°F (5.5 to 11°C) above the range of average annual air temperature. This indicates that the source of the springs is deep and it is likely to be the carbonate aquifer. Perennial yield has been estimated to range from 32,000 acre-ft/yr (39.5 hm^3/yr) (Nevada State Engineer, 1971) to 80,000 acre-ft/yr (98.6 hm^3/yr) (Hood and Rush, 1965).

3.10.3 Aquifer Characterisitcs

Five aquifer (pump) tests were performed in Snake Valley and four in Hamlin Valley. Transmissivity values in the valleys ranged from 432 gpd/ft (1.5 cm^2/sec) to 350,000 gpd/ft (1208 cm^2/sec) (Appendix E1-1). Transmissivities at the low end of this range are only adequate for small domestic or stock wells, while transmissivities greater than 100,000 gpd (345 cm^2/sec) are adequate for large irrigation wells of over 1000 gpm (63 l/s). The storage coefficient was computed for two aquifer tests in Snake Valley (Appendix E1-1). The values for Snake and Hamlin valleys ranged between 0.08 and 9.7×10^{-5}. The high value of storage coefficents indicates water table conditions and the low value indicates an artesian condition. The range of average hydraulic conductivity of the screened sections of silt, sand, and gravel ranged from 0.02 to 0.45 feet per minute (214 to 4847 gpd/ft^2). Values greater than about 0.1 feet per minute are generally found near the mountains and indicate the presence of well sorted, coarse sand or gravel. The lower values, which are concentrated at the central part of the valley, indicte the presence of finer grained, more poorly sorted sediments.

Well yields in the area range from a few gallons per minute for some flowing wells to over 1000 gpm (63 l/s) for some irrigation wells. Yields of wells depend upon the thickness and character of materials penetrated and well construction. In general, it is anticipated that well yields up to 1000 gpm (63 l/s) are obtainable throughout much of the suitable construction area with wells of about 300 feet (98 m) in depth.

3.10.4 Water Quality Limitations

The majority of the water in Hamlin and Snake valleys can be considered as calcium and/or magnesium bicarbonate water. This is especially true for ground water on the western side of the valleys. As the water moves to the north and east and passes through the playa deposits and salt lakes in the center of Snake Valley, it exchanges its calcium and magnesium ion to sodium and potassium and loses its bicarbonate nature. Ultimately, the water become sodium-, potassium-, cholride-, and sulphate-rich. Drawings D1-6 and D1-12 show areas of good, poor, and exceeding criteria water quality. Analysis of ground-water samples from the Ferguson Desert area indicates water quality which is classified as poor, based on high fluoride (0.8 to 1.4 mg/l) and total dissolved solid content (500 to 1500 mg/l). The Salt Marsh Lake area in Snake Valley contains water that exceeds criteria for drinking; however, it is surrounded by good quality water. Generally, most of the valley contains ground water of good quality. Most of the samples tested have bicarbonate concentration greater than 100 mg/l and one contained a bicarbonate concentration of 335 mg/l, which is probably a result of water slowly flowing through carbonate rocks in the bounding mountains and/or through sediments derived from them. The water quality from five ground-water samples in Snake Valley and six in Hamlin Valley were considered poor based on calcium (75 to 200 mg/l), magnesium (500 to 150 mg/l), fluoride (0.8 to 1.4 mg/l), and total dissolved solids content (500 to 1500 mg/l) (Tables C1-7 and C1-12). Appendix C1-1 lists the criteria used for judging water quality.

3.11 TULE VALLEY

3.11.1 Physiography and Geology

The Tule Valley drainage basin, encompasing about 940 mi^2 (2435 km^2), lies in Juab and Millard counties in west-central Utah (Figure 1). The north-trending basin is 65 miles (105 km) long and from 8 to 22 miles (13 to 35 km) wide. Approximately 395 mi^2 (1023 km^2) in the basin is suitable for MX deployment.

The mountains bounding Tule Valley are primarily composed of carbonate rocks of Mesozoic and Paleozoic age. Minor amounts of younger igneous rocks occur throughout these ranges. Numerous outcrops of carbonate rocks protrude through the valley-fill deposits in the central valley area. Mountain crests generally range between 7000 and 9000 feet (2130 and 2740 m) in elevation. The highest point in the drainage basin is Swasey Peak along the eastern side of the valley which has an elevation of 9669 feet (2947 m). Total relief in the basin is about 5370 feet (about 1640 m).

Valley-fill deposits consist predominantly of interfingering alluvial and lacustrine sediments which range from clays to gravels. The lacustrine sediments were deposited during Pleistocene Epoch when the valley was inundated by Lake Bonneville. Remnant shoreline terraces from Lake Bonneville are prominent in Tule Valley.

3.11.2 General Hydrology

Tule Valley is a topographically closed drainage basin with mountain ranges on the east and west side and low topographic divides on the north and south. Sand Pass, which forms a narrow divide separating the Fish Springs and House ranges along the north and east side of the valley, is severed by a major fault (Stokes, 1964) which may be a significant conduit for groundwater movement through and out of Tule Valley (Stevens, 1977).

In any basin which is in hydrologic equilibrium, the rate of recharge must equal the rate of discharge. Recharge in the Tule Valley drainage basin is by two processes:

1) Infiltration of precipitation from within the drainage area, and

2) Subsurface inflow from adjoining valleys.

Stephens (1977) has estimated an average annual recharge of 7600 acre-ft (9.4 hm^3) from precipitation. Based on the areal extent of phreatophytes, Stephens (1977) estimated an annual discharge rate of 40,000 acre-ft (49.3 hm^3) by evapotranspiration. Therefore, approximately 32,000 acre-ft (39.5 hm^3) of recharge may occur annually by subsurface inflow. The direction of migration and exact quantity of inflow cannot be determined with data presently available. However, based on the groundwater gradients presented on the potentiometric map for Snake Valley (Drawing B1-13), some inflow from Ferguson Desert is probably occurring in the southern Tule Valley area.

There is no interbasin surface flow and all streams in the valley are ephemeral. Numerous small springs provide the only perennial flow in the valley. A north-trending line of small springs occurs in the north-central valley floor. The water from these springs has a relatively high temperature 70° to 79°F (21° to 26°C). They are believed to indicate the presence of a fault or fault zone which provides a conduit for water moving upward under artesian head from deeper aquifers. This may indicate interbasin underflow. During the summer of 1979, all of these springs were flowing, but because they discharged into ponds, no discharge measurements could be taken. System yield in the valley has been estimated to be less than 5000 acre-ft (6.2 hm^3) (Eakin, et al., 1976).

Substantially greater ground-water withdrawals are possible by lowering the water table and reducing phreatophytes evapotranspiration losses from the aquifer, assuming no adverse environmental effect would result. Ground water in the basin generally flows toward the northern playa area under a hydraulic gradient of about 3 feet per mile (0.6 m/km) (Drawing B1-14). Where the evapotranspiration losses occur, the potentiometric surface is at or very near the ground surface in this area and the valley fill here is beleived to be saturated below an evelation of about 4425 feet (1349 m) (Stephens, 1977).

3.11.3 Aquifer Characteristics

Very few wells have been developed in Tule Valley and most are equipped with low-capaciy piston pumps which are not suitable for aquifer testing. An aquifer test was performed on well (C-16-16)34bcd, which is 260 feet (79 m) deep. This test provided a transmissivity value of about 2000 gpd/ft (2.9 cm^2/sec). This value is much lower than the results of aquifer tests conducted in other valleys, and is believed to be due to the well only partially penetrating the aquifer. It is expected that if the well had been deeper, the measured transmissivity value would have been greater. The storage coefficient of the aquifer could not be determined because an observation well was not present.

Tule Valley was formed under similar geological and environmental conditions as Snake Valley to the west. Because of known well yields in Snake Valley, it is expected that well yields over 100 gpm (63 l/s) can be obtained from large-capacity wells, in areas of especially coarse-grained aquifer materials, such as the alluvial fan area. Low-well yields are anticipated in playa areas because the sediments here are generally very fine-grained lacustrine deposits of low hydraulic conductivity. The valley-fill aquifer in Tule Valley is believed to be adequate to fulfill MX water requirements with proper well designs.

3.11.4 Water Quality Limitations

The U.S. Geologic Survey has analyzed eight ground-water samples from six separate locations over a period from 1935 to 1976. Fugro National analyzed an additional eight ground-water samples. A total of 12 ground-water sampling locations were used in Tule Valley. Eight of these locations are springs and four are wells. The results of these analyses are shown on Table C13. Areas of good, poor, and exceeds criteria water quality are shown on Drawing D1-13. Where Fugro National has reanalyzed a source previously tested by the U.S. Geological Survey, only the results obatined by Fugro are listed in Table C1-13. The criteria for judging water quality are listed in Table C1-1.

Of the ground-water samples from the 12 locations, two have good quality, seven have poor quality, and three exceed criteria. The seven samples that were considered poor had high constituent concentrations of calcium (75 to 79 mg/l), sulfate (314 to 330 mg/l), fluoride (1.1 to 1.3 mg/l), chloride (280 to 450 mg/l) and TDS (716 mg/l). Three samples exceeded criteria because of high concentrations of chloride (640 to 930 mg/l), sulfate (851 mg/l), nitrate (19 mg/l), and (240 mg/l). All of the samples were moderately high in bicarbonate (132 to 320 mg/l) due to ground-water interaction with carbonate rocks in the mountain ranges, as well as the soils and alluvium derived from these rocks. As shown in Drawing D1-13, only isolated areas in the mountain ranges are likely to have good quality water. The remaining area of the valley is divided about evenly between areas of poor quality and areas which exceed criteria. The poor quality areas are in the western and southern portion of the valley. The water deteriorates in quality downgradient toward the southeast.

3.12 WAH WAH VALLEY

3.12.1 Physiography and Geology

Wah Wah Valley trends northerly and lies within Millard and Beaver counties, Utah (Figure 1). It has a total area of about 600 mi^2 (1550 km^2), of which about 300 mi^2 (777 km^2) is suitable area for MX deployment. It is about 40 miles (64 km) long and 8 to 20 miles (13 to 32 km) wide. The valley is bounded on the west by the Wah Wah Range with peaks up to 8980 feet (2737 m) in elevation; on the east by the San Francisco Mountains with peaks up to 9660 feet (2944 m) in elevation, and on the northwest by the Confusion and House ranges. There is a low topographic divide with an elevation of about 4760 feet (1423 m) separating a playa in Wah Wah Valley (Wah Wah hardpan - local name) from Sevier Lake to the northeast. The playa is at an elevation of about 4637 feet (1413 m).

The Wah Wah Range is composed primarily of carbonate rocks, with minor exposures of quartzite of Paleozoic age. The southern end of the Wah Wah Range and the San Francisco Mountains are both covered with extensive extrusive igneous rocks of Tertiary age. The extrusive rocks are composed primarily of lava and ash flow tuffs. The San Francisco Range is composed of carbonate and quartzite rocks of Paleozoic age capped by an overthrust block of quartzites and argillites of Precambrian age. There is a minor intrusive body of quartz monzonite of Tertiary age in the Frisco Peak area.

The valley floor is covered primarily by alluvium and lacustrine deposits of Quaternary age, including fans and channel deposits consisting of coarse sands and gravels, and lacustrine (ancient Lake Bonneville deposits) and playa deposits consisting of gravel bars, clay and silt (locally called hardpan). The valley is believed to be filled to a depth of 2000 feet (610 m) by sediments of Tertiary and Quaternary age consisting of intermixed and interlayered alluvial fans, channel deposits, and lacustrine deposits ranging in size from clay to boulders. Drilling and geophysical work currently in progress or planned by Fugro National, will enable a more precise definition of the valley-fill.

3.12.2 General Hydrology

Wah Wah Valley is a topographically closed valley with a low divide separating it from Sevier Lake. The divide is only about 30 feet (9 m) above the Wah Wah hardpan which is the low point in Wah Wah Valley.

Annual precipitation in Wah Wah Valley is estimated to average 9 inches (23 cm), with up to 20 inches (51 cm) on the peaks and less than 8 inches (20 cm) in the lower part of the valley (Stephens, 1974). The total annual precipitation over the 600 square mile area is therefore about 290,000 acre-feet (360 hm^3). Recharge is believed to take place primarily on the alluvial fans where ephemeral streams flow out of the mountains. Very little recharge is believed to take place in either the playa or the fine sediments on the valley floor, or in the bedrock areas of the ranges. Stephens (1979) estimates the total annual recharge to be 2.5 percent of precipitation, or about 7000 acre-ft (8.6 hm^3). This estimate is based on estimated infiltration rates through the various materials exposed in the valley, and not on direct measurement.

In addition to annual precipitation, about 3000 acre-ft (3.7 hm^3) is contributed to Wah Wah Valley by subsurface inflow from Pine Valley (Stephens, 1974). Stevens based his conclusion on the belief that ground water migrates along bedding planes in strata of the Wah Wah Range dipping from Pine Valley to Wah Wah Valley. The total recharge then is about 10,000 acre-ft/yr (12.3 hm^3/yr).

Discharge is primarily by evapotranspiration and by flow under the divide into Sevier Lake Basin to the northeast. The flow direction is based on the direction of the potentiometric gradient as indicated by Drawing B1-15. The gradient is about 7 feet per mile (1 m/km) to the north along the valley axis. Discharge by evapotranspiration takes place predominantly in the area around Wah Wah Springs with minor amounts around some of the other springs and ephemeral stream channels. Stephens (1974) estimates total evapotranspiration to be about 640 acre-ft/yr (0.8 hm^3/yr). He estimates total spring and well discharge to be about 910 acre-ft/yr (1.1 hm^3/yr), of which the great majority, about 800 acre-ft/yr (1.0 hm^3/yr), is from the Wah Wah Springs which lies in the west central portion of the valley. Of the 910 acre-ft (1.1 hm^3) of discharge, about 300 acre-ft (0.4 hm^3) is applied to beneficial use such as irrigation, and stock and game watering. The rest of the annual discharge is lost by evapotranspiration.

The approximately 8500 acre-ft/yr (10.5 hm^3/yr) of excess recharge which is not accounted for above is believed to leave the valley by subsurface flow north through the valley-fill sediments to the Sevier Lake area. There may also be discharge by interbasin flow through the bedrock, although there is no direct evidence to support that hypothesis.

3.12.3 Aquifer Characteristics

The hydrologic properties of the valley-fill aquifer are not well defined. Existing data consist of logs from one exploration oil well, four alunite exploration borings, one BLM stock-water well, and one privately-owned stock well. Aquifer tests could not be performed at any of these wells. Earth Sciences, Inc., the owner of the alunite exploration wells, located in the southern portion of the valley, would not release any data concerning hydrologic testing, however public information from the Utah State Engineer indicates that the wells are capable of producing 1500 gpm (95 l/s) with drawdowns of about 100 feet (30 m). Wells for MX water supply should be able to produce similar amounts if they are sited in a similar geologic setting.

3.12.4 Water Quality Limitations

The U.S. Geologic Survey has tested 20 ground-water samples from 15 locations during the period 1935 to 1973, and Fugro National collected one ground water sample for laboratory analyses in 1979. In general, the quality of water in Wah Wah Valley is within the criteria for drinking water (Table C1-1). Water quality is generally good near the upstream end of the valley but deteriorates to exceeds criteria downstream. Of the 15 ground-water samples tested, three are from wells and 12 are from springs. Three of the 12 spring locations are in the Wah Wah Springs group. The water from the Wah Wah Springs group and from one well in Grover Wash on the slope of Antelope Peak in the south end of the San Francisco Mountain Range, were of good quality. Results of the analyses of ground water indicates four samples with poor quality and six samples with exceeds criteria classification. The exceeds criteria quality water was due to calcium (224 to 650 mg/l), magnesium (190 to 220 mg/l), sulfate (600 to 710 mg/l), chloride (600 to 2100 mg/l), and nitrate (10 to 73 mg/l). The poor quality water was due to concentration of calcium (100 to 190 mg/l), magnesium (64 mg/l), sulfate (288 mg/l), chloride (360 mg/l) and fluoride (1.0 mg/l).

All samples had moderately high bicarbonate concentrations in the range of about 130 mg/l to 390 mg/l, indicating the ground water has migrated through carbonate rocks, and/or sediments derived from these rocks. Wah Wah Springs, which has the largest rate of surface discharge of ground water in the valley, has very good water quality, with TDS of about 320 mg/l which has the largest rate of surface discharge of ground water in the valley, has very good water quality, with TDS of about 320 mg/l to 350 mg/l, most of which is bicarbonate. The Wah Wah Springs discharge through volcanic rocks from the underlying limestone. The recharge and flow paths are believed to be local (Stephens, 1974), based on the structural geology, low TDS values of water samples (324 to 348 mg/l) and low temperatures (16.5° to 19.5°C; 61.7° to 67.1°F). Areas of good, poor, and exceed criteria water are mapped on Drawing B-15. Results of quality analyses are in Table C-14.

3.13 WHIRLWIND VALLEY

3.13.1 Physiography and Geology

Whirlwind Valley as studied, is a large, gently-sloping extension of Sevier Desert which covers approximately 792 mi^2 (2051 km^2), of which 380 mi^2 (984 km^2) is considered suitable for MX deployment. The House Range separates Whirlwind Valley from Tule Valley to the west. Whirlwind Valley is separated from Fish Springs Flat and Dugway Valley on the north by low topographic divides. Highway 50 and 6 is a border of the study area on the south. Longitude 112°45' West is an study area boundary between Sevier Desert and Whirlwind Valley to the east. The area defined as Whirlwind Valley for this study is actually the southwestern portion of Sevier Desert studied by Mower and Feltis (1968).

That study defined Sevier Desert as the 3100 mi^2 (8029 km^2) area between the Canyon and Tintic Mountains on the east, the

House Range on the west, between Clear Lake and the northern end of Sevier Lake on the south, and the Sheeprock Mountains on the north. The highest peaks in the region are in the House Range where the highest elevation is 9290 feet (2832 m). The lowest point in the area is in the eastern valley area, near Topaz Slough, where the elevation is less than 4600 feet (1400 m).

Mountains of sedimentary, metamorphic, and igneous rocks of Precambrian to Tertiary age bound Whirlwind Valley (Mower and Feltis, 1968). The valley fill is composed of consolidated to unconsolidated sedimentary deposits along with volcanic rocks of Tertiary and Quaternary age. The sediments, composed of clay, silt, sand, and gravel were deposited under subaerial and lacustrine environments during the Pleistocene epoch. Lake Bonneville shoreline deposits, terraces, and cliffs of Pleistocene age are present on the lower alluvial slopes (Mower and Feltis, 1968).

3.13.2 General Hydrology

Whirlwind Valley, as defined for this study, forms the southwestern portion of Sevier Desert and is topographically open to the south. The Sevier River enters the desert near the midpoint of the eastern boundary and flows southwest toward Sevier Lake in the southwestern corner of the desert. The average flow of Sevier River between 1943 and 1964 was 122,700 acre-ft/yr (151 hm^3/yr) at Lynndyl and the combined flow of all other streams entering Sevier Desert was estimated at 50,000 to

65,000 acre-ft/yr (62 to 80 hm^3/yr) (Mower and Feltis, 1968). Most of this flow is believed to recharge the phreatic aquifer in Sevier Desert. No separate estimates for Whirlwind Valley recharge have been published.

The average annual precipitation ranges from less than 8 inches (20.3 cm) to more than 25 inches (63.5 cm), depending upon the elevation (Mower and Feltis, 1968). Most rainfall evaporates before it can percolate into the soil and recharge the ground-water reservoir. The most important source of water in the Sevier Desert region is snowpack in the mountains, which sustains stream flow and provides the source of recharge to the ground-water reservoirs (Mower and Feltis, 1968). Recharge in Whirlwind Valley is from intermittent stream flow where streams leave the mountains and flow over coarse grained and relatively permeable alluvial fans, and from subsurface inflow from Sevier Desert. Underflow from the Sevier Desert appears to be the major source of recharge to the ground-water reservoir. Drawing B1-16 indicates ground-water movement toward the southwest.

Ground-water discharge in Whirlwind Valley is primarily from wells and springs. Little evapotranspiration occurs within the valley study area. The only wells in the area are used for stock watering and have low discharge rates of generally less than 50 gpm (3.2 l/s).

Perennial yield has not been estimated for Whirlwind Valley because of lack of data. Any such estimate would have to take

Sevier Desert into consideration, where the perennial yield has been estimated to be 23,500 acre-ft/yr (28 hm^3/yr).

3.13.3 Aquifer Characteristics

As in the Sevier Desert, ground water occurs in unconsolidated deposits under unconfined and confined conditions. Most of the ground water discharged from wells originates either in the upper or lower confined aquifers, which are separated by 300 to 500 feet (91 to 152 m) of relatively impermeable clay, silt, and fine sand (Utah Division of Water Resources, 1964). Gravity surveys conducted by Fugro National (FN-TR-33-WW) in Whirlwind Valley on the western side of the Sevier Desert indicate that the valley-fill deposits are more than 2000 feet (610 m) thick. Very little data are available concerning the ground-water reservoir in the western half of Whirlwind Valley. Geophysical work now in progress by Fugro National will provide a better estimate of valley geometry in all portions of Whirlwind Valley.

Aquifer testing of existing wells was not conducted as part of the Fugro National field investigations because of a lack of suitable wells. Therefore, neither transmissivity nor storage coefficient of the valley-fill aquifer could be computed. However, given the similar Lake Bonneville depositional history of other valleys of known aquifer characteristics, some areas in Whirlwind Valley are expected to have moderate transmissivities and well yields on the order of a few hundred gpm. The drilling and testing of a 1000 foot (305 m) well in this valley is planned as part of the Fugro National Intermediate Depth Aquifer Program.

3.13.4 Water Quality Limitations

Fugro National was unable to obtain ground-water samples for water quality analyses during field reconnaissances in November 1979 and March 1980. Therefore, water quality evaluations for Whirlwind Valley were based on U.S. Geological Survey ground-water quality analyses compiled by Mower and Feltis (1964). Table C1-15 lists the results of the analyses and Drawing D1-15 shows the distribution of ground-water quality.

Ground-water quality data does not exist in the western half of the valley. The eastern half of the suitable MX siting area has poor to exceeds criteria ground-water quality as defined for this study in Table C1-1. Two water samples were collected from springs in the House Range by Fugro National and tested by CEP in 1979. Both were of good quality.

3.14 WHITE RIVER VALLEY

3.14.1 Physiography and Geology

White River Valley lies in northeast Nye County and portions of Lincoln and White Pine Counties in east-central Nevada (Figure 1). The basin includes about 1620 mi^2 (4196 km^2), of which 509 mi^2 (13.8 km^2) are suitable for MX deployment. The basin which trends north, is approximately 70 miles (133 km) long and ranges in width from 20 to 30 miles (32 to 48 km).

Mountain crests along the east and west sides of the valley generally range from 8000 to 10,000 feet (2438 to 3048 m) in elevation. Ward South Summit, at almost 11,000 feet (3353 m), is the highest peak in the basin. Hills and mountains of subdued relief and alluvial divides bound the valley on the north. The valley has open drainage to the south.

Mountain ranges bounding the valley are predominately composed of carbonate rocks (limestones and dolomites) of Paleozoic age. Quartzite of Cambrian age occurs near Lund, contributing particularly coarse-grained sediments to the basin. Volcanics of Tertiary age crop out in the southeastern and southern portions of the valley.

The valley-fill deposits are composed of thick sequences of lacustrine, alluvial, and fluvial sediments that generally overlie the volcanic bedrock of Middle-Tertiary age (Eakin, 1966). Deep exploratory wells drilled along the central axis of the valley penetrated thick sequences of lacustrine clay and silt interbedded with thin discontinuous zones of fluvial sand and gravel. These deposits average about 5000 feet in thickness in the central valley area. The lower slopes of the bounding mountain ranges are covered with broad alluvial fans of coarse grained sediments derived from the rocks of the mountain ranges.

3.14.2 General Hydrology

White River drainage basin is a topographically and hydrologically open system. According to Eakin (1966), the alluvial basin lies within a regional ground-water flow system of fractured carbonate rocks of Paleozoic age. The potentiometric head within the regional flow system (represented by spring elevations around the margins of the basin) appears to maintain the high ground-water levels in the valley fill aquifer.

The White River provides the major surface water drainage for the basin. During the winter, surface water flows to about 15 miles (24 km) south of the Adams-McGill reservoir before being totally consumed by percolation into the river bed. During the summer, the river flows as far south as Lund in the northern end of the valley before it is depleted by irrigation diversions, evaporation, and infiltration (Maxey and Eakin, 1949). The major source of water for the river is from precipitation in the surrounding mountains.

Drawing B1-17 shows the potentiometric surface of ground water in the valley-fill deposits for the White River Valley. This interpretation is based on published water well information and measurements by Fugro National, FY 79. As shown, approximately 40 percent of the valley has water at less that 50 feet (15 m) beneath the land surface and, along the White River channel, the depth to water is commonly less that 10 feet (3 m). The potentiometric surface slopes to the south at an average gradient of about 11 feet per mile (2 m/km), indicating flow in that direction.

Recharge to the valley fill aquifer is from infiltration of precipiation and subsurface inflow from Long and Jakes valleys on the north. Infiltration occurs where intermittent streams leave the canyons in the mountain ranges and flow over the coarse grained and relatively permeable alluvial fans, and in the White River channel. Recharge by infiltration is estimated to be 38,000 acre-ft/yr (47 hm^3/yr) (Eakin, 1966). Recharge by underflow from Long and Jakes valleys through a regional carbonate aquifer is estimated to be 25,000 acre-ft/yr (31 hm^3/yr) (Eakin, 1966). Total recharge is therefore estimated to be 63,000 acre-ft/yr (78 hm^3/yr).

Discharge from the valley-fill aquifer is from evapotranspiration by phreatophytes, wells, springs, and subsurface outlfow. Discharge by evapotranspiration is estimated to be 13,000 acre-ft/yr (16 hm^3/yr) (Eakin, 1966). Discharge from wells, primarily for irrigation, is estimated to be 26,000 acre-ft/yr (32 hm^3/yr). Discharge from the valley-fill aquifer by springs is minor. The total discharge accounted for is 45,000 acre-ft/yr (56 hm^3/yr). The 18,000 acre-ft/yr (22 hm^3/yr) of recharge not accounted for is believed to be discharged by subsurface outflow to the regional carbonate aquifer.

There are twelve springs in White River Valley which may discharge from carbonate rocks with flow rates of 200 to 4000 gpm (13 to 252 l/s). These are not included in the water budget discussed above because the discharge is not from the valley-fill aquifer. Perennial yield is estimated to be 37,000 acre-ft/yr (46 hm^3/yr).

3.14.3 Aquifer Characteristics

The primary source of ground water within the White River Basin is the alluvium and river bed deposits which underlie the lowland. These aquifers consist of moderately to highly conductive sand and gravel deposits interbedded with silt and clay (Maxey and Eakin, 1949). Well yields of over 1000 gpm (63 l/s) are commonly obtained in these aquifers. The aquifers generally vary from 5 to 150 feet (15 to 46 m) in thickness, and wells rarely penetrate below a depth of 400 feet (122 m). The thickness of this aquifer varies significantly throughout the valley. Two wells, White Pine County Test Well 8N/62E-5D1) and Fugro National's Observation Well No. (8N/61E-27dc) in White River Valley were both drilled to a depth of 1300 feet (396 m). The White Pine County well log indicated the presence of the sand and gravel aquifer to a depth of 800 feet (244 m). The Fugro well, however, had only low permeability lacustrine deposits below about 430 feet and did not establish the existence of an intermediate aquifer at that location.

Aquifer (Pump) tests conducted in the valley-fill aquifers in White River Basin provided transmissivity values that ranged from about 10,000 gpd/ft (34.5 cm^2/sec) along the central valley axis to about 72,000 gpd/ft (248 cm^2/sec) in the coarser-grained valley-fill deposits nearer the valley margin.

All water-level data for the pump tests in White River Valley were collected at the test wells themselves; no observation wells were available to monitor water-level declines. Therefore, values for the storage coefficent could not be calulated from aquifer test data.

3.14.4 Water Quality Limitations

Fugro National personnel collected ground-water samples from 11 wells and 12 springs in White River Valley in 1979, as shown in Drawing D1-16. Using the water quality criteria listed in in Table Cl-1, none of the samples collected exceeded the established criteria. The spring samples were tested for total dissolved solid (TDS) concentrations, which ranged from 250 to 348 mg/l, with a mean value of 294 mg/l. This range of concentration represents good quality water.

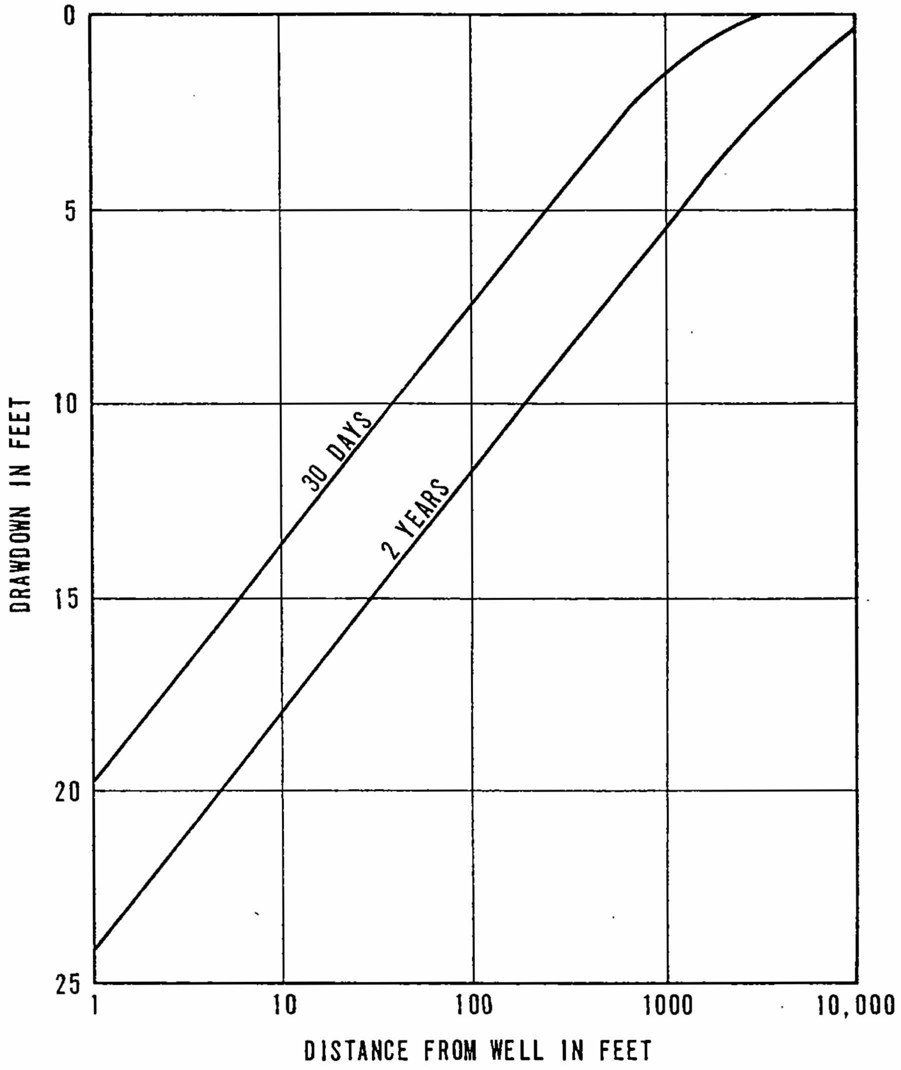
All spring waters were of the calcium/magnesium-bicarbonate type, indicating contact with and/or passage through carbonate rocks. The low TDS concentration indicates proximity to recharge areas. In general, TDS concentrations are fairly low (<300 mg/l) from springs and wells along the flanks of the valley but increase towards the central portion of the valley. Water from three of the springs located in the center of the valley, are classified as poor because they exceed the established limit for fluoride.

The well water samples had TDS concentrations ranging from 279 to 557 mg/l (Table Cl-16), which is considered good quality water. One 800 mg/l concentration was reported, but the analyses was considered questionable because the cation-anion milliequivalent balance differed by 50 percent and the mean was only 377 mg/l. All well waters except those from wells 11N/61Eac and 10N/61E-23 were of the calcium/magnesium-bicarbonate type, indicating some residence time in or passage through carbonate rocks.

4.0 POTENTIAL IMPACTS OF MX WATER RESOURCES DEVELOPMENT

This section discusses the potential impacts of MX ground-water withdrawals on the local water users, the environment and the aquifers in the 16 valleys studied to date. However, some general comments about impacts in the remainder of the siting area can be made. As discussed in Section 2.1, Water Availability, there are a few valleys in the siting area in which ground water is physically obtainable but the expected rate of MX withdrawals may exceed the estimated perennial yield. Figure 4 shows the estimated drawdown of the ground-water table, for a typical aquifer in the region, due to anticipated MX pumping rates of approximately 350 gpm (22.1 l/s). The drawdown is projected to range from approximately 25 feet (8 m) near the pumping well to about 1 foot at a distance of approximately 10,000 feet (3050 m). Also, it is expected that individual wells for MX withdrawals will be miles apart. Any undesirable effects of drawdown can largely be avoided through careful well placement. Thus, MX construction water withdrawals are not expected to have any significant impact on the aquifer(s), nearby water users, or the environment.

Several valleys in the siting area have been "designated" by the Nevada State Engineer as critical ground-water basins. These are Big Smoky, Lake, Ralston, Penoyer, Stone Cabin, and Steptoe valleys. The State Engineer may designate a basin when appropriations and/or ground-water use significantly exceed estimated perennial yield. The actual ground-water use is usually much



NOTE: DISTANCE VERSUS DRAWDOWN FOR A WELL DISCHARGING 350 GPM FROM AN AQUIFER WITH A TRANSMISSIVITY OF 30,000 GPD/FT AND A STORAGE COEFFICIENT OF 0.1 ASSUMES A FULLY PENETRATING WELL IN AN INFINITE, HOMOGENEOUS, ISOTROPIC AQUIFER WITH NO RECHARGE, AND SMALL DRAWDOWN RELATIVE TO AQUIFER THICKNESS

DISTANCE VERSUS DRAWDOWN FOR TYPICAL VALLEY FILL AQUIFER CONDITIONS

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

FIGURE
4

FUGRO NATIONAL, INC.

less than the water appropriated. Existing water rights may be available for lease during the construction period, thereby avoiding increased ground-water pumpage and detrimental effects in the valley.

4.1 BIG SMOKY VALLEY

The Nevada State Engineers Office has classifed Big Smoky Valley as a designated valley. This is because the current demand for and interest in developing ground water, as shown by applications for appropriation, significantly exceeds estimated perennial yield, and not because use exceeds perennial yield. Additional ground-water appropriations for MX needs may not be granted, and water rights would have to be purchased from current holders. In such cases there would be no effects on ground-water due to MX development over that which is currently allowed.

Aquifer studies indicated that in at least the western part of the valley the aquifer is capable of sustaining well yields of over 1000 gallons per minute. Accordingly, from a hydrological point of view, with proper well placement and design well, yields sufficient for MX water requirements could be attained in most parts of the valley with minimal impact.

4.2 CAVE VALLEY

The perennial yield in Cave Valley is estimated to be 2000 acre-ft/yr (2.5 hm^3/yr). Although ground water for MX construction needs is physically obtainable from the valley-fill aquifer, MX ground-water withdrawals could exceed the estimated perennial yield. However, current ground-water use in the valley is minimal and additional withdrawals are not expected to significantly affect the local water users. The springs in the valley are believed to be derived directly from precipitation and snowmelt due to the seasonal fluctuations in discharge, indicated by the differences in reported measurements (Eakin, 1962) and Fugro National, discussed in Section 3.2. Thus ground-water withdrawals from the valley fill aquifer are unlikely to affect spring discharge in Cave Valley. The only forseeable impact of MX ground-water withdrawals is the probable water-level decline in the vicinity of the MX construction wells. Drilling and aquifer testing in Cave Valley planned by Fugro National will yield valuable additional information about aquifer characteristics.

4.3 DRY LAKE/DELAMAR VALLEY

Considering that less than 3000 acre-ft/yr (3.7 hm^3/yr) of water are estimated to be needed for construction and the minimal current ground-water use in the valleys, the reported annual perennial yield of 6000 acre-ft (7.4 hm^3) is more than adequate to supply MX needs.

If all 6000 acre-ft (7.4 hm^3) were extracted annually, the result would be an overall lowering of the basin ground-water level by less than one-tenth foot (assuming an average specific yield of 0.1 and no recharge). Taking into consideration the hydraulic conditions found in the Dry Lake test well it is expected that with a pumping rate of 500 gpm (31 l/s) for a period of two years, only about 9 feet of drawdown would be realized at a radius of 1 mile from the pumped well assuming partial penetration of the valley-fill aquifer. At the cessation of pumping, water levels would rapidly return to nearly pre-pumping levels in a few weeks and completely recover in a few months. Thus, water supply wells for MX can easily be positioned throughout the basin so that there is little, if any, impact on existing wells,the aquifer, or the environment.

4.4 DUGWAY VALLEY

Competing uses of ground water in Dugway Valley are a few stock watering wells used mostly for watering sheep. There are no permanent inhabitants in the part of the valley being considered for MX development.

No estimate of perennial yield has been made by the Utah State Engineer. However, discharge from the valley which could be salvaged in part without undesirable effects include 8000 acre-ft/yr (9.9 hm^3/yr) from subsurface outflow to the Great Salt Lake Desert, and 3500 acre-ft/yr (4.3 hm^3/yr) by evapotranspiration from springs and phreatophytes. Current plans call for MX development to use only about 2500 acre-ft/yr (3.1 hm^3/yr) during a short construction period. Therefore, withdrawals can be planned in a way so as to have negligable impacts on present users, the aquifer, and the environment in the valley.

4.5 FISH SPRINGS FLAT

In Fish Springs Flat the only competing water users are for stock and culinary use from low-discharge wells at the Fish

Springs Ranger Station and Brush-Wellman Mine. Available evidence indicates that the springs on the west side of the valley, including the Fish Springs group, are not supplied from the valley-fill aquifer, and are therefore not considered to be competing users for that aquifer. Based on the assumption that the valley-fill aquifer has a specific yield of 0.1, a total withdrawal of 5000 acre-ft (6.2 hm^3) for construction from an aquifer having an area of 500 mi^2 (1295 km^2) would create a total average drawdown of only about 0.1 foot (.03 m). There will be areas of greater drawdown near pumping wells, of course, but this value gives an indication of the average magnitude of MX-related withdrawals throughout the valley with proper well placement and monitoring. Ground-water withdrawals are not expected to have any significanr impact on existing water users, the aquifer(s), or the environment.

There has been no estimate of perennial yield. However, the phreatophytes consumption of water is about 8000 acre-ft/yr (9.9 hm^3/yr) which could be considered a conservative measurement of the perennial yield. In part, the phreatophyte consumption and any outflow to the Great Salt Lake Desert could probably be easily extracted without any apparent undesirable environmental effects. The quality of ground water from the valley-fill aquifer exceeds drinking water criteria.

4.6 LITTLE SMOKY VALLEY

Current development consists of the Fish Creek Springs Ranch, which owns many of the small capacity stock wells and western springs, and other smaller ranches, located at the northern end of the valley, who have wells capable of yielding greater than 1000 gpm (63 l/s). The majority of water supplies of the 30 or so ranchers and farmers who work and live in Little Smoky Valley is utilized during the late spring and summer growing season. The presence of large capacity wells [1000 gpm (63 l/s)] in the valley indicates that the aquifer has sufficient transmissivity to sustain withdrawals to meet the MX needs during the construction period. Long-term withdrawals, however, could lower the water table locally and could capture some of the existing natural discharge in this valley. Lowering the ground-water level may result in increasing the amount of water available by reducing the rate of evapotranspiration. MX-related ground-water withdrawals in Little Smoky Valley probably would not significantly affect the availability of water for present users nor impact the aquifer or the environment.

4.7 PINE VALLEY

Current users of water in Pine Valley are the Desert Range Experiment Station (domestic use only) a few low-discharge stock watering wells, and the Pine Grove Associates wells. Pine Grove Associates has appropriated water rights, but is presently using only a small part of that appropriation as mining operations and the resulting water withdrawals have not yet begun. The springs in the mountains are used for stock watering but are not considered to be competing water users because the springs are believed to be supplied from the regional carbonate aquifer or from perched aquifers which are not likely to be affected by

MX-related withdrawals from the valley-fill aquifer. Because the competing users are located in only a few widely scattered places, it should be possible to locate wells which will have minimal drawdown effects on the existing wells, although the exact drawdown cannot be computed with the information currently available. Based on the assumptions that total water use for construction will be about 5000 acre-ft (6.2 hm^3) and the aquifer is phreatic and has a specific yield of 0.1 and excluding recharge, the average lowering of the water well over the entire valley will average about 0.1 feet (3 cm). Near the pumping wells, the drawdown will likely be 10 to 20 feet but this gives an idea of the magnitude of the average effects of MX development. Withdrawal of ground water for the MX construction water is not expected to have a significant impact on water users, the aquifer(s), or the environment.

4.8 RAILROAD VALLEY

Competing users in Railroad Valley are for irrigation, stock watering, and domestic uses of ground water from wells and springs. Water discharged by Duckwater and Blue Eagle Springs is believed to be from a regional aquifer system (Mifflin, 1968) and is therefore considered not affected by potential MX-related ground-water development from the valley-fill aquifer. Total water use amounts to about 13,500 acre-ft/yr (16.6 hm^3/yr), nearly all of which is for irrigation (Van Denburgh and Rush, 1974). The perennial yield is estimated at 75,000 acre-ft/yr (92.5 hm^3/yr) (Van Denburgh and Rush, 1974). The difference, 61,500 acre-ft/yr (75.8 hm^3/yr), is the quantity of water which could be salvaged for beneficial use without undesirable results. This quantity far exceeds the quantity of water needed for MX construction. The construction water wells could be sited far enough from areas of current pumping to minimize drawdown effects at those areas. Withdrawals are not expected to significantly impact other water users, the aquifer, or the environment.

4.9 SEVIER DESERT

The present rate of withdrawal of ground water in the Sevier Desert greatly exceeds the estimated perennial yield. The majority of the ground-water withdrawal occurs in the east-central part that is in the Delta-Lynndyl-Oak City area, where the depths to water are shallow and the water quality better than the surrounding area. If additional development of ground water for an Operating Base would occur, then it is likely that water level declines in the area would be accelerated. Mower and Feltis (1968) pointed out that a decrease in water quality would also occur in the area.

It may be possible to obtain an Operating Base water supply through the purchase of existing surface or ground-water rights or a combination of both. However, the Director of the Utah Division of Water Rights had indicated that this may not be an acceptable means of obtaining water in the Delta area (Dee Hansen, Personal Communication, 8 April 1980). It was pointed out by the Director that the additional purchase of water rights in an area where the Intermountain Power Project has already purchased a significant amount [48,000 acre-ft/yr (59.2 hm^3/yr)] may cause too many farms to cease operation, resulting in a detrimental effect on the local economy and life style. If water can be obtained through the purchase of existing irrigation water rights and the irrigated land is retired from agriculture, then MX water requirements for an Operating Base or construction could be withdrawn without an effect on other existing water users, the aquifer(s), or the environment. Under such use, it is likely that the total dissolved solids concentration in the ground-water would decline as the leaching action of irrigation water will have been decreased.

From a hydrological point of view and judging by the extensive agricultural development in the Delta area, it is likely that well yields in excess of 1000 gpm (63 l/s) could be obtained through proper well placement and design.

4.10 SNAKE/HAMLIN VALLEY

The estimated perennial yield in Snake and Hamlin valleys [32,000 to 80,000 acre-ft (39.5 to 98.6 hm^3)] is considerably larger than present beneficial use which is estimated by Fugro to be 14,000 acre-ft/yr (17.2 hm^3/yr). Any reasonable amount of water required for construction and operation of MX could be withdrawn in such a way that most of the impact would be on natural evapotranspiration losses or on outflow to the Great Salt Lake Desert or to the east, neither of which appear to have significant value to local users.

A numerical model (Trescott et al., 1976) developed for this study simulates the hydrological conditions in Snake Valley. The model assumes that seven production wells would be located within the valley to meet MX construction requirements. Pumping rates were estimated at 350 gpm (22.1 l/s) per well for total annual withdrawal rate of 3953 acre-ft (4.9 hm^3). The most representative simulation of the valley condition used recharge rates as given by Hood and Rush (1965), transmissivities ranging between 7000 and 76,000 gpd/ft, and a storage coefficient of 0.00001 for conservatism (Section 3.10.3). The resultant drawdowns ranged between 0.1 feet (0.03 m) and 4.3 feet (1.3 m) after five years of pumping. The results indicate that MX construction withdrawals would not significantly impact other water users, the aquifer(s), or the environment.

4.11 TULE VALLEY

Current development consists only of several small reservoirs that intercept local runoff and several small-capacity stock wells [approximately 1 gpm (.63 l/s) discharge]. MX groundwater withdrawals would probably not affect the surface reservoirs. Also, because existing stock-water wells are situated at a minimum of 10 miles (16 km) apart, spacing of wells for MX withdrawals could be designed to avoid significantly lowering the water table at existing wells.

Long-term withdrawals could lower the water table locally and could capture some of the existing natural discharge in this valley. As stated in Section 2.11.2, an annual discharge of

40,000 acre-ft (49 hm^3) has been estimated from rates of transpiration by phreatophytes and evaporation from unvegetated playas. Much of this water could be salvaged for beneficial use by lowering the water table beyond the reach of the roots of the phreatophytes. However, MX water withdrawals for construction activities in Tule Valley is much less than the above discharge quantity. Based on the assumption that the valley-fill aquifer has a specific yield of 0.1, and that total withdrawals will be about 5000 acre-ft (6.2 hm^3), then the drawdown averaged over the whole valley will be about 0.1 feet. There will, or course, be areas with greater drawdowns, but the average gives an indication of the overall drawdown for MX water needs.

4.12 WAH WAH VALLEY

There appears to be sufficient water available for MX development in Wah Wah Valley. However, wells will have to be deep [possibly up to 1000 feet (305 m)] to have sufficient yield. The only competing use will be the Earth Science wells and the one stock well at the north end of the valley. There is no present mining activity by Earth Science and thus no water use; however, their appropriations will have to be considered in planning a well system for the MX project.

Due to the localized nature of the competing users, it should be possible to design a well system to supply MX-construction needs without impacting these water users. The hydrologic conditions here are closely related to those in Tule Valley. Accordingly, based on the assumption that MX-construction withdrawals will be from valley-fill aquifers with a specific yield of 0.1, and that total withdrawal will be 5000 acre-ft (6.2 hm^3) over a two-year period, then the drawdown averaged over the valley will be on the order of 0.1 feet. There will be areas of greater drawdown near the MX pumping wells of about 25 feet (8 m) but this average gives an indication of the magnitude of MX-related effects. Withdrawing ground water for MX construction is not expected to significantly impact other water users, the aquifer(s), or the environment.

4.13 WHIRLWIND VALLEY

As stated in Section 3.13.2, the Whirlwind Valley ground-water system receives its recharge partly from nearby House Range as infiltration from precipitation and snowmelt and partly by underflow from the Sevier Desert ground-water system.

Recharge from the House Range, however, is probably small due to the limited recharge zone in the narrow range. Not much is known about the quantitative aspect of the ground-water underflow from Sevier Desert toward Whirlwind ground-water reservoir. Because MX-construction withdrawals are short term, a significant impact on the quality of the ground water in the valley is not expected to occur, although close monitoring of the quality is advisable.

Due to the localized nature of the competing users, it should be possible to design a well system to supply MX-construction needs without impacting these users. Withdrawing ground water for MX construction is not expected to significantly affect water levels except near the MX pumping wells. The planned drilling and testing program in Whirlwind Valley by Fugro National will provide valuable additional information about aquifer characteristics and water-quality conditions.

4.14 WHITE RIVER VALLEY

Preliminary perennial yield and consumptive use estimates indicate that the amount of ground water available in White River Valley is sufficient for MX construction needs. However, measurement of ground-water levels made during the Verification and Water Resources programs indicated that a localized water-level decline of over 10 feet as a probable result of agricultural activities has occurred since 1947 in some portions of the northern valley.

To predict the impacts of MX ground-water withdrawals from the valley fill a numerical model was used (Trescott el al., 1976). The numerical simulation of White River Valley used two different pumping plans for the two-year MX construction period. The first plan assumed that 14 wells would be constructed with each pumping 150 gpm (9.5 l/s) for a total withdrawal of about 3400 acre-ft/yr (4.2 hm^3/yr). The predicted drawdown of ground-water levels was only 1 foot (0.3 m) at a distance of 1 mile (1.6 km) from the pumping wells. The second plan assumed that only six wells would be constructed with each pumping 350 gpm (22 l/s) for a total withdrawal of about 3400 acre-ft/yr (4.2 hm^3/yr). The drawdown for this plan was 5 to 10 feet

(1.5 to 3 m) at the pumping well for the two-year construction period but the cone of depression at each well extends to only about 1 mile.

Moon River Spring, one of the principal springs in White River Valley, was selected to show the impacts from additional groundwater withdrawals for the MX project. The drawdown at Moon River Spring is neglible assuming a realistic storage coefficient of 0.1 (unconfined system) and a transmissivities ranging from 5000 to 10,000 gpd/ft (7.2 to 14.4 cm^2/sec). This indicates that withdrawing ground water for MX construction is unlikely to cause significant effects on the local water users, the aquifer(s), or the environment, assuming proper well-field design.

4.15 MUNICIPAL WATER-SUPPLY AND WASTEWATER-TREATMENT SYSTEM

The present capacity of municipal water-supply and wastewater treatment systems and their capacity to expand were investigated under subcontracts to the Desert Research Institute (DRI) in Nevada and the Utah Water Resource Laboratory (UWRL) in Utah. Their reports are included as Appendices K1-0 and L1-0. The results of the reports are summarized in Tables 3, 4, 5, and 6. There are 11 water-supply systems and 11 wastewater-treatment systems in the Nevada part of the siting study area that serve a total population of about 15,000, ranging in size from 400 in Eureka, Goldfield, and Lander County, to 6000 in Ely. Water sources for the water-supply system are wells and springs with one surface water source in Duck Creek which is used by McGill. There are five water-supply systems and five wastewater systems in the Utah study area that serve a total of about 18,000 people and range in size from 60 people in Garrison to 13,000 in Cedar City. The water sources in the Utah water-supply systems are wells and springs.

The conclusions arrived at by DRI in Nevada and UWRL in Utah, generally, are that significant capital expenditures will have to be made to accommodate water-supply and wastewater-treatment requirements of MX-related population growth. Many of the water-supply systems and wastewater-treatment systems do not now meet legal requirements. The wastewater systems can be improved and expanded if funding can be obtained. The water-supply systems are expandable given proper funding, but in some cases water rights are not available by appropriation and will have to be purchased from existing water users.

4.16 INDUSTRIAL ACTIVITIES IN UTAH

The industry activity inventory was conducted for Fugro National by the Utah Water Research Laboratory and covers only the Utah portion of the siting area. The study is in preliminary stages and a complete report will be presented at a later date. The industry activity in the Nevada portion of the siting area is being conducted by the Desert Research Institute.

The MX project could cause local impact on or be impacted by industrial activity in the Utah area. It is also possible that the MX project may interact favorably with industry. If industrial activity is initiated at the same time as MX construction, such as the proposed molybdenum and alunite mining operations in Pine and Wah Wah valleys, respectively, competition for ground water could result in the perennial yield to be exceeded during the possible one to two year construction period. This would probably cause local and temporary drawdown of the groundwater levels where withdrawals are concentrated. It may also be possible for the MX project to lease ground water from industrial concerns where unused ground water is available, and thereby allowing the industry to recover some of the costs of groundwater development for their operation.

The industries currently active in the MX siting area in Utah are mining, agriculture, grazing, electric power generation and recreation. Irrigated agriculture is by far the largest water user, with an estimated annual use of 400,000 to 600,000 acre-ft/yr (493 to 740 hm^3/yr). Most of this use, however, is concentrated in the Sevier and Escalante deserts, on the margins of the siting area. Grazing accounts for approximately 1400 acre-ft/yr (1.7 hm^3/yr). If electric power generation is developed to its fullest potential (four plants totaling 13,300 MWe, based on air quality criteria), water use for this purpose would be 144,000 acre-ft/yr (178 hm^3/yr). Geothermal energy development is not expected to compete for water with the MX project because the project potential for increase is about 50 MWe, with no water use over what is already being naturally discharged.

Ground water for recreational use is small and is estimated at 50 to 100 acre-ft/yr (.06 to 0.1 hm^3/yr).

5.0 MITIGATING MEASURES

The mitigating measures discussed in the following sections are for the 16 valleys investigated to date as part of the MX Water Resources program. An in-depth evaluation has not been conducted for the remaining 15 valleys intended for study by the end of FY 80. However, many of the mitigating measures for the effects of MX ground-water withdrawals discussed in the following sections may generally apply to other valleys not discussed here.

5.1 BIG SMOKY VALLEY

Big Smoky Valley is a "designated" ground-water basin and the surface and ground water is fully appropriated. As further ground-water withdrawals may not be approved by the State Engineer's Office, water supplies for the MX project would have to be obtained through purchases or lease from existing water users. After construction is completed, water withdrawals in the valley would return to their original use.

If the State Engineer's Office allows further ground-water withdrawals for the possible one to two year construction period, MX water supply wells would be located a sufficient distance away from existing wells and springs to largely avoid interference effects that may significantly lower water levels in wells and alter spring discharge. The springs in the valley are believed to be regional or meteoric in nature as discussed in Section 3.1 and pumping in the valley-fill aquifer is not expected to alter their discharge. The appropriate distance would be determined through field testing. A system of water level, spring discharge, and water quality monitoring stations would be established and monitored during construction to provide early detection of potential changes in the ground-water system. This information would be input to a computer model of the ground-water system to project the effects on the local water users and the environment.

Detrimental effects may be mitigated through monetary compensation in non-environmental instances, such as an increase in pumping lifts causing increased power and maintenance costs. The detection of decreasing discharge at a spring which harbors protected or endangered species if any, would likely necessitate the reduction or alteration of pumping patterns in that area. If this proved unsatisfactory, water for construction would then be best obtained through possible lease agreements with existing water users at an appropriate distance from the affected area. It may also be possible to reduce the rate of construction in the valley and thereby reduce the rate of ground-water withdrawals.

5.2 CAVE VALLEY

The current ground-water use in Cave Valley is minimal and is primarily located in the northern portion of the valley. Detrimental effects on those few water users in the valley would be avoided through proper well field design. The springs in Cave Valley are believed to be derived from precipitation and snowmelt as discussed in Section 3.2 and are unlikely to be affected by MX withdrawals from the valley-fill aquifer. Ground-water wells for MX construction would be located in the central or southern portions of the valley to avoid possible interference effects from pumping. If a significant lowering of the water table should occur, monetary reimbursement would provide one form of mitigation. If ground water available for stock watering should diminish, the Air Force could provide the needed water from construction water supplies. A significant reduction in discharge of springs that harbor protected or endangered species, if any, would require alteration of ground-water withdrawals in the vicinity of the affected area. If spring discharge continued to diminish, water for construction would possibly be obtained through other sources.

Development of the valley-fill aquifer in Cave Valley is the optimum source of MX construction water. An alternate source of water for construction is the possible importation from White River Valley to the west where ground water is more plentiful. Also, there is potential for development of the deep carbonate aquifer. Another solution might be to reduce the rate of construction in the valley to reduce the rate of ground-water withdrawals.

5.3 DRY LAKE/DELAMAR VALLEY

Water use in Dry Lake and Delamar valleys is limited to livestock watering ponds fed either by snowmelt and precipitation runoff or small discharge (<20 gpm) wells. Through careful well field design, significant lowering of the water table in stock water wells would largely be avoided. The Air Force could also provide construction water for livestock should any detrimental effects occur.

The few springs that occur in the valley are widely separated, of very small discharge, and are not believed to be derived from the valley-fill aquifer as discussed in Section 3.3. Detrimental effects of MX ground water withdrawals from the valley-fill aquifer, therefore, are unlikely. A system of ground-water and spring monitoring stations would be established and monitored during construction to provide early detection of potential changes in the ground-water system due to MX withdrawals. This information would be input to a computer model of the ground-water system to project the effects on the local water users and the environment. If it becomes necessary, there is potential for development of the carbonate aquifer in this area as an alternate to the valley-fill aquifer which is the most likely source of water for MX construction.

5.4 DUGWAY VALLEY

Existing ground-water withdrawals in Dugway Valley are minimal and careful well field design would minimize or largely avoid possible deterimental effects of MX ground-water withdrawals on the few water users that are present in the valley. A system of ground-water level, spring discharge, and water quality monitoring stations would be established and monitored during construction to detect potential changes in the ground-water system. This information would be input to a computer model of the ground-water system to project the effects on the local water users and the environment. If detrimental effects are detected, pumping patterns from wells in proximity to the affected area would be adjusted. Also, the Air Force could provide compensation, depending on the type of effect, in the form of monetary reimbursement for finanacial losses, or ground water for stock watering ponds from construction wells.

The valley-fill aquifer is the most likely source of water for MX construction. An alternate source of water for MX construction in Dugway Valley would be provided through import of ground water from Fish Springs Flat where it is more plentiful.

5.5 FISH SPRINGS FLAT

Existing water use in the valley is minimal and most of the springs in the valley are believed to be fed by carbonate aquifers which are part of the regional ground-water system. Through well field design and development of the valley-fill aquifer, significant water level declines in existing wells and alteration of spring discharges would largely be avoided. Ground-water wells for MX construction should be located a considerable distance from the wildlife refuge in the northwest portion of the valley to avoid possible interference effects with refuge spring discharges. A system of ground-water level, spring discharge, and water quality monitoring stations would be established and monitored to detect potential changes in the ground-water system. This information would be input to a computer model of the ground-water system to project the effects on the local water users and the environment.

The valley-fill aquifer is the most likely source of water for MX construction. An alternate source of water for construction in the valley, if necessary, could come from importation of water from Snake Valley to the west where ground water is also plentiful.

5.6 LITTLE SMOKY VALLEY

Current ground-water use in Little Smoky Valley is concentrated in the northeastern portion of the valley. MX ground-water withdrawals would be concentrated in the central and southern portions of the valley to largely avoid possible well interference effects and significant lowering of the ground-water table in the irrigation and stock watering wells in the northeast portion of the valley. Drawdown of the ground-water level in wells in other parts of the valley would largely be avoided through careful MX construction well placement.

A system of monitoring stations would be established and monitored in the valley to provide early detection of potential water level, spring discharge, and water quality changes that may develop from MX ground-water withdrawals. This information would be input to a computer model of the ground-water system to project the effects on the local water users and the environment.

The valley-fill aquifer is the most likely source of water for MX construction. An alternate source of construction water could be the lease of existing ground-water rights from current users in the valley for the possible one to two year construction period. This alternative water source could be employed if significant water level declines or spring discharge reductions were detected during construction.

5.7 PINE VALLEY

There is very little current ground-water use in Pine Valley. However, an investigation of ground-water supplies for a possible molybdenum mine in the southern portion of the valley is presently (May 1980) being conducted. Also, the Desert Range Experiment Station occupies the northwestern portion of the valley. A well field for MX construction requirements would be limited to the eastern and central portions of the valley should the possible mining operation be initiated. This would diminish the possibility of significantly drawing down the water levels in the pumping wells for the mining operation or the small capacity wells (<50 gpm) at the Desert Range Experiment Station.

The valley-fill aquifer is the most likely source of water for MX construction. An alternative source of construction water could come from the possible short term (one- to two-year) lease of a portion of the water rights for the molybdenum mining operation in the southern portion of the valley. There may also be some potential for development of the deep carbonate aquifer in this area as an alternate source of construction water, if necessary. The potential for development of the carbonate aquifer requires further evaluation of local and regional structure.

5.8 RAILROAD VALLEY

The ground-water use in Railroad Valley is concentrated in the east-central portion around the town of Nyala where irrigation for cropland occurs. There is also a large wildlife refuge in the central portion of the valley that receives water through springs, and extensive oil field operations in the northern portion of the valley. Through concentration of MX construction wells in the western and southern portions of Railroad Valley, significant drawdown of water levels in irrigation wells and reduction of spring discharge would likely be avoided.

A system of monitoring stations within the valley would be established and monitored during construction to provide early detection of potential water level, water quality, and spring discharge changes as a result of MX ground-water withdrawals. This information would be input to a computer model of the ground-water system to project the effects on the local water users and the environment. If the pumping lifts of irrigation wells are increased significantly resulting in increased power and maintenance costs the Air Force could provide monetary compensation. Significant reduction of spring(s) discharge could be corrected by the alteration of pumping patterns from construction wells in close proximity to the spring(s). Reduction of stock watering well yields could be mitigated by Air Force providing water for stock from construction wells.

The valley-fill aquifer is the most likely source of water for MX construction. An alternative source of water for MX construction in Railroad Valley could come through the possible lease of existing water rights from current water users for the possibly one to two year construction period. Water obtained in this manner would not increase the amount of current groundwater withdrawals from the valley.

5.9 SEVIER DESERT

All the surface and ground water in the Sevier Desert is appropriated and under current use. It is unlikely that further ground-water withdrawals would be approved by the Utah State Engineer's Office. Water for the likely one-to two-year construction period would be obtained through possible lease of existing water rights from current water users. Water obtained in this manner would not increase the amount of current groundwater withdrawals from the basin.

5.10 SNAKE/HAMLIN VALLEY

Current water use in Snake and Hamlin valleys is centered around the towns of Baker and Garrison in southern Snake Valley or northern Hamlin Valley. Other water uses are for stock watering ponds which are widely scattered over the valleys. Through concentration of MX construction wells away from these areas, potential detrimental effects would largely be avoided. Similar considerations in well field design would be applied to the numerous springs in Snake Valley to largely avoid a significant reduction in spring discharge.

A system of monitoring stations within the valley would be established and monitored during construction to provide early detection of potential water level, spring discharge, and water quality changes as a result of MX ground-water withdrawals. This information would be input to a computer model of the ground-water system to project the effects on the local water users and the environment. Should significant changes in the ground-water system be detected, the pumping pattern of wells in close proximity to the affected area would be altered, if necessary. In the event that MX ground-water withdrawals cause a significant reduction in stock water well yields and increased costs for irrigation due greater pumping lift, compensation could be provided or through monetary reimbursement for greater power and maintenance costs.

The valley-fill aquifer is the most likely source of water for MX construction. It is possible, however that the existing water rights of current water users could be leased for the duration of the construction period. Water obtained in this manner would not increase the amount of current ground-water withdrawals from the valley. Another potential source of water in the Snake and Hamlin valleys area is from possible deep carbonate aquifers that may lie beneath the valley. Further investigation of this water source would be necessary to determine its viability for development.

5.11 TULE VALLEY

Current water use in Tule Valley is minimal and is concentrated in the north-central portion. Through proper well field design detrimental effects on existing water users and the environment would largely be avoided or minimized. To ensure minimal effects on local water users and the environment, a system of monitoring stations within the valley would be established and monitored to provide early detection of potential ground-water level, spring discharge and water quality changes due to MX ground-water withdrawals. This information would be input to a computer model of the ground-water system to project the effects on the local water users and the environment. Should significant changes in the ground-water system be detected, the pumping patterns in well in close proximity to the affected area would be altered. If this proved unsatisfactory, compensation by the Air Force could be made through monetary reimbursement for possible increased power and maintenance costs or through supplying water for stock ponds, whichever is applicable. If it became necessary to cease all ground-water withdrawals in the valley, a possible alternative source of ground water could come by importation from Snake Valley to the west where ground water is more plentiful. It may also be possible to reduce the rate of construction in Tule Valley and thereby reduce the rate of ground-water withdrawal to a level that would cause no detrimental effects on the ground-water system.

5.12 WAH WAH VALLEY

There is very little current water use in Wah Wah Valley. However, there is a potential for development of an alunite resource in the southern portion of the valley. If the alunite is developed it would be necessary for the Air Force to concentrate their water withdrawals in the northern two-thirds of the valley. Proper location of construction wells would largely avoid detrimental effects on local water users and the environment. To ensure minimal effects on the local water users and the environment, a system of monitoring stations within the valley would be established and monitored to provide early detection of potential changes in ground-water levels, spring discharge and water quality due to MX ground-water withdrawals. If significant changes in the ground-water system are detected, the ground-water withdrawals in close proximity to the affected area would be altered. If this proved unsatisfactory, compensation by the Air Force could be made. It may also be possible, if necessary, to reduce the rate of construction in Wah Wah Valley and thereby reduce the rate of ground-water withdrawal to a level that would cause little or no detrimental effects to the ground-water system.

The most likely source of water for MX construction in Wah Wah Valley is the valley-fill aquifer. As an alternate source of water, there may be some potential for development of the possible carbonate aquifer.

5.13 WHIRLWIND VALLEY

There is minimal current ground-water use in Whirlwind Valley. Water use is confined to a few isolated stock watering ponds or reservoirs. Through proper well field design the likelihood of lowering the ground-water table in existing wells, or reducing the discharge of springs would be diminished. However, to ensure minimal effects on the local water users and the environment, a system of monitoring stations within the valley would be established and monitored to provide early detection of potential changes in ground-water levels, spring discharge, and water quality due to MX ground-water withdrawals. A computer model of the ground-water system would assist in the projection of the effects.

If significant changes in the ground-water system are detected, the pumping patter in wells in close proximity to the affected area would be altered. If this proved unsatisfactory, the Air Force could provide compensation. It may also be possible to bring water for construction into the valley from Fish Springs Flat where ground water is more plentiful. Another alternative is to reduce the rate of ground-water withdrawal through a reduction in the construction rate of the clusters.

5.14 WHITE RIVER VALLEY

Current water use in White River Valley is concentrated in the northern portion around the towns of Lund and Preston and to a lesser extent in the eastern portion along State Highway 38. Also, the Wayne Kirch Wildlife Refuge is located in the southeastern portion of the valley. MX construction wells would be located in the central and western portions of the valley to avoid possible interference effects and the significant lowering of ground-water levels in existing wells or the alteration of spring discharge. To ensure minimal effects on the local water users and the wildlife refuge, a system of monitoring stations within the valley would be established and monitored to provide early detection of changes in ground-water levels, spring discharges, and water quality due to MX ground-water withdrawals. The computer model of the White River ground-water system that Fugro National has developed would be utilized during construction to project the effects of MX withdrawals as part of the monitoring system. If changes are detected, the pumping pattern in wells in proximity to the affected area would be altered. If this proved unsatisfactory, in the case of existing wells, the water users could be compensated for their losses by the Air Force. If the wildlife refuge and springs that may harbor endangered species are threatened, it may be necessary to cease most or all Air Force ground-water withdrawals and utilize other sources of water for construction.

An alternative source of water for construction could possibly come from the lease of existing water rights of current water users, such as in the Lund-Preston area, for the possible one- to two-year construction period in the valley. Water obtained in this manner would not increase the quantity of existing ground-water withdrawals in the valley. Another potential source of water supply for the MX project in the White River

Valley is development of the carbonate aquifer, but testing and evaluation would be necessary to determine whether this is a viable alternative. It is also possible to reduce the rate of construction in the valley to a level where the rate of groundwater withdrawal is reduced sufficiently to eliminate detrimental effects on the environment or local water users.

6.0 OFFSETTING CONSIDERATIONS

The MX Water Resources program has included extensive field investigations over broad areas of central Nevada and western Utah. Several benefits to Nevada and Utah occur as a result of the MX project.

- An extensive and current data base of water levels, spring discharge, and water quality has been developed for potential future evaluation of ground water resources in a broad region across central Nevada and western Utah.
- Aquifer characteristics and the potential for further ground-water development in valleys with little or no data has been provided through a costly drilling and testing program that may otherwise not have been conducted.
- Increased knowledge of regional ground-water flow systems.
- Increased understanding of the potential for development of the deep carbonate aquifers.
- Extensive well fields that could provide a large quantity of ground water for range management, irrigation and other beneficial uses.
- Increased knowledge of the potential for ground-water resource development in arid and semiarid areas of the western U.S.

7.0 UNRESOLVED ISSUES

7.1 LOCATION OF MX DEPLOYMENT

The valleys in which the MX system will be deployed and the location of the operating bases have not yet been precisely decided although preferred areas have been indicated. The number of clusters, the duration of construction in each valley and the location of batch or pre-cast plants has not been finalized. This all affects where the water will be needed and the specific quantities required for construction in each valley. For the purposes of this report the estimated maximum potential water withdrawals for each valley (Section 2.1) was used for assessment of the potential impacts of the MX project on the ground-water resources of the area.

7.2 CHARACTERISTICS OF CARBONATE AQUIFERS

Several regional ground-water flow systems within the siting area have been delineated on the basis of variations in topography, geology, ground-water potentiometric surfaces and flow directions, water budget imbalances, and water chemistry trends. These flow systems link many valleys through deep carbonate aquifers. The impact of ground-water development in one valley on the ground-water system in an adjacent valley is largely conjectural and no precise data have been established heretofore.

The water transfer characteristics between valley fill aquifers and carbonate aquifers is also undetermined. It is believed that ground water from the valley fill aquifer leaks into the carbonate aquifer, but pumping of ground water in the valley fill aquifer will reduce the amount of water in storage and change flow directions which may result in reduction of recharge to the carbonate aquifer. Further, the quality of the water in the carbonate aquifers is not fully known and the aquifer's viability as a source of water for the MX project needs further study.

In order to evaluate the impact of ground-water withdrawal from the deep carbonate aquifer, Fugro National will construct and test a deep carbonate well in FY 80. It is anticipated that this well will provide valuable information about the viability of carbonate aquifers as a source of water for the MX project, and the impacts of withdrawals from carbonate aquifers on a regional basis as well as on adjacent springs and the valley-fill aquifers.

7.3 WASTEWATER TREATMENT

The type of wastewater treatment and treatment facilities to be employed during construction and operational phases of the MX project has not been determined. The type of treatment required will be guided by state requirements for quality criteria for recharge effluent to the valley ground-water systems.

7.4 GROUND-WATER AND SPRING MONITORING SYSTEM

A network of monitoring stations could be established within each valley to provide early detection of changes in ground-water levels, spring discharges, and water quality due to MX ground-water withdrawals. A decision to deploy such a monitoring system has not been made. Also, the precise locations and parameters to be monitored have not been determined, but would be developed in cooperation with state and federal agencies.

7.5 POTENTIAL FOR SHEAR FAILURE

The potential for shear failure and/or ground-surface subsidence due to MX ground-water withdrawals during construction has not been studied as of this report date. To date (15 May 1980), Fugro National knows of no documented cases of shear failure due to ground-water withdrawal in the study area. However, there are several unexplained features that have been observed on aerial photographs that could be related to subsidence.

LOCATION	POPULATION ESTIMATE SERVED	QUALITY	SOURCE	ADEQUACY	MAXIMUM POPULATION*	IMPROVEMENTS REQUIRED TO SERVE MAXIMUM POPULATION ESTIMATES
EUREKA COUNTY						
Eureka Water Assn. Eureka	400	Meets Public Health Standards - color, taste, turbidity problems	3 wells several springs	System inadequate to meet current level of demand due to inadequate storage	800	The system production capability at 200 gpm (12.6 L/S) could serve 800 persons. The system storage would need to be significantly increased and the replacement and expansion of the distribution system are required.
ESMERALDA COUNTY						
Goldfield Town Supply	400	Meets Public Health Standards	1 well 1 spring	Inadequate to meet current level of demand. System upgrade active	1500	The maximum population the Goldfield supply could support is based on the new well having a reliable capacity of 400 gpm (25 L/S) and expansion and replacement of the distribution system.
LANDER COUNTY						
Lander County Sewer & Water Dist. No. 2	400	Meets Public Health Standards	3 wells 2 springs	Inadequate to meet current demands during drought periods	600	Under normal hydrologic conditions the town supply system could serve approximately 200 additional people. The supply would not be adequate during dry years. Any further expansion would require sources from the Reese River Valley to be developed and pumped up to Austin.
LINCOLN COUNTY						
Alamo Farmstead Assn.	900	Meets Public Health Standards	4 wells	Inadequate to reliably meet present demands. System upgrade active. Distribution system deteriorated.	2400	The existing system is inadequate to meet present levels of demand. The system upgrade is based on the current population, but the potential new supply at 600 gpm (38 L/S) could meet this expanded demand with expanded storage and distribution and additional backup. At present the 600 gpm (38 L/S) is only well design criteria.
Caliente Public Utilities Caliente	1000	Meets Public Health Standards - hard, high F	3 wells	The existing sytems uses only one of the three wells. It is adequate to supply current demands, but backup capacity is inadequate	7500	To serve additional population the Caliente supply would require several new wells with reliable capacity near that of the primary well used today. Water quantity is adequate but quality and sustained production may be problems. Expansion of the distribution service area and storage increases would also be required.
Panaca Farmstead Assn. Panaca	725	Meets Public Health Standard	2 wells	System inadequate during high demand summer months due to inadequate storage	1800	The existing water rights and wells are capable of serving a population over double the existing population. Expansion to this level requires substantial addition of storage and increases in distribution main sizes as well as upgrading the pumping facilities.
Pioche Public Utilities Pioche	640	Meets Public Health Standards - supply very hard	3 wells 1 spring	Supply adequate for existing demand level. Distribution system needs replacement	650	The existing and proposed upgraded Pioche water supply system does not allow for any increase in demand. If the system were to be expanded new supply sources will be required together with additional storage.
NYE COUNTY						
Tonopah Public Utilities Tonapah	2700	Meets Public Health Standards	6 wells	System adequate to meet current level of demand	5000	The present supply system is believed to be capable of producing and distributing approximately twice the current water. It may be necessary to upgrade the pumping facilities at both booster stations on the transmission system. New growth will also require additional storage. Any demand beyond 5000 level may require sources of potable water. The actual supply system capacity is unknown.
WHITE PINE COUNTY						
Ely Municipal Water	6000	Meets Public Health Standards	2 wells 1 spring	System adequate to meet current level of demand	up to 50,000	The existing Ely supply system has a capability of furnishing approximately 4000 gpm from from springs and wells which can reliably supply 8000 persons considering a 100% backup. In order to meet very large growth up to maximum the city would have to acquire subtantial ground-water rights in Steptoe Valley. This has been estimated at 26 cfs (0.74 m^3/s) for average demand plus 36 cfs (1 m^3/s) for peak demand. Since Steptoe Valley is a designated basin these quantities may not be available for domestic purposes.
Ruth-McGill Water Company McGill	1500	Meets Public Health Standards	1 well 1 surface source (Duck Creek)	System adequate for current level of demand. Supply is excess from Kennecott Copper Corporation. Distribution system in poor condition	1500	The system is limited to current population level since the primary source of supply is "surplus" water from Kennecott Copper Corporation's Duck Creek supply. If additional growth were to occur groundwater from Steptoe Valley might be a source of supply if it could be acquired from present rights holers.
Ruth-McGill Water Company. Ruth	600	Meets Public Health Standards	2 springs	System inadequate for current level of demand during dry years. Distribution system needs replacement. Supply is surplus purchased from Kennecott Copper Corp.	600	The Ruth water supply is presently inadequate for current levels of demand. The water is supplied to Ruth as "surplus" by Kennecott Corporation and it does not appear that the amount of "surplus" will increase. There have been no other reliable potable supplies identified in the Ruth area.

*Maximum population was estimated using 350 gpcd for unmetered supply systems and the system reliable production unless otherwise noted in the discussion.

MUNICIPAL WATER SUPPLY SYSTEMS, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE
3

FUGRO NATIONAL, INC.

LOCATION	POPULATION ESTIMATE SERVED	QUALITY	SOURCE	ADEQUACY	MAXIMUM POPULATION*	IMPROVEMENTS REQUIRED TO SERVE MAXIMUM POPULATION ESTIMATES
Milford	1,500	Reversal of vertical gradient is causing salinity increase in lower aquifers.	5 wells, water rights for 1978 gpm (125 L/S).	The system is adequate for the present population with a 30 percent excess capacity. There is not enough capacity for a major (5 hour) fire.	1,950 (based on estimate of 30 percent over capacity)	System should be metered. Present flat rate produces no incentive to conserve. Mains are in poor repair. Reservoirs have some leakage. The area is presently over appropriated, so any increase in water rights would have to be purchased.
Delta City	2,100	Good TDS is 250 to 500 mg/l.	3 wells, water rights for 1910 gpm (121 L/S).	Wells and pumps are adquate for twice the present peak flow (1895 gpm with 90 percent use rate) storage for fire flow adequate.	5,000 (based on 1895 gpm and peak use of 546 gpd per capita)	Mains and wells are adequate. Storage needs to be increased from 600,000 gallons (2,271,000 L) to 1,800,000 gallons (6,813,000 L) to meet fire flow requirements. To accomodate MX related growth, water rights would have to be purchased from present holders. No additional appropriations are being allowed.
Cedar City	13,000	Has low TDS (less than 400 mg/l) but long term deterioration is expected due to the basin being closed	6 wells and 14 springs.	System is adequate on peak day of year with a 14 percent excess capacity.	14,900 (1987 population based on current trends (no MX)	Except for a few peak days per year, the system is adquate for non-MX normal growth through 1987. In 1987, with MX growth, the system will be adequate for average days, but for peak days it will be 32 percent short.
Hinckley, Desert, and Oasis	900	Aresenic exceeds allowable limits.	Hinckley has municipal system. The other communities have private wells. Rights total about 2100 gpm (132 L/S).	System adequate for present population, but increasing arsenic levels will necessitate a new well north of the towns.	900	Sixty thousand gallons (227,100 L) of storage capacity needs to be added to serve the population for fire requirements. Additional storage at 400 gallons (1516 L) per connection is recommended for new growth.
Garrison	60	Good.	Private wells.	There is currently no municipal system.	--	Adequate ground water is available in this area to accommodate a population of many thousands. All development would have to be done by the MX project, since there is no municipal institution responsible for water in Garrison.

MUNICIPAL WATER SUPPLY SYSTEMS, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE
4

FUGRO NATIONAL, INC.

LOCATION	POPULATION ESTIMATE SERVED	TREATMENT	ADEQUACY	MAXIMUM POPULATION	IMPROVEMENTS REQUIRED TO SERVE MAXIMUM POPULATION ESTIMATES
EUREKA COUNTY					
Eureka Water Assn. Eureka	400	Gravity sewer, two raw sewage oxidation ponds, active discharge to dry wash.	The existing treatment for Eureka wastewater does not meet standards. Collection system in need of replacement.	600	The community of Eureka is presently upgrading their wastewater facilities. The new system, oxidation ponds, has a design population of 600. The new facilities could easily be expanded to accommodate a larger population. The upgrade also includes replacement of 70% of the existing collection system.
ESMERALDA COUNTY					
Goldfield Town Supply	400	Gravity sewer. Three raw sewage oxidation, evaporation percolation ponds. No discharge.	The existing Goldfield wastewater treatment facilities are more than adequate to meet current levels of demand. There is no active discharge from the pond system. Collection system is in good condition.	1000	The existing Goldfield treatment ponds have a capacity for approximately 1000 persons. The collection system is in good condition. Expansion beyond the 1000 population will require an expansion of the ponds and increased collection facilities.
LANDER COUNTY					
Lander Co. Sewer & Water Dist. No. 2 Austin	400	Gravity sewer. Two 1/2 acre (0.2 hm2) oxidation ponds. Active discharge to dry wash.	The Austin wastewater treatment system does not meet state standards.. The collection system is in good condition.	600	The community of Austin does not now meet state standards. Its treatment system could be upgraded by expanding the oxidation pond system and eliminating active discharge. The collection system is adequately sized to serve at least 600 people. Further expansion would require expansion of the collection system.
LINCOLN COUNTY					
Alamo Farmstead Assn. Alamo	900	Three oxidation, evaporation percolation ponds--effluent pumped to ponds. No discharge.	The existing Alamo system is adequate for over twice the current population. The lift station is at capacity. The collection system is in good condition.	2500	The Alamo waste treatment facilities have a design capacity to serve 2500 persons. To meet this demand the collection system would have to be greatly expanded and the lift station to the treatment ponds would require new pumps since they are at capacity with the existing flows.
Caliente Public Utilities Caliente	1000	Gravity sewer, extended aeration, activated sludge plant. Discharge to Meadow Valley Wash. Has site discharge permit.	The treatment plant does not meet the discharg permit requirements. Hydraulic capacity more than adequate but high infiltration of fresh water into collection system decreases plant efficiency.	3200	The Caliente waste treatment facilities have a design population of 3200 persons at 125 gpcd. The existing plant influent is quite dilute. The plant operates below design efficiency. To meet the design population the city will have to eliminate the large quantities of fresh water in the influent. In order to meet their NPDES criteria the facility also requires a full time operator to keep the plant operating at design efficiency. Sludge handling procedures may have to be revised also.
Panaca Farmstead Assn. Panaca	725	Three raw sewage oxidation, evaporation, percolation ponds. No discharge.	The existing wastewater treatment collection and treatment facilities are adequate. There are some odor problems associated with the pond system.	700	The Panaca wastewater treatment pond system is designed to meet only the existing flows. Any expansion of service would require a revision of the treatment train, expanding the pond system and providing aeration. The collection system service area will require expansion to meet increased population demands.
Pioche Public Utilities Pioche	640	Gravity sewer, mechanical aeration, evaporation percolation. No discharge.	The Pioche wastewater treatment collection systems are more than adequate to meet current demands. Mechanical aerators are turned off during winter due to ice.	1500	The Pioche aerated lagoon system design population is 1500. The existing system could handle expansion beyond this population by increasing the ponds. Land is available to accommodate expansion. The collector system has more than adequate hydraulic capacity.
Tonopah Public Utilities Tonopah	2700	Two unsealed raw sewage oxidation, evaporation ponds. Some mechanical aeration.	The present pond system does not provide adequate waste treatment for Tonopah. The town is replacing the existing facility.	5000	The new treatment facility for Tonopah has a design population of 5000, an increase of approximately 2200 persons. This capacity will be adequate only to handle the expected increase due to increased mining activity and the plant will be at capcity within two years. If the major new development does not connect to the Tonopah system, there will be excess capacity. Beyond the new treatment facility Tonopah has no expansion plans. The treatment facilities are located in Esmeralda County which somewhat restricts Tonopah's disposal options.
WHITE PINE COUNTY					
Ely Municipal Water Ely	6000	Extended aeration and oxidation ponds. Possible discharge to Murry Creek.	The existing Ely wastewater treatment and collection systems are more than adequate for the present population. Influent is weak due to collection system infiltration. No active discharge at current levels of use.	18,000	The existing extended aeration and oxidation pond system in Ely should be able to provide waste treatment for triple the existing population. The city is planning to eliminate flush tanks and eliminate the high infiltration in the collection system in order to bring the system capability up to the design population. Expansion beyond the design capacity has not been seriously considered by the city but would most likely require relocation of the treatment facilities and include a reuse of plant effluent.
Ruth-McGill Water Company McGill	1500	Gravity sewer, two oxidation, evaporation, percolation ponds. No active discharge.	The existing pond system is adequate for the current McGill demand. The collection system needs replacement.	1500	The McGill wastewater system is in need of total replacement and has no expansion capability. Any increase in demand would require a complete new system. Cost estimates just to replace the existing system are in excess of $2,500,000.
Ruth-McGill Water Company Ruth	600	Gravity sewer, four oxidation, evaporation, percolation ponds. No active discharge.	The existing pond system has proved adequate. The upper two ponds are filling with sludge and the lower ponds need to be fenced. The collection system is adequate.	600	The Ruth wastewater system of four oxidation ponds is only adequate for the existing population. The upper ponds are filling with sludge, thereby reducing the hydraulic capacity of the pond system. Some limited expansion of the pond system is possible, but the system owner has no financial capability to expand.

MUNICIPAL WASTEWATER SYSTEMS, NEVADA

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE
5

FUGRO NATIONAL, INC.

LOCATION	POPULATION ESTIMATE SERVED	TREATMENT SYSTEM	ADEQUACY	MAXIMUM POPULATION* PROJECTION	IMPROVEMENTS REQUIRED TO SERVE MAXIMUM POPULATION ESTIMATES
Milford	1,500	Gravity clay sewer, one lift station, oxidation ponds.	Does not meet state standards. Collection system has inadequate grades, material breakdown and cracking, and under sized lines. No discharge.	14,500	A completely new collector system and replacement of major portions of the existing system will be required. Two hundred twenty-two acres (90 hm^2) of oxidation ponds will be required.
Delta City	2,100	Gravity clay sewer, three lift stations, one 6-cell oxidation pond. No discharge.	The system meets requirements for the present population.	15,000	Completely new collection system with lift stations will be required. A new containment lagoon of 187 acres (76 hm^2) will be required.
Cedar City	13,000	Gravity sewer, filtration, digesters, clarifiers.	The plant effluent currently exceeds state limits but is not operating at design criteria. It is designed for a population of 19,000.	19,000	The current system, operating at design criteria, would have a five percent overload. New oxidation ponds and sand filters would be required.
Hinckley Desert Oasis	900	Individual septic tank - drainfield systems.	Low percolation rates render drainfields ineffective. There are present health hazards due to surface discharge of sewage.	?	An entire system would have to be built to accommodate major growth.
Garrison	60	Individual septic tank - drainfield systems.	Systems are adequate for present population.	?	An entire system would have to be built to accomodate major growth.

* Maximum population is based on 1987 peak contruction period population projection.

MUNICIPAL WASTEWATER SYSTEMS, UTAH

MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE - BMO

TABLE
6

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