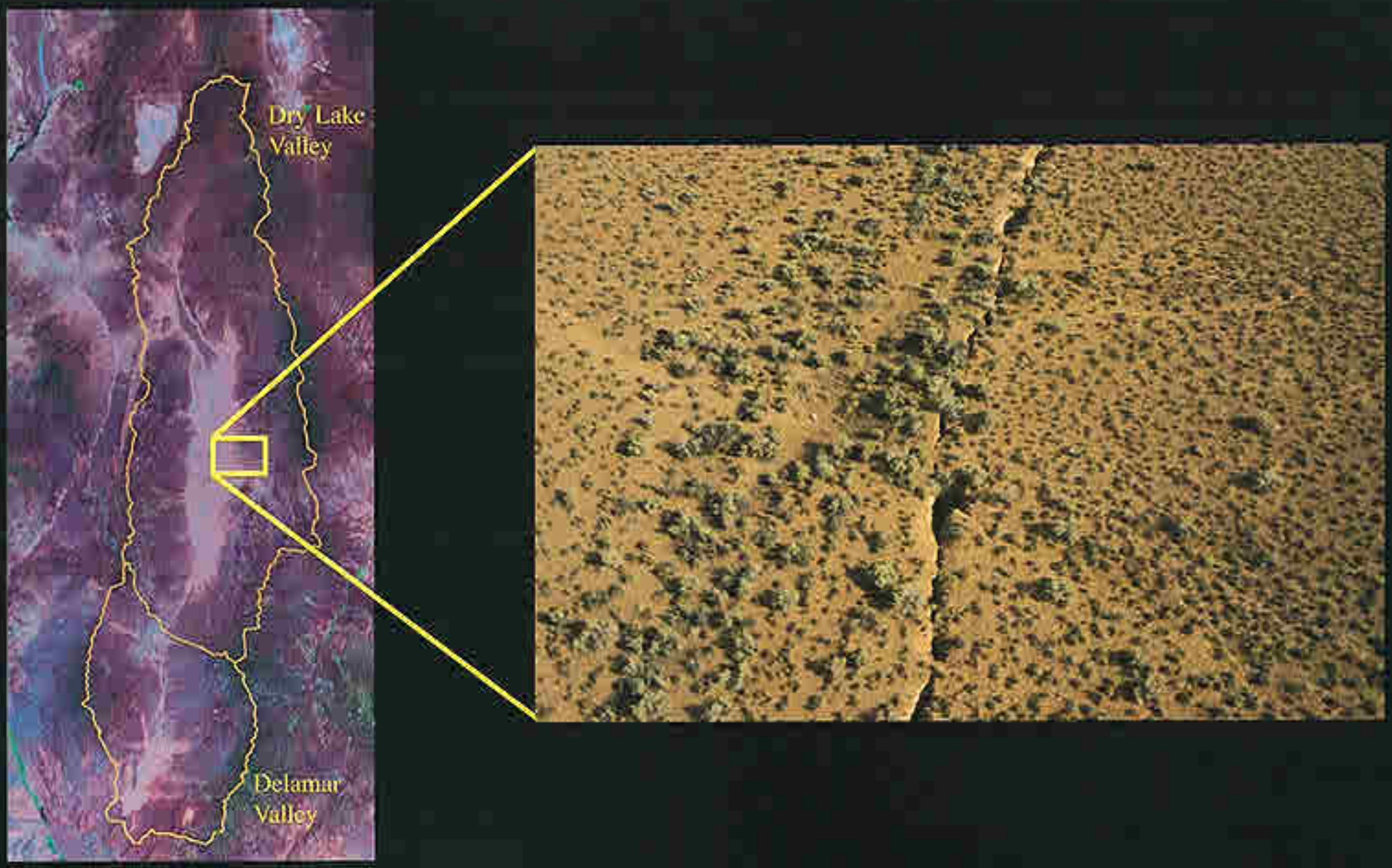

HYDROLOGY AND STEADY STATE GROUND-WATER MODEL OF DRY LAKE AND DELAMAR VALLEYS, LINCOLN COUNTY, NEVADA

1996

Las Vegas Valley Water District

COOPERATIVE WATER PROJECT
Water for Nevada's Future
Report No. 16
Hydrographic Basins 181 & 182

HYDROLOGY AND STEADY STATE GROUND-WATER MODEL OF DRY LAKE AND DELAMAR VALLEYS, LINCOLN COUNTY, NEVADA

By

Kay Brothers, Terry Katzer, and Michael Johnson
Las Vegas Valley Water District

1996

PREFACE

This report on the water resources and development potential of Dry Lake and Delamar Valleys is one of a series of reports on hydrographic basins in eastern and southern Nevada, prepared by the Las Vegas Valley Water District as part of the District's Cooperative Water Project. Kay Brothers developed the ground-water flow model and co-authored the report. Terry Katzer and Michael Johnson performed detailed evaluations of the available geologic information and prepared selected portions of the report. Chiuwen Ray prepared all the report figures. Richard Barrett performed satellite imagery analysis to make the report cover. Information used in performing this work was provided by the Nevada State Engineer's office, the U.S. Geological Survey, Summit Engineering, Inc., and the U.S. Air Force. Additional information and technical assistance was provided by the staff of the Research Department of the Las Vegas Valley Water District, under the direction of Terry Katzer, Director.

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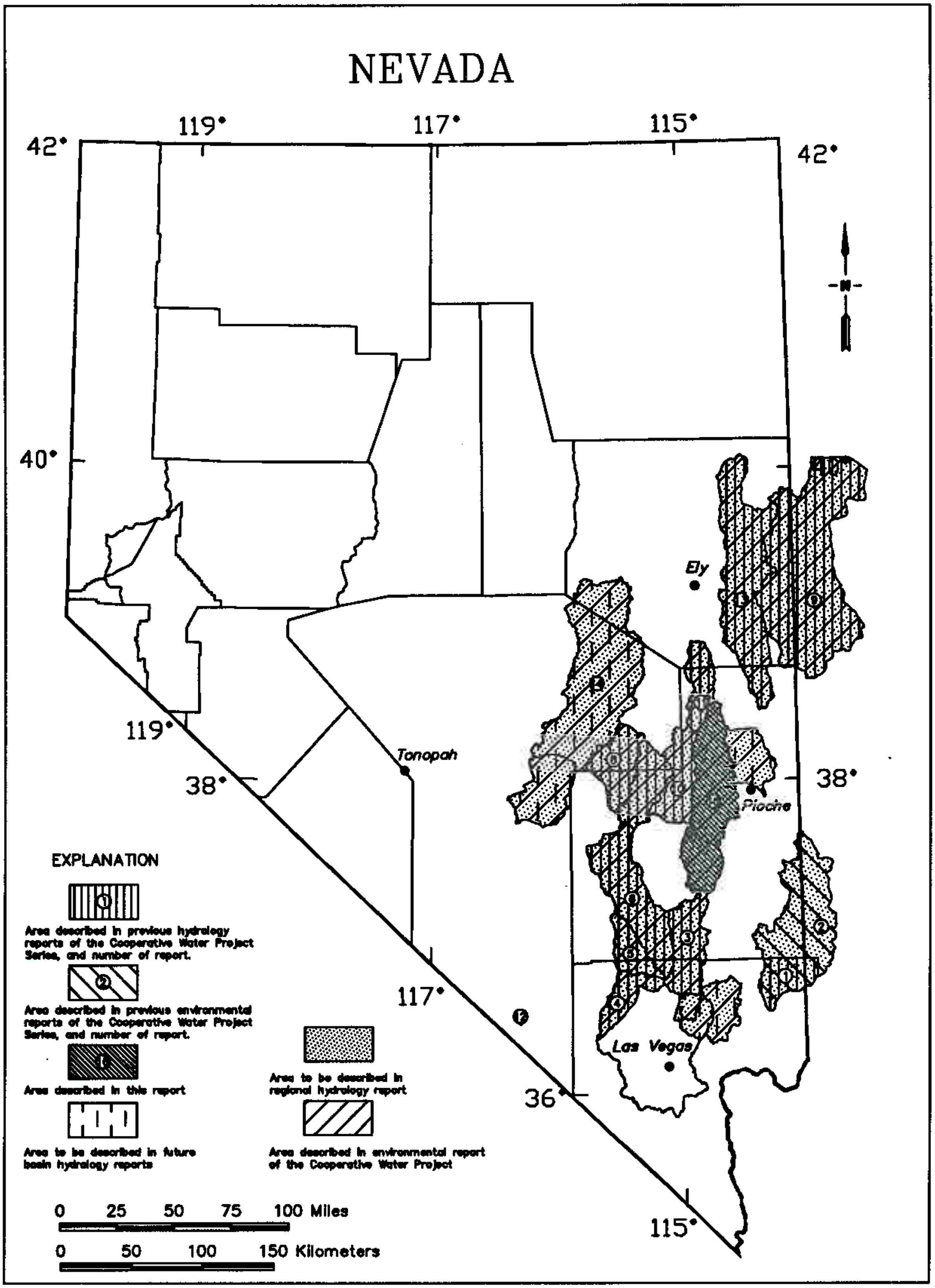


Areas described in previous reports of this series, the area described in this report and the areas to be described in future reports.

INTRODUCTION

In October 1989, the Las Vegas Valley Water District (District) filed four applications to obtain ground-water rights from Dry Lake and Delamar Valleys in Lincoln County, Nevada. Since the time of these water right filings, the District has conducted extensive investigations of Dry Lake and Delamar Valleys as well as adjacent areas including the collection of basic hydrologic data, a water rights inventory, the synthesis of all published and agency information on the water resources of the area, and the development of conceptual and numerical models of the valleys. This report details the hydrologic assessments of Dry Lake and Delamar Valleys that were conducted, and the steady-state ground-water flow model developed to represent the aquifer systems of the basins.

Background

The southern extent of Delamar Valley is located about 70 miles north of Las Vegas, Nevada (Figure 1). Dry Lake and Delamar Valleys are situated in Lincoln County. There are a total of about eleven well sites in both valleys with three of these sites containing production, test, and observation wells drilled as part of the U.S. Air Force's MX Missile Water Resource Program. Data concerning these wells provides information about the alluvial aquifer and one of the MX well sites is in the carbonate aquifer. On the basis of the geology of the basin, the hydrogeology of neighboring basins and limited test drilling performed, it is known that the regional carbonate aquifer underlies Dry Lake and Delamar Valleys.

To assist its efforts in understanding the water resources of Dry Lake and Delamar Valleys, the District developed a numerical model of the ground-water flow regime of these basins. A numerical model is a computer code which translates the mechanics of ground-water flow through the earth by solving a series of mathematical equations. By coupling the available information on these basins (and similar valleys in Nevada) with the predictive capabilities of the model, it is possible to estimate the response of the ground water to the proposed water withdrawals by the District.

The development of a ground-water flow model for Dry Lake and Delamar Valleys serves two additional important purposes. First, it is a useful planning tool in developing well field designs by allowing water supply design experts to simulate the efficiency of different design alternatives; secondly, it allows planners to simulate the potential effects of the water withdrawals, if any, on neighboring water users, and the environment.

Both beneficial and negative impacts may result from ground-water withdrawals from the valley-fill deposits and/or the regional carbonate aquifer in the arid basins of Nevada. The benefits derived from the application of currently unused ground water to beneficial use is, of course, the primary positive impact. The economic impact of large-scale ground-water development programs, such as that proposed by the District, is likely to be appreciable and the project is

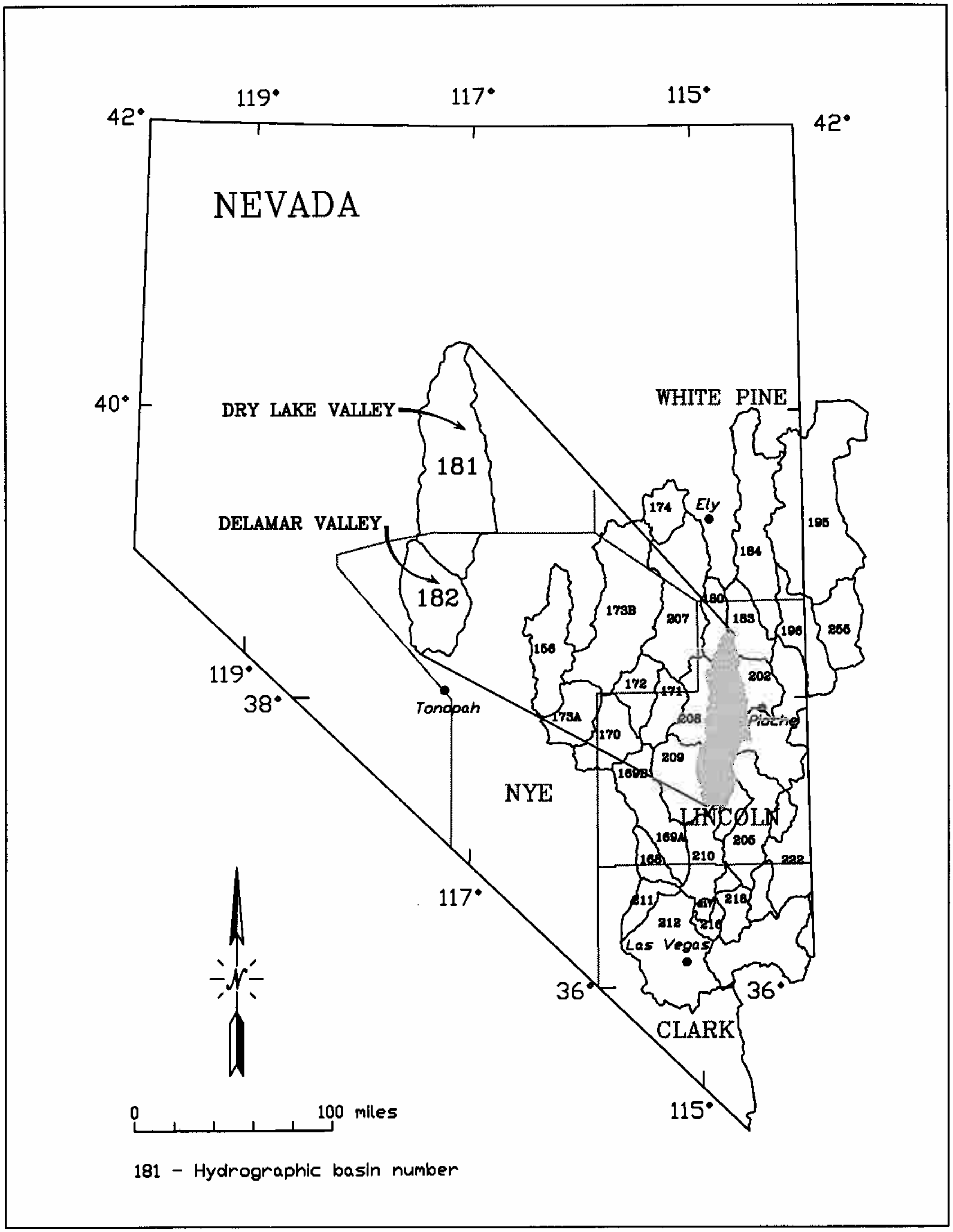


Figure 1. -- Location of the study area

likely to result in significant short-term and long-term economic benefits. The proposed program will require the cooperative efforts of large teams of scientists, engineers, and water planners, and the services of the water well and construction industries.

Beside the favorable economic impacts expected to result from the proposed development of ground-water basins in Nevada; negative impacts can occur. The primary negative impact of ground-water withdrawals is the lowering of ground-water levels in the vicinity of the production wells; this lowering of water levels is commonly referred to as drawdown. If the long-term drawdown near a pumping well, or a wellfield in any given valley, is significant, then the direction and rate of ground-water flow can be altered and potentially may result in:

- Increased pumping lifts and costs;
- Reductions in spring-flow rates;
- Reductions in surface-water flows; and
- Degradation of water quality.

The magnitude and significance of these impacts depends largely upon the overall hydrologic setting of the basin where the withdrawals occur. In remote, undeveloped basins with no surface water or large springs, as is the case in Dry Lake and Delamar Valleys, the drawdown that will result from ground-water development may not result in significant adverse impacts within the valley. In other instances, the presence of sensitive environments in a valley may be adversely impacted as a result of the same amount of drawdown. Examples of sensitive environments in Nevada include: 1) wetland areas that provide valuable habitat for many types of wildlife; 2) surface water flows and their associated riparian habitats; 3) springs that either support wildlife or have been developed for ranching, mining, quasi-municipal, or domestic uses; and 4) areas where ground water provides the sole source of drinking water for a community.

As mentioned above, Dry Lake and Delamar Valleys are remote essentially undeveloped areas with very few localized springs and no significant surface-water flows. Ground-water development in these valleys would probably result in no significant impacts. Currently ground-water use is limited to stock watering. Any development of ground water in these valleys could easily provide water for livestock. Ground-water levels in these valleys are in excess of hundreds of feet; therefore there are no phreatophytes present.

Because many of the valleys in central, eastern, and southern Nevada are hydraulically linked, via the regional carbonate aquifer, the drawdown that results from the development of ground water in one valley can impact the environment of another valley. Thus, the development of a numerical model of ground-water flow to simulate the impacts of pumping must take into account the environment in peripheral valleys as well as the valley actually being modelled. The District is in the process of preparing a computer model to evaluate these potential regional impacts. The steady-state individual model of Dry Lake and Delamar Valleys, described in this report, is tied to surrounding basins by general head boundaries and was developed to simulate steady-state conditions as defined by the U.S. Geological Survey (USGS), Eakin (1963), and Harrill et al. (1988) and does not simulate any ground-water withdrawals.

Dry Lake Valley is in hydraulic communication with Delamar Valley to the south. Natural recharge in Dry Lake and Delamar Valleys is thought to flow southwest into Pahranagat Valley, through faults in the Delamar Range (Harrill et al., 1988). No subsurface inflow to either of these valleys has been previously identified, however, as explained in the "Model Development" section and through recent geologic mapping by the USGS, several interbasin transverse structures were identified in the valleys (Page et al., 1995) indicating a possibility of ground-water flow from Lake or Patterson Valley.

The use of numerical methods to simulate water withdrawals in Dry Lake and Delamar Valleys provides a tool for predicting the effects that would be expected to result from potential development. Recently, the USGS has reported the findings of a cooperative study of the water resources potential of the carbonate aquifer conducted in cooperation with the U.S. Bureau of Reclamation, state and local agencies, including the District (Dettinger, 1989). This report recommends the effective use of computer models for predicting the site-specific effects of water withdrawals from the carbonate aquifer. The report concluded that increased confidence in such predictions can be achieved through a staged approach to development coupled with adequate monitoring and interpretation. The development of a computer model of the steady-state ground-water flow regime in Dry Lake and Delamar Valleys, performed as part of this investigation, represents one of the first steps in implementing such a staged approach.

The steady-state ground-water model, described in this report, provides a preliminary representation of the aquifer system based upon the information available at this time. As additional data become available through District efforts, the model of the ground-water flow regime for Dry Lake and Delamar Valleys can be updated accordingly to provide a more refined representation of the hydrologic system.

Purpose and Scope

The purpose of this project is twofold: 1) to define the hydrologic conditions of Dry Lake and Delamar Valleys, and 2) to develop a calibrated steady-state ground-water flow model of the valleys. The specific objectives of these investigations were to:

- Collect hydrologic, geologic, and land use data in the valleys;
- Compile and review published reports and unpublished data on the valleys;
- Interpret the available data and determine the hydrogeologic characteristics of the valleys; and
- Prepare a computer model to simulate steady-state ground-water flow in the valleys.

To achieve these objectives, a detailed investigation of the hydrology and geology of Dry Lake and Delamar Valleys was conducted. The scope of work included a review of all available published and unpublished data, the evaluation of the occurrence and movement of ground water and water chemistry, and the development of conceptual and steady-state numerical models of the hydrogeologic regime of the valley. The basin characterization information and steady-state flow model discussed in this report may be used by the District to develop a transient, regional model including the Dry Lake and Delamar Valleys ground-water regime.

Location and Physiographic Setting

Dry Lake and Delamar Valleys are within the Great Basin Physiographic Region as defined by Fenneman (1931). The location of the valleys and their general physiographic setting are shown in Figures 2 and 2A discussed below.

Dry Lake Valley is about 60 miles long and 20 miles wide encompassing an area of about 900 mi.^{2}, located between the North Pahroc Range on the west, the Fairview Range on the northeast, and the Bristol and Highland Peak Ranges on the east. Dry Lake Valley and Delamar Valley are separated by an alluvial divide at an altitude of about 4,875 feet above mean sea level (AMSL). Delamar Valley is about 20 miles long and 15 miles wide encompassing an area of about 360 mi.^{2}, surrounded by the South Pahroc Range on the west and the Delamar Range on the south and east. Both basins are topographically closed i.e., there is no surface water drainage out of these basins.

The highest point in the mountains surrounding Dry Lake and Delamar Valleys is Highland Peak with an elevation of about 9,500 feet. The lowest part of these valleys are of course the playa areas. The playa in Dry Lake has an elevation of about 4,600 feet, while the playa in Delamar Valley has an elevation of about 4,400 feet. The trough of Dry Lake and Delamar Valleys is higher than that of White River and Pahranagat Valleys to the west and Meadow Valley Wash on the east. The playa in Delamar Valley is about 1,200 feet higher than the floor of Pahranagat Valley in the area of Maynard Lake, the lowest feature in the valley.

The physiography of Dry Lake and Delamar Valleys is typical of other valleys in Nevada; mountains bound the valleys on the east and west and alluvial fans radiate from the major mountain watersheds, forming a somewhat continuous bajada. On the valley floor, the major features are the washes that drain the surrounding mountains and the Pleistocene lake beds in the central parts of the valleys. During the Pleistocene the maximum depths of these lakes were on the order of 75 feet in Dry Lake Valley and perhaps 50 feet in Delamar Valley, according to Carpenter (1915). The surface areas of these lakes were about 30 mi.^{2} in Dry Lake Valley and about 16 mi.^{2} in Delamar Valley.

Availability of Data

Dry Lake and Delamar Valleys are located in a remote and unpopulated area of Lincoln County, and only reconnaissance level evaluations of the water resources of the area are available. Limited data are available for about 11 sites where wells have been drilled in the two hydrogeologic valleys. Other available information includes published reports by the Nevada Bureau of Mines and Geology, the USGS, and the Desert Research Institute. In the late 1970s and early 1980s, these valleys were also investigated by the U.S. Air Force as part of their MX Water Resources Program. With the limited development, the hydrologic conditions are not well defined, even though one of the MX test wells is in the carbonate aquifer. Regional data from adjacent valleys are also available to supplement the existing valley-specific data.

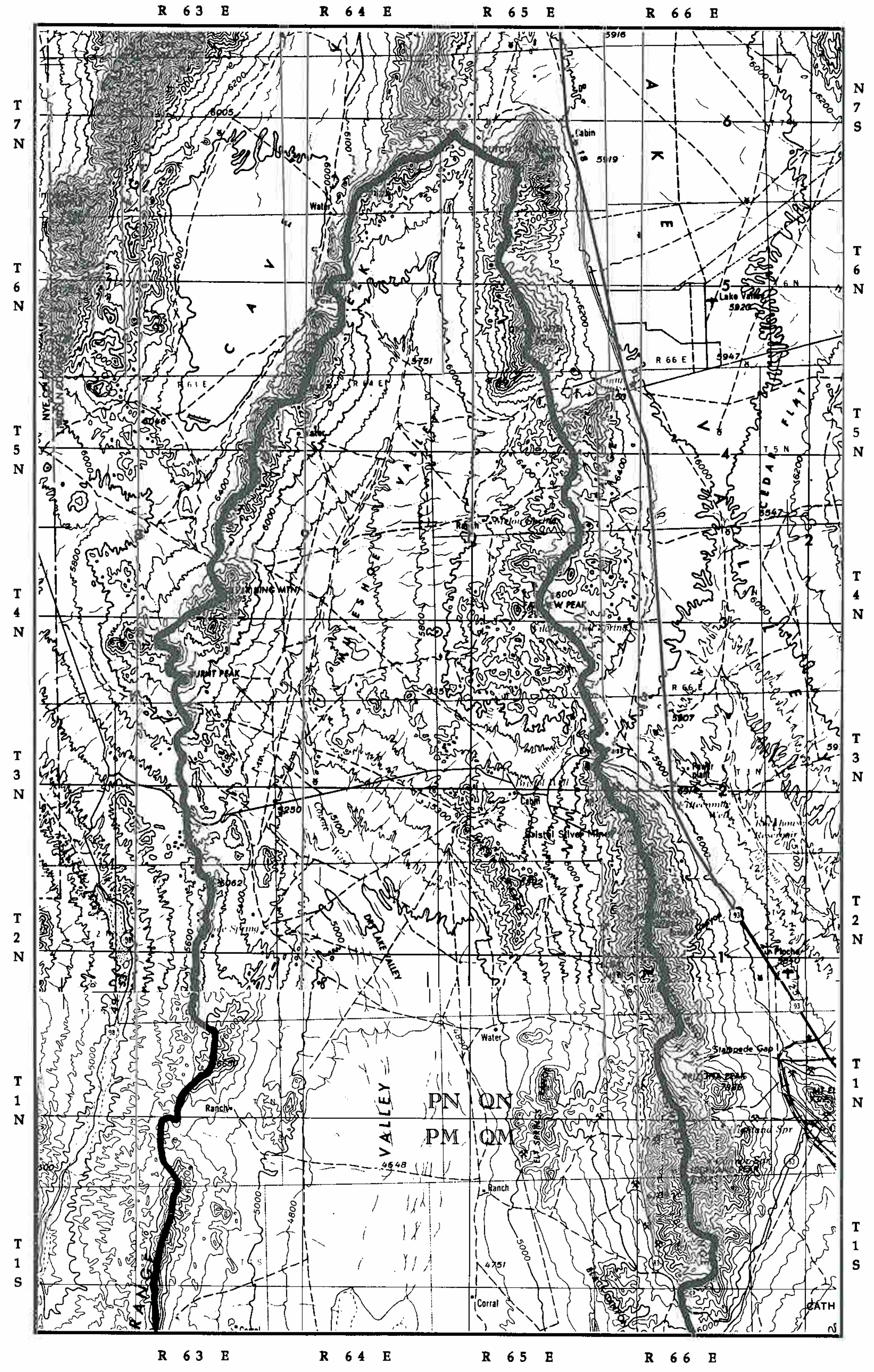
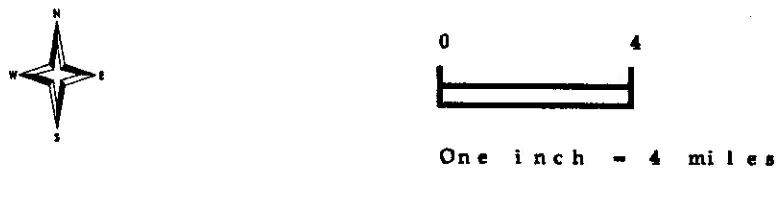


Figure 2. -- Physiography and Location of Delamar and Dry Lake Valleys (Northern Half).



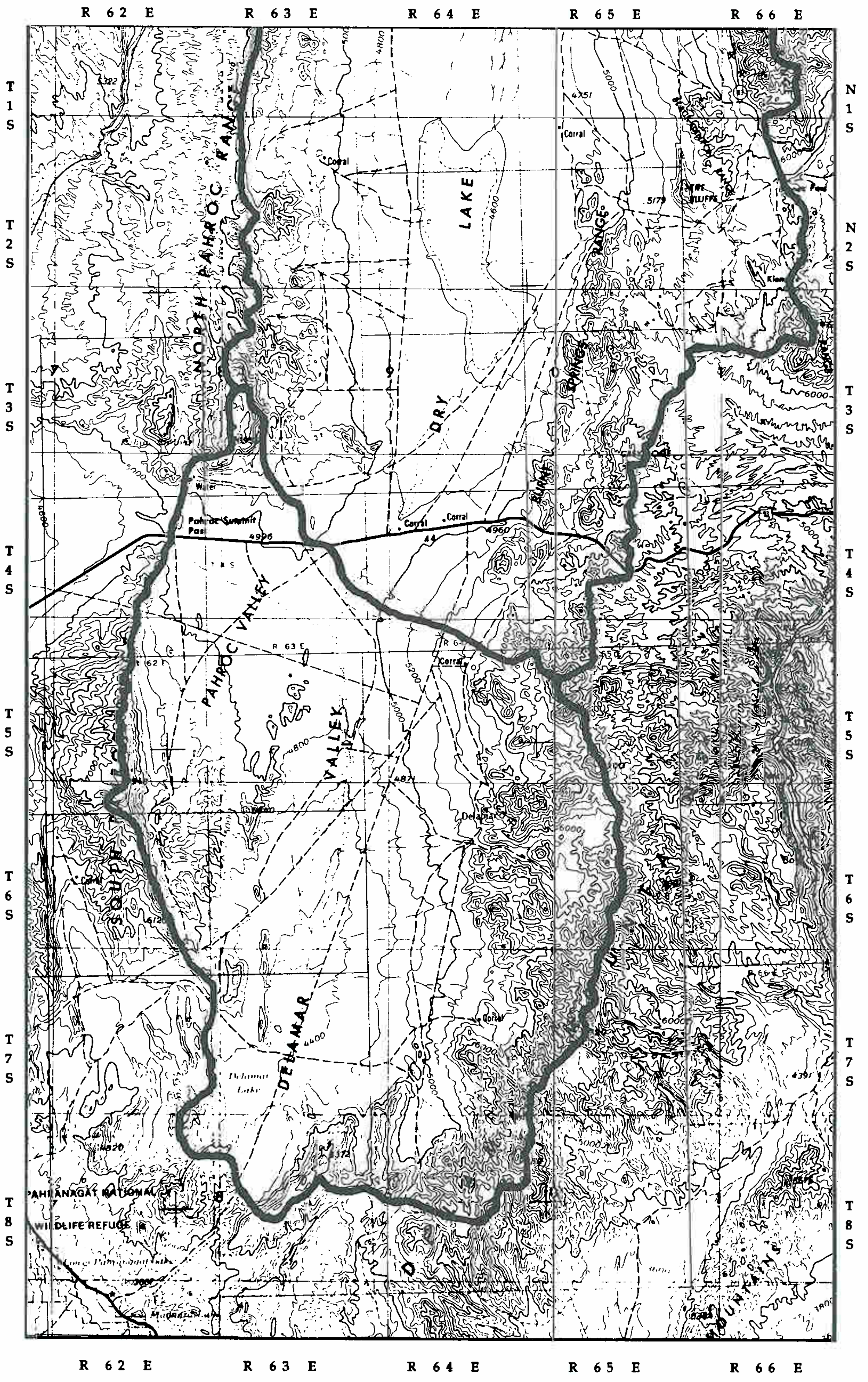


Figure 2A. -- Physiography and Location of Delamar and Dry Lake Valleys (Southern Half).

0 4

One inch = 4 miles.

The distribution of data points in the valley is limited with only eleven well sites, and large areas are lacking control. Table 1 provides summary data from the USGS data base and Bunch and Harrill (1984) for water level measurements in the valley for 12 well sites. The last well site was not found in the field and thought to have been misplotted in the data base; therefore, was not considered as valid. At MX sites more than one well was drilled to provide pumping and observation capabilities, however, only one site and corresponding water level is listed because the water levels do not vary significantly between wells. Appendix A provides an explanation of the well location designations used in this report.

Table 1.--Water level data in Dry Lake and Delamar Valleys.

ID	Location	Land Elev. (in feet AMSL)	Depth to Water (ft)	Water Elev. (in feet AMSL)	Date Measured
1	NO4 E64 O7DC2	5,370 [1]	255 268	5,115 5,102	4-28-94 [a] 9-81 [c]
2	N03 E65 21D	5,445 [1]	19.7 19	5,425 5,426	4-28-94 [a] 3-10-90 [b]
3	N03 E64 20BD	5,067 [1]	270.4 315 317	4,797 4,752 4,750	4-28-94 [a] 3-10-90 [b] 1960 [d]
4	N03 E63 27CA	5,390 [2]	849.7 851	4,540 4,539	2-08-91 [b] 2-81 [c]
5	N02 E64 03B	4,970 [1]	> 460 664R	[3] 4,306	4-28-94 [a] 1963 [d]
6	N01 E64 24A	4,705 [1]	405.9 398.2	4,299 4,307	4-28-94 [a] 3-10-90 [b]
7	N01 E65 02AA	5,659 [1]	10 R	5,649	1960 [d]
8	S02 E65 19AC	4,703 [1]	48.8 45.4	4,654 4.658	4-28-94 [a] 3-10-90 [a]
9	S03 E64 12AC2	4,660 [1]	392.4 394	4,268 4,266	4-28-94 [a] 5-80 [c]
10	S06 E63 12ADA1	4,710 [2]	871	3,839	3-10-90 [b]
11	S07 E64 12DD	5,720 [1]	38	5,682	5-80 [c]
12	S07 E64 19 [3]				

[1] Land surface elevation taken off 7.5' USGS Quadrangle Map
[2] Land surface elevation from Bunch and Harrill, 1984
[3] Misplotted not valid
[a] Data source Las Vegas Valley Water District
[b] Data source USGS
[c] Data source Bunch and Harrill, 1984
[d] Data source Eakin, 1963

The primary source of data for Dry Lake and Delamar Valleys is a reconnaissance report authored by Eakin (1963). Investigators of the regional flow system and adjacent valleys have included Ertec Western (1981); Thomas, et al. (1986); Harrill, et al. (1988); Kirk and Campana (1988); and Dettinger (1989). The sources of recent data available for the two valleys include: 1) details on water well construction from Well Drillers Reports filed with the Nevada State Engineer Office; 2) water level and water chemistry data from the USGS databases; and 3) the results of aquifer tests and exploratory drilling into the carbonate aquifer by the Air Force during 1980 and 1981.

Other available data include technical reports of the Nevada Department of Conservation and Natural Resources, and USGS Professional Papers, Water-Supply Papers, and Open-File Reports. Characterizations of the regional setting, provide important information on the regional carbonate aquifer that is also of use in evaluating conditions in Dry Lake and Delamar Valleys.

Information on the status of water rights in the valley was made available by Summit Engineering Corporation (SEC) in the form of water right abstracts which are included in Appendix B. According to SEC, these abstracts were based upon a thorough compilation and review conducted in 1990 of the public documents available from the Nevada State Engineer Office, the regulatory authority governing water rights in Nevada.

The conceptual and numerical models of Dry Lake and Delamar Valleys, discussed later in the report, were based on the available site-specific and regional data discussed in the previous paragraphs, the observations made during reconnaissance trips to the valley, and the knowledge of the overall regional ground-water setting.

Methods

In assessing the water resources potential of Dry Lake and Delamar Valleys, and developing a steady-state numerical model of the ground-water system of the valley, only standard approaches and procedures were used. In this section, the methods and procedures that were used are identified and discussed, along with a brief introduction to the selected numerical modelling code.

Data Collection and Compilation

Primary hydrologic data collection (i.e., new field measurements) were performed as part of this investigation by the MARK Group, Engineers and Geologists, Inc., and the District. Data from the USGS Water Resources Division's databases, that included the most recent measurements available, were provided through the District along with well drillers reports, published reports, and maps. A literature search was conducted to identify and compile data from available published sources.

The locations and data sources were verified by comparing reported or entered data point locations and parameters with field observations and/or the published source of information.

Spatial data sets (e.g., water levels, water chemistry, and water right locations), were plotted at uniform scales and annotated. The resulting maps were inspected for anomalous values and further verification was performed to resolve inconsistencies.

Numerical Model Development

The model used to simulate the ground-water regime of Dry Lake and Delamar Valleys is a computer code prepared by the USGS and referred to as MODFLOW (for "Modular Three-Dimensional Finite-Difference Ground-Water Flow Model"). The USGS has prepared comprehensive documentation for this code in one of their series of manuals on techniques of water-resources investigations (McDonald and Harbaugh, 1988). An overview of the code, a discussion of the general approach used in modelling, and the specifics of the model developed for the basin are detailed in the "*Model Development*" section.

GENERAL HYDROGEOLOGIC FEATURES

The development of numerical simulations of the proposed District ground-water withdrawals in Dry Lake and Delamar Valleys requires a thorough understanding of the hydrologic regime of the basin. The information that is available concerning the valleys, and adjacent or similar areas, is used to develop a conceptual model of the source of water in the valleys, its occurrence and flow in the subsurface, and the relationship between the valleys and adjacent areas. In this section, the regional and valley-specific hydrologic conditions in Dry Lake and Delamar Valleys are described and discussed.

Regional and Basin Hydrogeologic Features

Dry Lake and Delamar Valleys are situated in the Alluvial Basins Ground-Water Region as defined by Heath (1984). Individual hydrographic basins in this region are characterized by alluvial basins that are underlain by bedrock, and are separated by the bedrock outcrops in the bounding mountain ranges, or, in some instances, by lower divides in alluvial terrain.

When ground water flows from one basin to another, the basins are termed a flow system. Dry Lake and Delamar Valleys are part of the White River flow system, which is a subset of the Colorado flow system, as defined by Harrill, et al. (1988). The Colorado flow system encompasses about 16,300 mi^2 and 34 hydrographic basins in Nevada of which 13 make up the White River flow system. Figure 3 shows the White River flow system and the location of Dry Lake and Delamar Valleys within this system. The discharge from the lower part of the flow system is at the Muddy Springs located near Glendale, Nevada. Much of the recharge from the upper part of the White River flow system is discharged as evapotranspiration from springs and wetlands in White River and Pahranagat Valleys.

The overall component of ground-water flow is south from Dry Lake Valley to Delamar Valley, then southwest from Delamar Valley to Pahranagat Valley. Recharge from the bounding

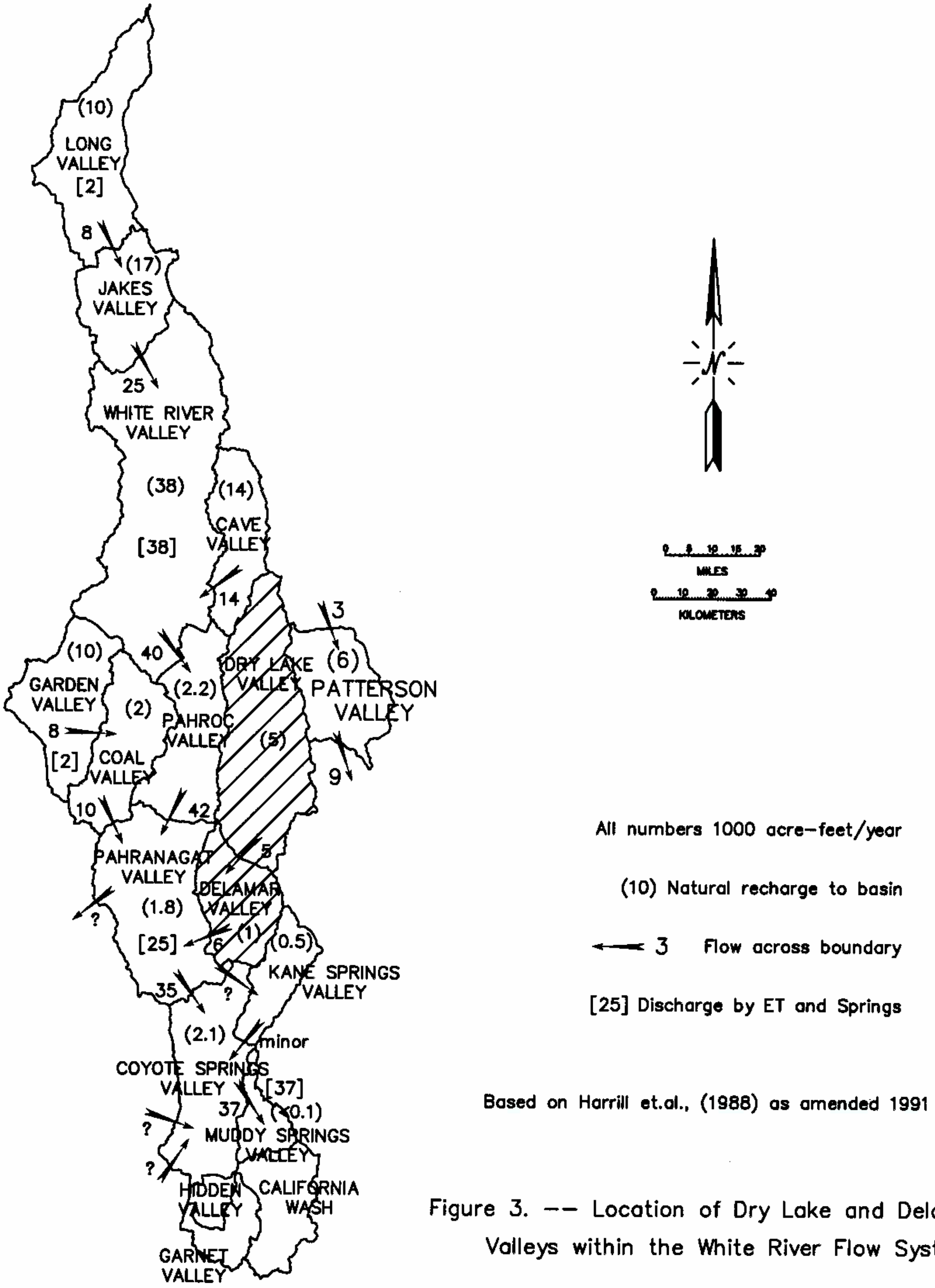


Figure 3. –– Location of Dry Lake and Delamar Valleys within the White River Flow System.

mountain ranges, within individual valleys in the flowsystem, results in a local flow component that generally coincides with the topography (i.e, from the mountains toward the axis of the valleys or toward playas with downward vertical hydraulic gradients).

Dry Lake Valley receives an estimated 5000 acre-feet per year of recharge from the surrounding mountains with Delamar Valley receiving an estimated 1000 acre feet per year of recharge. This combined recharge (6000 acre-feet per year) flows through the subsurface to Pahranagat Valley, probably through a fault zone where the South Pahroc Range meets the Delamar Range.

Lithologic and Hydrologic Features

The Dry Lake and Delamar Valley system is typical of the Basin and Range province with north trending valleys bounded by subparallel mountain blocks. During middle Pliocene to early Pleistocene (Tschanz and Pampeyan, 1970) there was a single lake about 100 miles long that occupied both valleys. The valleys are now separated by a low surface drainage divide in the alluvium.

The two valley system is somewhat unique in the Basin and Range province in that the valleys are situated between parallel surface drainages that are tributary to the lower Colorado River; the White River to the west and Meadow Valley Wash to the east. Dry Lake and Delamar Valleys have internal surface drainage, which is characteristic of the Great Basin, however ground-water outflow ultimately ends up in the White River ground-water flow system (Harrill et al., 1988), a tributary to the Colorado River. Additionally the valleys are classified as being in the Alluvial Basins Ground-Water Region by Heath (1984). Figure 4 shows the general direction of ground-water flow in the two valley system.

The valleys are bounded by nearly continuous mountain ranges; the Delamar Mountains on the south and east that are predominantly volcanic in origin, the Bristol Range on the east that is mostly carbonate rocks, and the volcanics of the Fairview Range on the northeast. The South Pahroc Range bounds the valleys on the southwest and is mostly volcanic as is the North Pahroc Range on the west. The Schell Creek Range on the northwest and north is made up mostly of carbonate rocks with some minor volcanics. Figure 2. shows these ranges and lessor mountains along with other physiographic features in the two valley area.

Hydrostratigraphy

The geologic framework of the valley system controls the movement, quality, and fate of the ground water and for that reason an understanding of that framework provides, in large part, the basis for this water resource evaluation.

There are essentially two principal aquifer systems in the Dry Lake and Delamar Valley system, the unconsolidated and the consolidated rocks. The unconsolidated rocks consist of younger and older alluvium that make up the basin fill sediments and where saturated at depth are considered the most likely to yield large quantities of water to wells. Consolidated rocks underlie the basin-

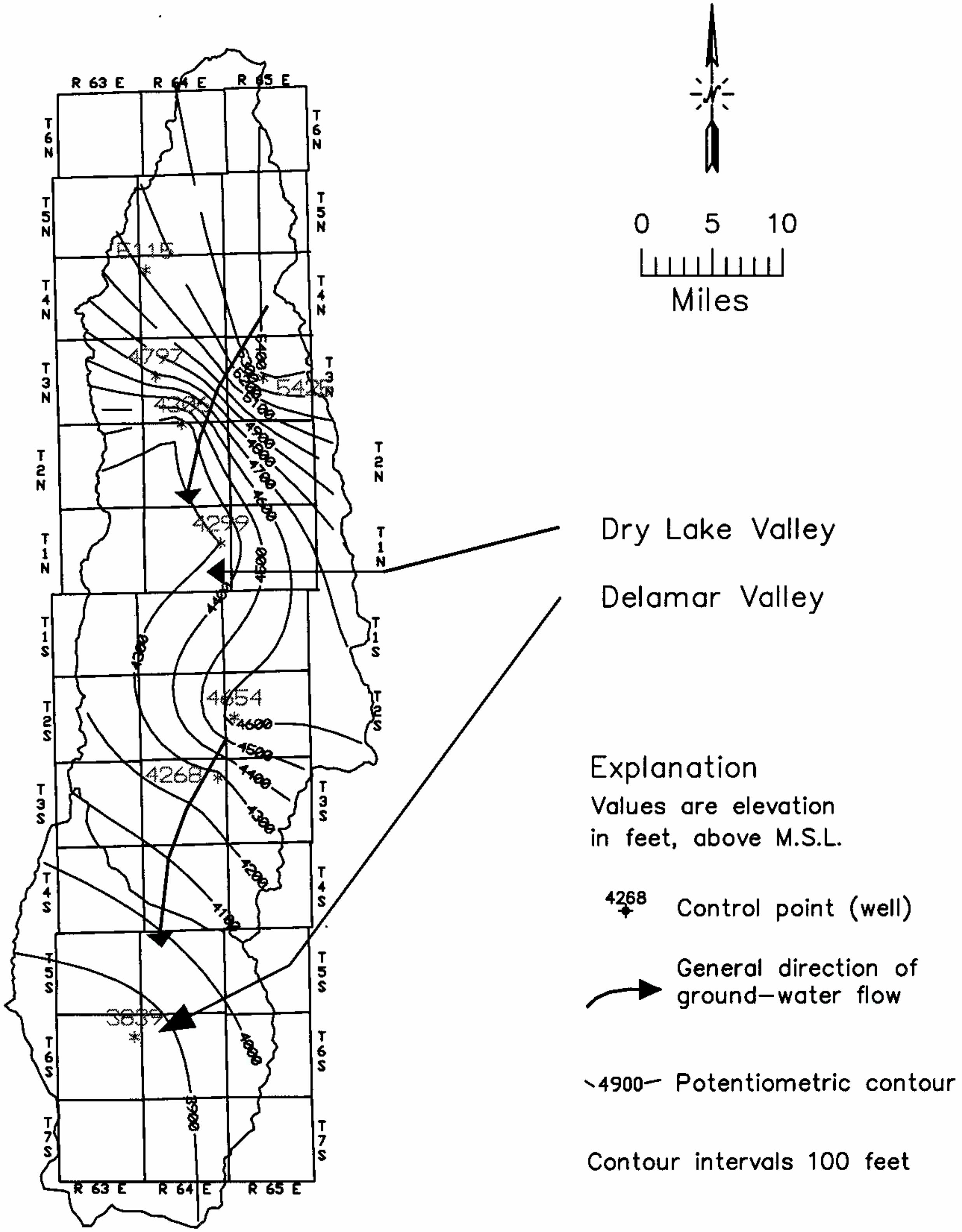


Figure 4. -- Potentiometric surface for Dry Lake and Delamar Valleys based on actual water levels.

fill sediments and bound these sediments on all sides. The consolidated rocks are further subdivided based on their lithology and their water bearing properties. The most important aquifer system within the consolidated rocks are the carbonate rocks. Table 2 summarizes the various hydrogeological units.

Unconsolidated Rock

The erosional process transports sediments into the basin from the surrounding mountain blocks. These sediments range in size from boulders to silt, with the coarse-grained material on the flanks of the valleys and the fine-grained material deposited in the lower parts of the valleys.

The various sediments have not been well dated, but sufficient data are available to subdivide the units as follows starting with the youngest units:

Holocene

This unit consists of unconsolidated sands and gravels deposited in the many ephemeral drainages that exit the mountain blocks and dissect the alluvial fans. Additionally this unit is found in the axial channel of northern Dry Lake Valley and on the flood plains and adjoining fan materials of drainages that are not well entrenched.

The fine-grained sediments from this unit are the silts and clays deposited in the valley lowlands such as are found on the playas of both valleys.

This unit is not significant as a water bearing aquifer because it is relatively thin and located, in most places, well above the valley ground-water table. One exception is the drainage that the Bristol Well is in where the depth to water over parts of the drainage is less than 20 feet. Eakin (1963) reports well yields in this area are low, probably in part because the unit is not very thick.

Late Tertiary to Quaternary

Lacustrine

Pliocene to Pleistocene lake deposits are found from southern Delamar Valley to northern Dry Lake Valley. There were at least two pluvial episodes, one in the Pliocene which formed the continuous lake connecting both valleys and the younger Pleistocene lakes, however these younger lakes were not connected. The lacustrine units are silts and clays and are important from a hydrologic standpoint if they are of sufficient thickness to be in contact with the underlying saturated sands and gravels thereby forming an aquitard; their thickness is unknown, but could be in excess of several hundred feet.

Table 2.--Hydrogeological units in Dry Lake and Delamar Valleys.

Unit and Age	Description	Location
Holocene Unit	Unconsolidated sands and gravels deposited in active channels and flood plains. Is a minor aquifer in Bristol well area. Silts and clays in valley low lands.	All ephemeral drainages, northern Dry Lake axel drainage.
Late Tertiary to Quaternary: Lacustrine Unit	Lake deposits of bedded silts and clays, possibly tuffaceous in some areas. Very low permeability, may act as an aquitard.	Pluvial lakes in Delamar Valley and most of Dry Lake Valley.
Alluvial Unit	Unconsolidated to semi-consolidated gravels, sands, silts and clay - grade into lacustrine units in central parts of valleys and into a fanglomorate near Delamar Mountains. Alluvial units, where saturated, are the principal aquifer system.	Alluvial fans; subdivided into three subunits based on thickness for transmissivity values. Thinnest unit is found east of Bristol Range northern part, next thickest is northern Dry Lake Valley, and thickest is remainder of two valley alluvial fill.
Tertiary Volcanic Unit Younger	Non-welded to densely welded dacite to rhyolitic ash flow tuffs with basalt flows and very minor sedimentary units. Generally considered poor aquifer, but locally may be well fractured and able to transmit water readily.	All mountain ranges except Highland and Bristol Ranges. Underlies all alluvial fill.
Older	Andesitic to latitic flows, welded tuffs, and intercalated sedimentary beds. Probably a poor aquifer, local areas of high permeability may exist along planes of recent faulting. Some volcanic rocks may be Mesozoic in age.	
Paleozoic Carbonate Unit	Limestones and dolomites. Unit is thick and massive and where fracture and containing dissolution cavities will readily transmit water. This unit can be important as an aquifer and is the unit that allows the occurrence of interbasin ground-water flow on a regional basis.	Found in all ranges except the South Pahroc. Also underlies the volcanic rocks at great depth.
Mid to lower Tertiary, and Lower Paleozoic to Pre-Cambrian Non-Carbonate and Non-Igneous Unit	Quartzites, shales, and siliciclastic that make up the regional lower clastic aquitard and inhibit interbasin ground-water flow. Not important from a local water supply resource.	Most mountain ranges except South Pahroc.

Alluvial

The alluvial fan units are made up of sediments that have been transported from the mountain blocks and range in size from boulders to clay particles. These units are unconsolidated to semi-consolidated and grade into and are inter-mingled with the lacustrine units. The thickness of the units is quite variable ranging from a few feet at the bedrock contact to a known thickness in Delamar Valley of at least 1,100 ft based on a drillers log to an inferred maximum of several thousand feet in southern Dry Lake Valley based on the Bouger gravity anomaly map of Nevada (Saltus, 1988). It is these valley-fill units that are considered the principal aquifer of the two valley system and, transmissivities vary depending on saturated thickness.

Fanglomerate

These units are found only in eastern Delamar Valley on the upper parts of the alluvial fans and in continuous aprons along the west side of the Delamar Mountains. The units are unsaturated, located well above the valley water table, and have no hydrologic significance.

Consolidated Rock

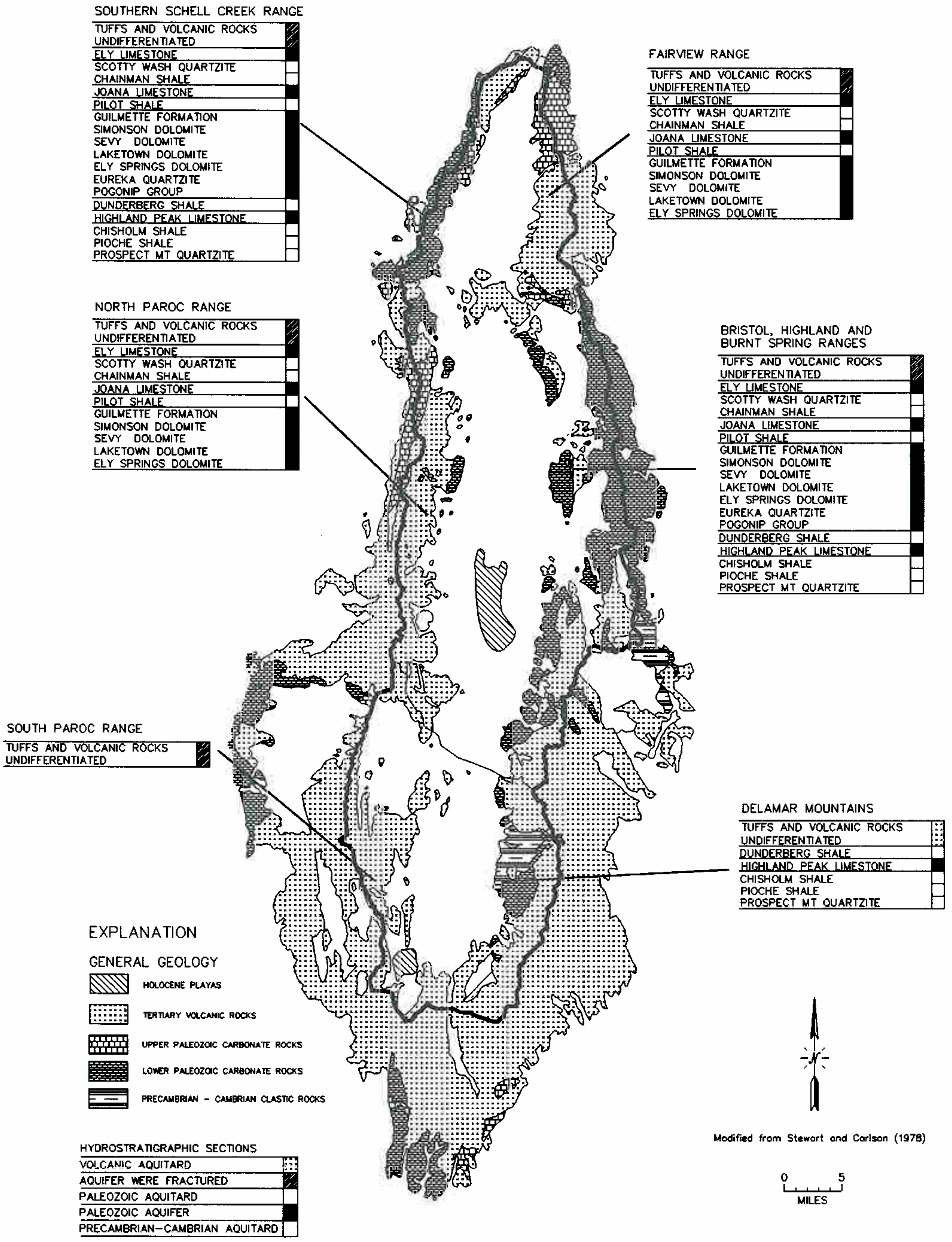
The consolidated rocks that make up the mountain blocks surrounding Delamar and Dry Lake Valleys range in age from the Paleozoic through the Cenozoic, with the exception that most if not all of the Mesozoic is missing. The rock types consist mostly of Paleozoic carbonates with some quartzites and shales and Tertiary volcanics.

The stratigraphy of the consolidated rocks have been well summarized by Tschanz and Pampeyan (1970). Figure 5 shows the general distribution of rocks and the associated hydrologic properties as mapped by Tschanz and Pampeyan, (1970) and Plume and Carlton, (1988).

Volcanics

The volcanic rocks are subdivided into younger and older units. The younger volcanics are dominantly non-welded to densely welded dacite to rhyolitic ash flow tuffs with basalt flows and very minor sedimentary units. The older volcanics include andesitic to latitic flows, welded tuffs, and intercalated sedimentary beds. Some of these older volcanics may be Mesozoic in age.

The volcanic rocks probably have low water transmitting ability as evidenced by an abrupt change in the depth to water in the vicinity of a belt of volcanics that are part of the southern end of the Fairview Range that transect the northern part of Dry Lake Valley. The reason the volcanic rocks are so shallow in this area is probably the result of structural uplift (Oral Commun., Ekren, 1994). North of the volcanics the depth to water is about 270 ft blsd with a north to south gradient of about 40 ft/mi. Immediately south of the volcanics the depth to water increases to about 660 ft blsd and the resultant hydraulic gradient to the south is about 2



Modified from Stewart and Carlson (1978)

Figure 5. -- Geological and hydrogeological units in Dry Lake and Delamar Valleys

ft/mi. This feature is in proximity to the Blue Ribbon Lineament as defined by Rowley (1978). In other parts of the basin, structural activity may have increased the permeability of the volcanics by fracturing the rocks and they may function as an aquifer to some degree. As an example, geologic mapping in the Pahroc Range, shows extensive faulting of the volcanics, increasing the permeability and should be classified as an aquifer (Ekren and Page, 1995; and Ekren et al., 1977). The volcanics probably underlie the alluvial aquifer over much of the two valley system

Intrusives

There are some very minor intrusive plutons of granodiorite and quartz monzonite that occur in the Delamar, Bristol, and Eagan Ranges. These plutons probably do not impact the movement of water unless they have great mass in the saturated zone and in that case, unless well fractured, they act as aquitards and barriers to ground-water flow; they are not included in Table 2.

Paleozoic

Carbonates

This unit is mainly limestone and dolomites that occur in all mountain ranges except the South Pahroc Range. The carbonates underlie the volcanics rocks at great depths and thus are considerably below the alluvial aquifer system. Exceptions to this are in areas where the volcanics have been eroded away or structurally faulted away. The carbonates are extremely important in the area of the Bristol, Burnt Springs and Highland Ranges, located on the eastern flank of Dry Lake Valley. Geologic mapping in the Bristol Wells (Page and Ekren, 1995) and the Coyote Springs (Ekren and Page, 1995) quadrangles identified highly brecciated and structurally deformed carbonates. Secondary permeability induced by the deformation, potentially enhances the transmissivity of the carbonates found in these ranges and allow inter basin transfer of ground water. The carbonates within the valley are considered an aquifer.

Structural Features

Dry Lake and Delamar Valleys are structural basins, termed grabens, which means the valleys have been down-dropped by earthquakes in relation to the bounding east and west mountain ranges. According to Ekren (Written Commun., 1993) most valleys in eastern and southern Nevada dip eastward as defined by volcanic strata on the flanks of the bounding mountain ranges. Further, the valleys are asymmetric with the eastern bounding faults having a much greater displacement than the western faults; Dry Lake and Delamar are quite typical in this respect. Figure 6 shows a typical east-tilted graben such as Dry Lake and Delamar Valleys.

Most prominent in Dry Lake Valley is the range bounding fault on the east side of the valley that extends throughout most of the length of the valley and is believed to extend into and through Delamar Valley to the south. According to Blank and Kucks (1989) the southern the Pahranagat shear zone. Thus both the mountain block to the west, the South Pahroc Range, and the basin block have moved to the west and south because of the extension on the normal fault and the accommodation along the strike-slip fault. Earth movements such as these increase the permeability of the consolidated rock allowing water to be readily transmitted down gradient. It is thought that ground water exits the Dry Lake and Delamar ground-water system through these fault caused fractures to the Pahranagat Basin, which is part of the White River ground-water system.

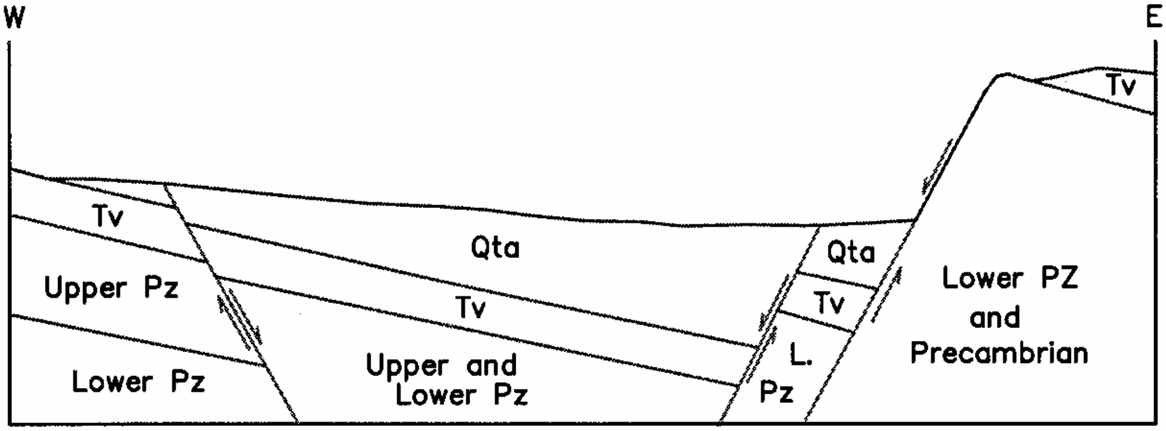


Figure 6. — Schematic drawing showing asymmetric, east-tilted graben typical of eastern Great Basin. Note: total throw is much greater on eastern fault zone than on western fault. Dry Lake Valley fits this general pattern.

The range bounding fault on the west side of the two valley system is less obvious and is marked by discontinuous high angle normal faults (shown in Figure 6). According to Saltus (1988) gravity data suggests the presence of a bounding fault at least in Dry Lake Valley.

According to Ekren et al. (1977) there is a very broad east-trending lineament that extends across much of southern Nevada and on into Utah called the Timpahute Lineament and is inferred to be a deep seated structure that "interrupted north trending ranges, controlled east trending ranges and the location of several intrusive masses, bounded areas of contrasting stress configurations, and served as a focus for strike-slip faulting". More recently Rowley (in press) defines the lineaments as "transverse structures" that form parallel to the direction of extension.

The implications of this type of structure upon ground-water movement are not clear. The more important aspect of the transverse structure may be its relationship to the strike slip faulting which in turn provides an increase in secondary permeability and thereby creates a preferred avenue for the passage of water to the southwest. Other features that have not previously been mapped that may be part of or related to the Timpahute transverse structure are also shown in Figure 7. These are large northeast trending lineaments that appear to be at least several valleys long and transect the bounding ranges in Dry Lake Valley. These lineaments were first identified by District employee Richard Barrett, a geologist utilizing LANDSAT imagery. Brief field investigations could not confirm the presence of these lineaments, which are readily apparent on the LANDSAT imagery. The implication for ground-water movement is simply creating secondary permeability through fracturing in the consolidated rocks and thus providing a preferred flow path.

Structure is also responsible for the steepness of the water levels in the alluvial aquifer, as shown on Figure 4, in the general vicinity of the township boundary common to T3N and T2N. As indicated previously, the water level gradient steepens considerably in this area due to relatively low transmissivity of the underlying volcanics which, according to Page and Ekren (1995) have been uplifted. This is consistent with the magnetic map of Hildebrand and Kucks (1988) which shows a magnetic anomaly caused by the shallow lying volcanic rocks that extend across the valley. The anomaly is probably related to the Blue Ribbon transverse structure which is expressed as a 15 mile wide, 175 mile long band of east-trending igneous centers, mineralize areas and magnetic anomalies, extending across the Wilson Creek Range and the southern Fairview and Shell Creek ranges. (Rowley, in press).

There are numerous fissures in Dry Lake and Delamar Valley that occur in the alluvial valley fill. Swadley (1995) characterizes the fissures as active, inactive and healed, with apparent formation caused by tectonics associated with the formation of the Pahranagat shear system. Of particular interest, are the north trending arcuate fissures located on the east side of Dry Lake Valley in the vicinity of Section 29 T.1N., R.65E. The most recent fissure is the furthest east and is about 5000 feet in length with a maximum top width of six feet and a depth estimated at 40-50 feet. According to Swadley (1995) and field investigations conducted by the District, this fissure is currently propagating at a approximate rate of 150 feet per year to the northeast. The implication for water resources is a preferred path to the ground-water system for surface-water runoff from the alluvial fan and mountain block to the east.

WATER RESOURCES APPRAISAL

To develop a steady-state ground-water flow model that is representative of Dry Lake and Delamar Valleys' hydrologic system, it is necessary to define the magnitude of the water resources available in the basins and their development history. The following sections present the available information on the ground-water resources of these valleys. Dry Lake and Delamar Valleys have a few very localized springs and no perennial streams. Therefore sections on surface-water resources are not included since they are minor.

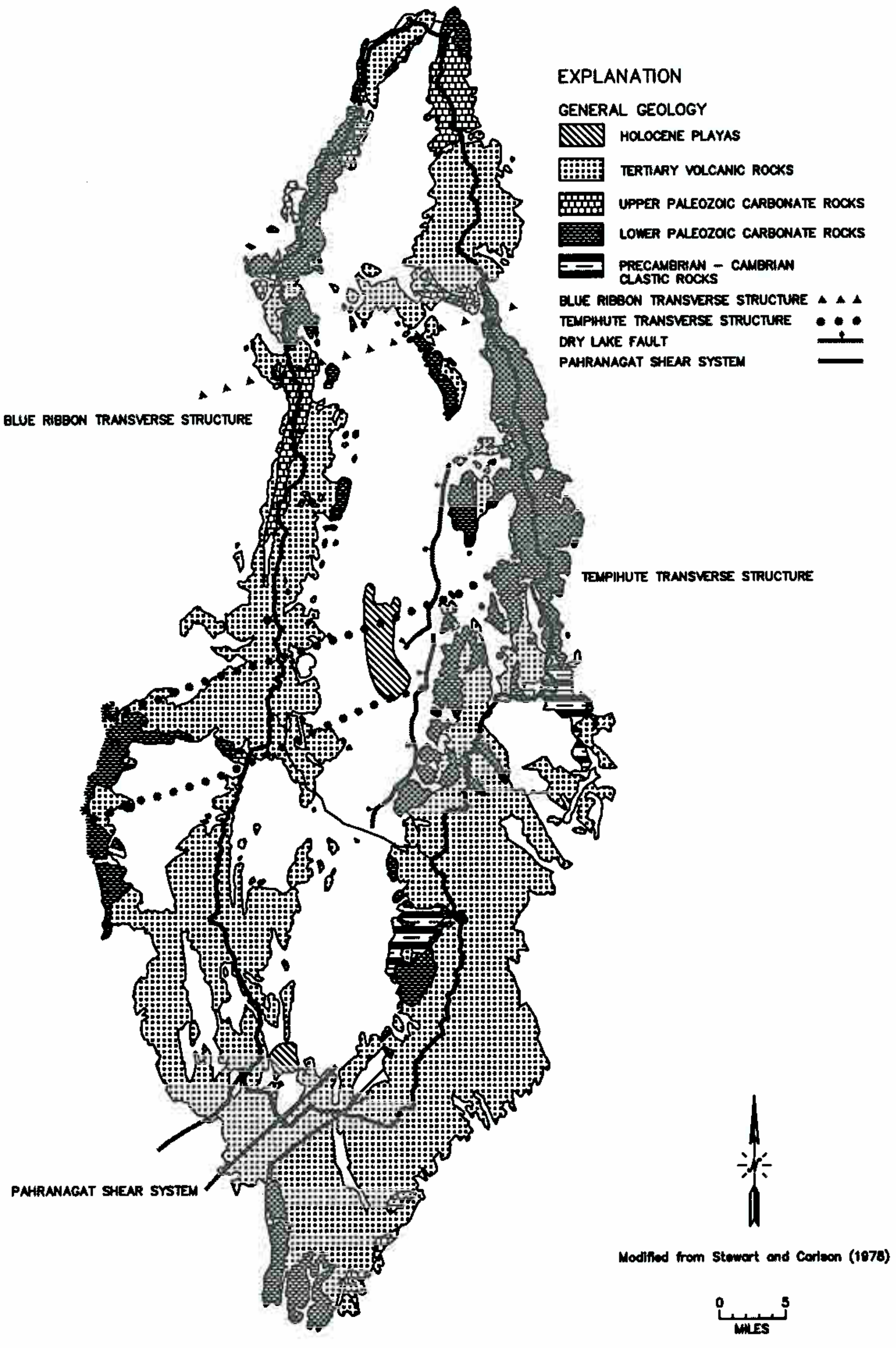


Figure 7. –– Transverse structures and major faults in Dry Lake and Delamar Valleys.

Ground Water

It is necessary to understand the conditions and characteristics of the ground water in Dry Lake and Delamar Valleys to develop an accurate numerical simulation. This section discusses the ground-water occurrence, source, movement, chemical quality, and water budget for Dry Lake and Delamar Valleys.

Occurrence

Ground water occurs in Dry Lake and Delamar Valleys at depths greater than several hundred feet over the majority of the valleys. In the mountain block and in areas on the east side of Dry Lake Valley, water levels are less than one hundred feet as shown in Table 1. In the northeast part of Dry Lake Valley, the alluvium is probably very thin and the transmissivities are low; therefore water levels are high. In the southern part of Dry Lake Valley the range front fault appears to act as a barrier, keeping water levels high to the east of this fault. However, in the central part of Dry Lake Valley, the water table appears to be very flat and drop abruptly from the area north of the east-west volcanic outcropping of the Fairview Range located just north of the West Range. For example the well in N03 E64 20BD has a water level of 4,797 feet AMSL while the water level about 13 miles to the south is 4,299 feet AMSL, a difference of about 500 feet. If the reported value for the well in N02 E64 03B is correct, the water level is 4,306 feet AMSL and this equates to a drop of about 500 feet within 3 miles, as shown in Figure 4.

Figure 4 shows the potentiometric surface for the alluvial aquifer in Dry Lake and Delamar Valleys based upon the water level data available. The questionable reported value for the well in N02 E64 03B was not included in the preparation of this graphic, nor was the one value from the carbonate aquifer since this figure depicts the alluvial potentiometric surface.. Figure 5 does show the barrier caused by the range front fault on the east side of the valley and the flat gradient in the southern part of Dry Lake and all of Delamar Valleys.

Data are generally lacking on the temporal variations in water levels in Dry Lake and Delamar Valleys. The few historic water level measurements for the same wells vary only a few feet with the exception of the well in N03 E64 20BD. The most recent measurement in April of 1994, shows the water table about 45 feet higher than the previous measurement in 1990. At the time the 1994 measurement was made, it was noted that the well appeared to have been reworked and a new pump installed. If the well was deepened and/or cleaned, this could account for some of the difference.

Head elevation data for the carbonate aquifer is provided by the one well in N03 E63 27CA. From this data point it appears the carbonate aquifer is lower in head than the alluvial system in this area, indicating that the alluvium and carbonate aquifers are not well connected in this part of Dry Lake Valley.

Source

The primary source of ground water within Dry Lake and Delamar Valleys is from recharge of precipitation over the Highland Peak and Bristol Ranges. Lesser amounts of recharge are derived from the North and South Pahroc and Delamar Ranges. The basins are closed topographically and no underflow was previously thought to enter from other basins (Harrill et al., 1988), however, as explained in the "Model Development" section there is an indication of ground-water flow from Lake and Patterson Valleys, which is supported by the numerous southwest trending faults previously described. Recharge in Dry Lake Valley, about 5000 acre-feet per year, moves south into Delamar Valley, combining with the 1000 acre-feet per year of recharge here, to make up the 6000 acre-feet per year of subsurface flow entering Pahranagat Valley from southwest Delamar Valley (Harrill et al., 1988).

Movement

Ground-water flow seems to be primarily controlled by the location of the source areas high in the surrounding mountains. In general, ground water flows westward from the Highland Peak and Bristol Ranges and eastward from the North and South Pahroc Ranges toward the valleys axes.

As stated above, Dry Lake Valley is considered to be a valley that does not receive any subsurface inflow from adjacent valleys (Harrill et al., 1988). However, Thomas et al. (1986) indicate water level elevations of 5,800 to 6,000 feet AMSL in Lake and northern Patterson Valleys while water level elevations are less than 5,500 feet AMSL in northern Dry Lake Valley in the alluvium. As discussed in more detail in the "*Model Development*" section, high water levels in the northern and eastern part of Dry Lake Valley were simulated with low transmissivities and the range front fault acting as a barrier. One other way to match these water levels would be to allow more water to enter Dry Lake Valley from Lake and/or Patterson Valleys.

Water moves from Dry Lake Valley, south into Delamar Valley where it continues to move southwest. The ground water is thought to exit Delamar Valley, through a series of east-west trending faults where the Delamar Range meets the South Pahroc Range, into southern Pahranagat Valley.

Chemical Water Quality

The chemical quality of the ground water in Nevada depends on its location in the geologic framework that contains the water. The chemical concentration in recharge areas is normally very low; however, the ground water comes into contact with soluble rock materials for long periods of time as it moves towards discharge areas where the chemical concentration is higher. The solubility, volume, type and distribution of rock materials, time of water contact with the rocks, temperature, and pressure in the ground-water system are factors that determine the extent to which the chemical constituents from the rock materials will be dissolved.

General

The water quality data for Dry Lake and Delamar Valleys is limited. There are a few localized springs in the surrounding mountain blocks in each valley. These springs and a couple of wells were analyzed for water quality during the U.S. Air Force's MX Missile Water Resources Program and the results are reported in Bunch and Harrill (1984). Figure 8 shows the electrical conductivity (EC) and temperature of the few springs and wells reported in Bunch and Harrill (1984). The U.S. Air Force test well located in T04N R64E 07DC is reported in Bunch and Harrill (1984) as having total dissolved solids (TDS) values of 1961 and 1121 mg/l. The other constituents listed do not have high enough values to support these TDS values. This discrepancy, with the significant difference in TDS values, makes these analyses suspect; therefore, they were not included in Figure 8.

With the exception of the two TDS values discussed above, the overall water quality is good and all the EC values listed are within the TDS limits specified by the Environmental Protection Agency's (EPA) Safe Drinking Water Act.

Water Resources Budget

A water resources budget consists of a complete accounting of all components of inflow and outflow for a hydrographic basin. The results of any model developed to simulate flow in a basin are dependent upon the accuracy of the budget. Table 3 summarizes the water budgets for Dry Lake and Delamar Valleys.

Table 3.--Water resources budget for Dry Lake and Delamar Valleys.

INFLOW Acre-feet/year (rounded)		
Precipitation Ground-Water Component		
Dry Lake Valley		5000
Delamar Valley		1000
	TOTAL	**6,000**
OUTFLOW		
Outflow (to Pahranagat Valley)		6,000
Other loss (mining, domestic, stock) insignificant	**TOTAL**	**6,000**

Source: Eakin (1963)

Estimated Average Annual Ground-Water Recharge

Recharge to Dry Lake and Delamar Valleys consists of one component, precipitation, mostly in the form of winter rain and snow in the Highland Range although summer convective storms may contribute significant amounts of rain.

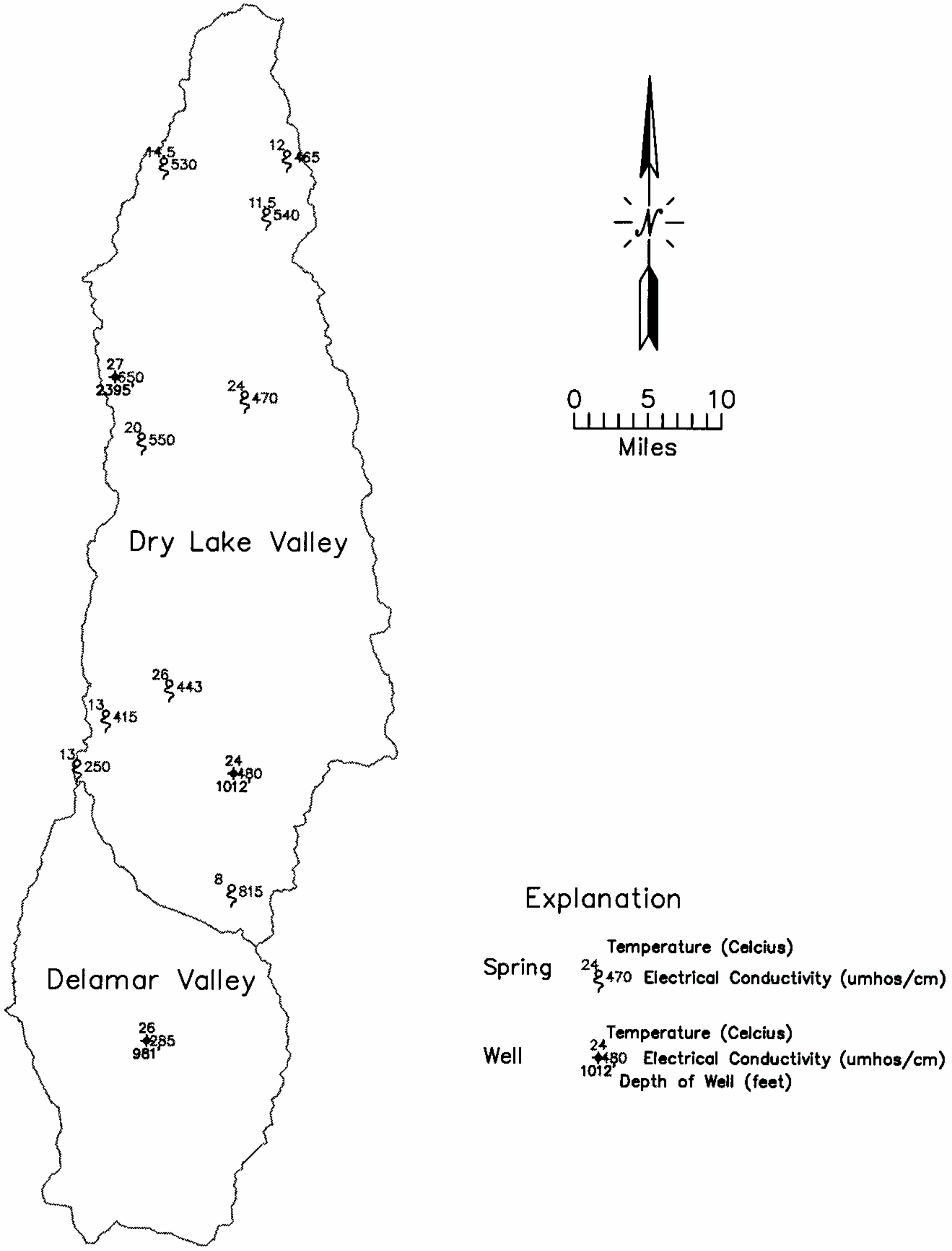


Figure 8.—— Select spring and well locations with respective temperature, electrical conductivity, and depth of well.

Precipitation

The source of recharge to the hydrologic system of Dry Lake and Delamar Valleys is the infiltration of precipitation over the basins. No meteorological stations are located in Dry Lake and Delamar Valleys and the characterization of precipitation over the area is inferred from records for Alamo, Pioche, and Caliente which are located in adjacent valleys. The total precipitation over Dry Lake and Delamar Valleys is estimated at about 152,000 acre-feet per year (Scott, et al., 1971). The total volume of ground-water recharge derived from precipitation is reported by Eakin (1963) to be 6,000 acre-feet per year, or about 4 percent of the precipitation.

The infiltration of precipitation does not occur evenly over a large area. Rather, as determined by Eakin et al. (1951) and Quiring (1965), the distribution of precipitation, and hence, infiltration and recharge, in the desert valleys of Nevada, is primarily a function of elevation and latitude. Thus, for the purposes of developing a ground-water flow model of Dry Lake and Delamar Valleys, recharge totalling about 6,000 acre-feet per year may be distributed according to the zones summarized in Table 4.

Table 4.--Recharge distribution zones for Dry Lake and Delamar Valleys (Eakin, 1963).

ELEVATION Feet Above Sea Level	PRECIPITATION Inches/Year	APPROX. AREA Acres	PRECIPITATION Acre-feet/year	RECHARGE RATE Percentage	RECHARGE FLUX acre-feet/year (rounded)
>9,000	>20	200	350	25	100
8,000-9,000	15-20	3200	4,700	15	700
7,000-8,000	12-15	20,000	22,500	7	1,600
6,000-7,000	8-12	149,000	124,000	3	3,600
<6,000	<8	650,000	-------	0	0
TOTALS (rounded)			152,000		6,000

There is some question concerning the accuracy of recharge rates based upon this methodology. As noted by Watson et al. (1976), the Maxey-Eakin method is simply a first approximation which, in lieu of basin-specific data, provides a method for making gross estimates of recharge. This methodology, while appropriate for reconnaissance level investigations, may have significant error when applied to any given basin. However, Avon and Durbin (1994, published initially as Cooperative Water Project Series, Report No. 7, 1992) concluded the method is a fairly good indicator and is probably more accurate than portrayed by Watson et al. (1976).

The recharge rates applied to the basins by Eakin (1963) were based on the recharge rates applied to adjacent basins, which were based on measurements of spring discharge and estimates of phreatophyte water use. Recent published information by Nichols (1992) indicates that phreatophyte transpiration might be as high as 3.5 times the values used by USGS reconnaissance studies for northern and eastern Nevada. Therefore, recharge estimates could be as low as 3.5 times that currently estimated. Therefore, even though there are no phreatophytes in Delamar and Dry Lake Valleys, to be consistent with the application of recharge rates in adjacent basins the rates would have to be higher in Delamar and Dry Lake Valleys if the rates are higher in adjacent valleys.

Subsurface Inflow

In order to maintain consistency with the published ground-water budget no inflow of ground water, other than natural recharge to Dry Lake and Delamar Valleys, is accounted for. However, recent investigation indicate a strong potential for interbasin subsurface flow from Patterson and Lake Valleys. The implications of this means there is unaccounted for recharge in Patterson and Lake Valleys and more water exits Pahranagat Valley than previously estimated.

Secondary Recharge

Secondary recharge is usually estimated based on the type of usage of the ground water and surface water. In many basins in Nevada, secondary recharge is minor. This is the case for Dry Lake and Delamar Valleys. The only ground-water use in these valleys is stock watering; therefore, secondary recharge is insignificant.

Estimated Average Annual Discharge

Components of discharge include evapotranspiration, which includes spring flow, well pumpage, and subsurface outflow. The only component of discharge in the Dry Lake and Delamar Valleys hydrologic system is subsurface outflow.

Evapotranspiration

Because of the depth to the water table, several hundred feet, over much of Dry Lake and Delamar Valleys, evapotranspiration (ET) is not a significant source of ground-water discharge.

Springs

There are a few localized springs in the mountains surrounding Dry Lake and Delamar Valleys. The flows of these springs are minor and not significant when considering the hydrologic budget.

Water Wells

Based on information provided by SEC, the majority of ground-water and surface-water rights or applications in Dry Lake and Delamar Valleys are for livestock watering. Wells in these valleys are used for stock watering or water-level observation, as the case with the U.S. Air Force's MX wells.

Outflow

Discharge through subsurface flow from Dry Lake and Delamar Valleys is to the southwest into Pahranagat Valley. This is the only source of ground-water outflow from Dry Lake and Delamar Valleys.

Total Discharge

As discussed above the only component of ground-water discharge from Dry Lake and Delamar Valleys is subsurface outflow. This is estimated by Harrill et al., (1988) and Eakin (1963) to be about 6,000 acre-feet per year.

Perennial Yield

Scott, et al. (1971) define perennial yield as "the maximum amount of natural discharge that can be salvaged each year over the long term without depleting the ground water reservoir." Eakin (1963) states that the magnitude of perennial yield ultimately equals total recharge to the valley; however, the recovery of this recharge is limited by economic issues, such as the number of wells and the deep pump settings that would be required to salvage the natural recharge from these valleys. Eakin (1963) goes on to state that to salvage a large part of Dry Lake and Delamar Valleys' recharge, water levels would have to be drawn down significantly.

Storage

The quantity of ground water stored in the geologic units underlying Dry Lake and Delamar Valleys is large; the amount of recoverable ground water in storage in the valley reservoir is estimated to average about 10 percent of the volume of the saturated valley-fill (Scott, et al., 1971). For Dry Lake and Delamar Valleys, Eakin (1963) estimated the quantity of recoverable ground water in the saturated valley fill to be substantial. If one assumes that about 60% of the valley is covered with alluvium, this equates to about 480,000 acres, therefore there would be about 4.8 million acre-feet of water in storage in the upper 100 feet of saturated alluvium.

No estimates have been made of the amount of ground water that is stored in the carbonate aquifer in Dry Lake and Delamar Valleys. Although the storage capacity of the carbonates is less than that of the valley-fill, the larger saturated thickness and greater areal extent of the carbonate aquifer suggests that the quantity of recoverable water from storage is still significant. Dettinger (1989) reported that the quantities of ground water in the regional carbonate aquifer are "enormous", and estimated that the total quantity of water stored in this regional aquifer south of Pioche and Tonopah is on the order of 800 million acre-ft. Adopting Dettinger's assumption of a total of one percent of the aquifer volume as being recoverable, then a rough estimate of the recoverable ground water in storage in Dry Lake and Delamar Valleys can be made. Based upon this recovery factor, the areal extent of the carbonates underlying the valley (approximately 1,260 square miles), the ground-water storage in Dry Lake and Delamar Valleys is estimated to be approximately 800,000 acre-feet in the upper 100 feet, about 16 percent of the amount in the same thickness of saturated valley fill.

INVENTORY OF WATER RIGHTS, PUMPAGE, AND LAND USE

An estimate of ground-water usage in a basin can be obtained from present water rights, pumpage, and application of pumped water to crops and other uses. These factors are examined in the following sections.

Present Development

The level of development of water resources in a basin can be illustrated by the water right allocations and the current ground-water pumpage within that basin. In Dry Lake and Delamar Valleys, water is used only for stock watering. There are mining water rights in these valleys; however mining operations have been inactive for a number of years. Agricultural development is not present even though there are Desert Land Entry (DLE) water right applications.

Water Right Status

Based on information supplied by SEC contained in Appendix B, the State Engineer has allocated water-right permits in Dry Lake and Delamar Valleys for both surface water and ground water totalling about 1,700 acre feet. Of this total about 300 acre feet per year represent ground-water rights. This is excluding two DLE ground-water right applications, one in each valley for a consumptive use amount of 1200 acre-feet each. The water right permits are listed by type of use for each valley in Table 5.

Table 5.--Existing permits (consumptive use) in Dry Lake and Delamar Valleys
(acre-feet per year).[1)]

	Dry Lake		Delamar	
	Surface	Underground	Surface	Underground
Irrigation/Domestic	25	0	45	0
Mining/Industrial	18	0	36	242
Stock	815	46	500	13
Totals	857	46	581	255

1) Excluding Desert Land Entries

Pumpage

Data on actual water use in Dry Lake and Delamar Valleys are not available; however is quite small since water is only used for stock watering in these valleys.

Land Use

Most of the land in Dry Lake and Delamar Valleys is public-domain land administered by the Bureau of Land Management. Some areas are used for livestock range.

Future Development

Plans for future development of Dry Lake and Delamar Valleys are unknown. The valleys have changed very little since the reconnaissance work done by Eakin (1963) and remain virtually undeveloped.

MODEL DEVELOPMENT

MODFLOW is a three dimensional ground-water flow model that simulates ground-water movement through gridded layered cell blocks by solving a series of finite difference equations. These equations preserve the quantity of ground water in the modelled area. For any further detail regarding the flow model, the MODFLOW documentation (McDonald and Harbaugh, 1988) should be consulted.

The first step in developing a ground-water flow model is the formulation of a conceptual hydrogeologic model of the area to be mathematically represented. This conceptual model is based upon the available hydrologic data, inferences based on observations of similar hydrologic settings, and assumed conditions or expected ranges of conditions for parameters that have not been measured or are not readily estimated for the subject hydrologic basin.

The first step in the mathematical representation of the conceptual model is the development of a grid system covering the hydrologic basin. The grid system can be either single or multiple layers with each cell in the model being identified by grid row, column, and layer designation. Usually the grid size and number of layers are chosen based on the amount of available hydrologic data for the particular basin. Each cell is given a number of parameters (i.e. transmissivity, storage (in transient scenarios), conductive characteristics for spring flow, recharge where appropriate, and rates of evapotranspiration when the water levels are within a set distance from land surface) which control water flow through the model. The District made the decision to make all the grids for the individual ground-water flow models one mile by one mile and each model two layers, one to represent the alluvial system and the other the consolidated bedrock. In some valleys there were not enough data to warrant this scale; however, preparation of the model on this scale will provide a framework for future data entry resulting in model refinement.

Approach and Assumptions

The approach taken in all the individual basin models was to produce a steady state model which replicated as closely as possible the hydrologic basin budget as defined by the USGS while attempting to match existing ground-water levels. The most important "constant" becomes the amount of water entering the system or the recharge and of course water levels which serve as calibration points. Eakin (1963) established the hydrologic budgets for Dry Lake and Delamar Valleys. As discussed previously, there are about a dozen wells in Dry Lake and Delamar Valleys which provide some data for model calibration, and one of these wells is completed in consolidated rock.

A one square mile grid, 83 rows by 25 columns as shown in Figure 9, consisting of two layers, was constructed to simulate ground-water flow in Dry Lake and Delamar Valleys. Both the upper alluvial fill and surrounding consolidated rock outcroppings and the lower consolidated rocks were modelled as confined fixed transmissivity units. Parameter selection (i.e. transmissivity and vertical leakance) was keyed to rock type. Figure 10 shows the lithology distribution for the upper layer, specifying alluvium and rock type based on the digital representation of the Nevada 1:500,000 scale geology map (Stewart and Carlson, 1978) prepared by Turner and Bawiec (1992). The lower layer or underlying consolidated rocks were assumed to be carbonates with some overlying volcanics which were simulated by using the vertical conductance between layers.

Parameter Estimates

Recharge and Discharge

Eakin (1963) estimated the recharge, based on the method described by Eakin et al. (1951), to Dry and Delamar Valleys to be a total of about 6000 acre-feet per year, 5000 acre-feet in Dry Lake Valley and 1000 acre-feet in Delamar Valley. Because there is no evapotranspiration in either Dry Lake or Delamar Valleys the total ground-water discharge is by underflow through bedrock and is estimated by Eakin (1963) to be equal to the ground-water recharge. The amount of ground water used in Dry and Delamar Valleys was estimated by Eakin (1963) to be that for livestock only, and was estimated to be about 100 acre-feet per year. The mining operations at Bristol in Dry Lake Valley and at Delamar in Delamar Valley had stopped prior to Eakin's inventory. A recent assessment of land use and water rights permits in these valleys confirmed that water use is for livestock only and probably does not exceed Eakin's previous estimate of 100 acre-feet per year.

Primary Recharge

Primary recharge in Dry Lake and Delamar Valleys occurs from the infiltration of precipitation into the ground-water system occurring in the higher elevations as well as from some infiltration of surface water runoff and spring flow. Dry Lake Valley receives a large part of its recharge from the Highland Peak and Bristol Ranges bordering the valley on the east side. Delamar

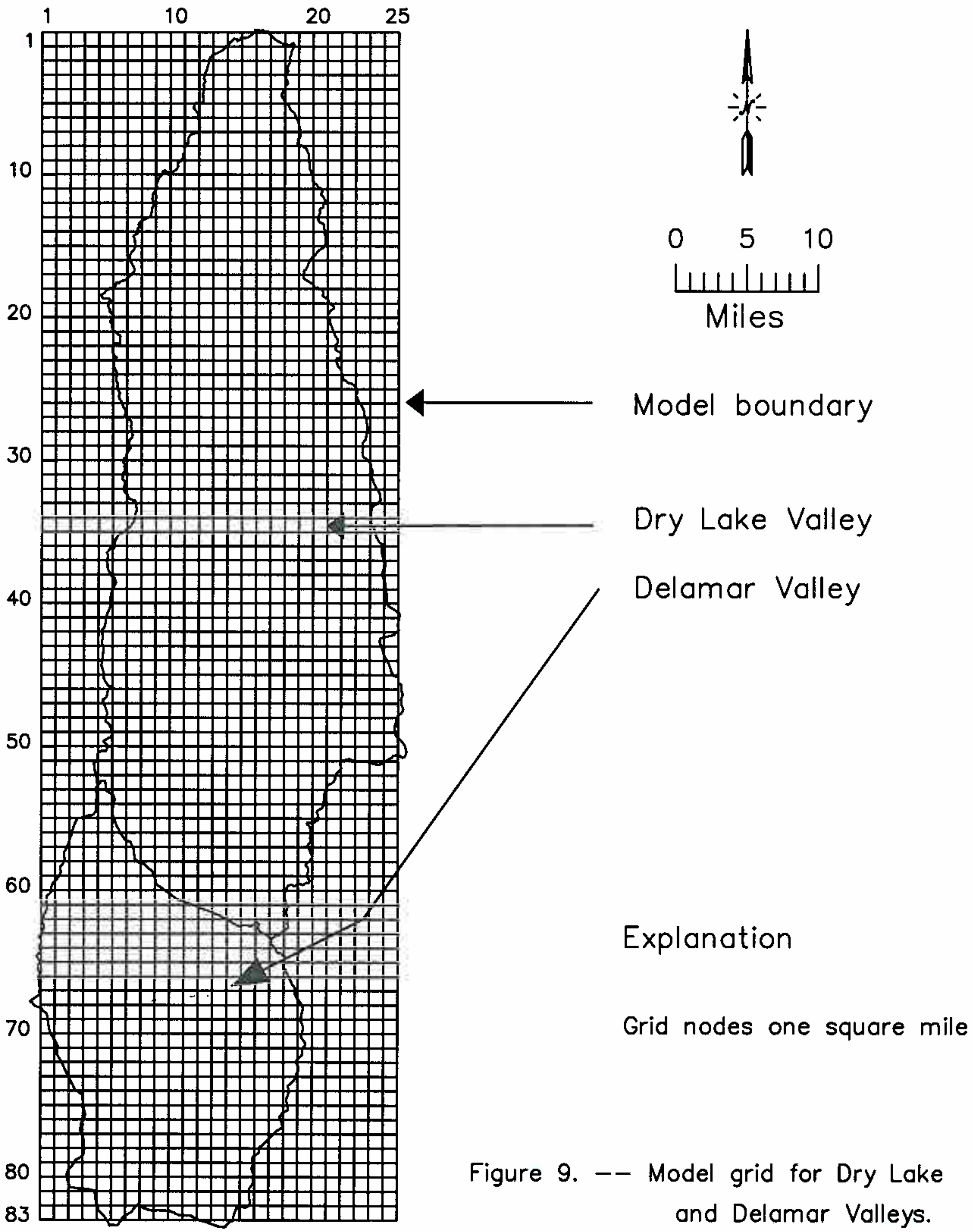
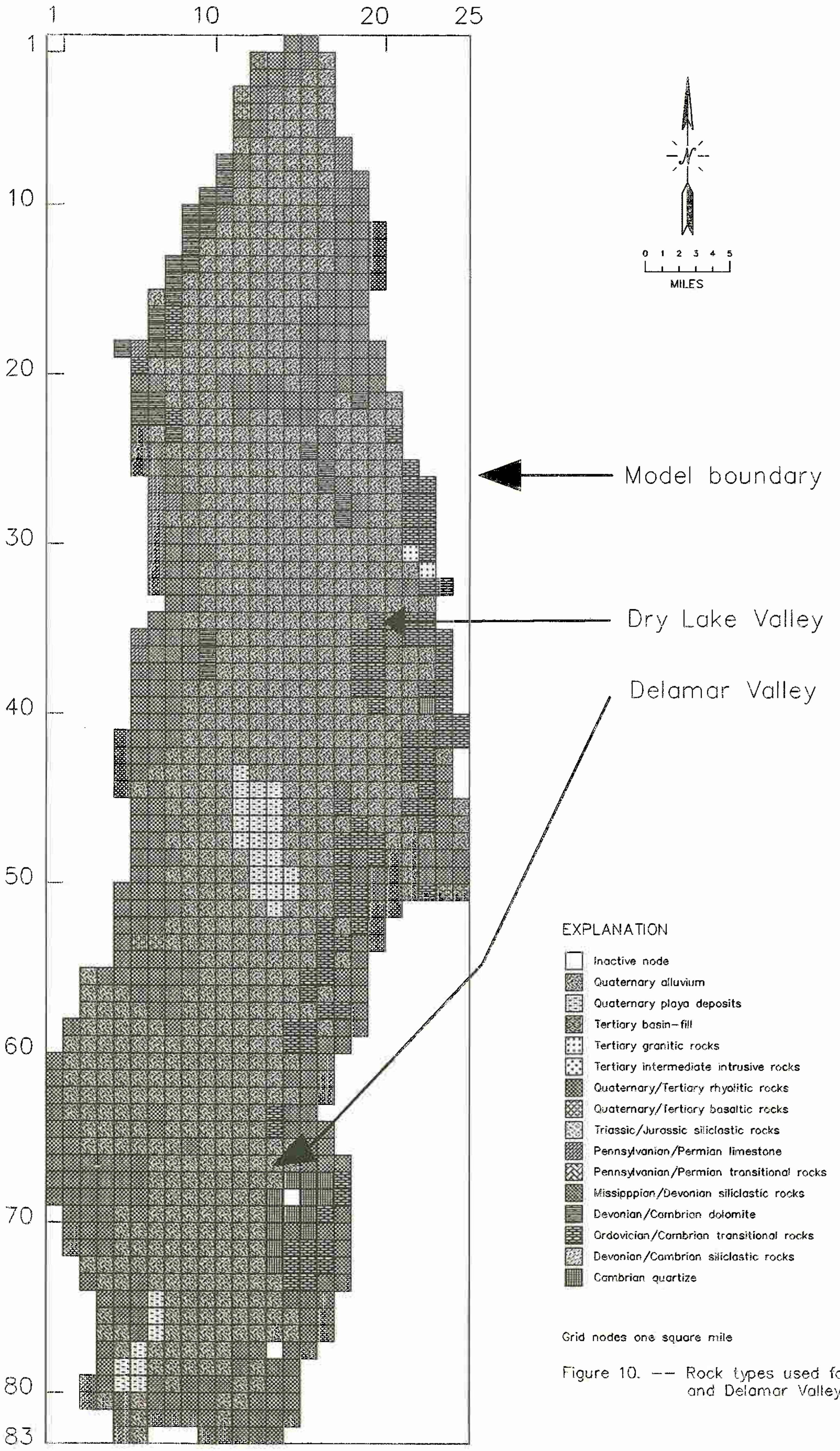


Figure 9. –– Model grid for Dry Lake and Delamar Valleys.



Grid nodes one square mile

Figure 10. -- Rock types used for Dry Lake and Delamar Valleys' model.

Valley receives most of it's recharge from the Delamar Range which flanks the valley on the south and east. Other ranges contributing to Dry Lake and Delamar Valley's recharge are the North and South Pahroc Ranges on the west sides of the valleys.

Digital elevation data were used to computer generate and distribute recharge based on the Maxey-Eakin method (Eakin et al., 1951) with the factors listed for Dry Lake and Delamar Valleys in the report by Eakin (1963) and shown in Table 4. Digital elevations were obtained for the complete Cooperative Water Project (CWP) area from the USGS, which are based on the 1:250,000 scale Army Map Series (AMS) maps and contain an elevation every 90 meters. This data was smoothed by finding the nearest neighbor then resampling at 150 meter intervals. The file was then subset for the Dry and Delamar Valleys grid area.

Dr. James Tracy developed a program to calculate recharge based on these digital elevations for each grid cell using the Eakin factors (precipitation and percentage infiltrating the ground-water system) listed in the various USGS reconnaissance reports. The product of the program is a matrix corresponding to the grid which specifies recharge rates for each cell. This program was used to generate such a matrix for the Dry Lake and Delamar Valleys area. Figure 11 is a graphical representation of the recharge distribution used in the Dry Lake and Delamar Valley model. Based on this method, the recharge for Dry Lake and Delamar Valleys was calculated to be about 6000 acre-feet per year, which equals the amount calculated by Eakin (1963).

Secondary Recharge

Secondary recharge is due to infiltration of water from anthropogenic uses such as irrigation or septic disposal systems. As stated above, the only water use in Dry Lake and Delamar Valleys is for livestock watering; therefore secondary recharge is non existent.

Discharge

Evapotranspiration

Depths to water in both Dry Lake and Delamar Valleys are in excess of hundreds of feet except high in the mountains, where there are localized springs and flow systems; therefore areas of evapotranspiration (ET) are not significant in Dry Lake and Delamar Valleys.

Springs

A few very small localized springs are found high in the mountain ranges in Dry Lake and Delamar Valleys. The flow rates are minor and, as stated above, evapotranspiration occurring as a result of these springs is minor and was not considered in the model.

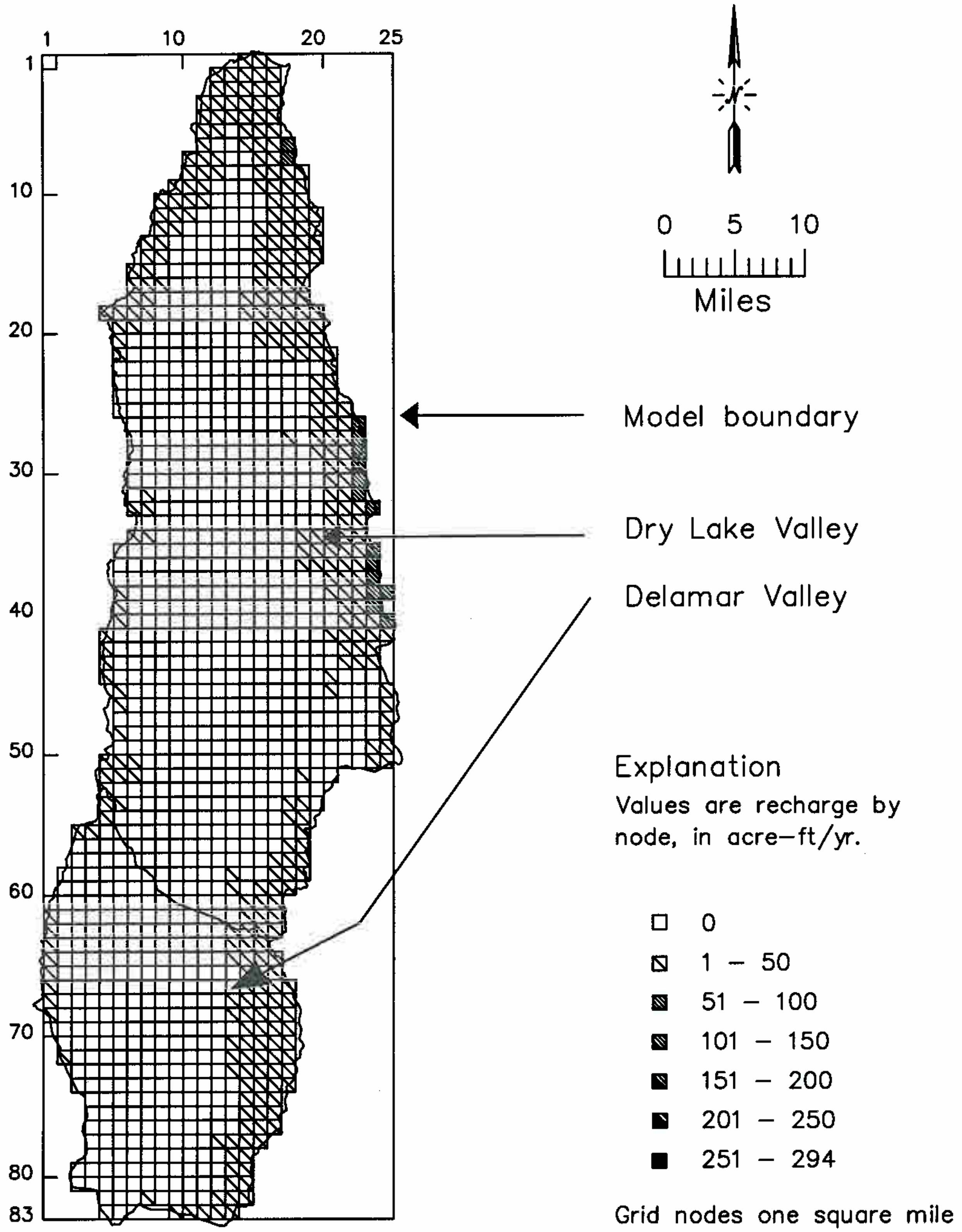


Figure 11. –– Model recharge conditions for Dry Lake and Delamar Valleys' model.

Hydraulic Characteristics

The hydraulic characteristics govern how the water introduced by recharge or interbasin flow moves through the modelled area to the areas of discharge. For a steady state simulation the important hydraulic characteristics are transmissivity, boundary conditions (conductances) and, since this is a two layer model, vertical leakance. These parameters are discussed below:

Boundary Conditions

Each individual basin was modelled as a "free body" tied to general head boundaries outside the existing basin boundary. The water levels specified for the general head boundaries were based on Thomas et al. (1986) for each layer. Conductances were established to simulate the USGS estimates for inflow and outflow in each layer, as well as match existing water levels. As discussed above, the only inflow to Dry Lake and Delamar Valley used in this report is natural recharge. There is no estimate for subsurface inflow to the two valley system; only subsurface outflow from the lower layer. Therefore, the upper layer has no flow boundaries and Figure 12 shows the location of the general head boundaries and the conductances used in the lower layer.

Inflow

Eakin (1963) and Harrill et al. (1988) estimate that the only inflow to Dry Lake and Delamar Valleys is the natural recharge of about 5000 acre-feet per year in Dry Lake Valley and 1000 acre-feet per year in Delamar Valley. The 5000 acre-feet per year in Dry Lake Valley is underflow to Delamar Valley. The final model's boundary conditions therefore do not allow any inflow other than natural recharge to Dry Lake and Delamar Valleys. As discussed later in this report under the Steady State Model Sensitivity (Appendix C), other boundary conditions were tested allowing water to flow into Dry Lake Valley through the Highland Peak and Bristol Ranges to match existing water levels. However, since one of the primary constraints of the steady state models developed by the District as part of the CWP was to match the hydrologic budget as defined by the USGS, the boundary conditions allowing no significant inflow into Dry Lake and Delamar Valleys were used.

Outflow

Harrill et al. (1988) estimate that about 6000 acre-feet per year exit southwestern Delamar Valley in the consolidated rocks through the fault zone separating the Delamar and the South Pahroc Ranges into Pahranagat Valley. The model's lower boundary conditions result in about 6000 acre-feet per year exiting in this area. However, these lower layer boundary conditions had to be coupled with an area of high transmissivity in the lower layer, as discussed below, to transmit this water while still attempting to match existing water levels.

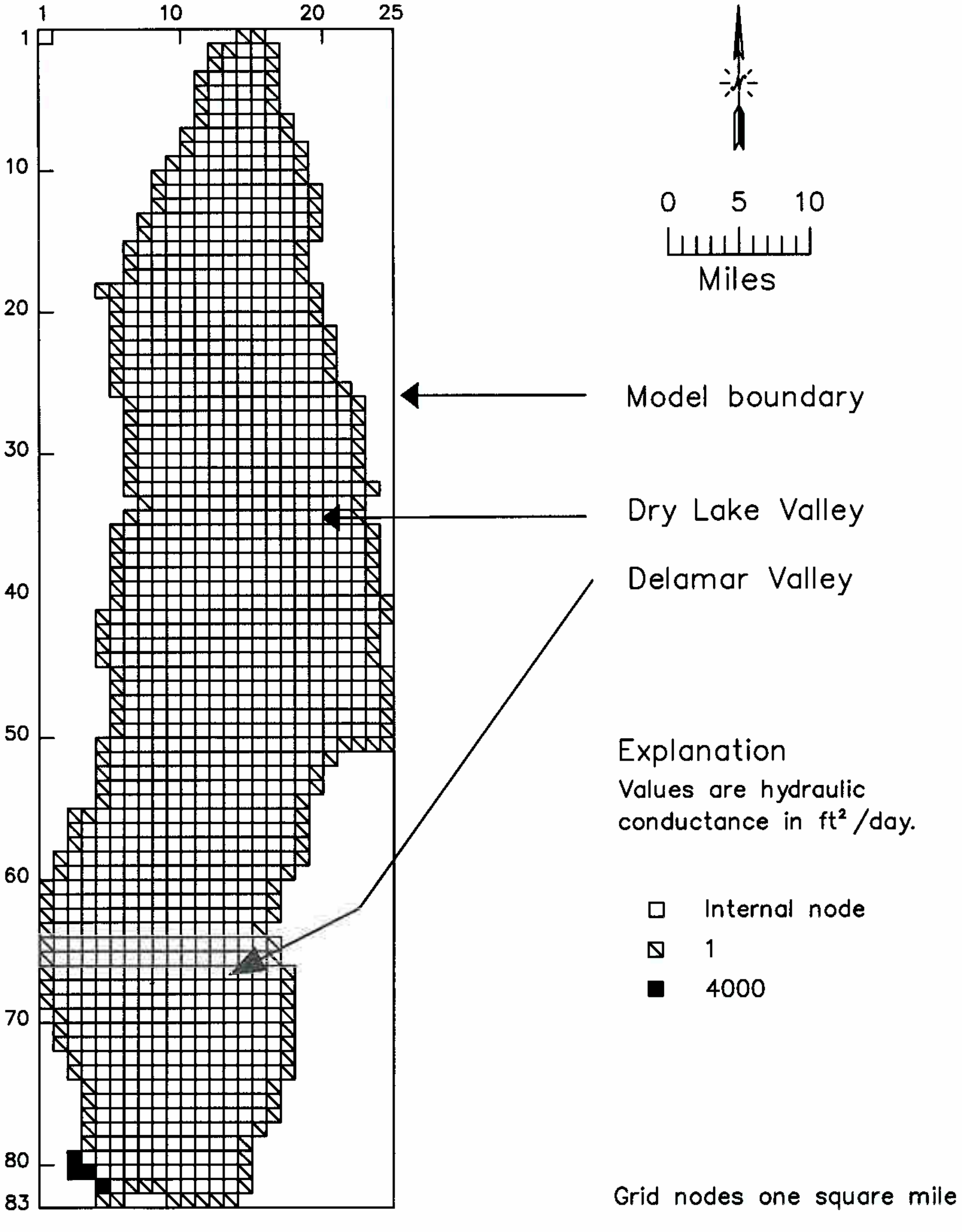


Figure 12. -- General head boundary conditions for Dry Lake and Delamar Valleys.

Transmissivity

Transmissivity values were assigned based on rock type. The USGS digital representation of the 1:500,000 scale Nevada Geology (Turner and Bawiec, 1992) was used to classify rock types into transmissivity zones. A raster file of the geology was created from the digital map by using the gridding function in ARC Info, subsetting a number corresponding to the geology type every half a mile for the complete CWP regional model area. This grid was then subset on mile nodes for the area corresponding to the Dry Lake and Delamar Valleys model, which included different geologic classifications as shown in Figure 10.

As part of the U.S. Air Forces MX Missile Water Resources Program siting investigation, several aquifer tests were conducted in the alluvium in Dry Lake and Delamar Valleys and one in the carbonate rock on the west side of Dry Lake Valley, as reported by Bunch and Harrill (1984). There were three sites tested in the alluvium with two in Dry Lake Valley. The first site with two wells (one pumping and one observation well completed at different depths) is in T03S R64E 12AC, where transmissivities ranged from 2700 ft^2/day to 6500 ft^2/day with an average of 4300 ft^2/day. The second site, again with two wells (one pumping and one observation well completed at different depths) is in T04S R64E 07DC, where transmissivities ranged from 15 ft^2/day to 126 ft^2/day with and average of 56 ft^2/day. The alluvial site in Delamar Valley was located in T06S R63E 12AD and yielded an average transmissivity estimate from the observation well of only 1200 ft^2/day. The site of the one aquifer test in carbonate bedrock is in Dry Lake Valley in T03N R63E 27CA, and resulted in a transmissivity estimate of 13,400 ft^2/day. These values provided a starting point for the model transmissivities.

The final model transmissivities are shown for the upper layer in Figure 13. Three alluvial transmissivities were necessary for the calibration of the model and are warranted based on the geology. The northern part of Dry Lake Valley is very narrow and somewhat separated from the remaining valley by an outcropping of volcanic rock which is part of the Fairview Range. Directly south of this east to west outcropping of volcanics is an outcropping (primarily comprised of carbonates) known as the West Range. This range separates an area of alluvium, east to the Bristol Range. These somewhat isolated areas of alluvium are much thinner, therefore requiring lower transmissivities. The final transmissivity used for the area of alluvium separated by the volcanics , the "northern" alluvium, was 750 ft^2/day and the transmissivity for the area east of the West Range, the "eastern" alluvium, was 10 ft^2/day. The highest calculated transmissivity of the MX well tested in T04N R64E 07DC, which is in this area, was 126 ft^2/day, so the overall low value of 750 ft^2/day is probably a fair representation of the total thickness of alluvium in this northern part. The remaining areas of alluvium, the "southern" alluvium, was modeled with a final transmissivity of 3000 ft^2/day.

The surrounding bedrock (all types) were modeled with a low transmissivity of 100 ft^2/day which was necessary to keep simulated water level elevations high. A significant north trending fault is mapped on the east side of Dry Lake Valley. A transmissivity of 1.0 ft^2/day was used to simulate this fault to keep simulated water levels east of the fault high enough to match existing water levels.

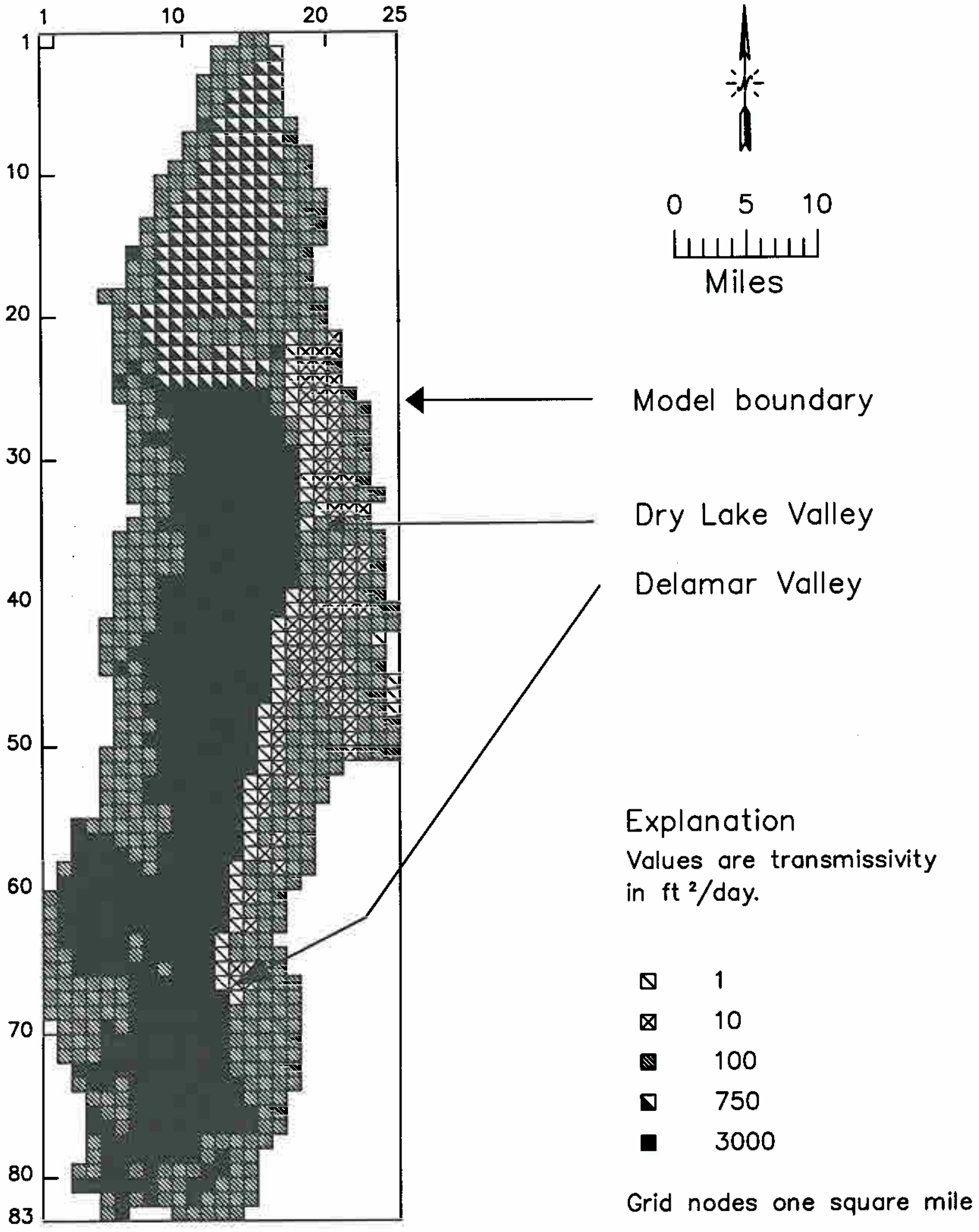


Figure 13. —— Transmissivity in upper layer for Dry Lake and Delamar Valleys' model.

The final model transmissivities for the lower layer are shown in Figure 14. For the majority of the lower layer, the transmissivities are in the range between 100 ft^2/day and 800 ft^2/day. There are a couple of notable exceptions. For the carbonate rock type in the area of the MX test well (T03N R63E 27CA) a value of 3000 ft^2/day was used to attempt to match actual water levels (the actual calculated value was 13,400 ft^2/day). A value much higher than the 3000 ft^2/day lowered the alluvial water levels significantly. The mapped fault zone on the east side of the valley was also simulated with a value of 1.0 ft^2/day in the lower layer as it was in the upper layer. A higher transmissivity zone was simulated as a north trending fault in the lower layer through the central part of Dry Lake and Delamar Valleys then trending west to the area of the bedrock contact between the South Pahroc Range and the Delamar Range where the water is exiting to Pahranagat Valley (Harrill et al. 1988). The actual location of this potential fault in the model was based on lineament analysis of Landsat (TM) satellite data. All transmissivity values for the upper and lower layers are shown on Figures 13 and 14, respectively.

Vertical Leakance

The vertical leakance values establishes the connection between the upper and lower model layers and were initially calculated as specified by McDonald and Harbaugh (1988) based on assumptions of overall general thicknesses. Recalculation was done as transmissivity values varied significantly during calibration. Because of the assumed transmissivities for the thinner alluvium and the probable presence of volcanics underlying this alluvium, the vertical conductance values were lower than that for the "southern" alluvium. Figure 15 shows all the vertical conductance values used in the model. As shown here, the values for the vertical conductance between the "northern" alluvium and the bedrock is 1.9×10^{-8} and for the "eastern" alluvial area the vertical conductance is 1.9×10^{-10}. The remaining vertical conductance for the "southern" alluvial area is 1.0×10^{-6}. Another area of relative high vertical conductance is that between the alluvium and the modeled fault running through the central part of the valleys, with a value of 1.9×10^{-6}. The sensitivities of the vertical leakance values are discussed in more detail in Appendix C entitled "Steady State Model Sensitivity".

Steady State Simulation

The potentiometric surfaces for the upper and lower layers resulting from the steady state simulation of Dry Lake and Delamar Valleys are shown in Figures 16 and 17 with the actual water levels measurements imposed. Table 6 shows the 8 wells used for calibration and the differences between the actual and simulated water levels for the Dry Lake and Delamar Valleys model. These measurements are the majority of water levels included in Table 1, with the same ID numbers. Three wells were excluded from the calibration; No. 7 and No. 11 because they are shallow wells completed in localized "perched" systems and No. 5 because a recent measurement could not be obtained and the previous one is reported and thought to be potentially in error. There is only one measurement in the bedrock or lower layer. A discussion of steady state model simulation is found in Appendix C.

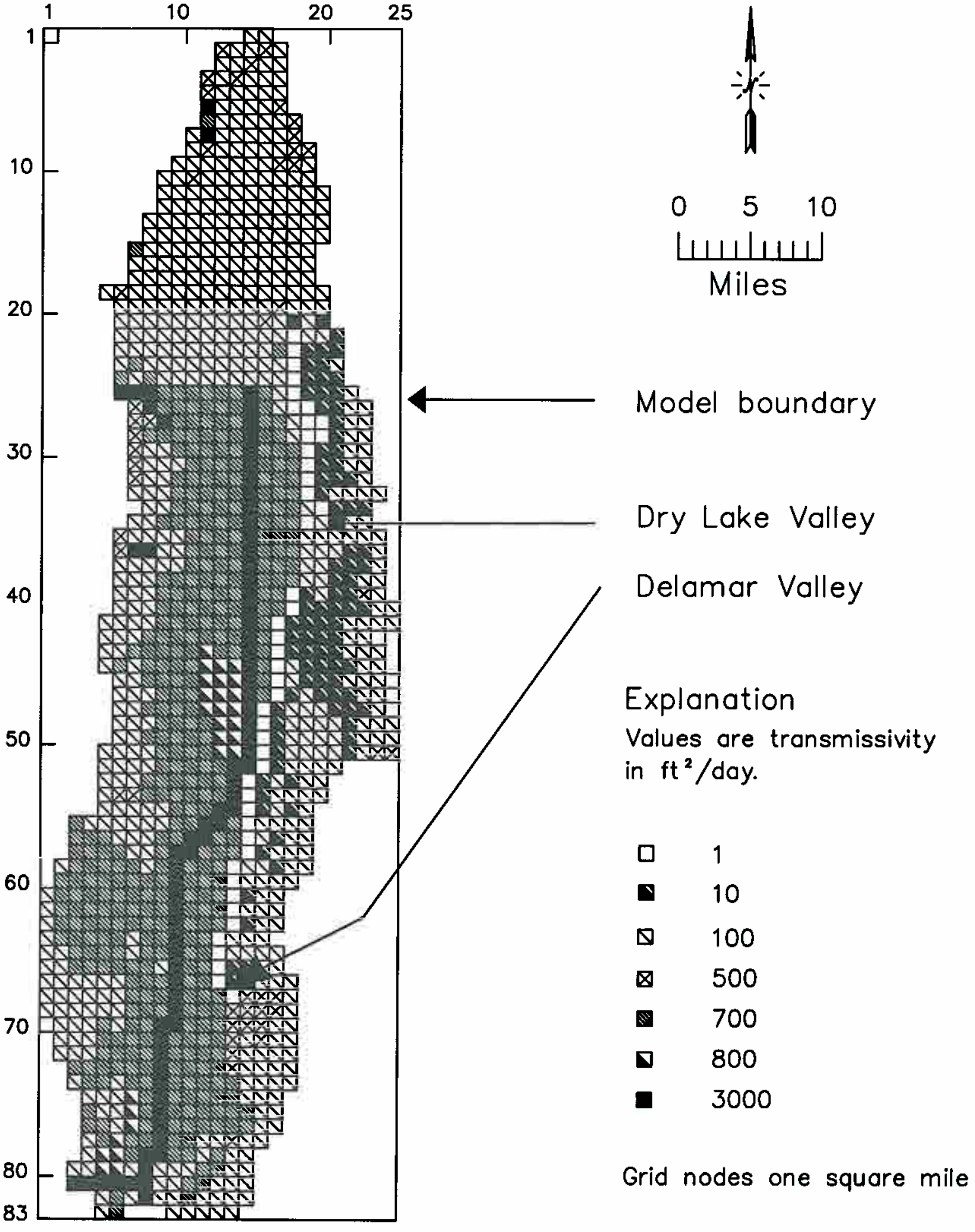


Figure 14. –– Transmissivity in lower layer for Dry Lake and Delamar Valleys' model.

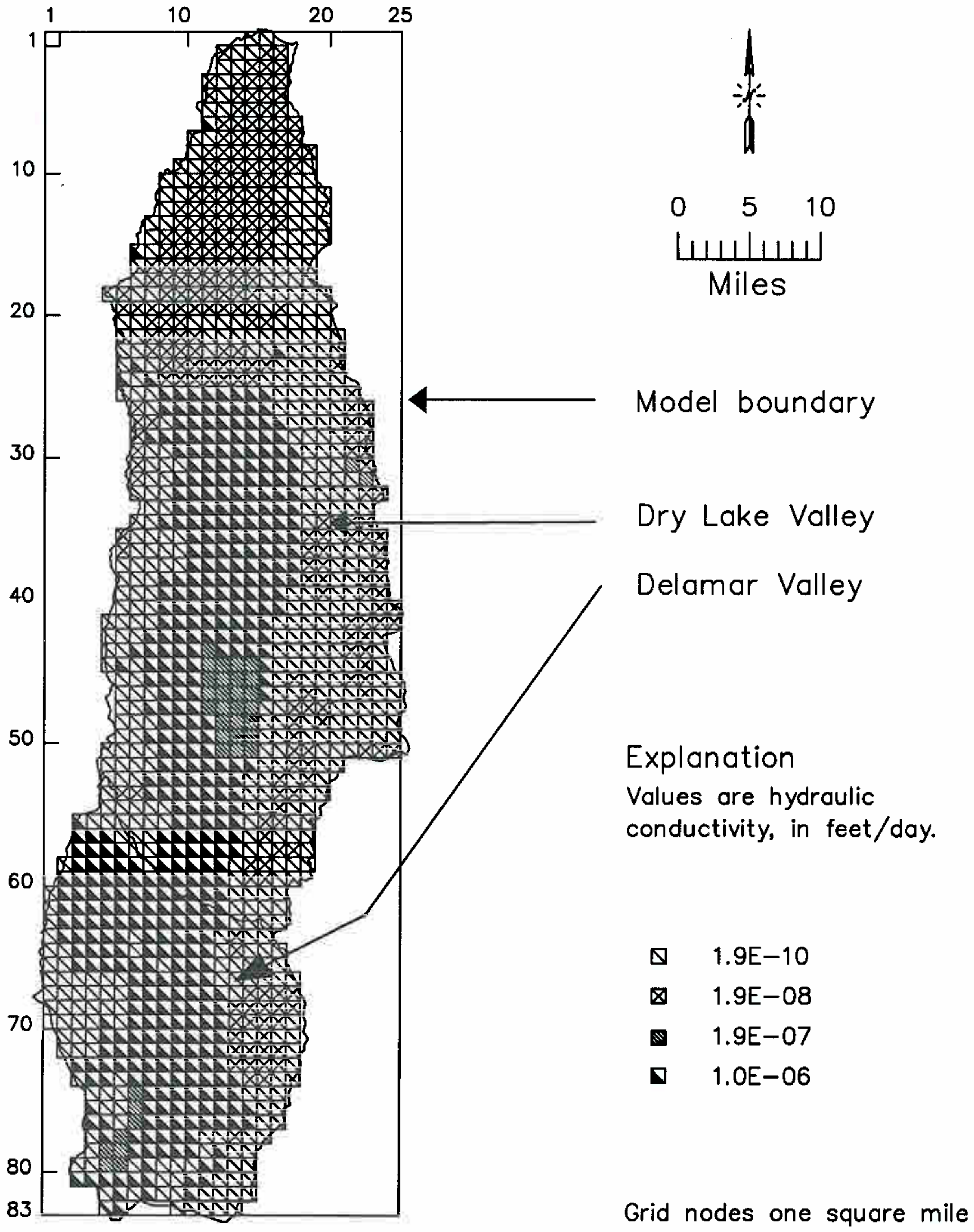


Figure 15. -- Vertical conductivity for Dry Lake and Delamar Valleys' model.

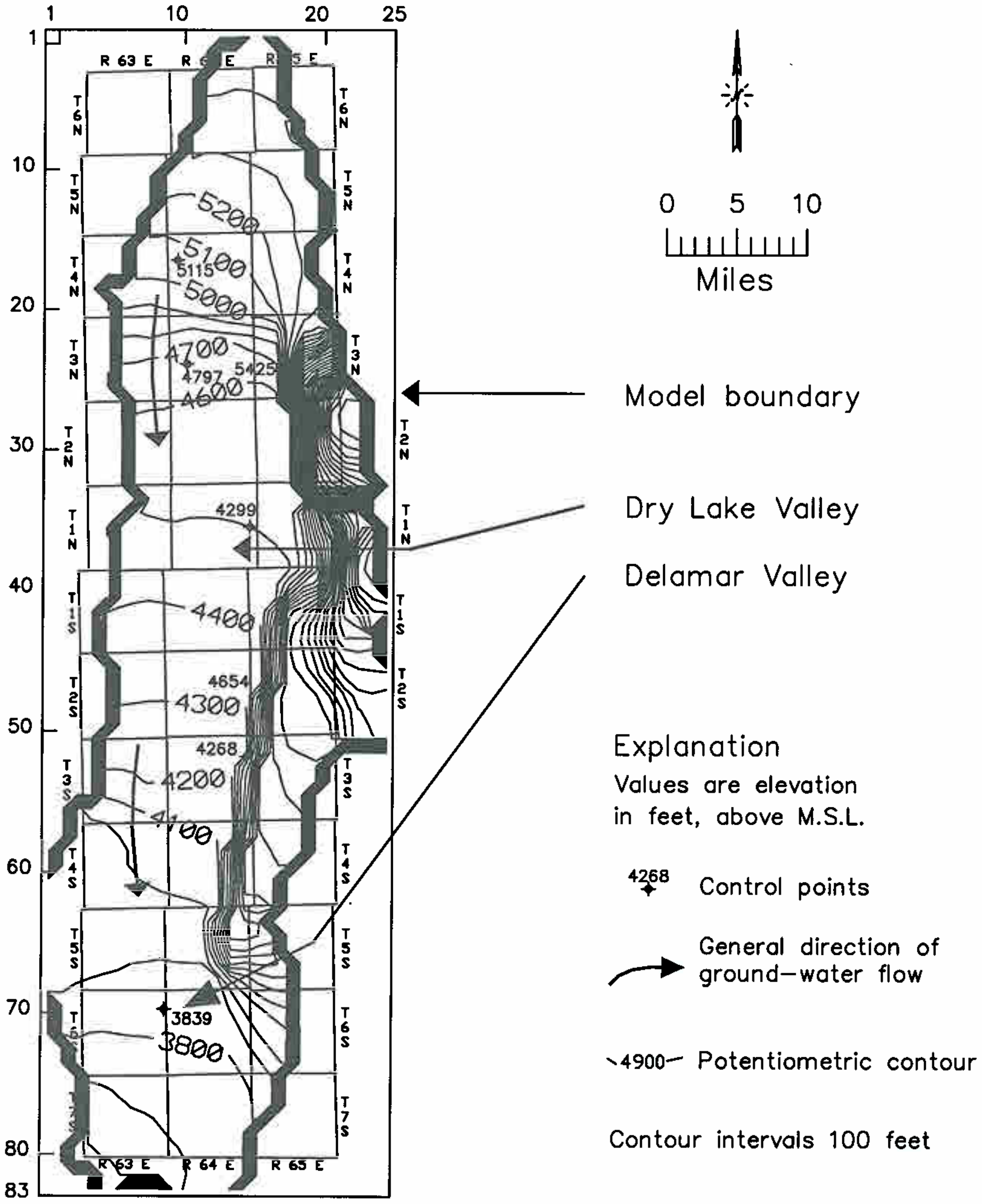


Figure 16. -- Potentiometric surface in upper layer for Dry Lake and Delamar Valleys' model.

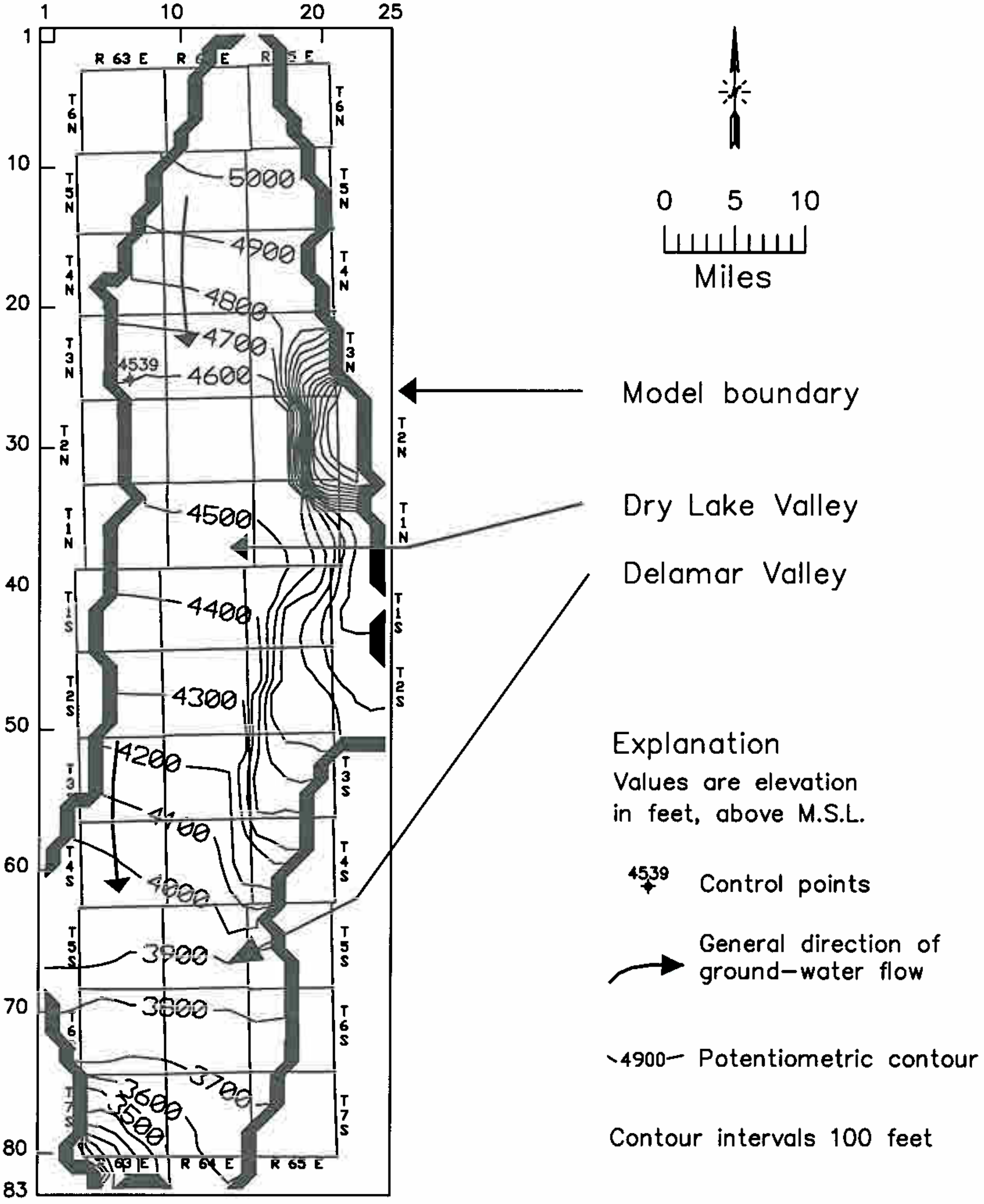


Figure 17. -- Potentiometric surface in lower layer for Dry Lake and Delamar Valleys' model.

Table 6.--Comparison of actual vs. simulated water levels for wells used in calibration.

Well ID No.	Location	Row	Column	Water Level (feet above sea level)		Residual Δ
				Actual	Simulated	
LAYER 1						
1	N04 E64 07DC	15	10	5115	5118	-3
2	N03 E65 21D	24	18	5425	5424	1
3	N03 E63 20BD	24	11	4797	4679	118
6	N01 E64 24A	36	15	4299	4499	-200
8	S02 E65 19AC	48	16	4654	4667	-13
9	S03 E64 12AC	52	15	4268	4253	15
10	S06 E63 12ADA	70	9	3893	3840	-1
LAYER 2						
4	N03 E63 27CA	26	8	4539	4592	-53

Upper Layer

Of the seven wells used in the upper layer for calibration, two are over a hundred feet from the simulated value. These two, shown on Figure 16, are within 15 miles of each other and the actual water level difference is about 500 feet. Even though different transmissivities for the "northern" and "southern" alluvium were used, it was not possible to create this extreme gradient if the transmissivities were keyed to rock type and match the other water levels. Therefore, the difference was essentially split, a positive variance in the northern well and a negative variance in the southern well. The other wells in the upper layer match actual water levels within 15 feet.

Lower Layer

The one well in the lower layer matches the simulated value within 53 feet. As stated previously, using a higher transmissivity for this area significantly reduced the upper simulated water levels. Therefore based on the bedrock geology in Dry Lake and Delamar Valleys, the model is thought to be a reasonable simulation of the steady state conditions.

Overall the match of the simulated values with the actual values is thought to be reasonable as well as the match with the USGS budget. Therefore, the steady state model provides a reasonable simulation of the potentiometric surface. Based on the available ground-water data and the uncertainties of the volume and flow paths, the steady state model provides a reasonable match to the existing water levels and the USGS ground-water budget. Table 7 compares the ground-water budget found in Eakin (1963), with the model generated budget.

Table 7.--Comparison of Dry Lake and Delamar Valleys' model ground-water budget with USGS (Eakin, 1963)

	USGS (Eakin, 1963)	Steady State Model (rounded)
INFLOW:		
RECHARGE		
Dry Lake Valley	5,000	5,000
Delamar Valley	1,000	1,000
Total:	6,000	6,000
OUTFLOW:		
SUBSURFACE		
Delamar to Pahranagat	6,000	6,000
Total:	6,000	6,000

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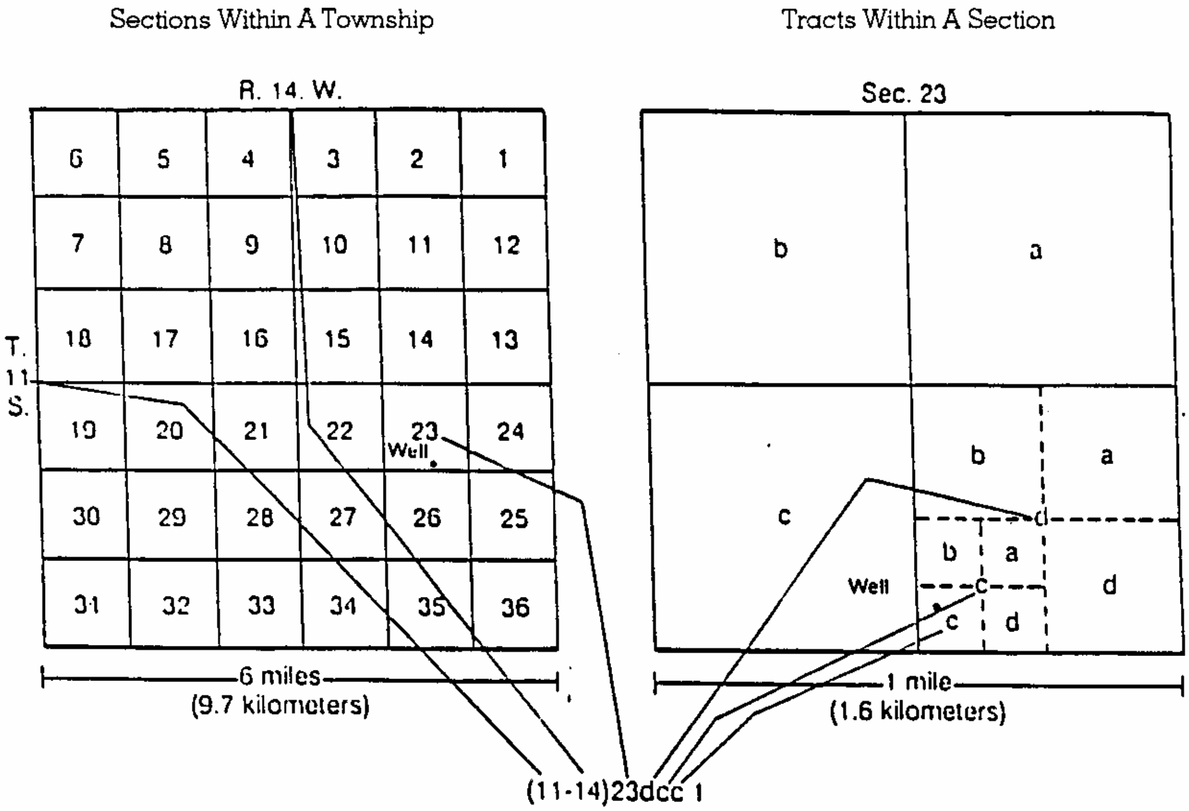
APPENDIX A

Location Designation



Well and spring locations are designated with respect to the Mount Diablo baseline and meridian as shown diagrammatically above. The first number within the parentheses represents the township south of the baseline and the second number represents the range east of the meridian. The section number follows along with the section 1/4, section 1/16th, and section 1/64th. The letter designations a, b, c, and d refer to the northeast, northwest, southwest, and southeast, respectively. If more than one well occurs within the same 1/64th section, a numerical identifier is added to the end of the designation. Thus (28-63) 27aba 1 represents the first well of record in the northeast quarter-section of the northwest quarter-section of the northeast quarter-section of Township 28 South, Range 63 East, Section 27.

APPENDIX B

WATER BASIN 181
DRY LAKE VALLEY
PERMITS AND APPLICATIONS

Application / Certificate		Point of Diversion				Diversion Rate	Consumption Allocated		Use	ACAD Block	Place of Use	Notes
Permit/Proof	Date of Priority	1/4/1/4	Sec.	Township Range			AcFt/Yr	Duty AcFt/Yr				
1134 None	01/01/93	SW NW	31	2N	66E	0.0250	6.72	6.72	Stockwater	SURF OTH	SW NW 31/2/66	PROOF 01134
1135 None	01/01/95	SE NE	36	2N	65E	0.0330	6.72	6.72	Stockwater	SURF OTH	SE NE 36/2/65	PROOF 01135
1250 None	01/01/93	SE SE	24	2N	65E	0.0125	3.36	3.36	Stockwater	SURF OTH	SE SE 24/2/65	PROOF 01250
1265 None	01/01/83	SW	28	1N	63E	0.0500	2.24	2.24	Stockwater	SURF OTH	SW 28/1/63]	PROOF 01265
1267 None	01/01/83	NE SW	21	1N	63E	0.2500	6.72	6.72	Stockwater	SURF OTH	NE SW 21/1/63	PROOF 01267
1268 None	01/01/83	SE SW	13	2N	63E	0.0127	22.40	22.40	Stockwater	SURF OTH	SE SW 13/2/63	PROOF 01268
1287 None	01/01/05	NW SW	15	4N	65E	0.0125	5.60	5.60	Stockwater	SURF OTH	NW SW 15/4/65	PROOF 01287
1289 None	01/01/05	SW SE	3	4N	65E	0.0125	5.60	5.60	Stockwater	SURF OTH	SW SE 3/4/65	PROOF 01289
1296 None	01/01/80	NE NE	8	4N	65E	0.0000	11.25	15.00	Irrigation	SURF PE	8/4/65	PROOF 01296. No diversion rate given.
1297 None	01/01/80	SW SE	30	4N	65E	0.0000	1.50	2.00	Irrigation	SURF PE	30/4/65	PROOF 01297. No diversion rate given.
1299 None	01/01/05	NW SW	29	4N	65E	0.0125	4.48	4.48	Stockwater	SURF OTH	NW SW 29/4/65	PROOF 01299
1302 None	01/01/05	NE SE	33	4N	65E	0.1250	4.48	4.48	Stockwater	SURF OTH	NE SE 33/4/65	PROOF 01302
1459 None	01/01/07	SE SW	33	2N	66E	0.1250	6.72	6.72	Stockwater	SURF OTH	SE SW 33/2/66	PROOF 01459
1787 None	01/01/99	NE SW	33	2N	66E	0.0250	6.72	6.72	Stockwater	SURF OTH	NE SW 33/2/66	PROOF 01787
3368 1980	04/26/15	SW SE	26	4N	65E	0.0300	11.00	14.67	Irrigation & Domestic	SURF PE	SW SE 26, NW NE, NE NE 35/4/65	
3818 726	04/10/16	NW SE	32	1S	64E	0.0300	24.64	24.64	Stockwater	SURF OTH	NW SE 32/1/64	
3839 None	01/01/90	NW SW	6	2N	65E	0.0044	11.20	11.20	Stockwater	SURF OTH	NW SW 6/2/65	PROOF 03839
3840 None	01/01/90	SW SW	30	3N	65E	0.0044	11.20	11.20	Stockwater	SURF OTH	SW SW 30/3/65	PROOF 03840
3875 724	04/10/16	NE NE	3	3S	64E	0.0000	24.64	24.64	Stockwater	SURF OTH	NE NE 3/3/64	No diversion rate given.
3876 725	04/10/16	SW SW	33	2S	64E	0.0000	22.64	24.64	Stockwater	SURF OTH	SW SW 33/2/64	No diversion rate given.
4622 729	10/08/17	SE NW	29	4S	65E	0.0015	0.56	0.56	Stockwater	SURF OTH	SE NW 29/4/65	
4697 None	01/01/84	NW NW	35	1N	65E	0.0500	11.20	11.20	Stockwater	SURF_OTH	SW NE 8, SE NE 10, SW NE 15, SW SE 17, SE SE 20, NW SW 23, NW SE 29, NE NE 32, SE SE 34, NE NW 35, NE SE 5, NE SE 26/1/65	PROOF 04697
4961 525	03/14/18	NW NE	23	1N	65E	0.0030	2.24	2.24	Stockwater & Domestic	SURF OTH	NW NE 23/1/65	
5300 1924	08/12/18	SW SE	26	4N	65E	0.0625	44.80	44.80	Stockwater	SURF OTH	NE SE 21/3/65	
5316 581	11/20/18	NW NE	31	3S	64E	0.0250	26,88	26.88	Stockwater	SURF OTH	NW NE 31/3/64	

WATER BASIN 181
DRY LAKE VALLEY
PERMITS AND APPLICATIONS

Application / Certificate		Point of Diversion				Diversion Rate	Consumption Allocated		Use	ACAD Block	Place of Use	Notes
Permit/Proof	Date of Priority	1/4/1/4	Sec.	Township Range			AcFt/Yr	Duty AcFt/Yr				
5356 526	01/16/19	SE NW	11	1N	65E	0.0022	0.44	0.44	Stockwater	SURF OTH	SE NW 11/1/65	
5371 1119	01/25/19	SW NW	24	2S	64E	0.0000	15.68	15.68	Stockwater	SURF OTH	SW NW 24/2/64	No diversion rate given.
5936 854	01/05/20	SE NW	14	5N	64E	0.0250	35.84	35.84	Stockwater	WELL OTH	SE NW 14/5/64	
5970 932	02/02/20	NW NW	5	3S	63E	0.0100	0.56	0.56	Stockwater	SURF OTH	NW NW 5/3/63	
6094 1053	05/06/20	NE SE	33	2S	63E	0.0090	6.72	6.72	Stockwater	SURF OTH	NE SE 33/2/63	
6619 835	01/27/22	NE SW	33	2S	66E	0.0150	10.75	10.75	Stockwater	SURF OTH	NE SW 33/2/66	
6638 2105	02/27/22	NE SE	21	5N	63E	0.0030.	11.20	11.20	Stockwater	SURF OTH	NE SE 21/5/63	
6718 1629	07/17/22	SW SW	32	1N	66E	0.0250	18.09	18.09	Mining, Milling & Domestic	SURF_PE	SW 32/1/66	
6803 971	10/23/22	NE SW	22	1N	65E	0.0022	15.68	15.68	Stockwater	SURF OTH	NE SW 22/1/65	
7117 1466	05/16/24	NW SW	13	2N	63E	0.0022	1.56	1.56	Stockwater	SURF OTH	NW SW 13/2/63	
7563 2209	11/04/25	SE NE	22	1N	63E	0.0060	4.48	4.48	Stockwater	SURF OTH	SE NE 22/1/63	
7564 2210	11/04/25	SE NW	22	1N	63E	0.0012	8.96	8.96	Stockwater	SURF OTH	SE NW 22/1/63	
8405 None	12/08/27	SE NW	15	6N	64E	0.5000	40.32	40.32	Stockwater	SURF OTH	SE NW 15/6/64	PROOF 08405
8670 8146	08/19/28	NE SE	3	6N	64E	0.0100	7.25	7.25	Stockwater	SURF OTH	NE SE 3/6/64	
8698 5702	09/17/28	NE SE	5	1S	65E	0.0167	22.40	22.40	Stockwater	SURF OTH	SW SW 7/2/65	
9618 2107	08/11/32	NE NW	11	3	64	0.0090	6.72	6.72	Stockwater	SURF OTH	NE NW 11/3/64	
9660 2293	05/06/33	SE NE	4	3S	65E	0.0011	2.55	2.55	Stockwater	SURF OTH	SE NE 4/3/65	
10119 2355	05/17/37	NE SW	22	1N	65E	0.0150	8.96	8.96	Stockwater	SURF OTH	NE SW 22/1/65	
10120 2356	05/17/37	NW NE	23	1N	65E	0.0150	8.96	8.96	Stockwater	SURF OTH	NW NE 23/1/65	
10551 2595	08/21/40	NW NE	24	4S	64E	0.0031	2.24	2.24	Stockwater	SURF OTH	SW SE 13/4/64	
10747 2805	10/17/41	NE SW	9	4S	65E	0.0100	7.84	7.84	Stockwater	SURF OTH	NE SW 9/4/65	
1118 2826	05/10/44	SW SE	33	2S	65E	0.0125	8.96	8.96	Stockwater	SURF OTH	SW SE 33/2/65	
12246 3583	02/06/48	SW SE	34	2N	63E	0.0125	8.96	8.96	Stockwater	SURF OTH	SW SE 34/2/63	
12247 3584	02/06/48	NW NW	35	2N	63E	0.0125	8.96	8.96	Stockwater	SURF OTH	NW NW 35/2/63	
12512 4391	06/18/48	SW SW	34	2S	63E	0.0031	2.24	2.24	Stockwater	SURF OTH	SW SW 34/2/63	
12793 4501	06/22/21	NE NW	27	2S	63E	0.0094	6.72	6.72	Stockwater	SURF OTH	NE NW 27/2/63	

WATER BASIN 181
DRY LAKE VALLEY
PERMITS AND APPLICATIONS

Application / Certificate		Point of Diversion				Diversion Rate	Consumption Allocated		Use	ACAD Block	Place of Use	Notes
Permit/Proof	Date of Priority	1/4/1/4	Sec.	Township Range			AcFt/Yr	Duty AcFt/Yr				
12840 4502	06/06/45	NE SW	27	2S	63E	0.0022	2.24	2.24	Stockwater	SURF OTH	NE SW 27/2/63	
14732 4712	12/24/52	SW NW	17	2S	66E	0.0000	24.19	24.19	Stockwater	SURF OTH	NE SW, SW NW 17/2/66	No diversion rate given.
18756 5059	04/26/60	NE NW	24	1N	64E	0.0156	11.20	11.20	Stockwater	SURF OTH	NW NE, NE NW 24/1/64	
35761 10204	08/18/78	NW NW	26	4N	65E	0.0045	10.08	10.08	Stockwater	SURF OTH	26/4/65	
35762 10205	08/18/78	SE SE	22	4N	65E	0.0045	10.08	10.08	Stockwater	SURF OTH	22/4/65	
35763 10206	08/18/78	NE SE	22	4N	65E	0.0045	10.08	10.08	Stockwater	SURF OTH	22/4/65	
35764 10207	08/18/78	SE NE	22	4N	65E	0.0045	10.08	10.08	Stockwater	SURF OTH	22/4/65	
35766 10208	08/18/78	NW SE	26	4N	65E	0.0141	10.08	10.08	Stockwater	SURF OTH	26/4/65	
35767 10209	08/18/78	SE NW	26	4N	65E	0.0067	10.08	10.08	Stockwater	SURF OTH	26/4/65	
35768 10210	08/18.78	NE SE	35	4N	65E	0.0045	10.08	10.08	Stockwater	SURF OTH	35/4/65	
35769 10186	08/18/78	SW NE	1	1N	64E	0.0045	10.08	10.08	Stockwater	SURF OTH	NE 1/1/64	
35770 10869	08/18/78	SW NE	4	2N	64E	0.0044	10.08	10.08	Stockwater	WELL OTH	4/2/64	
35771 10211	08/18/78	NW SW	11	2N	64E	0.0045	10.08	10.08	Stockwater	SURF OTH	11/2/64	
35772 10187	08/18/78	SE SW	19	2N	65E	0.0045	10.08	10.08	Stockwater	SURF OTH	19/2/65	
35773 10870	08/18/78	SE NW	20	3N	64E	0.0044	10.08	10.08	Stockwater	SURF OTH	20/3/64	
35774 10871	08/18/78	NW SE	21	3N	65E	0.0044	10.08	10.08	Stockwater	SURF OTH	21/3/65	
35775 10212	08/18/78	SE SE	5	4N	65E	0.0141	10.08	10.08	Stockwater	SURF OTH	5/4/65	
35849 None	09/06/78	NE SW	35	6N	64E	0.2500	11.42	11.42	Stockwater	SURF OTH	None given.	
35951 10217	10/03/78	SE SE	9	4N	65E	0.0044	10.08	10.08	Stockwater	SURF OTH	9/4/65	
35952 10218	10/03/78	NW NE	16	4N	65E	0.0044	10.08	10.08	Stockwater	SURF OTH	16/4/65	
35953 10219	10/03/78	NE NE	23	4N	65E	0.0044	10.08	10.08	Stockwater	SURF OTH	23/4/65	
35954 10220	10/03/78	NW SW	15	4N	65E	0.0044	10.08	10.08	Stockwater	SURF OTH	15/4/65	
36179 10222	11/20/78	NE NE	18	5N	64E	0.0080	10.08	10.08	Stockwater	SURF OTH	NE NE 18/5/64	
36180 10223	11/20/78	SW SE	26	4N	65E	0.0068	10.08	10.08	Stockwater	SURF OTH	26/4/65	
45588 None	04/26/82	SW NE	12	3S	64E	5.0000	1200.00	1200.00	Stockwater	SURF OTH	E2 12/3/64	
52103 None	05/18/88	SW NW	22	2S	63E	0.0090	6.72	6.72	Stockwater	SURF OTH	NW NW 22/2/63	
52104 None	05/18/88	SW NE	21	3S	65E	0.0280	0.44	0.44	Stockwater	SURF OTH	SEE 52109	SEE 52109

WATER BASIN 181
DRY LAKE VALLEY
PERMITS AND APPLICATIONS

Application / Certificate		Point of Diversion				Diversion Rate	Consumption Allocated		Use	ACAD Block	Place of Use	Notes
Permit/Proof	Date of Priority	1/4/1/4	Sec.	Township Range			AcFt/Yr	Duty AcFt/Yr				
52105 None	05/18/88	NW SE	21	3S	65E	0.0280	20.16	20.16	Stockwater	SURF OTH	NW SE 21/3/65	
52106 None	08/18/88	NW NE	28	3S	65E	0.0030	2.24	2.24	Stockwater	SURF OTH	NW NE 28/3/65	
52107 None	05/18/88	NW NW	16	4S	65E	0.0020	20.16	20.16	Stockwater	SURF OTH	SEE 52109	
52108 None	05/18/88	SW NW	29	4S	65E	0.0280	20.16	20.16	Stockwater	SURF OTH	SEE 52109	
52109 None	05/18/88	SE SE	25	4S	64E	0.0280	20.16	20.16	Stockwater	SURF_OTH	11-15,11-26,35-36/2/63,S2 7-10,15-23,25-36/2/64,29-33/2/65,1,2,11-26,35,36/3/63, 3/64,W2/3/65,1,2,11-14,23-26,35, 36/4/63, 4/64,4-9,W210,17-21,28-33/4/65 ETC.	
52110 None	05/18/88	SW SE	31	4S	65E	0.0015	1.12	1.12	Stockwater	SURF OTH	SEE 52109	
52111 None	05/18/88	SE SE	31	4S	65E	0.0030	2.24	2.24	Stockwater	SURF OTH	SEE 52109	
53989 None	10/17/89	SE SW	30	2S	64E	6.000	0.00	0.00	Stockwater	SURF OTH	NONE	
53990 None	10/17/89	NE SE	8	2S	65E	10.0000	0.00	0.00	Stockwater	SURF OTH	NONE	
						*** Total ***	2102.60	2512.52				

WATER BASIN 182
DELAMAR LAKE VALLEY
PERMITS AND APPLICATIONS

Application / Certificate		Point of Diversion				Diversion Rate	Consumption Allocated		Use	ACAD Block	Place of Use	Notes
Permit/Proof	Date of Priority	1/4/1/4	Sec.	Township Range			AcFt/Yr	Duty AcFt/Yr				
1022 None	01/01/90			5S	64E	0.0000	7.84	7.84	Stockwater	SURF OTH	5/64, 6/65	PROOF 01022. 2ND POD 6S 65E
1398 None	01/01/98	NE NW	18	5S	65E	0.0250	15.79	15.79	Stockwater	SURF OTH	NE NW 18/5/65	PROOF 01398
1399 None	01/01/98	NE NW	7	5S	65E	0.0250	15.79	15.79	Stockwater	SURF OTH	NE NW 7/5/65	PROOF 01399
1400 None	01/01/00	NE SE	3	5S	64E	0.0250	15.79	15.79	Stockwater	SURF OTH	NE SE 3/5/64	PROOF 01400
1418 None	01/01/05	SW SW	34	5S	62E	0.0250	15.68	15.68	Stockwater	SURF OTH	SW SW 34/5/62	PROOF 01418
1420 None	01/01/05	NW SW	27	5S	62E	0.0250	15.68	15.68	Stockwater	SURF OTH	NW SW 27/5/62	PROOF 01420
1520 None	01/01/00	SE SE	9	7S	64E	0.1000	1.12	1.12	Stockwater	SURF OTH	SE SE 9/7/64	PROOF 01520
1550 None	01/01/03	SE SE	15	7S	64E	0.0250	0.22	0.22	Stockwater	SURF OTH	SE SE 15/7/64	PROOF 01550
1822 None	01/01/93	NW SW	17	6S	65E	0.0500	1.68	1.68	Stockwater	SURF OTH	NW SW 17/6/65	PROOF 01822
3271 1923	02/15/15	NE NE	1	6S	62E	0.0125	8.96	8.96	Stockwater	SURF OTH	NE NE 1/6/62	

WATER BASIN 182
DELAMAR LAKE VALLEY
PERMITS AND APPLICATIONS

Application / Certificate		Point of Diversion				Diversion Rate	Consumption Allocated		Use	ACAD Block	Place of Use	Notes
Permit/Proof	Date of Priority	1/4/1/4	Sec.	Township Range			AcFt/Yr	Duty AcFt/Yr				
3475 427	06/30/15	NW SE	13	6S	64E	0.1200	45.00	60.00	Irrigation	SURF PE	NW NE 14/6/64	
4620 727	10/08/17	SE NE	33	6S	64E	0.0015	1.12	1.12	Stockwater	SURF OTH	None given	
4621 728	10/08/17	??	??	5S	64E	0.0030	2.24	2.24	Stockwater	SURF OTH	None given	POD U.S. MINERAL MONUMONT NO. 1
4693 730	11/12/17	??	??	5S	64E	0.0110	11.20	11.20	Stockwater	SURF OTH	None given	POD U.S. MINERAL MONUMENT NO. 2]
4695 731	11/12/17	??	??	5S	64E	0.0110	11.20	11.20	Stockwater	SURF OTH	None given	POD U.S. MINERAL MONUMENT NO. 2
4778 None	04/17/26	SE NE	8	6S	65E	0.0018	2.12	2.12	Public Watering	SURF PE	SE NE 8/6/65	PERMIT R-04778
4894 None	02/07/18	??	??	??	??	0.0250	0.00	0.00	Stockwater	SURF_OTH	None given	No duty given, POD N70 E 8800 ft from U.S. MINERAL MONUMENT 2
5301 736	10/25/18	??	??	5S	64E	0.0000	10.00	10.00	Stockwater	SURF_OTH	None given	No diversion rate given, POD U.S. MINERAL MONUMENT
5318 582	11/20/18	SW SE	26	4S	63E	0.5000	26.88	26.88	Stockwater	SURF OTH	None given	
5782 1005	09/29/19	NW NE	7	5S	64E	0.0125	11.20	11.20	Stockwater	SURF_OTH	N 37 E 15,620' FROM NE COR. OF EMMA MINE FERGUSON MINING DISTRICT	
5783 1006	09/29/19	NE NW	7	5S	64E	0.0150	11.20	11.20	Stockwater	SURF_OTH	N 36 E 14,245' FROM NE COR. OF EMMA MINE	
6576 1500	10/13/21	NW SW	21	4S	63E	0.5000	9.85	9.85	Stockwater	SURF OTH	None given	
6885 1225	04/28/23	NW SE	7	63E	0.0 000	4.48	4.48		Stockwater	SURF_OTH	Reservoir	No diversion rate given
6886 1226	4/28/23	SE NW	33	7S	63E	0.0000	10.00	10.00	Stockwater	SURF OTH	RUNOFF RESERVOIR	No diversion rate given
8921 1700	05/24/29	SW SW	20	5S	64E	0.0160	1.12	1.12	Stockwater	SURF OTH	None given	
9659 2109	05/13/33	NW NW	12	6S	63E	0.0094	6.00	6.00	Stockwater	SURF OTH	NW NW 12/6/63	
9713 2423	11/25/33	NE SW	17	6S	65E	0.0500	36.19	36.19	Mining, Milling & Domestic	SURF_PE	None given	
10088 2622	02/10/37	NE NE	1	6S	62E	0.0030	2.24	2.24	Stockwater	SURF OTH	NE NE 1/6/62	
10189 2403	12/03/37	NE SE	3	5S	64E	0.0250	33.60	33.60	Stockwater	SURF OTH	None given	
10440 2720	11/15/39	SW SE	20	7S	64E	0.0300	2.80	2.80	Stockwater	SURF OTH	SW SE 20/7/64	
10627 2615	02/21/41	NE NW	17	8S	64E	0.0100	7.28	7.28	Stockwater	SURF OTH	None given	
10629 2596	02/24/41	SW NW	20	6S	65E	0.0060	7.84	7.28	Stockwater	SURF OTH	SW NW 20/6/65	
10654 2633	04/28/41	SW NE	16	7S	63E	0.0000	5.60	5.60	Stockwater	SURF OTH	SW NE 16/7/63	No diversion rate given

WATER BASIN 182
DELAMAR LAKE VALLEY
PERMITS AND APPLICATIONS

Application / Certificate		Point of Diversion				Diversion Rate	Consumption Allocated		Use	ACAD Block	Place of Use	Notes
Permit/Proof	Date of Priority	1/4/1/4	Sec.	Township Range			AcFt/Yr	Duty AcFt/Yr				
10659 2637	05/10/41	NE SE	17	7S	63E	0.0000	8.96	8.96	Stockwater	SURF OTH	None given	No diversion rate given
10736 2668	10/02/41	NW NE	35	4S	63E	0.0055	6.72	6.72	Stockwater & Domestic	SURF OTH	None given	
10789 2722	03/04/42	NE SE	26	6S	63E	0.0125	8.96	8.96	Stockwater	SURF OTH	None given	
11167 3075	09/14/44	SE SE	9	7S	64E	0.0030	2.24	2.24	Stockwater & Domestic	SURF OTH	SE SE 9/7/64	
11378 4047	10/01/45	SE NW	19	6S	65E	0.0020	1.68	1.68	Stockwater	SURF OTH	SE NW 19/6/65	
12388 4085	05/29/48	SW SE	17	6S	65E	0.0330	23.52	23.52	Stockwater	SURF OTH	NW SE 12, SE NE 11/6/64	
22073 6683	06/23/64	SE SE	12	7S	64E	0.0100	13.44	13.44	Stockwater	WELL_OTH	SE SE 12, SW SE 9, NE NE 7, NE SW 19/7/64	
45589 None	04/26/82	SE NE	12	6S	63E	5.0000	1200.00	1600.00	Irrigation	WELL DLE	NE, NW 12/6/63	
51259 12369	09/02/87	SW SE	17	6S	65E	0.0170	17.92	17.92	Stockwater	SURF OTH	SE SW 31/6/64, SW NE 5/7/64	
51260 12370	06/30/15	SW SE	17	6S	65E	0.0170	17.00	17.92	Stockwater	SURF_OTH	SE SW 10, NW SW 20, NW NE 21, NW SW 31/6/64, SW NE 5/7/64	
51261 12371	06/23/64	SE SE	12	7S	64E	0.0100	13.44	13.44	Stockwater	SURF_OTH	SE SE 12/7/64, NE SW 19/7/64, NW NE 24/7/63	
52112 None	05/18/88	NW SW	2	5S	64E	0.0080	5.82	5.82	Stockwater	SURF_OTH	11-5,22-6,35 & 36/2/63, S2 7-10, 15-22, 25-36/2/64, 29-33/2/65, 1,2,11-26, 35,36/3/63, 3/64, W2 3/65, 1,2,11-14, 23-26, 35 & 36/4/63, 4/64 ETC.	
52114 None	5/18/88	NE NE	18	5S	65E	0.0139	20.16	20.16	Stockwater	SURF OTH	SEE 52112	
52115 None	5/18/88	SW NE	20	5S	65E	0.0016	1.17	1.17	Stockwater	SURF OTH	SEE 52112	
52116 None	5/18/88	NW SE	17	6S	65E	0.0020	1.68	1.68	Stockwater	SURF OTH	SEE 52112	
52117 None	5/18/88	NW SE	17	6S	65E	0.0278	20.16	20.16	Stockwater	SURF OTH	SEE 52112	
52118 None	5/18/88	NE NW	17	6S	65E	0.0278	20.16	20.16	Stockwater	SURF OTH	SEE 52112	
54144 None	11/06/89	SE NE	12	6S	63E	0.2000	242.00	242.00	Mining	WELL PP	1/6/64	
52366 None	08/03/88	NW SW	2	5S	64E	0.0250	33.60	33.60	Stockwater & Domestic	SURF OTH	SEE 52112	
52113 None	05/18/88	SE SE	6	5S	65E	0.0500	20.16	20.16	Stockwater	SURF OTH	SEE 52112	
53991 None	10/17/89	SE NE	4	5S	63E	6.0000	0.00	0.00	Municipal & Domestic	WELL LVP	NONE	
53992 None	10/17/89	NE NE	15	6S	64E	10.0000	0.00	0.00	Municipal & Domestic	WELL LVP	NONE	
						*** Total ***	2036.50	2451.86				

APPENDIX C

APPENDIX C

STEADY STATE MODEL SENSITIVITY

A steady state simulation is a simulation in which recharge and pumping rates are held constant with no change in ground-water storage, so that model-predicted ground-water levels are representative of long-term stabilized ground-water conditions in the natural environment. Therefore, the steady-state simulation will agree with historic measured water levels if appropriate hydraulic parameters are used in the simulation model. Model hydraulic parameters are adjusted until the steady-state simulation closely approximates the historical ground-water levels. The adjusted parameters must be reasonable. Both the number of differing and discernable values and the range of these values must be consistent with the occurrence of strata which possess these properties and the estimated range, or variabilities of these properties, based on field observations and testing of these properties of the strata.

The primary purpose of the steady-state simulations is to calibrate the model. Transmissivity can be calibrated if sufficient water level elevations are known. This was done as a part of the present study. Calibration of Dry and Delamar Valleys ground-water model was accomplished using several constraints that were identified in the "*Model Development*" section of this report.

The calibration of the model was carried out so that the total quantity of ground-water flow was matched, as closely as possible, the estimates made in Eakin (1963) and Harrill et al. (1988). The calculation of the recharge to the Dry and Delamar Valleys model resulted in a value equal to that calculated by Eakin (1963) of total of 6,000 acre-feet per year, 5,000 in Dry Lake Valley and 1,000 in Delamar Valley. The transmissivities of the modelled units, the leakance between these units, and the conductances used in the general head boundary conditions that connect the modelled area to adjacent hydrographic basins were constrained with the intent to replicate the quantities of water reported in Eakin (1963) and Harrill et al. (1988), while at the same time matching the actual water levels.

As stated above, the calibration of the model was also carried out so that observed ground-water levels and the gradient or changes between these levels within the modelled area were matched as well as possible with little subjective changes in the model parameters. Eleven wells were used in Dry and Delamar Valleys for model calibration. With the number of wells and the areal coverage, matching the actual water levels, while generally preserving the overall budget volumes became the most significant constraint.

The calibration of the model with these constraints resulted in areas with lower transmissivities than many of the other basin models developed. Also for the model of the Dry Lake and Delamar Valley ground-water system, geologic structural features were included, which was not done in many of the other valley ground-water models. However, if the water budget constraint was ignored and additional water was allowed to enter the lower layer from Lake and Patterson Valleys, water levels could have been simulated near observed values using higher transmissivities.

The ground-water levels in the wells shown in Table 1 and Table 6 of the report were used during the calibration. The potentiometric surface, resulting from the calibration are shown in Figures 16 and 17, together with the observed ground-water elevations.

Model Parameter Sensitivities

Sensitivity simulations were done to determine the effects of each parameter on the ground-water levels and flows and are reported in Table 1 below. These parameters are the transmissivities (L1T1, L2T1, etc.) and leakances (TK1, TK2). The sensitivities were performed about the calibrated values of the model and represent the linearized change in water level elevation that would occur with a change in the specific parameter value. The model rows and columns for the observation wells are listed in the attached Table 1 as well as designated in Table 6 in the report with each individual well for correlation. The sensitivities represent the estimated change in ground-water level at the wells with a 100 percent increase in the calibrated values that have been previously reported in the "Model Development" section of this report. The results of these sensitivity simulations are discussed briefly.

Analyses of the sensitivity simulations resulted in several general observations regarding the estimated model properties. All but one of the wells used for calibration were in the alluvial aquifer. The transmissivities of the alluvium and the carbonate aquifer underlying the alluvium produced the most significant changes in ground-water levels over the modelled area.

Table 1.--Wells used in calibration.

							RESULTS OF SENSITIVITY RUNS																
Well ID No.	Location	Row	Col	Actual	Simu-lated	Δ	T1L1 3000	T2L1 100	T3L1 750	T4L1 1	T5L1 10	T1L2 700	T2L2 800	T3L2 500	T4L2 100	T5L2 3000	T6L2 1	T7L2 10	TK1 $1x10^{-4}$	TK2 $1.9x10^{-7}$	TK3 $1.9x10^{-8}$	TK4 $1.9x10^{-10}$	TK52 $1.9x10^{-6}$
LAYER 1																							
1	N04 E64 07DC	15	10	5115	5118	-3	319	107	156	-6	-21	129	55	2	104	252	-3	-4	39	6	17	0	92
2	N03 E65 21D	24	18	5425	5424	1	311	170	50	153	4	126	54	1	97	250	5	13	34	31	43	3	91
3	N03 E63 20BD	24	11	4797	4679	118	332	19	8	-11	-16	130	56	1	85	258	-4	-4	33	5	5	0	94
6	N01 E64 24A	36	15	4299	4499	-200	287	7	-11	-11	-14	123	57	1	79	257	-4	-4	31	5	2	0	95
8	S02 E65 19AC	48	16	4654	4667	-13	201	77	-9	96	-9	101	53	1	87	237	3	2	29	5	46	1	93
9	S03 E64 12AC	52	15	4268	4253	15	187	7	-9	-12	-11	101	53	1	78	243	-4	-4	31	5	1	0	98
10	S06 E63 12ADA	70	9	3839	3840	-1	28	-8	-6	-6	-8	55	53	0	70	212	-2	-3	36	5	1	0	106
LAYER 2																							
4	N03 E63 27CA	26	8	4539	4592	-53	303	13	-6	-14	-16	146	53	1	73	261	-7	-7	18	1	-6	-3	91