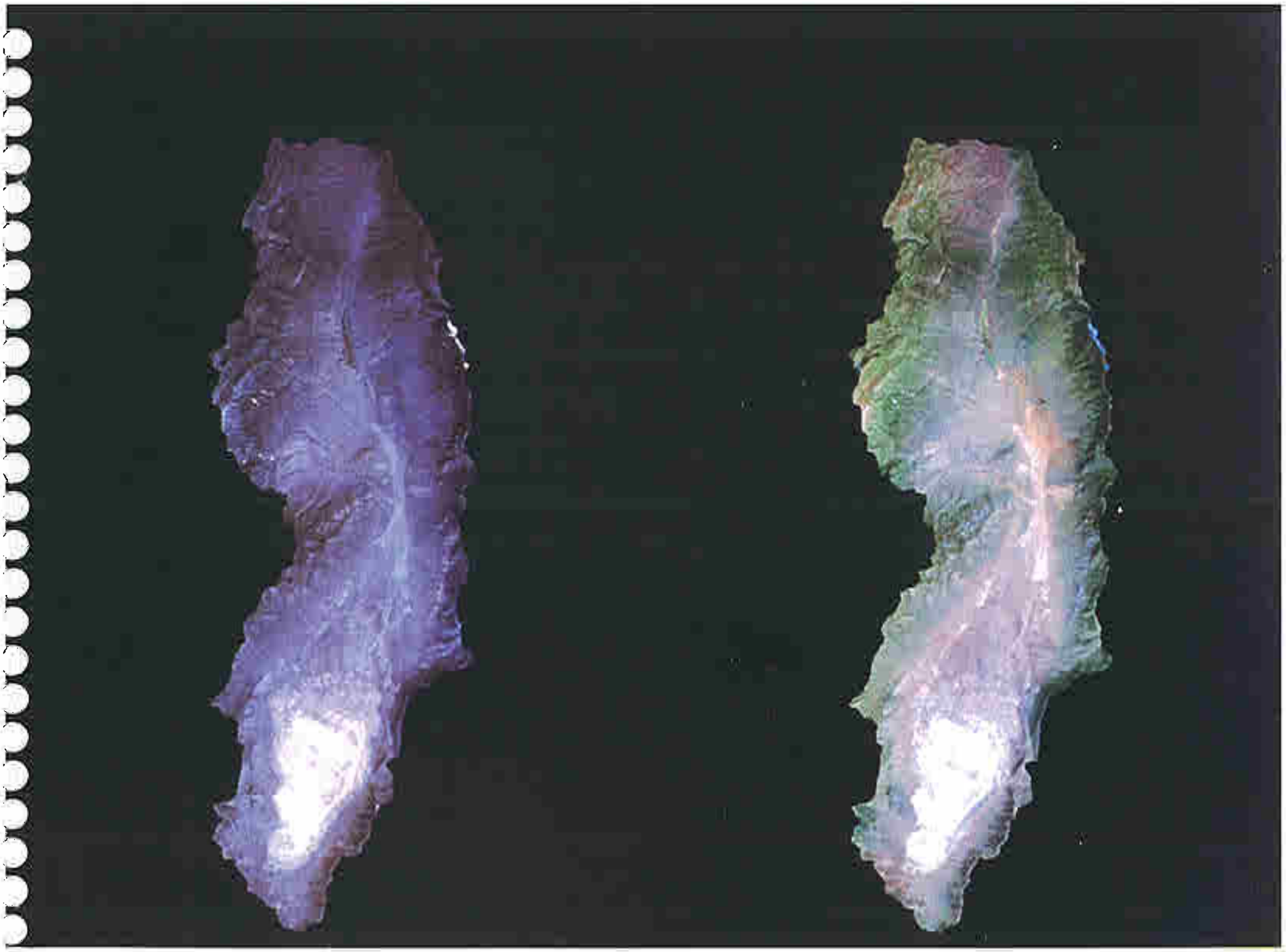

HYDROLOGY AND STEADY STATE GROUND-WATER MODEL OF CAVE VALLEY, LINCOLN AND WHITE PINE COUNTIES, NEVADA

1993

Las Vegas Valley Water District

COOPERATIVE WATER PROJECT
Water for Nevada's Future
Report No. 11
Hydrographic Basin 180

HYDROLOGY AND STEADY STATE GROUND-WATER MODEL OF CAVE VALLEY, LINCOLN AND WHITE PINE COUNTIES, NEVADA

By

Kay Brothers, Thomas S. Buqo, James V.Tracy
Mark Stock, Craig Bentley, Andrew Zdon, and John Kepper

1993

PREFACE

This report on the water resources and development potential of Cave Valley is one of a series of reports on hydrographic basins in southern and eastern Nevada. It was prepared by the staff of the Las Vegas Valley Water District and Thomas S. Buqo and James V. Tracy, both consulting hydrologists to the District, in conjunction with the staff of The MARK Group, Engineers & Geologists, Inc. Primary authors of this report are Kay Brothers, Thomas S. Buqo, James V. Tracy, Mark Stock, Craig Bentley, Andrew Zdon, and John Kepper. David J. Donovan prepared the report figures. 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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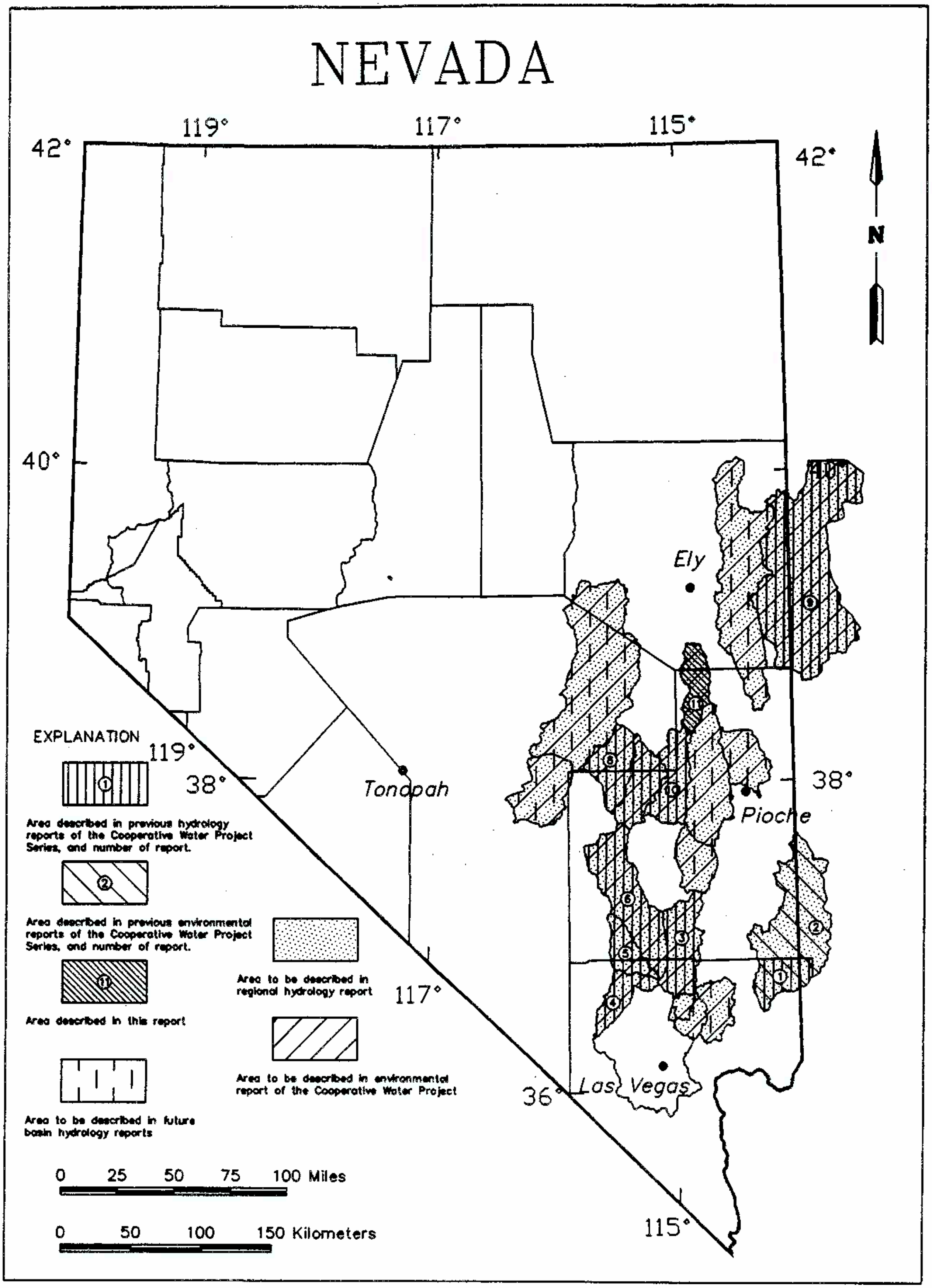


Areas described in previous reports of this series, the area described in this report and the areas to be described in future reports.

INTRODUCTION

In October 1989, the Las Vegas Valley Water District (District) filed two applications to obtain ground-water rights in Cave Valley located in Lincoln and White Pine Counties, Nevada. Since the time of these water right filings, the District has conducted extensive investigations of this area 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 Cave Valley that was conducted, and the steady-state ground-water flow model developed to represent the aquifer systems.

BACKGROUND

Cave Valley is located about 150 miles north of Las Vegas, Nevada, and 35 miles northwest of Pioche, Nevada (Figure 1). The northern third of Cave Valley is located in White Pine County and the southern part in Lincoln County. On the basis of the geology of the basin, the hydrogeology of neighboring basins and limited test drilling performed as part of the U.S. Air Force's MX Missile water resources program, it is known that the regional carbonate aquifer underlies Cave Valley.

The District plans to develop the water resources of Cave Valley through installation of a well field and distribution system that will convey the water to users in metropolitan areas of Clark County. Preliminary plans call for the drilling of water wells at two locations; final optimized wellfield designs will be developed in subsequent phases of the development program and will be based upon detailed planning and environmental studies.

To assist its efforts in formulating final plans for developing the water resources of Cave Valley, the District developed a numerical model of the ground-water flow regime. A numerical model is a computer code which translates the mechanics of ground-water flow through the earth through a series of mathematical equations. By coupling the available information on the basin (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 Cave Valley serves two 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.

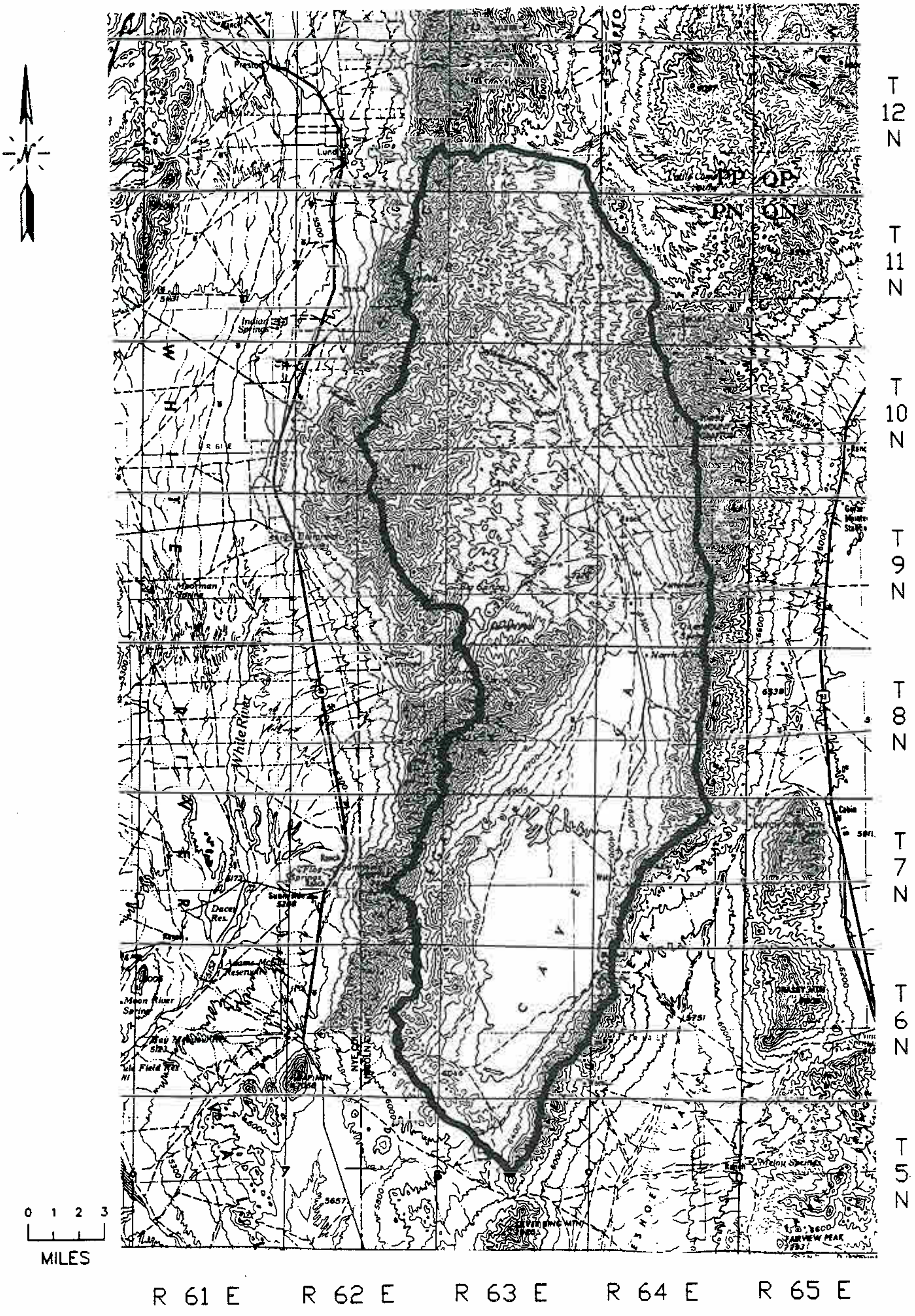


Figure 1. -- Physiography and location of Cave Valley

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 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 in Cave Valley, 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, such as Cave Valley, 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.

Because many of the basins in central 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 potentially 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.

Although there are no large springs or developed areas in Cave Valley, the valley is in direct hydraulic communication with White River Valley to the west. Ground-water withdrawals, unless strategically place and carefully monitored, could ultimately impact the ground-water system in White River Valley.

The use of numerical methods to simulate water withdrawals in Cave Valley provides a tool for predicting the effects that would be expected to result from proposed District development. Recently, the U.S. Geological Survey (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 Cave Valley, 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 becomes available through District efforts, the model of the ground-water flow regime for the valley can be updated accordingly to provide a more refined representation of the hydrologic system.

PURPOSE AND SCOPE

The purpose of this project was twofold: 1) to define the hydrologic conditions of Cave Valley, and 2) to develop a calibrated steady-state ground-water flow model of the valley. The specific objectives of these investigations were to:

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

To achieve these objectives, a detailed investigation of the hydrologic conditions of Cave Valley 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 valleys. The basin characterization information and steady-state flow model discussed in this report will be used by the District to develop a transient, regional model including Cave Valley's ground-water regime.

LOCATION AND PHYSIOGRAPHIC SETTING

Cave Valley (Figure 1) is located in northern Lincoln County and southern White Pine County, 150 miles north of Las Vegas and 35 miles northwest of Pioche, Nevada. Access to the area is by State Highway 118 or U.S. Route 93 and by graded dirt roads through Shingle and Patterson Pass in the middle of the valley or by roads extending into the north and south ends of the basin. Cave Valley is bounded on the west by the Egan Range and on the east by the

Schell Creek Range. The highest elevation in the Egan Range is Shingle Peak at 9,861 feet above mean sea level (msl). Mt. Grafton is the highest peak in the Schell Creek Range at 10,993 feet msl. Elevations along the crests of these ranges are between 8,000 and 9,000 feet msl. Elevations on the valley floor range from 7,200 feet in the north to around 6,000 feet msl on the playa at the south end.

Cave Valley lies in the Basin and Range Province, which is characterized by fault-bound north-trending mountain ranges\separated by broad alluviated valleys. Cave Valley is a closed basin with respect to surface drainage. The Egan Range is an east-tilted fault block that is bounded on the west by a west-dipping normal fault. A recent fault scarp parallels the west front of the range. To the east, the Schell Creek Range is a horst uplifted along the Cave Valley fault on its west side and the Coyote Wash fault on the east. A low ridge underlain by Tertiary volcanics closes off the south end of the basin and a narrow alluvial divide between the two carbonate ridges separates Cave Valley from Steptoe Valley to the north.

Pediments and fan surfaces in the basin are relatively short and steep, with gradients ranging from 500 feet to 700 feet per mile. Channels that dissect these surfaces have gradients in the range of 100 to 400 feet per mile. The northern half of the valley has an axial channel with gradients decreasing from 100 feet per mile to about 25 feet per mile toward the playa in the southern part of the basin. The playa is relatively featureless, with a sparse cover of sagebrush over silt and clay deposited by occasional floods. Gravel ridges representing the shorelines of Pleistocene lakes are present at the south end of the valley. Several springs occur along the side of the valley, generally on the flanks of carbonate ridges or near the contact between bedrock and alluvial fan material.

AVAILABILITY OF DATA

Cave Valley is located in a remote and largely unpopulated portion of Lincoln and White Pine Counties, and only reconnaissance level evaluations of the water resources of the area are available. 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, the valley was also investigated by the U.S. Air Force as part of their MX Water Resources Program. Regional data from adjacent valleys are also available to supplement the existing valley-specific data.

Well data are available for at least 16 locations in Cave Valley and shown in Table 1. Appendix A provides an explanation of the well location designations used in Table 1 and throughout this report.

The valley-specific data was supplemented by regional data. Previous investigations in neighboring valleys have generated a data base of regional information which can be used to help formulate a ground-water model for Cave Valley. These data provide specific measures or estimates of the ground-water conditions at selected points in time and values for key hydrologic parameters. Several of the wells in adjacent valleys that were drilled as part of the Air Force's MX investigations extend through the valley-fill into the underlying carbonate rocks.

Table 1.--Well inventory, Cave Valley.

Well No.	Well Location	Well Name/Owner	Year Drilled	Depth	Diameter	Use	Princ. Water Yield/Zone Drawdown	Specific Capacity	Well Elev.	Water Level	Water Level Elev.	Date Measured
1	N5 E63 22C1	BLM/Silver King Well				Unused			6220	8.90	6211.10	3/21/90
2	N7 E63 14BADD1	USGS-MX	1980	435	10	Unused	225/114.8	1.96	6009 6009 6009 6009 6009 6009	229.00 226.67 226.87 226.80 226.71 222.90	5780.00 5782.33 5782.13 5782.20 5782.29 5786.10	10/25/80 4/17/83 7/28/83 9/9/83 11/8/83 3/21/90
3	N7 E63 14BADB1	USGS-MX	1980	422	2	Unused			6010 6010	230.60 223.70	5779.40 5786.30	10/25/80 3/21/90
4	N7 E63 14BADB2	USGS-MX	1980	273	2	Unused			6010 6010	231.20 223.80	5778.80 5786.20	10/25/80 3/21/90
5	N7 E63 15DBAD1	BLM / Cave Valley Well		385	6	Stock			6020 6020 6020	233.00 231.94 228.50	5787.00 5788.06 5791.50	1980 4/17/83 3/21/90
6	N7 E64 19DD1	Gulf Oil		265					6000 6000	220.00 215.00	5780.00 5785.00	4/16/66 3/ /80
7	N8 E64 04ABDD1	BLM / Seeding Well				Stock			6220 6220	134.28 130.67	6085.72 6089.33	4/17/83 3/21/90
8	N8 E64 15BCBC1	BLM / Harris	1968	375		Stock			6160	272.31	5887.69	3/21/90
9	N8 E64 30CDBC1	Urrutia / Sawmill Well			6	Stock			6080 6080 6080 6080	330.90 322.00 319.81 314.80	5869.10 5758.00 5760.19 5765.20	4/22/60 3/ /80 4/17/83 3/21/90
10	N9 E63 01A1				36				6500	2.00	6498.00	10/16/62
11	N9 E64 6BDD1	Parker Station			4	Stock			6490	Flowing		3/ /80
12	N9 E64 18AA1	USGS-MX	1979	101	2	Unused			6440	Dry		
13	N9 E64 20AD1	USGS-MX	1980	200	2	Unused			6100	Collapsed		
14	N9 E64 27BCDD1	BLM / Cave Valley Well #2		315		Stock			6410 6410 6410	258.00 239.00 222.75	6152.00 6171.00 6187.25	6/8/64 3/ /80 3/21/90
15	N10 E63 25AAB1	M. Urrutia			20	Stock			6620 6620	17.80 19.60	6602.20 6600.40	7/15/58 10/16/62
16	N10 E64 06BD1	Robbers Roost Well			6	Stock			6848	149.30	6698.70	4/ /90

The primary source of data for Cave Valley is a reconnaissance report authored by Eakin (1962). 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 this valley includes: 1) details on water well construction from Well Drillers Reports filed with the Nevada State Engineer Office; 2) water level, spring discharge, and water chemistry data and the results of aquifer tests 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 included technical reports of the Nevada Department of Conservation and Natural Resources, USGS Professional Papers, Water-Supply Papers, and Open-File Reports, and cooperative reports on the regional carbonate aquifer study conducted in 1988. Characterizations of the regional setting, particularly those by Eakin (1962), Kirk and Campana (1988), and the recent publications by the USGS, provide important, and accepted regional interpretations that are also of considerable use in evaluating Cave Valley.

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 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 Cave Valley, 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 Cave Valley, and developing a steady-state numerical model of the ground-water system of the basin, 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 (i.e., new field measurements) were performed as part of this investigation by The MARK Group, Engineers & Geologists, Inc. 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 any anomalous data points.

Numerical Model Development

The model used to simulate the ground-water regime of Cave Valley 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). 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 Cave Valley requires a thorough understanding of the hydrologic regime of the basin. The information that is available concerning the valley, and adjacent or similar areas, is used to develop a conceptual model of the source of water in the valley, its occurrence and flow in the subsurface, and the relationship between Cave Valley and adjacent basins. In this section, the regional and valley-specific hydrologic conditions of Cave Valley are described and discussed.

REGIONAL AND BASIN HYDROGEOLOGIC FEATURES

Cave Valley is 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 to be part of a regional flow system. Cave Valley is located in the White River Flow System which is a subset of the Colorado River Flow System as defined by Harrill, et al. (1988). This flow system comprises 36 individual hydrographic basins. Some of the ground water that originates as precipitation over the upland areas of Cave Valley may ultimately, after hundreds or thousands of years, discharge out of the system at Moapa. This water, after being discharged from Cave Valley into White River Valley, ultimately reaches the Colorado River through a pathway combining ground-water, spring, and surface-water flows.

The general patterns of interbasin flow in the White River Flow System are shown in Figure 2. The overall component of regional ground-water flow is to the south. Within individual valleys in the flow system, recharge from the bounding mountain ranges 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).

Cave Valley does not appear to receive underflow from other adjacent basins. The east side of the basin forms part of the boundary between the White River and Meadow Valley Wash subsystems. Subsurface discharge from Cave Valley is into White River Valley, and is estimated at 14,000 acre feet per year according to Harrill et al. (1988).

LITHOLOGIC AND HYDROLOGIC FEATURES

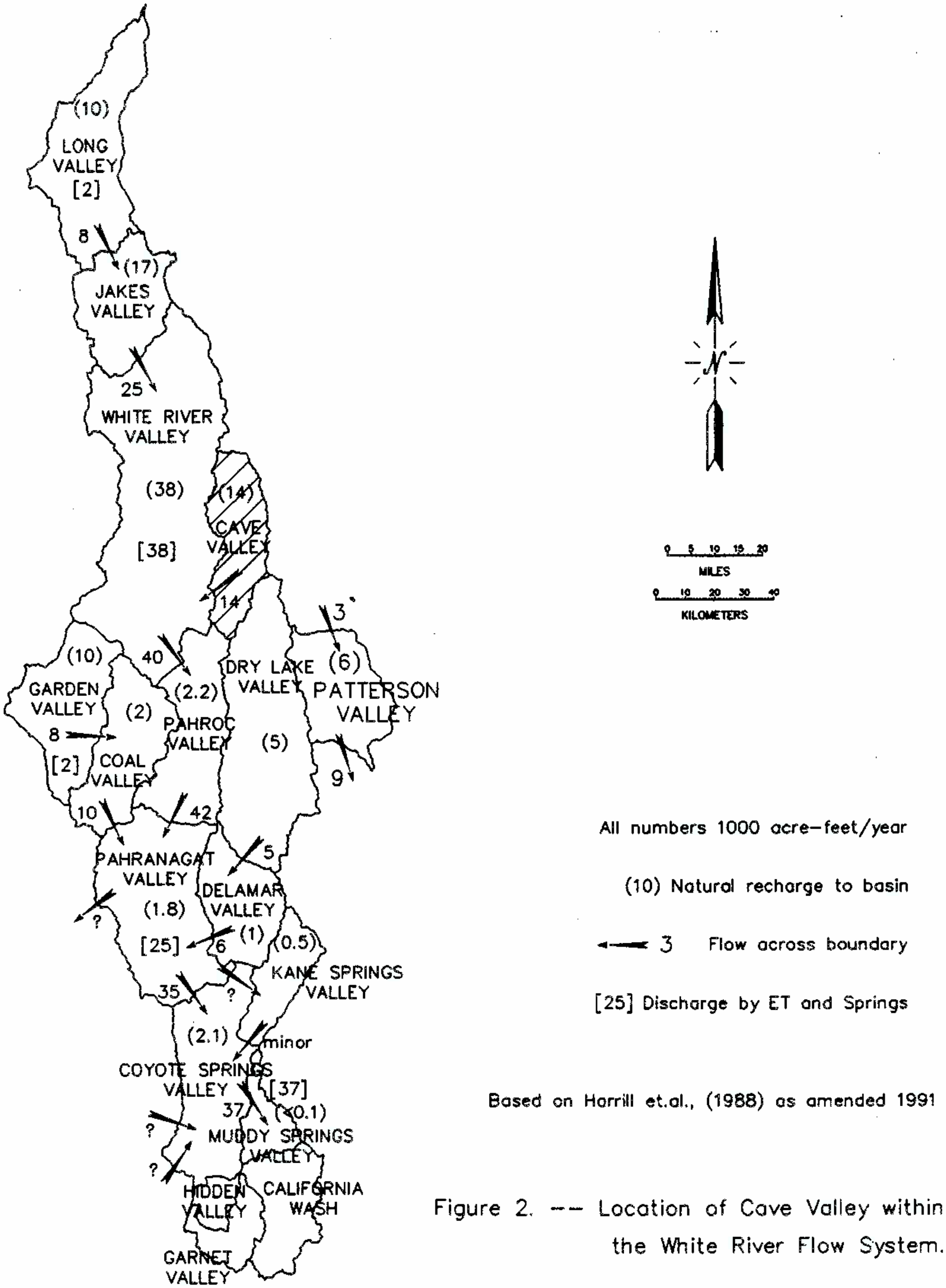
The hydrostratigraphic units present in Cave Valley and their ability to store and transmit ground water are important considerations in developing conceptual and numerical models of the flow regime. The type, thickness and depth, orientation, and water-bearing properties of the geologic units present in Cave Valley can be used to define the overall water resources potential. In this section, the geologic units that are present and their hydraulic properties are described and discussed.

Hydrostratigraphy

The stratigraphy of the Egan Range and Schell Creek Range have been detailed by Tschanz and Pampeyan (1970) for Lincoln County, by Hose and Blake (1976) for White Pine County, and Kleinhampl and Ziony (1985) for Nye County. The hydrostratigraphy of the area has been complicated by the extensive structural deformation that has occurred over the region.

The general stratigraphic sequences of the mountains bounding Cave Valley are shown in Figure 3 along with the general distribution of aquifers and aquitards as defined from the county level geologic maps. Five discrete hydrostratigraphic units have been categorized: younger alluvium: playa deposits, older alluvium, gravels, and lacustrine deposits; volcanic rocks; and, Paleozoic aquifers and aquitards.

According to Tschanz and Pampeyan (1970), the Egan Range is a east-dipping homocline comprising a thick sequence of Paleozoic and Tertiary Rocks. The rock units present, from youngest to oldest include: 1) Tertiary volcanic rocks (aquitards except where fractured); 2) the Sheep Pass Formation north of Shingle Pass (aquitard); 3) the Ely Limestone (aquifer); 4) the Chainman Shale (aquitard); 5) the Joana Limestone (aquifer), 6) the Pilot Shale south of Shingle Pass (aquitard); 7) the Guilmette formation and the Simonson, Sevy, Laketown, and Ely Springs dolomites (aquifer); 8) the Eureka Quartzite (aquitard); 9) the Pogonip Group and upper Cambrian limestone and dolomite (aquifer); and, 10) the Dunderberg Shale (aquitard).



Based on Horrill et.al., (1988) as amended 1991

Figure 2. -- Location of Cave Valley within the White River Flow System.

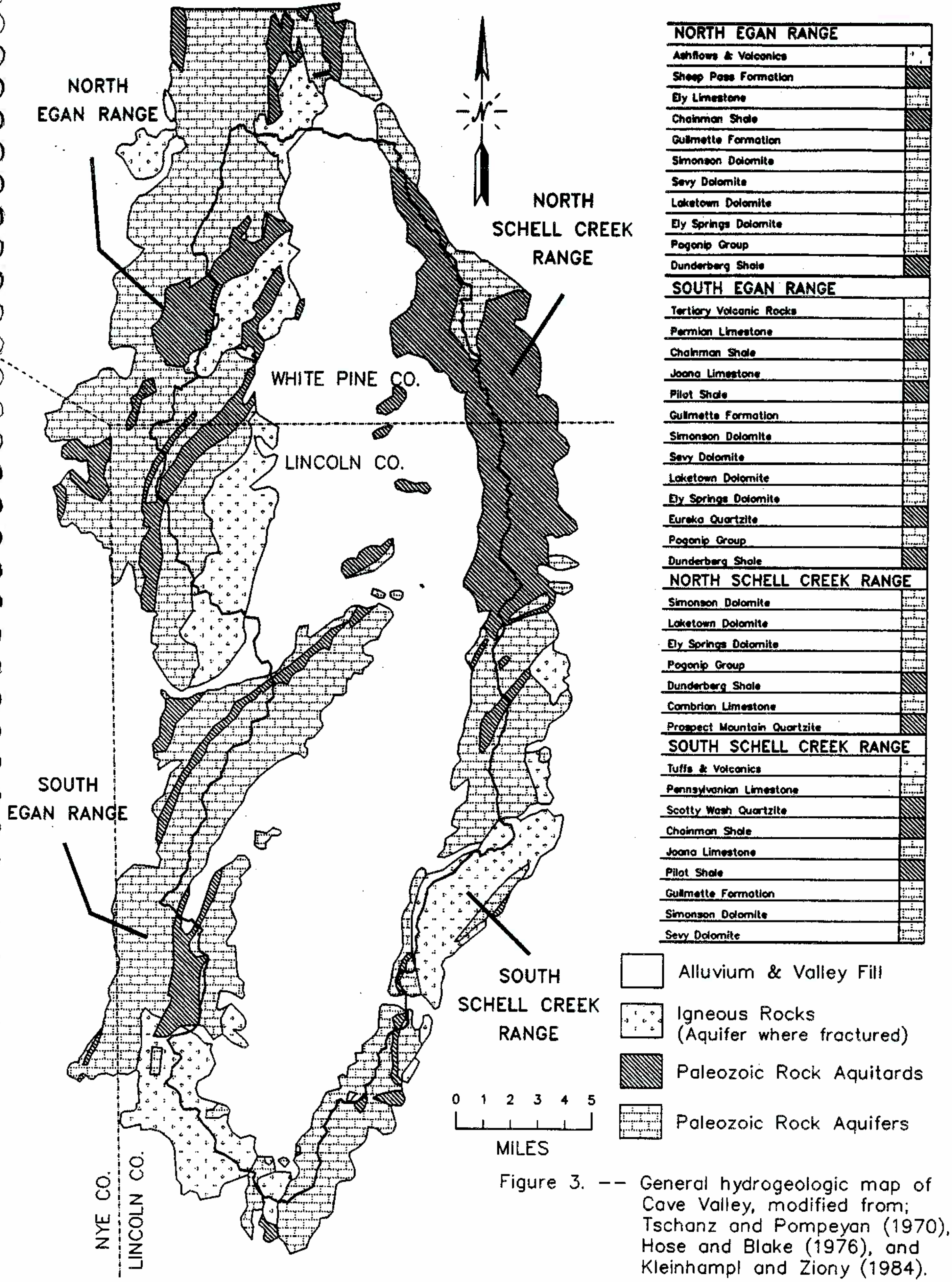


Figure 3. -- General hydrogeologic map of Cave Valley, modified from; Tschanz and Pompeyan (1970), Hose and Blake (1976), and Kleinhampl and Ziony (1984).

The sequence in the Schell Creek Range is similar to that in the Egan Range. Tuffs and dacitic volcanics overlie a Pennsylvanian limestone aquifer. In the northern part of Cave Valley, the older Paleozoic rocks (Devonian and older) are present while Silurian and younger Paleozoic rocks predominate in the southern part of the range. The Chainman Shale is present and is overlain by the Scotty Wash Quartzite (aquitards). Underlying the Chainman Shale is the same sequence of post-Cambrian, Paleozoic rocks present in the Egan Range. The Cambrian rocks of the Schell Creek Range include the upper limestone and dolomite which is included with the Pogonip Group as an aquifer, the Dunderberg Shale (aquitard), the Highland Peak Formation equivalents (Emigrant Springs limestone, Patterson Pass Shale, and Pole Canyon Limestone), a potential aquifer, the Pioche Shale, and the Prospect Mountain Quartzite (aquitards).

The aquitards, the Chainman Shale, Pilot Shale, Eureka Quartzite, Dunderberg Shale, Pioche Shale, and Prospect Mountain Quartzite are of particular significance because of their poor water transmitting characteristics. On the east side of the basin, in the Schell Creek Range north of T8N, sediments of Cambrian age predominate and include the Pole Canyon Limestone, the Pioche Shale, and the Prospect Mountain Quartzite. Although the limestone unit may be capable of transmitting some ground water, overall, the Cambrian units have low transmissivities and serve as an aquitard.

The springs in the upland areas in the northern part of Cave Valley appear to be the result of the hydraulic effects of these aquitards. A springline along the east side of the valley (including Wildcat Canyon, Sagehen, Brush, and Wall springs) suggests that the Cambrian units are not capable of transmitting all of the recharge that occurs over the Schell Creek Range. On the west springlines on both the eastern and western slopes of the Egan Range suggests that aquitards of Paleozoic age (Pilot Shale, Chainman Shale, and Eureka Quartzite) have a similar effect on recharge-discharge relationships.

Volcanic rocks, comprising primarily tuffs, occur along much of the eastern slopes of the Egan Range. In the Schell Creek Range, volcanics are limited to the southern part of the basin with tuffs and dacites present over an area of about five square miles located east and northeast of the playa. Undifferentiated volcanics have also been mapped at the southeastern most part of the basin. A small granitic stock is located just east of these volcanics, in the vicinity of the Silver King well. This intrusive and the volcanic rocks at the southern end of the basin may impede the flow of water between Cave Valley and White River Valley in this area.

In the valley floor area, the consolidated rocks are overlain by valley-fill deposits. These deposits include younger and older alluvium, playa deposits, older gravels, and younger lake beds. The older alluvium and older gravel deposits include fanglomerates deposited in a continuous apron along the eastern alluvial fan and along the northwestern and southwestern fans. The younger lake deposits have only been mapped in the southern part of the basin (south of T8N) but Tschanz and Pampeyan (1970) indicate that a middle Pliocene to Early Pleistocene lake was present in all of Cave Valley and that by Late Pleistocene time, the lake was reduced to only the southern part of the basin. Thus the valley-fill deposits in the northern part of the basin may be somewhat more fine-grained at depth. Younger alluvial deposits are limited to the vicinity of Cave Valley Wash.

Table 2 presents the available data on the hydraulic characteristics of the rocks and unconsolidated sediments that are present. These parameters, and other features, are discussed for each modelled hydrostratigraphic unit in the following sections.

Table 2.--Summary of transmissivity and hydraulic conductivity values in southern Nevada.

Transmissivity (ft^2/day)

Aquifer	Minimum	Maximum	Median	Number of Samples	Reference
Valley Fill	321	4,478	1,470	7	Winograd and Thordarson (1975)
	25,920	259,200	-	2	Burbey and Prudic (1985)
Tuff/Volcanic	6.7	9,090	281	5	Winograd and Thordarson (1975)
	259	-	-	1	Burbey and Prudic (1985)
Carbonate	174	11,496	1,470	11	Winograd and Thordarson (1975)
	11	250,000	2,100	31	Unpublished USGS Data
	86	43,200	4,320	5	Burbey and Prudic (1985)

Hydraulic Conductivity (ft/day)

Aquifer	Minimum	Maximum	Median	Number of Samples	Reference
Valley Fill	0.02	140	74*	7	Plume and Carlton (1988)
Carbonate	0.01	940	5.40	38	Unpublished USGS Data
	0.02	1.53	0.18	8	Winograd and Thordarson (1975)
Clastic	0.006	0.10	0.02	4	Unpublished USGS Data

* Average value for 18 tests in 14 basins

Valley-Fill Deposits

Based upon the available information, the alluvial deposits of Cave Valley can be considered as a single hydrostratigraphic unit. Unlike many other areas in the Great Basin, younger alluvial deposits are very limited in Cave Valley, forming only thin deposits along the major valley drainage. The playa sediments and older alluvium are less permeable and predominate over much of the basin.

The thickness of the valley-fill deposits in the northern part of the basin is about 2,600 feet with about 1,200 feet of Quaternary alluvium and lake beds and about 1,400 feet of older lake beds. In the southern part of the basin, more than 6,000 feet of valley-fill deposits are believed to be present.

The flow of ground water through the valley-fill aquifer is primarily through the interstitial porosity. However, flow is controlled by the variations in the relative permeabilities of the interbedded materials. The fine-grained deposits of the lake and playa and similar alluvial materials can be expected to be several orders of magnitude less than younger alluvial deposits of sand and gravel. The older alluvial deposits probably exhibit transmissivities between those of the lake deposits and younger alluvium while the fanglomerates, because of poor sorting and cementation, probably have transmissivities closer to those of the lake deposits.

On a regional basis, the transmissivity of the valley-fill deposits ranges from about 320 to 259,000 ft^2/day according to Burbey and Prudic (1985) and Winograd and Thordarson (1975). The transmissivity of the alluvium in a given valley or hydrologic setting is a function of both the permeability and the saturated thickness of the aquifer. Low values of transmissivity (less than 670 ft^2/day) generally indicate fair to poor well yield potential while high transmissivity wells (greater than 6,700 ft^2/day) may be capable of producing yields in the hundreds or even thousands of gallons per minute.

As with most of the undeveloped basins in east-central Nevada, data on the transmissivity of the valley-fill aquifer in Cave Valley is limited. Bunch and Harrill (1984) report two transmissivity values for Cave Valley, 8,800 ft^2/day for a well at Section 14AB2, T17N, R63E and 2,400 ft^2/day for a shallow (200-263 ft) observation well at the same location. Testing was conducted at a constant discharge rate of 225 gallons per minute for 160 hours. During testing, the maximum drawdown in the pumping well was 114.8 feet while only 3.6 feet of drawdown was measured in the observation well, 500 feet away. No drawdown was observed in a deeper (380-422 ft) observation well suggesting that the permeability of the deeper valley-fill units are appreciable smaller than those of the shallow deposits in this area.

Consolidated Rock

The carbonate sequence in Cave Valley consists of thick sequences of Paleozoic limestones and dolomites separated by thinner aquitards of shale or quartzite. Collectively, the Paleozoic rocks present comprise the numerous individual rock units that were previously discussed, and have an overall thickness of tens-of-thousands of feet. Flow through the carbonate aquifers is believed to occur primarily through fractures and solution openings, and is likely to the concentrated in areas of greater fracture frequency. Except in areas of structural or stratigraphic anomalies, the hydraulic gradient in the carbonate aquifers is likely to be low because of high transmissivity.

The movement of ground water across the contact between the valley-fill aquifer and the carbonate aquifers depends on the potentiometric heads in each aquifer. In areas where the head is higher in the valley-fill, the ground water is semi-perched and moves primarily downward into the underlying carbonate aquifer. Where the head in the carbonate aquifer is higher than the valley-fill, ground water can enter the overlying alluvial material through upward leakage from the carbonate rocks. There are no carbonate wells in Cave Valley that allow a comparison of heads between the two aquifer. However, the available valley-fill water level data suggests that head differentials may be different in the northern and southern parts of the basin. In the northern part of the basin, a flowing well occurs at Parker Station and the depth to water ranges from 2 to 18 feet below land surface at other wells along Cave Valley Wash. These data suggest that there is an upward gradient in the northern part of the basin with flow from the carbonate rocks into the valley-fill deposits.

In the southern part of the basin, water levels range from 130 to more than 300 feet below land surface and are generally more than 200 feet below the surface. In this area, the gradient is probably downward with flow from the valley-fill deposits into the carbonate rocks that underlie the basin.

No aquifer tests have been conducted in the carbonate rocks of Cave Valley. In nearby valleys, the transmissivity of the carbonate aquifer has been found to range from 11 to 250,000 ft^2/day (Winograd and Thordarson (1975); Burbey and Prudic (1985); and unpublished U.S. Geological Survey data), with values as high as several hundred thousand ft^2/day possible in fractured areas. In general, it is inferred that the transmissivity of the carbonate aquifer in Cave Valley is highly variable with the highest transmissivities occurring in the vicinity of major structural elements such as the Shingle Pass fault.

The Tertiary volcanic and intrusive rocks that outcrop in the mountains of Cave Valley probably represent a partial hydraulic barrier to ground-water flow. In the southernmost part of the basin, these rocks probably also underlie the valley-fill deposits. Except where intensely fractured, these rocks are not likely to be significant aquifers and probably tend to impede the regional flow of water in the subsurface.

Structural Features

Most of the faulting in Cave Valley is consistent with the features typical of the Basin and Range Province (i.e., horst and graben features oriented along north and northeast-trending normal faults. The Basin and Range is dominated by north-south trending fault scarps and lineaments that cut through the alluvium (Tschanz and Pampeyan, 1970). Several periods of regional tectonism have faulted, fractured, and displaced both bedrock and valley-fill materials. The major exception to this predominant trend in the Cave Valley area is the Shingle Pass fault, a northeast to southwest trending feature that has significantly offset a portion of the Egan Range.

As noted by Tschanz and Pampeyan (1970), the Egan Range consists of "two major east-dipping structural blocks ... separated by Shingle Pass." The Shingle Pass fault was interpreted by these authors as either a normal fault with very large stratigraphic offset or a strike-slip fault. The presence of intrusive volcanic rocks adjacent to the structural blocks suggests that they may be of gravity-glide origin. Regardless of their structural history, the blocks are of special significance with respect to ground-water flow in Cave Valley.

As mapped by Tschanz and Pampeyan, the sediments immediately south of the Shingle Pass fault dip to the south-southeast at about 30° and include, in ascending order, the Dunderberg Shale (aquitard), Pogonip Group (aquifer), Eureka Quartzite (aquitard), and the Ely Springs Dolomite through the Guilmette Formation (aquifer). The thickness of the Dunderberg Shale in outcrop and its attitude suggests that this unit represents a barrier to ground-water flow and effectively isolates most of northern Cave Valley from the southern part of the basin.

There may be some leakage across this barrier in the vicinity of Cave Valley Wash but, given the multiple aquitards present above the Dunderberg Shale (Eureka Quartzite, Pilot Shale, and Chainman Shale) such leakage is likely to be minimal. The presence of this barrier suggests that the flow of ground water out of Cave Valley is primarily through the Shingle Pass area into White River Valley.

This flow, estimated at about 14,000 acre-feet per year is restricted to a fairly narrow flow pattern that is coincident with the fracture zone associated with the Shingle Pass fault. The flow is probably predominately through the fractured Pennsylvanian and Permean carbonate rocks to the north of the fault.

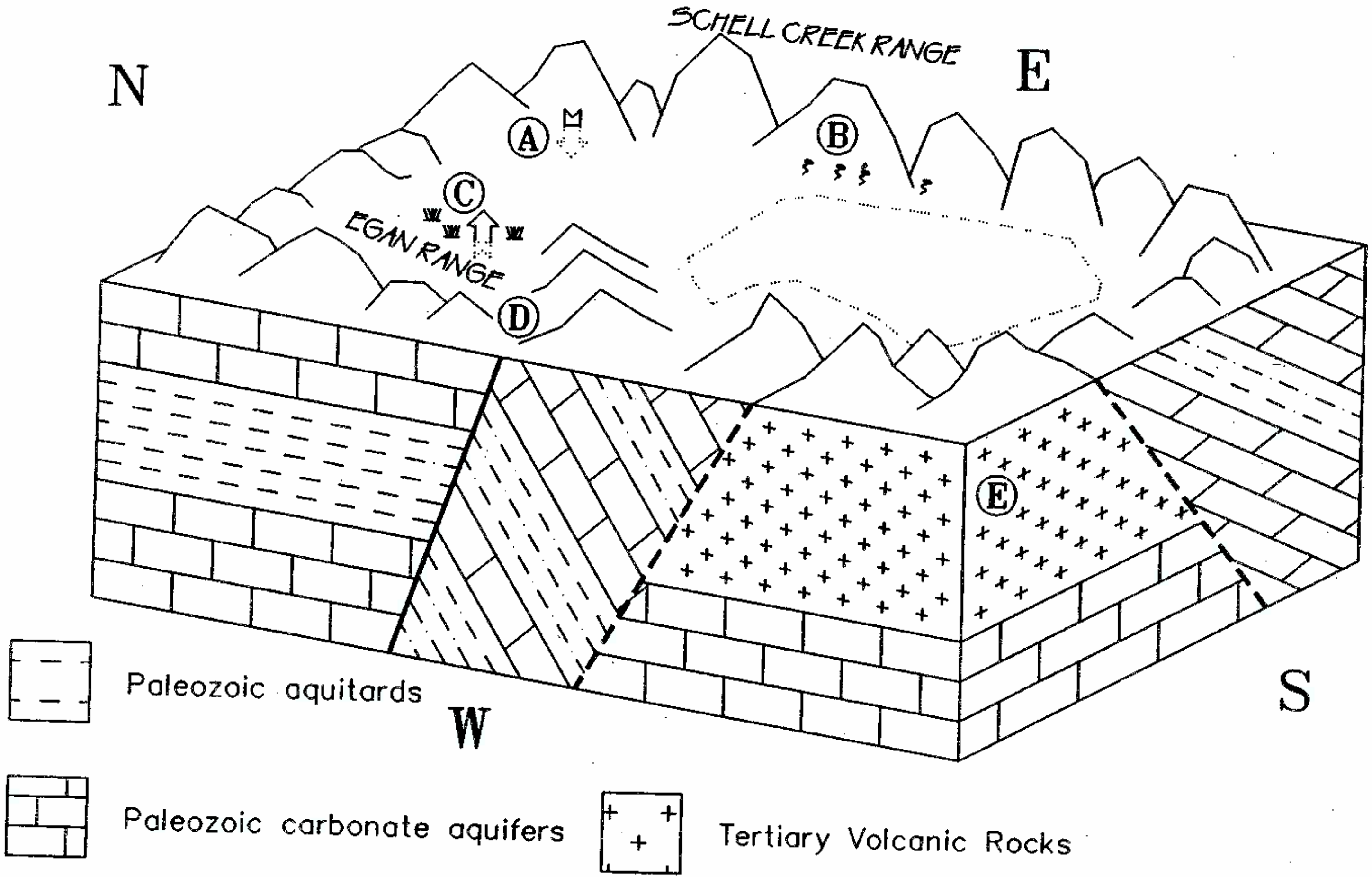
WATER RESOURCES APPRAISAL

To develop a steady-state ground-water flow model that is representative of Cave Valley's hydrologic system, it is necessary to define the magnitude of the water resources available in the basin and the basin's development history. The following sections present the available information on the surface and ground-water resources of the valley.

Figure 4 shows a conceptualization of the overall hydrologic system of Cave Valley. Each of the major components of the water budget for the basin is discussed in detail in the following sections. It should be noted that there are not a large number of wells in the basin, and detailed hydrologic studies have not been conducted. Therefore, the development of the conceptual model of the valley must rely, in part, upon inference based upon the data that are available and the analogy to other basins in eastern and southern Nevada that share similar characteristics.

SURFACE WATER

An accurate simulation of a hydrogeologic system requires an understanding of the surface water conditions and the significance of surface water in the overall water budget for a given hydrographic basin. This section describes the general conditions of the surface water regime of Cave Valley.



Ⓐ Ground water in Cave Valley originates as precipitation in the mountainous areas. A total of about 14,000 acre feet of recharge occurs each year.

Ⓑ Springs discharge in the upland areas and provide water for ranching and wildlife.

Ⓒ Shallow ground water is present only in northern Cave Valley. Evapotranspiration losses in this area are small.

Ⓓ Most of the 14,000 acre-feet/year of ground-water discharge out of Cave Valley is through the carbonate rocks in the Shingle Pass area into White River Valley. The rocks south of the Shingle Pass fault have been tilted to the southeast and form an effective barrier to flow between the northern and southern parts of the basin.

Ⓔ Volcanic rocks overlie the carbonate rocks in southwestern Cave Valley. These volcanic rocks probabably impede ground-water flow to a depth of 2,000 feet. Ground-water may flow at great depth through the carbonate rocks that underlie these volcanics.

Figure 4. -- Hydrogeologic conceptual model of Cave Valley.

General Conditions

Surface water in Cave Valley occurs as streamflow from the adjacent mountains, primarily as a result of winter and spring precipitation. Cave Valley Wash, which drains the basin from its north end to the playa in the south, is the axial stream in the valley. Principal tributaries are Silver Creek, Sheep Creek, Hagerty Wash, and Big Spring Wash. Except for a few spring- fed streams in their upper reaches, all of the streams are ephemeral and flow only in response to storms and snowmelt. No stream flow records or data are available for any of the drainages in Cave Valley, and no estimates of runoff have been published. Scott et al. (1971) estimated that the total runoff from the mountain front to the valley area is about 10,000 acre-feet per year.

GROUND WATER

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

Occurrence

The alluvial valley fill comprises the principal aquifer in Cave Valley. The Paleozoic carbonate rocks in the mountains, and where present beneath the valley floor, transmit water through fractures and solution channels. Solution channels in the cave and spring openings near the Gardner Ranch in Section 16, T9N, R64E and elsewhere in the valley attest to the ability of the carbonate rocks to transmit appreciable quantities of ground water (Eakin, 1962, p. 8).

Little is known of the Paleozoic rocks beneath the valley floor, except that they probably are too deep in most parts of the valley to be considered an economic source of ground water. Geophysical and lithologic logs from three oil exploratory test wells indicate that the top of the carbonate rocks is at a depth of about 4,800 feet below land surface at the north end of the valley, 3,344 feet near the center, and 6,205 feet in the south-central part of the valley (Garside, et al., 1988).

The Paleozoic rocks include a number of discrete aquifers and aquitards. As noted previously, faulting of the Paleozoic rock sequences has resulted in a hydraulic barrier between the northern and southern parts of the valley south of the Shingle Pass area.

Recharge to the aquifer is mostly from snowmelt over the upland areas and the infiltration of surface flow during periods of runoff and occurs primarily near the apexes of alluvial fans which extend into the mountain canyons. Surface water infiltrates the coarse fan deposits and moves downslope to the aquifer in the valleys. Recharge from precipitation on the valley floor (with the exception of the north end of the valley) probably is relatively minor because of the high evaporation rate and the presence of lacustrine beds, and other relatively impermeable fine-grained layers near the surface.

The depth to water in Cave Valley is variable and appears to reflect the geologic conditions present. One flowing well and two wells with depths to water ranging from 2 to 18 feet below land surface are present in the northern part of the basin. Across the inferred hydraulic barrier, the depth to water is significantly greater, more than 200 feet below land surface in the lowland areas. Figure 5 is a potentiometric map of the ground water in the alluvial aquifer. Well No. 1 shown in Table 1 was not included since this well is considered to be near the mountain block and representative of a very localized flow system. The potentiometric map was generated using an accepted statistical package for gridding data; however, the data is sparse enough, with the limits of the gridding package, that the hydraulic barrier thought to be present causing flow to White River Valley through the consolidated rocks is not evident.

Data are lacking upon which to define specific directions of ground-water flow for most of Cave Valley. In general, there are believed to be two different components of flow in the northern and southern parts of the basin. In the north, flow is probably from the upland areas toward the valley axis and then southwest through the fractured carbonate rocks in the Shingle Pass area. In the southern part of the basin, flow is probably radial from the upland areas toward the playa area. Flow from the playa area could either be southwestward through the fractured carbonate rocks of the Trough Spring Canyon area or to the southeast through similar rocks in the Side Hill Pass and Big Mud Pass area, or both.

Water-level measurements made between 1980 and 1990 at six wells between the middle of the valley and the playa show a rise in water levels of 4.5 to 16.2 feet (Table 1). Two other wells show water-level rises of 16.1 and 35.2 feet since the early 1960's. Hydrographs of four representative wells in the valley (Figure 6) illustrate this trend. The cause of the rising water levels is unknown; however, the trend appears to be regional, based on similar trends noted by MARK in current investigations in neighboring basins. Water level measurements made in April, July, September, and November of 1983 about 2 miles north of the playa show a fairly constant seasonal level with a fluctuation of 0.2 feet between mid-Spring and early Fall (Table 1 and Figure 6).

Movement

The hydraulic properties of the basin control the movement of ground water horizontally and vertically and are defined by volumetric changes within unit dimensions of the aquifer material. The primary property, hydraulic conductivity is defined as the volume of water at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient through a unit area at right angles to the direction of flow. Transmissivity is directly related to the hydraulic conductivity and is the aquifer's ability to transmit water through at the rate of hydraulic conductivity throughout the entire saturated thickness of the aquifer. The storage coefficient is a dimensionless number describing the aquifer ability to contain water interstitially. It is defined as the volume of water an aquifer releases from or takes into storage (interstitially to the aquifer material) per unit surface area of the aquifer per unit change in head (Lohman, et al., 1972, p.13).

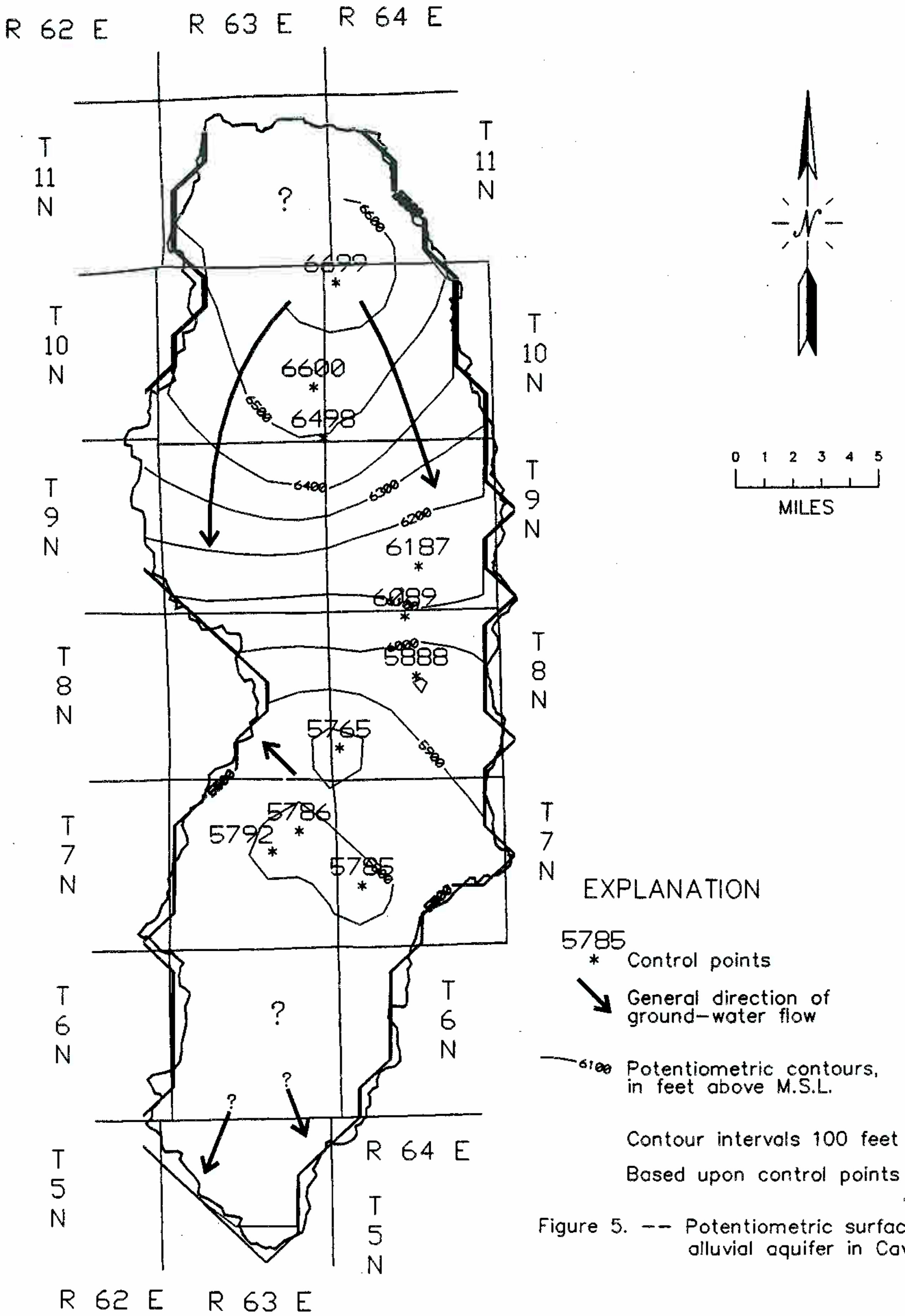


Figure 5. -- Potentiometric surface for the alluvial aquifer in Cave Valley.

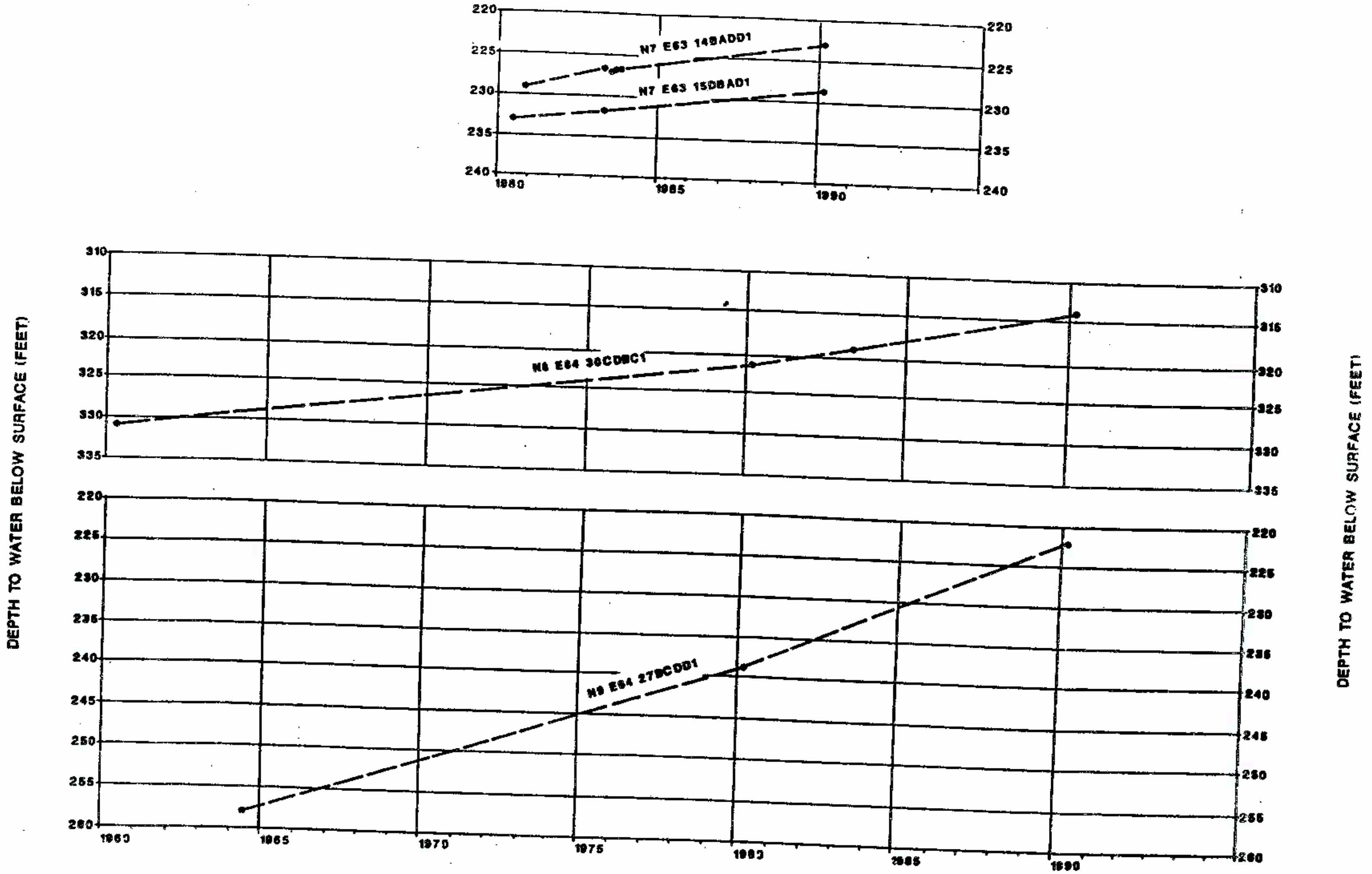


Figure 6.--Hydrographs of four wells in Cave Valley.

Based upon tests conducted during MX investigations, the transmissivities of 8,800 feet squared per day (ft^2/day) and 2,400 ft^2/day were estimated from drawdown data in the pumped well and the shallow observation well, respectively. The storage coefficient was estimated at 0.013, based on delayed yield drawdown data from the observation well (Bunch and Harrill, 1984, p. 115). The storage coefficient calculated for the aquifer in Cave Valley probably represents a minimum value based on the short length of the test in relation to the much longer time generally required to adequately test for delayed yield effects in thick alluvial aquifers (ERTEC, 1981, p. 14-18, 28). The long term storage coefficient is probably an order of magnitude greater as indicated by Eakin's (1962, p.14) estimate of 10 percent for the specific yield. For a given transmissivity, pumping rate, and duration of pumping, a smaller value of storage coefficient will result in greater water-level decline. The storage coefficient determines the rate of growth of a cone of depression induced by pumping.

Chemical Water Quality

The water chemistry of Cave Valley has not been well defined. Bunch and Harrill (1984) report on the water chemistry from four wells and three springs, as shown in Table 3 and Figure 7. Generally the water is of a calcium-magnesium-bicarbonate type. The chemistry of the spring samples indicate the rock source, with Cave Valley spring (which issues from carbonate rock) having a very low total dissolved solids (TDS) concentration with an electrical conductivity of 180 μs/cm (about 110 mg/l TDS). The higher TDS values of 740 mg/l and 840 mg/l TDS for Sidehill and Horse Springs, respectively, discharge from the clastic Paleozoic aquitards. The chemistry of the well samples indicate a good water quality with all samples exhibiting an estimated TDS concentration of about 300 mg/l (based on an electrical conductivity of 510 μs/cm) or less.

An anomalous electrical conductivity of 4100 μs/cm was reported by Bunch and Harrill (1984) for the Cave Valley Seeding Well (N8 E64 4abd). The analysis shown in Table 3 suggests the TDS should be significantly lower, about 120 mg/l. The reported conductivity value is probably in error.

Ground-Water Budget

A ground-water 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 4 summarizes the water budget parameters for Cave Valley. The following sections present the current estimates for recharge and discharge for Cave Valley.

Table 3.--Chemical analyses of water wells and springs in Cave Valley (modified from Bunch and Harrill, 1984, p. 31)

RESULTS IN MILLIGRAMS PER LITER EXCEPT AS INDICATED

	LOCATION						
	WELLS				SPRINGS		
	N7 E63 14BADD1	N8 E64 04ABDD1	N8 E64 15BCBC1	N10 E63 25AAB1	N9 E64 16BAD	N7 E64 33DCA	NV E63 19ADB1
Name Month/Year Collected	MX Well 10/60	Seeding Well 3/80	Harris Well 3/80	M. Urutia Well 3/80	Cave Valley Spr. 3/80	Sidehill Spr. 8/79	Horse Spr. 8/79
Temp (°C)	11		10	4	12	17	16
pH (unitless)		7.5	7.3	7.2	7.3	7.4	8.0
Silica (SiO_2)	49	1.3	1.1		2.1		
Calcium (Ca)	34	24	49	51	16	31	25
Magnesium (Mg)	20	6.7	13	12	4.0		
Sodium (Na)	13	7.5	6.2	10	5.1	11	11
Potassium (K)	4.6	1.4	0.9	4.0	0.6	0.9	1.2
Bicarbonate (HCO_3)	197	120	200	160	80	250	280
Chloride (Cl)	1.5	8.9	2.5	14	3.2	11	16
Sulfate (SO_4)	19	4	Not Detected	20	9	11	15
Fluoride (F)	0.1	0.1	0.0	0.2	0.0		
Nitrate (N)	1.3	0.4	1.2	2.4	4.4	0.3	1.2
Iron (Fe)	0.06						
Manganese (Mn)	0.01						
Dissolved Solids (TDS)	263					740	840
Conductivity (µs/cm)		4100*	468	510	180		

* Probably an error, not supported by analysis.

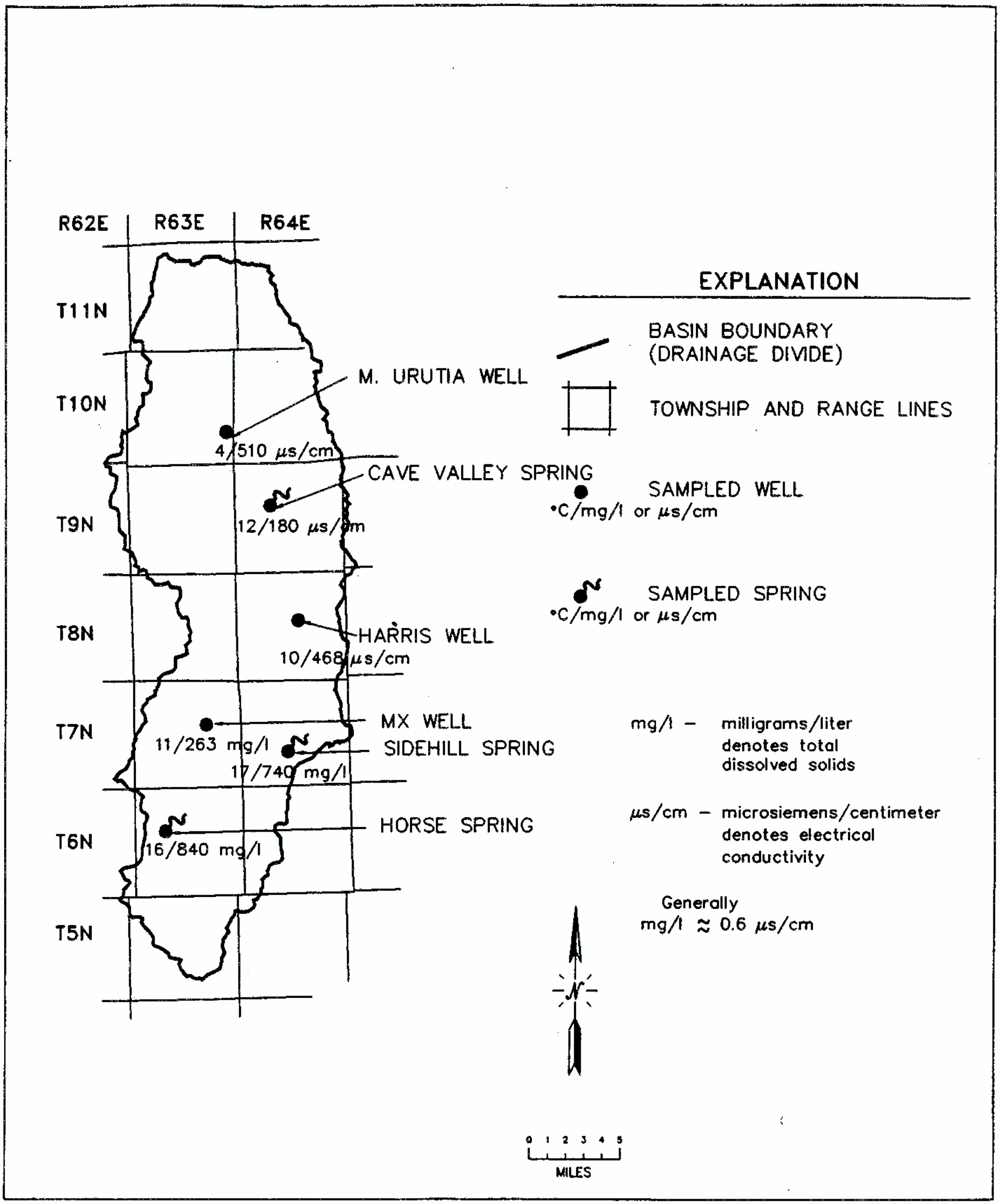


Figure 7. -- Temperature and total dissolved solids concentration or electrical conductivity of water from wells and springs in Cave Valley.

Table 4.--Ground-water budget for Cave Valley.

		Published Value Acre-feet/year (rounded)
RECHARGE		
Precipitation (Recharge)		14,000
Subsurface Inflow		0
Secondary Recharge		0

	TOTAL	14,000
DISCHARGE		
Evapotranspiration*		Minor
Pumpage*		Minor
Subsurface Outflow		14,000

	TOTAL	14,000

Source: Eakin (1962), Scott et al. (1971)
* not included in steady state model

Estimated Average Annual Recharge

Recharge to a basin usually consists of several components: precipitation, subsurface inflow, and secondary recharge. Estimates for these elements for Cave Valley are provided in the following sections.

Precipitation

The source of recharge to the hydrologic system of Cave Valley is the infiltration of precipitation over the basin. No meteorological stations are located in Cave Valley and the characterization of precipitation over the area is inferred from recording stations located in adjacent valleys. The total precipitation over Cave Valley is estimated at about 200,000 acre-feet per year (Eakin, 1962). The volume of recharge derived from precipitation is reported by this author to be about 14,000 acre-feet per year, or about 7 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 Cave Valley, recharge totalling about 14,000 acre-feet per year may be distributed according to the zones summarized in Table 5.

Table 5.--Recharge distribution zones for Cave Valley (Eakin, 1962).

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	3,500	6,125	25	1,500
8,000-9,000	15-20	19,500	28,500	15	4,300
7,000-8,000	12-15	69,000	77,300	7	5,400
6,000-7,000	8-12	114,000	94,600	3	2,800
<6,000	<8	29,000	---	0	0.0
		235,000	207,000		14,000

Subsurface Inflow

There is no inflow of ground water to Cave Valley from upgradient basins. Noted previously, there is subsurface flow from Cave Valley into White River Valley, estimated at about 14,000 acre-feet per year by Harrill et al. (1988).

Secondary Recharge

Secondary recharge is usually estimated based on the type of usage of the ground water. Currently, the ground water withdrawn within Cave Valley is used almost exclusively for livestock watering. Because of the small quantities of water that are removed from Cave Valley, the secondary recharge that may result is negligible and need not be considered in developing a numerical model of ground-water conditions in Cave Valley.

Estimated Average Annual Discharge

Components of discharge include evapotranspiration, springs, well pumpage, and subsurface outflow. Estimates of the quantity of these components are included in the following sections.

Evapotranspiration

In Cave Valley, evapotranspiration (ET) is negligible because of the lack of significant areas of shallow ground water and any significant springs. Minor ET may occur in upland areas where perched ground water may be present and in the areas immediately downgradient of discharging springs.

Springs

There are few springs in Cave Valley. Most of these springs are relatively small, meteoric springs (i.e., springs derived from local sources, usually snowmelt in the topographically higher portions of the mountains that bound the basin). Discharge from these springs is probably seasonal, with peak rates occurring between April and June each year.

The small volume of flow and localized nature of these springs indicates that the quantity of discharge associated with them is probably insignificant in terms of the overall water budget for Cave Valley, and, as a consequence, the presence of this minor spring discharge need not be simulated in a ground-water flow model of the valley.

Water Wells

Based on information provided by SEC, only two wells are permitted in Cave Valley and these are for livestock watering. According to the permits, total ground-water withdrawals are small, totalling less than 25 acre-feet per year which were not included in the model.

Outflow

Discharge through subsurface flow from the Cave Valley ground-water system is into White River Valley. Eakin (1962), Scott, et al. (1971), and Harrill, et al. (1988) estimate the quantity of this outflow to be 14,000 acre-feet per year. As noted previously, most of this flow is believed to be through the Shingle Pass area. Minor discharge into White River Valley south of Shingle Pass or into Delamar Valley are also possible, but, if indeed occurring, is probably limited to deep underflow.

Total Discharge

Based upon the preceding estimates and published values, the total discharge from Cave Valley is estimated to be about 14,000 acre-feet per year. Most of this discharge is out of Cave Valley into White River Valley.

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." The perennial yield of Cave Valley is reported to be at least 2,000 acre-feet per year (Scott et al., 1971).

Eakin (1962) stated that the perennial yield of the basin fill deposits is "not known but may not exceed a few thousand acre-feet per year. The extent to which the yield could be increased above this amount is related largely to the amount of underflow from the valley that could be salvaged." That this underflow is restricted to a small flow pattern through Shingle Pass suggests that it could indeed be salvaged and that the perennial yield could be appreciably greater than the published value of 2,000 acre-feet per year.

Storage

The quantity of ground water stored in the geologic units underlying Cave Valley 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 Cave Valley, Scott, et al. (1971) estimated the quantity of recoverable ground water in the saturated valley fill to be 1 million acre-feet in the upper 100 feet.

No estimates have been made of the amount of ground water that is stored in the carbonate aquifer in Cave Valley. Although the storage capacity of the carbonates is believed to be 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 may be even greater than that expected from the valley-fill deposits.

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.

INVENTORY OF WATER RIGHTS, PUMPAGE, AND LAND USE

An estimate of ground-water usage in a basin can be obtained from water rights records, pumpage inventories, and estimates 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 Cave Valley, little ground water has been pumped historically, and little is presently being used. The Nevada State Engineer has however allocated several water-right permits in the basin.

Water Right Status

Based on information supplied by SEC contained in Appendix B, the State Engineer has allocated water-right permits in Cave Valley for both surface and ground water. The permitted water rights and applications are shown on Table 6. A land use inventory in April of 1990 showed about 330 acres under irrigation. Based on a consumptive use rate of 3 ft/year per acre this would be about 1,000 acre-feet per year of surface water used for irrigation.

Table 6.--Water rights in Cave Valley (acre-feet/year consumptive use).

	Surface		Underground	
	Permits	Applications	Permits	Applications
Stockwater	450	0	22	0
Irrigation	1750	0	0	0
TOTAL	2200	0	22	0

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.

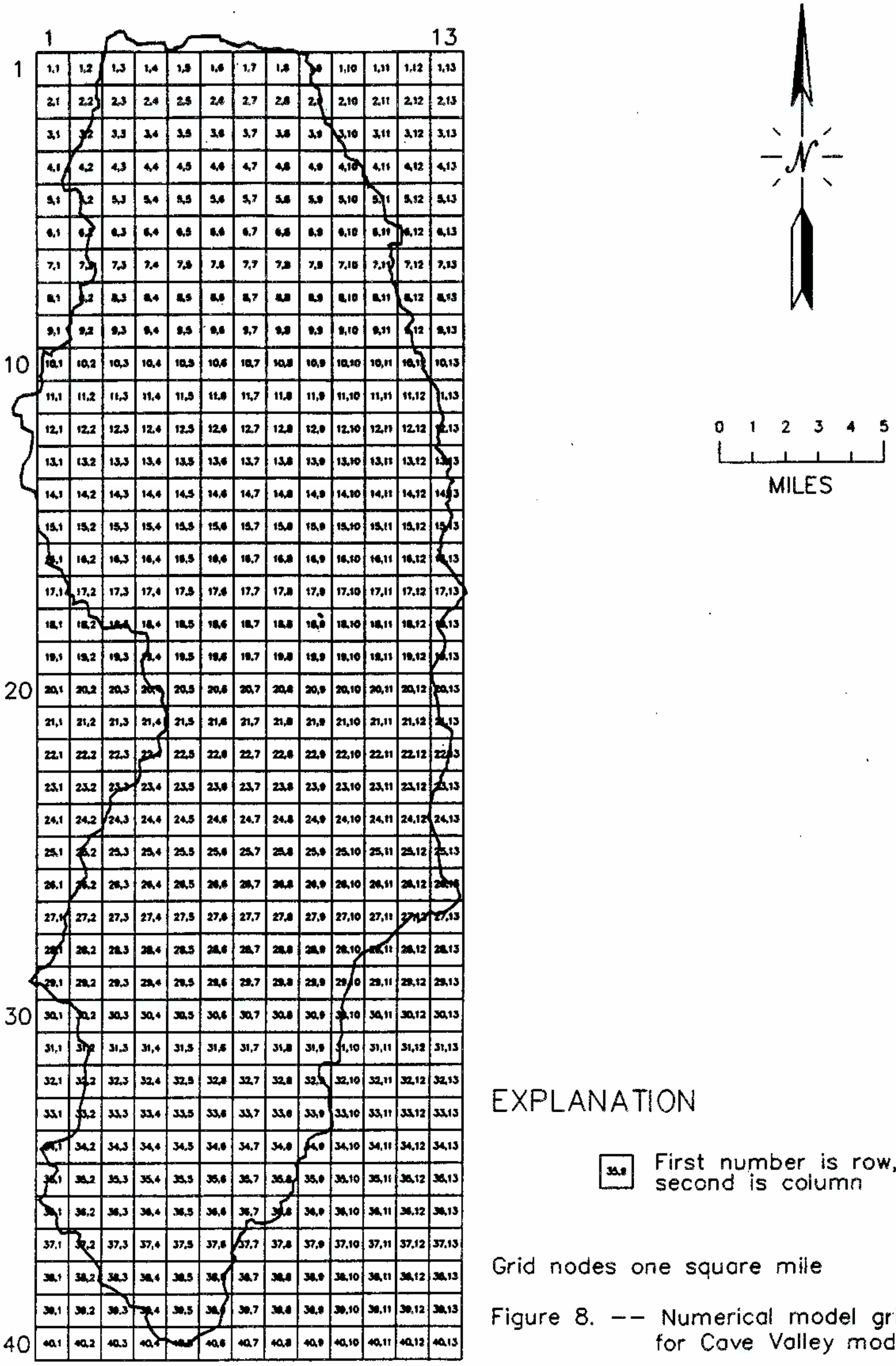
The first step in developing a ground-water flow model is the formulation of a conceptual hydrogeologic model of the area to be mathematically represented. This conceptual model is based upon the available hydrologic data, inferences based on observations of similar hydrologic settings, and assumed conditions 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. Eakin (1962) established the hydrologic budget for Cave Valley which is listed in Table 4.

A square mile grid, 40 rows by 13 columns as shown in Figure 8, consisting of two layers was constructed to simulated ground-water flow in Cave Valley. Both the upper alluvial and the lower consolidated rock layer were modelled as confined units. Parameter selection (i.e. transmissivity and vertical leakance) was keyed to rock type. Figure 9 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).



EXPLANATION

35,8 First number is row, second is column

Grid nodes one square mile

Figure 8. -- Numerical model grid for Cave Valley model.

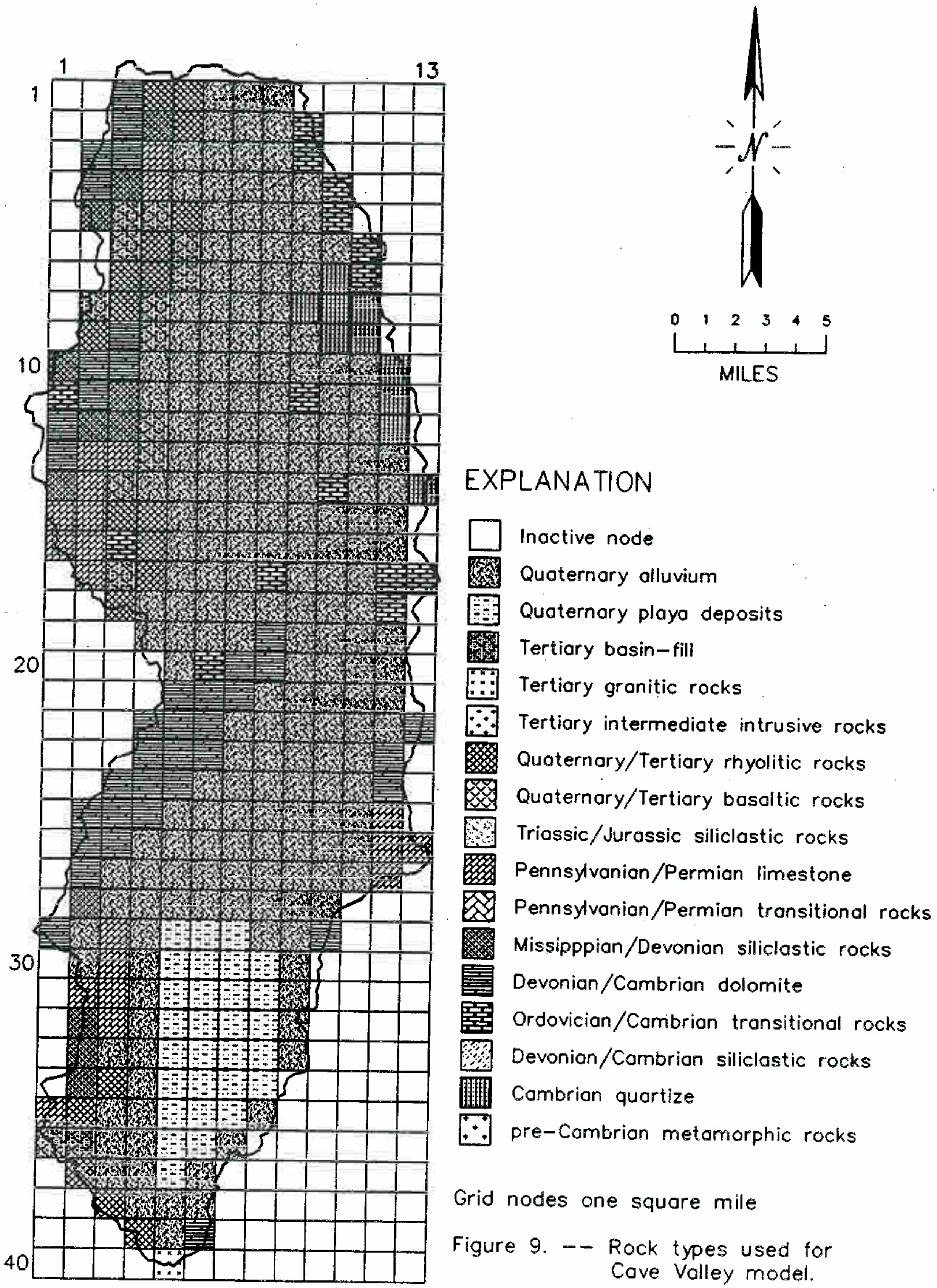


Figure 9. -- Rock types used for Cave Valley model.

PARAMETER ESTIMATES

Recharge and Discharge

Eakin (1962) estimates the recharge, based on the method described by Eakin et al. (1951), to Cave Valley to be 14,000 acre-feet per year, as shown in Table 5. Eakin also estimated the total discharge from evapotranspiration and wells to less than a few hundred acre-feet per year. A recent assessment of land use and water rights permits in these valleys confirmed that well pumpage is minimal and used primarily for livestock water.

Primary Recharge

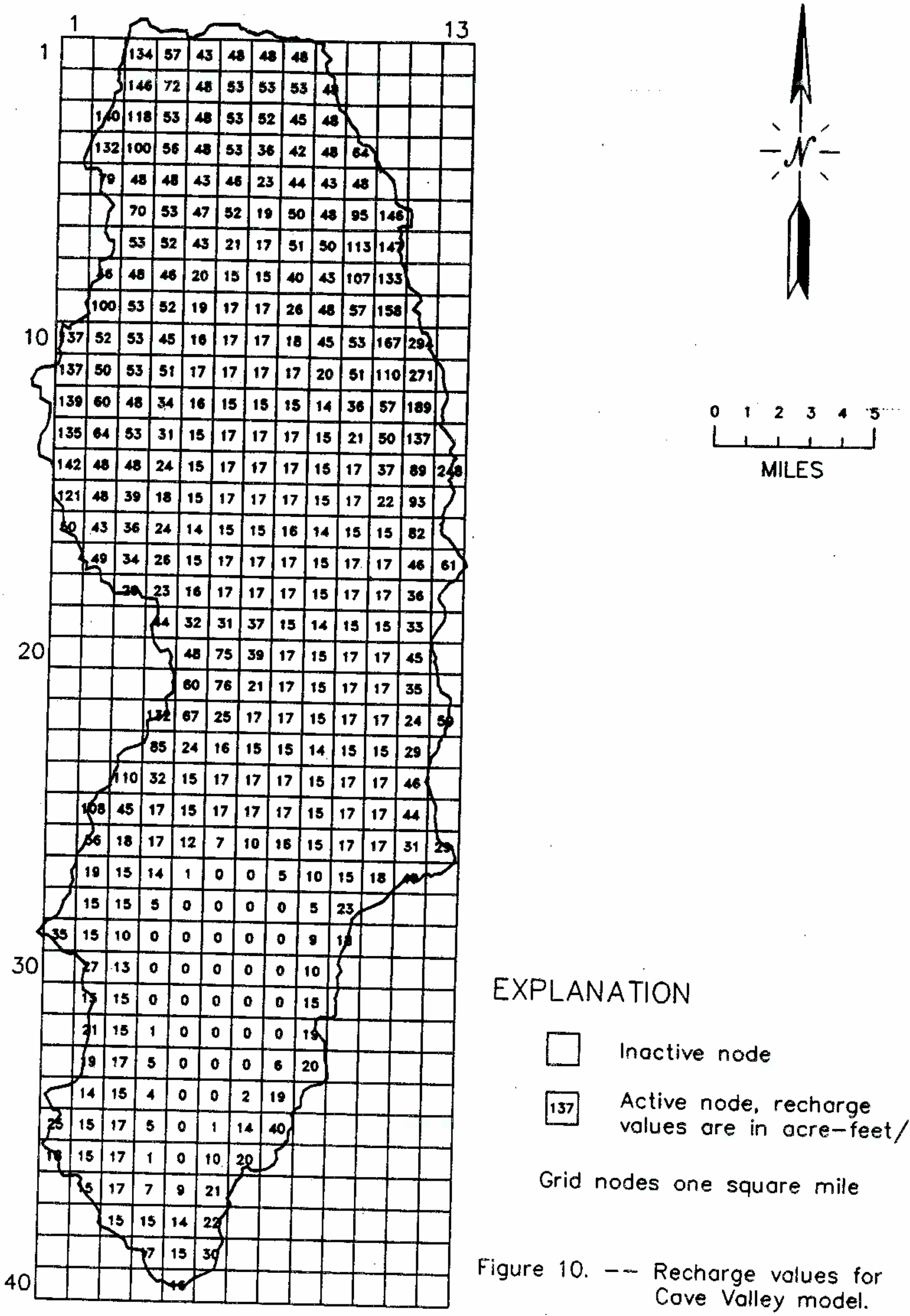
Primary recharge in Cave Valley is limited to the infiltration of precipitation into the ground-water system occurring in the higher elevations. Cave Valley receives the majority of its recharge in the north because of the higher elevations in the Schell Creek and Egan Ranges which border the east and west sides of the valley.

Digital elevation data was used to computer generate and distribute recharge based on the Eakin method (Eakin et al., 1951) with the factors listed for Cave Valley in the report by Eakin (1962) and shown in Table 5. 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 considering the nearest neighbor then resampling at 150 meter intervals. The file was then subset for the Cave Valley grid area. Dr. James Tracy developed a program to calculate recharge based on the digital elevations located within 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.

Figure 10 is a graphical representation of the recharge distribution used in the Cave Valley model. Based on this method, the recharge for Cave Valley was calculated to be about 13,000 acre-feet per year, about seven percent less than that calculated by Eakin (1962). Since the factors used to calculate recharge were the same, the difference could be due to different acreages calculated for each zone based on the model using the square mile grid and small areas that are actually in the basin were considered to be in an inactive mode. However the difference of seven percent is well within the accuracy of the estimation of natural recharge.

Secondary Recharge

Secondary recharge is due to infiltration of water from anthropogenic uses such as irrigation or septic disposal systems. Because there is little irrigation and very few wells are used for livestock water in this area, secondary recharge was not considered in the model.



	1												13
1			134	57	43	48	48	48					
			146	72	48	53	53	53	48				
		140	118	53	48	53	52	45	48				
		132	100	56	48	53	36	42	48	64			
		79	48	48	43	46	23	44	43	48			
			70	53	47	52	19	50	48	95	146		
			53	52	43	21	17	51	50	113	147		
		46	48	46	20	15	15	40	43	107	133		
		100	53	52	19	17	17	26	48	57	158		
10	137	52	53	45	16	17	17	18	45	53	167	294	
	137	50	53	51	17	17	17	17	20	51	110	271	
	139	60	48	34	16	15	15	15	14	36	57	189	
	135	64	53	31	15	17	17	17	15	21	50	137	
	142	48	48	24	15	17	17	17	15	17	37	89	248
	121	48	39	18	15	17	17	17	15	17	22	93	
	60	43	36	24	14	15	15	16	14	15	15	82	
		49	34	26	15	17	17	17	15	17	17	46	61
			[illegible]	23	16	17	17	17	15	17	17	36	
				44	32	31	37	15	14	15	15	33	
20					48	75	39	17	15	17	17	45	
					60	76	21	17	15	17	17	35	
				132	67	25	17	17	15	17	17	24	59
				85	24	16	15	15	14	15	15	29	
			110	32	15	17	17	17	15	17	17	46	
		108	45	17	15	17	17	17	15	17	17	44	
		56	18	17	12	7	10	16	15	17	17	31	29
		19	15	14	1	0	0	5	10	15	18	[illegible]	
		15	15	5	0	0	0	0	5	23			
	35	15	10	0	0	0	0	0	9	18			
30		27	13	0	0	0	0	0	10				
		15	15	0	0	0	0	0	15				
		21	15	1	0	0	0	0	19				
		19	17	5	0	0	0	6	20				
		14	15	4	0	0	2	19					
	25	15	17	5	0	1	14	40					
	18	15	17	1	0	10	20						
		15	17	7	9	21							
			15	15	14	22							
				17	15	30							
40					16								

EXPLANATION

☐ Inactive node

137 Active node, recharge values are in acre-feet/year

Grid nodes one square mile

Figure 10. –– Recharge values for Cave Valley model.

Discharge

The discharge from this valley was estimated by Eakin (1962) to be underflow to the west or south into the White River flow system. Harrill and others (1988) show the 14,000 acre-feet per year of recharge generated in Cave Valley flowing to the southwest into White River Valley through the lower Egan Range. Ground-water levels indicate the water is flowing to White River Valley. There is no significant transpiration of ground water from phreatophytes in Cave Valley and evaporation from spring flow is considered to be less than a few hundred acre-feet per year (Eakin 1962). Therefore, ground water is thought to discharge through the bedrock southwest into White River Valley.

Hydraulic Characteristics

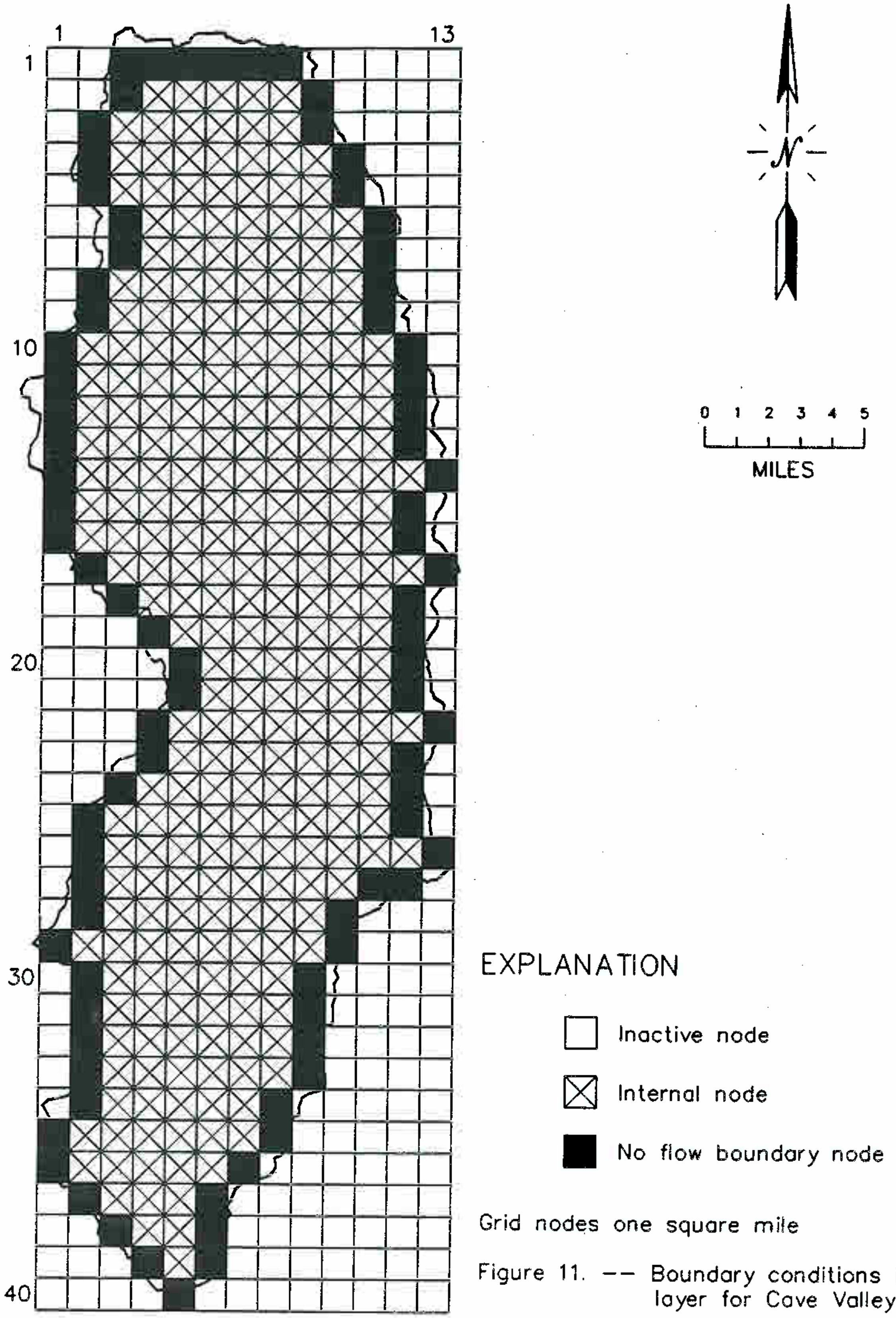
The hydraulic characteristics govern how the water introduced by recharge moves through the modelled area to the areas of discharge. For a steady state simulation the important hydraulic characteristics are transmissivity, boundary conditions (conductances) and, since this is a two layer model, vertical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

Boundary Conditions

The Cave Valley 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. The USGS does not estimate any inflow into Cave Valley from another hydrologic basin; therefore the estimated 13,000 acre-feet year recharge simulated for the model enters the upper layer primarily in the mountain ranges on the edges of Cave Valley. Because only natural ground-water recharge enters Cave Valley in the upper layer, the upper boundary conditions were simulated as no flow boundaries. The lower layer connects Cave Valley to the surrounding lower aquifer with low conductances for most all nodes except one on the western boundary in the Shingle Pass area.

This high conductance was needed at this node to match water levels in the southern part of the valley and to move the 13,000 acre-feet of water to White River Valley through the consolidated rock. As noted in the preceding section, the displacement of the thick Paleozoic sequence of aquifers and aquitards has resulted in a barrier to flow between the northern and southern portions of the basin. The high conductance node simulates the presence of the Shingle Pass fault and the interaction between upper model layer (representing primarily alluvium) and the lower layer (representing rock aquifers) in this area.

Figures 11 and 12 show the location of the general head boundaries and the conductances used in each layer. Again, the upper layer consists of "no flow" boundaries and the lower layer consists of low conductances with exception of one node on the western boundary. This higher conductance value relates to a high aquifer transmissivity (simulating fractures) which could



EXPLANATION

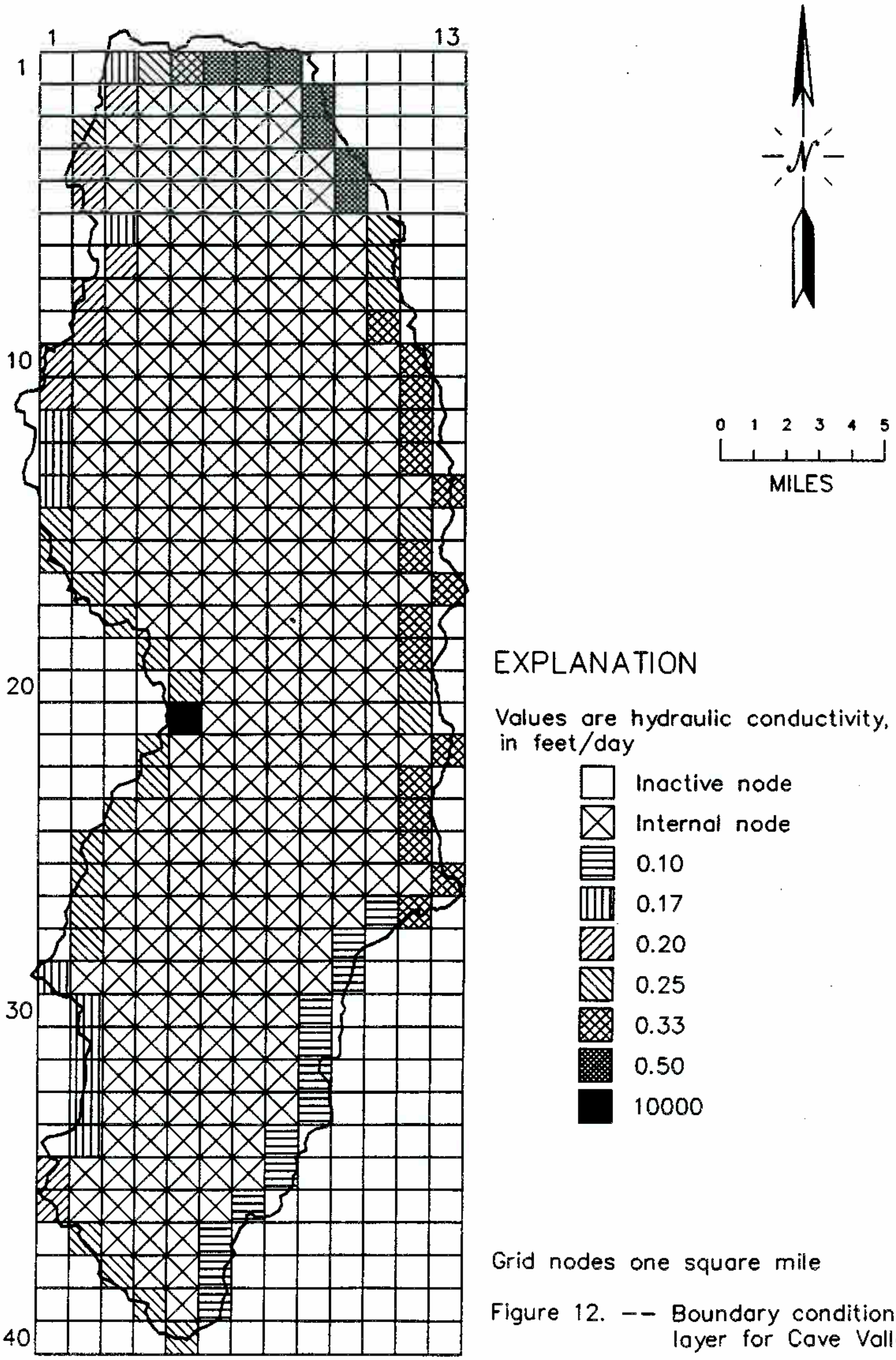
☐ Inactive node

☒ Internal node

■ No flow boundary node

Grid nodes one square mile

Figure 11. -- Boundary conditions in upper layer for Cave Valley model.



Grid nodes one square mile

Figure 12. -- Boundary conditions in lower layer for Cave Valley model.

potentially be moving water from Cave Valley to White River Valley. Using these boundary conditions the simulated flow across the west Cave Valley boundary is about 13,000 acre-feet per year in the lower consolidated rock layer.

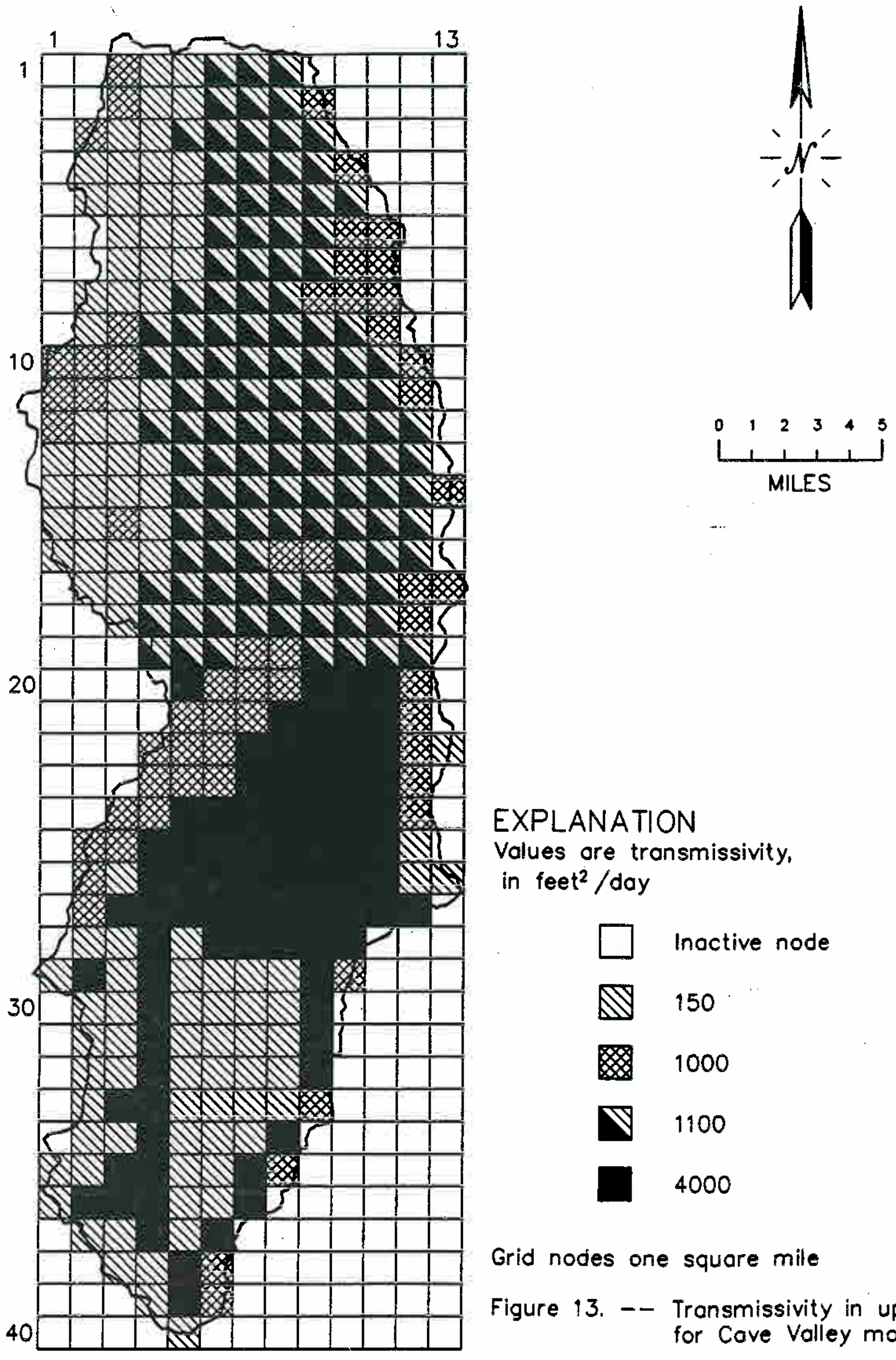
Transmissivity

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 Cave Valley model, which included eighteen different geologic classifications as shown in Figure 9.

As discussed above, as part of the MX Missile siting investigation (Bunch and Harrill, 1984) aquifer tests were conducted in Cave Valley. Transmissivity values in the alluvium are listed as 8800 and 2400 ft^2 per day. Originally the transmissivity value of 5000 ft^2 per day was assigned to alluvium, 1000 ft^2 per day for the carbonates, and 250ft^2 per day for clastics and volcanic rock classifications. In calibrating the model, it became apparent that the valley was split by the carbonate outcropping in the central part of the valley that is part of the Egan Range. This structure appears to be a barrier in the upper layer driving the water downward to the lower layer where it acts as a conduit which moves the ground water from Cave Valley to White River Valley. To match water levels it was necessary to use a higher transmissivity to simulate a fracture in these carbonates in layer 2. The thicknesses of alluvium varies significantly in north and south Cave Valley therefore it was necessary to use two different transmissivities for northern and southern alluvium. Calibrated transmissivity values used in layers 1 and 2 for the final steady state model are shown in Figures 13 and 14.

The modelled transmissivity of 4000 ft^2 per day for the southern alluvial aquifer is between the calculated transmissivity values reported for the aquifer tests in Cave Valley in Sec. 14, T7N, R63E (Bunch and Harrill, 1984). The calibrated transmissivity value for the northern alluvial aquifer is 1100 ft^2 per day, 1000 ft^2 per day for the upper carbonate units, and 150 ft^2 per day for the upper volcanic and clastic units. These values fall within the lower range of the values reported in Table 2. Given the presence of multiple aquitards within the Paleozoic sequences on the western and southwestern sides of Cave Valley and the extensive outcrops of Cambrian sediments on the eastern side, these somewhat lower transmissivity values are considered appropriate.

For the lower layer it was assumed that carbonate was underlying the alluvium. However only two transmissivity values were used as shown in Figure 14. The majority of the lower layer in the model used a transmissivity of 275 ft^2 per day with certain areas using a higher transmissivity of 8500 ft^2 per day. This higher transmissivity was needed to move ground water to match certain water levels in these areas. These areas could potentially be well fractured; however the transmissivity is well within the accepted range shown in Table 2.



Grid nodes one square mile

Figure 13. -- Transmissivity in upper layer for Cave Valley model.

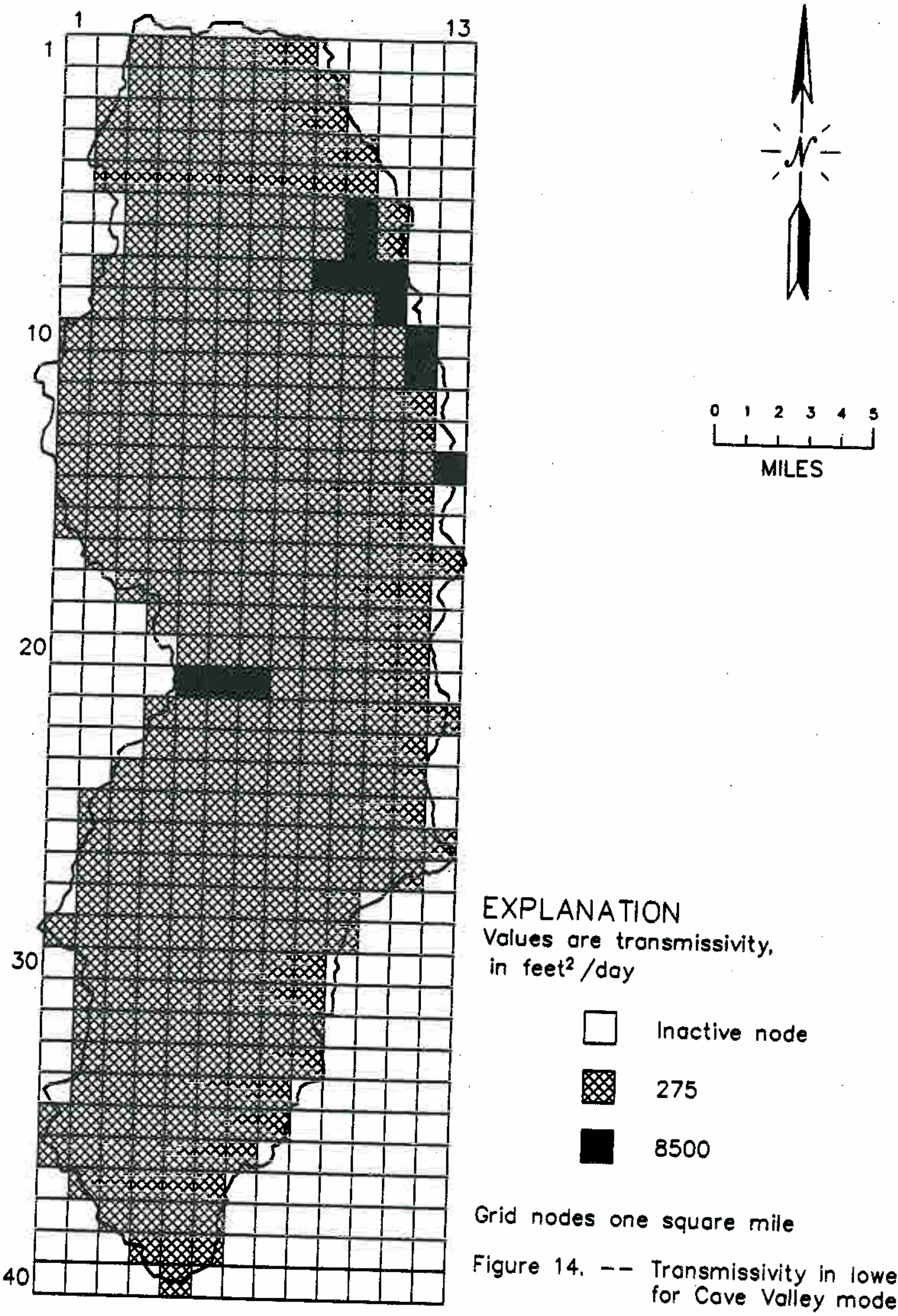


Figure 14. -- Transmissivity in lower layer for Cave Valley model.

The high transmissivity zones correspond with the inferred Shingle Pass fault on the west side of the basin and with an area on the east side of the basin where Hose and Blake (1976) mapped a number of east-west trending faults through the Ordovician and Cambrian rocks of the northern Schell Creek Range.

For transient modelling of the effects of water withdrawals, a sensitive parameter in the model is transmissivity. These low modelled values will result in transient simulations that will probably tend to overestimate the drawdown of water levels. The resulting simulations will thus be conservative, and given the available data base and uncertainties, such an approach is considered appropriate. The calibration and the match to existing water levels is discussed in further detail under the section entitled "Steady State Simulation" and Appendix C "Steady State Model Sensitivity".

Vertical Leakance

The vertical leakance value establishes the connection between the upper and lower model layers. Initially a value of 5×10^{-5} ft per day was used, based on assumptions for aquifer thickness. This value was too high for simulation of the connections between the southern alluvial aquifer and the bedrock and the upper and lower clastics and volcanics. A value of 2×10^{-6} was used for these areas of the model. Figure 15 shows the distribution of the vertical leakance numbers within the modelled area. The sensitivity of the vertical leakance values is discussed in more detail in Appendix C.

STEADY STATE SIMULATION

The potentiometric surfaces for the upper and lower layers resulting from the steady state simulation for Cave Valley are shown in Figures 16 and 17, respectively, with the actual water levels imposed for the upper layer. There are no water level measurements in the bedrock or lower layer.

Upper Layer

The model simulated potentiometric surface for the Cave Valley upper layer is shown in Figure 16. Table 7 shows all the water level data used for calibration and the differences between the actual and simulated water levels for the Cave Valley model. These measurements are a subset from the complete water levels included in Table 1. For these wells the most recent measurement was used for calibration. Only one water level for wells 2,3, and 4 was used since these wells are very close to each other being in the same model node and having very similar water levels. Wells 11, 12, and 13 were not used since there is no data because the first is flowing, the second is dry, and the third has collapsed. The only other water level not used in model calibration was well number 1. This well is just over the southern hydrographic basin boundary near the volcanics and is probably representative of a very localized flow system.

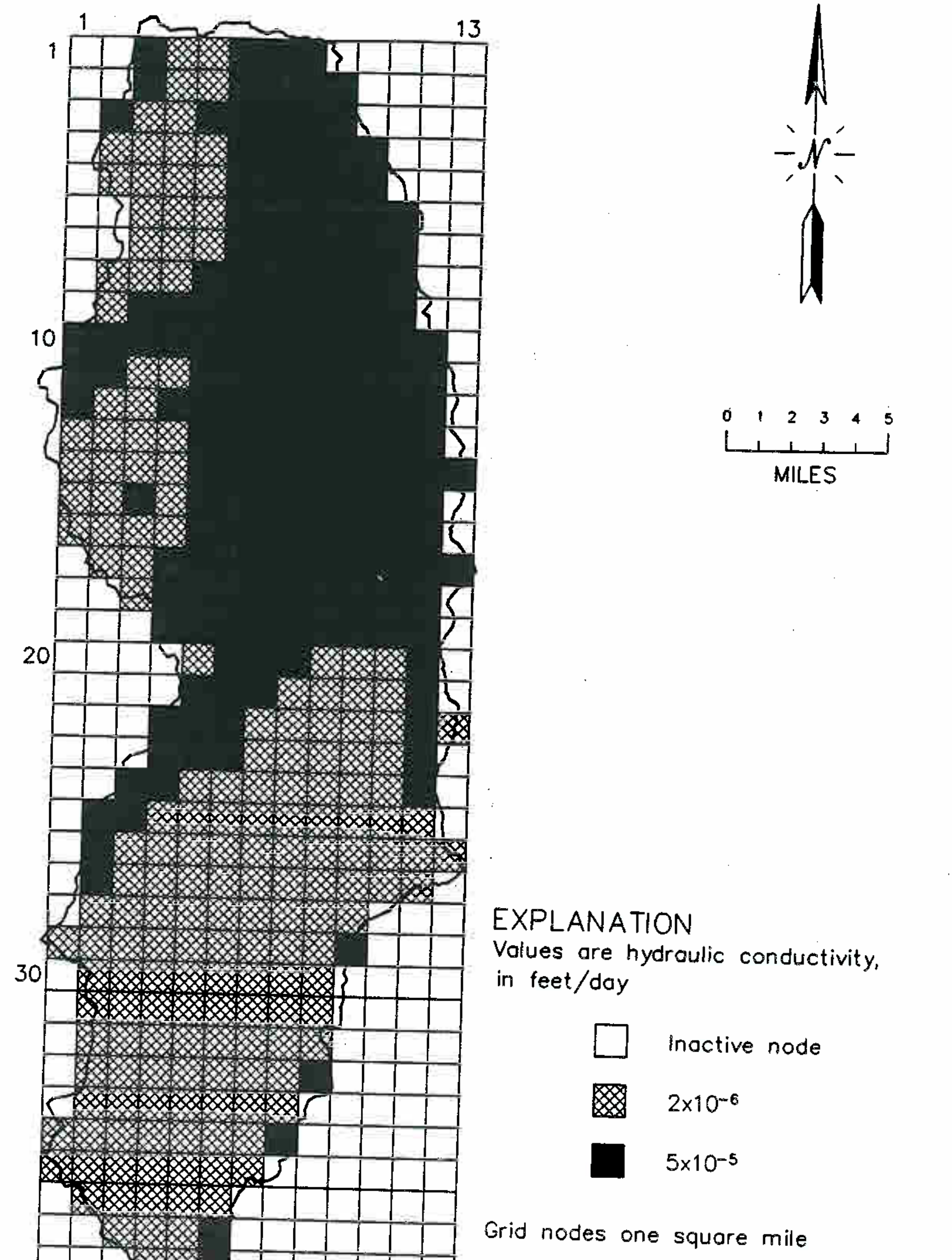


Figure 15. -- Vertical conductivity for Cave Valley model.

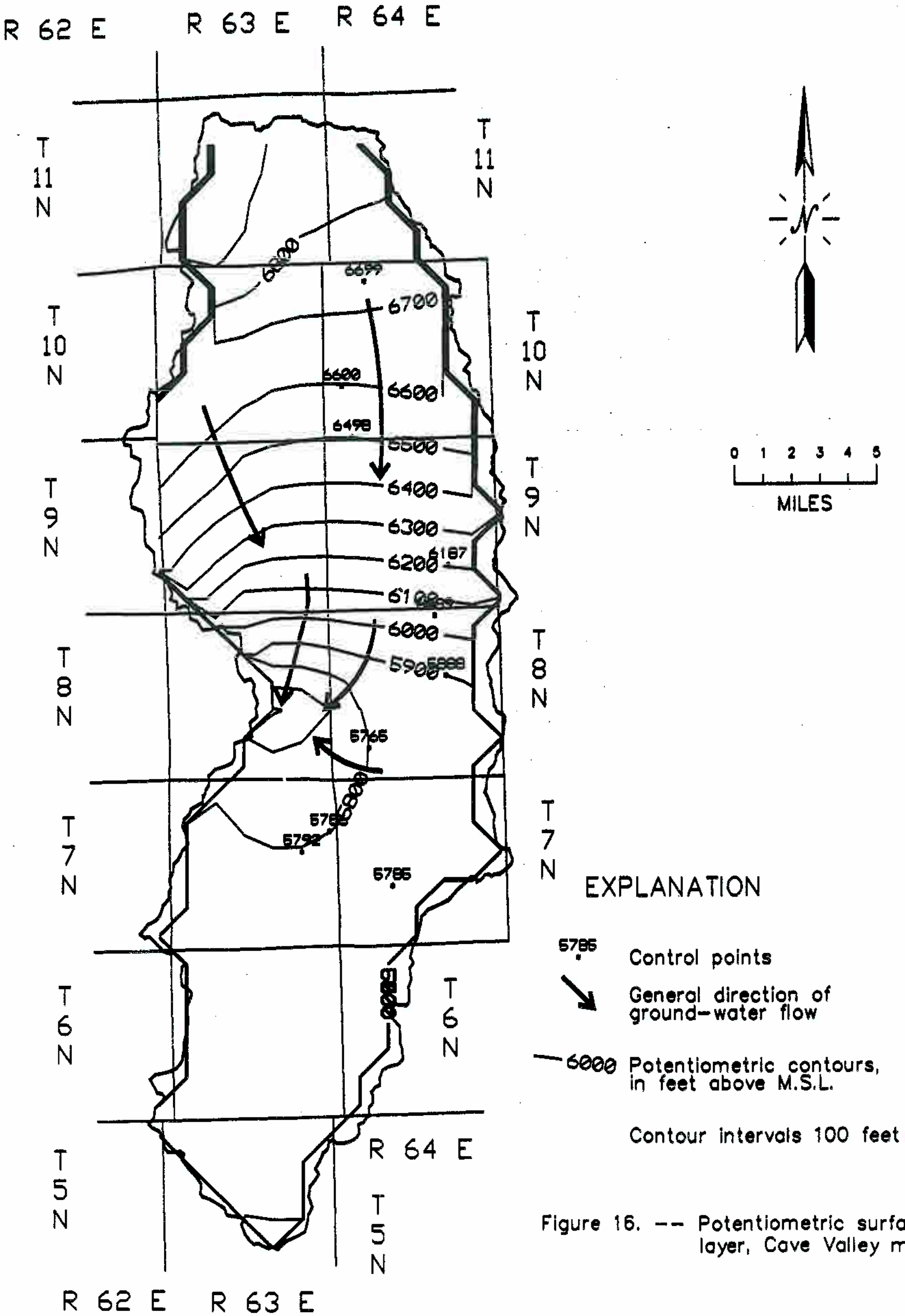
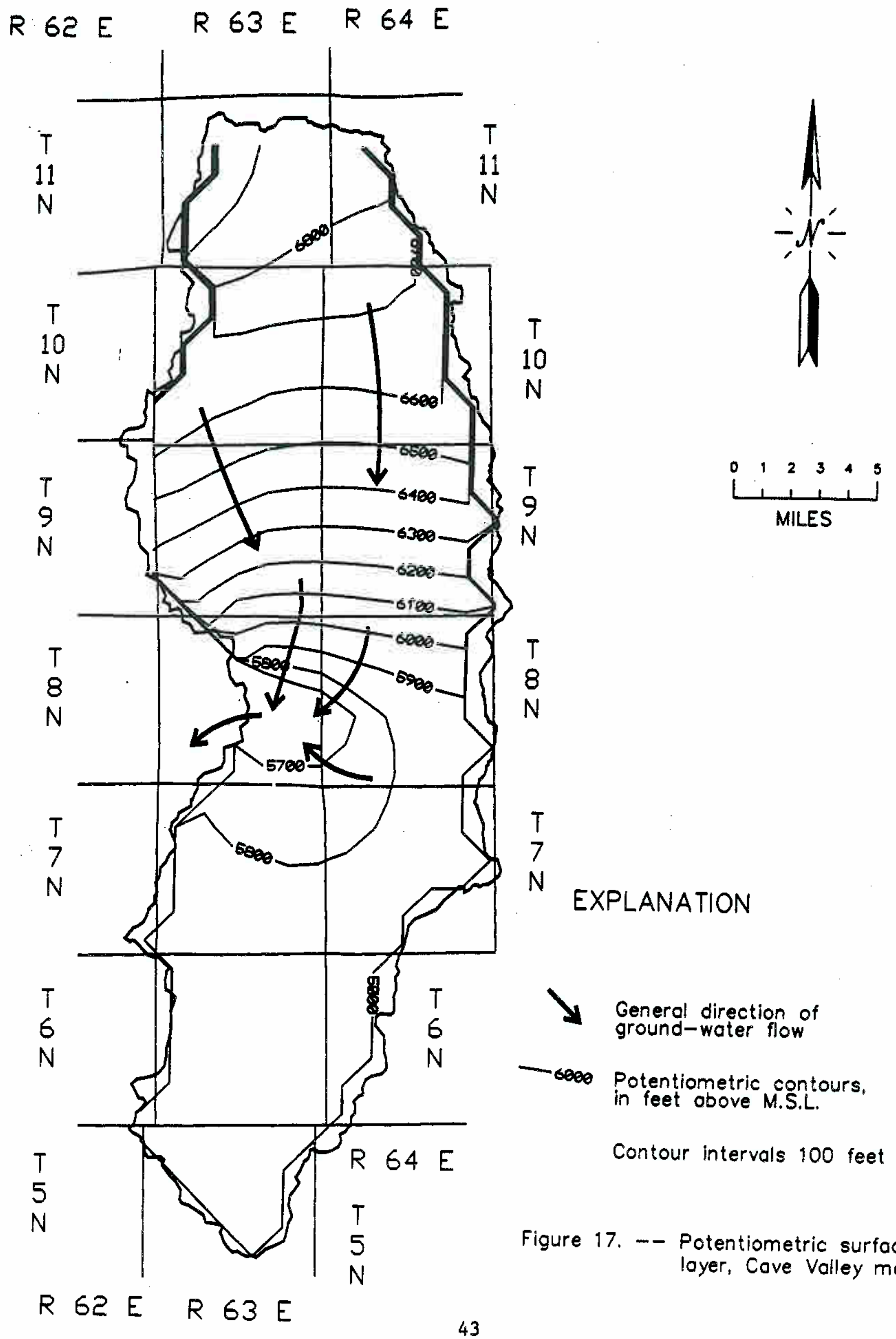


Figure 16. -- Potentiometric surface, upper layer, Cave Valley model.



EXPLANATION

General direction of ground-water flow

6000 Potentiometric contours, in feet above M.S.L.

Contour intervals 100 feet

Figure 17. -- Potentiometric surface, lower layer, Cave Valley model.

Table 7: Wells used in calibration.

Well No.	Well Location	R / C [1]	Actual Water Level	Model Water Level	Δ [2]
16	N10 E64 06 DB1	6 7	6699	6735	+36
15	N10 E63 25 AAB1	10 7	6600	6573	-27
14	N9 E64 27 BCDD1	16 11	6187	6190	+3
10	N9 E63 01 A1	12 7	6498	6461	-37
9	N8 E64 30 CDBC1	22 7	5765	5758	-7
8	N8 E64 15 BCBC1	20 10	5888	5873	-15
7	N8 E64 04 ABDD1	18 9	6089	6004	-85
6	N7 E64 19 DD1	27 8	5786	5810	+24
5	N7 E63 15 DBAD1	26 5	5792	5801	+9
2, 3, 4	N7 E63 14 BADB1	26 6	5786	5801	+15

1) R / C = row / column
2) Comparison of model water level to actual water level

Lower Layer

The potentiometric surface generated by the model for the lower layer is shown in Figure 17. There are no wells completed in the consolidated rock. Based on regional water levels, Thomas et al. (1986) estimates the potentiometric surface in the lower layer to be about 6200 feet at the center of Cave Valley and about 5200 feet on the east side of White River Valley. The simulated values closely match Thomas et al. (1986) for the central part of Cave Valley but do not show the water level gradient decline in the consolidated layer to 5200 feet on the south side of the valley. These potentiometric contours are dashed in Thomas et al. (1986) because there is no hard data to indicate this gradient other than the lower potentiometric surface in White River Valley. Based on the few water levels in the alluvium it appears the carbonate outcropping in the central part of the valley is acting as a barrier in the alluvial aquifer driving ground water down to the bedrock where it enters White River Valley. This feature also appears to be an effective barrier between significant flow between the northern and southern parts of the basin through the carbonate aquifer.

Based on the limited ground-water data, the steady state model provides a reasonable match to existing water levels and the USGS ground-water budget. Table 8 compares the budget found in Eakin (1962) with the model generated budget.

Table 8.--Comparison of Cave Valley model budget with USGS (Eakin, 1962), all values ac.ft./yr.

	USGS	Steady State Model (rounded)
RECHARGE:	14000	13000
ET:	Minor	0
FLOW: to White River Valley	14000	13000 (lower layer)

Figure 18 graphically illustrates the difference between the actual water levels and the model simulated levels for wells located from north to south in Cave Valley. All but one of the simulated values are within forty feet of actual measured values. Also the distribution of positive and negative residuals is about even. Therefore, the steady state model provides a reasonable simulation of the potentiometric surface.

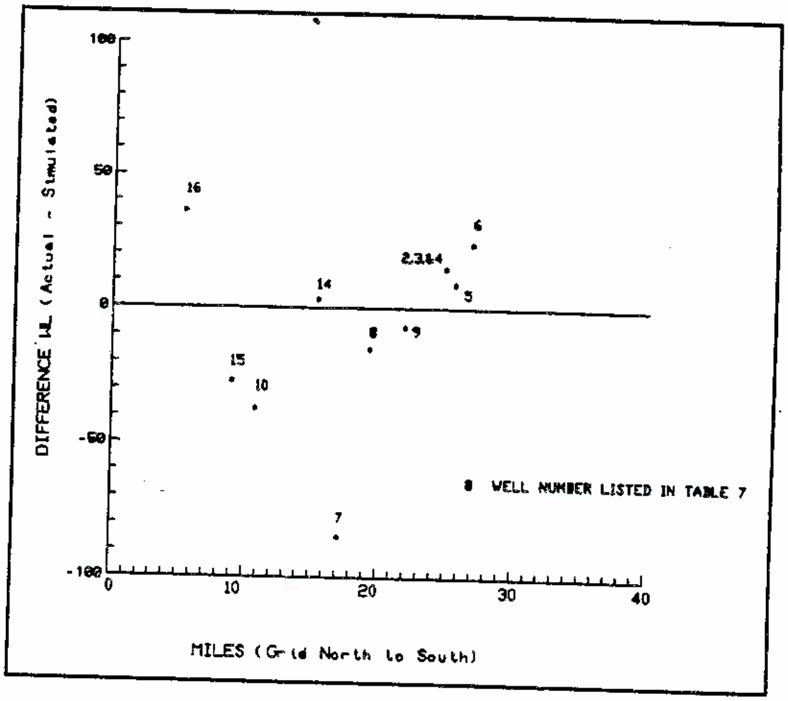


Figure 18.--Difference between simulated and actual water levels.

SUMMARY

As stated above, the goal of the steady state model was to duplicate as closely as possible the budget established by the USGS listed above, and match existing water levels. Although there is aquifer test data for Cave Valley there are insufficient data to vary cell by cell transmissivity values, therefore transmissivity values were keyed to rock type. The model "constant" becomes water entering the model as estimated by the USGS. There is no estimate of flow by the USGS entering Cave Valley other than ground-water recharge. The transmissivities, boundary conditions, and vertical leakance values described above provided a good match to the established USGS budget and to existing water level data.

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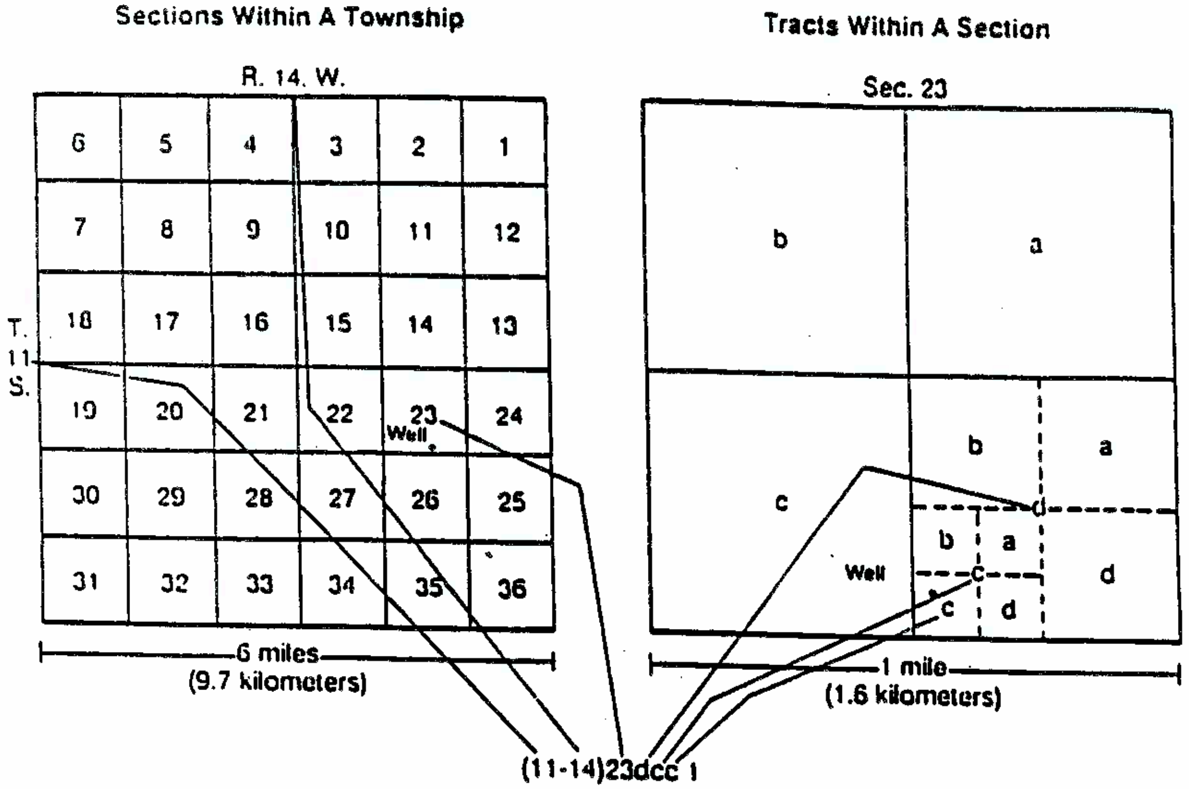
APPENDIX A

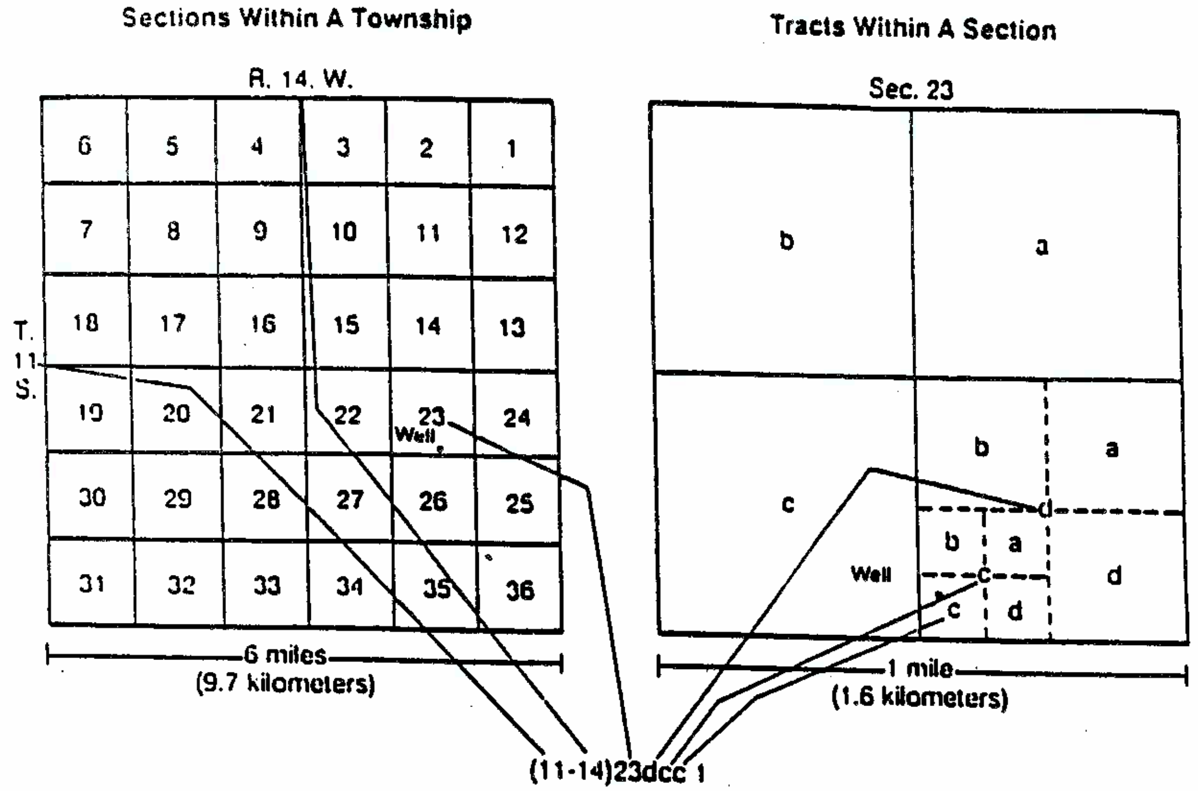
Location Designation

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) 27aba1 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.

LOCATION DESIGNATION



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APPENDIX B

WATER BASIN 180
CAVE 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				
1415 None	01/01/88	NW SW	17	11N	63E	0.1250	31.36	31.36	Stockwater	SURF OTH	NW SW 17/11/63	
1416 None	01/01/88	NE SE	30	11N	63E	0.1000	31.36	31.36	Stockwater	SURF OTH	NE SE 30/11/63	
1486 None	01/01/87	NE SE	20	11N	63E	0.5000	33.60	33.60	Stockwater	SURF OTH	NE SE 20/11/63	
1559 None	01/01/98	NW SW	10	10N	64E	0.5000	11.20	11.20	Stockwater	SURF OTH	NW SW 10/10/64	
1658 None	01/01/03	SW NW	23	10N	64E	0.3000	11.20	11.20	Stockwater	SURF OTH	SW NW 23/10/64	
1659 None	01/01/03	SE SE	22	10N	64E	0.3000	11.20	11.20	Stockwater	SURF OTH	SE SE 22/10/64	
1660 None	01/01/03	NW SE	22	10N	64E	0.3000	11.20	11.29	Stockwater	SURF OTH	NW SE 22/10/64	
1674 None	01/01/01	SW SE	12	11N	64E	0.0500	11.20	11.20	Stockwater	SURF OTH	SW SE 12/11/64	
1675 None	01/01/03	SE SW	22	10N	64E	0.0250	11.20	11.20	Stockwater	SURF OTH	SE SW 22/10/64	
1678 None	01/01/03	SW SE	34	10N	64E	1.0000	11.20	11.20	Stockwater	SURF OTH	SW SE 34/10/64	
1679 None	01/01/03	SW SE	34	9N	64E	1.0000	11.20	11.20	Stockwater	SURF OTH	SW SE 34/9/64	
1680 None	01/01/03	NE NW	2	9N	64E	1.0000	11.20	11.20	Stockwater	SURF OTH	NE NW 2, NW NE 3/9/64, S2 SE 33, SW SE 33/10/64	2nd POD NW NE 3/9/64, 3rd POD S2 SE 33, 4th POD SW SE 33/10/64
1681 None	01/01/03	NE NW	26	10N	64E	1.0000	22.40	22.40	Stockwater	SURF OTH	NE NW 26/10/64	
1696 None	01/01/90	SW SW	2	9N	64E	0.0250	11.20	11.20	Stockwater	SURF OTH	SW SW 2/9/64	
1697 None	01/01/90	NW SE	11	9N	64E	0.0250	11.20	11.20	Stockwater	SURF OTH	NW SE 11/9/64	
1698 None	01/01/90	NW NE	14	9N	64E	0.0250	11.20	11.20	Stockwater	SURF OTH	NW NE 14/9/64	
1699 None	01/01/90	NE SW	14	9N	64E	0.0250	11.20	11.20	Stockwater	SURF OTH	NE SW 14/9/64	
1807 None	01/01/80	SE NW	6	9N	64E	0.0000	263.85	351.80	Irrigation	SURF PE	31/10/64, 6/9/64	2nd POD AT NW SW 31/10/64
1878 None	04/18/25	SW SE	15	11N	63E	0.0000	0.00	0.00	Stockwater	SURF OTH	None Given	No Proof in File
1882 None	04/18/25	NE NW	10	11N	63E	0.0000	0.00	0.00	Stockwater	SURF OTH	None Given	No Proof in File
1883 None	04/18/25	SE SW	10	11N	63E	0.0000	0.00	0.00	Stockwater	SURF OTH	None Given	No Proof in File
1964 None	01/01/05	SE SE	19	6N	63E	0.0000	13.44	13.44	Stockwater	SURF OTH	SE NE 19/6/63	No Diversion Rate Given
1965 None	01/01/05	NE SW	30	6N	63E	0.0000	13.44	13.44	Stockwater	SURF OTH	NE SW 30/6/63	No Diversion Rate Given

WATER BASIN 180
CAVE 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				
2075 None	01/01/92	NW SE	9	10N	63E	0.2500	0.00	0.00	Stockwater	SURF OTH	NW SE 9/10/63	Proof 02075. No Duty Given
2079 None	01/01/92	SW SE	17	10N	63E	0.2500	0.00	0.00	Stockwater	SURF OTH	SW SE 17/10/63	Proof 02079. No Duty Given
2087 None	01/01/73	NW NW	3	9N	62E	0.0250	8.96	8.96	Stockwater	SURF OTH	NW NW 3/9/62	Proof 02087
2100 None	01/01/87	NE NW	36	10N	62E	0.0250	11.20	11.20	Stockwater	SURF OTH	NE NW 36/10/62	Proof 02100
2420 438	05/03/12	NE NE	20	10N	62E	2.9258	877.68	1170.24	Irrigation & Domestic	SURF PE	SW SW, NW SW 6/10/62/, NE SE, NW SE, SE SW 1/10/61, NW, NW SW, NE SW 12/10/62	
2692 None	01/01/85	SW NE	4	9N	63E	2.5000	360.00	480.00	Irrigation	SURF PE	3,10,11/9/63	Proof 02692, Comingled with 02693, 02694, 25322, 27814, 25411, 4599
2693 None	01/01/85	SE SW	3	9N	63E	2.5000	0.00	0.00	Irrigation	SURF PE	3,10,11/9/63	Proof 02693. See 02692
2694 None	01/01/85	SW NW	11	9N	63E	2.5000	0.00	0.00	Irrigation	SURF PE	NE SE, SE SE 11/9/63	Proof 02694. See 02692
3119 1979	09/23/14	NE NE	4	11N	63E	0.0060	4.48	4.48	Stockwater	SURF OTH	NE NE 4/11/63	
3139 1661	10/12/14	NE SW	29	11N	63E	0.0030	0.00	0.00	Stockwater	SURF OTH	NE SW 29/11/63	No Duty Given
3141 2333	10/23/14	SE NW	17	11N	63E	0.0050	3.58	3.58	Stockwater	SURF OTH	SE NW 17/11/63	
3142 2334	10/23/14	SW NW	21	11N	63E	0.0047	3.36	3.36	Stockwater	SURF OTH	SW NW 21/11/63	
4599 643	09/24/17	SE SE	11	9N	63E	0.1200	0.00	0.00	Irrigation & Domestic	SURF PE	SE SE 11/9/63	See 02692
5071 540	05/13/18	SW SE	25	8N	64E	0.0150	11.20	11.20	Stockwater	SURF OTH	SW SE 25/8/64	
5073 542	05/13/18	NE NW	25	8N	64E	0.0150	11.20	11.20	Stockwater	SURF OTH	NE NW 25/8/64	
5747 707	09/19/19	SW SE	30	11N	63E	0.0045	3.36	3.36	Stockwater	SURF OTH	SW SE 30/11/63	
6638 2105	02/27/22	NE SE	21	5N	63E	0.0300	11.20	11.20	Stockwater & Domestic	WELL OTH	NE SE 21/5/63	
7397 1175	06/14/25	SW SE	31	6N	63E	0.0150	11.20	11.20	Stockwater & Domestic	WELL OTH	SW SE 31/6/63	
7485 1876	08/20/25	SW SE	35	9N	64E	0.0125	8.96	8.96	Stockwater	SURF OTH	SW SE 35/9/64	
9001 4209	07/26/29	SW NE	16	9N	64E	0.0440	31.85	31.85	Stockwater	SURF OTH	SW SE 16/9/64	
9702 2135	10/09/33	SE NE	19	6N	63E	0.1000	11.20	11.20	Stockwater	SURF OTH	SE NE 19/6/63	

WATER BASIN 180
CAVE 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				
9720 2269	02/08/34	NW NE	14	9N	64E	0.0250	17.92	17.92	Stockwater	SURF OTH	NW NE 14/9/64	
9721 2270	02/08/34	SW SW	2	9N	64E	0.0250	17.92	17.92	Stockwater	SURF OTH	SW SW 2/9/64	
11649 3556	07/26/46	SE SE	33	11N	62E	0.9140	248.83	331.77	Irrigation & Domestic	SURF PE	NE NW, SE NW, SW NE, NE SW, NW SE, SW SE 33/11/63	2nd POD at NE NE 4/10/62
13102 4059	10/13/49	NE SE	33	11N	64E	0.0190	13.44	13.44	Stockwater	SURF OTH	NE SE 33/11/64	
25322 8358	10/15/69	SE SW	3	9N	63E	0.8900	0.00	0.00	Irrigation & Domestic	SURF PE	SW SE, SE SW S3, NW NE, NE NE, SE NE S10, SW NW S11 T9N R63E	See 02692
25411 8359	01/25/70	SW NW	11	9N	63E	0.5640	0.00	0.00	Irrigation & Domestic	SURF PE	NE SE, SE SE 11/9/63	See 02692
27814 9654	10/05/73	SW NW	11	9N	63E	0.6700	0.00	0.00	Irrigation	SURF PE	SE NW, SW NE, SW SE 11/9/63	See 02692
53987	10/17/89	SW NW	22	6N	63E	6.0000	0.00	0.00	Municipal & Domestic	WELL LVP		
53988	10/17/89	SE SE	21	7N	63E	10.0000	0.00	0.00	Municipal & Domestic	WELL LVP		
Total***							2222.59	2806.04				

APPENDIX C

Steady State Model Sensitivity

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 the Cave Valley 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 held fixed to the estimates made in Eakin (1962) and Harrill (1988). Therefore, 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 the White River ground-water flow system are constrained so that only these quantities of water are available.

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 also matched as well as possible with little subjective changes in the model parameters. All of the initial parameters of the model were set at the initial estimates for the hydrogeologic strata that comprised the aquifer units. All of the outflow from the modelled area occurs through the White River flow system; therefore, the properties, or parameters, related to the mechanisms of flow are constrained by the estimated rate of flow. In particular, the ground-water outflow from the modelled area occurs almost exclusively through the lower carbonate aquifer from Cave Valley to White River Valley so that the transmissivities and general head conductances relevant to this unit must result in the flow of this quantity of water under the known ground-water gradient.

The ground-water levels in the wells shown in Table 7 of the report were used during the calibration. The ground-water levels, resulting from the calibration are shown in Figures 16 and 17, together with the observed ground-water levels.

Model Parameter Sensitivities

Sensitivity simulations were done to determine the effects of each parameter on the ground-water levels and flows. 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 below in Table 1 as well as designated in Table 7 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.

Table 1: Wells used in calibration.

					RESULTS OF SENSITIVITY RUNS							
Well Location	R / C[1]	Actual Water Level	Model Water Level	Δ[2]	L1T1[3] (1100)	L1T2 (150)	L1T3 (4000)	L1T4 (1000)	L2T1 (275)	L2T2 (8500)	TK1 $(5x10^{-5})$	TK2 $(2x10^{-4})$
N10 E64 06 DB1	6 7	6699	6735	+36	-336	-29	-26	-91	-269	-50	-67	-3
N10 E63 25 AAB1	10 7	6600	6573	-27	-280	-22	-27	-84	-235	-48	-66	-3
N9 E64 27 BCDD1	16 11	6187	6190	+3	-125	-7	-30	-81	-158	-48	-64	-2
N9 E63 01 A1	12 7	6498	6461	-37	-238	-17	-27	-82	-213	-48	-66	-3
N8 E64 30 CDBC1	22 7	5765	5758	-7	-3	-1	+11	-40	-81	-50	-68	-4
N8 E64 15 BCBC1	20 10	5888	5873	-15	-6	-3	-37	-52	-101	-51	-65	-3
N8 E64 04 ABDD1	18 9	6089	6004	-85	-58	-3	-30	-66	-125	-49	-64	-2
N7 E64 19 DD1	27 8	5786	5810	+24	-4	-1	-11	-45	-93	-49	-65	-3
N7 E63 15 DBAD1	26 5	5792	5801	+9	-3	-1	-6	-47	-94	-48	-65	-3
N7 E63 14 BADB1	26 6	5786	5801	+15	-4	-1	-6	-46	-93	-48	-65	-3

1) R / C = row / column
2) Difference between actual and model water level
3) Variable - Layer 1, Transmissivity 1 - change in calculated ground-water level in feet

Analyses of the sensitivity simulations resulted in several general observations and estimated model properties. All of the wells located in Cave Valley are in the alluvium. However, the transmissivity of the alluvial, valley-fill aquifer produced less significant changes in ground-water levels and flows over the modelled area than did similar changes in the lower, carbonate aquifer transmissivities. The transmissivity of the alluvial aquifer in southern Cave Valley was based on an actual aquifer tests performed as part of the Air Force MX siting activity. The carbonate aquifer transmissivities were constrained by the water levels found in southern Cave Valley which results ground-water movement from Cave to White River Valley. Changes in the volcanic and clastic aquifers and upper layer carbonate aquifer transmissivities and the leakances between the layers did not produce significant changes in the majority of the ground-water levels.